**Alaska
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# Through-Ice Sampling Workshop

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# Through-Ice Sampling Workshop

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Photo: The Beaufort Sea in August 2008.Erika Acuna (NMFS-AFSC)

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# EXECUTIVE SUMMARY

Scientists from the Alaska Fisheries Science Center's Status of Stocks and Multispecies Assessment (SSMA) Program's Fishery Interaction Team (FIT) organized a workshop on methods for sampling the marine environment under the ice. The workshop was held at the University of Alaska, Fairbanks on 7-8 November 2007. Participants included fish biologists; fisheries acousticians; physical and biological oceanographers; and researchers with expertise in the operation of underwater vehicles, scientific diving, and the logistics of establishing ice camps. The purpose of the workshop was to gather information on state-of-the-art methods for fish and oceanographic surveys of the Beaufort Sea shelf during ice-covered periods.

This workshop was funded by the U.S. Department of the Interior, Minerals Management Service (MMS), Alaska Outer Continental Shelf Region, Anchorage Alaska, under Inter-Agency Agreement No. AKC-058 (Contract No. M07PG13152) as part of the MMS Alaska Environmental Studies Program.

The MMS has also provided funding to the Center for a pilot survey and test of hypotheses in the Beaufort Sea during an ice-free period. Center scientists and their collaborators at the University of Washington and University of Alaska Fairbanks conducted a survey in August 2008 (http://www.afsc.noaa.gov/REFM/Stocks/fit/PDFS/Beaufort_sea_cruise_report.pdf). Although the survey took place in ice-free waters, one of the project goals is to provide MMS with recommendations for how to optimally conduct an analogous survey during ice-covered periods. This was the motivation for the Through-Ice Sampling Workshop.

The following techniques for fish sampling were addressed: net sampling, fisheries acoustics (including DIDSON), and video cameras. Oceanographic sampling was also included in the agenda. Methods for deploying nets and instruments were discussed, specifically: remotely and autonomously operated vehicles and scientific diving. Finally, the logistics of establishing and maintaining ice camps were addressed.

The primary outcome of the workshop was a review of methods and recommendations for a full winter survey that would accomplish the goals of the MMS. In other words, methods suitable for a survey of ice-covered waters over the Beaufort Sea shelf that would replicate, to the extent feasible, the summer survey in ice-free waters are described above. The workshop also provided the opportunity for potential collaborations between institutions and individuals to be identified.

# CONTENTS

# BACKGROUND

The U.S. Department of the Interior's Minerals Management Service (MMS) requires information to assess and manage the potential environmental effects of offshore oil development on marine fish in the Beaufort Sea. The geographic area within the Beaufort Sea Outer Continental Shelf (OCS) Planning Area (3 miles or more beyond the coast) primarily encompasses the shallow continental shelf which averages 50 m in depth. Fisheries information is used in the National Environmental Protection Act (NEPA) analysis of lease sales, exploration plans, and development and production plans. These analyses are presented in NEPA documents that evaluate oil exploration as well as development and production activities, including analysis of the possible impact of oil spills. The foremost potential effects on fish that MMS analysts commonly evaluate in these NEPA documents are the effects 1) within the water column (e.g., from an unlikely but potentially widespread oil spill or from seismic exploration), and 2) in benthic habitats (e.g., from building and operating subsea pipelines).

In the Beaufort Sea, little is known about the biology and ecology of many of the marine fish species inhabiting the area. The highest priority MMS information needs are 1) species presence, 2) distribution, and 3) abundance. As offshore oil development interest radiates out to deeper and more widespread areas additional fisheries information is required. Important species to evaluate include sparsely distributed and poorly documented marine fish. The important seasons to evaluate include the poorly documented ice-covered and break-up periods. The important distribution and abundance parameters to measure include marine mating, spawning, rearing, feeding, and migration habitats which have not been delineated (*excerpted from the*

*Memorandum of Understanding between Alaska Fisheries Science Center and Minerals Management Service for Beaufort Sea Marine Fish Monitoring: Pilot Survey and Test of Hypotheses*).

The MMS provided funding to the Alaska Fisheries Science Center (AFSC) to conduct a pilot survey and test hypotheses in the Beaufort Sea during an ice-free period. Scientists from AFSC and their collaborators at the University of Washington and University of Alaska Fairbanks conducted this survey in August 2008 (Fig. 1). The distribution and abundance of fish was assessed with bottom trawls and fisheries acoustics. The distribution of zooplankton was sampled with bongo nets and oceanographic properties will be measured with conductivity-temperature-depth probes. A detailed cruise report can be found at http://www.afsc.noaa.gov/REFM/Stocks/fit/PDFS/Beaufort_sea_cruise_report.pdf . Although the survey took place in ice-free waters, one of the project goals is to provide MMS with recommendations for how to optimally conduct an analogous survey during ice-covered periods. This was the motivation for the Through-Ice Sampling Workshop.

