**UNITED STATES DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**
*National Marine Fisheries Service*
*P.O. Box 21668*
*Juneau, Alaska 99802-1668*

June 16, 2006

John Goll
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Minerals Management Service
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Dear Mr. Goll:

This document transmits the National Marine Fisheries Service's (NMFS) Biological Opinion for Federal oil and gas leasing and exploration by the Minerals Management Service (MMS) within the Alaskan Beaufort and Chukchi Seas, and its effects on the endangered bowhead whale in accordance with section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.). Your March 3, 2006 letter to NMFS requested re-initiation of consultation in this matter. The MMS has provided a Biological Evaluation of leasing and exploration actions in the Beaufort and Chukchi Seas, which was received on March 15, 2006. We acknowledged receipt of this information in our letter dated April 5, 2006.

This Biological Opinion is based on information provided in the March 2006 Biological Evaluation and other sources of information. A complete administrative record of this consultation is on file at the NMFS offices in Anchorage.

NMFS concludes that leasing and exploration are not likely to jeopardize the continued existence of the bowhead whale. In formulating this opinion, NMFS used the best available information, including information provided by MMS, recent research on the effects of oil and gas activities on the bowhead whale, and the traditional knowledge of Native hunters and the Inupiat along Alaska's north slope. Although we conclude that foreseeable exploration activities are not likely to jeopardize the continued existence of the bowhead whale, we remain concerned about the potential additive effects of oil and gas activities associated with exploration, production, and transportation throughout the Beaufort and Chukchi Seas. Conservation recommendations are provided with the opinion which are intended to improve our understanding of the impacts of oil and gas activities on the bowhead whale, as well as to minimize or mitigate adverse effects.

Sincerely,

Robert Mecum

Robert D. Mecum
Acting Administrator, Alaska Region

## ENDANGERED SPECIES ACT – SECTION 7 CONSULTATION

## BIOLOGICAL OPINION

**AGENCY:** Minerals Management Service
National Marine Fisheries Service

**ACTIVITY:** Oil and Gas Leasing and Exploration Activities in the U.S. Beaufort and Chukchi Seas, Alaska; and Authorization of Small Takes Under the Marine Mammal Protection Act

**CONSULTATION CONDUCTED BY:** National Marine Fisheries Service

**APPROVED BY:** Robert D Mecum

**DATE ISSUED:** 6/16/06

## I. DESCRIPTION OF THE PROPOSED ACTION

This opinion will address oil and gas leasing and exploration by the U.S. Department of the Interior, MMS, on the Outer Continental Shelf (OCS) waters of the Chukchi and Beaufort Seas. Its purpose is to provide an assessment of those actions on the continued existence of the bowhead whale, as well as to provide measures to conserve the species and mitigate impact. Federal oil and gas leasing consists of several stages, or increments; 1) leasing and exploration, 2) development, production, and transportation, and 3) abandonment. The MMS offers leases on the OCS through periodic sales. Exploration activities may occur prior to or after such sales, while later phases of leasing would all be post-lease actions. Various actions may be associated with each phases of the leasing process.

Leasing and Exploration
    * Seismic geophysical surveys
    * Exploratory drilling using various platforms
    * Boat and aircraft activity

Development, production, and transportation
    * Drilling from artificial islands, drilling platforms, or drill ships
    * Pipelines
    * Tankering

Abandonment
    * Rig demobilization
    * Platform removal
    * Site restoration

This consultation will address the first of these incremental steps; leasing and exploration. Subsequent phases of OCS development (production, transportation, and abandonment) will require additional consultation. This is due in part to uncertainty at this time and the many variables associated with individual tract development. There is, in fact, considerable chance that economic quantities of recoverable oil may not be discovered, and no subsequent phases would occur. However, some information on the later phases is presented and assessed in this opinion in order to provide an adequate evaluation regarding the reasonable likelihood of the entire action violating section 7(a)(2) of the Endangered Species Act, as amended. Should commercially producible quantities of oil be discovered and development and production be proposed, MMS would initiate new formal consultation. Further consultation would also occur if additional species were listed or critical habitat designated, if the proposed action were substantially modified, or if significant new effects-related information were developed. This Biological Opinion incorporates much of the information presented within the Biological Evaluation (BE) prepared by MMS, as well as pertinent research on the bowhead whale and matters related to oil exploration. Traditional knowledge and the observations of Inupiat hunters are presented, along with information gained through scientific research. This knowledge contributes, along with western science, to a more complete understanding of these issues. A reasonable assessment of potential effects can only be made by considering both these systems of knowledge.

This opinion will also address authorization of the incidental and unintentional taking of bowhead whales due to certain oil and gas exploration activities by NMFS. Section 101 (a)(5) of the Marine Mammal Protection Act (MMPA), directs the Secretary of Commerce to allow, upon request by U.S. citizens engaged in a specific activity (other than commercial fishing) in a specified geographical region, the incidental but not intentional taking of small numbers of marine mammals if certain findings are made. Such authorization may be accomplished through regulations and issuance of letters of authorization under those regulations, or through issuance of an incidental harassment authorization (IHA). These authorizations may be granted only if an activity would have no more than a negligible effect on the species (or stock) in question, would not have an unmitigable adverse impact on the availability of the marine mammal for subsistence uses, and that the permissible method of taking and requirements pertaining to the monitoring and reporting of such taking are set forth to ensure the activity will have the least practicable adverse effect on the species or stock and its habitat. These authorizations are often requested for oil and gas activities which produce underwater noise capable of harassing or harming marine mammals. Harassment is a form of taking otherwise prohibited by the MMPA and ESA.

The actions, consequence, and environmental effects of these MMPA authorizations are the same as those described here for the oil and gas leasing and exploration activities (i.e., the activities for which an MMPA authorization would be issued). However, the actual consequence of these incidental take authorizations are likely to be less overall than that associated with leasing and exploration, because 1) not all actions may be authorized, 2) these authorizations only apply to unintentional and incidental takes, 3) illegal activity such as an oil spill cannot be authorized under this program, and 4) the level of authorized take may not result in more than a negligible impact to the Western Arctic stock of bowhead whale.

## Background

Pursuant to requirements under the Endangered Species Act of 1973, as amended (ESA), Minerals Management Service (MMS) has previously consulted with the National Marine Fisheries Service (NMFS) on the potential effects of oil and gas leasing and exploration in the Arctic, including activities in the Beaufort Sea and Chukchi Sea Planning Areas. Between 1980 and 1987, inclusive, MMS and NMFS repeatedly consulted on lease sales in the Beaufort Sea, Chukchi Sea, and Hope Basin Planning Areas. Between 1982 and 1987, inclusive, NMFS issued seven Biological Opinions related to Outer Continental Shelf (OCS) lease sales. In November 1988, NMFS concluded an incremental step consultation; the Arctic Regional Biological Opinion (ARBO), which concerned leasing and exploration activities in the Arctic Region (Beaufort Sea, Chukchi Sea, and Hope Basin OCS Planning Areas). Because of the removal of the gray whale from the list of threatened and endangered species, the availability of new information on the potential impacts of oil and gas-related noise on bowhead whales, the use of new seismic survey technology in the Arctic, and trends in OCS activities in the Arctic Region, this consultation was re-initiated in 1999. Due to lack of industry interest in the Chukchi Sea and Hope Basin Planning Areas at that time this consultation concerned leasing and exploration activities only in the Beaufort Sea Planning Area. A revised Biological Opinion for Oil and Gas Leasing and Exploration Activities in the Beaufort Sea was issued May 25, 2001. The action area for that opinion was defined as the Alaskan Beaufort Sea Planning Area, extending from the Canadian border to the Barrow area. The 2001 Biological Opinion concluded that oil and gas leasing and exploration in the Beaufort Sea was not likely to jeopardize the continued existence of bowhead whales.

Due to industry response to MMS' recent Beaufort Sea lease sales and call for information and nominations in the Chukchi Sea, and based on discussions with industry, MMS requested re-initiation of consultation to update the 2001 opinion so that the area of coverage would included OCS planning areas in both the Beaufort and Chukchi Seas.

## Term of this Opinion

This opinion will be valid upon issuance and remain in force until re-initiation may become necessary. Consultation will be re-initiated if there are significant changes in the type of exploratory activities occurring on the OCS, if new information indicates these actions are impacting the bowhead stock or other listed species/critical habitats to a degree or in a manner not previously considered, or if new species or critical habitats become listed under the Act.

## Action Area

The action area for purposes of this Biological Opinion is defined as the Alaskan Beaufort and Chukchi Sea OCS planning areas. The direct and indirect effects of this action on the endangered bowhead whale are expected to be confined to the action area **(FIGURE 1).**

## Leasing and Exploration Activities

The MMS provides an exploration scenario based on a composite of feasible options that could be developed. The options are the result of discussions within MMS, with other government agencies, and with industry. The locations of existing infrastructure, sites with potential as support facilities, area-resource estimates, and scenarios developed for previous OCS sales in these waters were all considered in developing this scenario. A summary of the major exploration assumptions follows:

### Exploration Activities in the Beaufort Sea

A detailed description of all exploratory activity associated with this action cannot be made at this time, as it will depend on the interests of the oil and gas industry, oil prices and other economic considerations, and other factors. However, for purposes of analyses MMS assumes that a maximum of two drilling rigs would operate at any time, with a total of six exploration and six delineation wells expected to be drilled over the 8-year exploration period. Exploration activity (seismic surveys and drilling) will begin with seismic surveying in summer of 2006 and continue through 2013, with delineation wells drilled through 2014. Because of the short open-water drilling season in the Beaufort Sea, it is likely that a single drilling rig would drill a single well at any drilling site in any one year. The type of units that might be used in exploration drilling would depend on water depth, sea-ice conditions, ice-resistance of the units, and availability of drilling units. Artificial ice islands grounded on the seabed are likely to be used as drilling platforms in shallow water (less than 10 meters [m]), and nearshore operations would be supported by ice roads over the landfast ice. Gravel islands are not likely to be constructed for exploration drilling in OCS waters (generally deeper than 10 m), although older artificial islands or natural shoals could be used as a base for temporary gravel or ice islands. Movable platforms resting on the seafloor likely would be used for exploration drilling. These platforms are designed to withstand winter ice forces, and drilling could be conducted year-round. Bottom-founded platforms (set on the seafloor) could be used to drill prospects in water depths of 10-20 m, and drillships or other types of floating platforms would be used in deeper water. These floating systems can operate only in open-water and broken-ice conditions and not in midwinter pack-ice conditions. Because mobile ice conditions in deeper water make ice roads unfeasible, deeper water (Far Zone) operations would take place during the summer open-water season and would be supported by icebreakers and supply boats. They would be stored in protected inshore areas when not in use.

Based on geologic studies, MMS assumes that exploration and delineation wells generally would test prospects from 3,000-15,000 feet (ft) (914-4,572 m), and a representative exploration-well depth of 7,000 ft (2,133 m). At this depth, each exploratory or delineation well would require 425 short tons of drilling muds (dry weight) and produce approximately 525 short tons of dry rock cuttings. MMS assumes that 80% of the drilling muds would be recycled, leaving 85 tons of “spent mud” to be discharged along with all the drill cuttings at each exploration site or disposed of onshore. MMS estimates that 935-1,040 short tons (dry weight) of drilling muds and 5,775-6,300 short tons (dry weight) of bore cuttings would need to be disposed of for the exploration and delineation activities for each sale. The higher figures are the estimates for Sale 195 (and applied also to Sale 186). These materials would be disposed of primarily at the drill site under conditions prescribed by the Environmental Protection Agency’s National Pollution Discharge Elimination System (NPDES) (Clean Water Act of 1977, as amended [33 U.S.C. 1251 et seq.).

Before exploration activities, the MMS requires the lessee/operator to identify any shallow hazards or archaeological resources that may be present. A high-resolution seismic survey is the preferred method used by the oil and gas industry to provide required information on shallow hazards, archaeological resources, and potential benthic communities to the MMS in support of proposed exploration and development plans in OCS leased areas. Typical high-resolution seismic survey operations are described in Section IV. For purposes of analysis, MMS assumes that up to three high-resolution site-clearance surveys would occur in the Beaufort Sea OCS in 2006 and two surveys would occur annually in 2007-2010.

Offshore exploration-drilling operations in the Beaufort Sea OCS would require onshore support facilities. Where possible, existing facilities within the Prudhoe Bay or Kuparuk unit areas would be used or upgraded. These onshore facilities would have to provide the following:

- a staging area for construction equipment, drilling equipment, and supplies;
- a transfer point for drilling and construction personnel;
- a harbor to serve as a base for vessels required to support offshore operations; and
- an airfield for fixed-wing aircraft and helicopters.

Barges transport most heavy and bulky cargo to the NSB. Prudhoe Bay has barge-docking facilities at both the East Dock and the West Dock; however, the West Dock facility is larger and more active. Crowley Maritime operates several heavy-lift cranes, barges, and barge docks in addition to support vessels from the West Dock. Oliktok Dock was constructed in 1982 to expedite shipping to the Kuparuk Field. Barge traffic in support of continued development on the North Slope of Alaska typically has ranged from 10-15 barges per year. During the initial development of the Prudhoe Bay Unit in 1970, 48 barges were used; however, newer barges are larger and more efficient and would sharply reduce that number. Barges supporting exploration activities would travel directly to the drill site to offload any cargo. Typically, a mobile drilling platform used for exploration drilling would enter its area of operation fully supplied for the drilling season.

The number of support vessels required for each bottom-founded drilling unit would depend, at least in part, on the type and characteristics of the unit and the sea-ice conditions. If drilling operations occur during the open-water season, MMS requires an emergency-standby vessel within the immediate vicinity (5 mi or a 20-minute steaming distance, whichever is less) of the drilling unit to ensure emergency evacuation of personnel. This vessel also could assist in deploying the oil boom in the event of an oil spill. If operations are planned during broken-ice conditions, two or more icebreaking vessels may be required to perform ice-management tasks for the floating units. One to two potential drilling units might be operating during the open-water period. During the open-water season (again, assuming a 45-day season), a supply boat would make one trip per rig per week. The MMS estimates the total number of supply boat trips per open-water season could be as high as 14 trips during years that exploration drilling is occurring. The level of support-boat traffic would vary by distance from shore and/or support base and whether or not the facility can be supported by vehicles using ice roads in the winter.

Ice roads are assumed to be the principal route for transporting routine supplies and materials to ice islands and/or nearshore gravel islands. For drilling platforms farther offshore in the broken-ice zone, material and supplies would be transported by support/supply boats (with icebreaking capacity, if necessary) during the open-water season and by helicopter at all other times. For both types of drilling structures, it is probable that most personnel would be transported by helicopters. The number of helicopter trips flown in support of exploration and delineation well drilling is assumed to range from about 90-270 each year, depending on the number of wells (1-3) that are drilled. For each drilling operation, we assume there would be one flight per day of drilling. The time required to drill and test a well is about 90 days. For Sales 186, 195, and 202, the annual number of helicopter trips to the drill sites should average between 140 and 155.

### Exploration Activities in the Chukchi Sea

Exploration work could begin before a lease sale to identify prospective tracts for bidding. This pre-sale work will likely include 2D/3D seismic surveys. Approximately 100,000 line-miles of 2D seismic surveys have been collected to-date in the Chukchi Planning Area, so we assume that most of the additional geophysical surveys will be 3D surveys focusing on specific leasing targets. The 3D surveys are likely to be proposed during the early phase of exploration. For proposed Chukchi Sea Sale 193, scheduled for 2007, prelease, 3D, exploration seismic surveying is expected to occur in the open-water season of 2006, with possible additional surveying in 2007. The number of surveys is expected to decrease over time as data is collected over most prospects. MMS assumes that up to four surveys could be conducted during each open-water season. The 3D seismic surveys can only be conducted during open water (approximately June to November). Seismic surveys in the Chukchi OCS will probably be coordinated with surveys in the Beaufort OCS to employ the same vessels. An icebreaker may be used as a support boat and this would ensure that the large seismic vessel could exit the area at the end of the season. The rate of seismic survey mayl average 20-30 days (with downtime) to cover a 200-mi$^2$ area. At normal vessel speeds, the airgun array would produce a sound signal every 10-15 seconds. One or more seismic surveys may be conducted (with down time) during the entire open water period as compatible with mitigation requirements. Each permit may authorize multiple surveys in a planning area. So, surveys in different parts of a planning area may overlap in time.

Based on mapping of the subsurface structures using 3D seismic data, several well locations will be proposed. Prior to drilling deep test wells, high-resolution site-clearance seismic surveys and geotechnical studies will examine the proposed exploration drilling locations for geologic hazards, archeological features, and biological populations. Site clearance and studies required for exploration will be conducted during the open water season before the drill rig is mobilized to the site.

Considering water depth and the remoteness of this area, drilling operations are likely to employ drillships with icebreaker support vessels. Water depths greater than 100 ft and possible pack-ice incursions during the open water season will preclude the use of bottom-founded drilling platforms. Using drillships allows the operator to temporarily move off the drill site, if sea or ice conditions require it, and the suspended well is controlled by so-called blow-out-prevention equipment installed on wellheads on the seabed. Bottom-founded platforms that are more permanently installed are better choices for production platforms. Drilling operations are expected to range between 30 and 90 days at different well sites, depending on the depth to the target formation, difficulties during drilling, and logging/testing operations. Considering the relatively short open water season in the Chukchi (June-November), only 1-2 wells are expected per drilling season. MMS assumes that one well could be drilled, tested, and abandoned and another well could be started each summer season. Five exploration wells have been drilled to-date on the Chukchi shelf and MMS assumes that 7-14 additional wells will be needed to discover and delineate the first commercial field.

Seismic geophysical operations will occur during exploration phases of leasing for both the Chukchi and Beaufort Seas. The MMS anticipates a maximum of four 2D/3D marine streamer seismic operations to be conducted in the Chukchi Sea evaluation area starting in 2006 and continuing through 2008. Beginning in 2009, the level of activity is expected to decline to a maximum of three marine streamer seismic operations per year. In the Beaufort Sea program area, MMS anticipates a maximum of four 2D/3D marine streamer or bottom-cable seismic operations to be conducted annually over the next 3 years. The level of activity is not expected to decline due to the number of active leases in the Beaufort.

## II. STATUS OF THE SPECIES (RANGEWIDE)

NMFS has determined the only ESA-listed species under its jurisdiction which may occur within the action area and is likely to be adversely affected by these actions is the Western Arctic stock of the endangered bowhead whale (*Balaena mysticetus*).

The MMS's BE included consideration of the potential effects of this action on humpback and fin whales. However, available information does not indicate these whales inhabit the Chukchi Sea or Beaufort Sea Planning Areas. Mizroch et al. (In prep.) summarized that there have only been rare observations of fin whales into the eastern half of the Chukchi. Three (including a mother and calf) fin whales were observed together in the southern Chukchi at 67° 10.5' N., 168° 44.8' directly north of the Bering Strait in July 1981 (Ljungblad et al., 1982). No other sightings of fin whales were reported during aerial surveys of endangered whales in summer (July) and autumn (August, September and October) of 1979-1987 in the Northern Bering Sea (from north of St. Lawrence Island), the Chukchi Sea north of 66° N. and east of the International Date Line, and the Alaskan Beaufort Sea from 157° 01' W. east to 140° W. and offshore to 72° N. (Ljungblad et al., 1988). Mizroch et al. (In prep.:15) summarized that "No other sightings…of fin whales have ever been reported from the coast of Arctic Alaska…." They have not been observed during annual aerial surveys of the Beaufort Sea conducted in September and October from 1982-2004 (e.g., Treacy, 2002; Moore, DeMaster, and Dayton, 2000).

Thus, fin whales can occur within the Chukchi Sea, but would be rare in the Alaskan Chukchi except at the far southern regions near the Bering Strait. Within the Chukchi Sea, fin whales are more likely to occur near the Bering Strait, in the southwestern portion, along the coast of the Chukotka Peninsula, and are more likely in open water than in ice-covered waters.

*Fin whales are not expected to occur in the northeastern Chukchi Sea, in the Chukchi Sea Planning Area, or in the Alaskan Beaufort Sea.*

NMFS (1991b) summarized that the northern Bering Sea, Bering Strait, and southern Chukchi Sea along the Chukchi Peninsula are the northern extreme of the range of the humpback whale (see also Johnson and Wolman, 1984). However, neither the most recent stock assessment for the Western North Pacific stock nor for the central North Pacific stock (Angliss and Outlaw-2005) depict the Chukchi Sea as part of the "approximate distribution" of humpback whales in the North Pacific. The draft stock assessment for the Western North Pacific Stock strikes reference to the Chukchi Sea. Available information does not indicate they inhabit northern portions of the Chukchi Sea or enter the Beaufort Sea. No sightings were reported during aerial surveys of endangered whales in summer (July) and autumn (August, September, and October) of 1979-1987 in the Northern Bering Sea (from north of St. Lawrence Island), the Chukchi Sea north of 66º N. and east of the International Date Line, and the Alaskan Beaufort Sea from 157º 01' W. east to 140º W. and offshore to 72º N. (Ljungblad et al., 1988). They have not been observed during annual aerial surveys of the Beaufort Sea conducted in September and October from 1982-2004 (e.g., Monnett and Treacy, 2005; Moore et al., 2000; Treacy, 2002). Recently, during a research cruise in which all marine mammals observed were recorded from July 5 to August 18, 2003, in the Chukchi and Beaufort Seas, no humpback whales were observed (Bengtson and Cameron, 2003). While humpback whales could occur in the southern Chukchi Sea, they do not tend to occur further north and *are not expected to occur within the Chukchi Sea Planning Area*. Humpback whales do not occur in the Alaskan Beaufort Sea.

Because fin and humpback whales are not likely to occur within the action area (planning areas of the Chukchi and Beaufort Seas), they are not likely to be adversely affected by these actions and will not be addressed in this opinion. Our assessment of leasing and exploration within the Chukchi and Beaufort Sea OCS found both primary and secondary effects of this action to be confined to the action area. A large oil spill occurring in the Chukchi Sea has potential to be transported into the Bering Sea, and therefore could affect other listed species or critical habiat. However, no significant risk of oil spills is associated with leasing and exploration. MMS has concluded that impacts to fin and humpback whales from large oil spills are discountable, as large spills originating in the southernmost part of the Chukchi Planning Area cannot be reasonably expected to occur. Their conclusion is based on the following:

- The resource potential of the southwest corner of the Chukchi (the area associated with the highest associated probabilities of contact, in the event of a large spill, to fin and humpback whale summer feeding habitat) is low compared with other areas and highly gas-prone.
- This area has not been identified for collection of seismic data in 2006 and MMS has never received bids for tracts located there.
- MMS does not reasonably expect to receive bids on tracts in this part of the Chukchi for the next 10 years at a minimum.

## ESA Listing History and Current Status

The bowhead whale was listed as a Federal endangered species on June 2, 1970 (35 FR 8495). No critical habitat has been designated for the species.

The bowhead whale was historically found in all arctic waters of the northern hemisphere. Five stocks are currently recognized by the International Whaling Commission (IWC, 1992:27). Three of these stocks are found in the North Atlantic and two in the North Pacific, some or all of which may be reproductively isolated (Shelden and Rugh, 1995). The Spitsbergen stock is found in the North Atlantic east of Greenland in the Greenland, Kara, and Barents Seas. Thought to have been the most numerous of bowhead stocks (Woodby and Bodkin, 1993 estimate the unexploited stock at 24,000 animals), the Spitsbergen bowhead is now severely depleted, possibly in the tens of animals (Shelden and Rugh, 1995).

The Davis Strait stock is found in Davis Strait, Baffin Bay, and along the Canadian Arctic Archipelago. This stock is separated from the Bering Sea stock by the heavy ice found along the Northwest passage (Moore and Reeves, 1993). The stock was estimated to have originally numbered over 11,700 (Woodby and Botkin, 1993) but was significantly reduced by commercial whaling between 1719 and 1915. The stock is today estimated at 350 animals (Zeh, et al., 1993) and recovery is described as "at best, exceedingly slow" (Davis and Koski, 1980). Canadian Inuit have recently expressed interest in resuming subsistence hunting of this stock, although the International Whaling Commission (IWC) has not acted on this request.

The Hudson Bay stock is differentiated from the Davis Strait stock by their summer distribution, rather than genetic or morphological differences (Reeves, et al. 1983). No reliable estimate exists for this stock, however Mitchell (1977) places a conservative estimate at 100 or less. More recently, estimates of 256-284 whales have been presented for the number of whales within Foxe Basin (Cosens et al. 1997). There has been no appreciable recovery within this stock.

The Okhotsk Sea stock occurs in the North Pacific off the western coast of Siberia near the Kamchatka Peninsula. The pre-exploitation size of this stock may have been 3,000 to 6,500 animals (Shelden and Rugh, 1995), and may now number somewhere in the 300-400 range, although reliable population estimates are not currently available. It is possible this stock has mixed with the Bering Sea stock, although the available evidence indicates the two stocks are essentially separate (Moore and Reeves, 1993).

The Bering Sea stock of the bowhead whale is the only listed species under the jurisdiction of the National Marine Fisheries Service which is known to occur in the action area and which is likely to be adversely affected by oil and gas activity. The Bering Sea stock of bowhead is hunted by the Natives of the Alaskan Beaufort Sea coast for subsistence. In 1964, the IWC began to regulate commercial whaling worldwide (Burns et al., 1993:7). The bowhead gained further protection when the ESA and the Convention on International Trade in Endangered Species of wild flora and fauna were passed in 1973. Since 1978, the IWC has imposed a quota on the number of bowheads landed and/or struck by Alaskan natives.

The Bering Sea stock of bowhead whales was reduced greatly by commercial whaling in the late 19th and early 20th centuries, from an estimated original population of 10,400 to 23,000 (Woodby and Botkin, 1993:403) to a few thousand by about 1910. Whales taken by commercial whaling in the Bering Sea may have been representatives of a population that did not migrate (Bockstoce and Botkin, 1983, Bockstoce, 1986). Shore-based visual surveys conducted at Point Barrow from 1978 through 1983 yielded a population estimate for that period of about 3,500 to 5,300 animals (Zeh et al., 1993:479).

Shelden et al. (2001) proposed that the bowhead whale species should be listed under the ESA as five distinct population segments, based on the distinct population segment definition developed by the NMFS and FWS in 1996. The five separate stocks of bowhead whales are the Bering Sea stock (referred to in IWC documents as the Western Arctic stock of Seas bowhead and as the Western Arctic stock in the NMFS's Alaska Marine Mammal stock assessments), the Spitsbergen stock, the Davis Strait stock, the Hudson Bay stock, and the Okhotsk stock. Shelden et al. (2001) evaluated each proposed distinct population segment to determine whether one or more should be reclassified. The authors presented two models to evaluate the status of bowhead whale stocks, one that they developed based on World Conservation Union criterion D1 and E (World Conservation Union, 1996, as referenced in Shelden et al., 2001), and a model developed by Gerber and DeMaster (1999) for ESA classification of North Pacific humpback whales. Under each of these classification systems, the authors determined that the Bering Sea population of bowhead whales should be delisted, whereas the other four populations of bowheads should continue to be listed as endangered (see also criticism of this determination by Taylor, [2003], the response of Shelden et al. [2003] and discussion by the IWC's Scientific Committee [IWC, 2003a]).

## Bowhead Population and Stock Structure

Of the five stocks of bowheads whales currently recognizes by the IWC for management purposes (IWC, 1992), the Western Arctic stock is the largest, and the only stock to inhabit U.S. waters. All of the stocks except for the Western Arctic are "comprised of only a few tens to a few hundreds of individuals" (Angliss and Outlaw, 2005:209). Thus, the Western Arctic stock of bowheads is the most robust and viable of surviving bowhead populations. The viability of bowheads in the Western Arctic stock is critical to the long-term future of the biological species as a whole.

The Scientific Committee of the IWC previously concluded that the Western Arctic stock of bowheads comprise a single stock (DeMaster et al., 2000). However, after an in-depth evaluation of available data, the Scientific Committee (IWC, 2004a) concluded that there is temporal and spatial heterogeneity among these bowheads, but analyses do not necessarily imply the existence of subpopulations with limited interbreeding; it was premature to draw conclusions about the relative plausibility of any hypotheses about stock structure or to reject any of them. Subsequently, NMFS and the North Slope Borough created a set of five stock-structure hypotheses, modified this set, and currently recommends testing of the following hypotheses: (1) a single stock; (2) spatial segregation; (3) temporal; (4) feeding; and (5) immigration. After more recent information provided to the IWC Subcommittee on bowhead, right and gray whales (IWC, 2005b), the subcommittee agree that what is termed the "Oslo Bump" (a significant increase in genetic difference between pairs of whales sampled approximately 1 week apart at Barrow during the fall migration) appears to be a real pattern within the data that are available. However, additional data are needed to determine if these data actually typify the bowhead population, and there is no single hypothesis adequate to explain the pattern. Stock structure is unclear at the time of this writing. The IWC will be conducting an Implementation Review focusing on the stock structure of the Western Arctic stock of bowhead with the goal of completing this at the 2007 annual meeting (IWC, 2005a). Two related intersessional workshops, one that occurred in 2005 and one that will occur in spring 2006, are focusing on this topic (IWC, 2005a,b).

The uncertainty about the stock structure of bowheads that inhabit the Chukchi and Beaufort seas adds uncertainty to the analysis of potential effects. It is not currently clear whether one or more population stocks of bowheads potentially could be impacted by the proposed activities. If more than one population may be affected, it may be that the areas in which the two stocks are likely to be vulnerable to adverse effects varies. If there is more than one stock, it is not clear what the estimated population sizes of the potentially affected population stocks are.

Woody and Botkin (1993) estimated that the historic population abundance of bowheads in the Western Arctic stock was between 10,400 and 23,000 whales in 1848 before the advent of commercial whaling, which severely depleted bowhead whales. They estimated that between 1,000 and 3,000 animals remained in 1914 near the end of the commercial-whaling period. Based on both survey data and the incorporation of acoustic data, the abundance of the Western Arctic stock of bowhead whales was estimated between 7,200 and 9,400 individuals in 1993 (Zeh, Raftery, and Schaffner, 1995), with 8,200 as the best population estimate. This estimate was recently revised by Zeh and Punt (2004) to 8,167 (CV= 0.017) and is the estimate used by the NMFS in their draft 2005 stock assessment (Angliss and Outlaw, 2005). An alternative method produced an estimate of 7,800 individuals, with a 95% confidence interval of 6,800-8,900 individuals. Data indicate that the Western Arctic stock increased at an estimated rate of about 3.1% (Raftery, Zeh, and Givens, 1995) to 3.2% (Zeh, Raftery, and Schaffner, 1995) per year from 1978-1993. The estimated increase in the estimated population size most likely is due to a combination of improved data and better census techniques, along with an actual increase in the population.

George et al. (2004) estimated abundance in 2001 to be 10,470 (SE = 1,351) with a 95% confidence interval of 8,100-13,500. This estimate indicates a substantial increase in population abundance since 1993 and suggests that population abundance may have reached the lower limits of the historical population estimate. Zeh and Punt (2004, cited in Angliss and Outlaw, 2005) provided a slightly revised population estimate of 10,545 CV(N) =0,128 to the IWC in 2004. George et al. (2004) estimated that the annual rate of increase (ROI) of the population from 1978-2001 was 3.4% (95% CI 1.7%-5%) and Brandon and Wade (2004) estimate an ROI of 3.5% (95% CI 2.2-4.9%). The number of calves (121) counted in 2001 was the highest ever recorded for this population and this fact, when coupled with the estimated rate of increase, suggests a steady recovery of this population (George et al., 2004). This steady recovery is likely due to low anthropogenic mortality, a relatively pristine habitat, and a well-managed subsistence hunt (George et al., 2004).

### Reproduction, Survival and Non-Human Sources of Mortality

Information gained from the various approaches at aging Western Arctic stock of bowhead whales and estimating survival rates all suggest that bowheads are slow-growing, late-maturing, long-lived animals with survival rates that are currently high (Zeh et al., 1993; see below). Female bowheads probably become sexually mature at an age exceeding 15 years, from their late teens to mid-20’s (Koski et al., 1993) ( Schell and Saupe, 1993: about 20 years). Their size at sexual maturity is about 12.5-14.0 meters (m) long, probably at an age exceeding 15 years (17-29 years: Lubetkin et al., 2004 cited in IWC, 2004b). Most males probably become sexually mature at about 17-27 years (Lubetkin et al., 2004 cited in IWC, 2004b). Schell and Saupe (1993) looked at baleen plates as a means to determine the age of bowhead whales and concluded that bowheads are slow-growing, taking about 20 years to reach breeding size. Based on population structure and dynamics, Zeh et al. (1993) also concluded that the bowhead is a late-maturing, long-lived animal (George et al., 1999) with fairly low mortality. Photographic recaptures by Koski et al. (1993) also suggested advanced age at sexual maturity of late teens to mid-twenties.

Mating may start as early as January and February, when most of the population is in the Bering Sea but has also been reported as late as September and early October (Koski et al., 1993). Mating probably peaks in March-April (IWC, 2004b). Gestation has been estimated to range between 13 and 14 months (Nerini et al., 1984; Reese et al., 2001) and between 12 and 16 months by Koski et al. (1993) (see also information and discussion in IWC, 2004b). Reese et al. (2001) developed a nonlinear model for fetal growth in bowhead whales to estimate the length of gestation, with the model indicating an average length of gestation of 13.9 months. Data indicate most calving occurs during the spring migration when whales are in the Chukchi Sea. Koski et al. (1993) reported that calving occurs from March to early August, with the peak probably occurring between early April and the end of May (Koski et al., 1993). The model by Reese et al. (2001) also indicated that conception likely occurs in early March to early April, suggesting that breeding occurs in the Bering Sea. The conception date and length of gestation suggests that calving is likely to occur in mid-May to mid-June, when whales are between the Bering Strait and Point Barrow (in the Chukchi Sea). Reese et al. (2001) said this is consistent with other observations in the region, including: (a) relatively few neonate-cow pairs reported by whalers at St. Lawrence Island; (b) many neonates seen during the whale census in late May; (c) relatively few term females taken at Barrow; (d) taken females with term pregnancies appeared close to parturition; and (e) most of the herd believed to have migrated past Barrow by late May. Females give birth to a single calf probably every 3-4 years.

Discussion during the in-depth assessment by the IWC (2004b) also indicated that differences in lipid content between females of the same length and size are attributable to pregnant versus nonpregnant females. This may imply a high biological cost of reproduction, a fact noteworthy in considering the potential impact of excluding females from feeding areas. George et al. (2004) estimated pregnancy rates of 0.333/year and an estimated interbirth interval of 3.0 years using data from postmortem examinations of whales landed at Barrow and Kaktovik in the winter.

There is little information regarding causes of natural mortality for Western Arctic bowhead whales. Bowhead whales have no known predators except, perhaps, killer whales and subsistence whalers. The frequency of attacks by killer whales probably is low (George et al., 1994). A relatively small number of whales likely die as a result of entrapment in ice (Philo et al., 1993). Little is known about the effects of microbial or viral agents on natural mortality.

The discovery of traditional whaling tools recovered from five bowheads landed since 1981 (George et al., 1995) and estimates of age using aspartic-acid racemization techniques (George et al., 1999) both suggest bowheads can live a very long time, in some instances more than 100 years. The oldest harvested females whose ages were estimated using corpora albicans accumulation to estimate female age were more than 100 years old (George et al., 2004, cited in IWC, 2004b). Discussion in the IWC (2004b) indicated that neither lifespan nor age at sexual maturity is certain. Lifespan may be greater than the largest estimates.

Using aerial photographs of naturally marked bowheads collected between 1981 and 1998, Zeh et al. (2002:832) estimated "the posterior mean for bowhead survival rate…is 0.984, and 95% of the posterior probability lies between 0.948 and 1." They noted that a high estimated survival rate is consistent with other bowhead life-history data.

## Migration, Distribution, and Habitat Use

The Western Arctic stock of bowheads generally occur north of 60° N. and south of 75° N. (Angliss and Outlaw, 2005) in the Bering, Chukchi, and Beaufort seas. They have an affinity for ice and are associated with relatively heavy ice cover and shallow continental shelf waters for much of the year. Bowhead whales of the Western Arctic stock overwinter in the central and western Bering Sea. Most mating probably occurs in the Bering Sea. The amount of feeding in the Bering Sea in the winter is unknown as is the amount of feeding in the Bering Strait in the fall (Richardson and Thomson, 2002). In the Bering Sea, bowheads frequent the marginal ice zone, regardless of where the zone is, and polynyas. Important winter areas in the Bering Sea include polynyas along the northern Gulf of Anadyr, south of St. Matthew Island, and near St. Lawrence Island. Bowheads congregate in these polynyas before migrating (Moore and Reeves, 1993).

Observations by Mel'nikov, Zelensky, and Ainana (1997) from shore-based observations of waters adjacent to the Chukotka Peninsula in 1994-1995 indicate that bowheads winter in the Bering Sea along leads and polynyas adjacent to the Asian coastline. Mel'nikov, Zelensky, and Ainana (1997) summarized that in years when there is little winter ice, bowheads inhabit the Bering Strait and potentially inhabit southern portions of the Chukchi Sea.

During their southward migration in the autumn, bowheads pass through the Bering Strait in late October through early November on their way to overwintering areas in the Bering Sea. Large numbers of bowheads were taken in June and July during commercial whaling over large portions of the northwestern and northcentral Bering Sea (Figure 1b in Dahlheim et al., 1980, from Townsend, 1935).

Some, or nearly all of the bowheads that winter in the Bering Sea migrate northward through the Bering Strait to the Chukchi Sea and through the Alaskan Beaufort Sea to summer feeding grounds in the Canadian Beaufort Sea. The bowhead northward spring migration appears to coincide with ice breakup and probably begins most years in April (possibly late March depending on ice conditions) and early May. It is thought to occur after the peak of breeding, which is believed to occur in March-April (C. George, cited in IWC, 2004b).

Bowheads congregate in the polynyas before migrating (Moore and Reeves, 1993; Mel'nikov, Zelensky, and Ainana, 1997). Large numbers of bowheads were taken in June and July during commercial whaling over large portions of the northwestern and northcentral Bering Sea (Figure 1b in Dahlheim et al., 1980, from Townsend, 1935). Bowheads migrate up both the eastern and western sides of the Bering Strait in the spring (Mel'nikov, Zelensky, and Ainana, 1997;

Mel’nikov et al., 2004). They pass through the Bering Strait and eastern Chukchi Sea from late March to mid-June through newly opened leads in the shear zone between the shorefast ice and the offshore pack ice. During spring aerial surveys in the late 1980’s, bowheads were documented to be migrating in shorefast leads and polynyas up the coast of northwestern Alaska (see Figures 4 and 5 in Mel’nikov, Zelensky, and Ainana, 1997).

Based on shore-based surveys in 1999-2001, Mel’nikov et al. (2004) observed that the start of spring migration from the Gulf of Anadyr varies between cold and mild years by up to 30 days, but in both instances, continues at least until June 20. Mel’nikov et al. (2004) also reported that weather influenced migration, with migration seeming to stop when there were storms or high winds in the western Bering Strait or at the exit from the Gulf of Anadyr.

