Main research questions considering migration ecology of *Calanus*

- *Seasonal migrations:* Which factors determine the timing of seasonal migrations (diapause initiation and emergence) in copepods? What is the role of body condition (lipid levels) and food availability?
- *DVM:* To what extent is zooplankton, particularly *Calanus*, in an Arctic fjord performing DWM? What is the role of season (light), food availability (and predation risk)

Introduction

The Arctic is a region which has only been opened to scientific exploration for a few hundred years, but whose threatened future currently makes it a region of great importance and interest. The polar regions are expected to experience the effects of global warming more acutely than lower latitudes, with models predicting warming of 40% higher than the global average (#1). In light of the changes already underway in the physical environment of the Arctic, it is important to understand the ecology of the species inhabiting the Arctic in order to predict and track their possible responses to climatic changes.

This project will examine the overwintering ecology of two key Arctic zooplankton species, *Calanus glacialis* and *Calanus finmarchicus*, in a high-Arctic fjord in Svalbard (78°N). These calanoid copepods are specifically adapted to life in the Arctic, with large lipid reserves and seasonal vertical migration which allow them to survive a long winter and unpredictable environmental conditions. Though these species have been extensively studied in the summer months, little is known about their biology in the long, cold, and dark polar winter due to the logistical difficulty of fieldwork.

Background

Calanus species constitute 70-80% of the zooplankton biomass in the Arctic (#10). Their considerable lipid reserves (50-70% of dry weight, #2) make them some of the most important prey species in Arctic waters for economically, ecologically and culturally important predators such as fish, whales, and seabirds. They reproduce in the spring in surface waters, where the offspring remain during the summer, feeding and accumulating lipids. As autumn comes, they migrate to deep waters (200-1000m), where they overwinter in diapause, a state of suspended development and reduced metabolism (#3). In spring, they ascend once again to the surface waters, where they feed on the annual spring phytoplankton bloom. Diapause allows *Calanus* to endure the Arctic's long winter and high seasonality in food availability (#4). The triggers which determine the timing and length of this diapause are not known, but may be lipid storage, photoperiod, or intrinsic developmental rates (#5). These cues are essential to understanding how *Calanus* has adapted to life at high latitudes and how it may adapt to future changes.

The physical environment of the Arctic is changing rapidly, the effects of which are already evident (e.g.#6). Arctic sea ice has undergone drastic reductions in recent years, with consecutive minimums from 2002- 2006 (#7). **The breakup of sea ice strongly affects the timing of the spring phytoplankton bloom, which provides the main food source for *Calanus* copepods when they ascend from diapause.** If the timing of ice breakup shifts to earlier in the spring, it may create a mismatch in timing between the resulting phytoplankton bloom and the ascent of the *Calanus* population to the surface waters, wherein the *Calanus* population ascends too late to fully exploit the phytoplankton bloom (#8). This would reduce reproductive success and lower the ability of the next generation to store sufficient lipids for winter. Thus, **determining the factors which influence the timing of diapause termination and ascent are important in understanding how *Calanus*, and resultantly the whole Arctic marine ecosystem, will respond to the decline of sea ice with climate change.**

Hypotheses

This project seeks to understand the overwintering diapause of two species of *Calanus* (*C. finmarchicus* and *C. glacialis*) in a high-Arctic, ice-covered fjord in Svalbard. Specifically, it will look at the timing of the seasonal descent to and ascent from diapause of different developmental stages and varying lipid richness levels.

Descent

We hypothesize that the accumulation of sufficient lipid stores for overwintering is the trigger which initiates diapause. We therefore expect that lipid-rich individuals will descend for diapause first, while younger or lipid-poor individuals will remain at the surface longer in order to feed before descending.

Ascent

In the spring, we hypothesize that Calanus ascend to the surface before the sea ice breakup and the consecutive phytoplankton bloom. If the length of diapause is fixed developmentally, the variation in timing of ascent will be similar to the variation in descent timing. However, if it is linked to environmental cues (i.e. photoperiod), the ascent will be more synchronous.

Project Sampling Plan and Analysis Methods

This project will carry out zooplankton sampling throughout the winter to gain a data set with high temporal resolution in a logistically difficult and relatively unstudied season. Sampling will include depth-stratified net hauls which will allow the analysis of the vertical distribution of the population and timing of diapause. To determine the lipid sac size of *Calanus* at each depth, live copepods will be photographed under a stereomicroscope using a high definition camera, and the images will be analyzed using ImageJ to approximate a lipid sac volume.

The study will be conducted in Billefjorden, Spitsbergen (78°40'), a fjord 60km from Longyearbyen, the only large town in Svalbard (population: 2000) and the location of the University Centre in Svalbard (UNIS). Billefjorden is a true Arctic fjord, with seasonal ice cover and cold water masses (-1.86°C to 5°C) (#9). It is also an ideal fjord to study population development, with a shallow underwater shelf in the entrance of the fjord which restricts the inflow of outer water masses. This ensures that the population sampled throughout the year is the same population and not advected populations. A mooring has been deployed in Billefjorden, equipped with two 300 kHz acoustic Doppler current profilers (ADCP) and a fluorometer, which will provide yearlong data on vertical fluxes of biomass and the timing of the spring bloom.

The sampling field season of this project will last from August 2008- May 2009. Sampling excursions to Billefjorden will be conducted every three weeks by boat when the fjord is ice free and by snow mobile once sea ice has formed. Labwork will happen concurrently with sampling. A Master's thesis and scientific paper will be written, starting in May 2009 and completed by June 2010. Three remaining courses required for my Master's degree will be completed at UNIS in Svalbard (August-September 2009) and at the University of Tromsø in the spring of 2010. With the exception of the spring semester 2010 in Tromsø, **I will be based at UNIS, Svalbard for the duration of this project (August 2008-June 2010).**

UNIS is the northernmost university in the world, providing a unique location and excellent logistical support for fieldwork in high-Arctic conditions throughout the year, making winter studies possible. Drs. Janne Søreide and Øystein Varpe will be my advisors for the project, which will be linked to the UNIS-led ArcWin Project ("The Arctic sea in Wintertime: ecosystem structuring due to environmental variability during the polar night"). As a Fulbright Scholar at UNIS in 2007-2008 and as a Master's student since August 2008, I have appreciated the international cooperation which is consciously cultivated at UNIS, which draws students and staff from over 20 countries. This is crucial for scientific progress, especially in regions such as the Arctic where its possession, stewardship, enjoyment, and scientific interest are shared by so many nations. This project will allow me to contribute to pioneering research in a time when the Arctic is changing rapidly, as well as make the connections for the international cooperation that will be needed for its future monitoring and protection.

1) IPCC 2007
2) Scott et al. 2000
3) Hirche 1996
4) Dahms 1995
5) Heath 1999
6) Berge et al. 2005
7) Comiso 2006
8) Hansen et al. 2003
9) Arnkværn et al. 2005
10) Conover 1988

IPCC 2007 *Climate Change 2007: The Physical Basis—Summary for Policymakers*
Accessed at http://www.ipcc.ch/SPM2feb07.pdf