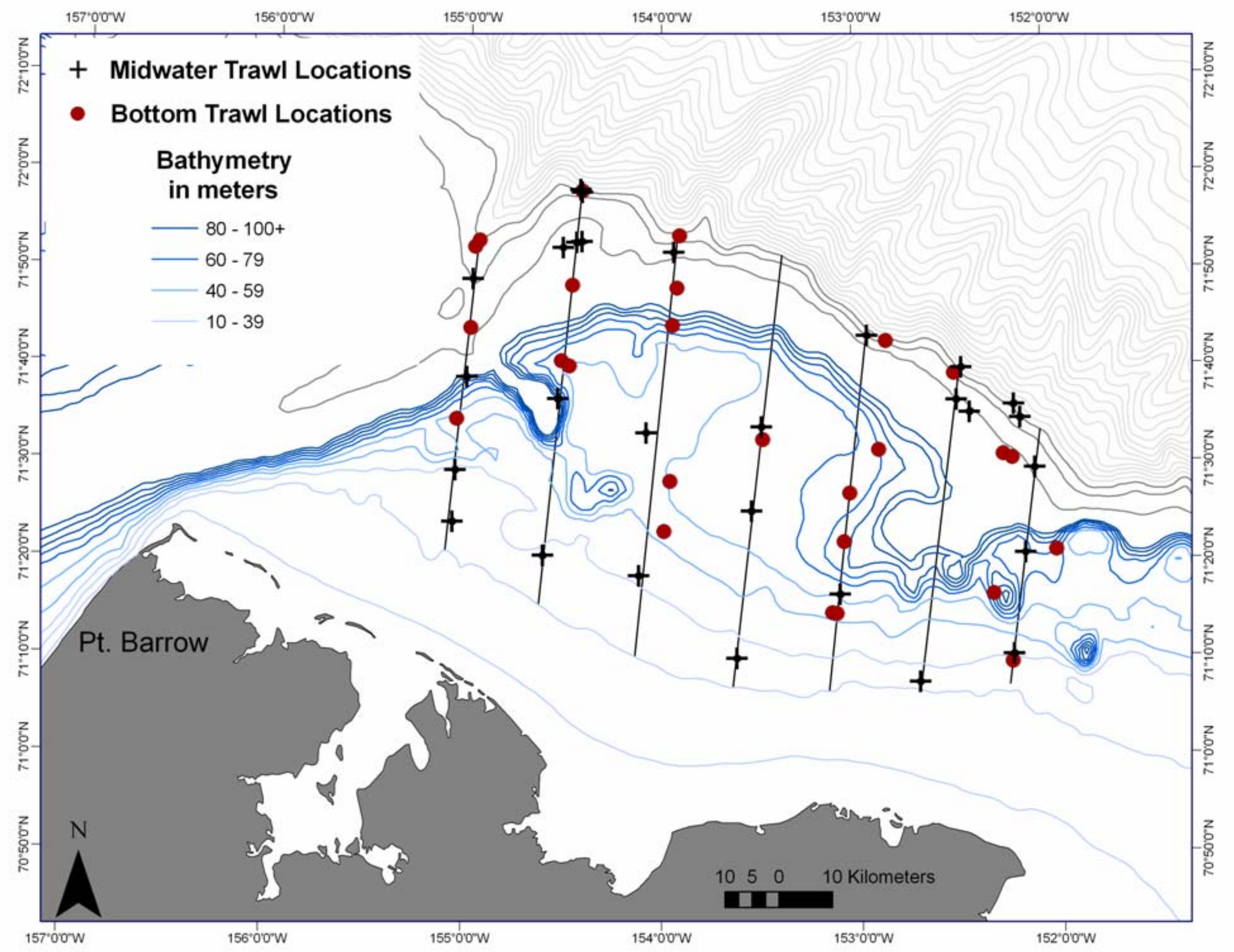

Figure 1. -- August 6-22, 2008 survey of the Beaufort Sea shelf. Acoustic transects (black lines), bottom trawls (solid red circles) and midwater trawls (black crosses) are shown.

## WORKSHOP TOPICS

The following techniques for fish sampling were addressed: net sampling, fisheries acoustics including the Dual-frequency Identification Sonar (DIDSON), and video cameras. Oceanographic sampling was also included in the agenda. Methods for deploying nets and instruments were discussed, specifically: remotely and autonomously operated vehicles and scientific diving. Finally, the logistics of establishing and maintaining ice camps were addressed.

## WORKSHOP FORMAT AND DISCUSSION QUESTIONS

Researchers with relevant expertise were invited to give short (~ 30-minute) presentations on one of the topics described above. The intention of the presentations was to provide enough background information to "prime" the workshop participants for focused discussion on the use of a particular method for a through-ice survey of the Beaufort Sea shelf. Up to one hour was allotted for discussion after each presentation (see Appendix A for the agenda). The presentations and discussions focused on several questions. The general questions are listed below (solid bullets), followed by examples of specific questions (open bullets).

- What is the ideal use of the method (or instrument, net, etc.) under consideration?
    - Can it be used to assess the species, distribution, abundance, and/or size of fish?
    - Can it be used to survey a grid and/or set of transects similar to the AFSC-MMS Beaufort Sea survey described above?
    - What are some likely combinations of instruments and methods (e.g., acoustics on AUVs)?

- What are the limitations of the method?
    - What depth of water?

    - What thickness of ice?
    - Would cold air and water temperatures limit the use of this method?

- What kind of platform is required?
    - Can it be deployed through a hole in the ice?  How large a hole?
    - Can it be deployed from a U.S. Coast Guard ice-breaker?

- What logistical support is required to conduct a survey using this method?
    - How would equipment and personnel be transported to study sites?
    - How would equipment and personnel be protected from the elements?
    - What are the important safety considerations?

- What are the costs associated with the method?
    - How many people are needed?
    - How much time?
    - How much does it cost to purchase, operate and maintain the equipment?

Thirty people attended the 2-day workshop.  The primary outcome of the workshop was the general overview of methods that may be useful for implementing a full winter survey that would accomplish the goals of MMS.  In other words, methods suitable for a survey of ice-covered waters over the Beaufort Sea shelf that would replicate, to the extent feasible, the summer survey in ice-free waters described above.  The workshop also provided the opportunity for potential collaborations between institutions and individuals to be identified.

The intended audiences for this report are researchers or funding agencies considering a survey of fish distribution and habitat/oceanographic characteristics of the Beaufort Sea shelf during ice-covered seasons.  This report compares and contrasts the instruments and methods available and thus supports decisions on sampling methods and survey design.  This report is not intended to be an exhaustive review of each sampling method, but we hope we have provided sufficient information (and references to the literature) in a format that allows investigators to effectively weigh the pros and cons of each method.

## SAMPLING TYPES

### Net, Trap and Long-line Sampling

Presenters:

Pete Cott (Fisheries and Oceans Canada, Yellowknife, Northwest Territories, Canada)

Andy Majewski (Fisheries and Oceans Canada, Winnipeg, Manitoba, Canada)

Pete Cott and Andy Majewski presented details of their unpublished offshore pilot fish survey that was conducted in the Canadian Beaufort Sea.  They specifically targeted the location of a proposed exploratory natural gas well to assess its potential impact on fish and fish habitat. Although their initial focus was on fish presence/absence and fish habitat usage they sampled across trophic levels to give a snapshot of the winter ecology present in that area. Sampling included: sediment, benthos, phytoplankton, zooplankton, ice-algae, macro-invertebrates, and fishes. To facilitate net deployment, an area of flat ice within a rubble ice field was selected for the survey. In addition to gill nets, a small remotely operated vehicle (ROV) equipped with a camera, Gee minnow traps, a baited longline, and seal scat analysis were used to assess fish presence. Over the course of net deployments, no fishes were captured or observed. Sampling for fish species under the ice, in general, requires some sort of active movement of fish past either bait (such as on a longline) or a gill net set through holes in the ice. Setting nets under ice can be challenging even in flat-ice conditions (i.e., no pressure ridges, crevasses, or fissures). In the Arctic, ice thickness can range from 1 to 3 m for several months and is further complicated by moving ice floes and pressure ridges (Cott et al. In prep.)

The absence of fish catches at the location sampled is likely due to a combination of factors including: low fish densities, low fish movements, and the necessity to sample in areas that facilitate gear deployment but not necessarily where fish are likely to congregate (e.g., under-ice rubble). Sampling other trophic levels was successful despite the environmental constraints put on workers and equipment. The samples they collected indicate that the Canadian Beaufort Sea, in the area sampled (approximately 50 km northwest of Tuktoyaktuk, Northwest Territories), has low productivity in March (Cott et al. In prep.).

Under-ice research for zooplankton abundance has been conducted in Antarctica. In Kirkwood and Burton (1987), three zooplankton nets were designed specifically to collect zooplankton at various depths. For example, the “Umbrella Net” was designed to collect zooplankton from all depths through a very small hole in the ice. The second, a “collapsible free fall net”, was intended to capture mobile zooplankton that may be able to avoid towed nets. A third net deployed by divers was designed to sample the top 15 cm of the water column (under-ice ceiling) (Kirkwood and Burton 1987). Sampling for zooplankton captures “snapshots” through holes in the ice and does not require setting a net to cover a wide expanse of water column, such as a gill net.

### Strengths

Net sampling for zooplankton and lower trophic levels, in general, is plausible and requires only a small opening through the ice to deploy equipment. It may be possible for under-ice divers to deploy gill nets for fish over larger areas in habitats with complex structure (i.e., below pressure ridges). Once the initial “clothesline” setup is complete, gill nets can be easily retrieved and re-deployed without additional hole cutting or running of lines. Gill nets are effective at capturing many species of fish common to the Beaufort Sea during open water conditions and could be effective under-ice as well. Multi-mesh, also called “experimental”, gill nets allow for capture of a wide range of species and size classes. Once entangled, fish retention in gill nets is generally good. Although deployment of gill nets under-ice can be laborious and time consuming, deploying gill nets is simple relative to other types of common fishing equipment (Pete Cott and Andrew Majewski, Department of Fisheries and Oceans, pers. comm.; Cott et al. In prep.).