The migration past Barrow takes place in pulses in some years (e.g., in 2004) but not in others (e.g., 2003) (Koski et al., 2004, cited in IWC, 2004b). At Barrow, the first migratory pulse is typically dominated by juveniles. This pattern gradually reverses and by the end of the migration, there are almost no juveniles. Currently, the whales are first seen at Barrow around April 9-10. In later May (May 15-June), large whales and cow/calf pairs are seen (H. Brower, in USDOC, NOAA and NSB, 2005; IWC, 2004b). Koski et al. (2004b) found that females and calves constituted 31-68% of the total number of whales seen during the last few days of the migration. Their rate of spring migration was slower and more circuitous than other bowheads. Calves had shorter dive duration, surface duration, and blow interval than their mothers. Calf blow rate was nearly 3 times that of their mothers. Most calving probably occurs in the Chukchi Sea. Some individuals or subset of the population may summer in the Chukchi Sea.

Several studies of acoustical and visual comparisons of the bowhead’s spring migration off Barrow indicate that bowheads also may migrate under ice within several kilometers of the leads. Data from several observers indicate that bowheads migrate underneath ice and can break through ice 14-18 centimeters [cm] (5.5-7 inches [in]) thick to breathe (George et al., 1989; Clark, Ellison, and Beeman, 1986). Bowheads may use cues from ambient light and echoes from their calls to navigate under ice and to distinguish thin ice from multiyear floes (thick ice). After passing through Barrow from April through mid-June, they move easterly through or near offshore leads. East of Point Barrow, the lead systems divide into many branches that vary in location and extent from year to year. The spring-migration route is offshore of the barrier islands in the central Alaskan Beaufort Sea.

Bowheads arrive on their summer feeding grounds near Banks Island from mid-May through June (July: IWC, 2005b) and remain in the Canadian Beaufort Sea and Amundsen Gulf until late August or early September (Moore and Reeves, 1993). Bowhead whales are seen also in the central Chukchi Sea and along the Chukotka coast in July and August. They may occupy the northeastern Chukchi Sea in late summer more regularly than commonly believed (Moore, 1992; USDOC, NOAA, and NSB, 2005), but it is unclear if these are “early-autumn” migrants or whales that have summered nearby (Moore et al., 1995) or elsewhere. Bowhead whales have been observed near Barrow in the mid-summer (e.g., Brower, as cited in USDOI, MMS, 1995). Eight bowheads were observed near Barrow on July 25, 1999, 2 at 71° 30’ N., 155° 40’W. to 155° 54’ W. from a helicopter during a search, and six at 71° 26’ N., 156° 23’ W. from the bridge of the icebreaker Sir Wilfrid Laurier (Moore and DeMaster, 2000). Moore and DeMaster (2000:61) noted that these observations are consistent with Russian scientist suggestions that

"…Barrow Canyon is a focal feeding area for bowheads and that they 'move on' from there only when zooplankton concentrations disperse (Mel'nikov et al. 1998)" and consistent with the time frame of earlier observations summarized by Moore (1992.)

Some biologists conclude that almost the entire Bering Sea bowhead population migrates to the Beaufort Sea each spring and that few whales, if any, summer in the Chukchi Sea. Incidental sightings suggest that bowhead whales may occupy the Chukchi Sea in the summer more regularly than commonly believed. Moore (1992) summarized observations of bowheads in the northeastern Chukchi in late summer. Other scientists maintain that a few bowheads swim northwest along the Chukotka coast in late spring and summer in the Chukchi Sea. Observation by numerous Russian authors (cited in Mel'nikov, Zelensky, and Ainana [1997:8]) indicates that bowheads occur in waters of the Chukchi Sea off the coast of Chukotka in the summer.

Harry Brower, Jr. observed whales in the Barrow area in the middle of the summer, when hunters were hunting bearded seals on the ice edge (Brower, as cited in USDOI, MMS, 1995). The monitoring program conducted while towing the single steel drilling caisson to the McCovey location in 2002 recorded five bowhead whales off Point Barrow on July 21.

Recent systematic data about bowhead distribution and abundance in the Chukchi Sea OCS Planning Area are lacking. The MMS funded large-scale surveys in this area when there was oil and gas leasing and exploration, but while surveys in the Beaufort Sea have continued, the last surveys in the Chukchi Sea were about 15 years ago.

Bowheads found in the Bering and Chukchi Seas in the summer may be part of the expanding Western Arctic stock (Rugh et al. 2004), as referenced in Angliss, DeMaster, and Lopez, 2001). Evidence indicates that the number of bowheads in the Western Arctic stock has increased substantially since the time of the surveys (Brandon and Wade, 2004, cited in IWC, 2004b). Temporal and spatial patterns of distribution also may be modified. Conversely, earlier information may have inferred less variability in distribution than actually existed.

Those bowheads that have been summer feeding in the Canadian Beaufort Sea begin moving westward into Alaskan waters in August and September. While few bowheads generally are seen in Alaskan waters until the major portion of the migration takes place (typically mid-September to mid-October), in some years bowheads are present in substantial numbers in early September (Greene and McLennan, 2001; Treacy, 1998). In 1997, Treacy (1998) reported sighting 170 bowheads, including 6 calves, between Cross Island and Kaktovik on September 3 during the first flight of the survey that year. In 1997, Treacy (1998) observed large numbers of bowheads between Barrow and Cape Halkett in mid-September. Large numbers were still present between Dease Inlet and Barrow in early October (although they may not have been the same individuals).

There is some indication that the fall migration, just as the spring migration, takes place in pulses or aggregations of whales (Moore and Reeves, 1993). Eskimo whalers report that smaller whales precede large adults and cow-calf pairs on the fall migration (Braham et al., 1984, as reported in Moore and Reeves, 1993). During the autumn migration Koski and Miller (2004, cited in IWC, 2004b) found decreasing proportions of small whales and increasing proportions of large whales as one moved offshore. "Mothers and calves tended to avoid water depths less than (<) 20 m." (Koski and Miller, cited in IWC, 2004b:14). These authors also found that in the Central Beaufort Sea in late August, the vast majority of the whales were subadults and this percentage declined throughout the autumn to about 35% by early October. They reported that mother/calf pairs "arrived in September and were common until early October" (Koski and Miller, 2004, cited in IWC, 2004b).

Inupiat whalers estimate that bowheads take about 2 days to travel from Kaktovik to Cross Island, reaching the Prudhoe Bay area in the central Beaufort Sea by late September, and 5 days to travel from Cross Island to Point Barrow (T. Napageak, 1996, as cited in NMFS, 1999).

Individual movements and average speeds (approximately 1.1-5.8 kilometers per hour [km/h]) vary widely (Wartzog et al., 1990; Mate, Krutzikowsky, and Winsor, 2000). Much faster speeds (e.g., up to 9.8 + 4.0 km/h) were estimated for bowheads migrating out of the Gulf of Anadyr during the northward spring migration (Mel'nikov et al., 2004).

Wartzog et al. (1989) placed radio tags on bowheads and tracked the tagged whales in 1988. One tagged whale was tracked for 915 km as it migrated west at an average speed of 2.9 km/h in ice-free waters. It traveled at an average speed of 3.7 km/h in relatively ice-free waters and at an average speed of 2.7 km/h through eight-tenths ice cover and greater. Another whale traveled 1,291 km at an average speed of 5.13 km in ice-free waters but showed no directed migratory movement, staying within 81 km of the tagging site. Additional tagged whales in 1989 migrated 954-1,347 km at average speeds of 1.5-2.5 km/h (Wartzog et al., 1990). Mate, Krutzikowsky, and Winsor (2000) tagged 12 juvenile bowhead whales with satellite-monitored radio tags in the Canadian Beaufort Sea. The whale with the longest record traveled about 3,886 km from Canada across the Alaskan Beaufort Sea to the Chukchi Sea off Russia and averaged 5.0 km/h. This whale's speed was faster, though not significantly faster, in heavy ice than in open water.

Oceanographic conditions can vary during the fall migration from open water to more than nine-tenths ice coverage. The extent of ice cover may influence the timing or duration of the fall migration. Miller, Elliot, and Richardson (1996) observed that whales within the Northstar region (long. 147°-150° W.) migrate closer to shore in light and moderate ice years and farther offshore in heavy ice years, with median distances offshore of 30-40 km (19-25 miles [mi]) in both light and moderate ice years and 60-70 km (37-43 mi) in heavy ice years. Moore (2000) looked at bowhead distribution and habitat selection in heavy, moderate, and light ice conditions in data collected during the autumn from 1982-1991. This study concluded that bowhead whales select shallow inner-shelf waters during moderate and light ice conditions and deeper slope habitat in heavy ice conditions. During the summer, bowheads selected continental slope waters and moderate ice conditions (Moore, DeMaster, and Dayton, 2000). Interseasonal depth and ice-cover habitats were significantly different for bowhead whales. Ljungblad et al. (1987) observed during the years from 1979-1986 that the fall migration extended over a longer period, that higher whale densities were estimated, and that daily sighting rates were higher and peaked later in the season in light ice years as compared to heavy ice years.

Fall aerial surveys of bowhead whales in the Alaskan Beaufort Sea have been conducted since 1979 by the Bureau of Land Management and the MMS (Ljungblad et al., 1987; Treacy, 1988-1998, 2000). Over a 19-year period (1982-2000), there were 15 years with some level of offshore seismic exploration and/or drilling activity and 4 years (1994, 1995, 1999, and 2000) in which neither offshore activity took place during September or October. The parametric Tukey HSD test was applied to MMS fall aerial-transect data (1982-2000) to compare the distances of bowhead whales north of a normalized coastline in two analysis regions of the Alaskan Beaufort Sea from 140-156° W. longitude (see USDOI, MMS, 2003). While the Tukey HSD indicates significant differences between individual years, it does not compare actual levels of human activity in those years nor does it test for potential effects of sea ice and other oceanographic conditions on bowhead migrations (Treacy, 2000). Treacy (2000) showed in a year-to-year comparison that the mean migration regionwide in fall 1998 was significantly closer to shore in both the East and West Regions than in 1999, a year with no offshore seismic or drilling activity during the fall season in the Alaskan Beaufort Sea.

While other factors may have dominating effects on site-specific distributions, such as prey concentrations, seismic activities, and localized vessel traffic, broad-area fall distributions of bowhead whale sightings in the central Alaskan Beaufort Sea may be driven by overall sea-ice severity (Treacy, 2001). Treacy (2002) concluded that:

<u>Bowhead whales occur farther offshore in heavy-ice years during fall migrations across the Central Alaskan Beaufort Sea (142° W to 155° W longitudes). Bowheads generally occupy nearshore waters in years of light sea-ice severity, somewhat more offshore waters in moderate ice years, and are even farther offshore in heavy ice years. While other factors…may have localized effects on site-specific distributions, broad-area distributions of bowhead whale sightings in the central Alaskan Beaufort Sea are related to overall sea-ice severity.</u>

Further evidence that bowhead whales migrate at varying distances from shore in different years also is provided by site-specific studies monitoring whale distribution relative to local seismic exploration in nearshore waters of the central Beaufort Sea (Miller et al., 1997; Miller, Elliot, and Richardson, 1998; Miller et al., 1999). In 1996, bowhead sightings were fairly broadly distributed between the 10-m and 50-m depth contours. In 1997, bowhead sightings were fairly broadly distributed between the 10-m and 40-m depth contours, unusually close to shore. In 1998, the bowhead migration corridor generally was farther offshore than in either 1996 or 1997, between the 10-m and 100-m depth contours and approximately 10-60 km from shore.

Aerial surveys near the proposed Liberty development project in 1997 (BPXA, 1998) showed that the primary fall-migration route was offshore of the barrier islands, outside the proposed development area. However, a few bowheads were observed in lagoon entrances between the barrier islands and in the lagoons immediately inside the barrier islands, as shown in Figures 4-4 and 4-5 of the Environmental Report submitted by BPXA for the Liberty development project (BPXA, 1998). Because survey coverage in the nearshore areas was more intensive than in offshore areas, maps and tabulations of raw sightings overestimate the importance of nearshore areas relative to offshore areas. Transects generally did not extend south of the middle of Stefansson Sound. Nevertheless, these data provide information on the presence of bowhead whales near the then-proposed Liberty development area during the fall migration. Probably only a small number of bowheads, if any, came within 10 km (6 mi) of the area.

Some bowheads may swim inside the barrier islands during the fall migration. For example Frank Long, Jr. reported that whales are seen inside the barrier islands near Cross Island nearly every year and are sometimes seen between Seal Island and West Dock (U.S. Army Corps of

Engineers, 1999). Crews from the commercial-whaling ships looked for the whales near the barrier islands in the Beaufort Sea and in the lagoons inside the barrier islands (Brower, 1980). Whales have been known to migrate south of Cross Island, Reindeer Island, and Argo Island during years when fall storms push ice against the barrier islands (Brower, 1980). Inupiat whaling crews from Nuiqsut also have noticed that the whale migration appears to be influenced by wind, with whales stopping when the winds are light and, when the wind starts blowing, the whales started moving through Captain Bay towards Cross Island (Tuckle, as cited in USDOI, MMS, 1986). Some bowhead whales have been observed swimming about 25 yards from the beach shoreline near Point Barrow during the fall migration (Rexford, as cited in USDOI, MMS, 1996). A comment received from the Alaska Eskimo Whaling Commission on the Liberty draft EIS indicated that Inupiat workers at Endicott have, on occasion, sighted bowheads on the north side of Tern Island. No specific information was provided regarding the location of the whale.

Data are limited on the bowhead fall migration through the Chukchi Sea before the whales move south into the Bering Sea. Bowhead whales commonly are seen from the coast to about 150 km (93 mi) offshore between Point Barrow and Icy Cape, suggesting that most bowheads disperse southwest after passing Point Barrow and cross the central Chukchi Sea near Herald Shoal to the northern coast of the Chukotka Peninsula. However, sightings north of 72° N. latitude suggest that at least some whales migrate across the Chukchi Sea farther to the north. Mel'nikov, Zelensky, and Ainana (1997) argued that data suggest that after rounding Point Barrow, some bowheads head for the northwestern coast of the Chukotka Peninsula and others proceed primarily in the direction of the Bering Strait and into the Bering Sea. Mel'nikov (in USDOC, NOAA, and NSB, 2005) reported that abundance increases along northern Chukotka in September as whales come from the north. More whales are seen along the Chukotka coast in October. J.C. George (cited in IWC, 2004b) noted that bowheads pass through the Bering Strait into the Bering Sea between October and November on their way to overwintering areas in the Bering Sea.

The timing, duration, and location of the fall migration along the Chukotka Peninsula are highly variable and are linked to the timing of freezeup (Mel'nikov, Zelensky, and Ainana, 1997). Whales migrate in "one short pulse over a month" in years with early freezeup, but when ice formation is late, whales migrate over a period of 1.5-2 months in 2 pulses (Mel'nikov, Zelensky, and Ainana, 1997:13.

### Bowhead Feeding

Bowheads are filter feeders, filtering prey from the water through baleen fibers in their mouth. They apparently feed throughout the water column, including bottomfeeding as well as surface skim feeding (Würsig et al., 1989). Skim feeding can occur when animals are alone and conversely may occur in coordinated echelons of over a dozen animals (Würsig et al., 1989). Food items most commonly found in the stomachs of harvested bowheads include euphausiids, copepods, mysids, and amphipods. Euphausiids and copepods are thought to be their primary prey. Lowry, Sheffield, and George (2004) documented that other crustaceans and fish also were eaten but were minor components in samples consisting mostly of copepods or euphausiids.

Available data indicate that bowhead whales feed in both the Chukchi and Beaufort Sea Planning Areas and that this use varies in degree among years, among individuals, and among areas. It is likely that bowheads continue to feed opportunistically where food is available as they move through or about the Alaskan Beaufort Sea, similar to what they are thought to do during the spring migration. Observations from the 1980's documented that some feeding occurs in the spring in the northeastern Chukchi Sea, but this feeding was not consistently seen (e.g., Ljungblad et al., 1987; Carroll et al., 1987). Stomach contents from bowheads harvested between St. Lawrence Island and Point Barrow during April into June also indicated it is likely that some whales feed during the spring migration (Carroll et al., 1987; Shelden and Rugh, 1995, 2002). Carroll et al. (1987) reported that the region west of Point Barrow seems to be of particular importance for feeding, at least in some years, but whales may feed opportunistically at other locations in the lead system where oceanographic conditions produce locally abundant food. Lowry (1993) reported that the stomachs of 13 out of 36 spring-migrating bowheads harvested near Point Barrow between 1979 through 1988 contained food. Lowry estimated total volumes of contents in stomachs ranged from less than 1 to 60 liters (L), with an average of 12.2 L in eight specimens. Shelden and Rugh (1995) concluded that "In years when oceanographic conditions are favorable, the lead system near Barrow may serve as an important feeding ground in the spring (Carroll et al., 1997)." Richardson and Thomson (2002) concluded that some, probably limited, feeding occurs in the spring.

It is known that bowhead whales feed in the Canadian Beaufort in the summer and early fall (e.g., Würsig et al, 1985), and in the Alaskan Beaufort in late summer/early fall (Lowry and Frost, 1984; Ljungblad et al., 1986; Schell and Saupe, 1993; Lowry, Sheffield, and George, 2004; summarized in Richardson and Thomson, 2002). Available information indicates it is likely there is considerable inter-annual variability in the locations where feeding occurs during the summer and fall in the Alaska Beaufort Sea, in the length of time individuals spend feeding, and in the number of individuals feeding in various areas in the Beaufort Sea.

In at least some years, some bowheads apparently take their time returning westward during the fall migration, sometimes barely moving at all, with some localities being used as staging areas due to abundant food resources or social reasons (Akootchook, 1995, as reported in NMFS, 1). The Inupiat believe that whales follow the ocean currents carrying food organisms (e.g., Napageak, 1996, as reported in NMFS, 2001). Bowheads have been observed feeding not more than 1,500 feet (ft) offshore in about 15-20 ft of water (Rexford, 1979, as reported in NMFS, 2001). Nuiqsut Mayor Nukapigak testified at the Nuiqsut Public Hearing on March 19, 2001, that he and others saw a hundred or so bowhead whales and gray whales feeding near Northstar Island (USDOI, MMS, 2002). Some bowheads appear to feed east of Barter Island as they migrate westward (Thomson and Richardson, 1987).

Interannual variability in the use of areas of the Beaufort Sea by bowheads for feeding also has been observed during aerial surveys by MMS and others. Ljungblad et al. (1986) reported that feeding bowheads comprised approximately 25% of the total bowheads observed during aerial surveys conducted in the Beaufort Sea from 1979 through 1985. Miller, Elliott, and Richardson (1998) reported observing many aggregations of feeding whales in nearshore waters near or just offshore of the 10-m depth contour during late summer/autumn 1997. In some years (e.g., 1997) (Miller, Elliot, and Richardson, 1998; Treacy, 2002), many aggregations have been seen feeding (e.g., between Point Barrow and Smith Bay), whereas in other years very little feeding was observed. Bowheads occasionally have been observed feeding north of Flaxman Island.

Treacy (2002) summarized data regarding the frequency of feeding and milling of bowhead whales observed on transect during aerial surveys conducted by MMS in the Beaufort Sea between 1982 and 2001. Because whales exhibiting milling behavior also may be feeding whales, whales with milling behavior were included with whales with apparent feeding behavior, even though some milling whales may have been engaged in other forms of social behavior. Feeding and milling whales observed per unit effort for each fall season (1982-2001) were mapped for visual comparison of relative occurrence of these behaviors in the Alaskan Beaufort Sea. Treacy (2002) summarized that a greater relative occurrence of feeding and/or milling behavior in bowhead whales was detected on transect near the mouth of Dease Inlet during aerial surveys of bowhead whales in the Beaufort Sea in 6 out of 20 years (1984, 1989, 1997, 1998, 1999, and 2000). In 4 of those years (1989, 1997, 1998, and 1999), Treacy also reported that a similar frequency of feeding and/or milling behavior was observed on transect near Cape Halkett, Alaska. During this 20-year period, there were 9 years when feeding and/or milling behaviors were noted on transect, but not in or near either Dease Inlet or Cape Halkett (1982, 1983, 1985, 1986, 1988, 1990, 1993, 1995, and 1996). In 1987, 1991, 1992, 1994, and 2001, Treacy (2002) reported that neither feeding nor milling behaviors were noted on transect at any location in the study area. Interannual and geographic variation in prey availability likely accounts for opportunistic feeding aggregations in particular years and locations (Treacy, 2002).

Of 245 whales observed during 2003 during MMS BWASP, 31% were classified as milling but none as feeding (Monnett and Treacy, 2005). Monnett and Treacy (2005) reported concentrations of milling whales nearshore north and northwest of Oliktok Point on September 20, 2003. In 2004, 29% of 253 bowheads observed were classified as feeding and 10% as milling. Locations of feeding whales included northeast of Barrow, in Smith Bay, and to the west of Kaktovik. Milling whales were in the far eastern portions of the study area.

Data from MMS's BWASP surveys (e.g., Treacy, 1998, 2000) shows high numbers of whales, many of which were feeding, in some areas over relatively long periods (e.g., weeks) of time in some years (e.g., 1997) in areas in the western Alaskan Beaufort but not in others. In the years that feeding whales are seen in a given area over a period of time, if the same individuals are staying in the areas and feeding for these lengths of time, in those years they could be deriving a higher than typical percentage of their yearly energetic requirements from the Alaskan Beaufort Sea.

Based on stomach content data supplemented by behavioral evidence, far more than 10% of the bowheads that passes through the eastern Alaskan Beaufort Sea during late summer and autumn feed there. Based on examination of the stomach contents of whales harvested in the autumn between 1969-2000, Lowry, Sheffield, and George (2004) found that there were no significant difference in the percentages of bowheads that had been feeding between those harvested near Kaktovik (83%), Barrow (75%), or between subadults (78%) versus adults (73%). Twenty-four out of 32 whales taken during the fall at Kaktovik from 1979-2000 and included in this analysis were considered to have been feeding (Lowry and Sheffield, 2002). The status of three other whales was uncertain. Copepods were the dominant prey species by volume. Seventy-seven out of 106 whales harvested during the fall near Barrow from 1987-2000 and included in this analysis were considered to have been feeding. The status of two other whales was uncertain. There was no estimate of stomach contents for 61 whales. Of the 77 whales classified as feeding whales, there were estimates of stomach volume for 16 autumn-feeding whales. Euphausiids were the dominant prey species by volume.

Stomach volumes are reported for 34 of 90 whales harvested in the autumn at Kaktovik and Barrow. The stomach of the harvested whales contained highly variable amounts of food (range=2-150 L at Kaktovik, with 39% containing with >20 L and 11% containing >100 L; n=18) (range =1-189 L at Barrow, with 56% containing with >20 L and 31% containing >100 L; n=16) (Table 6 in Lowry, Sheffield, and George, 2004:219). Four out of five whales taken during the fall at Cross Island from 1987-2000 were considered to have been feeding (at least 10 items or 1 L of prey). Length-girth relationships show that subadult bowheads, and possibly adults, gain weight while in the Beaufort Sea in summer and lose weight while elsewhere. Lipid content of blubber, at least in subadults, is higher when they leave the Beaufort in fall than when they return in spring. This evidence suggests the importance of feeding in the Beaufort Sea during summer and early autumn. They do not show what fraction of the annual feeding occurs in the eastern and central Beaufort Sea. Lowry, Sheffield, and George (2004:221) concluded that:

…Bowhead whales feed regularly in the nearshore waters of the eastern, central and western Alaskan Beaufort Sea during September and October…this entire region should be considered an integral part of the summer-autumn feeding range of bowhead whales. Results of stomach contents analysis, aerial observations, and traditional knowledge suggest that reference to the passage of bowhead whales through this region as a 'westward autumn migration' is misleading…it is a very incomplete description of their activities in the region. Second, feeding near Barrow during the spring migration is not just occasional, but rather a relatively common event…However, the amount of food in the stomachs tends to be lower in spring than in autumn….

However, examination of stomach contents only showed whether or not bowhead whales had fed and what prey were eaten, and it does not directly address the relative significance of feeding in various regions…This unresolved issue remains important in the evaluation of possible cumulative effects of oil and gas development on bowhead whales…..

Because the standard for classifying a whale as feeding is set so low, but prey volumes are rarely reported, we find it difficult to critically evaluate these findings relative to the issue of assessing the importance of various areas as bowhead feeding area, either to the population as a whole or to segments of the population. As pointed out by Thomson, Koski, and Richardson (2002), there is a large difference between a stomach with a small amount of prey (10 prey items) and one that is full. It is unclear how important this feeding is in terms of meeting the annual food needs of the population or to meeting the food needs of particular segments of the population (e.g., see discussion in Richardson and Thomson, 2002). Many assumptions, such as those about residence time and approximations, influence current conclusions. Because marked individuals have not been studied, it is unclear how much variability also exists among classes of individuals or individuals within a class in habitat residency times, or what factors influence residency times.

Richardson and Thomson (2002) pointed out that bowhead activity throughout the year needs to be considered when evaluating the importance of feeding in the eastern Alaskan Beaufort Sea in late summer and autumn. Although numerous observations have been made of bowheads feeding during both the spring migration north to the Beaufort Sea and the fall migration west across the Alaskan Beaufort Sea, quantitative data showing how food consumed in the Alaskan Beaufort Sea contributes to the bowhead whale population's overall annual energy needs is fairly limited. A study by Richardson (1987) concluded that food consumed in the eastern Beaufort Sea contributed little to the bowhead whale population's annual energy needs, although the area may be important to some individual whales. The study area for this 1985-1986 study extended from eastern Camden Bay to the Alaska/Canada border from shore to the 200-m depth contour for the intensive study area, and beyond this contour only for aerial survey data (Richardson and Thomson, 2002). The conclusion was controversial. The NSB's Science Advisory Committee (1987) believed the study was too short in duration (two field seasons, one of which was limited by ice cover), suboptimal sampling designs, and difficulties in estimating food availability and consumption. The Committee did not accept the conclusion that the study area is unimportant as a feeding area for bowhead whales.

Richardson and Thomson (2002) finalized the report from the MMS-funded feeding study entitled Bowhead Whale Feeding in the Eastern Alaskan Beaufort Sea: Update of Scientific and Traditional Information, which compiled and integrated existing traditional and scientific knowledge about the importance of the eastern Alaskan Beaufort Sea for feeding by bowhead whales. The project was an extension, with additional fieldwork (mainly in September of 1998, 1999, and 2000), of the previous study conducted in 1985 and 1985. The primary study area for this study extended the westward boundary about 1° longitude from that of the 1985-1986 study. Thus the boundary for the latter study was near the middle of Camden Bay (145° W. longitude). With the concurrence of the NSB Scientific Review Board, efforts in deep offshore areas were de-emphasized in this latter study so as to concentrate efforts in shallow areas of particular concern to Kaktovik hunters and, potentially, to oil industry. Boat-based zooplankton sampling in 1998-2000 was limited to areas seaward of the 50-m contour. Aerial surveys extended to the 200-m contour, and MMS surveys extended further.

Griffiths (1999) noted that the average zooplankton biomass in the study area was higher in 1986 than in 1998. Habitat suitable for feeding appears to have been less common in the eastern Alaskan Beaufort Sea in 1998 than it was in 1986. In 1998, the principal feeding area within the eastern study area appeared to have been near Kaktovik. Griffiths, Thomson, and Bradstreet (2002) discussed zooplankton biomass samples collected in the Canadian Beaufort Sea during the 1980's and in the Alaskan Beaufort Sea in 1986, 1998, and 1999, where bowhead whales were either observed feeding or where whales had been observed feeding the previous day. Bowhead whales feed in areas with a higher than average concentration of zooplankton. The distribution of biomass values at locations with feeding bowheads indicates that the feeding threshold for bowheads may be a wet biomass of ~800 milligrams per cubic meter (mg/m3).

Most whales observed where zooplankton were sampled were subadults. "Adult bowheads tend to feed where large copepods predominate" (Richardson and Thomson, 2002).

Koski (2000) summarized that the most common activity of bowheads in the eastern Alaskan Beaufort Sea during late summer and autumn was feeding. Bowhead use of the eastern Alaskan Beaufort Sea during late summer and autumn can be highly variable from year to year, with substantial differences in the numbers, size classes, residence times, and distributions of bowheads recorded there during 1985, 1986, 1998, and 1999.

Although various types of evidence (with the exception of isotope ratios) (see below) indicate that the eastern Beaufort Sea as a whole, including the Canadian Beaufort, is important to bowhead whales for feeding, the eastern Alaskan Beaufort Sea is only a small fraction of that area (Richardson and Thomson, 2002. Similarly, data indicate that the amount of time bowheads spend feeding in the fall in the eastern Alaskan Beaufort Sea is highly variable among years. Available evidence indicates that in many years, the average bowhead does not spend much time in the eastern Alaskan Beaufort Sea and, thus, does not feed there extensively. Bowhead whales moved quickly through the area in 1998 and did not stop to feed for any great period of time. In contrast, during 1986, subadult whales stopped to feed in the study area for periods of at least several days. In 1999, adult whales stopped to feed in the Flaxman-to-Herschel zone for extended periods (Koski et al., 2002). In 1999, the main bowhead feeding areas were 20-60 km offshore in waters 40-100 m deep in the central part of the study area east and northeast of Kaktovik, between Kaktovik and Demarcation Bay (Koski, Miller, and Gazey, 2000). In 1999, one bowhead remained in the study area for at least 9 days, and 10 others remained for 1-6 days. Their mean rate of movement was about one-eighth of the rate observed in 1998.

Koski et al. (2002) used six calculation methods to estimate residence time for whales in the eastern Alaskan Beaufort Sea area, from Flaxman Island to Herschel Island. The annual residence time varied from 2.1-8.3 days and averaged 5.1 days. Of the individual bowheads that traveled through this portion of the Alaskan Beaufort Sea, some spent at least 7 days. Miller et al. (2002) pointed out that it is difficult to recognize feeding behavior during typical aerial surveys. More focused observations are usually needed to obtain evidence of feeding below the surface.

Baleen from bowhead whales provides a multiyear record of isotope ratios in prey species consumed during different seasons, including information about the occurrence of feeding in the Bering Sea and Chukchi Sea system. The isotopic composition of the whale is compared with the isotope ratios of its prey from various geographic locations to make estimates of the importance of the habitat as a feeding area. Carbon-isotope analysis of bowhead baleen has indicated that a significant amount of feeding may occur in wintering areas (Schell, Saupe, and Haubenstock, 1987). Carbon-isotope analysis of zooplankton, bowhead tissues, and bowhead baleen indicates that a significant amount of feeding may occur in areas west of the eastern Alaskan Beaufort Sea, at least by subadult whales (Schell, Saupe, and Haubenstock, 1987). Subadult whales show marked changes in the carbon isotope over the seasons, indicating that carbon in the body tissues is replaced to a large extent from feeding in summer and feeding in the autumn-winter months. In contrast, adult animals sampled show very little seasonal change in the carbon isotope and have an isotopic composition best matched by prey from the western and southern regions of their range, implying that little feeding occurs in summer (Schell and Saupe, 1993).

The importance of the Alaskan Beaufort Sea as a bowhead feeding area also may have changed, or be changing, due to changes in prey availability elsewhere in their range. Isotope data indicate that primary productivity in the Bering and southern Chukchi seas is declining. Schell

(1999a) looked at baleen from 35 bowheads that were archived, in addition to whales from the recent harvest, and constructed an isotopic record that extends from 1947-1997. He inferred from this record that seasonal primary productivity in the North Pacific was higher over the period from 1947-1966, and then began a decline that continues to the most recent samples from 1997. Isotope ratios in 1997 are the lowest in 50 years and indicate a decline in the Bering Sea productivity of 35-40% from the carrying capacity that existed 30 years ago. If the decline in productivity continues, the relative importance of the eastern Beaufort Sea to feeding bowheads may increase (Schell, 1999b).

Lee and Schell (2002) analyzed carbon isotope ratios in bowhead whale muscle, baleen, and fat, and in bowhead food organisms. They found that the isotopic signatures in zooplankton from Bering and Chukchi waters, which sometimes extend into the western Beaufort Sea, are similar and cannot be differentiated from one another. Zooplankton from the eastern Beaufort Sea (summer and early autumn range) has an isotopic signature that is distinct from that in Bering/Chukchi zooplankton. Lee and Schell compared these isotopic signatures in zooplankton to isotopic signatures in bowhead tissues. Lee and Schell (2002) found that carbon isotopes in the muscle sampled in the fall were not significantly different from those in muscle sampled in the spring. Carbon isotopes in the muscle during both seasons closely matched the isotope ratios of zooplankton from the Bering and Chukchi waters, indicating most of the annual food requirements of adults and subadults are met from that portion of their range. Based on the comparison of carbon isotopes in the zooplankton and in bowhead tissues, they estimate that 10-26% of the annual bowhead feeding activity was in the eastern and central Beaufort Sea waters, roughly east of Prudhoe Bay.

Isotope data from baleen showed different feeding strategies by adult and subadult whales. Subadults acquired sufficient food in the eastern Beaufort Sea to alter the carbon isotope ratios in baleen relative to baleen representing feeding in Bering and Chukchi waters. Baleen plates from subadults showed a wider range in isotope ratios than those from adults, suggesting active feeding over all parts of their range. Much of the isotopic evidence seems to indicate that especially adult bowhead whales feed primarily on prey from the Bering and/or Chukchi Sea (Schell, Saupe, and Haubenstock, 1987; Schell and Saupe, 1993; Lee and Schell, 2002). Hoekstra et al. (2002) found seasonal values were consistent for all age classes of bowhead whales and suggested that the Bering and Beaufort seas are both important regions for feeding. In contrast, Hoekstra et al. (2002) concluded that seasonal fluctuations in carbon isotope values was consistent for all age classes of bowhead whales and suggests that the Bering and Beaufort seas are both important regions for feeding. Hoekstra et al. (2002) included data on isotope ratios in tissue subsamples from some of the same individual bowheads from Kaktovik and Barrow that were analyzed by Lee and Schell. There was an apparent discrepancy in the data from these two studies and somewhat different conclusions. The source of the discrepancy related to differences in the results from the Kaktovik whale-muscle samples. Hoekstra et al. (2002) suggest the percentage of annual feeding activity in the eastern Beaufort Sea could be on the order of 37-45% (compared to 10-26%). This discrepancy was considered critical in assessing the importance of feeding in the eastern Beaufort Sea. Lee and Schell subsequently repeated their isotopic analyses on additional subsamples from the same Kaktovik whales and obtained the same results they obtained initially (Lee and Schell, 2002). These re-analyses confirm the accuracy of the measurements reported by Lee and Schell in their draft report.

Hoekstra et al. have not repeated their isotopic analyses at this time; therefore, the reason for the discrepancy between the two sets of data remains uncertain.

Recently, Lee at al. (2005) published data from isotope ratio analyses of bowhead baleen from whales all except one of whom had been harvested in the autumn of 1997. Results of these samples were compared to data from baleen collected in past studies from both spring (predominantly) and autumn whales in 1986-1988 (see Table 1 in Lee et al., 2005:274). Lee et al. (2005:285) concluded that the new data continue to indicate that the "bowhead whale population acquires the bulk of its annual food intake from the Bering-Chukchi system…. Our data indicate that they acquire only a minority of their annual diet from the eastern and central Beaufort Sea…although subadult bowheads apparently feed there somewhat more often than do adults."

Thomson, Koski, and Richardson (2002) tried to reconcile the low estimates of summer feeding, as indicated by the isotope data of Lee and Schell, with other data: behavioral observations showing frequent feeding in the eastern Beaufort Sea during the summer and early autumn; zooplankton sampling near bowheads feeding in those areas shows that whales concentrate their feeding at locations with much higher than average biomasses of zooplankton; frequent occurrence of food in the stomachs of bowheads harvested in the Alaskan Beaufort Sea during late summer and autumn; and length-girth relationships show that subadult bowheads, and possibly adults, gain weight while in the Beaufort Sea in summer and lose weight while elsewhere; and lipid content of blubber, at least in subadults, is higher when they leave the Beaufort in fall than when they return in spring. Although some of this evidence suggests the importance of feeding in the Beaufort Sea during summer and early autumn, those types of data on summer and early fall feeding in the Beaufort Sea do not specifically show what fraction of the annual feeding occurs in the eastern and central Beaufort Sea. No comparable data on feeding, girth, or energy content have been obtained during and after the whales feed in the Chukchi sea in mid- to late fall. They concluded that bowheads fed for an average of 47% of their time in the eastern Alaskan Beaufort Sea during late summer and autumn. A substantial portion of the feeding occurred during travel. Among traveling whales, feeding as well as travel was occurring during a substantial percentage of the time, on the order of 43%.

Assumptions about residence times influence these energetics-related estimates. As noted, available data indicate there is variability in habitat use among years. Because marked individuals have not been studied, it is unclear how much variability also exists among individuals in habitat residency times or what factors influence residency times. Estimated food consumption by bowheads in the eastern Alaskan study area (Flaxman Island to the Alaska/Canada border) was expressed as a percentage of total annual consumption by the population (Thomson, Koski, and Richardson, 2002). This was done separately for each year of the study and averaged for the 5 years of the study.

The amount of feeding in the Chukchi Sea and Bering Strait in the fall is unknown as is the amount of feeding in the Bering Sea in the winter (Richardson and Thomson, 2002). Richardson and Thomson (2002:xxxviii) concluded that: "…behavioral, aerial-survey, and stomach-content data, as well as certain energetics data…show that bowheads also feed widely across the eastern and central Beaufort Sea in summer and fall."

They also concluded (Richardson and Thomson, 2002:xliii) that in an average year, the population of bowhead whales derives an estimated 2.4% of annual energetic requirements in the eastern part of the Alaskan Beaufort Sea studied. In 1 of 5 years of study, the population may have derived 7.5% or more of annual energetic requirements from the area. Utilization of the study area varies widely in time and space depending on zooplankton availability and other factors. In 4 of 5 study years, the bowhead population was estimated to consume <2% of its annual requirements within the eastern Alaskan Beaufort Sea during late summer and autumn…. Sensitivity analysis indicated that the upper bound of the 95% confidence interval was below 5% in four of the years. This upper bound was 16.5% in 1999, when the best estimate was 7.5%. Richardson and Thomson (2002) stated that they suspected the whale-days figure for 1999 was overestimated, and that the 16.5% upper bound on that confidence interval was unrealistically high. Richardson and Thomson (2002:xliv) concluded that: "It is implausible that the population would consume more than a few percent of its annual food requirements in the study year in an average year."

One source of uncertainty that affected the analyses related to bowhead energetics is that the amount of feeding in the Chukchi Sea and Bering Strait in the fall is unknown as is the amount of feeding in the Bering Sea in the winter (Richardson and Thomson, 2002). In mid to late fall, at least some bowheads feed in the southwest Chukchi. Detailed feeding studies have not been conducted in the Bering Sea in the winter. Thomson, Koski, and Richardson (2002) offered a feeding scenario, parts of which are speculative, that might be consistent with all these data. In this scenario, feeding occurs commonly in the Beaufort Sea in summer and early autumn, and bowheads gain energy stores while feeding there. However, zooplankton availability is not as high in the Beaufort Sea during summer as in the Chukchi and northern Bering seas during autumn. Also, feeding in the western Beaufort in autumn effectively may be on Chukchi prey advected to that area. Thus, bowheads might acquire more energy from Bering/Chukchi prey in autumn than from eastern and central Beaufort prey in summer/early autumn. Given this, plus an assumed low turnover rate of body components, the overall body composition of bowheads may be dominated by components from the Bering/Chukchi system, even at the end of the summer when leaving the Beaufort. Energy gained in the Beaufort and Chukchi seas during summer and fall presumably is used during winter when food availability is low, resulting in reduced girth and energy stores when returning to the Beaufort Sea in spring than when leaving in autumn.

