Healy – Louis Science

Developed from Notes from meetings 5-6 June, 2008 and subsequent edits

I. Science Priorities

The primary purpose of the two-ship experiment is to collect seismic and bathymetric data in support of delineating the extended continental shelf in the western Arctic Ocean for both Canada and the United States. The extended continental shelf is that region beyond 200 nautical miles where a nation can show it satisfies the conditions of Article 76 of the United Nations Convention on the Law of the Sea. The data most often required for fulfilling the conditions of Article 76 are bathymetric and seismic data. The logistical difficulties of collecting seismic data in ice-covered regions make it much more likely that the data will be collected successfully if two ice-breakers participate, one in the lead to break a path for the second following with the towed seismic acquisition system. *USCGC Healy* is equipped to collect multibeam bathymetric, high-resolution subbottom, and gravity data during the expedition and the *CCGS Louis S. St. Laurent (Louis)* is equipped to collect multichannel seismic reflection and refraction data as well as gravity data. With two ships, the priority areas will be those locations where ice cover requires a two-ship operation.

Because acquiring seismic data is the reason for having a two-ship experiment, alterations to the original science plan during the experiment (due to unexpected circumstances) need to be decided first to ensure successful acquisition of seismic data with coincident bathymetric data to foot of slope, and second on obtaining additional multibeam bathymetric data. If the ice is too thick for ship profiling along the seismic profile in the vicinity of the foot of the slope, the fall-back strategy is to take spot soundings using the helicopter and use those spot sounding to define foot of slope. Ice conditions and ship loction with respect to the continental margin will determine when the helicopter soundings will be employed in this manner.

Along the Canadian continental margin north of Banks Island, where the planned ship tracks are parallel to the margin, a secondary priority is to collect bathymetric data to identify the foot of the slope between the seismic profiles. To fulfill this secondary objective, it may be optimal to have *Louis* as the lead vessel to break ice for *Healy*. If ice conditions are heavy, a decision at sea will need to be made to determine how much effort to expend obtaining bathymetry along the continental margin between seismic profiles. If this secondary operation delays the seismic survey significantly, it will be abandoned and a faster route taken to the start of the next seismic line. The foot of slope information between seismic profiles is useful but not essential.

If there are light ice conditions for significant portions of the seismic profiles so that an escort is not required, it may be an opportunity for the Healy to run parallel to the Louis and double the bathymetric profiles collected. Or this may be an opportunity for *Healy* to depart the area to conduct contingency bathymetric soundings elsewhere. Consultation and consensus among the lead scientists on both vessels is expected in deciding alternative plans.

II. General Science Plan

Although track lines, distance, and times presented here are laid out as part of prudent planning, this science plan is considered subject to change due to ice conditions, equipment problems, and or other unexpected circumstances. Because of uncertainties inherent in this kind of experiment, the science plan attempts to describe the planned operations as well as the decision points at which changes might be expected to occur. Some of the operations are not scheduled because we are anticipating doing them in particular ice conditions, which will not be known until the time of the cruise. We have tried to identify decision points in the following discussion, but recognize that conditions during surveying may require other unanticipated changes.

Part 1 (Fig. 1, waypoints A-G): *Louis* is scheduled to depart Kugluktuk, NT on August 21 and will spend about 3 days setting up the seismic gear while proceeding to the beginning of the survey. There may be as much as two days required to test the seismic gear and record signature (sound source) tests using a special hydrophone system. Once these tests are completed, the the seismic operation will commence in single-ship mode[1]. The ship track from waypoints A to F connects to and crosses existing seismic data.

> *Decision Point – Waypoint F*: If ice conditions allow progress to waypoint F, the decision will be made whether to proceed along track FfG or FG.

Part 1 of the cruise will end at or between waypoints G and H when *Healy* arrives.

Part 2 (Fig. 1, waypoints G-H): *Healy* is scheduled to depart Barrow, AK on September 6 and proceed north. Part 2 begins on or about September 8-9 when Healy meets *Louis* at or near waypoint G and the two-ship operation begins. Part 2 consists of the track from waypoints G to H. Planned waypoint H is sufficiently far up the continental slope to determine foot of slope, though probably no shallower than 2,500 m. At the 2,500-m contour (which will be before the end of the line), the seismic gear will be recovered (in accordance with conditions of the permitting).

If the ice conditions do not allow for the profiling using the vessels, then a profile of bathymetric spot soundings through the ice will be made using the helicopter system (assuming the Louis can get close enough to the margin to be within helicopter range). Neither the length of time allotted for this acquisition nor contingency operations for *Healy* have been decided.