### Weaknesses

#### *Fish*

Net sampling using gill nets is difficult through thick marine ice particularly if the ice-ceiling is not flat. Passive net sampling, such as setting a gill net in transect fashion, would require some sort of active movement of fishes. Deploying nets would require a minimum of two persons, and depending on the size of the net and deployment gear used, may require up to four individuals. Some fish species that are present under ice-cover may not be susceptible to capture by gill nets due to decreased mobility during the winter months and /or morphology that allows them to pass through the nets without entangling.

### *Zooplankton*

Compared to sampling for fish, sampling zooplankton is very simple. The main limitation is that net diameter has to be smaller than the ice-hole diameter. However, it is relative as smaller ice holes can be made quickly and easily for deployment with small diameter plankton net. For example, it would be much faster to deploy an 8-inch diameter net in several 10-inch diameter auger hole several times (thus sampling a large volume of water) than it would be to try and deploy a large net that would require a large hole in the ice as the time and difficulty making the hole in the ice is the limiting factor (Cott et al. In prep.).

## **Under-Ice Sampling**

Large-scale sampling for fish species with a net under the ice in the Arctic may not be feasible in dynamic ice conditions, such as pressure ridges.  Setting stationary nets (gill nets) may not be an effective means of surveying fish presence/absence if fish activity drops off in colder, winter months.  Collecting zooplankton samples from under the ice can provide good “snapshots” of vertical distributions of zooplankton in the water column across a wide range of sizes.  The experience of workshop participants (Cott and Majewski) was that using gillnets under-ice was both time consuming and unproductive (no fish were caught) in the survey area and time of year that they sampled. Other, less labor intensive methods such as the use of remotely operated vehicles and autonomous underwater vehicles should be investigated for further utilization. Additional citations below provide some instances where fish were sampled in the Chukchi and Beaufort Seas during the winter-time months.

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## Fisheries Acoustics

Presenter: Sandra Parker-Setter (University of Washington, Seattle, Washington, USA)

Fisheries acoustics can evaluate the abundance, distribution, and relative size of fish and zooplankton. Acoustics operates by transmitting a pulse of acoustic energy into the water and when that energy encounters a target, energy is reflected back to a transducer and recorded. Acoustics should be combined with direct sampling, such as nets, to verify targets (e.g., is the "target" Arctic char or saffron cod?). Over time, increased knowledge of target strengths may reduce the required sampling. Deploying video cameras could alleviate the need to verify targets by extractive methods. However, video may not replace direct sampling in certain situations as viewing range may be limited, difficulties in assigning species identity, and changes in fish density due to the use of lights (Benoit-Bird and Au 2003) could restrict their utility.

Acoustic deployment in ice-covered waters can be stationary (mounted from the surface or on the bottom) or mobile (such as attaching the echosounder and transducer to a remotely operated vehicle (ROV) or autonomous underwater vehicle (AUV)). In Finland, scientists attached an echosounder to a propeller-driven watertight box and accurately assessed fish biomass under the ice (Jurvelius et al. 1999). This method required several holes to be drilled in transect fashion and the echosounder direction was controlled by pulling two ropes. Jurvelius et al. (1999) verified fish targets by seining, but this may be difficult in a dynamic ice environment such as the Beaufort Sea (i.e., pressure ridges, ice floes).

In the Antarctic, wintertime krill densities were estimated under the ice using a 120 kHz echosounder deployed via an AUV (Brierley et al. 2002). To test the accuracy of under-ice krill estimates, open water tests of the AUV and shipboard acoustics were compared. The echosounder on the AUV was directed upward to the sea surface while vessel acoustics were directed downward. The results of the two methods were comparable (Brierley et al. 2002). It was concluded that split-beam acoustics could accurately estimate krill under the ice via an AUV (Brierley et al. 2002). Echosounders mounted on ice-capable vessels can also be used to detect and estimate fish and plankton aggregations under the ice if care is taken in acoustic installation and data post-processing. (e.g., correcting for ice/bubbles under the transducer and noise from ship striking ice), (Alex DeRobertis, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA, pers. comm.).

### Strengths

Acoustics can detect targets such as zooplankton or fish from the surface to much greater depths than the Dual-frequency Identification Sonar (DIDSON), although the horizontal swath of the water column that is sampled is less than that of the DIDSON. Sound reflecting from the ice in the study by Jurvelius et al. (1999) did not affect the data quality. Acoustics also work well in low-light and turbid environments where video alone is insufficient. Horizontal beaming and/or beaming from the seafloor bottom to the surface, in addition to the vertical split-beam, may be able to capture fish closer to the surface or within a few meters of the ice underside.

### Weaknesses

Due to the presence of an acoustic “dead zone” (~1 m off the bottom), fisheries acoustic methods may not detect flatfish or benthic invertebrates. Acoustics also requires direct sampling for species (or target) verification. A stationary acoustic set-up would require active movement of fish into the transducer beam and often fish activity decreases in lower water temperatures. Due to the irregular surface of the ice-ceiling, mobile acoustic surveys with AUVs or ROVs may need to be deployed at depth and utilize both upward-looking and downward-looking transducers to capture the entire water column. Finally, the composition of the ice (e.g., sediment or air that is trapped in the ice ceiling) could affect strength of signal return, but further research is needed on acoustic signaling under the ice.

### Under-Ice Sampling

For an area-wide, under-ice survey, it may be most effective to deploy an echosounder on a device such as an ROV or AUV. Because of reduced fish behavior in colder temperatures, numerous stationary deployments throughout the survey area would be required to provide an adequate evaluation of fish or invertebrate assemblages, making this approach labor-intensive. The largest obstacle in using an echosounder under the ice is how to verify the target sign (i.e., net sampling, video/still camera). Winter seining under the ice for fish does not appear to work well making video imaging necessary (see Net, Trap, and Long-line Sampling). However, video verification may have limitations such as low observation range and negative fish/invertebrates reactions to lights.

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## Dual-frequency Identification Sonar (DIDSON)

Presenter:

George Cronkite (Fisheries and Oceans Canada, Nanaimo, British Columbia, Canada)

The Dual-frequency Identification Sonar (DIDSON) is a high-definition acoustic imaging sonar that can produce near video quality images of fish, sea bottom, or ice. The sonar was developed by the University of Washington's Applied Physics Lab (www.apl.washington.edu) and is distributed by Sound Metrics Corporation (www.imagingsonar.com). It is often deployed in lieu of, or in addition to, underwater video and is especially useful in turbid and low-light environments (e.g., under-sea ice). The DIDSON operates at two frequencies and can detect objects within a range window of 1.25 m to 10 m for the high-frequency mode, and 4.5 m to 36 m for the low-frequency mode. These range windows may be set at start ranges of 0.38 m to 11.63 m in steps of 0.38 m for the high-frequency, and from 0.75 m to 23.25 m in steps of 0.75 m in the low-frequency mode.

The DIDSON is often deployed in one of two ways: 1) a stationary method in which a hole is drilled into the ice and the DIDSON is lowered while connected to a cable for data feed and power, or 2) deployed as a self contained instrument attached to a remotely operated vehicle (ROV) or autonomous underwater vehicle (AUV) of sufficient size. If the DIDSON remains tethered to an "umbilical" (such as on an ROV), data can be recorded and power supplied indefinitely (the amount of data recorded could be significant depending on research goals).