Richardson and Thomson (2002) pointed out that the isotopic, behavioral, and stomach content data might not be in conflict, if prey availability in the Chukchi and/or Bering Sea were "notably better" than in the eastern Beaufort Sea. However, they also point out that: "…it is difficult to understand why bowheads would migrate from the Bering-Chukchi area to the Beaufort Sea if feeding in the Beaufort Sea were unimportant."

Richardson and Thomson (2002) note that while the study has provided many new data about bowhead feeding ecology and related biology, "…there are still numerous approximations, assumptions, data gaps, and variations of opinion regarding the interpretation of data. This is inevitable…." The authors do not claim that the project has resolved all uncertainty about the importance of the eastern Alaskan Beaufort Sea for feeding by bowhead whales.

Thus, the aforementioned study acknowledges certain limitations and the results of this study confirmed that the eastern Alaskan Beaufort Sea is used by bowhead whales for feeding (Stang and George, 2003). Richardson and Thomson (2002) summarized that this use varies widely in degree among years and individuals.

## III. ENVIRONMENTAL BASELINE

For the purposes of interagency consultations under Section 7 of the ESA, the environmental baseline is defined to include the past and present impacts of all Federal, State, or private actions and other human activities in an action area, the anticipated impacts of all proposed Federal projects in an action area that have already undergone formal or early Section 7 consultation, and the impact of State or private actions that are contemporaneous with the consultation in process [50 CFR §402.02].

The following factors, other than the proposed action, have had or are having potential effects on the Western Arctic stock of bowhead whales:

historic commercial whaling;
subsistence hunting;
oil- and gas-related activity;
non-oil and gas industrial development within the range of the bowhead;
research activities;
marine vessel-traffic and commercial-fishing;
pollution and contaminants baseline; and
climate change.

There are no data available that indicate that, other than historic commercial whaling, any previous human activity has had a significant population-level adverse impact on the current status of the Western Arctic stock of bowheads or their recovery. The uncertainty of the stock structure adds some uncertainty to summaries of the status of bowhead populations that may be impacted by the proposed actions. However, currently available information indicates that at the population level bowheads that use the Beaufort and Chukchi Sea Planning Areas are currently resilient at least to the level of human-caused mortality and disturbance that currently exists within their range, and has existed since the cessation of commercial whaling. Data indicate that at least some bowheads are extremely long-lived (100+ years or more). Thus, many of the individuals in this population may already have been exposed to a high number of disturbance events in their lifetimes. The primary known current human-related cause of mortality is a regulated subsistence hunt by Alaska Natives, which occurs at different times of the year in many of the coastal portions of their range. The existence of this hunt has focused Native, local, state, federal, international, and industry research and monitoring attention on this stock and the development of mitigations intended to ensure its continued availability for subsistence take adequate to meet the needs of bowhead-hunting Native communities. Since the level of take is directly linked to the population abundance and status of this population, protection of the availability of whales for subsistence take is linked to protection needed to ensure the long-term viability of the population. Whether there are long-lasting behavioral effects from this activity is unknown, but overall habitat use appears to be relatively unaffected.

## Historical Commercial Whaling

It is clear that commercial whaling between 1848 and 1915 was the human activity that had the greatest adverse effect on this population. Commercial whaling severely depleted bowhead whales. Woody and Botkin (1993) estimated that the historic abundance of bowheads in this population was between 10,400 and 23,000 whales in 1848, before the advent of commercial whaling. Woody and Botkin (1993) estimated between 1,000 and 3,000 animals remained in 1914, near the end of the commercial-whaling period. Commercial whaling also may have caused the extinction of some subpopulations and some temporary changes in distribution. Following protection from whaling, this population (but not some other bowhead populations) has shown marked progress toward recovery. As noted in the affected environment section, population estimates for 2001 range between 10,470 (SE = 1,351) with a 95% confidence interval of 8,100–13,500 (George et al., 2004) and 10,545 CV(N) =0,128 (Zeh and Punt, 2004, cited in Angliss and Outlaw, 2005(draft). Thus estimated population size is within the lower bounds of estimates of the historic population size. Recently, Shelden et al. (2001, 2003) concluded that this population should be removed from the list of species designated as endangered under the ESA.

## Subsistence Hunting

Indigenous peoples of the arctic and subarctic of what is now Alaska have been hunting bowhead whales for at least 2,000 years (Stoker and Krupnik, 1993). Thus, subsistence hunting is not a new contributor to cumulative effects on this population. There is no indication that, prior to commercial whaling, subsistence whaling caused significant adverse effects at the population level. However, modern technology has changed the potential for any lethal hunting of this whale to cause population-level adverse effects if unregulated. Under the authority of the IWC, the subsistence take from this population has been regulated by a quota system since 1977. Federal authority for cooperative management of the Eskimo subsistence hunt is shared with the Alaska Eskimo Whaling Commission (AEWC) through a cooperative agreement between the AEWC and the United States Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) (see Appendix 9.5 of NMFS, 2003b).

The sustainable take of bowhead whales by indigenous hunters represents the largest known human-related cause of mortality in this population at the present time. Available information suggests that it is likely to remain so for the foreseeable future. While other potential effectors primarily have the potential to cause, or to be related to, behavioral or sublethal adverse effects to this population, or to cause the deaths of a small number of individuals, little or no evidence exists of other common human-related causes of mortality. Subsistence take, which all available evidence indicates is sustainable, monitored, managed, and regulated, helps to determine the resilience of the population to other impacts that could potentially cause lethal takes.
Currently, Alaskan Native hunters from 10 villages harvest bowheads for subsistence and cultural purposes under a quota authorized by the IWC. Chukotkan Native whalers from Russia also are authorized to harvest bowhead whales under the same authorized quota. The status of the population is closely monitored, and these activities are closely regulated. Strike limits are established by the IWC and set at a 5-year quota of 280 landings. The sustained growth of the Western Arctic bowhead population indicates that the level of subsistence take has been sustainable. Because the quota for the hunt is tied to the population size and population parameters (IWC, 2003a; NMFS, 2003b), it is unlikely this source of mortality will contribute to a significant adverse effect on the recovery and long-term viability of this population.

There are adverse impacts of the hunting to bowhead whales in addition to the death of animals that are successfully hunted and the serious injury of animals that are struck but not immediately killed. Available evidence indicates that subsistence hunting causes disturbance to the other whales, changes in their behavior, and sometimes temporary effects on habitat use, including migration paths. Modern subsistence hunting represents a source of noise and disturbance to the whales. Whales in the vicinity of a struck whale could be disturbed by the sound of the explosive used in the hunt, the boat motors, and any sounds made by the injured whale. NMFS (2003a) pointed out that whales that are not struck or killed may be disturbed by noise associated with the approaching hunters, their vessels, and the sound of bombs detonating: "…the sound of one or more bombs detonations during a strike is audible for some distance. Acousticians, listening to bowhead whale calls as part of the census, report that calling rates drop after such a strike …" (NMFS, 2003a:35). We are not aware of data indicating how far hunting-related sounds (for example, the sounds of vessels and/or bombs) can propagate in areas where hunting typically occurs, but this is likely to vary with environmental conditions. It is not known if whales issue an "alarm call" or a "distress call" after they, or another whale, are struck.

NMFS (2003a) reported that:
…whales may act skittish" and wary after a bomb detonates, or may be displaced further offshore (E. Brower, pers. com.). However, disturbances to migration as a result of a strike are temporary (J. George, 1996), as evidenced when several whales may be landed at Barrow in a single day. There is some potential that migrating whales, particularly calves, could be forced into thicker offshore ice as they avoid these noise sources. The experience of Native hunters suggests that the whales would be more likely to temporarily halt their migrations, turn 180 degrees away…(i.e., move back through the lead systems), or become highly sensitized as they continue moving (E. Brower, pers. com.).

Because evidence indicates that bowhead whales are long-lived, some bowhead whales may have been in the vicinity where hunting was occurring on multiple, perhaps dozens or more, occasions. Thus, some whales may have cumulative exposure to hunting activities. This form of noise and disturbance adds to noise and disturbance from other sources, such as shipping and oil and gas-related activities. To the extent such activities occur in the same habitats during the period of whale migration, even if the activities (e.g., hunting and shipping) themselves do not occur simultaneously, cumulative effects from all noise and disturbance could affect whale habitat use. However, we are not aware of information indicating long-term habitat avoidance has occurred with present levels of activity. Additionally, if whales become more "skittish" and more highly sensitized following a hunt, it may be that their subsequent reactions, over the short-term, to other forms of noise and disturbance are heightened by such activity. Data are not available that permit evaluation of this possible, speculative interaction.

## Climate Change

Environmental effects compatible with climate change have already occurred in the arctic. There is a growing consensus that more such changes are likely to occur. The Arctic Climate Impact Assessment (2004) stated "The Arctic is now experiencing and is likely to experience some of the most rapid and severe climate change on Earth. Over the next 100 years, climate change is expected to contribute to major physical, ecological, social, and economic changes, many of which have already begun."

Changes in sea level, snow cover, ice extent, and precipitation are consistent with a warming climate near the Earth's surface. Examples include…increases in sea level and ocean-heat content, and decreases in snow cover and sea-ice extent and thickness (IPCC, 2001a). Projections using the SRES emissions scenarios in a range of climate models result in an increase in globally averaged surface temperature of 1.4-5.8 ºC over the period 1990 to 2100. This is about two to ten times larger than the central value of observed warming over the 20th century and the projected rate of warming is very likely to be without precedent during at least the last 10,000 years, based on paleoclimate data. For the periods 1990-2025 and 1990-2050, the projected increases are 0.4-1.1 ºC and 0.8-2.6 ºC, respectively (IPCC, 2001a:8).

The IPCC (2001a) also highlights uncertainty and inconsistencies in local and regional model projections and the ability to predict quantitative changes at these scales due to the capabilities of regional scale models (especially regarding precipitation). The NRC (2001:3) concluded that: "<u>The predicted warming is larger over higher latitudes than over low latitudes, especially during winter and spring, and larger over land than over sea</u>."

Sandven and Johannessen (2004, in Brigham and Ellis, 2004) reported that data obtained using passive microwave satellite data have shown a decrease of total ice area in the arctic of 3-4% per decade and a more significant reduction of 7-8% per decade in multi-year ice. Significant reductions in the thickness of arctic sea ice (Rothrock, Yu, and Maykut, 1999) and winter multiyear ice (Johannessen et al., 1999) have been reported. In 1998, record sea-ice retreat was observed for the Beaufort and Chukchi seas (Maslanik, 1999). Vincent, Gibson, and Jeffries (2001) reported a decrease in pack ice thickness by 27% from 1867-1999 in the Canadian high Arctic with the collapse of the Ellesmere Ice Shelf (90% reduction). Whether ice cover and ice thickness will continue to decrease in the arctic is uncertain. Analysis of ice thickness from six submarine cruises from 1991-1997 showed no trend towards a thinning ice cover (Winsor, 2001).

Atmospheric temperature increases due to climate change may be more pronounced in the arctic region than in geographic areas closer to the equator (Peters and Darling, 1985; Peters, 1991). Heavy precipitation events are projected to become more common in the arctic with flooding events likely to increase in frequency, and sea-levels are expected to rise (Walsh, 2003; Gough, 1998).

climate change could potentially affect bowheads in several ways including:

increased noise and disturbance related to increased shipping, and possibly related to increased development, within their range;
increased interactions with commercial fisheries, including increased noise and disturbance, incidental take, and gear entanglement;
decreases in ice cover with the potential for resultant changes in prey species concentrations and distribution; related changes in bowhead whale distributions; changes in subsistence-hunting practices that could result in smaller, younger whales being taken and, possibly, in fewer whales being taken;
more frequent climatic anomalies, such as El Niños and La Niñas, with potential resultant changes in prey concentrations; and

a northern expansion of other whale species, with the possibility of increased overlap in the northern Bering and/or the Chukchi seas.

The potential effects of climate change on this population of bowhead whales are uncertain. There is no current evidence of negative effects on the whales. There is no evidence suggesting that many of the changes that could occur, such as changes in timing of migrations and shifts in distribution, would be associated with overall adverse effects on these whales. In Shelden et al.'s (2003) response to Taylor's statements regarding the expectation of future downward trends in abundance based on what he termed "available evidence" regarding climate change, they point out that Taylor did not provide citations supporting this claim. Shelden et al. (2003:918-919) state that:

Although available data do indicate that the Bering Sea environment is changing (e.g., Angel & Smith 2002), we are aware of no evidence that environmental changes will be detrimental to the population in the foreseeable future. In fact, our review…on this issue suggests that climate change may actually result in more favorable conditions for Western Arctic bowheads.

### Commercial-Fishing, Marine Vessel-Traffic, and Research Activities

Based on available data, previous incidental take of bowhead whales apparently has occurred only rarely. The bowhead's association with sea ice limits the amount of fisheries activity occurring in bowhead habitat. However, the frequency of such interactions in the future would be expected to increase if commercial-fishing activities expand northward. There is some uncertainty about whether such expansion will occur. Increases in spatial overlap alone could result in increased interactions between bowheads and derelict fishing gear. In a discussion of population climate warming impacts on bowheads at the meeting of the Subcommittee on Bowheads, Right Whales and Gray Whales at the IWC's annual meeting, P. Wade (referred to in IWC, 2005b:4) reported that that the commercial crab fishery extended further north the previous winter (winter 2004-2005) than in previous years.

Between 1989 and 1994, logbook data on incidental take of bowheads are available, but after that time, the requirement is for fishers to self report. Angliss and Lodge (2002:173) reported that "the records are considered incomplete and estimates of mortality based on them represent minimums." There are no observer program records of bowhead whale mortality incidental to commercial fisheries in Alaska (Angliss and Lodge, 2002). New information on entanglements of bowhead whales indicates that bowheads do have interactions with crab-pot gear. There have been two confirmed occurrences of entanglement in crab-pot gear, one in 1993 and one in 1999 (Angliss and Lodge, 2002). Table 29 in Angliss and Lodge (2002, page 173) details reports of scarring of bowhead whales attributed to entanglement in ropes. Citing a personal communication from Craig George of the NSB, Department of Wildlife Management, Angliss and Lodge (2002) report a preliminary result from reexamination of bowhead harvest records suggest that there may be more than 20 cases indicating entanglements or scarring attributable to ropes in the bowhead harvest records. Angliss and Lodge (2002) reported that the average rate of bowhead entanglement in crab pot gear for 1996-2000 is 0.2. Based on currently available data, the estimated annual mortality rate incidental to commercial fisheries also is 0.2 (see Appendix 2 in Angliss and Lodge, 2002:179).

Potential effects on bowhead whales from commercial-fishing activities include incidental take in the fisheries and/or entanglement in derelict fishing gear resulting in death, injury, or effects on the behavior of individual whales; disturbance resulting in temporary avoidance of areas; and whales being struck and injured or killed by vessels. Bowheads have been entangled in ropes from crab pots, harpoon lines, or fishing nets; however, the frequency of occurrence is not known.

Marine vessel traffic, in general, can pose a threat to bowheads because of the risk of ship strikes. Shipping and vessel traffic is expected to increase in the arctic if warming continues. Additionally, noise associated with ships or other boats potentially could cause bowheads to alter their movement patterns or make other changes in habitat use. Pollution from marine vessel traffic, especially from large vessels such as large cruise ships, also could cause degradation of the marine environment and increase the risk of the whales' exposure to contaminants and disease vectors. The frequency of observations of vessel-inflicted injuries suggests that the incidence of ship collisions with bowhead whales is low but may be increasing. Between 1976 and 1992, only three ship-strike injuries were documented out of a total of 236 bowhead whales examined from the Alaskan subsistence harvest (George et al., 1994). The low number of observations of ship-strike injuries suggests that bowheads either do not often encounter vessels, or they avoid interactions with vessels, or that interactions usually result in the animals' death. The NMFS (2003b, citing a pers. commun. with C. George of the NSB) states that since the 1994 publication by George et al. (1994), ship-strike injuries have been observed on 6 additional whales out of about 180 whales examined between 1995 and 2002.

Available evidence indicates that bowheads either do not often encounter vessels or they avoid interactions with vessels, or that interactions usually result in the animals' death. We believe this general conclusion about ship strikes is likely to be valid. We also believe this rate may have increased slightly in recent years. Clapham and Brownell (1999) summarized that "…<u>effects of ship noise on whale behavior and ultimately on reproductive success are largely unknown</u>." NMFS (2003b) concluded that the greatest potential impact to bowhead whales from research in the arctic was from underwater noise generated by icebreakers. Citing the Western Arctic Shelf Basin Interactions (SBI) project, which operated from the U.S. Coast Guard *Healy* and *Polar Star* icebreakers. This was a multiyear, interdisciplinary program aimed at investigating the impacts of climate change on biological, physical, and geochemical processes in the Chukchi and Beaufort Shelf Basin in the Western Arctic Ocean. The SBI's cruise track in 2002 departed from Nome in early May , traveled through the Bering Strait and into the Chukchi Sea north to approximately 75º N. longitude, then west, and then gradually south to a nearshore region on June 5 and about 150º W. latitude. The ship then generally followed the coast to Pt. Lisburne. From that point, it returned directly to Nome on June 15. In 2002, the *Healy* also traveled into the Bering Sea to research the land bridge that once linked Russia and Alaska. According to a U.S. Coast Guard Pacific Area webpage on the project (http://www.uscg.mil/pacarea/healy/deploymets/aws02/science/aws02science.htm), this mission used towed sonar arrays, bottom coring, and CTD profiling.

Richardson et al. (1995a:Table 6.5) reported estimated source levels for similarly sized icebreakers to range from 177-191 db re 1 μPa-m. During icebreaking, extremely variable increases in broad-band (10-10,000 Hz) noise levels of 5-10 dB are caused by propeller cavitation. Based on previous studies of bowhead response to noise, such sound could result in temporary avoidance of animals from the areas where the icebreakers were operating and potentially cause temporary deflection of the migration corridor, depending of the location of the icebreakers. Richardson et al. (1995a:301) concluded that: "Ships and larger boats routinely use fathometers, and powerful side-looking sonars are common on many military, fishing, and bottom-survey vessels…. Sounds from these sources must often be audible to marine mammals and apparently cause disturbances in some situations."

Active sonars were used in commercial whaling after World War II, and whaling boats sometimes tracked whales underwater using active sonar. Ash (1962, cited in Richardson et al., 1995a) reported that this often caused strong avoidance by baleen whales. Reeves (1992) reported that ultrasonic pulses were used to scare baleen whales to the surface. Maybaum (1990, 1993) reported that humpback whales on the wintering grounds moved away from 3.3 kHz sonar pulses and increased their swimming speed and swim-track linearity in response to 3.1- to 3.6-kHz sonar sweeps.

Some of the research ships that have previously made trips into the range of the bowhead are likely to do so again in the future. All large research ships that are active in the range of the bowheads during periods when they are present have the potential to cause noise and disturbance to the whales, potentially altering their movement patterns or other behavior. However, available evidence does not indicate such disturbance will have a significant effect on this population over the approximate life of the project, even when added to the effects of other effectors. The Western Arctic bowhead has been the focus of research activities that could, in some instances, cause minor temporary disturbance of the whales. During research on the whales themselves, the reactions of the whales generally are closely monitored to minimize potential adverse effects. Additionally, research conducted primarily for reasons other than the study of the bowhead has also occurred within the range of the bowhead. In some cases, such research has the potential to adversely affect the whales through the introduction of additional noise, disturbance, and low levels of pollution into their environment.

Some of the research projects discussed here are continuing in the future, but have already been initiated. Previous research on bowheads has included aerial surveys, ship-based observations, acoustic studies, shore-based censuses, studies involving samples and examination of carcasses of animals killed in the subsistence hunt, and satellite tracking. NMFS recently initiated photo-identification studies. MMS will be procuring a large study aimed at better understanding the importance of feeding areas in the western Alaskan Beaufort Sea. In these future activities, as in the past, the primary result of ship-based activities could be temporary disturbance of individual whales from a highly localized area. Whales might slightly and temporarily alter their habitat use to avoid large vessels. Whales also could be temporarily harassed or disturbed by low-flying airplanes during photo-identification work. These effects would be as described for low-flying aircraft. All such effects are expected to be of short duration. Aerial surveys generally are flown at a height such that they do not cause harassment.

Submarines are highly valued platforms for a variety of oceanic research in part because they are relatively quiet, enabling the use of active and passive acoustic technologies for a variety of studies. U.S. Navy submarines are likely to continue to be used as platforms in the future. In recent years, there also have been scientific field operations in the Arctic Ocean that have used U.S. Navy submarines as platforms. Other ships have made numerous research trips into the range of the bowhead. For example, in 1995, the NRC reported that the *Alpha Helix* had performed numerous research cruises in the North Pacific, Bering Sea, Chukchi Sea, and

Alaskan coastal waters over the past 15 years (NRC, 1995). Operation of this vessel is primarily limited to open water. The R/V *Alpha Helix* has modest ice-strengthening characteristics but no icebreaking capability.

**Pollution and Contaminants**

Initial studies of bowhead tissues collected from whales landed at Barrow in 1992 (Becker et al., 1995) indicate that bowhead whales have very low levels of mercury, PCB's, and chlorinated hydrocarbons, but they have fairly high concentrations of cadmium in their liver and kidneys. The study concluded that the high concentration of cadmium in the liver and kidney tissues of bowheads warrants further investigation. Becker (2000) noted that concentration levels of chlorinated hydrocarbons in bowhead whale blubber generally are an order of magnitude less than what has been reported for beluga whales in the arctic. This probably reflects the difference in the trophic levels of these two species; the bowhead being a baleen whale feeding on copepods and euphausiids, while the beluga whale being toothed whale feeding at a level higher in the food web. The concentration of total mercury in the liver also is much higher in beluga whales than in bowhead whales.

Bratton et al. (1993) measured organic arsenic in the liver tissue of one bowhead whale and found that about 98% of the total arsenic was arsenobetaine. Bratton et al. (1997) looked at eight metals (arsenic, cadmium, copper, iron, mercury, lead, selenium, and zinc) in the kidneys, liver, muscle, blubber, and visceral fat from bowheads harvested from 1983-1990. They observed considerable variation in tissue metal concentration among the whales tested. Metal concentrations evaluated did not appear to increase over time between 1983 and 1990. Based on metal levels reported in the literature for other baleen whales, the metal levels observed in all tissues of the bowhead are similar to levels in other baleen whales. The bowhead whale has little metal contamination as compared to other arctic marine mammals, except for cadmium, which requires further investigation as to its role in human and bowhead whale health. The study recommended limiting the consumption of kidney from large bowhead whales pending further evaluation.

Cooper et al. (2000) analyzed anthropogenic radioisotopes in the epidermis, blubber, muscle, kidney, and liver of marine mammals harvested for subsistence food in northern Alaska and in the Resolute, Canada region. The majority of samples analyzed had detectable levels of $^{137}$Cs. Among tissues of all species of marine mammals analyzed, $^{137}$Cs was almost always undetectable in the blubber and significantly higher in epidermis and muscle tissue than in the liver and kidney tissue. The levels of anthropogenic radioisotopes measured were orders of magnitude below levels that would merit public health concern. The study noted there were no obvious geographical differences in $^{137}$Cs levels between marine mammals harvested in Resolute, Canada and those from Alaska. However, the $^{137}$Cs levels in marine mammals were two to three orders of magnitude lower than the levels reported in caribou in northern Canada and Alaska.

Based on the use of autometallography (AMG) to localize inorganic mercury in kidney and liver tissues for five bowhead whales, Woshner et al. (2002:209) reported that "AMG granules were not evident in bowhead tissues, confirming nominal mercury (Hg) concentrations." Detected concentrations ranged from 0.011-0.038 micrograms per gram (µg/g) wet weight for total mercury. Mössner and Ballschmiter (1997) reported that total levels of 310 nanograms per gram (ng/g) polychlorinated biphenyls and chlorinated pesticides in bowhead blubber from the North Pacific/Arctic Ocean, an overall level many times lower than that of other species from the North Pacific or Arctic Ocean (beluga whales [2,226 ng/g]; northern fur seals [4,730 ng/g]) and than that of species from the North Atlantic (pilot whale [6,997 ng/g]; common dolphin [39,131 ng/g]; and harbor seal [70,380 ng/g]). However, while total levels were low, the combined level of 3 isomers of the hexachlorocyclohexanes was higher in the bowhead blubber (160 ng/g) tested than in either the pilot whale (47 ng/g), the common dolphin (130 ng/g), and the harbor seal (140 ng/g). These results confirmed results expected due to the lower trophic level of the bowhead relative to the other marine mammals tested.

In the Beaufort Sea multiple-sale EIS in 2003, MMS concluded that the levels of metals and other contaminants measured in bowhead whales appear to be relatively low, with the exception of cadmium. Since the finalization of the multiple-sale EIS, additional information (included in the review presented above) on contaminants in Western Arctic bowheads has become available. This information supports this same general conclusion.

## Offshore Oil- and Gas-Related Activities and other Industrial Activities

Offshore petroleum exploration, development, and production activities have been conducted in Alaska State waters or on the Alaska OCS in the Beaufort and Chukchi seas as a result of previous lease sales since 1979. Extensive 2D seismic surveying has occurred in both program areas. The MMS-permitted seismic surveys have been conducted in the Chukchi and Beaufort seas since the late 1960's and early 1970's. Much more seismic activity has occurred in the Beaufort Sea OCS than in the Chukchi Sea OCS. The 2D marine seismic surveys in the Beaufort Sea began with two exploration geophysical permits issued in 1968 and 4 in 1969. Both over-ice (29 permits) and marine 2D (43 permits) seismic surveys were conducted in the 1970's. With one exception, all 80 marine and 43 over-ice surveys permitted in the Beaufort Sea OCS by MMS in the 1980's were 2D. In the Beaufort Sea, 23 MMS G&G permits were issued in 1982 (11 marine and 12 over-ice 2D surveys) and 24 MMS G&G permits were issued in 1983 (1, 3D over-ice survey; 14, 2-D over-ice surveys; and, 9, 2D marine surveys). The first 3-D on-ice survey occurred in the Beaufort Sea OCS in 1983. In the 1990's, both 2D (2 on-ice and 21 marine) and 3D (11 over-ice and 7 marine OBC) seismic surveys were conducted in the Beaufort Sea. The first marine 3D seismic survey in the Beaufort Sea OCS occurred in 1996. To date, all 3D marine seismic surveys in the Beaufort Sea OCS have been OBC operations. The most exploration geophysical permits issued in any one year in the Chukchi Sea was 7 (6 marine and 1 over ice) in 1986.

Thirty exploratory wells have been drilled in the Federal Beaufort over a 20+ year period between 1981 and 2002. This drilling occurred from a variety of drilling platforms (e.g., gravel islands, SSDC, drillships, etc.) and, during different seasons of the year, including the open water period. The last exploration well drilled in the Beaufort Sea OCS was drilled in the winter of 2002 at the McCovey prospect.

Compared to the North Slope/Beaufort Sea, there has been little oil- and gas-related activity in the Chukchi Sea. There are no existing OCS offshore leases in the Chukchi Sea and, except for the Barrow gas fields (local use only), no substantive existing development. Five exploratory wells have been drilled, all using drillships, in the Chukchi Sea OCS. These wells were drilled between 1989 and 1991, inclusive. The last Chukchi Sea well was drilled in 1991 at the

Diamond Prospect. No seismic survey activity has occurred in the Chukchi Sea since 1991 and there has been no 3D seismic survey activity in the Chukchi Planning Area.

Many of offshore activities also required ice management (icebreaking), helicopter traffic, fixed wing monitoring, other support vessels, and, in some cases stand-by barges.

Available information does not indicate that oil- and gas-related activity (or any recent activity) has had detectable long-term adverse population-level effects on the overall health, current status, or recovery of the Western Arctic population. Data indicate that the Western Arctic population has continued to increase over the timeframe that oil and gas activities has occurred. There is no evidence of long-term displacement from habitat. However, there are no long-term oil and gas developments in the offshore within bowhead high use areas. Northstar is at the southern end of the migratory corridor and Endicott is within the barrier islands. Past behavioral (primarily, but not exclusively, avoidance) effects on bowhead whales from oil and gas activity have been documented in many studies. Inupiat whalers have stated that noise from seismic surveys and some other activities at least temporarily displaces whales farther offshore, especially if the operations are conducted in the main migration corridor. As noted in the section on effects, recent monitoring studies indicated that most fall migrating whales avoid an area with a radius about 20-30 km around a seismic vessel operating in nearshore waters. We are not aware of data that indicate that such avoidance is long-lasting after cessation of the activity.

The MMS study 2002-071 titled *GIS Geospatial Data Base of Oil-Industry and Other Human Activity (1979-1999) in the Alaskan Beaufort Sea* provided a compilation of available data on the location, timing, and nature of oil- and gas-related activities from 1979-1999. It was intended to provide a "…database to address concerns expressed by subsistence hunters and others living within …villages of the Beaufort Sea about the possible effects that oil and gas activity, particularly seismic activity, drilling, and oil and gas support vessel activities may have on the behavior of...especially the bowhead whale." However, "(S)uch an analysis requires an adequate level of detail…", "…there are significant gaps in the data for the period 1979-1989" (Wainwright, 2002:viii) and "(V)ery limited information was obtained on ice management" (Wainwright, 2002:52). For all but 2 years, 1985-1986, during the period 1979-1989, inclusive, Wainwright (2002:Table 2, p. 8) assessed the availability of information about 2D/3D seismic surveys conducted under OCS permit as a 0 out of a possible 3. This score of 0 indicates: "Significant data sets are missing. These data are not suited for statistical analysis." During this same period, they also provide a rank of 0 out of 3 to categorize the completeness and adequacy of information on seismic surveys under state MLUP permit. For the entire period of study (1979-1998), they rate the completeness and adequacy of information on seismic and acoustic surveys in State waters without permits, ice management, and other vessel activity all as 0 (see Wainwright, 2002:Table 2, p. 8). Thus, while data on the bowhead status are adequate to determine that the Western Arctic population apparently continued to recover during the periods when past and current levels of oil and gas activities were occurring, we cannot adequately assess potential effects on patterns or durations of bowhead habitat use. Wainwright (2002:13) summarized that "…it was not possible to compile adequate data on seismic activity prior to 1990." Because of the inadequacy of the data on activities, and because of the limitations inherent in studying large baleen whales, we also cannot assess whether there were any adverse health effects to individuals during the period of relatively intensive seismic survey activity in the 1980's.

Data for the 1990s are better, and the levels of activity are more comparable to those anticipated in the near future. There were no geohazard (high-resolution seismic surveys) surveys during the fall migration period in the 1990s (Wainwright, 2002). Table 4 of Wainwright (2002:45) gives information about the kinds and levels of seismic and acoustic activity in the 1990s. On Figure 11 of Wainwright (2002:41) summarizes that except in 1990 and 1998, seismic surveying activity was completed by September 30th and most of the activity was between September 1-15. During 3 of the years, there was no seismic surveying activity during the fall migration period. Figures 2a through 10c of Wainwright (2002) depict all known seismic, acoustic, and drilling activity during the period of September 1-October 20 from 1990-1998.

Data on past drilling in both federal and state waters is relatively complete, especially since 1990. Data on other activities, such as hunting activity, barge traffic, and shipping noise are incomplete. Thus, while it is clear there have been multiple noise and disturbance sources in the Beaufort Sea over the past 30 years, because of the incompleteness of data, even for the 1990s, for many types of activities, we cannot evaluate the totality of past effects on bowhead whales resulting from multiple noise and disturbance sources (e.g., 2D seismic in state and federal waters, drilling, ice-management, high-resolution acoustic surveys, vessel traffic, construction, geotechnical bore-hole drilling, aircraft surveys, and hunting). Because data are also incomplete for the Chukchi Sea, we reach the same general conclusions.

## IV. EFFECTS OF THE ACTION

One of the greatest concerns associated with the impacts of oil and gas exploration on marine mammals has to do with potential impacts of noise. During OCS oil and gas exploration, human-caused noise is transmitted through the air and through marine waters from a variety of sources including, but not limited to: 2D/3D seismic surveys; pipeline, platform, and related shorebase construction; drilling; icebreakers and other ships, barge transit; high-resolution seismic surveys; and helicopter and fixed-winged aircraft traffic. Because of the importance of this issue, we provide two background sections. The first provides very general information relevant to understanding the fate of noise in the marine environment. The second provides general background about potential types of effects of noise on marine mammals.

### Background on Noise in the Marine Environment

Properties of sound that influence how far that sound is transmitted, what species hear it, and what physical and behavioral effects it can have include the following: its intensity, frequency, amplitude, wavelength, and duration; distance between the sound source and the animal; whether the sound source is moving or stationary; the level and type of background noise; and the auditory and behavioral sensitivity of the species (Richardson et al., 1995a). The frequency of the sound is usually measured in hertz (Hz), pressure level in micropascals (μP) (Gausland, 1998), and intensity levels in decibels (dB) (Richardson et al., 1995a; McCauley et al., 2000). McCauley et al. (2000) and others (see references in McCauley et al., 2000) express this in terms of its equivalent energy decibels re 1 $\mu Pa^2$. The perceived loudness of any given sound is influenced by many factors including both the frequency and pressure of the sound (Gausland, 1998), the hearing ability of the listener, the level of background noise, and the physical environment through which the sound traveled before reaching the animal. Based on summaries in key references (e.g., Richardson et al, 1995a; Gausland, 1998; and Ketten, 1998), and other references as noted, the following information about sound transmission is relevant to understanding potential impacts of sound on marine mammals:

1. Sound travels faster and with less attenuation in water than it does in air.
2. The fate of sound in water can vary greatly, depending on characteristics of the sound itself, characteristics of the location where it is released, characteristics of the environment through which it travels (Richardson et al., 1995a; McCauley et al., 2000), and the characteristics (for example, depth, orientation) of the receiver (Richardson et al., 1995a; Gausland, 1998).
3. Sound propagation can vary seasonally in the same environment.
4. Extrapolation about the likely impacts of a given type of sound source in a given location within the Chukchi Sea or Beaufort Sea OCS Planning Areas on a particular marine mammal, based on published studies conducted elsewhere, are somewhat speculative because characteristics of the marine environment such as bathymetry, sound-source depth, and seabed properties greatly impact the propagation of sound horizontally from the source (McCauley et al., 2000; see also Chapter 4 in Richardson et al., 1995a and references provided therein). Richardson et al. (1995a:425) summarized that: "…a site-specific model of sound propagation is needed to predict received sound levels in relation to distance from a noise source." Especially within the Chukchi Sea Planning Area, differences in site characteristics in different parts of the planning area make predictions about sound propagation relatively difficult.
5. There is a great deal of naturally occurring noise in the ocean from volcanic, earthquake, wind, ice, and biotic sources (see Richardson et al., 1995a:Chapter 5). Ambient noise levels affect whether a given sound can be detectable by a receiver, including a living receiver, such as a whale. Ambient noise levels can change greatly throughout the course of a season at a particular site, and vary from site to site (e.g., see acoustic environment section).
6. Because the air-water interface acts as a good reflector, sound generated underwater generally will not pass to the air (Gausland, 1998).

### General Background on Potential Effects of Noise and Disturbance on Cetaceans

In this section, we provide background about potential effects of impacts of OCS oil- and gas-related noise and disturbance. This section should not be interpreted as indicating effects that are likely to occur due to the proposed actions on the bowhead whale, humpback or fin whale. Hearing (auditory) systems and perception are species specific and habitat dependent. As noted in the previous section, and elsewhere in this evaluation, the fate of sound after it is produced is also site (especially in the arctic), season, and weather specific. Because of these fundamental facts, the potential for a given sound to cause adverse effects to an animal also is species specific and habitat dependent. Because of differences in bathymetry and seabed characteristics of sites throughout the Chukchi Sea and Beaufort Sea Planning Areas, the distances that sounds of various frequencies, intensities, and pressures will propagate, and the resulting effects such sounds could have, also are expected to differ greatly among specific sites (for example, among specific leasing blocks that differ in seabed properties, bathymetry, and the amount of wave action). Thus, the exact location of any sound source will determine the fate of sound released at that site and, therefore, will affect the possibility of impact on threatened and endangered species in or near the area. The time of year such sound is released will determine whether there is potential for individuals of a species to be exposed to that sound.

Many marine mammals rely primarily on hearing for orientation and communication (e.g., Erbe and Farmer, 1998; NRC, 2003, 2005). The scientific community generally agrees that hearing is an important sense used by cetaceans (for example see Richardson et al., 1995; NRC, 2003, 2005; National Resources Defense Council (NRDC), 1999, 2005; Marine Mammal Commission Sound Advisory Panel Minutes from meetings, MMC website). Marine mammals rely on sound to communicate, to find mates, to navigate, to orient (Erbe et al, 1999), to detect predators, and to gain other information about their environment. Because of their reliance on hearing, there is an increasing concern about the impacts of proliferation of anthropogenic noise on marine mammals, especially cetaceans. NMFS (Carretta et al., 2001) summarized that a habitat concern for all whales, and especially for baleen whales, is the increasing level of human-caused noise in the world's oceans. Increased noise levels could interfere with communication among whales, mask important natural sound, cause physiological damage, or alter normal behavior, such as causing avoidance behavior that keeps animals from an important area or displace a migration route farther from shore. Noise from various sources has been shown to affect many marine mammals (e.g. Richardson et al., 1995; Kraus et al., 1997; NRC, 2003; 2005) in ways ranging from subtle behavioral and physiological impacts to fatal effects.

Several important documents that summarize information on this topic include: Richardson et al. (1995a); Hoffman (2002); Tasker et al. (1998); NRC (2003, 2005); National Resources Defense Council (NRDC) (1999, 2005); IWC (2004a). Two particularly relevant summaries by the NRC have occurred within the last few years: *Ocean Noise and Marine Mammals* (NRC, 2003) and Marine *Mammal Populations and Ocean Noise, Determining when Noise Causes Biologically Significant Effects* (NRC, 2005). The IWC (2004) Scientific Committee Standing Working Group on Environmental Concerns held a mini symposium on acoustics with a section of the report dealing with seismic surveying. Lastly, the Marine Mammal Commission (MMC) convened an Advisory Committee on Acoustic Impacts on Marine Mammals which is producing summaries of areas of agreement and disagreement concerning the impacts of noise on marine mammals as well as a summary from a subcommittee on mitigation and management of anthropogenic noise (summaries not available for citation at the time of writing, but minutes of meetings are available on their website).

Results from several experimental studies have been published regarding sound exposure metrics incorporating sound pressure level and exposure duration. Recently, several investigators have examined noise-induced temporary threshold shift (TTS) in hearing in some odontocetes and pinnipeds exposed to moderate levels of underwater noise of various bandwidths and durations. Kastak et al. (2005:3154) summarized that "Because exposure to...noise in the marine environment is sporadic and interrupted, it is necessary to examine variables associated with varying noise sound pressure levels, intermittence of exposure, and total acoustic energy of exposure, in order to accurately predict the effects of noise on marine mammal hearing." However, while there is scientific acknowledgement of this statement, there are few instances where data are sufficient to evaluate the total energy exposure of a marine mammal from a given source. We acknowledge that evaluation of total energy could change our analyses. However, at present, we do not have the data necessary to make such a determination. NMFS (2004) is preparing an EIS to evaluate the impacts of new acoustic criteria for evaluating take under the MMPA.