On profile GH a grid of spot soundings between profiles may be obtained using the helicopter and through-ice techniques. The objective of this helicopter sounding operation is to fill in gaps in the bathymetry of the area and is not a direct requirement for UNCLOS.

Part 3 (Fig. 1, waypoints H-M): Assuming that the ice conditions have allowed the two-ship operation to waypoint H, the roles of the ships will be reversed from waypoints H to I and L to M, with *Healy* collecting multibeam bathymetry while *Louis* breaks ice as the lead ship. The exact location of the track between waypoints H and I (and between waypoints L and M) will be decided at the start of Part 3 so that the foot of slope can be mapped with bathymetric profiling.

[1] On 7 August, 2008, GSC will make a decision whether to divert a second (Canadian) ice breaker to support the Louis for Part 1 of the cruise. This will be based on ice conditions in the general area of operations.

This bathymetry is a secondary objective and the time and effort to collect multibeam between seismic profiles must be weighed with delay it causes in collecting seismic profiles. It is useful to document the shape of the slope and the fact that an attempt was made to acquire multibeam along foot of slope, but is a lower priority than the seismic profiles and obtaining foot of slope along the seismic profiles. Seismic profiles will be collected along track IJKL in two-ship mode with *Healy* leading and *Louis* following.

Part 4 (Fig. 1, waypoints M-N): At waypoint M, the two ships will begin the long track west across the Canada basin to waypoint N, with deployment of the seismic system at the 2,500-m isobath. Part 4 ends at waypoint N most of the way across the Canada basin.

If an escort is not required on this leg, then options include running Healy parallel to the Louis to collect an additional bathymetric profile in an area with few soundings or releasing the Healy to collect bathymetry of priority elsewhere.

> Decision Point – Waypoint N: At point N, the science leaders and commanding officers need to consider ice conditions, time remaining, fuel remaining, and other parameters to determine how much further the vessels can continue in two-ship configuration and when it is necessary for the vessels to separate for return to their respective ports of disembarkation. *Louis* might be able to collect seismic data in single-ship mode before proceeding to Tuktyuktuk to arrive on 1 October, 2008 for refuelling and a possible media event. *Healy* returns to Barrow on 1 October, 2008.

Part 5 (*Louis* from Tuktyuktuk to Kugluktuk): There are tentative plans for a Canadian minister and an undetermined number of media representatives to embark on *Louis* in Tuktyuktuk and disembark in Kugluktuk where the ship will arrive on October 2, 2008 for disembarking of the science party.