However, the range or area sampled would be limited by the length of the umbilical. If the DIDSON is not attached to an “umbilical”, some models of the DIDSON can record up to 4 hours of data internally. In this case the DIDSON could be mounted on an AUV with no connection to the surface, and the data viewed after recovery.

In Holmes et al. (2006), the DIDSON was deployed via a stationary pole mount in a riverine environment. Fish counts detected by the DIDSON were compared with visual counts (both unrestricted and restricted through a channel). The agreement between the two methods was high. A long-range DIDSON is available (up to 80 m range window), however this lower frequency system uses half the number of sonar beams and exhibits reduced resolution over the standard version making the detection/identification of smaller targets more difficult, but much longer ranges can be attained. A new larger lens is available that enhances the resolution of the long-range DIDSON which may help with the detection of smaller fish species. Fish off the deep ocean shelf of Oregon have been clearly detected at 220-366 m of depth, within 9.7 m of the DIDSON in a study by Rose et al. 2005. The DIDSON was also effective at determining fish sizes and abundance in isolated freshwater pools at ranges up to 16 m in the Sagavanirktok River Delta in Alaska (Mueller et al. 2006).

### Strengths

The DIDSON is less invasive than fish capture with nets. Also, the DIDSON is often used to assess avoidance behaviors associated with artificial lighting used for video. As the DIDSON can be deployed on an ROV, larger areas under the ice can be sampled as opposed to static acoustic imaging (single location captured with a side-scan sonar or echosounder). However, the sampling range varies as mentioned above, with resolution decreasing with distance due to attenuation. The DIDSON is small, robust, and generally runs on external power (excluding the diver held model) and is easily deployed in the field, requiring little support (i.e., few people). The images from the DIDSON can be adjusted in several ways using the provided software to help with target detection. The DIDSON can be tilted to capture multiple angles with the use of underwater rotators. Compared to video, the DIDSON can detect fish at a much greater distance without the potential bias due to the effect of light on fish behavior. The DIDSON is best at detecting individual fish and estimating fish size, whereas side-scan sonar systems and calibrated echosounders can be used to determine fish biomass and to measure bottom depths in deep water. The DIDSON is very accurate at measuring fish length using shorter range windows (i.e., 10 m or less).

### Weaknesses

DIDSON imaging relies on verifying the observed species at some point in time. Although individual fish can be seen using the DIDSON, independent information about fish species, presence, and size is needed. The DIDSON can only provide “clues” as to species identification. Fish that are closely associated with the substrate (and possibly surface ice) such as flatfish or other benthic species, are difficult to detect especially if the observed fish does not exhibit movement. The sampling range for the DIDSON, although greater than video, is shorter when compared with other types of hydroacoustic systems such as split-beam, for example.

## Under-Ice Sampling

Ideally the DIDSON would be deployed via an ROV or AUV in addition to video imaging. The DIDSON technology is commonly used is in turbid riverine environments where fish migrate past sampling points. However, under-ice sampling with video and acoustic imaging could provide information on presence or absence of fish species, where the limitation of one method (e.g., video in low light conditions) could be the strength of the other (e.g., DIDSON's ability to detect a fish that cannot be viewed with video). For example, fish numbers and size under the ice can be estimated by the DIDSON and video can assist in classifying species (Mueller et al. 2006).

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## Video

Presenter: Robert Mueller (Pacific Northwest National Laboratory, Richland, Washington, USA)

Video and still cameras can be deployed in several ways, similar to those described earlier for Fisheries Acoustics. Cameras can be deployed statically (e.g., mounted on a pole and deployed through an ice hole) or actively on a remotely operated vehicle (ROV) or autonomous underwater vehicle (AUV), or carried by an ice-diver. Video cameras can record and collect images in real time over short time periods (2-3 hours) or over longer periods using a time-lapse recorder or digital video recorder.

Underwater video cameras are encased in waterproof housings and pressure rated depending on the application. They are often combined with a light source to increase the visual sampling distance or imaging the substratum. Additional light sources are particularly important in under-ice conditions because ambient light is greatly reduced due to thick ice, snow cover, and little daylight in northern latitudes. Halogen light sources may be used in association with the camera to provide a longer viewing range; however, these lights can act as a fish deterrent/attractant whereas infrared lighting has limited range but would likely not act as a fish deterrent. The type of lighting required depends on the environment, available power and whether fish avoidance is a problem (e.g., for density estimates).

Various video lenses can be used depending on the type of sampling and/or research goals to be addressed (Mueller et al. 2006). Video cameras can record images in color or monochrome.

Monochrome cameras are normally better suited for low-light conditions. Video cameras can be used to identify fish species, estimate fish density, fish swimming speed, fish behavior, fish size, and to identify habitat structure. Estimating abundance, fish swimming speed, and size all require some reference point relative to the cameras viewing field, such as a laser(s) or a fixed object of known distance (e.g., as suggested in Mueller et al. 2006), A white-colored PVC pole lowered in an additional ice hole at a known distance from the camera can be used to determine the maximum viewing range of the camera.

The images collected using video can be overlaid with location information from a global positioning system (GPS) and incorporated into other geographic information system (GIS) type maps (e.g., bathymetric if available). Video cameras can be deployed with oceanographic instruments that measure depth and water column properties (e.g., temperature, dissolved oxygen, pH, turbidity, and salinity) to provide information on fish habitat association. Video can be powered using deep-cycle batteries, generators, propane tanks, or solar panels. Wireless systems can also be used in some long-term monitoring applications. The power required depends on the survey goals and areas to be covered.

### Strengths

A video or still camera system is a relatively inexpensive way to gather *in situ* information that may be used in an adaptive survey design; adjusting research objectives based on conditions encountered (e.g., high current, rapid ice movement, high/low turbidity). Video can offer a “peek” at conditions below the surface of the ice. For example, a video camera can provide information on fish species presence/absence in the immediate vicinity. Depending on water conditions, video cameras can sample a relatively large area. In clear water, under optimal lighting conditions, an optical camera with a 2.8 mm lens was shown to have a maximum range out to ~10 m resulting in an approximate coverage area of approximately 152.3 $m^2$. In contrast, DIDSON at a range of 10 m has an approximate coverage area of 10.6 $m^2$ (Mueller et al. 2006, Table 2). A video system can also be programmed to collect images over prolonged intervals using portable digital recorders and some have the ability to be triggered to record when motion is detected which would be beneficial in determining fish occurrences in sparsely populated regions.

### Weaknesses

The lighting required to increase the viewing range of video can affect fish behavior; the extent to which avoidance occurs should be seriously considered before sampling. Lasers can be used to determine fish size provided they are not disturbed by the laser beam and are relatively close to the camera. Lasers can be used effectively for characterization of the substrates. When sampling under the ice in low light and deeper water conditions and/or turbid water, video alone may not be sufficient in estimating abundance because the video range is greatly reduced. In addition, external lighting that would be required may result in a deterrent to some fish species.