Despite the increasing concern and attention noted above, there is still uncertainty about the potential impacts of sound on marine mammals, on the factors that determine response and effects, and especially, on the long-term cumulative consequences of increasing noise in the world's oceans from multiple sources (e.g., NRC, 2003, 2005). The NRC (2005) Committee on Characterizing Biologically Significant Marine Mammal Behavior concluded that it is unknown how or in what cases responses of marine mammals to anthropogenic sound rise to the levels of biologically significant effects. This group also developed an approach of injury and behavioral "Take equivalents". These take equivalents use a Severity Index that estimates the fraction of a take experienced by an individual animal. This severity index is higher if the activity could be causing harassment at a critical location or during a critical time (e.g., calving habitat). Because we have uncertainty about exactly where and how much activity will occur in 2006, we incorporate recommendations from the NRC (2005) qualitatively. Available evidence indicates that reaction to sound, even within a species, may depend on the listener's sex and reproductive status, possibly age and/or accumulated hearing damage, type of activity engaged in at the time or, in some cases, group size. For example, reaction to sound may vary depending on whether females have calves accompanying them, or whether individuals are feeding or migrating. It may depend on whether, how often, and in what context, the individual animal has heard the sound before. All of this specificity greatly complicates our ability, in a given situation, to predict the impacts of sound on a species or on classes of individuals within a species. Because of this, and following recommendations in McCauley et al. (2000), we attempt to take a conservative approach in our analyses and base conclusions about potential impacts on potential effects on the most sensitive members of a population. In addition, we make assumptions that sound will travel the maximums observed elsewhere, rather than minimums.

While there is some general information available, evaluation of the impacts of noise on marine mammal species, particularly on cetaceans, is greatly hampered by a considerable uncertainty about their hearing capabilities and the range of sounds used by the whales for different functions (Richardson et al., 1995a; Gordon et al., 1998; NRC, 2003, 2005). This is particularly true for baleen whales. Very little is known about the actual hearing capabilities of the large whales or the impacts of sound on them, especially physical effects. While research in this area is increasing, it is likely that we will continue to have great uncertainty about physiological effects on baleen whales because of the difficulties in studying them. Baleen whale hearing has not been studied directly. There are no specific data on sensitivity, frequency or intensity discrimination, or localization (Richardson et al., 1995a). Thus, predictions about probable impact on baleen whales generally are based on assumptions about their hearing rather than actual studies of their hearing (Richardson et al., 1995a; Gordon et al., 1998; Ketten, 1998). Ketten (1998) summarized that the vocalizations of most animals are tightly linked to their peak hearing sensitivity. Hence, it is generally assumed that baleen whales hear in the same range as their typical vocalizations, even though there are no direct data from hearing tests on any baleen whale. Most baleen whale sounds are concentrated at frequencies less than 1 kHz, but the frequency range in bowhead songs can approach 4,000 Hz (Richardson et al., 1995a). Most calls emitted by bowheads are in the frequency range of 50-400 Hz, with a few extending to 1,200 Hz. Based on indirect evidence, at least some baleen whales are quite sensitive to frequencies below 1 kHz but can hear sounds up to a considerably higher but unknown frequency. Most of the manmade sounds that elicited reactions by baleen whales were at frequencies below 1 kHz (Richardson et al., 1995a). Some or all baleen whales may hear infrasounds, sounds at frequencies well below those detectable by humans. Functional models indicate that the functional hearing of baleen whales extends to 20 Hz, with an upper range of 30

Hz. Even if the range of sensitive hearing does not extend below 20-50 Hz, whales may hear strong infrasounds at considerably lower frequencies. Based on work with other marine mammals, if hearing sensitivity is good at 50 Hz, strong infrasounds at 5 Hz might be detected (Richardson et al., 1995a). Bowhead whales, as well as blue and fin whales, are predicted to hear at frequencies as low as 10-15 Hertz. McDonald, Hildebrand, and Webb (1995) summarize that many baleen whales produce loud low-frequency sounds underwater a significant part of the time. Thus, species that are likely to be impacted by low-frequency sound include baleen whales including bowheads.

Most species also have the ability to hear beyond their peak range. This broader range of hearing probably is related to their need to detect other important environmental phenomena, such as the locations of predators or prey. Ketten (1998:2) summarized that, "The consensus of the data is that virtually all marine mammal species are potentially impacted by sound sources with a frequency of 500 Hertz or higher. This statement refers solely to the probable potential for marine mammal species to hear sounds of various frequencies. If a species cannot hear a sound, or hears it poorly, then the sound is unlikely to have a significant effect. Other factors, such as sound intensity, will determine whether the specific sound reaches the ears of any given marine mammal." Considerable variation exists among marine mammals in hearing sensitivity and absolute hearing range (Richardson et al., 1995; Ketten, 1998). Because of suspected differences in hearing sensitivity, it is likely that baleen whales and pinnipeds are more likely to be harmed by direct acoustic impact from low- to mid-sonic range devices than odontocetes. Conversely, odontocetes are more likely to be harmed by high-frequency sounds.
Little data are available about how most marine mammal species, especially large cetaceans, respond either behaviorally or physically to intense sound and to long-term increases in ambient noise levels, especially over the long term. Large cetaceans cannot be easily examined after exposure to a particular sound source.

Whales often continue a certain activity (for example, feeding) even in the presence of airgun, drilling, or vessel sounds. Such continuation of activity does not confirm that the sound is not harmful to the cetacean. In many or all cases, this may be true: it may not be harmful. However, this type of interpretation is speculative. Whales, other marine mammals, and even humans, sometimes continue with important behaviors even in the presence of noise or other potentially harmful factors. Whales often fast for long lengths of time during the winter. The need to feed or to transit to feeding areas, for example, is possibly so great that they continue with the activity despite being harmed or bothered by the noise. For example, Native hunters reported to Huntington (2000) that beluga whales often ignore the approach of hunters when feeding, but at other times will attempt to avoid boats of hunters.

## Potential damage to hearing

Ketten (1998) reported that hearing loss can be caused by exposure to sound that exceeds an ear's tolerance (i.e., exhaustion or overextension of one or more ear components). Hearing loss to a marine mammal could result in an inability to communicate effectively with other members of its species, detect approaching predators or vessels, or echolocate (in the case of the toothed whales). Hearing loss resulting from exposure to sound often is referred to as a threshold shift. Some studies have shown that following exposure to a sufficiently intense sound, marine mammals may exhibit an increased hearing threshold, a threshold shift, after the sound has ceased (for example, Nachtigall et al., 2004; Kastak et al., 1999; Schlundt et al., 2000;

Finneran et al., 2002). Thus, a threshold shift indicates that the sound exposure resulted in hearing loss causing decreased sensitivity. This type of hearing loss is called a temporary threshold shift if the individual recovers its pre-exposure sensitivity of hearing over time, or a permanent threshold shift if it does not.

Ketten (1998) reported that whether or not a temporary threshold shift or a permanent threshold shift occurs will be determined primarily based on the extent of inner ear damage the received sound and the received sound level causes. In general, whether a given species will tend to be damaged by a given sound depends on the frequency sensitivity of the species. Long-lasting increases in hearing thresholds, which also can be described as long-lasting impairment of hearing ability, could impair the ability of the affected marine mammal to hear important communication signals or to interpret auditory signals. Most experiments have looked at the characteristics (for example, intensity, frequency) of sounds at which temporary threshold shift and permanent threshold shift occurred. However, while research on this issue is occurring, it is still uncertain what the impacts may be of repeated exposure to such sounds and whether the marine mammals would avoid such sounds after exposure even if the exposure was causing temporary or permanent hearing damage if they were sufficiently motivated to remain in the area (for example, because of a concentrated food resource). There are not data on which to determine the kinds or intensities of sound that could cause a TTS in a baleen whale. Permanent threshold shifts are less species dependent and more dependent on the length of time the peak pressure lasts and the signal rise time. Usually if exposure time is short, hearing sensitivity is recoverable. If exposure to the sound is long, or if the sound is broadband in higher frequencies and has intense sudden onset, loss might be permanent. Repeated long exposures to intense sound or sudden onset of intense sounds generally characterize sounds that cause permanent threshold shift in humans. Ketten (1998) stated that age-related hearing loss in humans is related to the accumulation of permanent-threshold-shift and temporary-threshold-shift damage to the ear. The NRC (2005:31) concluded that: "…there is evidence of age-related hearing loss" in marine mammals. A very powerful sound at close range can cause death due to rupture and hemorrhage of tissues in lungs, ears, or other parts of the body. At greater distance, that same sound can cause temporary or permanent hearing loss. Noise can cause modification of an animal s behavior (for example, approach or avoidance behavior, or startle).

Long-term impacts of OCS seismic survey noise on the hearing abilities of individual marine mammals are unknown. Information about the hearing capabilities of large baleen whales is mostly lacking. As noted previously, the assumption is made that the area of greatest hearing sensitivity are at frequencies known to be used for intraspecific communication. However, because real knowledge of sound sensitivity is lacking, we assume in our analyses that sensitivities shown by one species of baleen whale also could apply to another. This assumption is conservative, especially when using studies on a species such as the humpback, which uses a large sound repertoire in intraspecific communication, to infer possible impacts on other species such as the fin whale.

### Masking

When noise interferes with sounds used by the marine mammals (for example, interferes with their communication or echolocation), it is said to "mask" the sound (for example, a call to another whale might be masked by an icebreaker operating at a certain distance away). Noises can cause the masking of sounds that marine mammals need to hear to function (Erbe et al.,

1999). That is, the presence of the masking noise can make it so that the animal cannot discern sounds of a given frequency and at a given level that it would be able to do in the absence of the masking noise. If sounds used by the marine mammals are masked to the point where they cannot provide the individual with needed information, harm can result (Erbe and Farmer, 1998). In the presence of the masking sounds, the sounds the animal needs to hear must be of greater intensity for it to be able to detect and to discern the information in the sound.
Erbe and Farmer (1998:1386) summarize that in "…the human and dolphin ear, low frequencies are more effective at masking high frequencies than *vice versa*; masking is maximum if the characteristic frequencies of the masker are similar to those of the signal…" They proposed that the factor most important for determining the masking effect of the noises was their temporal structure. The noise that was the most continuous with respect to frequency and time masked the beluga vocalization most effectively, whereas sounds (for example, natural icebreaking noise) that occurred in sharp pulses left quiet bands in between and left gaps through which the beluga could detect pieces of the call. In a given environment, then, the impact of a noise on cetacean detection of signals likely would be influenced by both the frequency and the temporal characteristics of the noise, its signal-to-noise ratio, and by the same characteristics of other sounds occurring in the same vicinity (for example, a sound could be intermittent but contribute to masking if many intermittent noises were occurring). It is not known whether (or which) marine mammals can (Erbe and Farmer, 1998) and do adapt their vocalizations to background noise.

### Behavioral Reactions

Available evidence also indicates that behavioral reaction to sound, even within a species, may depend on the listener's sex and reproductive status, possibly age and/or accumulated hearing damage, type of activity engaged in at the time or, in some cases, on group size. For example, reaction to sound may vary depending on whether females have calves accompanying them, whether individuals are feeding or migrating (for example, see discussion of impacts of noise on humpback whales in McCauley et al., 2000, and Section IV.B.1.f(3)(d)2) of the Cook Inlet multiple-sale EIS [USDOI, MMS, 2003b. Response may be influenced by whether, how often, and in what context, the individual animal has heard the sound before. All of this specificity greatly complicates our ability, in a given situation, to predict the behavioral response of a species, or on classes of individuals within a species, to a given sound. Because of this, and following recommendations in McCauley et al. (2000) (discussed above), we attempt to take a conservative approach in our analyses and base conclusions about potential impacts on potential effects on the most sensitive members of a population. In addition, we evaluate the potential for effects on bowheads by making the implicit assumptions that sound may travel the maximums observed, rather than minimums and that whales engaged in a particular activity may respond at the maximum, not the minimum, distances observed in studies to date. However, these assumptions may overestimate potential effect in many cases. However, since at least some of the airgun arrays being proposed for use in the Chukchi and Beaufort Seas in 2006 have greater total output than many of those in previous studies, we may also underestimate impact in some cases.
It is with the aforementioned caveats and level of uncertainty, but based on the best available information about impacts of OCS oil and gas noise on cetaceans from studies conducted elsewhere, that we evaluate potential impacts of oil- and gas-related seismic survey noise and disturbance on bowhead whales.

## Potential Exposure of Bowhead Whales to Seismic Survey Activities

Bowhead whales have documented use of portions of both the Chukchi Sea and Beaufort Sea evaluation areas for: spring and fall migration; feeding; calving; resting; and limited breeding. Most of the calving for this population probably occurs between the Bering Strait and Point Barrow. Bowhead whales have a demonstrated sensitivity to some noise and disturbance, including noise and disturbance from seismic surveys. It is clear that if 2D/3D seismic surveys impacted areas of the spring lead and polynya system during the spring migration, impacts could be potentially biologically significant. We note that the general location of the spring lead system in the Chukchi and Beaufort seas is based on relatively limited survey data and is not well defined. Noise-producing activities, such as seismic surveys, in the spring lead system during the spring bowhead migration have a fairly high potential of affecting the whales, including females with newborn calves.

## Sources of Noise and Disturbance from Seismic Surveys

During OCS oil and gas 2D/3D seismic exploration, human-caused noise can be transmitted through the air and through marine waters from a variety of sources including, but not limited to: the seismic noise sources themselves that purposely release noise into the water; icebreakers, other ships, and boats; high-resolution seismic surveys; and helicopter and fixed-winged aircraft traffic. Endangered cetaceans conceivably could be disturbed or struck by ships or boats during seismic surveys. Small fuel spills could occur. Any or all of these factors potentially could adversely affect bowhead whales in and/or near the Chukchi Sea or Beaufort Sea Planning Areas during OCS oil and gas seismic exploration activities.

Sound from seismic exploration is a potential source of noise disturbance to bowhead in and near areas where the surveys may occur. Marine seismic operations use high-energy airguns to produce a burst of underwater sound from the release of compressed air, which forms a bubble that rapidly expands and then contracts. Typically, seismic sources used in such surveys involve the rapid release of compressed air to produce an impulsive signal that is directed downward through the seabed. Thus, the source for the sound is called an airgun.

Seismic airguns are meant to produce low-frequency noise, generally below 200 Hz. However, the impulsive nature of the collapse of the air bubbles inevitably results in broadband sound characteristics. Goold (1996, cited in Stone, 2001) reported that high-frequency noise is also produced. Goold also found significant levels of energy from airguns across the bandwidth up to 22 kilohertz. Seismic surveys using airguns, especially 2D and 3D seismic surveys, produce at the source, underwater sound levels exceeding those of other activities discussed in this section. This means animals sensitive to either low-frequency or high-frequency sounds may be affected. Bowhead whales emit tonal frequency modulated sounds at 50-400 Hz. A few calls have energy extending to 1,200 Hz. Bowheads also emit pulsive sounds in the frequency range of 25-3,500 Hz, as well as songs of about 20-500 Hz (Richardson et al., 1995a:Table 7). Airgun arrays are designed to focus the sound energy downward. Despite this, sound pulses also are projected horizontally, with the distance traveled depending on many factors, such as those discussed by Richardson et al. (1995a) and McCauley et al. (2000).

Airgun arrays produce short-duration (transient) noise pulses with very high peak levels. The high peak level and impulsive nature of airguns have caused concern in the scientific and environmental communities.

McCauley et al. (2000) concluded that the most consistent measure of a received airgun signal was a measure of its energy, as was suggested by Richardson et al. (199a) for pulsed sounds.

In Alaska, 2D/3D seismic surveying, during which large areas are surveyed to obtain information on the subsurface, are generally undertaken before a proposed lease sale. The 2D/3D seismic surveys are also undertaken after lease sales or between one lease sale and the next. On-lease high-resolution seismic profiling usually is undertaken for engineering purposes to determine the suitability of locations for emplacement of seafloor-founded structures (drilling rigs, platforms, pipelines). The energy level in these types of surveys is much lower than that used in the 2D/3D seismic surveys; thus, the radius of noise exposure is many times smaller. Seismic surveys often employ other activities that may result in an increase in noise and disturbance to whales (see below). Seismic ships have navigational equipment that produces noise, and the ships themselves introduce noise, cause disturbance and may strike cetaceans. Marine vessel traffic and aircraft traffic, in support of the surveys and used in marine mammal monitoring, all introduce noise and disturbance into the marine environment, with potential adverse impacts on the whales.

McCauley et al. (2000) stated that a precise definition of the seabed to at least 50-100 m is required to accurately predict horizontal propagation along a travel path**.** Based on experimental measurement of signals from a single airgun, McCauley et al. (2000) found signal differences of airgun broadband levels of up to 10 dB at a 1-km range. They concluded that such large differences in levels, measured for the same source at a given range within the same bay, demonstrated the importance of localized properties of seabeds in determining sound propagation. Other factors that also can significantly affect sound propagation include the orientation of the receivers (the orientation of living animals could similarly affect reception), alignments and depths of array components and of functioning guns within the array, and airgun source depth. The depth at which the firing airgun is placed plays a crucial role in the potential for propagation. Increasing source depth consistently increased the received signal at any specified receiver depth (for example, the depth of the animal) and horizontal range. If the animal is in a shallow-water area and on the bottom, and the airgun is in much deeper water and downslope from the animal, attenuation will greatly affect the sound the animal will receive. Based on all of the aforementioned, McCauley et al. (2000) concluded that predicting sound propagation from any specified airgun array needs to be done on a case-by-case basis.

Bain (2002) found that approximately one-third of sound levels measured during seismic surveys varied by 6 dB from expected values. Shadow zones caused sound levels lower than expected, and land was an effective barrier to direct sound propagation. Cases of levels higher than expected probably were due to upslope enhancement of sound. Long-range propagation through the Strait of Juan de Fuca was better than expected, resulting in airgun noise being clearly audible at ranges of 60-70 km. This was the longest distance at which signal measurement was attempted, and it is possible that the sound was audible at even greater distances. Bain (2002) reports that high frequencies attenuated faster with distance (this would decrease impacts to beluga whales), and low frequencies were filtered out by propagation through shallow water.

Tolstoy et al. (2004) compared measured versus modeled noise level radii associated with different seismic arrays in shallow and very deep water in the Gulf of Mexico and concluded that models may have been underestimating noise level radii in shallow water and overestimating those in very deep waters. Richardson et al. (1995a:290-291) summarized:

"Underwater sound pulses from airgun arrays and similar sources are often audible many tens of kilometers away." Transient noise from such a survey has been recorded on land seismometer arrays 6,100 km away after traveling the deep sound channel (Okal and Talandier, 1986). However, McDonald, Hildebrand, and Webb (1995) suggest that these same sounds may not have been detectable by a whale near the surface in the mid-Pacific because of entrapment in the deep sound channel. During monitoring using passive acoustics in the mid-Atlantic Ocean, Nieukirk et al. (2004) frequently recorded sounds from seismic airguns from locations more than 3,000 km from their array of autonomous hydrophones moored near the mid-Atlantic Ridge. Trends in the patterns of detection were similar in the two years of monitoring with airguns being detected every 10-20 seconds. Nieukirk et al. (2004:1838) reported that "Although airgun sounds tended to dominate recordings during the summer months, loud whale vocalizations could still be detected during intense airgun activity…The high received level of these impulses on multiple hydrophones made it possible to estimate the location of the ships conducting the airgun surveys."

### Timing of Potential Exposure to Noise and Disturbance from Active Seismic Surveys

In the proposed actions under consideration, we assume that 2D/3D seismic surveys could occur during the entire open water period in the Chukchi Sea and Beaufort Sea, except as restricted by mitigations. Further, ice conditions within the Chukchi would be likely to prevent seismic earlier than July 1 of any year.

Open-water 2D/3D seismic surveys in the Beaufort Sea Planning Area likely would be feasible only in the months of August, September, and October. Depending on the restrictions usually agreed to in past conflict avoidance agreements, it is likely that 2D/3D seismic surveys will not occur after the bowhead westward migration has occurred, except in areas outside of hunting areas or after hunting for a given Beaufort Sea village has ceased. We assume that steps will be taken to avoid an unmitigable adverse effect on the availability of bowhead whales for take for subsistence, or that steps will be taken to avoid unreasonable conflict with such activities. Timing to avoid effects on subsistence takes may amplify disturbance on the whales, since it may concentrate seismic activity in between hunting activity, both spatially and temporally.
In the Chukchi Sea, depending on ice conditions and conflict avoidance requirements, seismic surveys could not begin until July 1 (unless authorized by NMFS) and end in November. Thus, the total period of seismic surveys is likely to be considerably longer in the Chukchi Sea than in the Beaufort Sea.

### High-Resolution Seismic Surveys

High-resolution seismic surveys generally are conducted on lease following a lease sale to evaluate potential shallow hazards and identify seafloor features and resources (e.g., shipwrecks, potential archaeological sites). Vessels used for high-resolution seismic are typically smaller (about 37 to 47 m) than those used for 2D/3D seismic surveys.
Some high-resolution seismic surveys, such as those using airguns, emit loud sounds; but the sounds would not be as loud as sounds from 2D/3D seismic surveys. The sound also would not be likely to propagate as great a distance as sounds from 2D/3D seismic surveys.

A "typical" high-resolution survey involves a ship towing an airgun about 25 m behind the ship and a 600-m streamer cable with a tail buoy. The ship travels at 3-3.5 kn (5.6-6.5 km/h), and the airgun is fired every 7- 8 seconds (or about every 12.5 m). Typical surveys cover one lease block, which is 4.8 km on a side.

### Potential Effects of High-Resolution Seismic

Because high-resolution seismic surveys use relatively lower energy and sound would be less likely to travel as far as sound from 2D/3D seismic surveys, these activities are less likely to have significant effects on endangered whales. Bowheads appear to continue normal behavior at closer distances to high-resolution seismic surveys than to 2D/3D seismic surveys. In the study by Richardson, Wells, and Wursig (1985), four controlled tests were conducted by firing a single 40 in$^3$ (0.66-L) airgun at a distance of 2-5 km (1.2-3.1 mi) from the whales. Bowheads sometimes continued normal activities (skim feeding, surfacing, diving, and travel) when the airgun began firing 3-5 km (1.86-3.1 mi) away (received noise levels at least 118-133 dB re 1 µPa) rms. Some bowheads oriented away during an experiment at a range of 2-4.5 km (1.2-2.8 mi) and another experiment at a range of 0.2-1.2 km (0.12-0.75 mi) (received noise levels at least 124-131 and 124-134 dB, respectively). Frequencies of turns, predive flexes, and fluke-out dives were similar with and without airgun noise; and surfacing and respiration variables and call rates did not change significantly during the experiments.

Because the site-clearance activities are of shorter duration and have a smaller zone of influence than 2D/3D seismic surveys, we believe it unlikely they would result in a biologically significant effect on bowhead whales. A high-resolution survey near a 2D/3D program could result in a concentration of noise and disturbance-producing factors which could keep bowhead whales from high value areas.

### 2D/3D Seismic Surveys.

### Description and Discussion of the Activity

Offshore geophysical exploration seismic surveys conducted in the summer, and on-ice seismic surveys conducted in the winter, are other sources of noise in the arctic marine environment. Airgun arrays are the most common source of seismic survey noise. A typical full-scale array produces a source level of 248-255 dB re 1 µPa -m, zero to peak (Barger and Hamblen, 1980; Johnston and Cain, 1981). These surveys emit loud sounds, which are pulsed rather than continuous, and can propagate long distances (in some habitats, very long distances) from their source. However, most energy is directed downward, and the short duration of each pulse limits the total energy. Received levels within a few kilometers typically exceed 160 dB re 1 µPa (Richardson et al., 1995a), depending on water depth, bottom type, ice cover, etc. We provide a full description of typical 2D/3D seismic surveying operations in Appendix II.

In their application for an Incidental Harassment Authorization, Shell (2005) describes that during their proposed 2006 Beaufort and Chukchi Seas open-water 3D seismic survey in 2006, the seismic vessel will tow two source arrays, comprising three identical subarrays each, which will be fired alternately as the ship sails downline in the survey area. They specify that the ship will tow up to 6 streamer cables up to 5,400 m long. In the Beaufort and Chukchi seas, we anticipate that the seismic vessels will be accompanied by another vessel, which will be used for supplying and other needs, including refueling.

While the seismic airgun pulses are directed towards the ocean bottom, sound propagates horizontally for several kilometers (Greene and Richardson, 1988; Hall et al., 1994). In waters 25-50 m deep, sound produced by airguns can be detected 50-75 km away, and these detection ranges can exceed 100 km in deeper water (Richardson et al., 1995a). Sounds produced by seismic pulses can be detected by mysticetes and odontocetes that are from 10-100 km from the source (Greene and Richardson, 1988; Bowles et al., 1994; Richardson et al., 1995a) or potentially further under some conditions.

Since MMS and NMFS last consulted on either of these two planning areas, new data have been published regarding measured versus modeled noise level radii associated with different seismic arrays in shallow and very deep water (Tolstoy et al., 2004) that indicate models may have been underestimating noise levels in shallow water. Because we explicitly assume that seismic surveys could occur anywhere within any portion of the Beaufort Sea or Chukchi Sea evaluation areas, and because the characteristics of the surveys themselves are likely to vary from those undertaken previously in either planning area, we assume that the propagation characteristics might also vary from those determined during previous seismic activities in these two planning areas. We summarize the information available about noise levels at distance determined or estimated during previous studies in these planning areas (primarily in the Beaufort Sea) and present and consider also the levels measured by Tolstoy et al. (2004).

In the Biological Evaluation prepared for Beaufort OCS Lease Sale 195 in 2003, MMS concluded that, "Geophysical surveys conducted in conjunction with proposed Lease Sale 195 are likely to cover much smaller areas to fill in gaps from earlier seismic surveys. Also, some of the seismic work that may be needed may be conducted when whales are not present in the area." However, recent interest in 2D/3D seismic exploration by oil and gas companies in the Beaufort and Chukchi Seas indicate that this assumption is no longer true. We now expect regular 2D/3D, as well as high-resolution seismic survey activity in Federal waters of the Beaufort Sea over the next 5 years. We expect this level of activity to be greater than that during the period of the previous 5 years (2000-2005). However, new seismic survey activity is expected to be mostly 3D seismic. We still expect that some of the seismic survey work will be conducted when whales are not present. However, at present, much of the proposed seismic survey work in both the Beaufort Sea and Chukchi Sea Planning Areas is expected to be open water 2D or 3D seismic surveys using streamers.

## Potential Effects of 2D/3D Seismic Surveys on Bowhead Whales

Numerous studies have been conducted on the effects of noise from seismic surveys on bowhead whales. The results from these studies have varied, in some cases considerably. Among some of these studies important variables were different. These included the type of seismic survey (2D versus 3D), the location of the study, and the year in which the study was conducted. Ice (and other weather-related factors) also varies among years as does the use of total available habitat by bowhead whales. Some of the studies employed different methodologies, some of which have been criticized by peer reviewers and others of which are more widely adopted. Because of the importance of the issue of potential noise disturbance of bowhead whales, we provide considerable detail on these studies below. However, we preface this section with an observation: In numerous reports regarding whale response to sound, it has been shown that multiple factors may be important in the whale's response (e.g., McCauley et al., 2000). In some studies, these factors have been shown to include (but may not be limited

to): the physical characteristics of the location into which the sound is released and the physical characteristics of the location where the whale is located at the time the sound is released; the whale's sex and reproductive condition (e.g., groups with or without calves); the behavior of the whale (e.g., migrating or feeding); specific characteristics of the sound (e.g., frequency, duration, whether impulsive or not, etc.), and prior exposure to the sound.
Thus, the fact that results from different studies of bowhead response to oil and gas-related sound have varied is not surprising. The studies involving the response of bowheads to 3D marine streamer seismic surveys are most relevant to evaluating the potential effects of the proposed action.

During the 1980's, the behavior of bowhead whales exposed to noise pulses from seismic surveys was observed during the summer in the Canadian Beaufort Sea and during the fall migration across the Alaskan Beaufort Sea. In general, many of the seismic surveys conducted during the 1980's were 2D seismic surveys that covered fairly large areas in deeper waters. Additional studies on seismic surveys were conducted in the central Alaskan Beaufort Sea during the fall migration in 1996-1998. These surveys were 3D ocean bottom cable (OBC) seismic surveys that covered fairly small areas in relatively shallow water fairly close to shore. Reeves, Ljungblad, and Clarke (1983) conducted aerial surveys to observe bowhead whale behavior in the presence of active seismic vessels. Whales were observed as close as 3 km (1.86 mi) and as far away as 135 km (83.9 mi) from active seismic vessels. A pair of whales observed at a distance of 3 km (1.83 mi) were not moving while at the surface although the two whales' heads were in contact. This pair of whales was closer to a shooting seismic vessel than any other whales observed during the study. No obvious response was apparent, but the observation time was brief. (The received level of low-frequency underwater sound from an underwater source, generally is lower by 1-7 dB near the surface (depth of 3 m) than at deeper (greater than 9 m) depths (Richardson et al., 1995a). It is possible these whales may have been at the surface to avoid the louder noise in deeper water. For the group of 20 whales at a distance of approximately 135 km (83.9 mi), the blow frequency per surfacing and time at the surface were greater during the period immediately after the seismic vessel began shooting than before it began shooting. The authors stated that no major changes in whale behavior (such as flight reactions) were observed that could unequivocally be interpreted as responses to seismic noise. They noted a possible exception of "huddling behavior", which they thought may have been caused by the onset of seismic sounds. The authors concluded that although their results suggest some changes in behavior related to seismic sounds, the possibility that unquantified factors could be correlative dictates caution in attempting to establish causative explanations from the preliminary findings.

Ljungblad et al. (1985) also reported findings from early tests of bowhead reactions to active seismic vessels in the Beaufort Sea. However, methodological problems with this early study preclude us from drawing conclusions about probable bowhead reactions based on its findings. A subcommittee of the Scientific Committee of the IWC previously reviewed the data from this study and some members were critical of the methodology and analysis of the results. Comments included reference to: the small sample size; inconsistencies between the data and the conclusions; lack of documentation of calibration of sound monitoring; and possible interference from other active seismic vessels in the vicinity. The subcommittee acknowledged the difficulty of performing experiments of this kind, particularly in the absence of a control environment free of industrial noise. The subcommittee recommended that additional research taking into account the concerns expressed above be undertaken, and that the 1984 experimental results be subjected to rigorous reanalysis, before it could be used to draw any conclusions about the effects of seismic activity on this species (IWC, 1987).

In the May 25, 2001 Biological Opinion for Federal Oil and Gas Leasing and Exploration by the MMS within the Alaskan Beaufort Sea and its effects on the endangered bowhead whale, NMFS (2001:20) noted that early tests of bowhead reactions to active seismic vessels by Ljungblad et al. (1985):
…<u>were not conducted under controlled conditions (i.e., other noise sources were operating at the time), and approaches at greater ranges were not conducted, so results cannot be used to determine the range at which the whales first begin to respond to seismic activity.</u>

In Fraker et al. (1985), an active seismic vessel traveled toward a group of bowheads from a distance of 19 km (11.8 mi) to a distance of 13 km (8.18 mi). The whales did not appear to alter their general activities. Most whales surfaced and dove repeatedly and appeared to be feeding in the water column. During their repeated surfacing and dives, they moved slowly to the southeast (in the same direction as seismic-vessel travel) and then to the northwest (in the opposite direction of seismic-vessel travel). The study first stated that a weak avoidance reaction may have occurred but then stated there is no proof that the whales were avoiding the vessel. The net movement was about 3 km (1.86 mi). The study found no evidence of differences in behavior in the presence and absence of seismic noise, but noted that observations were limited.

In another study (Richardson, Wells, and Wursig, 1985) involving a full-scale seismic vessel with a 47-L airgun array (estimated source level 245-252 dB re 1 μPa), bowheads began to orient away from the approaching ship when its airguns began to fire from 7.5 km (4.7 mi) away. This airgun array had about 30 airguns, each with a volume of 80-125 in$^3$. The *Mariner* had been shooting seismic about 10 km to the west of a group of six whales. Prior to the start of the experimental seismic period, the whales were surfacing and diving and moving at slow to medium speed while at the surface. The vessel ceased shooting and moved within 7.5 km of the whales and began firing the airgun array while approaching the whales. The study reported no conspicuous change in behavior when the *Mariner* resumed shooting at 7.5 km away. The bowheads continued to surface and dive, moving at slow to medium speeds. The received level was estimated at 134-138 dB at 7 km (4.35 mi). Some near-bottom feeding (evidenced by mud being brought to the surface) continued until the vessel was 3 km (1.86 mi) away. The closest point of approach to any whale was approximately 1.5 km (0.93 mi), with the received level probably well over 160 dB. When the seismic vessel was within 1.5 km of whales at the original location, at least two of the whales were observed to have moved about 2 km to the south of the original location. The movements of the whales, at least while they were at the surface, were at the usual slow to moderate speeds. The study reported no conspicuous changes in behavior when the *Mariner* ceased shooting at 6 km beyond the whales. The bowheads were still surfacing and diving and moving at slow to medium speed. The most notable change in behavior apparently involved the cessation of feeding when the vessel was 3 km away. The whales began feeding again about 40 minutes after the seismic noise ceased.

While conducting a monitoring program around a drilling operation, Koski and Johnson (1987) noted that the call rate of a single observed bowhead whale increased after a seismic operation had ceased. During the 6.8 hours of observation, the whale was within 23-27 km (14.3-16.8 mi) from the drillship. A seismic vessel was reported to be from 120-135 km (74.58-83.9 mi) from the sonobuoy; the two loudest calls received were determined to be approximately 7 km (4.35 mi) and 9 km (5.6 mi) from the sonobuoy, with received levels of 119 and 118 dB, respectively. Approximate signal-to-noise ratios were 24 and 22 dB, respectively. No information is provided regarding the exact distance the whale was from the operating seismic vessel. The increase in call rate was noted within 25 minutes after seismic noise ceased. It also needs to be noted that there were few, if any, calls heard during the 2 hours prior to the start of seismic operations, so it is unclear whether the increase in call rate relates to cessation of seismic noise, the presence of the operating drillship, the combination of both activities, or some other factor that occurred in the late afternoon. During this same study a subgroup of four to seven whales within a larger group (15-20 whales) was noted moving rapidly away from an approaching seismic vessel at a distance of 22-24 km (13.7-14.9 mi). The received level of seismic pulses was 137 dB at 19 km (11.8 mi) from the sonobuoy and 22 km from the whales. The surfacing and diving were unusually brief, and there were unusually few blows per surfacing. No information was available regarding the time required for these whales to return to normal behavior.

The North Slope Borough (NSB) believes that many studies were different from the real-world situation, and various limitations have been pointed out. Most studies did not involve actively migrating whales; and those whales were being approached by the seismic ships whereas in the real world, the fall migrating whales are actively moving to the west and they are approaching a distant seismic boat that is firing. The MMS has noted that many studies were observational and involved opportunistic sightings of whales in the vicinity of seismic operations. The studies were not designed to show whether more subtle reactions are occurring that can displace the migration corridor, so no definitive conclusions can be drawn from them on whether or not the overall fall migration is displaced by seismic activity.

Based on early data, Richardson and Malme (1993) concluded that collectively, scientific studies have shown that most bowheads usually show strong avoidance response when an operating seismic vessel approaches within 6-8 km (3.8-5.0 mi). Strong avoidance occurs when received levels of seismic noise are 150-180 dB re 1 µPa (Richardson and Malme, 1993). Strong pulses of seismic noise often are detectable 25-50 km (15.5-31 mi) from seismic vessels, but in early studies, bowheads exposed to seismic sounds from vessels more than about 7.5 km (4.7 mi) away rarely showed avoidance. Seismic pulses can be detectable 100 km (62.2 mi) or more away. Bowheads also may show specific behavioral changes, such as reduced surfacing; reduced dive durations; changes in respiration rates, including fewer blows per surfacing, and longer intervals between successive blows; and they may temporarily change their individual swimming paths. The authors noted that surfacing, respiration, and dive cycles may be altered in the same manner as those of whales closer to the vessels. Bowhead surface-respiration-dive characteristics appeared to recover to pre-exposure levels within 30-60 minutes following the cessation of the seismic activity.

Inupiat whalers suggested that the fall bowhead migration tended to be farther offshore when there was abundant seismic work off northern Alaska. Aerial surveys have been conducted since 1979 to determine the distribution and abundance of bowhead whales in the Beaufort Sea during their fall migration. These surveys have been used for comparing the axis of the bowhead whale migration between years. Survey data from 1982-1987 were examined to determine whether industrial activity was resulting in displacement of bowhead whales farther offshore (Ljungblad et al., 1988). It was determined that a good indicator of annual shifts in bowhead distribution could be obtained by analyzing the distance of random bowhead sightings from shore (Zeh, as cited in Ljungblad et al., 1988). An analysis of the distance of random bowhead sightings from shore (a total of 60 bowhead sightings) was conducted, but no significant differences were detected in the bowhead migratory route between years. The axis of the bowhead migratory route near Barrow was found to fall between 18 and 30 km (7.76 and 18.6 mi) from shore. Although the analysis involved a relatively small sample size, these observations provide some insight into migration patterns during these years. The NSB, in a letter dated July 25, 1997, questioned the sample size and the precision of the Ljungblad et al. (1988) report to determine whether or not a displacement of fall migrating whales had occurred and how big a displacement would have to be before it could be detected.

Using larger sample sizes (for which confidence intervals were calculated) obtained over a larger study area, the aerial survey project found many between-year (1982-1996) differences in the median water depth at whale sightings that were highly significant (P less than 0.05) (Treacy, 1997). Median depths ranged between 18 m (59 ft) in 1989 and 347 m (1,138 ft) in 1983, with an overall cumulative depth of 37 m (121 ft, confidence interval = 37-38 m). The aerial survey project has reported a potential association between water depth of the bowhead migration and general ice severity, especially in 1983, when severe ice cover may have forced the axis of the migration into waters 347 m (1,138 ft) deep. To address short-term bowhead whale displacement within a given year from site-specific industrial noise, MMS and NMFS require industry to conduct site-specific monitoring programs when industrial activity occurs in the Beaufort Sea Planning Area during fall bowhead migrations.

Since 1996, many of the open water seismic surveys in State of Alaska waters and adjacent nearshore Federal waters of the central Alaskan Beaufort Sea were ocean-bottom cable surveys. These surveys were 3D seismic programs. The area to be surveyed is divided into patches, each patch being approximately 5.9 by 4.0 km in size. Within each patch, several receiving cables are laid parallel to each other on the seafloor. Seismic data are acquired by towing the airguns along a series of source lines oriented perpendicular to the receiving cables. While seismic-data acquisition is ongoing on one patch, vessels are deploying cable on the next patch to be surveyed and/or retrieving cables from a patch where seismic surveys have been completed. Airgun arrays have varied in size each year from 1996-1998 with the smallest, a 560 $in^3$ array with 8 airguns, and the largest, a 1,500 $in^3$ array with 16 airguns. A marine mammal and acoustical monitoring program was conducted in conjunction with the seismic program each year in accordance with provisions of the NMFS Incidental Harassment Authorization. Based on 1996-1998 data, there was little or no evidence that bowhead headings, general activities, or swimming speeds were affected by seismic exploration. Bowheads approaching from the northeast and east showed similar headings at times with and without seismic operations. Miller et al. (1999) stated that the lack of any statistically significant differences in headings should be interpreted cautiously. Changes in headings must have occurred given the avoidance by most bowheads of the area within 20 or even 30 km of active seismic operations. Miller et al. (1999) noted that the distance at which deflection began cannot be determined precisely, but they stated that considering times with operations on offshore patches, deflection may have begun about 35 km to the east. However, some bowheads approached within 19-21 km of the airguns when they were operating on the offshore patches. It appears that in 1998, the offshore deflection might have persisted for at least 40-50 km west of the area of seismic operations. In contrast, during

1996-1997, there were several sightings in areas 25-40 km west of the most recent shotpoint, indicating the deflection in 1996-1997, may not have persisted as far to the west.