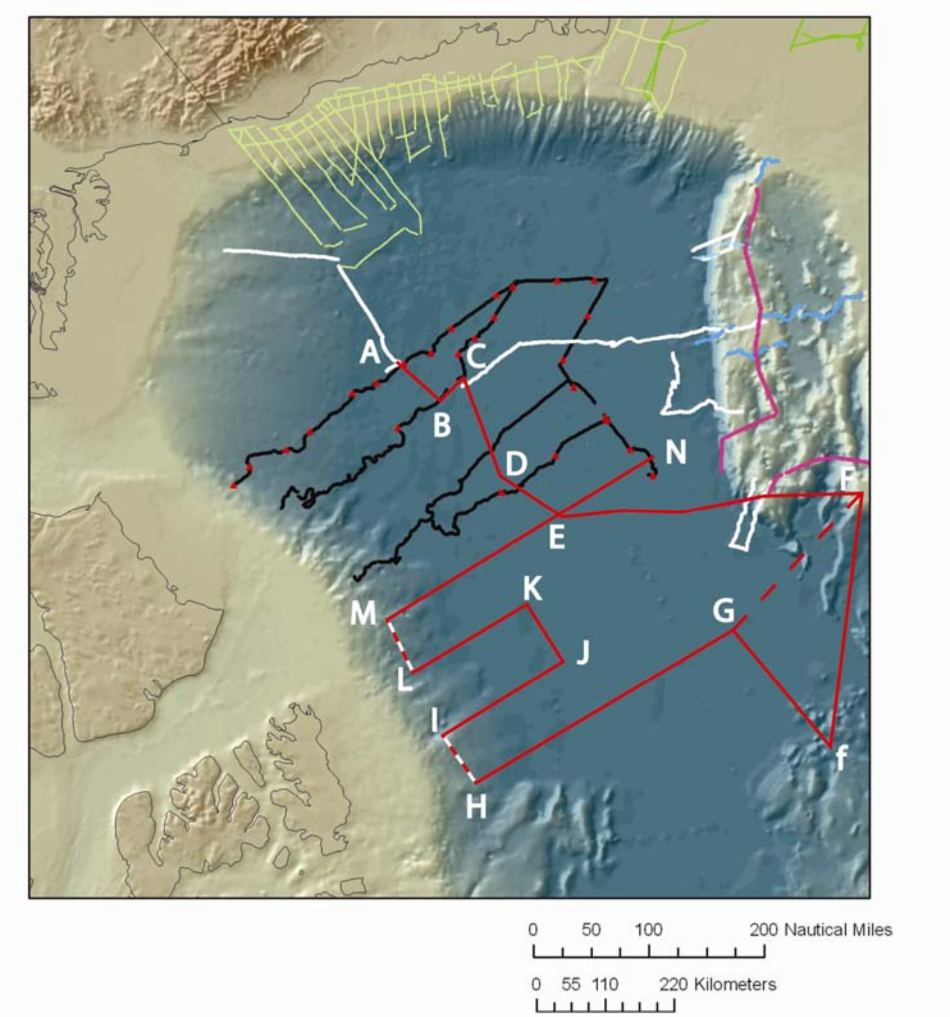

Figure 1: Preliminary tracklines proposed for the Law of the Sea seismic reflection work (shown in red), summer, 2008. Waypoints are indicated by white letters. Existing seismic track locations are shown in black (NRCan, 2007), USGS (white, yellow, and blue), and magenta (Healy 2005). North is down.

III. General Science Plan for Communications: Two Ships

An experiment involving two scientific and ship operations is by its nature complex. Because of the remoteness and fickle ice conditions involved in Arctic Ocean work, the success of the experiment will depend critically on open communication between the scientists and officers of both vessels. The suggestions developed below are considered a guideline for developing this open communication. Other suggestions for ensuring successful communications are welcome!

Louis: **a daily science planning meeting** takes place every day after the evening meal, in which science operations expected for the next 24 hours will be formulated. To avoid confusion, this plan will be written and distributed electronically to appropriate science and coast guard personnel on both vessels.

***Louis/Healy* teleconference**: Following the formulation and distribution of the 24-hour science plan, the two ships will hold a teleconference to exchange this information as well as concerns and questions among the science leaders and officers.

***Louis* morning science update**: Pulling the seismic gear for routine maintenance will occur at least every 48 hours. Every morning during seismic operations, Borden Chapman holds a meeting with his technical/watch staff to assess the state of the seismic gear and the need for maintenance or other actions that might interrupt the acquisition of the seismic data. The outcome of this meeting will be relayed to the Chief Scientist on *Louis*, who will pass the information and any associated changes in the 24-hour plan to appropriate scientists and officers aboard both vessels. If significant changes to the 24-hour plan are anticipated, additional communication between the ships and their scientists/officers needs to be undertaken accordingly.

***Louis/Healy* ice observers**: The ice observers aboard both vessels are a critical component of the science planning because of their knowledge and insight about local and regional ice conditions that affect the seismic operations and the tracks that the ships steer. Ice radar and other ice information will be shared and the Healy observer will be included on Louis helicopter reconnaissance flights as appropriate. These observers are expected to communicate with each other as well as the respective chief scientists and officers about ice conditions as part of the daily science planning and more frequently as warranted by ice conditions.

Louis: The Louis helicopter will allow personnel exchanges for day visits as appropriate.

Marine Mammal and Community Observers: The marine mammal and community observers play a vital role in the permitting process and act as the eyes and recorders of contacts with marine mammals during the experiment. If observers on the lead vessel *Healy* spot marine mammals, they are expected to communicate this to their counterparts on *Louis*, and ensure that the appropriate scientists and officers are informed (and vice versa). The observers on *Louis* will determine the appropriate actions to be taken with respect to the seismic operations. Marine mammal observers aboard *Healy* will serve two functions: (a) provide additional observations that the *Louis* marine mammal observers can use in making decisions regarding seismic operations. Only the *Louis* marine mammal observers have authority to modify seismic operations; and (b) collect data about marine mammal observations and scientific operations that might be relevant to future permitting. If possible, a day-exchange to allow the observers (especially the community observer) to meet their counterpart(s) on the other vessel will be arranged.