### Under-Ice Sampling

An ice hole with a minimum diameter of 25.4 cm is required for deploying a small video camera in conjunction with DIDSON, described below (see Mueller et al. 2006, Fig. 4). A hole this size in 2 m of ice can be easily drilled by two individuals using a portable gas-powered auger. During workshop discussions, it was suggested by Larry Moulton (MJM Research) that an upward-viewing video camera would benefit under-ice applications to survey fish that may be located in the crevices and cracks formed by pressure ridges. The research conducted by Mueller et al. (2006) found the combination of video (for fish identification) and DIDSON (for estimating abundance and fish size) was successful in conducting fish surveys in the winter months. A video sampling set-up for under-ice surveys could be accomplished with a small field party (minimum of two individuals) along with associated transportation equipment. The DIDSON can also be used to estimate under-ice formations. Sampling via stationary methods such as mounted on a pole and lowered through the ice can only be achieved in fairly shallow water depths (up to ~5 m) due to the limited range of the video as ambient lighting is decreased. However, active sampling with video and DIDSON mounted to an AUV/ROV or carried by a diver could potentially sample the water column from ice ceiling to greater depths.

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## Sampling Oceanographic Properties

Presenter: Chris Petrich (University of Alaska, Fairbanks, Alaska, USA)

In the Arctic, oceanographic characteristics can be vastly different between the brief open water season and during ice-covered months. Oceanographic sampling in the Arctic during wintertime months can occur over a survey time period of a few weeks to several months. Oceanographic instruments can be deployed at the beginning of a survey period and retrieved at the end. Static sampling stations can collect a suite of oceanographic data, such as temperature, salinity and fluorescence (for monitoring chlorophyll). Instruments are mounted to poles and secured to an opening in the ice, potentially for long periods of time. An "active" oceanographic sampling suite deployed using a remotely operated vehicle (ROV), autonomous underwater vehicle (AUV) or diver can characterize the water column at each station, possibly visiting several stations in one survey day. The following reference provides some basic information on oceanographic processes (chemical, biological, and physical) in the Beaufort Sea during the fall and wintertime months.

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# SAMPLING PLATFORMS

## Remotely Operated Vehicles (ROV)

Presenter: Russ Hopcroft (University of Alaska Fairbanks, Alaska, USA)

Remotely operated vehicles (ROV) are motorized, unoccupied devices operated below the surface of the water and are physically connected to a base station (on a ship or ice) that “drives” the vehicle and generally provides its power. In contrast, autonomous underwater vehicles (AUV) are self-powered and untethered and can therefore operate over larger areas (limited by power consumption) but execute only preprogrammed activities.

An ROV can be configured in two ways: the umbilical is neutrally buoyant giving the ROV maximum range from the control point, but it must work hard to drag the umbilical, which may be impossible in higher currents. Alternatively the “umbilical” is heavy and acts as a weight, so the ROV only operates in a shorter radius of neutral umbilical. The umbilical on smaller units can be deployed “by hand” while larger units require dedicated winches and cranes for deployment.

An ROV can range in size from a very small, highly mobile unit to large units that require a large ship-based platform to launch and retrieve the unit. The larger ROVs (700 kg) are able to descend to much greater depths (up to 5,000 m) than smaller units, but with increasing size/depth comes increased cost of operation. Medium to large units are easier to control in swift currents, such as those that may be found under moving pack-ice.  An ROV is an underwater robot and is used to perform scientific tasks, such as collecting benthic samples from the seafloor bottom or retrieving oceanographic instruments.  An ROV can maintain position and travel at slower speeds (necessary for live video feedback) than an AUV, although advances in AUV technology are decreasing that gap.  All ROVs contain video camera(s) and lighting systems that provide live feedback to a base station.  This enables scientists to make *in situ* decisions, such as collecting an unusual species, changing course to make observations, or deploying/recovering instruments.  An ROV is able to extend to depths greater than 5,000 m, although the cost increases with increasing depth.

### Strengths

An ROV can collect specimens from the seafloor or fragile species within the water column, such as jellyfish.  An ROV potentially has unlimited power and time in the water in contrast to submersibles or AUVs whose power is drawn from the unit itself rather then being fed through an umbilical on the ship or land/ice-based station.

### Weaknesses

If an ROV is used to detect the presence/absence of fish species, the potential for fish avoidance due to the lights and/or noise should be addressed.

### Under-Ice Sampling

An ROV could be used to survey a grid under the ice through holes drilled in the ice in a grid pattern.  During workshop discussions, it was recommended that a medium-sized ROV would be best for detecting fish presence/absence, species identification and distribution. Species identification relies on relatively low turbidity as fish would be identified via video and/or still camera images. Cold Arctic air temperatures could freeze or affect parts of the ROV; however, problems due to cold can be avoided by launching and retrieving in a shelter. Often an ROV is rented along with an operator who is familiar with the technology and operations of an ROV. One issue to consider when launching an ROV from an ice hole is defining the scale at which fish presence/absence is needed. For example, is it necessary to get the exact location of the ROV as it surveys as area (perhaps by lowering transponders in ice holes around sampling site? Or is the survey site location from where the ROV was launched sufficient? When launching an ROV from the ice, how the unit will be powered must be considered. Although the unit is not dependent on an internal power source, maintaining power via generators, for example, may create noise levels that affect survey results. The amount of power required for an ROV depends on the unit size and survey design.

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## Autonomous Underwater Vehicles (AUV)

Presenter: Alex Forrest (University of British Columbia, Vancouver, British Columbia, Canada)

Autonomous underwater vehicles (AUV) are self-propelled vehicles that travel underwater at cruising speeds of 2 – 6 knots at various depth ratings. These vehicles are not physically connected to surface operations (as compared to remotely operated vehicles (ROV) which are tethered to a ship, land or ice-based station). An AUV can range in size from being small enough to be man-portable (less than 50 kg) carried by two individuals to large AUVs that require a large ship-based infrastructure. There are three basic AUV platform types; the torpedo-shaped AUV which depend on forward motion for stability and control, the hovering AUV, and the bottom crawling AUVs which are considered "rover" (i.e., such as one developed by Kenneth L. Smith at MBARI (www.mbari.org/mars/general/rover.html). The hovering type AUV may be suitable for operating in the Arctic under the ice.

An AUV is preprogrammed to accomplish a variety of scientific goals and subsurface surveys on a scale of several hours to a day. Although an AUV can be operated *in situ* via ship, land or ice-based station, this is generally not the case due to limited underwater communications. An AUV can be navigated in the Arctic using some combination of global positioning system (GPS) on the surface, ultra-short and long baseline systems (USBL and LBL), an inertial navigation system (INS), and a Doppler velocity log (DVL) for estimating AUV speed; magnetic compasses are not effective close to the poles (see Whitcomb et al. 1999 for additional information on current navigation technology). Although INS-based navigation systems have the same trouble near the poles, field operations have proven their performance above 82°N.

Depending on the scientific payload, the navigation system of an AUV generally requires the largest amount of operating power. For scientific purposes, AUVs have been used to collect a variety of data including seafloor and habitat mapping (dual beam and multibeam sonar), digital photography (still and video) and oceanographic (physical, chemical, and biological) processes. Sensors that can be fitted to AUVs include sidescan and other sonar technologies (e.g., dual-frequency identification sonar (DIDSON)), imaging (video and/or camera), and instruments to measure conductivity, temperature, optical backscatter (i.e., fluorometer), and dissolved oxygen. An AUV can be comprised of multiple modular units that can be rotated out depending on requirements of a given scientific mission. An AUV could be used for fish detection via hydroacoustics and/or the DIDSON. Video and camera for capturing still images of fish and seafloor mosaics can also be attached to an AUV (Singh et al. 2004). An AUV can be programmed to do transect and/or grid surveys, possibly replicating open water surveys in wintertime months under the ice.