LGL Ltd.; Environmental Research Assocs., Inc.; and Greeneridge Sciences Inc. conducted a marine mammal monitoring program for a seismic survey near the Northstar Development Project in 1996 (Miller et al., 1997). The marine mammal monitoring program was continued for subsequent seismic surveys in nearshore waters of the Beaufort Sea in 1997 and 1998 (Miller, Elliot, and Richardson, 1998; Miller et al., 1999). Details of these studies are provided in the Beaufort Sea multiple-sale final EIS. These studies indicated that the bowhead whale-migration corridor in the central Alaskan Beaufort Sea during 1998 was similar to the corridor in many prior years, although not 1997. In 1997, nearly all bowheads sighted were in relatively nearshore waters. The results of the 1996-1998 studies indicated a tendency for the general bowhead whale-migration corridor to be farther offshore on days with seismic airguns operating compared to days without seismic airguns operating, although the distances of bowheads from shore during airgun operations overlapped with those in the absence of airgun operations. Aerial-survey results indicated that bowheads tended to avoid the area around the operating source, perhaps to a radius of about 20-30 km. Sighting rates within a radius of 20 km of seismic operations were significantly lower during seismic operations than when no seismic operations were happening. Within 12-24 hours after seismic operations ended, the sighting rate within 20 km was similar to the sighting rate beyond 20 km. There was little or no evidence of differences in headings, general activities, and swimming speeds of bowheads with and without seismic operations. Overall, the 1996-1998 results show that most bowheads avoided the area within about 20-30 km of the operating airguns. Within 12-24 hours after seismic operations ended, the sighting rate within 20 km was similar to the sighting rate beyond 20 km.
The observed 20-30 km area of avoidance is a larger avoidance radius than documented by previous scientific studies in the 1980s and smaller than the 30 mi suggested by subsistence whalers, based on their experience with the types of seismic operations that occurred in the Beaufort Sea before 1996 (Richardson, 2000). The seismic activities in the 1980s were 2D in deeper water. Recent seismic activities were 3D OBC concentrated in shallow water.
Based on recordings of bowhead whale calls made during these same studies, Greene et al. (1999), summarized that results for the 3 years of study indicated that: (1) bowhead whales call frequently during the autumn migration through the study area; (2) calling continued at times when whales were exposed to airgun pulses; and (3) call-detection rates at some locations differed significantly when airguns were detectable versus not detectable. However, there was no significant tendency for the call-detection rate to change in a consistent way at times when airguns started or stopped.

Richardson provided a brief comparison between observations from seismic studies conducted in the 1980s and the 1996 seismic survey at the Arctic Seismic Synthesis Workshop in Barrow (USDOI, MMS, 1997). Observations from earlier seismic studies during the summer and early autumn show that most bowhead whales interrupt their previous activities and swim strongly away when a seismic ship approaches within about 7.5-8 km. At the distances where this strong avoidance occurs, received levels of seismic pulses typically are high, about 150-180 dB re 1 μPa. The surfacing, respiration, and dive cycles of bowheads engaged in strong avoidance also change in a consistent pattern involving unusually short surfacing and diving and unusually few blows per surfacing. These avoidance and behavioral effects among bowheads close to seismic vessels are strong, reasonably consistent, and relatively easy to document. Less consistent and weaker disturbance effects probably extend to longer distances and lower received sound levels at least some of the time. Bowheads often tolerate much seismic noise and, at least in summer, continue to use areas where seismic exploration is common. However, at least one case of strong avoidance has been reported as far as 24 km from an approaching seismic boat (Koski and Johnson, 1987) and, as noted above, the aerial survey data (Miller et al., 1999) indicated that bowheads tended to avoid the area around the operating source, perhaps to a radius of about 20-30 km. Richardson noted that many of the observations involved bowheads that were not actively migrating. Actively migrating bowheads may react somewhat differently than bowheads engaged in feeding or socializing. Migrating bowheads, for instance, may react by deflecting their migration corridor away from the seismic vessel. Monitoring of the bowhead migration past a nearshore seismic operation in September 1996 provided evidence consistent with the possibility that the closest whales may have been displaced several miles seaward during periods with seismic activity.

With respect to these studies conducted in the Beaufort Sea from 1996-1998, the peer-review group at the Arctic Open-Water Noise Peer Review Workshop in Seattle from June 5-6, 2001, prepared a summary statement supporting the methods and results reported in Richardson (1999) concerning avoidance of seismic sounds by bowhead whales:
Monitoring studies of 3-D seismic exploration (8-16 airguns totaling 560-1,500 in$^3$) in the nearshore Beaufort Sea during 1996-1998 have demonstrated that nearly all bowhead whales will avoid an area within 20 km of an active seismic source, while deflection may begin at distances up to 35 km. Sound levels received by bowhead whales at 20 km ranged from 117-135 dB re 1 µPa rms and 107-126 dB re 1 µPa rms at 30 km. The received sound levels at 20-30 km are considerably lower levels than have previously been shown to elicit avoidance in bowhead or other baleen whales exposed to seismic pulses.

A recent study in Canada provides recent information on the behavioral response of bowhead whales in feeding areas to seismic surveys (Miller and Davis, 2002). During the late summer and autumn of 2001, Anderson Resources Ltd. conducted an open-water seismic exploration program offshore of the Mackenzie Delta in the Canadian Beaufort Sea. The program consisted of streamer seismic surveys and associated bathymetric surveys conducted off the Mackenzie Delta. The bathymetric surveys were conducted by two medium-sized vessels equipped with side-scan sonar and single-beam echo sounders. The seismic vessel was the *Geco Snapper*. The acoustic sources used in the seismic operations were two 2,250 in$^3$ arrays of 24 sleeve-type airguns. Each 2,250 in$^3$ airgun array was comprised of 24 airguns with volumes ranging from 40-150 in$^3$. The two airgun arrays fired alternately every 8 seconds along the survey lines. The airgun arrays were operated at a depth of 5 m below the water surface. Water depths within the surveyed areas ranged from 6-31 m and averaged 13 m (Miller, 2002). Because marine seismic projects using airgun arrays emit strong sounds into the water and have the potential to affect marine mammals, there was concern about the acoustic disturbance of marine mammals and the potential effects on the accessibility of marine mammals to subsistence hunters. Although there are no prescribed marine mammal and acoustic monitoring requirements for marine seismic programs in the Canadian Beaufort Sea, it was decided that monitoring and mitigation measures in the Canadian Beaufort Sea should be as rigorous as those designed and implemented for marine seismic programs conducted in the Alaskan Beaufort Sea in recent years. The monitoring program consisted of three primary components: acoustic measurements, vessel-based observations, and aerial surveys. The NMFS-recommended criterion that exposure of whales to impulse sound not exceed 180 dB re 1 Pa rms (65 *FR* 16374) was adopted as a mitigation standard for this monitoring program. Estimates of sound-propagation loss from the airgun array were used to determine the designated 1,000-m safety radius for whales (the estimated zone within which received levels of seismic noise were 180 dB re 1μPa rms or higher).

Aerial and vessel-based surveys confirmed the presence of substantial numbers of bowheads offshore of the Mackenzie Delta from late August until mid-September. The distribution of bowheads in the study area was typical of patterns observed in other years and suggests that there were good feeding opportunities for bowheads in these waters during that period. A total of 262 bowheads were observed from the seismic vessel *Geco Snapper* (Moulton, Miller, and Serrano, 2002). Sighting rates during daylight hours were higher when no airguns were operating than during periods with airguns operating. During the period when bowheads were most abundant in the study area (August 23-September 19), the bowhead sighting rate during periods with no seismic (0.85 bowheads/hour) was about twice as high as that recorded during periods with seismic (0.40 bowheads/h) or all seismic operations combined (0.44 bowheads/h). Average sighting distances from the vessel were significantly ($P < 0.001$) lower during no airguns (a mean radial distance of 1,368 m) versus line-seismic periods (a mean radial distance of 1,957 m). The observed difference in sighting rates and the significant difference in sighting distances suggest that bowheads did avoid close approach to the area of seismic operations. However, the still substantial number of sightings during seismic periods and the relatively short (600 m) but significant difference in sighting distances suggests that the avoidance may have been localized and relatively small in nature. At a minimum, the distance by which bowheads avoided seismic operations was on the order of 600 m greater than the average distance by which they avoided general vessel operations. The lower sighting rates recorded during seismic operations suggest that some bowheads avoided the seismic operations by larger distances and, thereby, stayed out of visual range of the marine mammal observers on the *Geco Snapper*.

In this study, a total of 275 bowhead whale sightings were recorded during aerial transects with good lighting conditions (Holst et al., 2002). Bowheads were sighted at similar rates with and without seismic, although the no feeding-seismic sample was too small for meaningful comparisons. Bowheads were seen regularly within 20 km of the operations area at times influenced by airgun pulses. Of 169 transect sightings in good conditions, 30 sightings were seen within 20 km of the airgun operations at distances of 5.3-19.9 km. The aerial surveys were unable to document bowhead avoidance of the seismic operations area. The area of avoidance around the seismic operations area was apparently too small to be evident from the broadscale aerial surveys that were flown, especially considering the small amount of surveying done when seismic was not being conducted. General activities of bowheads during times when seismic operations were conducted were similar to times without seismic.

The bowheads that surfaced closest to the vessel (323-614 m) would have been exposed to sound levels of about 180 dB re 1 μPa rms before the immediate shutdown of the array (Miller et al., 2002). There were seven shutdowns of the airgun array in response to sightings of bowheads within 1 km of the seismic vessel. Bowheads at the average vessel-based sighting distance (1,957 m) during line seismic would have been exposed to sound levels of about 170 dB re 1 μPa rms. The many aerial sightings of bowheads at distances from the vessel ranging from 5.3-19.9 km would have been exposed to sound levels ranging from approximately 150-130 dB re 1 µPa rms, respectively.

The results from the study in summer 2001 are markedly different from those obtained during similar studies during the autumn migration of bowheads through the Alaskan Beaufort Sea (Miller et al., 2002). For example, during the Alaskan studies only 1 bowhead whale was observed from the seismic vessel(s) during six seasons (1996-2001) of vessel-based observations compared with 262 seen from the *Geco Snapper* in 2001. The zone of avoidance for bowhead whales around the airgun operations in 2001 was clearly much smaller (~2 km) than that observed for migrating bowhead whales in recent autumn studies in Alaskan waters (up to 20-30 km). Davis (1987) concluded that migrating bowheads during the fall migration may be more sensitive to industrial disturbance than bowheads on their summering grounds, where they may be engaged in feeding activities.

Inupiat subsistence whalers have stated that industrial noise, especially noise due to seismic exploration, has displaced the fall bowhead migration seaward and, thereby, is interfering with the subsistence hunt at Barrow (Ahmaogak, 1989). Whalers have reported reaction distances, where whales begin to divert from their migratory path, on the order of 10 mi (T. Albert cited in USDOI, MMS, 1995) to 35 mi (F. Kanayurak in USDOI, MMS, 1997. Kanayurak stated that the bowheads "…are displaced from their normal migratory path by as much as 30 miles." Also at the March 1997 workshop, Mr. Roxy Oyagak, Jr., a Nuiqsut whaling captain, stated in written testimony:
"Based on the industrial activity, there is an unmitigable adverse impact on the village of Nuiqsut on subsistence whaling. i.e., 1) by causing the whales to abandon the hunting area …and 3) placing physical barriers between the subsistence whalers and marine mammals, including altering the normal bowhead whale migration route."

Data available from MMS' BWASP surveys over about a 27 year period indicate that, at least during the primary open water period during the autumn (when open water seismic activities are most likely to occur), there are areas where bowheads are much more likely to be encountered and where aggregations, including feeding aggregations and/or aggregations with large numbers of females and calves, are more likely to occur in the Beaufort . Such areas include the areas north of Dease Inlet to Smith Bay, northeast of Smith Bay, and Northeast of Cape Halkett, as well as areas near Brownlow Point. Such aggregations have been observed in multiple years during BWASP surveys. However, in some years no large aggregations of bowheads were seen anywhere within the study area. In their Biological Evaluation, the MMS voiced particular concern for the potential for seismic to impact significant life history stages of bowhead whales. If 2D/3D seismic surveys occurred in these areas when large aggregations were present, and particularly if multiple 2D/3D seismic surveys occurred concurrently in these areas, MMS concluded either hundreds of whales could be excluded (through avoidance) from a large area for a relatively long portion of the season, or many more individuals would likely avoid the area as they sequentially came in to use the area.

We are aware that the extent of avoidance will vary both due to the actual noise level radii around each seismic vessel, the context in which it is heard, and the motivation of the animal to stay within the area. It also may vary depending on the age, and most likely, the sex and reproductive status of the whale. It may be related to whether subsistence hunting has begun and/or is ongoing. Because the areas where large aggregations of whales have been observed during the autumn also are areas used, at least in some years, for feeding, it may be that the whales would show avoidance more similar to that observed in studies of whales on their summer feeding grounds. However, as noted above, it is not clear that reduced avoidance should be interpreted as a reduction in impact. It may be that bowheads are so highly motivated to stay on a feeding ground that they remain at noise levels that could, with long term exposure, cause adverse effects.

Seismic activity should have little effect on zooplankton. Bowheads feed on concentrations of zooplankton. Zooplankton that are very close to the seismic source may react to the shock wave, but little or no mortality is expected (LGL Ltd., 2001). A reaction by zooplankton to a seismic impulse would be relevant only if it caused a concentration of zooplankton to scatter. Pressure changes of sufficient magnitude to cause zooplankton to scatter probably would occur only if they were very close to the source. Impacts on zooplankton behavior are predicted to be negligible and would have negligible effects on feeding bowheads (LGL Ltd., 2001).

Various vessels are necessary to support seismic work, and may impact bowhead whales. Bowheads react to the approach of vessels at greater distances than they react to most other industrial activities. According to Richardson and Malme (1993), most bowheads begin to swim rapidly away when vessels approach rapidly and directly. This avoidance may be related to the fact that bowheads have been commercially hunted within the lifetimes of some individuals within the population and they continue to be hunted for subsistence throughout many parts of their range. Avoidance usually begins when a rapidly approaching vessel is 1-4 km (0.62-2.5 mi) away. A few whales may react at distances from 5-7 km (3-4 mi), and a few whales may not react until the vessel is less than 1 km (less than 0.62 mi) away. Received noise levels as low as 84 dB re 1 μPa (rms) or 6 dB above ambient may elicit strong avoidance of an approaching vessel at a distance of 4 km (2.5 mi) (Richardson and Malme, 1993).
In the Canadian Beaufort Sea, bowheads observed in vessel-disturbance experiments began to orient away from an oncoming vessel at a range of 2-4 km (1.2-2.5 mi) and to move away at increased speeds when approached closer than 2 km (1.2 mi) (Richardson and Malme, 1993). Vessel disturbance during these experimental conditions temporarily disrupted activities and sometimes disrupted social groups, when groups of whales scattered as a vessel approached. Reactions to slow-moving vessels, especially if they do not approach directly, are much less dramatic. Bowheads often are more tolerant of vessels moving slowly or in directions other than toward the whales. Fleeing from a vessel generally stopped within minutes after the vessel passed, but scattering may persist for a longer period. After some disturbance incidents, at least some bowheads returned to their original locations (Richardson and Malme, 1993). Some whales may exhibit subtle changes in their surfacing and blow cycles, while others appear to be unaffected. Bowheads actively engaged in social interactions or mating may be less responsive to vessels.

Bowhead whales could encounter noise and disturbance from multiple seismic vessels and multiple support vessels as they migrate and feed in the Beaufort and Chukchi Seas. The significance of such encounters is expected to depend on the area in which the vessels are transiting, the total number of vessels in the area, the presence of other vessels (see cumulative effects section), and variables already identified regarding the number, behavior, age, sex and reproductive condition of the whales. Depending on ice conditions, it is likely that vessels actively involved in ice management or moving from one site to another would be more disturbing to whales than vessels idling or maintaining their position. In either case, bowheads probably would adjust their individual swimming paths to avoid approaching within several kilometers of vessels attending a drilling unit and probably would move away from vessels that approached within a few kilometers. Vessel activities associated with exploration are not expected to disrupt the bowhead migration. Small deflections in individual bowhead-swimming paths and a reduction in use of possible bowhead-feeding areas near exploration units may result in adverse effects on the species. During their spring migration (April through June), bowheads likely would encounter few, if any, vessels along their migration route, because ice at this time of year typically would be too thick for seismic-survey ships and supply vessels to operate in. Because MMS is not allowing seismic shooting in the spring lead system until July 1 unless authorized by NMFS, we do not expect seismic survey vessel interaction to be an important source of disturbance during the northward migration.

In addition to acting as a source of noise and disturbance, marine vessels could potentially strike bowhead whales, causing injury or death. As noted in the baseline section of this evaluation, available information indicates that current rates of vessel strikes of bowheads are low. At present, available data do not indicate that strikes of bowheads by oil and gas-related vessels will become an important source of injury or mortality in the Beaufort Sea Planning Area. Risk of strikes would increase as vessel traffic in bowhead habitat increases. We assume travel corridors would be established to minimize the amount of bowhead habitat that would be affected by oil and gas-related vessel traffic. If oil and gas-related vessel traffic increases substantially in areas commonly frequented by bowhead whales during periods when the bowheads are present, vessel strike rates should be carefully monitored.

If seismic survey vessels are attended by icebreakers involving active ice management, additional disturbance and noise will be introduced by the noise of the icebreaker. There are no observations of bowhead reactions to icebreakers breaking ice. Response distances would vary, depending on icebreaker activities and sound-propagation conditions. Based on models, bowhead whales likely would respond to the sound of the attending icebreakers at distances of 2-25 km (1.24-15.53 mi) from the icebreakers (Miles, Malme, and Richardson, 1987). Zones of responsiveness for intermittent sounds, such as an icebreaker pushing ice have not been studied. This study predicts that roughly half of the bowhead whales show avoidance response to an icebreaker underway in open water at a range of 2-12 km (1.25-7.46 mi) when the sound-to-noise ratio is 30 dB. The study also predicts that roughly half of the bowhead whales would show avoidance response to an icebreaker pushing ice at a range of 4.6-20 km (2.86-12.4 mi) when the sound-to-noise ratio is 30 dB. Richardson et al. (1995b) found that bowheads migrating in the nearshore lead often tolerated exposure to projected icebreaker sounds at received levels up to 20 dB or more above the natural ambient noise levels at corresponding frequencies. The source level of an actual icebreaker is much higher than that of the projectors (projecting recorded sound) used in this study (median difference 34 dB over the frequency range 40-6,300 Hz). Over the two-season period (1991 and 1994) when icebreaker playbacks were attempted, an estimated 93 bowheads (80 groups) were seen near the ice camp when the projectors were transmitting icebreaker sounds into the water, and approximately 158 bowheads (116 groups) were seen near there during quiet periods. Some bowheads diverted from their course when exposed to levels of projected icebreaker sound greater than 20 dB above the natural ambient noise level in the one-third octave band of the strongest icebreaker noise.

However, not all bowheads diverted at that sound-to-noise ratio, and a minority of whales apparently diverted at a lower sound-to-noise ratio. The study concluded that exposure to a single playback of variable icebreaker sounds can cause statistically but probably not biologically significant effects on movements and behavior of migrating whales in the lead system during the spring migration east of Point Barrow. The study indicated the predicted response distances for bowheads around an actual icebreaker would be highly variable; however, for typical traveling bowheads, detectable effects on movements and behavior are predicted to extend commonly out to radii of 10-30 km (6.2-18.6 mi). It should be noted that these predictions were based on reactions of whales to playbacks of icebreaker sounds in a lead system during the spring migration and are subject to a number of qualifications. The predicted typical radius of responsiveness around an icebreaker like the *Robert Lemeur* is quite variable, because propagation conditions and ambient noise vary with time and with location. In addition, icebreakers vary widely in engine power and noise output, with the *Robert Lemeur* being a relatively low-powered icebreaker. Furthermore, the reaction thresholds of individual whales vary by at least 10 dB around the typical threshold, with commensurate variability in predicted reaction radius.

While conducting aerial surveys over the Kuvlum drilling location, Brewer et al. (1993) showed that bowhead whales were observed within about 30 km (18.6 mi) north of the drilling location. The closest observed position for a bowhead whale detected during the aerial surveys was approximately 23 km (14.3 mi) from the project icebreakers. The drilling rig was not operating on that day, but all three icebreakers had been actively managing ice periodically during the day. The study did not indicate what the whale's behavior was, but it did not appear to be avoiding the icebreakers. Three whales were sighted that day, and all three appeared to be moving to the northwest along the normal migration route at speeds of 2.4-3.4 km/h (1.5-2.1 mi/h). Bowhead whale call rates peaked when whales were about 32 km (19.9 mi) from the industrial activity. There was moderate to heavy ice conditions throughout the monitoring area, with heavy, grounded icefloes to the west, north, and east of the drilling site. Brewer et al. (1993) were unable to determine if either ice or industrial activity by themselves caused the whales to migrate to the north of the drilling location, but they concluded that ice alone probably did not determine the observed distribution of whales.

### Effects from Aircraft Traffic

Most offshore aircraft traffic in support of the oil industry involves turbine helicopters flying along straight lines. Underwater sounds from aircraft are transient. According to Richardson et al. (1995a), the angle at which a line from the aircraft to the receiver intersects the water's surface is important. At angles greater than 13 degrees from the vertical, much of the incident sound is reflected and does not penetrate into the water. Therefore, strong underwater sounds are detectable while the aircraft is within a 26-degree cone above the receiver. An aircraft usually can be heard in the air well before and after the brief period while it passes overhead and is heard underwater.

Data on reactions of bowheads to helicopters are limited. Most bowheads are unlikely to react significantly to occasional single passes by low-flying helicopters ferrying personnel and equipment to offshore operations. Observations of bowhead whales exposed to helicopter overflights indicate that most bowheads exhibited no obvious response to helicopter overflights at altitudes above 150 m (500 ft). At altitudes below 150 m (500 ft), some bowheads probably would dive quickly in response to the aircraft noise (Richardson and Malme, 1993). This noise generally is audible for only a brief time (tens of seconds) if the aircraft remains on a direct course, and the whales should resume their normal activities within minutes. Patenaude et al. (1997) found that most reactions by bowheads to a Bell 212 helicopter occurred when the helicopter was at altitudes of 150 m or less and lateral distances of 250 m or less. The most common reactions were abrupt dives and shortened surface time and most, if not all, reactions seemed brief. However, the majority of bowheads showed no obvious reaction to single passes, even at those distances. The helicopter sounds measured underwater at depths of 3 and 18 m showed that sound consisted mainly of main-rotor tones ahead of the aircraft and tail-rotor sounds behind the aircraft; more sound pressure was received at 3 m than at 18 m; and peak sound levels received underwater diminished with increasing aircraft altitude. Sound levels received underwater at 3 m from a Bell 212 flying overhead at 150 m ranged from 117-120 dB re 1 µPa in the 10-500-Hz band. Underwater sound levels at 18 m from a Bell 212 flying overhead at 150 m ranged from 112-116 dB re 1 µPa in the 10-500-Hz band.

Fixed-wing aircraft flying at low altitude often cause hasty dives. Reactions to circling aircraft are sometimes conspicuous if the aircraft is below 300 m (1,000 ft), uncommon at 460 m (1,500 ft), and generally undetectable at 600 m (2,000 ft). Repeated low-altitude overflights at 150 m (500 ft) during aerial photogrammetry studies of feeding bowheads sometimes caused abrupt turns and hasty dives (Richardson and Malme, 1993). Aircraft on a direct course usually produce audible noise for only tens of seconds, and the whales are likely to resume their normal activities within minutes (Richardson and Malme, 1993). Patenaude et al. (1997) found that few bowheads (2.2%) during the spring migration were observed to react to Twin Otter overflights at altitudes of 60-460 m. Reaction frequency diminished with increasing lateral distance and with increasing altitude. Most observed reactions by bowheads occurred when the Twin Otter was at altitudes of 182 m or less and lateral distances of 250 m or less. There was little, if any, reaction by bowheads when the aircraft circled at an altitude of 460 m and a radius of 1 km. The effects from an encounter with aircraft are brief, and the whales should resume their normal activities within minutes.

While the obvious behavioral reaction of a bowhead to a single low-flying helicopter or fixed-winged aircraft flying overhead is probably temporary (Richardson et al., 1995a), most “fleeing” reactions in mammals are accompanied by endocrine changes, which, depending on other stressors to which the individual is exposed, could contribute to a potentially adverse effect on health

### On-Ice 2D/3D Seismic Surveys

The 2D/3D seismic surveying in shallow water could also be conducted during the winter over the ice and we anticipate that some on-ice surveys could occur. Seismic profiling on shore-fast ice using vibroseis is another source of introduction of noise into the arctic environment. Richardson et al. (1995a) summarized that typical signals associated with this kind of seismic activity sweep from 10-70 Hz but harmonics extend to about 1.5 kHz (Richardson et al., 1995a). In this activity, hydraulically driven pads mounted beneath a line of trucks are used to vibrate, and thereby energize the ice. Noise incidental to the activity is introduced by the vehicles associated with this activity.

These on-ice surveys often extend into the period in April when bowhead whales begin to be observed at Barrow and are present in the Chukchi and Beaufort Sea in the spring lead system. However, during that period in the Beaufort Sea, the whales are far offshore in the spring leads and distant from shallow water areas where such surveys could occur. On-ice surveys are not expected in the Chukchi Sea. These surveys have occurred regularly in nearshore areas of the Alaska Beaufort Sea over the past 30 years. If bowhead whales detect these sounds, there is no indication of any adverse effect on their migration or population recovery. For these reasons, we believe that on-ice surveys are not likely to have detectable adverse effects on bowhead whales.

### Potential Effects from Exploratory Drilling Operations

Exploration drilling units and other drilling units are sources of noise and disturbance to bowhead whales. Exploration drilling in the Beaufort Sea can be conducted from manmade gravel islands, ice islands, caisson-retained islands, bottom-founded drilling platforms such as the concrete island drilling system or single steel drilling caisson, or from drillships in deeper water supported by icebreakers. The type of drilling platform used depends on water depth, oceanography, ice cover, and other factors. Stationary sources of offshore noise (such as drilling units) appear less disruptive to bowhead whales than moving sound sources (such as vessels). Drilling operations from many of these structures except drillships are likely to be conducted during the winter months. Drilling from ice islands would occur only during the winter when bowheads are not present, and noise from these activities would not affect bowhead whales. Therefore, this type of drilling activity is not discussed here.

MMS anticipates that gravel islands are not likely to be constructed for exploratory drilling in OCS waters, but that old artificial islands might be used temporarily. In the near future MMS expects that exploratory drilling in the Beaufort Sea will also be conducted from other platforms and during the open water period depending on water depth, sea ice conditions, availability of drilling units, and the ice-resistance of units. MMS said moveable platforms resting on the seafloor could be used to drill in water depths of 10-20 m, but that drillships or other floating units would be used in deeper water. Drilling from these units will be in open water. Such drilling would be supported by icebreakers and supply boats.

In the Beaufort Sea, MMS assumes a maximum of two drilling rigs would operate at any one time with a total of six exploration wells and six delineation wells drilled over an eight year period, beginning in 2007. Exploration drilling in the Chukchi Sea evaluation area could begin after the proposed Chukchi Sea Sale 193 in late 2007. Drilling operations in the Chukchi Sea are likely to employ drillships with ice-breaker support vessels and to operate at a given well site between 30 and 90 days. MMS assumes one to two exploration wells per season drilled between June-November. No exploration drilling from Sale 193 would occur in the polynya. If the polynya is offered as part of the proposed sales in the 2007-2012 5-Year Program, no exploration drilling activities would occur before 2011.

Thus, based on the aforementioned scenario, bowhead whales could potentially encounter a total of 3 exploration drilling units within evaluation areas, with icebreaker support possible in the Chukchi Sea and likely in the Beaufort Sea. Beginning in 2012, production and injection wells may also be drilled.

Noise-producing activities, such as drilling operations, in the spring lead and polynya system during the spring bowhead migration have a fairly high potential of affecting the whales. While MMS has decided not to allow seismic survey activity in the spring lead system through late June, or as prescribed by NMFS to protect bowhead whales. No exploration activities would occur in the spring lead system from Sale 193, as excluded in the current 2002-2007 5-Year Program. Exploration drilling from future OCS sales would not occur before 2011. At this time, it is unknown whether future Chukchi Sea Sales will include or exclude the spring lead system. The general location of the spring lead system is based on relatively limited survey data and is not well defined.

Previously, MMS concluded that exploratory drilling operations using floating platforms within the portion of the Beaufort Sea spring lead system during the bowhead migration are unlikely, because the ice at this time of year would be too thick for floating drilling platforms to get to the location and conduct drilling operations, even with icebreaker support. Thus, in the Beaufort Sea multiple-sale EIS, MMS concluded that spring-migrating bowheads are not likely to be exposed to drilling noise from activities on leases from Sales 186, 195, or 202. MMS concluded that areas in or near the spring lead system in the Beaufort Sea could be leased during these sales, but any exploratory drilling operations likely would be conducted during the open-water season (August-October) using floating drilling platforms.

Future lease sale decisions will determine whether the polynya area deferred from leasing in the 2002-2007 5-Year Program will be offered for lease in the future. No exploratory drilling in the Chukchi Sea portion of the lead system could begin unless tracts within the polynya area are offered and leased. Open water in this polynya area typically begins in June and continues through November.

Some bowheads in the vicinity of drilling operations would be expected to respond to noise from drilling units by slightly changing their migration speed and swimming direction to avoid closely approaching these noise sources. Miles, Malme, and Richardson (1987) predicted the zone of responsiveness to continuous noise sources. They predicted that roughly half of the bowheads likely would respond at a distance of 0.02-0.2 km (0.12-1.12 mi) to drilling from an artificial island when the signal-to-noise ratio is 30 dB. By comparison, they predicted that roughly half of the bowheads likely would respond at a distance of 1-4 km (0.62-2.5 mi) from a drillship drilling when the signal-to-noise ratio is 30 dB. A smaller proportion would react when the signal-to-noise ratio is about 20 dB (at a greater distance from the source), and a few may react at a signal-to-noise ratio even lower or at a greater distance from the source.

Drilling for oil and gas generally produces low-frequency sounds with strong tonal components. There are few data on the noise from conventional drilling platforms. Recorded noise from an early study of one drilling platform and three combined drilling production platforms found that noise was so weak, it was almost not detectable alongside the platform at sea states of 3 or above. The strongest tones were at very low frequencies near 5 Hz, and received levels of these tones at near-field locations were 119-127 dB re 1 µPa (Richardson et al., 1995a).

Although underwater sounds from drilling on some artificial islands and caissons have been measured, little information is available about reactions of bowheads to drilling from these structures. Underwater noise levels from drilling operations on natural barrier islands or artificial islands are low and are not audible beyond a few kilometers (Richardson et al., 1995a). Noise is transmitted very poorly from the drill-rig machinery through land into the water. Even under open-water conditions, drilling sounds are not detectable very far from the structure. Drilling noise from caisson-retained islands is much stronger. At least during open-water conditions, noise is conducted more directly into the water than from island drill sites. Noise associated with drilling activities at both sites varies considerably with ongoing operations. The highest documented levels were transient pulses from hammering to install conductor pipe. NMFS (2001:27) concluded that:

...bowhead whale responses to noise from drilling and exploration activities are expected to depend on the type of activity and its location relative to the whales' normal migration corridors…Thus, a drill ship operating offshore and closer to the center of the migration is expected to have a greater biological impact than a drilling operation from an artificial island situated in very shallow water along the nearshore edge of the migration.

### Artificial Gravel Islands

The following is a brief discussion of several studies on the measurement of underwater noise and the effects of noise from drilling operations on gravel islands on bowhead whales.

**Seal Island:** Noise measurements were made during the open-water season near Seal Island, a manmade gravel island off Prudhoe Bay in water 12 m deep. Seal Island is the current approximate location for the Northstar Project. Davis, Greene, and McLaren (1985) measured underwater noise from Seal Island during the open-water season while well logging was occurring but not drilling operations. Underwater sound levels recorded from bottom hydrophones 1.65-2.4 km from Seal Island were strongly affected by wind speed and active barge or tug traffic at the island. The strongest tone measured was 486 Hz from turbochargers on the generators used for well-logging operations. This tone was measured by a hydrophone on a boat at distances of up to 5 km from Seal Island. Noise associated with barge or tug movement at the island readily could be detected at 2.4 km from the island, even during high winds. Noise levels in the 20-1,000-Hz band from barge traffic were about 118 dB re 1 µPa at 1.6 km and had decreased to 108-110 dB re 1 µPa at 2.4 km. At that rate of sound attenuation, the noise level from barges was estimated to be about 92 dB at 6 km. Underwater sounds from Seal Island were not detectable 2.3 km away while people were on the island and power generators were operating, but no logging or drilling operations were ongoing.

Aerial surveys for bowhead whales near Seal Island in 1982 (during island construction) and 1984 found that most whales were in water deeper than 18 m, which is consistent with data from previous studies (Davis, Greene, and McLaren, 1985). In 1982, one whale was sighted in 12 m of water about 11 km northwest of Seal Island. In 1984, there were two sightings of single whales in 12-15 m of water. Whales migrating in water deeper than 18 m would have been too far away to detect noise from Seal Island, because industrial noise was not audible in the water more than a few kilometers away. Acoustic data collected in 1982 and 1984 suggest that some bowheads were closer to Seal Island in 1984 than in 1982. Localizations made by the hydrophone array on three occasions indicated the whales were present between 2.5 and 6 km from Seal Island. Bowhead calls recorded on hydrophones were thought to be from whales that were in water at least 18 m deep. The study concluded that there was no evidence to suggest that bowheads avoided Seal Island in 1984 compared to 1982.

**Sandpiper Island:** Johnson et al. (1986) measured underwater noise from Sandpiper Island, a manmade gravel island in water 15 m deep. Sound was measured using a bottom-hydrophone system at 0.5 km from the island and sonobuoys at greater distances from the island. The median sound levels observed at a fixed location 0.5 km from Sandpiper Island were relatively low. Median noise levels in the 20-1,000-Hz band were 93 and 95 dB re 1 µPa during two periods without drilling and 100 dB re 1 µPa during one period with drilling. In the absence of shipping or other industrial sounds, the expected level of noise in the 20-1,000-Hz band is about 100 dB re 1 µPa for Beaufort Sea State 2 conditions (wind speeds at 7-10 kn and wave heights up to 0.5 m). The most obvious components were tones at 20 and 40 Hz, which were attributed to power generation on the island.

The low-frequency industrial sounds from Sandpiper Island attenuated rapidly with increasing range, at least partially due to the shallow water. The low-frequency sounds were evident when ambient noise levels were low but were largely masked during periods when ambient noise was above average. Sound levels received at a sonobuoy 3.7 km from Sandpiper Island (76 dB re 1 µPa in both the 20- and 40-Hz bands) were 24-30 dB lower than the levels received at the bottom hydrophone 0.5 km from the island. The bottom hydrophone measured drilling sounds of 100 dB re 1 µPa in the 20-Hz-frequency band at 0.5 km from Sandpiper Island. The sounds were severely attenuated at 3.7 km and not detectable at 9.3 km. The effective source level of the 40-Hz tone was estimated at 145 dB re 1 µPa at 1 m.

Impulsive hammering sounds associated with installation of a conductor pipe were as high as 131-135 dB re 1 µPa at 1 km, when pipe depth was about 20 m below the island. In contrast, broadband drilling noise at this distance was about 100-106 dB. During hammering, the transient signals had the strongest components at 30-40 Hz and about 100 Hz. Moore et al. (1984, as cited in Richardson, et al., 1995b) reported that received levels for transient piledriving sounds recorded at 1 km from a manmade island near Prudhoe Bay were 25-35 dB above ambient levels in the 50- to 200-Hz band. They estimated that the sounds might be received underwater as far as 10-15 km from the source, farther than drilling sounds.
Aerial surveys for bowhead whales in 1985 indicated that no bowheads were seen closer than 30 km from Sandpiper Island (Johnson et al., 1986). Almost all of the migrating bowheads traveled in water deeper than 18 m, as was found in the surveys for Seal Island. Sandpiper and Northstar islands are both about 6 km south of the 18-m-depth contour. Industrial noise from Sandpiper Island, with or without drilling, was not audible in the water more than a few kilometers away. Because the migration route of almost all bowheads is north of the 18-m contour, few individual whales moved into the zone where industrial noise potentially was detectable.

The authors concluded that the number of whales that passed along the southern edge of the migration route and approached the artificial islands, both Seal and Sandpiper, must have been a very low fraction of the total population given the absence of sightings close to the islands.

**Tern Island:** Studies at Tern Island were conducted to determine sound levels that could be expected from the proposed Liberty development project. The studies provide information on distances that sound travels as a result of activities on gravel islands.

Greene (1997) measured underwater sounds under the ice at the proposed Liberty Island location from drilling operations on Tern Island in Foggy Island Bay in February 1997. Sounds from the drill rig generally were masked by ambient noise at distances near 2 km. The strongest tones were at frequencies below 170 Hz, but the received levels diminished rapidly with increasing distance and dropped below the ambient noise level at ranges of about 2 km. Drilling sounds were not detected at frequencies above 400 Hz, even at 200 m from the drill rig.

Greene noted that if production proceeded at Liberty, the types and frequency characteristics of some of the resulting sounds would be similar to those from the drilling equipment in this study. Electric power generation, pumps, and auxiliary machinery again would be involved, as would a drill rig during the early stages of production. However, the production island also would include additional processing and pumping facilities. If this equipment requires significantly more electric power, generators may produce sounds that are detectable at greater distances. However, these sounds would diminish rapidly with increasing distances due to high spreading losses (35 dB/tenfold change in range) plus the linear attenuation rates of 2-9 dB per km (0.002-0.009 dB/m). Sound transmission within the lagoon for activities at Liberty would be similar to the sound transmission measured for activities at Tern Island, but the barrier islands to the north and the lagoon's very shallow water near those islands should make underwater sound transmission very poor beyond the islands and into the Beaufort Sea.

Greene (1998) measured ambient noise and acoustic-transmission loss underwater at the proposed Liberty Island site in Foggy Island Bay during the open-water season of 1997 to complement transmission loss and ambient-noise measurements made under the ice at Liberty in February 1997. For wind speeds of zero, 10, 20, and 30 km, typical overall ambient noise levels in the 20-5,000-Hz band were 85, 94, 104, and 114 dB re 1 μPa, respectively. For the data from both recorders taken together, the median 20-5,000-Hz band level for the 44 days was 97 dB re 1 μPa, or 9 dB above the corresponding level for Knudsen's standard for Sea State 0 (Greene, 1998). The levels were consistent with other ambient noise measurements made in similar locations at similar times of the year. The measured ambient levels in winter generally were lower than those measured in summer, which means that industrial sounds would be expected to be detectable at greater distances during the winter. Bowheads are not present in the winter.