Other actions to encourage open communication:

- A liaison officer (Capt. John Stewart) from *Louis* will sail on *Healy* to facilitate communications between the vessels and to help explain *Louis* operations. Capt. Stewart will embark on *Healy* in Barrow, but disembark on *Louis* in Kugluktuk. At

- A USGS scientist, Dr. Deborah Hutcinson (Gove) will sail on *Louis* to provide USGS input to scientific decisions made during the cruise. She will embark and disembark in Kugluktuk with the rest of the *Louis* science crew.
- Commanding Officer of the Louis will visit Healy via helicopter at the rendezvous of the two ships and prior to start of the two-ship work to finalize bridge to bridge communications, protocols, and understandings of commonly used technical and other terms of the experiment.
- A self-contained wireless internet link is being installed that will enable wireless communication between the two vessels when they are within 10-20 km of each other.
- A forward-looking video camera on *Healy* shows continual ice conditions.
- A similar video camera may be on *Louis* from IPY cruises.
- A web camera on a white board is projected around *Healy* with science updates written by the Chief Scientist or other designated person.
- *Louis* has a daily ships plan distributed around the vessel on the ship's network in powerpoint form that might be expanded to contain science updates.

IV. Seismic Operations

Seismic operations on *Louis* are essential for being able to use the sediment thickness formula of Article 76 of the Law of the Sea. The seismic operations involve three types of work: (1) the bulk of the cruise will be dedicated to multichannel seismic reflection profiling, towing airguns and a streamer from a weighted sled off the stern of *Louis*; (2) at predetermined intervals during the seismic reflection profiling, floating sonobuoys will be deployed aft of *Louis* to record seismic refraction information, ie., airgun signals at progressively larger distances as the vessel moves away from the sonobuoy; and (3) Special conditions will warrant that *Louis* stop so that acoustic information of interest can be recorded during the cruise.

Seismic reflection profiling generally begins with the ship steaming forward at low speed deploying the streamer off the stern and ends with deploying the weighted sled (from which the two air guns are suspended and to which the streamer is attached) into the water so that it tows at a depth of about 10 m. Once in the water, the start up sequence is to fire one gun at low energy level, gradually increasing to full strength, then repeating the ramp-up procedure for the second gun. After the guns are firing at the appropriate predetermined intervals, there is a start up sequence in the electronics lab to coordinate shot number and recording of the seismic signal for the start of the line, which may take several minutes. Average time from the start of deploying the streamer to being ready to record the first shot is about ½ hour. This start up procedure is likely to take longer at the beginning of the cruise when the systems are being tested and shorter towards the end of the cruise when the bugs are worked out.

A principal objective of the mission is to acquire parallel seismic reflection profiles that are as linear and continuous as possible, along predetermined tracklines separated by approximately 50 nm. In ice-free conditions, course made good should deviate no more than 0.5 nm from the preplotted track. In the presence of ice coverage, course made good should deviate no more than 5 nm from preplotted track.   Course changes should not exceed 1 degree per minute.

Experience from the 2007 *Louis* cruise is that the seismic equipment can go no more than 48 hours before requiring maintenance and overhaul. Often, overhaul is done every 24 hours and can last from a few to several hours, depending on the extent of maintenance required. During these maintenance periods, *Louis* should move to a position that allows for overlap of at least 1-2 nm when the gear is back in the water and the seismic line is resumed. When one ship is escorting, the re-start point should allow at least an additional 1 nm for deployment at 1 knot. *Hence there needs to be coordination between the two ships in determining appropriate start-up positions and overlaps to ensure no gaps in line coverage when lines are restarted after breaks.*

Seismic Refraction data are collected by deploying floating sonobuoys while simultaneously acquiring seismic reflection data. Sonobuoys, which are self contained floating units containing a hydrophone and appropriate electronics, are released approximately every 8 hours, although the exact time spacing depends on how strong and identifiable the sonobuoy signals are and how far the ship is from the sonobuoy. The data acquired through the sonobuoy are relayed to the ship via radio link. In order to maximize the potential distances over which data are recovered, the receiving antenna on *Louis* is placed as high as possible on the ship. Sonobouys are not recovered after being deployed.

Special Conditions refer to those situations where additional acoustic data will be recorded independently of normal seismic operations.