In Brierley et al. (2002), an AUV was successfully used with acoustic echosounders (38 and 120 kHz) to estimate krill abundance under the ice in Antarctica. Sampling occurred along transects in open water and extended up to 27 km under the ice (Brierley et al. 2002). Previously, it had not been feasible to gather accurate estimates of krill abundance with ship-based acoustics due to the noise generated by the ice breakers moving through the ice (Brierley et al. 2002).

The logistical support for an AUV may be greater than what is required for an ROV; however it is highly dependent on the size of the vehicle used. Retrieval of an AUV from under the ice may be problematic. However, several different methods have been used to locate a lost vehicle under the ice: an avalanche transceiver/ receiver (457 kHz) was demonstrated to work through the ice (Forrest et al. 2008); an acoustic fish tag can provide a redundant system for vehicle location, and acoustic communications (acoustic modem or ultra short baseline) can provide communications with the stalled vehicle.

Fish disturbance by AUVs is, for the most part, still unknown; however, advances in AUV noise reduction may provide insight for future investigation (Zimmerman et al. 2005).

### Strengths

An AUV has the ability to navigate and collect data independent of a ship, land or ice-based stations over large areas and long periods of time. An AUV can conduct transect and/or grid-like surveys using hydroacoustics and/or video/still imaging. An AUV may be outfitted with sidescan and multibeam sonars (sampling both down and up) and could potentially perform fisheries acoustic surveys in both open and under-ice environments (Fernandes et al. 2003). Similar to an ROV, an AUV can attain depths much greater than divers.

### Weaknesses

The cost of an AUV, the trained personnel needed to operate the AUV, insurance requirements, and logistical support could make an AUV campaign costly, especially in the Arctic wintertime months. Post-processing large datasets generated by AUVs can be time, money, and personnel consuming, however advances in post-data analysis are increasing (Ferrini and Singh 2006).

## Under-Ice Sampling

Operating an AUV in the Arctic environment may be complex and would require a great deal of research and planning (i.e., how do temperature extremes affect the AUV?). Several factors must be considered, such as research objectives (e.g. fish abundance estimates vs. presence/absence), the amount of funding available (e.g., AUV daily operation includes skilled personnel, insurance costs) and if an AUV can meet a particular research objective that an ROV is not capable of (may be less costly). A comprehensive guide for AUV operations in Polar Regions can be found at: www.srcf.ucam.org/polarauvguide/.

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## Diving

Presenter: Brenda Konar (NOAA's West Coast and Polar Regions Underwater Research Center and University of Alaska Fairbanks, Alaska, USA)

Ice diving requires specialized training in addition to a standard research dive certification, such as that done by the American Academy of Underwater Sciences (AAUS: www.aaus.org) and the NOAA Dive Program (NDP; www.ndc.noaa.gov). Both AAUS and NDP offer uniform standards that promote safety and enable the goals of the scientific mission. Certification in one of these programs (or similar) must be completed to participate in a project that involves university or government agency personnel (either paid or volunteer).

Scientific diving is a feasible tool to use in shallow cold waters (Heine 1996, Lang and Sayer 2007). Decompression diving begins at 40 m, which makes diving at depths greater than 40 m difficult in the Arctic environment. Divers are often tethered (required if blue water diving or poor visibility) to safety lines on the surface and can enter through holes made in solid first or multi-year ice, pack-ice, and cracks. For safety, two ice-holes per site are optimum, especially in solid ice. In general, diving under the ice in the Arctic environment requires a minimum team of three individuals for safety and support.

The equipment required for diving in the Arctic must be "ice-approved" and includes regulators (Clarke 2007), dry suits (Lang 2007), proper thermal insulation (Stinton 2007), and effective communication (e.g., from diver to surface). Depending on the research requirements and diving conditions, other equipment may be needed such as full face masks, hot water suits, and flashlights. The air source for the diver can come from SCUBA tanks or a surface supply powered by a generator. Secondary air sources, such as bail-out bottles, are optimum. Shelter is favored for diver preparations, equipment protection (to prevent freezing), post-dive operations, and overall diver safety. A solid emergency evacuation plan should be in place in case of a diver accident, including immediate access to oxygen and medivac ability to a hyperbaric chamber.

### Strengths

Ice divers can deploy and retrieve sampling instruments and survey transects or grids. Divers can access areas where other technologies may not be able to reach, (e.g., in cracks and crevices formed by pressure ridges). Ice-divers can conduct surveys to record presence or absence of fish species, abundance, and size. They can also collect photo or video images, biological specimens, and deploy oceanographic instruments.

### Weaknesses

Ice-diving can be dangerous and requires unique logistical support, such as maintaining a helicopter on stand-by in the event of a medical emergency such as transport to a hyperbaric chamber. Ice-diving should occur in water less than 40 m, depths beyond this range require time to decompress at shallower depths. Ice-diving requires a minimum ice-hole of 36 inches in diameter to be drilled or melted out. An ice-hole 36 inches in diameter is larger than what is needed for deploying a small remotely operated vehicle (ROV) or stationary acoustic set-up and the equipment required to drill a hole this size can be costly and time consuming. The number of dives a particular diver can do in one work day is often not more than 3 dives, limiting the amount of area that could be covered in one survey day.

### Under-Ice Sampling

Diving under the ice would be useful in areas of high relief or structure, such as pressure ridges. Pressure ridges often extend much farther below the surface than what is observed, making this a difficult environment to sample with other gear and technologies (e.g., fish nets, ROV, and autonomous underwater vehicles (AUV)). It was mentioned during workshop discussions that fish were not often found under flat ice but were observed in highly structured areas, often tucked into crevices and cracks formed by pressure ridges (pers. com., Shawn Harper, University of Alaska Fairbanks).

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# ICE CAMP LOGISTICS

Presenter: Jenny Hutchings (University of Alaska Fairbanks, Alaska, USA)

In general, when choosing locations to deploy long-term ice camps, locations on multi-year ice floes are less problematic and tend to be safer than 1st year ice floes. Ideal locations are often found off the continental shelf in 1 m thick ice, with a refrozen lead close by (providing easy access to water under the ice). It is not common to set up ice camps on 1st year ice as conditions are very dynamic and unpredictable, such as those often encountered in winter months in the proposed survey area. An ice camp that may be potentially useful for inshore work would be one that could sustain 5-10 individuals, with 2-3 supply flights over the course of a 2-week occupation period. Ice camp logistical needs depend on the survey design, sampling goals, time needed to complete the survey, and the number of individuals required to conduct the survey.

Important things to consider in choosing a short-term ice camp include:

- **Ice**
    - Stability (multi-year or first-year ice)
    - Thickness
    - Proximity of leads
    - How weather will affect ice motion
    - Requires expertise in sea ice dynamics and suitable conditions for locating camp
    - Requires aircraft pilots experienced with ice landings

- **Supplies**
    - Number of supply flights required
    - Aircraft runway (dictates kind of aircraft)
    - Equipment required for maintaining living conditions
    - Gear and equipment for scientific data collecting (and spare parts)
    - Equipment necessary for melting ice holes
    - Equipment necessary for gear transport
    - Power requirements for living and science activities
    - Communication within and outside camp
    - If ice diving, access to hyperbaric chamber is required

Equipment should be tested prior to undertaking a field study to ensure that equipment will function in extremely cold conditions.