Acoustic-transmission loss was measured using a four-element sleeve-gun array and a minisparker as sources. The sleeve-gun array is a relatively low-frequency source (63-800 Hz) compared to the minisparker (315-3,150 Hz). Received sounds were recorded quantitatively at distances up to 8.1 km southeast and 10.1 km north of Liberty. At greater distances (up to 10 km), the sounds from the sleeve-gun array diminished generally according to -25 log(R), while the minisparker sound diminished at approximately -10 log(R), corresponding to cylindrical spreading. This difference is attributed to the sleeve-gun array being a low-frequency source compared to the minisparker. Propagation-loss rates varied with frequency. The minisparker had a higher linear loss rate, which corresponds to higher absorption and scattering losses at higher frequencies.

Richardson et al. (1995a) summarized that noise from drilling activities varies considerably with operations. The highest documented levels were transient pulses from hammering to install conductor pipe. Underwater noise associated with drilling from natural barrier or artificial islands usually is weak and is inaudible beyond a few kilometers. Richardson et al. (1995a) estimated that drilling noise generally would be confined to low frequencies and would be audible at a range of 10 km only during unusually quiet periods, while the audible range under more typical conditions would be approximately 2 km.

### Bottom-Founded Structures

Two types of drilling platforms have been used for offshore drilling in the Alaska Beaufort Sea: the concrete island drilling system, which is a floating concrete rig that is floated into place, ballasted with seawater, and sits on the seafloor; and the single steel drilling caisson, which is a section of a ship with a drill rig mounted on it and also is floated into place, ballasted with seawater, and sits on the seafloor. Drilling from these platforms generally begins after the bowhead whale migration is done and continues through the winter season.

In the absence of drilling operations, radiated levels of underwater sound from the concrete island drilling system were low, at least at frequencies above 30 Hz. The overall received level was 109 dB re 1 μPa at 278 m, excluding any infrasonic components. When the concrete island drilling system was operating in early winter, radiated sound levels above 30 Hz again were relatively low (89 dB at 1.4 km). However, when infrasonic components were included, the received level was 112 dB at 1.4 km. More than 99% of the sound energy received was below 20 Hz. Received levels of sound at 222-259 m ranged from 121-124 dB. The maximum detection distance for infrasonic sounds was not determined. Such tones likely would attenuate rapidly in water shallow enough for a bottom-founded structure. Overall, the estimated source levels were low for the concrete island drilling system, even when the infrasonic tones were included (Richardson et al., 1995a).

Sounds from the steel drilling caisson were measured during drilling operations in water 15 m deep with 100% ice cover. The strongest underwater tone was at 5 Hz (119 dB re μPa) at a distance of 115 m. The 5-Hz tone apparently was not detectable at 715 m, but weak tones were present at 150-600 Hz. The broadband (20-1,000 Hz) received level at 215-315 m was 116-117 dB re μPa, higher than the 109 dB reported for the concrete island drilling system at 278 m.

Inupiat whalers believe that noise from drilling activities displace whales farther offshore, away from their traditional hunting areas. These concerns were expressed primarily for drilling activities from drillships with icebreaker support that were operating offshore in the main migration corridor. Concerns also have been expressed about noise generated from the single steel drilling caisson, the drilling platform used to drill two wells on the Cabot Prospect east of Barrow in October 1990 and November 1991. Mr. Jacob Adams, Mr. Burton Rexford, Mr. Fred Kanayurak, and Mr. Van Edwardson, all with the Barrow Whaling Captain's Association, stated in written testimony at the Arctic Seismic Synthesis and Mitigating Measures Workshop on March 5-6, 1997, in Barrow: "<u>We are firmly convinced that noise from the Cabot drilling platform displaced whales from our traditional hunting area. This resulted in us having to go further offshore to find whales</u>" (USDOI, MMS, 1997).

### Drillships and other Floating Platforms

Bowhead reaction to drillships is variable. Bowhead whales whose behavior appeared normal have been observed on several occasions within 10-20 km (6.2-12.4 mi) of drillships in the eastern Beaufort Sea, and there have been a number of reports of sightings within 0.2-5 km (0.12-3 mi) from drillships (Richardson et al., 1985a; Richardson and Malme, 1993). On several occasions, whales were well within the zone where drillship noise should be clearly detectable by them. In other cases, bowheads may avoid drillships and their support vessels at 20-30 km (see below and NMFS, 2003a). The factors associated with the variability are not fully identified or understood.

Richardson and Malme (1993) point out that the data, although limited, suggest that stationary industrial activities producing continuous noise, such as stationary drillships, result in less dramatic reactions by bowheads than do moving sources, particularly ships. It also appears that bowhead avoidance is less around an unattended structure than one attended by support vessels. Most observations of bowheads tolerating noise from stationary operations are based on opportunistic sightings of whales near ongoing oil-industry operations, and it is not known whether more whales would have been present in the absence of those operations. Because other cetaceans seem to habituate somewhat to continuous or repeated noise exposure when the noise is not associated with a harmful event, this suggests that bowheads will habituate to certain noises that they learn are nonthreatening. Additionally, it is not known what components of the population were observed around the drillship (e.g., adult or juvenile males, adult females, etc.).

In Canada, bowhead use of the main area of oil-industry operations within the bowhead range was low after the first few years of intensive offshore oil exploration in 1976 (Richardson, Wells, and Wursig, 1985), suggesting perhaps cumulative effects from repeated disturbance may have caused the whales to leave the area. In the absence of systematic data on bowhead summer distribution until several years after intensive industry operations began, it is arguable whether the changes in distribution in the early 1980's were greater than natural annual variations in distribution, such as responding to changes in the location of food sources. Ward and Pessah (1988) concluded that the available information from 1976-1985 and the historical whaling information do not support the suggestion of a trend for decreasing use of the industrial zone by bowheads as a result of oil and gas exploration activities. They concluded that the exclusion hypothesis is likely invalid.

The distance at which bowheads may react to drillships is difficult to gauge, because some bowheads would be expected to respond to noise from drilling units by changing their migration speed and swimming direction to avoid closely approaching these noise sources. For example, in the study by Koski and Johnson (1987), one whale appeared to adjust its course to maintain a distance of 23-27 km (14.3-16.8 mi) from the center of the drilling operation. Migrating whales apparently avoided the area within 10 km (6.2 mi) of the drillship, passing both to the north and to the south of the drillship. The study detected no bowheads within 9.5 km (5.9 mi) of the drillship, and few were observed within 15 km (9.3 mi). The principal finding of this study was that migrating bowheads appeared to avoid the offshore drilling operation in fall 1986. Thus, some bowheads may avoid noise from drillships at 20 km (12.4 mi) or more.

In other studies, Richardson, Wells, and Wursig (1985) observed three bowheads 4 km (2.48 mi) from operating drillships, well within the zones ensonified by drillship noise. The whales were not heading away from the drillship but were socializing, even though exposed to strong drillship noise. Eleven additional whales on three other occasions were observed at distances of 10-20 km (6.2-12.4 mi) from operating drillships. On two of the occasions, drillship noise was not detectable by researchers at distances from 10-12 km (6.2-7.4 mi) and 18-19 km (11.2-11.8 mi), respectively. In none of the occasions were whales heading away from the drillship. Ward and Pessah (1988, as cited in Richardson and Malme, 1993) reported observations of bowheads within 0.2-5 km (0.12-3 mi) from drillships.

The ice-strengthened Kulluk, a specialized floating platform designed for arctic waters, was used for drilling operations at the Kuvlum drilling site in western Camden Bay in 1992 and 1993. Data from the Kulluk indicated broadband source levels (10-10,000 Hz) during drilling and tripping were estimated to be 191 and 179 dB re µPa at 1 m, respectively, based on measurements at a water depth of 20 m in water about 30 m deep (Richardson et al., 1995a).

Hall et al. (1994) conducted a site-specific monitoring program around the Kuvlum drilling site in the western portion of Camden Bay during the 1993 fall bowhead whale migration. Results of their analysis indicated that bowheads were moving through Camden Bay in a significantly nonrandom pattern but became more randomly distributed as they left Camden Bay and moved to the west. The results also indicated that whales were distributed farther offshore in the proximal survey grid (near the drill site) than in the distant survey grid (an area east of the drill site), which is similar to results from previous studies in this general area. The authors noted that information from previous studies indicated that bowheads routinely were present nearshore to the east of Barter Island and were less evident close to shore from Camden Bay to Harrison Bay (Moore and Reeves, as cited in Hall et al., 1994). The authors believed that industrial variables such as received level were insufficient as a single predictor variable to explain the 1993 offshore distribution of bowhead whales, and they suggested that water depth was the only variable that accounted for a significant portion of the variance in the model. They concluded that for 1993, water depth, received level, and longitude accounted for 85% of the variance in the offshore distribution of the whales. Based on their analyses, the authors concluded that the 1993 bowhead whale distribution fell within the parameters of previously recorded fall-migration distributions.

Davies (1997) used the data from the Hall et al. study in a Geographic Information System model to analyze the distribution of fall-migrating bowheads in relation to an active drilling operation. He also concluded that the whales were not randomly distributed in the study area, and that they avoided the region surrounding the drill site at a range of approximately 20 km (12.4 mi). He noted that the whales were located significantly farther offshore and in significantly deeper water in the area of the drilling rig. As noted by Hall et al. (1994), the distribution of whales observed in the Camden Bay area is consistent with previous studies (Moore and Reeves, 1993), where whales were observed farther offshore in this portion of the Beaufort Sea than they were to the east of Barter Island. Davies concluded, as did Hall et al., that it was difficult to separate the effect of the drilling operation from other independent variables. The model identified distance from the drill rig and water depth as the two environmental factors that were most strongly associated with the observed distribution of bowheads in the study area. The Davies analysis, however, did not note that surface observers (Hall et al., 1994) observed whales much closer to the drilling unit and support vessels than did aerial observers. In one instance, a whale was observed approximately 400 m (436 yd) from the drill rig. Hall et al. suggest that bowheads, on several occasions, were closer to industrial activity than would be suggested by an examination of only aerial-survey data.

Schick and Urban (2000) also analyzed data from the Hall et al. study and tested the correlation between bowhead whale distribution and variables such as water depth, distance to shore, and distance to the drilling rig. The distribution of bowhead whales around the active drilling rig in 1993 was analyzed and the results indicated that whales were distributed farther from the drilling rig than they would be under a random scenario. The area of avoidance was localized and temporary (Schick and Urban, 2000); Schick and Urban stated they could not conclude that noise from the drilling rig caused the low density near the rig, because they had no data on actual noise levels. They also noted that ice, an important variable, is missing from their model and that 1992 was a particularly heavy ice year. Because ice may be an important patterning variable for bowheads, Schick and Urban said they were precluded from drawing strong inference from the 1992 results with reference to the interaction between whales and the drilling rig. Moore and DeMaster (1998, as cited in Schick and Urban, 2002) proposed that migrating bowheads are often found farther offshore in heavy ice years because of an apparent lack of feeding opportunities. Schick and Urban (2002) stated that ultimately, the pattern in the 1992 data may be explained by the presence of ice rather than by the presence of the drilling rig.

In playback experiments, some bowheads showed a weak tendency to move away from the sound source at a level of drillship noise comparable to what would be present several kilometers from an actual drillship (Richardson and Malme, 1993). In one study, sounds recorded 130 m (426 ft) from the actual Karluk drill rig were used as the stimulus during disturbance test playbacks (Richardson et al., 1991). For the overall 20- to 1,000-Hz band, the average source level was 166 dB re 1 μPa in 1990 and 165 dB re 1 μPa in 1989. Bowheads continued to pass the projector while normal Karluk drilling sounds were projected. During the playback tests, the source level of sound was 166 dB re 1 μPa. One whale came within 110 m (360 ft) of the projector. Many whales came within 160-195 m (525-640 ft), where the received broadband (20-1,000 Hz) sound levels were about 135 dB re 1 μPa. That level was about 46 dB above the background ambient level in the 20- to 1,000-Hz band on that day. Bowhead movement patterns were strongly affected when they approached the operating projector. When bowheads still were several hundred meters away, most began to move to the far side of the lead from the projector, which did not happen during control periods while the projector was silent.

In a subsequent phase of this continuing study, Richardson et al. (1995b) concluded:

…<u>migrating bowheads tolerated exposure to high levels of continuous drilling noise if it was necessary to continue their migration. Bowhead migration was not blocked by projected drilling sounds, and there was no evidence that bowheads avoided the projector by distances exceeding 1 kilometer (0.54 nautical mile). However, local movement patterns and various aspects of the behavior of these whales were affected by the noise exposure, sometimes at distances considerably exceeding the closest points of approach of bowheads to the operating projector</u>.

Richardson et al. (1995b) reported that bowhead whale avoidance behavior has been observed in half of the animals when exposed to 115 dB re 1 μPa rms broadband drillship noises. However, reactions vary depending on the whale activity, noise characteristics, and the physical situation (Richardson and Greene, 1993).

Some migrating bowheads diverted their course enough to remain a few hundred meters to the side of the projector. Surfacing and respiration behavior, and the occurrence of turns during surfacings, were strongly affected out to 1 km (0.62 mi). Turns were unusually frequent out to 2 km (1.25 mi), and there was evidence of subtle behavioral effects at distances up to 2-4 km

(1.25-2.5 mi). The study concluded that the demonstrated effects were localized and temporary and that playback effects of drilling noise on distribution, movements, and behavior were not biologically significant.

The authors stated that one of the main limitations of this study (during all 4 years) was the inability of a practical sound projector to reproduce the low-frequency components of recorded industrial sounds. Both the Karluk rig and the icebreaker *Robert Lemeur* emitted strong sounds down to ~10-20 Hz, and quite likely at even lower frequencies. It is not known whether the under-representation of low-frequency components (less than 45 Hz) during icebreaker playbacks had significant effects on the responses by bowheads. Bowheads presumably can hear sounds extending well below 45 Hz. It is suspected but not confirmed that their hearing extends into the infrasonic range below 20 Hz. The authors believed the projector adequately reproduced the overall 20- to 1,000-Hz level at distances beyond 100 m (109 yd), even though components below 80 Hz were under-represented. If bowheads are no more responsive to sound components at 20-80 Hz than to those above 80 Hz, then the playbacks provided a reasonable test of the responsiveness to components of Karluk sound above 20 Hz.

The authors also stated that the study was not designed to test the potential reactions of whales to nonacoustic stimuli detected via sight, olfaction, etc. At least in summer/autumn, responses of bowheads to actual dredges and drillships seem consistent with reactions to playbacks of recorded sounds from those same sites. Additional limitations of the playbacks identified by the authors included low sample sizes and the fact that responses were only evident if they could be seen or inferred based on surface observations. The numbers of bowhead whales observed during both playback and control conditions were low percentages of the total Beaufort Sea population. Also, differences between whale activities and behavior during playback versus control periods represent the incremental reactions when playbacks are added to a background of other activities associated with the research. Thus, playback results may somewhat understate the differences between truly undisturbed whales versus those exposed to playbacks.

### Icebreakers

If drillships are attended by icebreakers, as typically is the case during the fall in the U.S. Beaufort Sea, and we expect to be the case in the Chukchi Sea, the drillship noise frequently may be masked by icebreaker noise, which often is louder. Response distances would vary, depending on icebreaker activities and sound-propagation conditions. Based on models, bowhead whales likely would respond to the sound of the attending icebreakers at distances of 2-25 km (1.24-15.53 mi) from the icebreakers (Miles, Malme, and Richardson, 1987). Zones of responsiveness for intermittent sounds, such as an icebreaker pushing ice have not been studied. This study predicts that roughly half of the bowhead whales show avoidance response to an icebreaker underway in open water at a range of 2-12 km (1.25-7.46 mi) when the sound-to-noise ratio is 30 dB. The study also predicts that roughly half of the bowhead whales would show avoidance response to an icebreaker pushing ice at a range of 4.6-20 km (2.86-12.4 mi) when the sound-to-noise ratio is 30 dB.

Richardson et al. (1995b) found that bowheads migrating in the nearshore lead often tolerated exposure to projected icebreaker sounds at received levels up to 20 dB or more above the natural ambient noise levels at corresponding frequencies. The source level of an actual icebreaker is much higher than that of the projectors (projecting recorded sound) used in this study (median difference 34 dB over the frequency range 40-6,300 Hz). Over the two-season period (1991 and 1994) when icebreaker playbacks were attempted, an estimated 93 bowheads (80 groups) were seen near the ice camp when the projectors were transmitting icebreaker sounds into the water, and approximately 158 bowheads (116 groups) were seen near there during quiet periods. Some bowheads diverted from their course when exposed to levels of projected icebreaker sound greater than 20 dB above the natural ambient noise level in the one-third octave band of the strongest icebreaker noise. However, not all bowheads diverted at that sound-to-noise ratio, and a minority of whales apparently diverted at a lower sound-to-noise ratio. The study concluded that exposure to a single playback of variable icebreaker sounds can cause statistically but probably not biologically significant effects on movements and behavior of migrating whales in the lead system during the spring migration east of Point Barrow. The study indicated the predicted response distances for bowheads around an actual icebreaker would be highly variable; however, for typical traveling bowheads, detectable effects on movements and behavior are predicted to extend commonly out to radii of 10-30 km (6.2-18.6 mi).

It should be noted that these predictions were based on reactions of whales to playbacks of icebreaker sounds in a lead system during the spring migration and are subject to a number of qualifications. The predicted “typical” radius of responsiveness around an icebreaker like the *Robert Lemeur* is quite variable, because propagation conditions and ambient noise vary with time and with location. In addition, icebreakers vary widely in engine power and thus noise output, with the *Robert Lemeur* being a relatively low-powered icebreaker. Furthermore, the reaction thresholds of individual whales vary by at least 10 dB around the “typical” threshold, with commensurate variability in predicted reaction radius.

Richardson et al. (1995a) reported that broadband (20-1,000 Hz) received levels at 0.37 km for the icebreaking supply vessel the Canmar Supplier underway in open water was 130 dB and 144 dB when it was breaking ice. The increase in noise during icebreaking is apparently due to propeller cavitation. Richardson et al. (1995a) summarized that icebreaking sound from the Robert Lemeur pushing on ice were detectable >50 km away. We anticipate that an icebreaker would attend a drillship in the Chukchi Sea. Brewer et al. (1993) reported that in the autumn of 1992, migrating bowhead whales avoided an icebreaker-accompanied drillship by 25+ km. This ship was icebreaking almost daily. However, Richardson et al. (1995a) noted that in 1987, bowheads also avoided another drillsite with little icebreaking.

### Vessel Traffic

Bowheads react to the approach of vessels at greater distances than they react to most other industrial activities. According to Richardson and Malme (1993), most bowheads begin to swim rapidly away when vessels approach rapidly and directly. This avoidance may be related to the fact that bowheads have been commercially hunted within the lifetimes of some individuals within the population and they continue to be hunted for subsistence throughout many parts of their range. Avoidance usually begins when a rapidly approaching vessel is 1-4 km (0.62-2.5 mi) away. A few whales may react at distances from 5-7 km (3-4 mi), and a few whales may not react until the vessel is less than 1 km (less than 0.62 mi) away. Received noise levels as low as 84 dB re 1 μPa or 6 dB above ambient may elicit strong avoidance of an approaching vessel at a distance of 4 km (2.5 mi) (Richardson and Malme, 1993).

In the Canadian Beaufort Sea, bowheads observed in vessel-disturbance experiments began to orient away from an oncoming vessel at a range of 2-4 km (1.2-2.5 mi) and to move away at increased speeds when approached closer than 2 km (1.2 mi) (Richardson and Malme, 1993). Vessel disturbance during these experimental conditions temporarily disrupted activities and sometimes disrupted social groups, when groups of whales scattered as a vessel approached. Reactions to slow-moving vessels, especially if they do not approach directly, are much less dramatic. Bowheads often are more tolerant of vessels moving slowly or in directions other than toward the whales. Fleeing from a vessel generally stopped within minutes after the vessel passed, but scattering may persist for a longer period. After some disturbance incidents, at least some bowheads returned to their original locations (Richardson and Malme, 1993). Some whales may exhibit subtle changes in their surfacing and blow cycles, while others appear to be unaffected. Bowheads actively engaged in social interactions or mating may be less responsive to vessels. Data are not sufficient to determine sex, age, or reproductive characteristics of response to vessels. We are not aware of data that would allow us to determine whether females with calves tend to show avoidance and scattering at a greater, lesser, or at the same distances as other segments of the population.

The encounter rate of bowhead whales with vessels associated with exploration would be determined by which areas were being explored. Bowhead whales probably would encounter relatively few vessels associated with exploration activities during their fall migration through the Alaskan Beaufort Sea. Vessel traffic generally would be limited to routes between the exploratory-drilling units and the shore base. Each floating drilling unit probably would have one vessel remaining nearby for emergency use. Depending on ice conditions, floating drilling units may have two or more icebreaking vessels standing by to perform ice-management tasks. It is likely that vessels actively involved in ice management or moving from one site to another would be more disturbing to whales than vessels idling or maintaining their position. In either case, bowheads probably would adjust their individual swimming paths to avoid approaching within several kilometers of vessels attending a drilling unit and probably would move away from vessels that approached within a few kilometers. Vessel activities associated with exploration are not expected to disrupt the bowhead migration, and small deflections in individual bowhead-swimming paths and a reduction in use of possible bowhead-feeding areas near exploration units should not result in significant adverse effects on the species. During their spring migration (April through June), bowheads likely would encounter few, if any, vessels along their migration route, because ice at this time of year typically would be too thick for seismic-survey ships, drillships, and supply vessels to operate in.

In 2003, there was concern by Alaskan Native whalers that barge traffic associated with oil and gas activities might have caused bowhead whales to move farther offshore and, thus, to be less accessible to subsistence hunters. Because of the concern over this issue, MMS provided the following summary of this issue, based solely on information provided by ConocoPhillips to MMS (Majors, 2004, pers. commun.; Greene, 2003).

Drilling rigs and equipment associated with the Puviaq exploration well west of Teshekpuk Lake were moved to Camp Lonely for barge out to Deadhorse in the summer of 2003, prior to the autumn whaling season. Camp Lonely is about 85 miles east of Barrow. While barge activities originally were scheduled to be completed prior to September 1, 2003, stormy weather and eroded beach conditions prevented their completion until October 10, 2003. Barrow whalers landed their first whale of the autumn migration on October 8, 2003. The hunters located whales more than 20 mi offshore of Barrow. Some whalers were concerned that

ConocoPhillips' barging activities caused deflection of the whales farther offshore. ConocoPhillips contracted with Greeneridge Sciences to determine noise propagation distances associated with the barging activities. Greene (2003:2) concluded that a broadband source level of 171 dB re 1 μP at 1 m is a reasonable and potentially a conservative (higher than the likely actual source level) estimate to use as a source level for the "relatively small tug and barge used by ConocoPhillips in its demobilization activities." After evaluating alternative models for estimating transmission loss, and considering likely ambient noise levels (based on data collected in 1996 offshore of Northstar), Greene (2003) applied the estimated source level to what he viewed as the most reasonable sound propagation loss model to estimate the received level of sound at four distances (0.1-63 km) from the tug and barge. The estimated hearing distances are based on the assumption that the whales do not hear sounds below the background noise level. Greene acknowledged that this assumption oversimplifies the hearing process but believes it is reasonable, given the approximations made for source level and for propagation loss. Greene (2003) estimated the following received sound levels at specific distances: 131 dB re 1 μPa at 0.1 km; 111 dB re 1 μPa at 1.0 km; 102 dB re 1 μPa at 2.8 km; and 75 dB re 1 μPa at 63 km. Given the assumptions that were required about hearing and the approximations regarding sound transmission loss, Greene (2003:4) stated it would be best to consider the estimates of received sound levels as "guidelines." ConocoPhillips also evaluated traditional knowledge information available from a 1997 workshop held in Barrow (Major, 2004, pers. commun.). Based on this information, they concluded that whales would have returned to their original headings about 45 mi before reaching Barrow if they had encountered noise from the barging operation at Camp Lonely. We cannot critically evaluate this conclusion, because it is unclear exactly which information it is based upon. ConocoPhillips and the NSB both researched the timing of vessel activities in the region. ConocoPhillips reported that this research revealed that another barge, unrelated to oil industry activities, departed Barrow for Deadhorse on October 8, 2003, which was the first day a whale was landed in Barrow (Major, 2004, pers. commun.). They also reported that an elder Barrow whaling captain reported that migration patterns of many species were different in 2003. For example, he reported that bowhead whales were spotted on the west side of Barrow in August, 2003. On the NSB map reporting the locations of landed whales offshore of Barrow, the waters nearshore to about 20 mi offshore were recorded to be muddy. ConocoPhillips concluded that their barging operations were not the cause of deflected whales offshore of Barrow in the fall of 2003 (Major, 2004, pers. commun.). There are no other data available to MMS regarding potential effects of the barge operations. Thus, we cannot critically evaluate the potential influence of the barging operations on whale movements near Barrow in 2003.

Considerable information regarding vessel traffic in 2001 in the Beaufort Sea near BPXA's Northstar facility are provided by Williams and Rodrigues (2003). Much of this information was for vessel traffic during the 2002 whaling season, and was collected by AEWC's whaling communication center. See pages 2-20 to 2-28 of William and Rodrigues (2003) for this detailed information.

In addition to acting as a source of noise and disturbance, marine vessels could potentially strike bowhead whales, causing injury or death. As noted in the baseline section of this evaluation, available information indicates that current rates of vessel strikes of bowheads are low. At present, available data do not indicate that strikes of bowheads by oil and gas-related vessels will become an important source of injury or mortality in the Beaufort Sea Planning Area. Risk of strikes would increase as vessel traffic in bowhead habitat increases. In our Conservation Recommendations, we offer means to establish travel corridors to minimize the amount of bowhead habitat that would be affected by oil and gas-related vessel traffic. If oil and gas-related vessel traffic increases substantially in areas commonly frequented by bowhead whales during periods when the bowheads are present, vessel strike rates should be carefully monitored.

### Other Construction Activities

Island-construction activities could cause noise and disturbance to bowhead whales. Placement of fill material for island construction generally occurs during the winter, when bowhead whales are not present. Completion of island construction and placement of slope-protection materials may take place during the open-water season, but these activities generally are completed before the bowhead whale fall migration. Placement of sheetpile, if used, would generate noise during the open-water period for one construction season but also should be completed in early to mid-August, before the whales migrate. Noise is not likely to propagate far due to the shallow water and the presence of barrier islands that, in many cases, may lie between the drilling location and the migration corridor used by bowhead whales, depending on the island location. Even during the migration, noise from these activities would be minor and would not affect bowhead whales. If such construction were to occur in an area where large numbers of whales were attempting to feed (such as has been observed in a few years (but not in many other years) in the Dease Inlet/Smith Bay area, the whales might be displaced from a small portion of the feeding range for that year.

Preliminary analysis of noise measurements during the open-water construction season at Northstar Island by Blackwell and Greene (2001) indicated that the presence of self-propelled barges had the largest impact on the level of sound coming from Northstar Island. Self-propelled barges remained at Northstar for days or weeks and always had their engines running, because they maintained their position by “pushing” against the island. Sound measurements on a day when there were no self-propelled barges showed that sounds were inaudible to the field acoustician listening to the hydrophone signal beyond 1.85 km, even on a relatively calm day. By comparison, the sounds produced by self-propelled barges, while limited in their frequency range, were detectable underwater as far as 28 km north of the island. Other vessels, such as the crew boat and tugs, produced qualitatively the same types of sounds, but they were present intermittently, and their effect on the sound environment was lower.

### Summary of Potential Effects of Noise and Disturbance Sources

Available information indicates that bowhead whales are responsive, in some cases highly responsive, to anthropogenic noise in their environment. At present, the primary response that has been documented is avoidance, sometimes at considerable distance. Response is variable, even to a particular noise source and the reasons for this variability are not fully understood.

Oil and gas exploration could result in considerable increase in noise and disturbance in the spring, summer, and autumn range of the Western Arctic bowhead whales. This noise may result from various activities, including seismic, vessel traffic and icebreaker operation, drilling, and construction, and support activities. Depending on their timing, location, and number, these activities potentially could produce sufficient noise and disturbance that bowhead whales might avoid an area of high value to them and suffer consequences of biological significance. These consequences would be of particular concern if such areas included those used for feeding or resting by large numbers of individuals or by females and calves. In other species of mammals, including cetaceans, females with young are more responsive to noise and human disturbance than other segments of the population.

If seismic operations overlap in time, the zone of seismic exclusion or influence could potentially be quite large, depending on the number, and the relative proximity of the surveys. NMFS is concerned these simultaneous seismic activities could result in effects that are biologically significant, if they cause avoidance of feeding, resting, or calving areas by large numbers of females with calves over a period of many weeks. The impact to individuals would likely be related to the importance of the food source or resting area to the component of the population that would have utilized it, had not the disturbance caused them to avoid the area. This is likely to remain unknown. Potential impacts to the population would be related to the numbers and types of individuals that were affected (e.g., juvenile males versus females with calves). Activities that cause active avoidance over large distances may reduce the availability of any rest areas. Such areas may provide important energetic needs for bowheads during their autumn migration and other use of the Beaufort Sea.

The observed response of bowhead whales to seismic noise has varied among studies. The factors associated with variability are not entirely clear. However, data indicate that fall migrating bowheads show greater avoidance of active seismic vessels than do feeding bowheads. Recent monitoring studies (1996-1998) and traditional knowledge indicate that during the fall migration, most bowhead whales avoid an area around a seismic vessel operating in nearshore waters by a radius of about 20 km and may begin avoidance at greater distances. Received sound levels at 20 km ranged from 117-135 dB re 1 µPa rms and 107-126 dB re 1µ Pa rms at 30 km. This is a larger avoidance radius than was observed from scientific studies conducted in the 1980’s. Avoidance did not persist beyond 12-24 hours after the end of seismic operations. In some early studies, bowheads also exhibited tendencies for reduced surfacing and dive duration, fewer blows per surfacing, and longer intervals between successive blows. Available data indicate that behavioral changes are temporary. Bowheads respond to drilling noise at different distances depending on the types of platform from which the drilling is occurring. Data indicate that many whales can be expected to avoid an active drillship at 10-20 km or possibly more. The response of bowhead whales to construction in high use areas is unknown and is expected to vary with the site and the type of facility being constructed. Similarly, the long-term response of bowheads to production facilities other than gravel islands located at the southern end of the migration corridor is unknown.

Exploration will result in an increase in marine vessel activity, and depending on location and season, may include icebreakers, barges, tugs, supply and crew boats, and other vessels. Whales respond strongly to vessels directly approaching them. Avoidance of vessels usually begins when a rapidly approaching vessel is 1-4 km away, with a few whales possibly reacting at distances from 5-7 km. Received noise levels as low as 84 dB re 1 µPa or 6 dB above ambient may elicit strong avoidance of an approaching vessel at a distance of 4 km. Fleeing from a vessel generally stopped within minutes after the vessel passed, but scattering may persist for a longer period.

Icebreaker response distances vary. Predictions from models indicate that bowhead whales likely would respond to the sound of the attending icebreakers at distances of 2-25 km, with roughly half of the bowhead whales showing avoidance response to an icebreaker underway in open water at a range of 2-12 km when the sound-to-noise ratio is 30 dB and roughly half of the bowhead whales showing avoidance response to an icebreaker pushing ice at a range of 4.6-20 km when the sound-to-noise ratio is 30 dB. Whales appear to exhibit less avoidance behavior with stationary sources of relatively constant noise than with moving sound sources.

Exploration also results in increased aircraft traffic, including possible whale monitoring flights. Most bowheads exhibit no obvious response to helicopter overflights at altitudes above 150 m (500 ft). At altitudes below 150 m (500 ft), some bowheads probably would dive quickly in response to the aircraft noise. Bowheads are relatively unaffected by aircraft overflights at altitudes above 300 m (984 ft). Below this altitude, some changes in whale behavior may occur, depending on the type of plane and the responsiveness of the whales present in the vicinity of the aircraft. Fixed-wing aircraft flying at low altitude often cause hasty dives. Reactions to circling aircraft are sometimes conspicuous if the aircraft is below 300 m (1,000 ft), uncommon at 460 m (1,500 ft), and generally undetectable at 600 m (2,000 ft). The effects from such an encounter with either fixed-wing aircraft or helicopters generally are brief, and the whales should resume their normal activities within minutes. If numerous flights for exploration or development and production occur, depending on the location, bowheads may be repeatedly exposed to helicopter noise in areas between shorebases and/or airports and the production facilities. Depending on where shorebases for activities are located, effects could be mitigated by ensuring that flight paths avoided whale aggregations or that flights were high enough to avoid disturbance.

We anticipate that gravel islands are not likely to be constructed for exploratory drilling in OCS waters, but that old artificial islands might be used temporarily. In the near future we expect that exploratory drilling in the Beaufort Sea will also be conducted from other platforms and during the open water period depending on water depth, sea ice conditions, availability of drilling units, and the ice-resistance of units. Moveable platforms resting on the seafloor could be used to drill in water depths of 10-20 m, but drillships or other floating units would be used in deeper waster. Drilling from these units will be in open water. Such drilling would be supported by icebreakers and supply boats. This is expected to be the norm in the Chukchi Sea.

If gravel islands were used for exploration drilling, noise produced probably would not have large effects on bowhead whales, because gravel islands are constructed in fairly shallow water shoreward of the main migration route, and noise from operations on gravel islands generally is not audible beyond a few kilometers. In the Beaufort Sea, island-construction activities likely would be conducted during the winter and generally are in nearshore shallow waters shoreward of the main bowhead whale migration route. However, as evidenced by Northstar, such construction was supported by numerous trips by barges and other vessels providing materials.

As development moves farther offshore, we anticipate much greater aircraft and vessel support. For example, MMS estimates that marine transport requirements during construction in the Far Zone would range between 150-250 vessel trips including numerous barges during the open water period. Bowheads may exhibit temporary avoidance behavior if approached by vessels at a distance of 1-4 km (0.62-2.5 mi). Marine-vessel traffic also may include seagoing barges transporting equipment and supplies from Southcentral Alaska to drilling locations, most likely between mid-August and mid- to late September. If the barge traffic continues into September, some bowheads may be disturbed. Fleeing behavior from vessel traffic generally stopped within minutes after the vessel passed, but scattering may persist for a longer period. Given results from Northstar regarding noise from barges, and the bowheads reaction to moving vessels, the level of barge and vessel activity that would occur if development and production proceeds as envisioned in the scenario, could potentially cause bowhead whales to avoid the area between the production platform and docking facilities during the period of activity. The significance of such a potential effect would depend on where the production facility was located.

Overall, bowhead whales exposed to noise-producing activities such as vessel and aircraft traffic, drilling operations, and seismic surveys most likely would experience temporary, nonlethal effects. Bowhead whale response to certain noise sources varies. Some of the variability appears to be context specific (i.e., feeding versus migrating whales) and also may be related to reproductive status and/or sex or age. As time goes on, many of these activities can and probably will occur in both program areas in the same season and, in some cases, in closely adjacent areas. In 2006, 2D and 3D seismic surveys, icebreaker activity for transit, high resolution surveys, and other support vessel traffic are expected in the Beaufort Sea. Aerial surveys also may be conducted. In 2007, exploration drilling, 2D and 3D seismic surveying, and high-resolution seismic surveys are anticipated in the Beaufort Sea and 2D and 3D seismic are anticipated in the Chukchi Sea. If these activities are coincident in space and time, especially during migrations or in areas of aggregations, large numbers of bowheads could be adversely affected.

Data are sufficient to conclude that all response to future noise and disturbance is likely to vary with time of year; sex and reproductive status of individuals exposed; site (because of differences in noise propagation and use by bowheads); activity and the exact characteristics of that activity (e.g., drilling versus seismic, airgun array and configuration, etc.); the animal's motivation to be in an area; and options for alternative routes, places to feed, etc. While habituation is seen in some species, and behavioral studies have suggested that bowheads habituate to noise from distant, ongoing drilling or seismic operations, localized avoidance still occurred. Bowheads may be less likely to habituate to at least certain types of noise than some other species because they are hunted annually, and thus, many individuals may have a strong negative association with human noise.

The potential total adverse effects of long-term added noise, disturbance, and related avoidance of feeding and resting habitat in an extremely long-lived species such as the bowhead whale are unknown. Available information does not indicate any long-term adverse effects on the Western Arctic stock from the high level of seismic surveys and exploration drilling during the 1980's in the Beaufort and Chukchi seas. However, sub-lethal impacts on health (such as reduced hearing or increased stress) could not be detected in this population. The rate of this population's increase in abundance does not indicate any sub-lethal effects (if they occurred) resulted in an effect on this population's recovery. There has been no documented evidence that noise from previous OCS operations has served as a barrier to migration. Because bowheads respond behaviorally to loud noise, they are less likely to suffer hearing loss from increased noise. However, bowheads are more tolerant of noise when feeding and future work is needed to determine potential effects on hearing due to long periods over many years of exposure to loud noise at distances tolerated in feeding areas. Similarly, concern needs to be given to other potential physiological effects of loud noise on bowheads, including the potential for increased noise to cause physiological stress responses.

We are not certain about the effects of multiple seismic surveys and other noise and disturbance sources over many years within areas which may be frequently used for feeding or resting by large numbers of bowhead whales. Concentrations of loud noise and disturbance activities during the open water period have the potential to cause large numbers of bowheads to avoid using areas for resting and feeding for long periods of time (days to months) while the noise producing activities continue.

## Effects from Discharges

Exploration drilling activity and other OCS exploratory actions would require the discharge of certain pollutants into the receiving waters of the Chukchi and Beaufort Seas. The EPA must permit such discharges under their National Pollutant Discharge Elimination System (NPDES) program. The NPDES discharges are not part of this action, and EPA must consulted with NMFS and USFWS on the effects of that program on listed species and critical habitat. However, the following discussion is presented to provide general information on these discharges and their potential affects.

There could be alterations in bowhead habitat as a result of exploration, including localized pollution and habitat destruction. Any potential adverse effects on bowhead whales from discharges are directly related to whether or not any potentially harmful substances are released, if they are released to the marine environment, what their fate in that environment likely is (for example, different hypothetical fates could include rapid dilution or biomagnification through the food chain), and thus, whether they are bioavailable to the species of interest.

Disposal of drilling muds and cuttings would be as specified under conditions prescribed by the EPA's. Discharge of drilling muds and cuttings during exploration activities is not expected to cause population-level effects, either directly through contact or indirectly by affecting prey species. Any effects would be localized primarily around the drill rig because of the rapid dilution/deposition of these materials. Exploration drilling muds and cuttings may cover portions of the seafloor and cause localized pollution. However, the effects likely would be negligible, because bowheads feed primarily on pelagic zooplankton and the areas of sea bottom that are impacted would be inconsequential in relation to the available habitat.

Bottom-founded drilling units and/or gravel islands may cover areas of benthic habitat that support epibenthic invertebrates used for food by bowhead whales. Muds and cuttings from development drilling from platforms are expected to be treated and disposed of in disposal wells, Muds and cuttings from satellite development wells are expected to be barged either to the host platform for downhole disposal or to shore for disposal. Produced waters are expected to be reinjected.