- The first of these special-condition experiments is to accurately record the amplitude and characteristics of the airgun signal using a special, calibrated hydrophone. This recording is expected to happen near the beginning of the *Louis* cruise and involves *Louis* being stationary in the water with the hydrophone and airguns deployed in the water.
- The second of these special conditions will involve recording the noise of icebreaking. The intention is to record the noise of *Healy* breaking ice in moderate-ice and heavy-ice conditions (although not backing and ramming). A control recording would record the noise of *Healy* in open-water conditions. The geometry of the ships during these configurations would be for *Louis* to be stationary with the calibrated hydrophone deployed near the stern of the vessel and *Healy* to steam transverse to the stern of *Louis* as close to *Louis* as the captains are comfortable. The *Healy* trackline need not be very long, 1-2 nm is probably more than adequate. Duration of recording should not be more than 3 hours at each station. *The planning for this experiment will depend on ice conditions and will probably coincide with a break in normal seismic recording.*

V. Bathymetry Operations

Bathymetry data are essential data within the Law of the Sea Convention for showing the morphology of the continental margin, providing evidence for the foot of the slope, and locating the 2,500-m isobath. On the Canadian margin, mapping the 2,500-m contour is not a priority. Three kinds of bathymetric data will be potentially collected during the two-ship operation: multibeam bathymetry (*Healy*), single beam bathymetry (*Louis*), and soundings on the ice utilizing the *Louis* helicopter. Measuring the velocity of sound in the water column is integral to collecting the bathymetric data. Both *Healy* and *Louis* have systems for collecting these data, as discussed below.

Multibeam bathymetry is acquired from hull-mounted receivers and transducers on *Healy* that measure the depth to the seafloor in discrete angular increments (or sectors) in a swath that is perpendicular to the ship's track. The highest quality multibeam data are collected in open-water or pancake ice conditions, when the signal is least compromised by changes in ship motion or direction or by interference with ice. The quality degrades during ice breaking, especially during backing and ramming. Based on data collection strategies utilized by Larry Mayer and others aboard *Healy* in previous ECS cruises in the Arctic, *the optimum data quality for multibeam sensors in heavy ice can be achieved by backing and ramming during ice-breaking.* The backing allows for a clear signal to be emitted and received by the sensors for short periods, as opposed to the signal being constantly attenuated by uninterrupted forward motion over the ice.

Single beam Echosounder data: Single beam bathymetry witll be collected on along all seismic tracklines using the Knudsen 12 KHz sounder installed on *Louis*.

Helicopter soundings: Collecting spot soundings using the *Louis* helicopter is planned in the Canadian area of interest. In each case, the data will be obtained by the helicopter landing at predetermined locations, the sound transducer placed on the ice and the depth measured. An alterate approach in areas where the ice cover will not support landing on the ice is to suspend the transducer from the cargo hook and hover with the transducer touching the water.

- Soundings will be collected in a 20 x 25-km grid between ship profiles to fill in gaps in the bathymetry within the Canadian area of interest. This will be carried out in parallel with the ship sounding with the ship underway.
- Helicopter soundings will be used to extend the ship-based sounding profiles to the foot of the slope if the ice is impenetrable. In this scenario, spot soundings would be collected at a spacing between 2 km and 10 km along the intended ship track. In this scenario, the ship will either stand by or begin to make its way toward the start of the next line while the helicopter collects the soundings.

Velocity of Sound in Water: Measuring the velocity of sound in the water column is a necessary component of processing both the multibeam and single-beam bathymetric data. Because each vessel has independent methods of determining speed of sound, some of the measurements may be used for intercomparison and some may be substituted for the other (for example, if entanglement with the seismic gear is a problem from *Louis*, it may be that more measurements are done from *Healy*.

- *Healy* utilizes a Conductivity-Temperature-Depth (CTD) instrument augmented by expendable bathythermographs (XBTs). CTD measurements record salinity and temperature data which control the speed of sound in the water. CTD deployments are done with the ship stationary and take upwards of one to several hours depending on water depth and winch rate as the instrument descends to near the sea floor and returns to the ship. CTD measurements are planned at the beginning and end of the cruise and at any time during the cruise when other data indicate that there may be changes in the water column velocity structure. XBTs are planned probably once per day. These XBTs are deployed from the moving ship directly into the water and should not interfere with other operations.

- *Louis* utilizes a Sound Velocity Profiler (SVP) instrument, which is lowered to the maximum depth surveyed using a winch. The frequency of the casts will depend on the variability of the speed of sound. Typically these are done at the start and end of a line. The SVP measurements are supplemented by Expendable Sound Velocity Profiler (XSVP) deployments. XSVP are good to either 1,000 or 2,000 m and can be done underway in ice-free waters. Care must be taken to ensure that the XSVP wire does not snag the seismic gear behind the ship - so may require that the ship make a slight course correction so the XSVP wire clears the gear. Ice alongside or in the wake can also break the thin copper wire that sends back the speed of sound measurements from different depths.
  The speed of sound can also be derived from Expendable Conductivity Temperature and Depth (XCTD) deployments. There will be a number of XCTD casts done either in lieu of XSVP deployments or in addition to them. XCTD casts can be done while underway or stopped. The same issues of entanglement with the seismic gear or loss due to ice that apply to the XSVP apply to the XCTD operation.