- **Hazards**
    - Polar bears (both for people and scientific gear)
    - Extreme cold temperatures and wind
    - Traveling on ice
    - Ice stability (especially in 1st year ice)
- **Science**
    - Plan extra days for weather
    - Land-fast ice extent could affect the survey area

- Rapidly moving ice could affect the location of survey area (if attempting to replicate summer survey)

**Strengths**

Establishing an ice camp provides 24-hour access to the survey location. Daily transportation to and from the survey location, in the absence of an ice camp, can be costly in both time and money. Establishing a suitable ice camp can thus result in an increase in the survey area that is covered.

**Weaknesses**

Establishing an ice camp in the Beaufort Sea Outer Continental Shelf Planning Area could prove to be problematic due to the relative near-shore location. Ice near-shore will more than likely consist of dynamic 1st year ice and the extent of land-fast ice is variable and could extend into the survey area. Remaining on the ice for periods of time greater than 2-3 days can be dangerous due to extreme weather exposure, polar bears and the moving ice. The greater the scope of research objectives, the amount of personnel and infrastructure needed greatly increases, making the camp more difficult to move should ice conditions change rapidly.

**For Additional Information**

The Office of Polar Programs of the National Science Foundation provides additional information and links to other resources: www.nsf.gov/od/opp/arctic/res_log_sup.jsp

# WORKSHOP SYNTHESIS

After the workshop, the report authors (Rand and Logerwell) constructed the following two scenarios for surveys of fish distributions in the Beaufort Sea during the winter ice-covered season. The scenarios are based on informal discussions conducted throughout the workshop and the report authors' synthesis of the material presented by the participants. These scenarios do not represent all possible methods for conducting winter fish surveys, and details such as sample size, sampling gear (i.e., AUV vs. ROV), survey costs, etc. should be regarded as preliminary. The goal of the scenarios is to provide a very broad and general overview of the resources required to conduct a winter survey in the Beaufort Sea and the kind of data that could reasonably be obtained, in other words, a starting point. The first scenario is of a survey of fish distributions on the shelf, involving a team of scientists occupying temporary ice camps (Scenario A). It is the more expensive of the two scenarios. The second scenario is of a survey in nearshore waters involving periodic sampling by local fishers (Scenario B). This scenario is expected to be less expensive than the first.

## Scenario A

### Survey design

This scenario represents the most comprehensive sampling of the OCS Planning Area in the ice-covered season and consequently is the most expensive. The under-ice marine survey will occur in three stages. Initially, local residents in Beaufort Sea villages will be interviewed on their knowledge of marine fish species types and distribution to identify species seasonality and habitats. Local residents will also be recruited to conduct passive fishing (pots, traps) under the ice through the ice-covered season. Time lapse cameras will also be installed on existing stationary Beaufort Sea moorings. The second component will use the results of the initial sampling to design a pilot survey using both passive gear and active surveys by divers and underwater vehicles to estimate spatial and temporal patterns of fish abundance. The third component, an active under-ice survey will evaluate Arctic cod abundance in three types of habitats on the under surface of the ice (smooth, rough, and creviced). These surveys will be performed by DIDSON sonar, a remotely operated vehicle (ROV) and scuba diver transects. Once the under-ice habitat has been evaluated, estimates of Arctic cod abundance will be calculated. Each survey component will collect physical, chemical, biological and other environmental data necessary to evaluate and test the significance of independent variables that potentially affect fish presence and distribution. The pilot study will provide statistical hypothesis testing between the open water, ROV and dive surveys, providing a baseline for subsequent surveys and provide sampling statistics, including variance estimators, for future time-series analysis.

## Logistics

### *First stage – local knowledge, passive sampling and time-lapse cameras*

For the initial passive fishing under the ice, ice augers would be needed, but depending on the sampling gear, the holes would only need to be 12-24 inches in diameter. Fish sampling gear (pots and traps) would be lightweight, portable and relatively inexpensive. The majority of the project costs for this stage would be for fishers' transit to the sampling sites (e.g., fuel for snow machines) and compensation for their time and effort. In addition, project scientists would need to make several trips to North Slope communities for interviewing, training, project monitoring and outreach. Costs for this component would be expected to be on the order of 100,000's of dollars.

Two sets of cameras with IR lights and measuring lasers would need to be purchased for deployment on moorings. Additional requirements would be underwater housing and data feed cables designed for extreme cold temperatures. The total cost would be approximately $50,000.

*Second stage – pilot survey*

Depending on the success of the first stage of the project, local fishermen could implement the passive sampling component of the pilot survey. The costs would thus be similar to the first stage, on the order of 100,000's of dollars.

A dive team of three people (minimum) would be required for the active sampling during the pilot survey. Ice-approved equipment including communication equipment would be needed. A shelter would need to be constructed at the dive site. A chartered helicopter would need to be available for evacuation to a hyperbaric chamber, at a cost of about $6,000/day plus $1,500/hour of flight time.

A medium-sized ROV could be leased for the project, along with an operator. Other requirements include a shelter for launch and retrieval of the ROV. Two sets of video cameras with IR lights and measuring lasers would need to be purchased, along with underwater housing and data feed cables designed for extreme cold temperatures. The total cost would be approximately $50,000.

An Ice Camp would be required to support the active sampling. In addition to basic camping equipment, a gas-powered generator for living and science activities would be needed. However, it is the logistic costs of setting up and maintaining an ice camp that are most important to address. Helicopter support would cost on the order of $6,000/day plus $1,500/hour of flight time. For purposes of cost estimation we assume that each site requires 4 days occupation (including camp setup and removal), with a daily average crew size of 6 people on the ice and 6 people onshore (housed in Prudhoe Bay, for example). We also consider 6 helicopter trips/day for camp setup and take down (2 days) and 4 trips/day for the two days of sampling effort for a total of 20 helicopter flights/station. The helicopter operations alone amount to about $900,000 with the science costs (field staffing, sample collection, data processing, and reporting) being the same order of magnitude if 30 stations are occupied.

### *Third stage – active Arctic cod survey*

The first step in the Arctic cod survey would be an aerial survey of ice habitat types. In addition to a survey airplane, still (digital) cameras and photographers would be needed. The price of the aerial survey will depend on the number of days it takes to survey the OCS. A generous allocation for bad weather days should be provided. The cost of an aerial survey can be expected to be on the order of $80,000 or more.

In addition to leasing the ROV, two sets of DIDSON cameras would need to be purchased, along with underwater housing and data feed cables designed for extreme cold temperatures. The total cost would be approximately $160,000.

As in the pilot survey, a dive team of three people would be required for the active sampling during this stage (with helicopter support). Also required would be a shelter for deploying the ROV and an Ice Camp to support the entire field party.

Based on the preliminary cost estimates described above, the annual cost of Scenario A would be over $2,000,000.

## Scenario B

### Survey design

This scenario does not replicate the 2008 summer survey effort in the OCS, but it is less costly than the scenario described above.

This fish survey would be accomplished by periodic (e.g. bi-weekly) sampling through the ice by local fishers. Stations inshore of the 20m isobath, which defines the stamukhi zone (or the edge of the landfast ice) could be reached by snow machine, Rologon, or sled dog teams. The survey design would be a collaborative effort by local fishers and project scientists, and thus would take advantage of the traditional ecological knowledge afforded by the fishers' experience. The fishers would design the sampling gear (e.g., gill nets, hook and line, etc.) and the scientists would train the fishers on methods of catch processing and data recording (counting, weighing, measuring and preserving specimens). The relatively high frequency of sampling would help to compensate for the expected low catch rates.