Gravel-island-construction activities, including placement of fill material, or installation of sheetpile or gravel bags for slope protection could cause loss of habitat, depending on the location of the gravel island. This construction would cause temporary sediment suspension or turbidity in the water as well as noise and disturbance (see noise and disturbance section).

### Potential Effects of Oil Spills from Exploration Activity

The MMS estimates the chance of a large (≥1,000 bbl) oil spill from exploratory activities to be very low. On the Beaufort and Chukchi Federal OCS, the oil industry drilled 35 exploratory wells. During the time of this drilling, industry has had 35 small spills totaling 1,120 gallons (gal) or 26.7 bbl. Of the 26.7 bbl spilled, approximately 24 bbl were recovered or cleaned up. Small (1,000 gal or less) operational spills of diesel, refined fuel, or crude oil may occur. The MMS estimates this to be the typical scenario during exploratory drilling in the Beaufort and Chukchi seas. These small spills often are onto containment and gravel islands or ice and can be cleaned up. No exploratory drilling blowouts have occurred on the Arctic or the Alaskan OCS. Since 1971, industry has drilled approximately 172 exploration wells in the Pacific, 51 in the Atlantic, 10,524 in the Gulf of Mexico, and 97 in Alaska, for a total of 10,844 wells (Brajas, Howard, and Monkelein, 1999). From 1971-1999, there were 53 blowouts during exploration drilling. With the exception of three spills, 200, 100, and 11 bbl, respectively, no additional oil spills have occurred. Therefore, more than 13,000 wells have been drilled, and three spills resulted in crude reaching the environment during exploration.

Small spills are unlikely to have significant effects on bowheads because of their reduced volumes and areas of impact and because it is anticipated that bowheads will generally avoid exploration activities and, hence, not be in the immediate vicinity at the time of a spill. Fuel spills associated with the vessels used during exploration activities could occur, especially during fuel transfer. There could be localized short-term alterations in bowhead habitat and bowhead habitat use as a result of such a spill. Whales exposed to a small fuel spill likely would experience temporary, nonlethal effects. It is difficult to accurately predict the effects of oil on bowhead whales (or any cetacean) because of a lack of data on the metabolism of this species and because of inconclusive results of examinations of baleen whales found dead after major oil releases.

Although there is no conclusive evidence that large baleen whales would be killed as a result of contact with spilled oil, it is well documented that exposure of at least some mammals to petroleum hydrocarbons through surface contact, ingestion, and especially inhalation can be harmful. Surface contact with petroleum hydrocarbons, particularly the low-molecular-weight fractions, can cause temporary or permanent damage of the mucous membranes and eyes (Davis, Schafer, and Bell, 1960) or epidermis (Hansbrough et al., 1985; St. Aubin, 1988; Walsh et al., 1974). Contact with crude oil can damage eyes (Davis, Schafer, and Bell, 1960). Ingestion of petroleum hydrocarbons can lead to subtle and progressive organ damage or to rapid death. Inhalation of volatile hydrocarbon fractions of fresh crude oil can damage the respiratory system (Hansen, 1985; Neff, 1990), cause neurological disorders or liver damage (Geraci and St. Aubin, 1982), have anesthetic effects (Neff, 1990) and, if accompanied by excessive adrenalin release, cause sudden death (Geraci, 1988).

The effects of a large oil spill, associated with production and development, are discussed in Section VII.

## V. CUMULATIVE EFFECTS

Cumulative effects are defined in 50 CFR 402.02 (Interagency Cooperation on the ESA of 1973, as amended): "…those effects of future State or private activities not involving Federal activities that are reasonably certain to occur within the action area of the Federal action subject to consultation." Reasonable foreseeable future federal actions and potential future Federal actions that are unrelated to the proposed action are not considered in the analysis of cumulative effects because they would require separate consultation pursuant to section 7 of the ESA. Cumulative effects are usually viewed as those effects that impact the existing environment and remain to become part of the environment. These effects differ from those that may be attributed to past and ongoing actions within the area since they are considered part of the environmental baseline. Additionally, most structures and major activities within the Chukchi and Beaufort Sea OCS require Federal authorizations from one or more agencies, such as the MMS, Army Corps of Engineers, and the Environmental Protection Agency. Such projects must consult under the ESA on their effects to the bowhead whale, and are therefore not addressed here as cumulative impacts.

The State of Alaska is currently leasing State-owned portions of the Beaufort Sea for oil and gas exploration and production. No sales have occurred nor are planned for the Chukchi Sea by the State. The current State of Alaska Five-Year Oil and Gas Leasing Program published in January 2006 lists Beaufort Sea areawide sales beginning in March 2006 and continuing with additional sales in October 2006-2010. The proposed sales consists of all unleased tide and submerged lands between the Canadian Border and Point Barrow as well as some upland acreage. If any of the scheduled sales occur, additional effects similar to those described for OCS lease sales could occur. All producing fields on the North Slope are onshore and on State leases, with the exception of the Duck Island Unit (which contains the Endicott field). Endicott is on State leases and is the first offshore production facility developed in the Beaufort Sea. Endicott has been producing oil since 1987. Endicott is located on a manmade gravel structure inside the barrier islands in relatively shallow water. Support traffic is over a gravel causeway that also contains the pipeline to shore.

Oil and gas development is also underway in the Eastern Beaufort Sea off the Canadian Mackenzie Delta. This includes seismic surveys, drilling, and infrastructure and support facilities as described for the US OCS. Seismic programs were recently conducted off the Mackenzie Delta in 2001 and 2002.

Bowhead whales may be disturbed during the summer in the Canadian Beaufort Sea, if offshore oil and gas exploration and development and production activities occur there in the future. The main area of industry interest to date has centered around the Mackenzie River Delta and offshore of the Tuktoyaktuk Peninsula. There has been little industry activity in this area in recent years, and we are not aware of any proposed activities. This area comprises a minor portion of the bowhead's summer range. Possible disturbance to bowhead whales from helicopters, vessels, seismic surveys, and drilling would be as previously described.

Since offshore oil and gas activities in State waters are generally well shoreward of the bowheads' main migration route, and some of the activities occur inside the barrier islands, the overall effects on bowheads from activities on State leases is likely to be minimal. These impacts could be magnified, however, if construction activity associated with additional development projects were to occur simultaneously, rather than consecutively. For example, construction and drilling noise from multiple drilling sites could result in a long-term, offshore shift in bowhead migration routes. The extra distance and heavier ice encountered could result in slower migration or physiological stress that may noticeably affect the whales. However, the majority of bowhead whales are generally found offshore of State waters.

Some effects on bowhead whales may occur because of activities from lease sales within State waters (within 3 miles of shore). Generally, bowhead whales remain far enough offshore to be found mainly in Federal waters, but they may occur in State waters in some areas, such as the Beaufort Sea southeast and north of Kaktovik and near Point Barrow. If exploration and development and production activities occur on leases from previous or proposed State sales, noise effects on whales may occur as described previously. These effects could include behavioral responses, including local avoidance to noise from aircraft and vessel traffic; seismic surveys; exploratory drilling; construction activities, including dredging; and development drilling and production operations that occur within several miles of the whales.

Future exploration and development within the Canadian Beaufort would present concerns beyond those associated with leasing in the Alaskan Beaufort Sea. The main area of industry interest has been the Mackenzie Delta and offshore of the Tuktoyaktuk Peninsula (MMS, 1995). The large estuarine front associated with the Mackenzie Delta and upwellings near the Tuktoyaktuk Peninsula provide conditions which concentrate zooplankton (Moore and Reeves, 1993). These areas are important feeding habitat to the Bering Sea stock. There are no reported plans for oil and gas exploration or production within the Canadian Beaufort Sea at this time (D. Matthews, pers. comm.) however, and this activity would not be considered reasonably expected to occur.

Current State leases with production, such as Endicott, are well removed from the normal fall migration route of the bowhead whale. Bowhead whales are not likely to be affected by noise from the Endicott project due to its distance from the bowhead's fall migration route and the limited distance into the marine environment that noise travels from gravel structures.

Each of the projects described would require some equipment and supplies to be transported to the site by barge or sealift should development and production plans proceed. The process modules and permanent living quarters and other equipment and supplies likely would be transported to these sites on seagoing barges during the open-water season. Barge traffic around Point Barrow is likely to be limited to a short period from mid-August through mid-to-late September and should be completed before the bowhead whale migration reaches this area unless it encounters severe ice conditions. Barge traffic continuing into September is likely to disturb some bowheads during their migration. Whales may react briefly by diving in response to low-flying helicopters and they would seek to avoid close approach by vessels. Oil spill probabilities associated with exploration are extremely low. In the event an oil spill occurred on State leases during the fall bowhead migration, the effects of an oil spill on bowheads would be as have been described earlier in this document. These effects include inhalation of hydrocarbon vapors, a loss of prey organisms, ingestion of spilled oil or oil-contaminated prey, baleen fouling with a reduction in feeding efficiency, and skin and/or sensory organ damage. These effects would be most pronounced whenever whales were confined to an area of freshly spilled oil. Of course, if the spill occurred over a prolonged period of time, more individuals could be contacted. Some individuals could be killed as a result of prolonged contact with freshly spilled oil, particularly if spills were to occur within ice-lead systems.

Activities that are not oil and gas related also affect bowhead whales. Between 1976 and 1992, only three ship-strike injuries were documented out of a total of 236 bowhead whales examined from the Alaskan subsistence harvest (George et al., 1994). The low number of observed ship-strike injuries suggests that bowheads either do not often encounter vessels or they avoid interactions with vessels, or that interactions usually result in the death of the animals. However, as discussed in section III, there is recent evidence that interaction of bowhead whales with ships and fishing gear may be increasing.

Subsistence harvest by Alaska Natives is another non-OCS activity that affects the bowhead whale. Bowheads are taken in the northern Bering Sea and in the Chukchi Sea on their spring migration and in the Beaufort Sea on their fall migration. Barrow whalers harvest whales during both the spring and the fall migrations. Requests to harvest bowheads also have been made by Canadian and Russian Natives. The Canadian Government granted permission in 1991 to kill one bowhead, and a bowhead was harvested in Mackenzie Bay in the fall of 1991. Additional permits were granted in 1993 and 1994, but no bowheads were harvested in either year. There has been a renewed interest by villages along the Russian Chukchi Sea coast to hunt bowhead whales. At the 1997 IWC, the Commission approved a combined quota allowing an average of 56 bowheads to be landed each year to meet the needs of Eskimos in Alaska and Chukotka Natives of the Russian Far East.

There currently is a 5-year block quota of 280 bowhead whales landed, authorized by the IWC for 2003-2007. The number of bowheads struck in each year may not exceed 67, except that any unused portion of a strike quota from any year may be carried forward. No more than 15 strikes may be added to the strike quota for any one year. This level of harvest was approved by the IWC under the supposition that it still would allow for continued growth in the bowhead population. It is likely the bowhead whale population will continue to be monitored and that harvest quota will be set accordingly to maintain a healthy bowhead population level.

The cumulative effects of noise on bowheads from offshore oil and gas activities would be similar to that described and summarized for OCS leasing and exploration. The effects from an encounter with aircraft generally are brief, and the whales should resume their normal activities within minutes. Bowheads may exhibit temporary avoidance behavior to vessels at a distance of 1-4 kilometers. Fleeing from a vessel generally stopped within minutes after the vessel passed, but scattering may persist for a longer period. Bowheads also exhibited tendencies for reduced surfacing and dive duration, fewer blows per surfacing, and longer intervals between successive blows. Bowheads appear to recover from these behavioral changes within 30-60 minutes following the end of seismic activity. However, recent monitoring studies indicate that bowhead whales during the fall migration avoid an area around a seismic vessel operating in nearshore waters by a radius of about 20 kilometers. Avoidance did not persist beyond 12 hours after the end of seismic operations. This work also stated that bowhead whales may begin to deflect around a seismic source at distances up to 35 km.

Bowheads have been sighted within 0.2-5 kilometers from drill ships, although bowheads change their migration speed and swimming direction to avoid close approach to most noise-producing activities. Bowheads may avoid drilling noise at 20-30 kilometers. There are no observations of bowhead reactions to icebreakers breaking ice, but it has been predicted that roughly half of the bowheads would respond at a distance of 4.6-20 kilometers when the S:N is 30 dB. Overall, bowhead whales exposed to noise-producing activities most likely would experience temporary, nonlethal effects. Some avoidance behavior could persist up to 12 hours.

Some bowhead whales could be exposed to spilled oil, resulting in temporary, nonlethal effects, although some mortality might result if there were a prolonged exposure to freshly spilled oil. Overall, bowhead whales exposed to noise-producing activities and oil spills associated with the proposal and other future and existing projects within the Arctic region—combined with the other activities within the range of the migrating bowhead whale—most likely would experience temporary, nonlethal effects. However, exposure to oil spills could result in lethal effects.

Vessel traffic and, perhaps, aircraft activity may be expected to occur in the future in both the Chukchi and Beaufort Seas. The effects of these actions would be the same as that presented for traffic associated with oil and gas actions. NMFS is aware of speculation that warmer ocean temperatures associated with climate change may allow for increased commercial fishing in the Chukchi Sea. However, we have no further information which would substantiate or quantify such development.

## VI. CONCLUSIONS

This Biological Opinion has considered the effects of the oil and gas leasing and exploration on the Outer Continental Shelf portion of the U.S. Chukchi and Beaufort Seas on the bowhead whale. These actions are likely to adversely affect bowhead whales due to vessel operations, marine geophysical (seismic) exploration, aircraft traffic, and drilling noises from various structures. The probability of a large oil spill is remote during exploration, but spill probabilities may be significant during latter phases.

Elevated noise levels in the marine environment could alter the hearing ability of whales, causing temporary or permanent threshold shifts. However, information suggests most continuous and impulsive underwater noise levels would be at levels or durations below those expected to injure hearing mechanisms. Nonetheless, marine seismic activities may present concerns with respect to hearing, and should be closely conditioned and monitored to avoid these effects. Noise has also been shown to cause avoidance in migrating bowhead whales. Seismic geophysical surveys and the possible use of ice breakers to support OCS activities present the highest probability for avoidance of any of the activities associated with oil exploration. Studies have shown noise from ice breakers may be detected at distances exceeding 50 km. It is reasonable to assume that bowheads could also detect this noise at this distance, however the distance at which bowheads may react to such noise is poorly described.

Available data do not indicate that noise and disturbance from oil and gas exploration and development activities since the mid-1970s had a lasting population-level adverse effect on bowhead whales. Data indicate that bowhead whales are robust, increasing in abundance, and have been approaching (or have reached) the lower limit of their historic population size at the same time that oil and gas exploration activities have been occurring in the Beaufort Sea and, to a lesser extent, the Chukchi Sea.

Research on the effects of offshore seismic exploration in the Beaufort Sea, supported by the testimony of Inupiat hunters based on their own experience, has shown bowhead whales avoid these operations when within 20 km of the source and may begin to deflect at distances up to 35 km (Richardson, 1999a). Davies (1997) concludes bowheads avoided an active drilling rig at a distance of 20 km. While such deflections during migration may not be injurious to individual animals, concern is warranted for cumulative noise and multiple disturbance; the consequences of which might include long-term shifts in migrational paths or displacement from nearshore feeding habitats. However, it is unlikely that even these impacts would prevent the survival and recovery of this species, as the primary feeding habitat is considered to be in the Canadian Beaufort and, perhaps, the Bering Sea (Shell, 1998.). The Alaskan Beaufort Sea certainly provides feeding habitat for bowhead whales, however the importance of this habitat is not fully studied at this time. Similarly, current data do not fully identify the importance of the Chukchi Sea to bowhead whales (it is known to be important as a migrational corridor). Concern is warranted over the distribution in time and space of several noise-producing activities. The most potentially disruptive of these would be seismic operations, with the potential to deflect whales at a distance of 30 km. It may be prudent, then, to avoid creating an acoustic gauntlet caused by multiple operations in a common area by requiring minimum separations between operations. We offer a Conservation Recommendation regarding this concern. Such effect is at least partially mitigated by the activity itself; all but very small operations would have to avoid other seismic signals by 15 miles (24.1 km) to eliminate interference from that signal. Additional mitigative measures are offered (see Conservation Recommendations). Because of the potential for noise disturbance to displace whales from important feeding areas, special scrutiny should be given to seismic and drilling operations which may impact these areas. While many feeding areas are dynamic and may change location from year to year, Native hunters have reported the Kaktovik area as a traditional feeding area for bowheads.

Consideration of the potential impacts of oil spills to the bowhead whale must assess 1) the probabilities for a spill to occur and to make contact with the whales and/or their habitat, 2) the effects of oil spills and spill responses on these whales, and 3) the ability of industry to prevent, control, and recover spilled oil. The estimated physical and behavioral effects of an oil spill on the Western Arctic stock of bowhead have been described. While it is clear additional research is needed to assess these effects and that no consensus has been reached regarding the degree to which oiling might impact the bowhead, we believe that whales contacting oil, particularly freshly-spilled oil, could be harmed and possibly killed. Additionally, an oil spill reaching into the spring lead system has the potential to impact a significant number of bowheads. Several coincidental events would be necessary for this scenario; the spill would have to occur, the spill would have to coincide with the seasonal occurrence of whales in these waters, the spill would have to be transported to the area the whales occupy (e.g. the migrational corridor or spring lead system), and clean-up or response efforts would have to have been at least partially unsuccessful. The impact of such an event would be significant, yet the statistical probability for the coincident occurrence of these events would be low. It must also be recognized that the spring lead system is not static, as leads open and close and whales navigate not only through the leads but surrounding ice (Clark and Ellison, 1988). Because of this it is often difficult to assess the potential effects of exploration within the spring lead system.

The ability to prevent, identify, locate, contain, and remove spilled oil is a significant concern. NMFS believes that, while spills represent low-probability events, their biological impacts are significant and that the operator should make every reasonable effort to meet these challenges. We are especially concerned with the ability to contain and remove or recover spilled oil under broken or newly-forming ice conditions. Spill response drills have failed to demonstrate industry can adequately respond under these conditions in the Beaufort Sea (ADEC, 2000). Presently, no spill response protocols, technologies, plans, or infrastructure exist to respond to spills in the Chukchi Sea. While oil spills are not expected during exploration, we believe MMS must recognize this failing, and take actions prior to later phases of development which task industry to develop effective response capabilities during all possible conditions and spill scenarios, and that each operator is held to strict standards to further reduce any likelihood of oil spills.

After reviewing the current status of the bowhead whale, the environmental baseline for the action area, the biological and physical impacts of oil leasing and exploration, and cumulative effects, and in consideration that the described actions are expected to impact only the Western Arctic stock of bowhead whales, it is NMFS's biological opinion that oil and gas leasing and exploration in the Chukchi and Beaufort Seas is not likely to jeopardize the continued existence of the *Balaena mysticetus* endangered bowhead whale. No critical habitat has been designated for the bowhead whale, therefore none will be affected.

## VII. INCREMENTAL STEP CONULTATION

This opinion addresses the incremental step of leasing and exploration in the Beaufort Sea. For the Federal agency to proceed with the incremental step, there must be a reasonable likelihood the entire action will not violate section 7 (a)(2) of the ESA (50 CFR 402.14(k)). Therefore, NMFS is providing its views on the subsequent phases of development and production, should commercially-viable discoveries of oil occur.

### Development and Production Scenario

The MMS provides a scenario for development and production from a composite of feasible options that could be developed.

Following are summaries of the major development and production assumptions:

1. Industry to install from three to five production platforms between 2004 and 2009. Drilling of production and service wells to begin in 2004 and continue through 2010, with a total of 87-111 wells drilled. Production expected to begin in 2006 and continue through 2027. Pipeline laying is expected to begin in 2005 and conclude in 2010.

2. A typical production well will use about 150-680 tons of drilling mud and produce about 1,180 tons of dry rock cuttings. It is probable these materials would be re-injected through a disposal well(s).

3. Gravel islands probably will be constructed for production facilities in water depths less than 40 feet. Bottom-founded structures of metal or concrete that rest on manmade berms on the seafloor likely would be used in water depths between 40 and 125 feet. These structures will be

designed for extreme ice conditions, so they can operate through the winter season. Floating concrete structures anchored to the seafloor and connected to satellite subsea wells likely would be used in water less than 125 feet.

4. Onshore support probably would be from Prudhoe Bay. Support for operations on production islands in nearshore shallow waters is expected to be by ice roads during the winter. Drilling operations farther offshore would be supported during the open-water season by barge and one helicopter flight/drilling unit/day. There also may be one standby vessel for each drilling unit.

5. Pipelines would be used to transfer oil from the production platforms to existing onshore pipeline systems within the Prudhoe Bay/Kuparuk field areas and transported to the Trans-Alaska Pipeline System Pump Station No. 1.

6. An estimated 276-460 square kilometers (106.6-177.7 square miles) of seismic surveys requiring from 21-35 days would be conducted under the development/production scenario.

If commercial quantities of oil are discovered and development and production proceed, gravel island construction/platform installation and pipeline construction activities would occur. Activities during development and production, like those occurring during exploration, will result in noise, altered habitat, and adverse effects on behavior, distribution, and abundance of individuals or populations occurring in or adjacent to the sale area. In addition, cleanup activities associated with any oil spill may result in disturbance.

Oil or other petroleum products released during development or production may cause adverse effects on individuals either through direct contact or indirectly as a result of effects on prey populations or important habitats. Contaminants, other than crude oil, such as drilling muds and cuttings, are not expected to cause significant effects, because they are likely to become rapidly diluted near the point of release. Moreover, the Environmental Protection Agency's discharge permits may require re-injection of muds and cuttings whenever possible, eliminating these discharges. The Northstar project has been so designed.

Noise effects associated with development and production activities on endangered whales would be similar to those described earlier. Whales would exhibit avoidance behavior from noise associated with aircraft traffic, supply vessels, barge traffic, icebreakers, drilling operations or seismic-survey vessels. Whales may temporarily interrupt their activities and swim away from the vessel's path. In most cases such behavioral changes last from minutes to as much as an hour. Avoidance movements around a stationary noise source such as a production platform could require several hours. Recent studies on the effects of seismic operations on bowheads indicate the avoidance behavior may persist for as much as 12-24 hours.

As stated earlier, underwater industrial noise, including drilling noise, measured from artificial gravel islands, has not been audible in the water more than a few kilometers away. Because the bowhead whale's main migration corridor is 10 kilometers or more seaward of the barrier islands, drilling and production noise from inside the barrier islands may not reach many migrating whales. It also likely would not affect the few whales that may be in lagoon entrances or inside the barrier islands because of the rapid attenuation of industrial sounds in a shallow-water environment. Marine-vessel traffic outside the barrier islands probably would include only seagoing barges transporting equipment and supplies from Southcentral Alaska, most likely between mid-August and mid-to-late September. Barge traffic continuing into September is likely to disturb some bowheads during their migration. Whales would avoid being within 1-4 kilometers of barges. Fleeing behavior usually stops within minutes after a vessel has passed but may last longer. Vessels and aircraft inside the barrier islands should not affect bowhead whales.

Offshore production within the normal fall migration route of the bowhead whale is likely to disturb some bowhead whales on their fall migration. Marine-vessel traffic probably would include, but not be limited to, seagoing barges transporting equipment and supplies from Southcentral Alaska to the location, most likely between mid-August and mid- to late September. Barge traffic continuing into September is likely to disturb some bowheads during their migration. Whales would try to avoid close approach by vessels. Aircraft traffic, such as helicopters from Deadhorse, would cause bowheads to dive if they pass low overhead. We do not have enough evidence to know whether or not industrial activity for several years would keep bowheads from using an area, although abandonment of feeding habitat is a significant concern.

There would be additional noise-producing activities such as dredging (trenching) for pipeline construction. Dredging or trenching may be used in constructing the gathering pipeline from the production platform to shore. Bowhead reactions to dredge noise have been observed to be similar to their reactions to drilling noise, including avoidance of the near vicinity of the activity. In one instance, as many as 12 bowheads were observed within 5 kilometers (3 miles) from active dredging operations on their summer-feeding grounds. However, some bowheads were detected within 800 meters (2,625 feet) of the site (Richardson and Malme, 1993). Dredge sounds were well above ambient levels up to several kilometers away (22 dB above average ambient level at 1.2 kilometers [0.75 miles] from the dredge). In other instances, bowheads were observed at distances where they were well within the ensonified area of dredging operations. However, in playback experiments, some whales responded to the onset of similar levels of dredge noise by exhibiting weak avoidance. Bowheads seen in the vicinity of actual dredging operations may have habituated to the activity, or there may be variation among bowheads in the degree of sensitivity toward noise disturbance, so that bowheads seen in the vicinity of dredging operations may have been the more tolerant individuals. Noise from these activities may cause whales to avoid the immediate vicinity of the pipeline construction and platforms. It is likely that the area of avoidance would be relatively small, because whales appear to exhibit less avoidance behavior with stationary sources of relatively constant noise than with moving sound sources. Dredging activities may occur during the winter through the ice and therefore, would not affect bowheads.

Cleanup activities associated with an oil spill, other than during winter, are likely to result in disturbance to bowhead whales. If an oil spill does occur, it is likely that large numbers of personnel, vessels, and aircraft will be present and conducting cleanup operations in the Beaufort Sea. If spilled oil is present during the bowhead whale migration, it could result in disturbance and possible displacement of whales from their normal migration route. Disturbance effects on the bowhead whale are expected to persist for the duration of cleanup operations if the operations are conducted during the whale migration period. The effects of oil spills on bowhead whales have been discussed previously in this document.

Development within the spring lead system may be limited by current technology. However, any such activity within this area of the Beaufort Sea presents several unique and unanswered concerns with respect to this stock. Operation in relatively deep waters subject to heavy ice is likely to require ice management. The drilling structure alone may cause spring-migrating bowheads to deflect around the source, possibly into the pack ice if other leads are not available. While Eskimo hunters have often observed that whales can travel through ice, breaking ice up to a foot or more in thickness, other smaller whales and calves may be unable to do so. Additionally, any oil spills within the spring lead system would be detrimental to the migrating bowheads, and would present the potential to impact a significant percentage of the stock.

We are not, and we cannot be, certain of the level of effects on bowheads should a large or very large oil spill occur. Should development and production occur in the Chukchi Sea OCS, the estimated chance of spills >1,000 bbl occurring in the Chukchi Sea OCS is estimated to be about 40%. The estimated chance of one or more 1,000-bbl spills occurring in the Beaufort Sea OCS is about 10-11%. Oil spilled in the Beaufort Sea OCS could contact resources in the Chukchi Sea OCS and vice versa. Thus, bowhead whales could conceivably be exposed to oil and oil spill response from spills in both planning areas. The estimated chance of one or more large spills occurring, based on lease sales in both areas, is 47%.

Adult whales exposed to spilled oil likely would experience temporary, or perhaps permanent, nonlethal effects, although prolonged exposure to freshly spilled oil could kill whales. This conclusion is supported by the best available information. There are no data available to MMS that definitely link a large oil spill with a significant population-level effect on a species of large cetacean.

However, while data from previous spills in other locations worldwide are broadly informative, we acknowledge uncertainty about the potential for population level effects or other potential outcomes should a large or very large spill occur in instances where whales are aggregated and/or constrained in their option for alternative routes (for example, in the spring lead and polynya system due to ice conditions) or are aggregated in a feeding area, especially if aggregations contained large numbers of females and calves. The potential for a population level effect may exist if large numbers of females and calves, especially newborn or very young calves, were to be contacted by large amounts of freshly spilled oil. The uncertainty arises because:

- of the unique ecology of the bowhead whale;
- existing information about the effects of oil on very large cetaceans is inconclusive and, thus, it is not possible to confidently estimate the likelihood that serious injury to individuals of bowhead whales could or would occur with oil exposure;
- there is lack of agreement over the interpretation of post-Exxon Valdez oil-spill cetacean studies;
- there are not data sufficient to determine the vulnerability of newborn or other baleen calves to freshly spilled crude oil;
- it is very difficult, if not impossible, to obtain many of the kinds of data that have been gathered on some other marine mammals to assess acute or chronic adverse sublethal effects from an oil spill (or other affecters) on large cetaceans; and
- there is no other situation comparable to that which could exist if a large or very large oil spill occurred in, or moved into, the spring lead and polynya system, especially if this occurred when there were large

> numbers of females with newborn calves, occurred when calving was occurring, or occurred when hundreds of individuals were in the leads and polynya on their northward migration.

### Well Abandonment

On completion of production, wells would be abandoned and sites rehabilitated as may be required by the MMS. Noise, disturbance, and possible injury to threatened and endangered species during OCS oil and gas exploration are activities associated with abandonment of exploration and delineation wells. The casings for wells can be cut mechanically or with explosives during the process of well abandonment. The use of explosives could result in injury or even death to bowhead whales that are in the area at the time of the explosions, although the threshold levels for injury or death are not well established (for example, Ketten, Lien and Todd, 1993; Richardson et al., 1995). With respect to well abandonment, the MMS (USDOI, MMS, Pacific OCS Region, 2001) previously summarized that:

…the use of explosives for delineation well abandonment would involve the detonation of a relatively small, 16- to 20-kilogram charge in the well casing 5 meters below the sea floor. This positioning of the charge would dampen the explosion and restrict shock and acoustic effects primarily to the area of water immediately above the well head. However, a marine mammal close to the detonation site potentially could be injured or killed, or suffer permanent or temporary hearing damage. Some disturbance of marine mammals present in the vicinity of the detonation area could also occur, but these would be expected to be minor and temporary…Overall, impacts from this source are expected to be low.

Impacts to bowhead whales from well-abandonment activities could be avoided if these activities were implemented only when bowheads were absent or if sufficient monitoring (e.g., aerial surveys and passive acoustic monitoring) for bowheads occurred prior to the use of any explosives and protocols were implemented to ensure that such explosives were not used if such species were in areas where there was a potential for them to be adversely impacted by the explosives.

### Analyses of Potential Effects of an Oil Spill on Bowhead Whales.

Following a large or very large oil spill, bowhead or other baleen whales could suffer adverse effects due to:

- inhalation of toxic components of crude oil;
- ingesting oil and/or contaminated prey;
- fouling of their baleen;
- oiling of skin;
- reduced food source; and
- displacement from feeding areas.

### Effects of Inhalation of Toxic Components of Crude Oil

The greatest threat to large cetaceans probably is from inhalation of volatile compounds present in fresh crude oil. Based on literature on other mammals indicating severe adverse effects of inhalation of the toxic aromatic components of fresh oil, mortality of bowheads or other cetaceans could occur if they surfaced in large quantities of fresh oil. Inhalation of volatile hydrocarbon fractions of fresh crude oil can damage the respiratory system (Hansen, 1985; Neff, 1990), cause neurological disorders or liver damage (Geraci and St. Aubin, 1982), have anesthetic effects (Neff, 1990) and, if accompanied by excessive adrenalin release, cause sudden death (Geraci, 1988).

Based on evidence of observation of individuals from the AB pod of killer whales in heavy oil, and large disappearances of whales from the AB pod in the 2 years following that exposure (Dahlheim and Matkin, 1994; Harvey and Dahlheim, 1994), one could conclude that whales are vulnerable, probably due to inhalation, if they are present within a large spill. However, this link is circumstantial, and there is not agreement in the scientific community as to whether or not there likely was an oil-spill impact on killer whales after the EVOS. Similarly, gray whales with apparently abnormal behavior were observed in oil after the EVOS in an area where fumes from the spill were apparently very strong (J. Lentfer, cited in Harvey and Dahlheim, 1994). Subsequently large numbers of gray whale carcasses were discovered. One of three of these whales had elevated levels of polycyclic aromatic hydrocarbons in its blubber. Loughlin (1994) concluded it was unclear what caused the death of the gray whales. During the oil spill off Santa Barbara in 1969, an estimated 80,000 bbl of oil may have entered the marine environment. Gray whales were beginning their annual migration north during the spill. Whales were observed migrating northward through the slick. Several dead whales were observed and carcasses recovered, including six gray whales, one sperm whale, one pilot whale, five common dolphins, one Pacific white-sided dolphin, and two unidentified dolphins. Brownell (1971, as reported by Geraci, 1990) acknowledged that these whales totaled more than the usual number of gray whales and dolphins stranding annually on California shores, and concluded that increased survey efforts had led to the higher counts. Several of the whales examined were thought to have died from natural causes, and one may have been harpooned. No evidence of oil contamination was found on any of the whales examined. The Batelle Memorial Institute concluded the whales were either able to avoid the oil, or were unaffected when in contact with it.

Based on all available information, if individual, small groups or, less likely, large groups of whales were exposed to large amounts of fresh oil, especially through inhalation of highly toxic aromatic fractions, they might be seriously injured or die from such exposure. Although there is very little definitive evidence linking cetacean death or serious injury to oil exposure, disappearances (and probable deaths) of killer whales and the deaths of large number of gray whales both coincided with the EVOS and with observations of members of both species in oil. However, in these two cases, even if one assumed the disappearances of the killer whales and the high number of gray whale carcasses both were the result of the coinciding oil spill, and one assumed impacts on bowhead whales of the same magnitude, it is unlikely that there would be a significant population-level adverse effect in the event of a large oil spill.

As noted above, we know of no bowhead whale deaths resulting from an oil spill. For the reasons discussed in the previous paragraph, it is difficult to predict the impact of a large or very large spill on bowhead whales, fin whales, or humpback whales. Based on literature on other mammals indicating severe adverse effects of inhalation of the toxic aromatic components of fresh oil, mortality of cetaceans could occur if they surfaced in large quantities of fresh oil. We believe this is most likely if bowhead calves were exposed to fumes from a large spill. Calves take more breaths than do their mothers and spend more time at the surface. Thus, it is likely they would be most likely to succumb to inhalation of toxic aromatic compounds.

The potential for there to be long-term sublethal (for example, reduced body condition, poorer health, reduced immune function, reduced reproduction or longer dependency periods) effects on large cetaceans from a large oil spill is essentially unknown. There are no data on large cetaceans adequate to evaluate the probability of sublethal effects.

Geraci and St. Aubin (1982) calculated the concentrations of hydrocarbons associated with a theoretical spill of a typical light crude oil. They calculated the concentrations of the more volatile fractions of crude oil in air. The results showed that vapor concentrations could reach critical levels for the first few hours after a spill. If a whale or dolphin were unable to leave the immediate area of a spill during that time, it would inhale some vapors, perhaps enough to cause damage. Fraker (1984) stated that a whale surfacing in an oil spill will inhale vapors of the lighter petroleum fractions, and many of these can be harmful in high concentrations. Animals that are away from the immediate area or that are exposed to weathered oils would not be expected to suffer serious consequences from inhalation, regardless of their condition. The most serious situation would occur if oil spilled into a lead that bowheads could not escape. In this case, Bratton et al. (1993) theorized the whales could inhale oil vapor that would irritate their mucous membranes or respiratory tract. They also could absorb volatile hydrocarbons into the bloodstream. Within hours after the spill, toxic vapors from oil in a lead could harm the whales' lungs and even kill them. The number of whales affected would depend on how large the spill was, its behavior after being spilled, and how many whales were present in areas contacted in the first several days following the spill.

## Effects of Direct Contact of Skin and other Surfaces with Spilled Oil

Oil first would contact a whale's skin as it surfaces to breathe. The effects of oil contacting skin are largely speculative. We do not know how long spilled oil will adhere to the skin of a free-ranging whale. Oil might wash off the skin and body surface shortly after bowheads vacated oiled areas, if they left shortly after being oiled. However, oil might adhere to the skin and other surface features (such as sensory hairs) longer, if bowheads remained in these areas or after it left the oiled area.

Bowhead whale eyes may be vulnerable to damage from oil on the water due to their unusual anatomical structure. It is documented that crude oil can damage eyes (Davis, Schafer, and Bell, 1960). Corneal ulcers and abrasions, conjunctivitis, and swollen nictitating membranes were observed in captive ringed seals placed in crude oil-covered water (Geraci and Smith, 1976), and in seals in the Antarctic after an oil spill (Lillie, 1954). Corneal ulcers and scarring were observed in otters captured in oiled areas (Monnett and Rotterman, 1989) and in oiled otters brought into oil-spill treatment centers (Wilson et al., 1990) after the EVOS.

In a study on nonbaleen whales and other cetaceans, Harvey and Dahlheim (1994) observed 80 Dall's porpoises, 18 killer whales, and 2 harbor porpoises in oil on the water's surface from the EVOS. They observed groups of Dall's porpoises on 21 occasions in areas with light sheen, several occasions in areas with moderate-to-heavy surface oil, once in no oil, and once when they did not record the amount of oil. Thirteen of the animals were close enough to determine if oil was present on their skin. They confirmed that 12 animals in light sheen or moderate-to-heavy oil did not have oil on their skin. One Dall's porpoise had oil on the dorsal half of its body. It appeared stressed because of its labored breathing pattern. The authors gave no other information on effects. The 18 killer whales and 2 harbor porpoises were in oil but had none on their skin. None of the cetaceans appeared to alter their behaviors when in areas where oil was present. The authors concluded their observations were consistent with other reports of cetaceans behaving normally when oil is present. However, as noted above in the review of observations following other spills, observations of cetaceans behaving is a lethargic fashion or having labored breathing has been documented in more than one species, including one in which large numbers of individuals were subsequently found dead.

Histological data and ultrastructural studies by Geraci and St. Aubin (1990) showed that exposures of skin to crude oil for up to 45 minutes in four species of toothed whales had no effect. They switched to gasoline and applied the sponge up to 75 minutes. This produced transient damage to epidermal cells in whales. Subtle changes were evident only at the cell level. In each case, the skin damage healed within a week. They concluded that a cetacean's skin is an effective barrier to the noxious substances in petroleum. These substances normally damage skin by getting between cells and dissolving protective lipids. In cetacean skin, however, tight intercellular bridges, vital surface cells, and the extraordinary thickness of the epidermis impeded the damage. The authors could not detect a change in lipid concentration between and within cells after exposing skin from a white-sided dolphin to gasoline for 16 hours in vitro.

Geraci and St. Aubin also investigated how oil might affect healing of superficial wounds in a bottlenose dolphin's skin. They found that following a cut, newly exposed epidermal cells degenerate to form a zone of dead tissue that shields the underlying cells from seawater during healing. They massaged the superficial wounds with crude oil or tar for 30 minutes, but the substances did not affect healing. Lead-free gasoline applied in the same manner caused strong inflammation, but it subsided within 24 hours and was indistinguishable from control cuts. The authors concluded that the dead tissue had protected underlying tissues from gasoline in the same way it repels osmotic attack by seawater. The authors further concluded that in real life, contact with oil would be less harmful to cetaceans than they and others had proposed.

While petroleum can damage mammalian skin, Geraci and St. Aubin (1985) reported little effects with exposures of 75 minutes. We noted that after a real spill, oil could be in contact with skin for much longer periods. Lipid composition was not modified, and epidermal cell proliferation was not significantly reduced. However, as pointed out by Harvey and Dahlheim (1994), the significance of these results is uncertain because of small sample sizes and the uncertainty of their applicability to natural situations. It is not clear why some cetaceans that are observed in oil do not become oiled while at least a few apparently do. It is not clear how long crude oil would remain on a free-ranging cetacean's skin once it was oiled. Bratton et al. (1993) synthesized studies on the potential effects of contaminants on bowhead whales. They concluded that no published data proved oil fouling of the skin of any free-living whales, and conclude that bowhead whales contacting fresh or weathered petroleum are unlikely to suffer harm.