VI. Auxiliary Science (Healy)

A. IABP - National Ice Center
Pedro Clemente-Colon (NIC/NOAA)

This effort represents continued participation of NIC personnel and the testing and deployment of International Arctic Buoy Programme (IABP) buoys. Pre-loading of IABP open ocean drifting buoys and tools will take place in the Seattle or Everett area between 6/21 and 6/25. Coordination of shipment is being done by Ignatius Rigor of the Polar Science Center (PSC). Drifting buoys will be deployed in open water during the most western and southern tracks of the cruise. A total of 2 (two) AXIB seasonal ice buoy prototypes will also be shipped by Legnos Boat, Inc. (LBI) for testing and possible deployment in the marginal ice zone or open water during the previous cruise (HLY0805). None of these deployments should require on ice operations. Although unlikely, depending on need, opportunity, and sea ice conditions encountered, one of the seasonal buoys may instead be deployed on multiyear sea ice (MYI). In this case, the deployment on MYI, if needed, would be scheduled to take advantage of other planned stops but in all cases will be conducted strictly as independent and separate field activities from other cruise plans. Typical deployments on MYI take 30-45 minutes of on-the-ice time. The seasonal buoys testing and deployment should be completed during HLY0805. If this is not achieved and there is berth availability will be requested for Legnos and Lincoln to continue on board during HLY0806. All buoy deployments will be done in close coordination with the cruise Chief Scientist on a non-interference basis so as not to impact mapping activities. A pre-cruise nowcast analysis of sea ice conditions in the Beaufort Sea and Canada Basin region will be provided by the NIC to the Chief Scientist. In addition to on board sea ice analysis and imagery cruise support, the NIC personnel will collect hourly observations of sea ice characteristic as the Healy navigates ice infected waters. Recorded observations will include estimates of ice thickness and snow depth during icebreaking operations in the ice pack. NIC personnel will also coordinate with the Louis St. Laurent the acquisition and analysis of satellite imagery from NIC and Canadian Ice Service sources under the North American Ice Service collaboration. Tools and any buoys not deployed during the cruise will be unloaded in Seattle for shipment back to PSC and LBI.

B. Mixotrophy in Arctic Protists – Alternative Nutritional Strategies
Rebecca J. Gast (WHOI) and Robert Sanders (Temple University)

One-celled plankton traditionally have been divided into either phototrophic (algal, using light for metabolism) or heterotrophic (using complex organic compounds for metabolism). However, mixotrophic behavior, whereby organisms combine both modes of nutrition within a single cell, has been increasingly recognized and documented in recent decades. The potential nutritional benefits of being able to use chemosynthesis as well as particle ingestion gives greater survival potential to the phytoplankton, by enabling it to utilize potential diverse sources of energy, major nutrients, and micronutrients including vitamins and trace metals during long periods of polar darkness when chemosynthesis is not practical. This science experiment involves taking water samples in the Arctic to test for the presence of mixotrophic one-celled organisms. The participating scientists have conducted numerous studies of mixotrophy off Antarctica and are unaware of similar studies in the Arctic.

Water Sampling on Healy:
Water samples are to be collected via CTD equipped with the 12-place rosette with 30L niskin bottles and silicone O-rings, Chelsea fluorometer, and PAR sensor. We would like to collect water about every other day (so about 12-13 casts total), at the near surface (5m) and the chlorophyll maximum (around 20-30m in the Antarctic). We are flexible in this scheduling. Normally these casts take less than an hour.

Lab requirements on Healy:
Distilled water (about 20L per day), access to a climate controlled chamber set at ambient seawater temperature and with lights, a -80C freezer, a –20 freezer and a fume hood. For actual lab space, we will be slopping some water around, so wet lab space would be good. Unfortunately, we will need to work with some chemicals that are considered hazardous (formaldehyde, ethanol and hydrochloric acid), but these are usually small volumes and we will work with the Healy folks regarding shipping and waste issues.

VII. Louis Supplemental Science

There is no supplemental science planned on Louis at this time.