This survey design would provide information on fish species presence/absence and habitat association. Although an abundance estimate analogous to the summer survey would not be possible, this survey could provide an index of relative abundance within the 20 m isobath. In addition, temporal changes in fish presence or abundance at the scale of weeks-months could be documented.

### Logistics

The logistic complexity and costs for this scenario would be much lower than for the first scenario. Ice camps would not be required, because the stations would be close enough to shore to be sampled over the course of several day-long trips. Ice augers would be needed, but depending on the sampling gear, the holes would only need to be 12-24 inches in diameter. Fish sampling gear (e.g., nets, hook and line, etc.) would likely be lightweight, portable and relatively inexpensive. The majority of the project costs would be for fishers' transit to the sampling sites (e.g., fuel for snow machines) and compensation for their time and effort. In addition, project scientists would need to make several trips to North Slope communities for training, project monitoring and outreach.

Total project costs for this scenario would be expected to be on the order of 100,000s of dollars.

## APPENDIX A - Workshop Agenda

### Wednesday - 7 November 2007

10:00 am **Introduction and Overview**
Libby Logerwell, Alaska Fisheries Science Center, Seattle, Washington
Kate Wedemeyer, Minerals Management Service, Anchorage, Alaska

10:15 am **Presentation: Dual-frequency Identification Sonar (DIDSON)**
George Cronkite, Fisheries and Oceans Canada, Nanaimo, British Columbia

10:30 am **Discussion**

11:15 am **Presentation: Under-Ice Diving**
Brenda Konar, NOAA Underwater Research Program and University of Alaska, Fairbanks, Alaska

11:30 am **Discussion**

12:00 pm **Lunch Break**

1:00 pm **Presentation: Under-Ice Net Sampling**
Pete Cott, Fisheries and Oceans Canada, Yellowknife, Northwest Territories
Andy Majewski, Fisheries and Oceans Canada, Winnipeg, Manitoba

1:30 pm **Discussion**

2:30 pm **Break**

2:45 pm **Presentation: Hydroacoustics**
Sandy Parker-Stetter, University of Washington, Seattle, Washington

3:15 pm **Discussion**

4:00 pm **Break**

4:15 pm **Presentation: Autonomous Underwater Vehicles (AUV)**
Alexander Forrest, University of British Columbia, Vancouver, British Columbia

4:45 pm **Discussion**

5:30 pm **Adjourn**

## Thursday - 8 November 2007

| | |
|---|---|
| 9:00 am | **Presentation: Remotely Operated Vehicles (ROV)**<br>Russ Hopcroft, University of Alaska, Fairbanks, Alaska |
| 9:30 am | **Discussion** |
| 10:30 am | **Break** |
| 10:45 am | **Presentation: Oceanography**<br>Chris Petrich, University of Alaska, Fairbanks, Alaska |
| 11:15 am | **Discussion** |
| 12:00 pm | **Lunch Break** |
| 1:00 pm | **Presentation: Video**<br>Robert Mueller, Pacific Northwest National Laboratory, Richland, Washington |
| 1:30 pm | **Discussion** |
| 2:30 pm | **Break** |
| 2:45 pm | **Presentation: Logistics in the Ice Covered Arctic**<br>Jenny Hutchings, International Arctic Research Center, University of Alaska, Fairbanks, Alaska |
| 3:45 pm | **Workshop Adjourn** |

# APPENDIX B – Workshop Attendees

| *Name* | | *Affiliation and email address* |
|---|---|---|
| Bodil | Bluhm | University of Alaska Fairbanks, Alaska, USA<br>bluhm@ims.uaf.edu |
| Rob | Chadwell | University of Alaska Fairbanks, IARC, Alaska, USA<br>rchad@iarc.uaf.edu |
| David | Christie | West Coast / Polar Regions Undersea Research Center, Fairbanks, Alaska, USA<br>dchristie@guru.uaf.edu |
| John | Clary | Alaska Fisheries Science Center, Seattle, Washington, USA<br>john.c.clary@noaa.gov |
| Pete | Cott | Fisheries and Oceans Canada, Yellowknife, Northwest Territories, Canada<br>Pete.Cott@dfo-mpo.gc.ca |
| George | Cronkite | Fisheries and Oceans Canada, Nanaimo, British Columbia, Canada<br>CronkiteG@pac.dfo-mpo.gc.ca |
| Alex | Forrest | University of British Columbia, Vancouver, British Columbia, Canada<br>forrest@civil.ubc.ca |
| Craig | George | Department of Wildlife, North Slope Borough, Barrow, Alaska, USA<br>Craig.George@north-slope.org |
| Rolf | Gradinger | University of Alaska, Fairbanks, Alaska, USA<br>rgradinger@ims.uaf.edu |
| Shawn | Harper | University of Alaska, Fairbanks, Alaska, USA<br>fssth@uaf.edu |
| Russ | Hopcroft | University of Alaska, Fairbanks, Alaska, USA<br>hopcroft@ims.uaf.edu |
| Jenny | Hutchings | University of Alaska, Fairbanks, IARC, Alaska, USA<br>jenny@iarc.uaf.edu |
| Katrin | Iken | University of Alaska, Fairbanks, Alaska, USA<br>iken@ims.uaf.edu |
| Brenda | Konar | NOAA Undersea Research Program, University of Alaska Fairbanks, Alaska, USA<br>bkonar@guru.uaf.edu |
| *Libby | Logerwell | Alaska Fisheries Science Center, Seattle, Washington, USA<br>libby.logerwell@noaa.gov |
| Andy | Majewski | Fisheries and Oceans Canada, Winnipeg, Manitoba, Canada, USA<br>Andrew.Majewski@dfo-mpo.gc.ca |
| Bruce | McIntosh | Alaska Department of Fish and Game, Fairbanks, Alaska, USA<br>Bruce.Mcintosh@alaska.gov |
| Pat | McKeown | University of Alaska Fairbanks, IARC, Alaska, USA |
| Larry | Moulton | MJM Research, Lopez Island, Washington, USA<br>lmoulton@rockisland.com |
| Bob | Mueller | Pacific Northwest National Laboratory, Richland, Washington, USA<br>robert.mueller@pnl.gov |
| Mitch | Osborne | U.S. Fish and Wildlife Service, Fairbanks, Alaska, USA<br>Mitch_Osborne@fws.gov |
| Sandy | Parker-Stetter | University of Washington, Seattle, Washington, USA<br>slps@u.washington.edu |

| *Name* | | *Affiliation and email address* |
|---|---|---|
| Chris | Petrich | University of Alaska Fairbanks, Alaska, USA<br>chris.petrich@gi.alaska.edu |
| Kim | Rand | Alaska Fisheries Science Center, Seattle, Washington, USA<br>kimberly.rand@noaa.gov |
| Jennifer | Reynolds | NOAA Underwater Research Program, Fairbanks, Alaska, USA<br>jreynolds@guru.uaf.edu |
| Chris | Rooper | Alaska Fisheries Science Center, Seattle, Washington, USA<br>chris.rooper@noaa.gov |
| Craig | Rose | Alaska Fisheries Science Center, Seattle, Washington, USA<br>Craig.Rose@noaa.gov |
| Mark | Savoie | Kinnetic Laboratories, Anchorage, Alaska, USA<br>msavoie@kinneticlabs.com |
| Kate | Wedemeyer | Minerals Management Service, Anchorage, Alaska, USA<br>Kathleen.Wedemeyer@mms.gov |
| Tom | Weingartner | University of Alaska Fairbanks, Alaska, USA<br>weingart@ims.uaf.edu |

*Workshop organizer