Although oil is unlikely to adhere to smooth skin, it may stick to rough areas on the surface (Henk and Mullan, 1997). Haldiman et al. (1985) found the epidermal layer to be as much as seven to eight times thicker than that found on most whales. They also found that little or no crude oil adhered to preserved bowhead skin that was dipped into oil up to three times, as long as a water film stayed on the skin's surface. Oil adhered in small patches to the surface and vibrissae (stiff, hairlike structures), once it made enough contact with the skin. The amount of oil sticking to the surrounding skin and epidermal depression appeared to be in proportion to the number of exposures and the roughness of the skin's surface.

Albert (1981) suggested that oil would adhere to the skin's rough surfaces (eroded areas on the skin's surface, tactile hairs, and depressions around the tactile hairs). He theorized that oil could irritate the skin, especially the eroded areas, and interfere with information the animal receives through the tactile hairs. Because we do not know how these hairs work, we cannot assess how any damage to them might affect bowheads. Albert (1981) noted that eroded skin may provide a point of entry into the bloodstream for pathogenic bacteria, if the skin becomes more damaged. Evidence from Shotts et al. (1990) suggests that the lesions are active sites of necrosis. The authors noted that 38% of the microorganisms in lesions contained enzymes necessary for hemolytic activity of blood cells (breaking down of red blood cells and the release of hemoglobin) compared to 28% of the microorganisms on normal skin. Many of these species of bacteria and yeast were determined to be potential pathogens of mammalian hosts.

The potential effect of crude oil on the function of the cetacean blowhole is unknown. As noted, a Dall's porpoise was observed after the EVOS with crude oil covering its skin and blowhole. This individual was described as having labored breathing. Other porpoise swimming in the same area in oil did not appear to be oiled or to have abnormal behavior (Harvey and Dahlheim, 1994).

### Effects of Ingestion of Spilled Oil

It is documented that, with respect to mammals in general, ingestion of petroleum hydrocarbons can lead to subtle and progressive organ damage or to rapid death. Also as noted above, many polycyclic aromatic hydrocarbons are teratogenic and embryotoxic in at least some mammals (Khan et al., 1987). Maternal exposure to crude oil during pregnancy may negatively impact birth weight and health of young in at least some mammals (Khan et al., 1987; Currie et al., 1970). In at least some marine mammals, digestion and behavior is affected with decrease food assimilation of prey eaten (for example, St. Aubin, 1988), increased gastrointestinal motility, increased vocalization, and decreased sleep (Geraci and Smith, 1976; Engelhardt, 1985, 1987) (see discussion above for more detail). Oil ingestion can decrease food assimilation of prey eaten (for example, St. Aubin, 1988).

Bowheads sometimes skim the water surface while feeding, filtering a lot of water for extended periods. If oil were present, they could swallow it. Albert (1981) suggested that whales could take in tarballs or large "blobs" of oil with prey. He also said that swallowed baleen "hairs" mix with the oil and mat together into small balls. These balls could block the stomach at the connecting channel, which is a very narrow tube connecting the stomach's fundic and pyloric chambers (the second and fourth chambers of the stomach) (Tarpley et al., 1987). Hansen (1985; 1992) suggests that cetaceans can metabolize ingested oil, because they have cytochrome p-450 in their livers (Hansen, 1992). The presence of cytochrome p-450 (a protein involved in the enzyme system associated with the metabolism and detoxification of a wide variety of foreign compounds, including components of crude oil) suggests that cetaceans should be able to detoxify oil (Geraci and St. Aubin, 1982, as cited in Hansen, 1992). He also suggests that digestion may break down any oil that adheres to baleen filaments and causes clumping (Hansen, 1985). Observations and stranding records do not reveal whether cetaceans would feed around a fresh oil spill long enough to accumulate a critical dose of oil. There is great uncertainty about the potential effects of ingestion of spilled oil on bowheads, especially on bowhead calves. Decreased food assimilation could be particularly important in very young animals, those that seasonally feed, and those that need to put on high levels of fat to survive their environment.

Bowheads may swallow some oil-contaminated prey, but it likely would be only a small part of their food. It is not known if bowheads would leave a feeding area where prey was abundant following a spill. Some zooplankton eaten by bowheads consume oil particles and bioaccumulation can result (see section on Potential Effects on Food Source below). Tissue studies by Geraci and St. Aubin (1990) revealed low levels of naphthalene in the livers and blubber of baleen whales. This result suggests that prey have low concentrations in their tissues, or that baleen whales may be able to metabolize and excrete certain petroleum hydrocarbons.

### Potential Effects of Baleen Fouling

If a bowhead encountered spilled oil, baleen hairs might be fouled, which would reduce a whale's filtration efficiency during feeding. In a recent peer-reviewed paper in the Journal of Mammalogy, Lambertsen et al. (2005:349) concluded that because previous "(E)xperimental assessment of the effects of baleen function...thus far has considered exclusively the role of hydraulic pressure in powering baleen function..." but "...our present results indicate that more subtle hydrodynamic pressure may play a critical role in the function of the baleen in the...balaenids...the current state of knowledge of how oil would affect the function of the mouth of right whales and bowheads can be considered poor, despite considerable past research on the effects of oil on cetaceans."

Lambertsen et al. (2005) contended that oil could be efficiently ingested if globules of oil behave like prey inside the mouth. They point out that if oil is of low viscosity and does not behave like prey, only small amounts would be ingested. Lambertsen et al. (2005:350) characterize these two conditions as being of "questionable validity" and note that if, on the other hand, the resistance of the baleen is significantly increased by oil fouling, as experimental evidence on the baleen of other mysticetes indicates it may be, the most likely adverse effect "...would be a substantial reduction in capture of larger, more actively mobile species, that is euphausiids, with possible reductions in capture of copepods and other prey" (Lambertsen et al., 2005:350). They concluded that their results highlight the uncertainty about how rapidly oil would depurate at the near zero temperatures of arctic waters and whether baleen function would be restored after oiling.

Earlier studies on baleen fouling were summarized by Geraci (1990) who, with colleagues, had also undertaken studies of the effects of oil on baleen function. Geraci (1990:184) noted that while there was "A great deal of interest...in the possibility that residues of oil may adhere to baleen plates so as to block the flow of water and interfere with feeding. The concerns are largely speculative." He also noted that "Such an effect may be imperceptible, though leading to subtle, long-term consequences to the affected animal." Geraci (1990:184) concluded that "A safe assumption is that any substance in seawater which alters the characteristics of the plates, the integrity of the hairs, or the porosity of the sieve may jeopardize the nutritional well-being of the animal."

Braithwaite (1983, as cited in Bratton et al., 1993) used a simple system to show a 5-10% decrease in filtration efficiency of bowhead baleen after fouling, which lasted for up to 30 days. Geraci (1990:186) stated that the "Details of the experimental protocol" used in that study "...are not entirely clear."

Geraci (1990) summarized studies by Geraci and St. Aubin (1982, 1985) where the effects of contamination by different kinds of oil on humpback, sei, fin, and gray whale baleen were tested in saltwater ranging from 0 to 20 $^{o}$C. In these studies, resistance to flow of some humpback baleen was increased more than 100%, less than 75% in gray and sei whale baleen, and gray whale samples were "relatively unaffected" (Geraci, 1990:186). Resistance to water flow through baleen was increased the greatest with contamination by Bunker C oil at the coldest temperatures. He summarized that oil of medium weight had little effect on resistance to water flow at any temperature. Fraker (1984) noted that there was a reduction in filtering efficiency in all cases, but only when the baleen was fouled with 10 millimeters of oil was the change statistically different.

In the study in which baleen from fin, sei, humpback, and gray whales was oiled, Geraci and St. Aubin (1985) found that 70% of the oil adhering to baleen plates was lost within 30 minutes (Geraci, 1990) and in 8 of 11 trials, more than 95% of the oil was cleared after 24 hours. The study could not detect any change in resistance to water flowing through baleen after 24 hours. The baleen from these whales is shorter and coarser than that of bowhead whales, whose longer baleen has many hairlike filaments. Geraci (1990:187) concluded that:

> Combined evidence...suggests that a spill of heavy oil, or residual patches of weathered oil, could interfere with the feeding efficiency of the fouled plates for several days at least. Effects would likely be cumulative in an animal feeding in a region so blanketed by weathered oil that the rate of cleansing is outpaced by fouling. That condition could describe the heart of a spill, or a contaminated bay or lead.

Lighter oil should result in less interference with feeding efficiency. Lambertsen et al. (2005:350) concluded that results of their studies indicate that Geraci's analysis of physiologic effects of oiling on mysticete baleen "considered baleen function to be powered solely by hydraulic pressure," a perspective they characterized as a "gross oversimplification of the relevant physiology."

A reduction in food caught in the baleen could have an adverse affect on the body condition and health of affected whales. If such an effect lasted for 30 days, as suggested by the experiments of Braithwaite (1983), this could potentially be an effect that lasted a substantial proportion of the period that bowheads spend on the summer feeding grounds. Repeated baleen fouling over a long time, however, might also reduce food intake and blubber deposition, which could harm the bowheads. As pointed out by Geraci (1990), the greatest potential for adverse effects to bowheads would be if a spill occurred in the spring lead system.

### Potential Effects on Food Source

Data from a recent study (Duesterloh, Short, and Barron, 2002) indicated that aqueous polyaromatic compounds (PAC) dissolved from weathered Alaska North Slope crude oil are phototoxic to subarctic marine copepods at PAC concentrations that would likely result from an oil spill and at UV levels that are encountered in nature. *Calanus marshallae* exposed to UV in natural sunlight and low doses (~2µg of total PAC per liter (PAC/L) of the water soluble fraction of weathered North Slope crude oil for 24 hours) showed an 80-100% morbidity and mortality as compared to less than 10% with exposure to the oil-only or sun-light only treatments. At 100% mortality occurred in *Metridia okhotensis* with the oil and UV treatment, while only 5% mortality occurred with the oil treatment alone. Duesterloh, Short, and Barron (2002) reported that phototoxic concentrations to some copepod species were lower by a factor of 23 to >4,000 than the lethal concentrations of total PAC alone (0.05-9.4 mg/L).

This research also indicated that copepods may passively accumulate PACs from water and could thereby serve as a conduit for the transfer of PAC to higher trophic level consumers. Bioaccumulation factors were ~2,000 for *M. okhotensis* and about ~8,000 for *C. marshallae*. *Calanus* and *Neocalanus* copepods have relatively higher bioaccumulation than many other species of copepods because of their characteristically high lipid content. The authors concluded that phototoxic effects on copepods could conceivably cause ecosystem disruptions that have not been accounted for in traditional oil spill damage assessments. Particularly in nearshore habitats where vertical migration of copepods is inhibited due to shallow depths and geographical enclosure, phototoxicity could cause mass mortality in the local plankton population. (Duesterloh, Short, and Barron, 2002:3959).

An oil spill probably would not permanently affect zooplankton populations, the bowhead's major food source, and major effects are most likely to occur nearshore (Richardson et al., 1987, as cited in Bratton et al., 1993). The amount of zooplankton lost, even in a large oil spill, would be very small compared to what is available on the whales' summer-feeding grounds (Bratton et al., 1993).

The potential effects to bowheads of exposure to PACs through their food are unknown. Because of their extreme longevity, bowheads are vulnerable to incremental long-term accumulation of pollutants. With increasing development within their range and long-distance transport of other pollutants, individual bowheads may experience multiple large and small polluting events within their lifetime.

### Effects of Displacement from Feeding Areas

We have no observations from western science of the response of bowhead whales following a large oil spill to determine whether they may be temporarily displaced from an area because of an oil spill or cleanup operations. However, Thomas Brower, Sr. (1980) described the effects on bowhead whales of a 25,000-gallon (595-bbl) oil spill at Elson Lagoon (Plover Islands) in 1944. It took approximately 4 years for the oil to disappear. For four years after the oil spill, Brower observed that bowhead whales made a wide detour out to sea when passing near Elson Lagoon/Plover Islands during fall migration. Bowhead whales normally moved close to these islands during the fall migration. These observations indicate that some displacement of whales may occur in the event of a large oil spill, and that the displacement may last for several years. Based on these observations, it also appears that bowhead whales may have some ability to detect an oil spill and avoid surfacing in the oil by detouring around the area of the spill.

Several other investigators have observed various cetaceans in spilled oil, including fin whales, humpback whales, gray whales, dolphins, and pilot whales. Typically, the whales did not avoid slicks but swam through them, apparently showing no reaction to the oil. During the spill of Bunker C and No. 2 fuel oil from the *Regal Sword*, researchers saw humpback and fin whales, and a whale tentatively identified as a right whale, surfacing and even feeding in or near an oil slick off Cape Cod, Massachusetts (Geraci and St. Aubin, 1990). Whales and a large number of white-sided dolphins swam, played, and fed in and near the slicks. The study reported no difference in behavior between cetaceans within the slick and those beyond it. None of the observations prove whether cetaceans can detect oil and avoid it. None of these observations is sufficient to determine the long-term impacts of such exposure. Some researchers have concluded that baleen whales have such good surface vision that they rely on visual clues for orientation in various activities. In particular, bowhead whales have been seen "playing" with floating logs and sheens of fluorescent dye on the sea surface of the sea (Wursig et al., 1985, as cited in Bratton et al., 1993). These observations suggest that if oil is present on the sea surface and is of such quality or in such quantity that it is readily optically recognizable, bowhead whales may be able to recognize and avoid it (Bratton et al., 1993). However, the observation of their playing with dye may also indicate that they would play with it.

After the EVOS, researchers studied the potential effects of an oil spill on cetaceans. Dahlheim and Loughlin (1990) documented no effects on the humpback whale. von Ziegesar, Miller, and Dahlheim (1994) found no indication of a change in abundance, calving rates, seasonal residency time of female-calf pairs, or mortality in humpback whales as a result of that spill, although they did see temporary displacement from some areas of Prince William Sound. It was difficult to determine whether the spill changed the number of humpback whales occurring in Prince William Sound. This study could not have detected long-term physiological effects to whales or to the humpback's prey.

Cleanup operations following a large or very large spill would be expected to involve multiple marine vessels operating in the spill area for extended periods of time, perhaps over multiple years. Based on information provided in the above section on vessel traffic, bowheads react to the approach of vessels at greater distances than they react to most other industrial activities. According to Richardson and Malme (1993), most bowheads begin to swim rapidly away when vessels approach rapidly and directly. Avoidance usually begins when a rapidly approaching vessel is 1-4 km (0.62-2.5 mi) away. A few whales may react at distances from 5-7 km (3-4 mi).

After a large or very large spill, there are typically overflights using helicopters and fixed-winged aircraft to track the spill and to determine distributions of wildlife that may be at risk from the spill. We summarize the response of bowheads to aircraft here. Most bowheads are unlikely to react significantly to occasional single passes by helicopters flying at altitudes above 150 m (500 ft). At altitudes below 150 m (500 ft), some bowheads probably would dive quickly in response to the aircraft noise (Richardson and Malme, 1993; Patenaude et al., 1997) and may have shortened surface time (Patenaude et al., 1997). Bowhead reactions to a single helicopter flying overhead probably are temporary (Richardson et al., 1995a). Whales should resume their normal activities within minutes. Fixed-wing aircraft flying at low altitude often cause hasty dives. Reactions to circling aircraft are sometimes conspicuous if the aircraft is below 300 m (1,000 ft), uncommon at 460 m (1,500 ft), and generally undetectable at 600 m (2,000 ft). Repeated low-altitude overflights at 150 m (500 ft) sometimes caused abrupt turns and hasty dives (Richardson and Malme, 1993). The effects from an encounter with aircraft are brief, and the whales should resume their normal activities within minutes.

Based on all of the above information, we conclude that there could potentially be displacement of bowhead whales from a feeding area following a large or very large spill and this displacement could last as long as there is a large amount of oil and related clean-up vessels present.

### Areas and Circumstances Where Effects of an Oil Spill are Likely to be Greater than Typical

The number of bowhead or other whales contacting spilled oil would depend on the size, timing, and duration of the spill; how many whales were near the spill; and the whales' ability or inclination to avoid contact. Bowhead whales may be particularly vulnerable to oil-spill effects due to their use of ice edges and leads where spilled oil may accumulate (Engelhardt, 1987:104). Primarily because of the uniqueness of the bowhead and its apparently obligate use of spring lead and polynyas as its migratory path between wintering and summering grounds, we are uncertain of the potential severity of impact should a large or very large oil spill occur within such a system, especially if spring migration were underway and hundreds of females were calving in or near those leads.

There are two situations in which bowheads are at particular risk in the event of a large oil spill. The first situations would be if a large or very large spill occurred while the whales were migrating north through the Chukchi Sea, or east through the Beaufort Sea, traveling through the spring lead and polynya system, particularly during the period when large numbers of females are calving or accompanied by very young calves. The effects of an oil spill on cetacean newborns or other calves are not known. The potential effects of contact or detection of spilled oil by near term, or post partum females are not known. The migration path through the Chukchi Sea is relatively constrained, the area appears to be the, or a, primary calving ground of the Western Arctic stock, and it must be assumed that essentially the whole stock needs to make this migration in order to get to summering grounds.

The potential for there to be adverse effects from a large oil spill would also likely be greater (than in more typical circumstances) if a very large spill of fresh oil (with high concentrations of aromatics) contacted one or more large aggregation of bowheads especially (but not exclusively) if such an aggregation contained large numbers of females and calves. Such aggregations occasionally have been documented in MMS aerial bowhead whale surveys. For example, Treacy (1998) observed large feeding aggregations, including relatively large numbers of calves (for example, groups of 77[6], 62[5], 57[7], and 51[0], where the numbers given in brackets are the numbers of calves) of feeding bowheads in waters off of Dease Inlet/Smith Bay in 1997 and in 1998. However, in some years no large aggregations of bowheads were seen anywhere within the study area. When seen, the aggregations were in open water. The likelihood of a very large spill occurring and contacting such a group is low but not outside the range of possibilities. The factors associated with the presence of such groups are not yet clear. It is not known if they would leave the area heavily contaminated with crude oil.

## Oil Spill Response Activities

An industry consortium stockpiles response equipment in the Prudhoe area for all three operating seasons in the Arctic: solid ice, open water, and broken ice (USDOI, MMS, 2003a:Section IV.A.6 in the Beaufort Sea multiple sale EIS, USDOI, MMS, 2003a). For the solid-ice season, spill-response demonstrations have shown that there are effective tactics and equipment for oil recovery. For the open-water season, the effectiveness of spill-response equipment is similar to that for other OCS areas. For the broken-ice season, the Beaufort Sea multiple-sale EIS explained that research was ongoing. Spill demonstrations and drills have shown that the mechanical effectiveness of response equipment still is reduced greatly by broken ice. Non-mechanical response tactics (e.g. in situ burning) would be applied during these conditions.

## Probabilities of Contacting an Oil Spill

Variability in the distribution of bowhead whales in the Beaufort Sea over time and among years, and lack of recent data on bowhead seasonal distribution and abundance in the

Chukchi Sea makes attempts to quantitatively model the numbers of whales that might be contacted by oil problematic. Whether, and how many, bowhead whales would come into contact with oil would depend on the location, timing, and magnitude of the spill; the location of whales when the spill occurred and over time following the spill; weather at the time of the spill; the presence and extent of shorefast and broken ice; the effectiveness of cleanup and possibly hazing activities; the motivation of the whales to get to where they were going or to stay where they were; and their options for alternate routes to their destinations (e.g., whether or not they were in leads adjacent to pack ice).

Probably the greatest potential for a large number of whales to contact spilled oil would be if there was an oil spill in the spring lead system, or if an oil spill occurred when whales were aggregated in large feeding groups.

Geraci and St. Aubin (1990) stated that the notable weakness in modeling is that there is no information on the type and duration of oil exposure required to produce an effect. They further stated that for all but the sea otter, the premise that contact is necessarily fatal is indefensible. Models commonly overestimate the impact of a spill. They further stated that few, if any, cetaceans have been claimed by spilled oil. They did not address potential impacts within lead systems or potential effects on calves or females with calves.

## Conclusions of Potential Oil-Spill Effects

The effects of a large oil spill and subsequent exposure of the bowhead whale population to fresh crude oil are uncertain, speculative, and controversial. The effects would depend on how many whales contacted oil; the ages and reproductive condition of the whales contacted; the duration of contact, the amount of oil spilled, and the age/degree of weathering of the spilled oil at the time of contact. The number of whales contacting spilled oil would depend on the size, timing, and duration of the spill; how many whales were near the spill; and the whales' ability or inclination to avoid contact. If oil got into leads or ice-free areas frequented by migrating bowheads, a large portion of the population could be exposed to spilled oil. If a very large slick of fresh oil contacted a large aggregation or aggregations of feeding bowheads, especially with a high percent of calves, the effect might be expected to be greater than under more typical circumstances. There is great uncertainty about the effects of fresh crude oil on cetacean calves. Prolonged exposure to freshly spilled oil could kill some adult whales, but, based on available information, the number likely would be small if the spill contacted bowheads in open water. However, Engelhardt (1987) theorized that bowhead whales would be particularly vulnerable to effects from oil spills during their spring migration into arctic waters because of their use of ice edges and leads, where spilled oil tends to accumulate. Several other researchers (Geraci and St. Aubin, 1982; St. Aubin, Stinson, and Geraci, 1984) concluded that exposure to spilled oil is unlikely to have serious direct effects on baleen whales. There is some uncertainty and disagreement within the scientific community on the results of studies on the impacts of the EVOS on large cetaceans (for example, Loughlin, 1994, Dahlheim and Matkin, 1994, Dahlheim and Loughlin, 1990). Bowheads may also have heightened vulnerability to spilled oil because of the functional morphology of their baleen. If baleen in fouled, and if crude oil s ingested, there could be adverse effects on the feeding efficiency and food assimilation of bowhead whales. Such effects are expected to be of most importance to calves, pregnant females, and lactating females. However, loss of feeding efficiency could potentially reduce the chance of survival of any whale and could affect the amount of energy female whales have to invest in reproduction.

Assuming that development and production occurs, large oil spills are less likely to occur in the Beaufort Sea than in the Chukchi Sea. MMS estimates about a 40% chance of a spill of 1,000 bbl in the Chukchi Sea Planning Area should production occur.

Despite the fact that there is no definitive mortality of a large cetacean due to an oil spill, based on the fact that certain components of crude oil are highly toxic to other mammals, such mortality could potentially occur. Ingestion, surface contact with, and especially inhalation of fresh crude oil has been shown to cause serious damage and even death in many species of mammals. This does not mean that such effect would occur. Such an assumption, if it provides an overestimate of potential effects, is more protective of the population than erring on the side of assuming that such impacts could not occur because they previously have not been documented. Relatedly, because of unique ecological characteristics of the bowhead, they may be more vulnerable than other cetaceans to large and very large oil spills within their range (see below).

Larger groups could be adversely affected if a large spill occurred when large aggregations of bowheads were feeding. Cetaceans that inhabit areas that are in the path of a major oil spill can be impacted in several different ways. First, individuals potentially could be directly affected by contact with the oil or its toxic constituents through inhalation of aromatic fractions of unweathered oil (probably the most serious threat to cetaceans), ingestion (of the oil itself or of contaminated prey), fouling of their baleen, and surface contact. Second, they could be indirectly impacted if the quality or quantity of their prey were reduced. Third, individuals could be directly or indirectly affected due to maternal effects (for example, changes in food assimilation during pregnancy, or reduced maternal health) or in-utero exposure to toxic components of oil. Fourth, they could be affected by disturbance of spill response and cleanup activities. Although there is evidence for all of the aforementioned types of effects in other types of mammals from experiments and/or posts-pill studies, there is very little evidence regarding the probability for any of the aforementioned in cetaceans due to limitations discussed above.

There are no data available on which to evaluate the potential effect of a large or very large spill on baleen whale newborn or other calves, on females who are very near term or who have just given birth, or on females accompanied by calves of any age. However, it is not unlikely that newborn and other young calves would be more vulnerable to the acute and chronic effects of oil than would adult whales. Calves swim slower, take more breaths, are on the surface more often, and have higher metabolisms than do adults. They could be exposed to oil on their mother's skin during nursing. They could receive pollutants through their mothers' milk, as well as through direct ingestion.

It is likely that some whales would experience temporary or perhaps permanent nonlethal effects, including one or more of the following symptoms:

- inhaling hydrocarbon vapors;
- ingesting oil and oil-contaminated prey;
- fouling of their baleen and reduced foraging efficiency;
- oiling their skin, causing irritation;
- losing some proportion of their food source; and
- temporary displacement from some feeding areas.

Some whales could die as a result of contact with spilled oil, particularly if there is prolonged exposure to freshly spilled oil, such as in a lead. The extent of the effects would depend on how many whales contacted oil, the duration of contact, and the age/degree of weathering of the spilled oil. The number of whales contacting spilled oil would depend on the location, size, timing, and duration of the spill and the whales' ability or inclination to avoid contact. If oil got into leads or ice-free areas frequented by migrating bowheads, a large portion of the population could be exposed to spilled oil. Under some circumstances, some whales could die as a result of contact with spilled oil. Prolonged exposure to freshly spilled oil could kill some whales, but the number likely would be small.

In conclusion, we reiterate that there is uncertainty about effects on bowheads (or any large cetacean) in the unlikely event of a very large spill. There are, in some years and in some locations, relatively large aggregations of feeding bowhead whales within the proposed lease-sale area. If a large amount of fresh oil contacted a significant portion of such an aggregation, effects potentially could be greater than typically would be assumed. Additionally, highly significant effects could occur if a large number of females and newborn or very young calves were contacted by a large amount of fresh crude oil. Available information indicates it is unlikely that bowhead whales would be likely to suffer significant population-level adverse affects from a large spill originating in the Beaufort Sea. However, individuals or small groups could be injured or potentially even killed in a large spill. Oil spill response activities (including active attempts to move whales away from oiled areas) could cause short-term changes in local distribution and abundance.

### Conclusion

The effects of noise on bowheads from various OCS production activities have been described. The effects from an encounter with aircraft generally are brief, and the whales should resume their normal activities within minutes. Bowheads may exhibit temporary avoidance behavior to vessels at a distance of 1-4 kilometers. Many earlier studies indicate that most bowheads exhibit avoidance behavior when exposed to sounds from seismic activity. Bowheads also exhibited tendencies for reduced surfacing and dive duration, fewer blows per surfacing, and longer intervals between successive blows. Bowheads appeared to recover from these behavioral changes within 30-60 minutes following the end of seismic activity. Monitoring has shown bowheads avoid areas exposed to seismic sounds, with near total avoidance of the area within 20 km or 11 n. mi. (12 st. mi.) of the source vessel at times influenced by airgun operations. Data from monitoring seismic operations from 1996-98 suggested that the offshore displacement may have begun roughly 35 km (19 n. mi. or 22 st. mi.) east of the activity, and may have persisted >30km to the west (Richardson, 1999a).

Bowheads have been sighted within 0.2-5 kilometers from drill ships, although bowheads change their migration speed and swimming direction to avoid close approach to noise-producing activities. Bowheads may avoid drilling noise at 20-30 kilometers. There are no observations of bowhead reactions to icebreakers breaking ice, but it has been predicted that roughly half of the bowheads would respond at a distance of 4.6-20 kilometers when the S:N is 30 dB. Overall, bowhead whales exposed to noise-producing activities most likely would experience temporary, nonlethal effects. Some avoidance behavior could persist up to 12-24 hours.

MMS investigated the probability of spilled oil contacting bowhead whales (MMS, 2000). Specific offshore areas (Ice/Sea Segments or ISS) were identified and modeled for probability of contact. Certain of these ISS's overlay the migratory corridor of the bowhead. Using data from the MMS oil spill analysis for Sale 170, and assuming an oil spill of 1,000 barrels or more occurred at any of several offshore release areas (launch boxes) during the summer season, the chance of that oil contacting these ISS's within 30 days during the summer season ranged from 5-82%. The reader should note that the MMS model includes ISS's that are within the launch box. That is, some of the offshore habitats being assessed for probability of contact lay within the area of the theoretical spill release. Despite the statistical probabilities presented, which depend on a spill contacting a discrete area, NMFS believes there are many scenarios for which the conditional probability of spilled oil reaching areas utilized by bowhead whales is 100%.

Most whales exposed to spilled oil are expected to experience temporary, nonlethal effects from skin contact with oil, inhalation of hydrocarbon vapors, ingestion of oil-contaminated prey items, baleen fouling, reduction in food resources, or temporary displacement from some feeding areas. A few individuals may be killed as a result of exposure to freshly spilled oil. However, the combined probability of a spill occurring and also contacting bowhead habitat during periods when whales are present is considering to be low, and the percentage of the Beaufort Sea stock so affected is expected to be very small.

The probability of an oil spill increases as more oil fields become active. Oil has been documented to be highly toxic to polar bears (Oritsland et al., 1981:6), ringed seals (Geraci and Smith, 1977:402), harbor seals (Frost and Lowry, 1994:I), and sea otters (Mulcahy and Ballachey, 1994:327). No measurable impact on humpback whales in Prince William Sound was observed in 1989 as a result of the Exxon Valdez oil spill (von Ziegesar et al., 1994:188), but a suspicious decline in numbers of killer whales following this spill suggests that whales may be severely impacted by an oil spill (Matkin et al., 1994:160). Without conclusive data, it is assumed that bowhead whales would be susceptible to an oil spill during feeding and migration, particularly if they came in contact with oil in the lead system during spring migration. A number of small oil spills have occurred during oil and gas exploration in the Alaskan Beaufort Sea in past years. Only five spills have been greater than one barrel, and the total spill volume from drilling 52 exploration wells (1982 through 1991) was 45 barrels (USDOI, MMS, 1996:IV.A-10). Based on historical data, most oil spills would be less than one barrel, but a larger oil spill could also occur. Considering the number of days each year that bowhead whales may be present in or migrating through the area, the probability that a spill would occur, the probability for a spill to occur or persist during periods when whales are present, and the probability that oil would move into the migration corridor of the bowheads (at least that portion of the corridor outside of the barrier islands), it is unlikely that bowhead whales would be contacted by oil. Significant adverse affects would only be expected if all of the low probability events occurred at the same time.

Taking these factors into consideration, NMFS concludes that, at this time, there is a reasonable likelihood that oil and gas development and production in the Alaskan Beaufort and Chukchi Seas, as described, would not violate section 7(a)(2) of the ESA.

## VIII. CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information.

The National Marine Fisheries Service and the Minerals Management Service should implement the following measures for these purposes:

1. MMS and NMFS should initiate an effort to update environmental inventories for the Chukchi Sea. New marine mammal surveys should be conducted at the earliest time. MMS should consider a comprehensive program for this purpose which employs aerial and ship-based efforts as well as the use of passive acoustics. In particular, the current BWASP program should be expanded to include Block 13. Because of the importance and sensitivities of the bowhead whale, MMS should particularly engage in research to describe bowhead behavior, movements, distribution, and residency timing, identify or refine migratory pathways, and important bowhead habitats in these waters.

2. Vessel operations in the Beaufort Sea, including seismic geophysical exploration, should be scheduled to minimize operations in order to reduce potential harassment of bowhead whales. These activities should, to the extent practicable, avoid migratory periods in the spring and fall. The MMS should advise operators of vessels to maximize separation with the bowhead whale migrational corridor by remaining 35 miles offshore whenever possible.

3. The MMS should continue research to describe the impact of exploration activities on the migrational movements and feeding behavior of the bowhead whale. Specific plans should be developed and implemented to monitor the cumulative effects of exploration, development, and production on the bowhead whale. These research designs and results should be reviewed annually to ensure that the information collected is addressing the concerns of NMFS and the affected Native communities.

4. The MMS should continue to provide Information to Lessees and Lease Stipulations intended to reduce impacts to the bowhead whale, including stipulations on protection of biological resources, industry site-specific bowhead whale monitoring program, and conflict avoidance mechanisms to protect subsistence whaling and other subsistence activities.

5. To minimize potential harassment of bowhead whales, MMS should advise operators that aircraft (other than monitoring flights) should observe a minimum altitude of 1500 feet (approximately 500 meters), weather and safety factors permitting, whenever seaward of the barrier islands during spring and fall migrations.

6. Major oil spills are not anticipated during exploration activities. However, to avoid adverse effects should a major oil spill occur, MMS should cooperate with the USCG to ensure that areas occupied by bowhead whales are clear of spilled oil. Special precautions should be taken

to ensure that spilled oil does not reach or persist in areas in or near the spring lead system (SLS) used by bowhead whales during their spring migration (April through June), the fall migrational corridor, or whale feeding areas. The MMS should investigate the possible use of airguns as a deterrent for bowhead whales near an oil spill. Research has shown most whales avoid these noise sources by at least 20 km, and an airgun system may be an effective tool in any North Slope offshore response arsenal for the intentional hazing of bowhead whales.

7. Upon learning of any unauthorized take of bowhead whales which occurs as a result of OCS exploratory activity, MMS should immediately notify the assistant Regional Administrator for Protected Resources at (907) 586-7235 of this taking to determine the appropriate and necessary course of action.

8. MMS and NMFS should use their authorities to avoid multiple seismic work operating in such manner as to significantly impair the bowhead migration. Multiple seismic operations should be prohibited from operating offshore of one another (i.e., to the north or south). This measure does not include high-resolution seismic operations, or seismic work nearshore or in shallow waters which have less potential to harass or harm bowhead whales.

9. The MMS and NMFS should continue to coordinate research associated with OCS actions and the bowhead whale, with emphasis on cumulative impacts of OCS activities. These agencies are encouraged to cooperatively approach this issue.

10. The MMS should continue to investigate the use of the Chukchi and Beaufort Seas by feeding bowhead whales, and assess the importance of this feeding to the health and well being of these animals.

11. The MMS should consider the traditional observations of Eskimo hunters of the importance of the nearshore waters of the Chukchi and Beaufort Seas in their leasing planning and decision making. The MMS should take measures to protect and conserve these values, including consideration of deferral areas, to protect important habitat areas.

12. The MMS should investigate methods to acquire necessary geophysical data using alternative methods for airguns, or to develop improved software or other technologies which would effectively reduce the level of noise from airguns used for geophysical research.

13. The MMS should defer from leasing those tracts within the SLS of the Chukchi and Beaufort Seas. Additionally, seismic geophysical surveys should not occur within these areas prior to open-water conditions, and MMS should consider means to minimize any activities which may cross or occupy the SLS, such as pipelines.

In order for NMFS to be kept informed of actions minimizing or avoiding adverse effects on listed species or their habitats, NMFS requests notification of the implementation of these conservation recommendations.

## IX. REINITIATION OF CONSULTATION

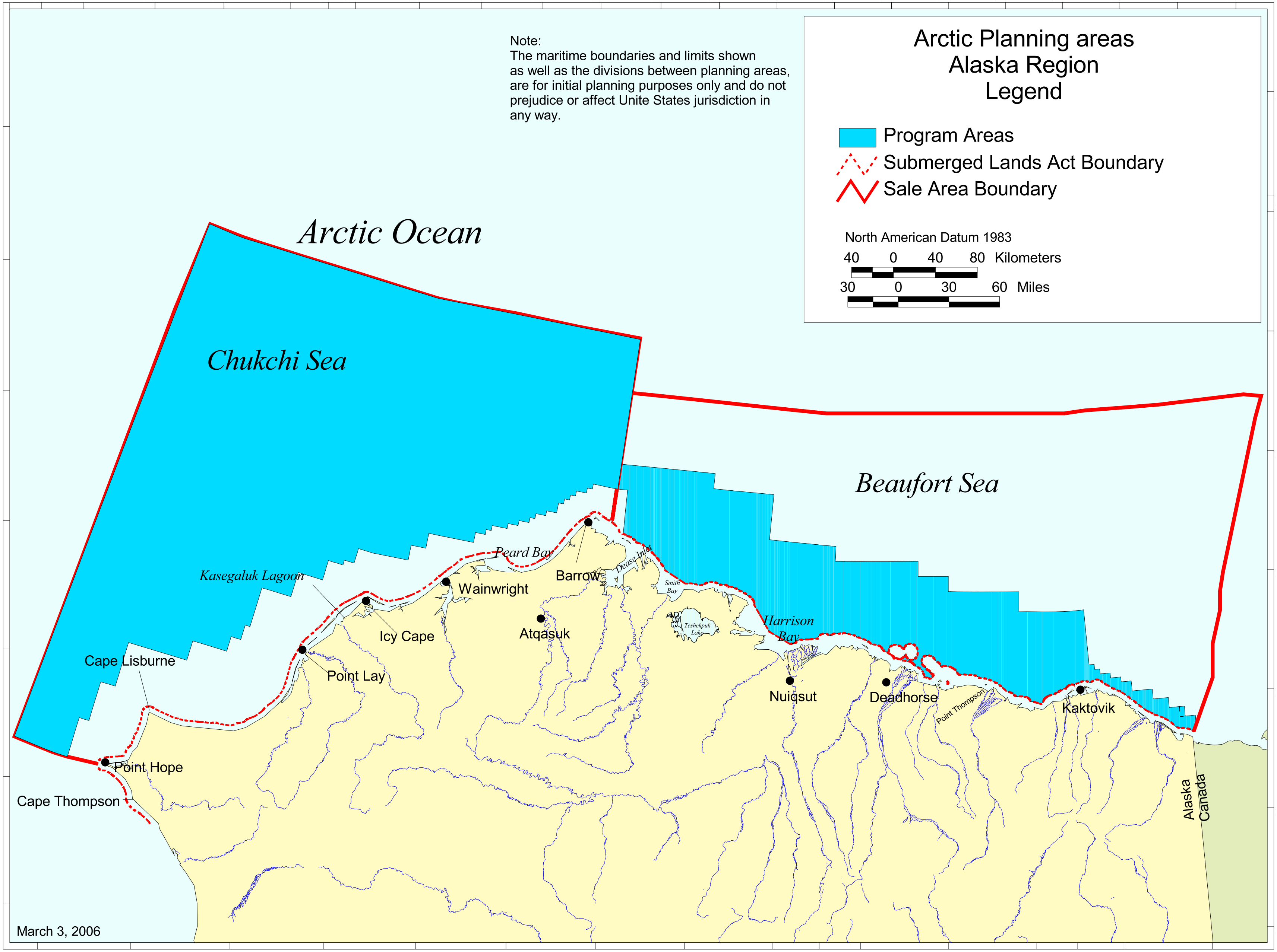
This concludes formal consultation on this action. As provided in 50 CFR §402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this Biological Opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this Biological Opinion; or (4) a new species is listed or critical habitat designated that may be affected by this action. In circumstances where the amount or extent of incidental take is exceeded, any operations causing such take must cease pending reinitiation.

Also, leasing and exploration activities within the area of the Chukchi and Beaufort Sea which includes the spring lead/polynya system are not expected to occur during the spring bowhead whale migration (April through June). If new technology, procedures, etc. are developed which allow for these activities during this period, additional and separate consultation under section 7 (a)(2) of the ESA will be necessary.

## X. INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the ESA provided that such taking is in compliance with the terms and conditions of this incidental take statement.

This opinion does not include an incidental take statement at this time. Upon issuance of regulations or authorizations under Section 101(a)(5) of the Marine Mammal Protection Act and/or its 1994 Amendments, NMFS will amend this opinion to include a incidental take statement(s) for the described work.



Note:
The maritime boundaries and limits shown as well as the divisions between planning areas, are for initial planning purposes only and do not prejudice or affect Unite States jurisdiction in any way.

March 3, 2006

Figure 1