Application of Ice-Tethered Instrumentation to Understanding Arctic Biology

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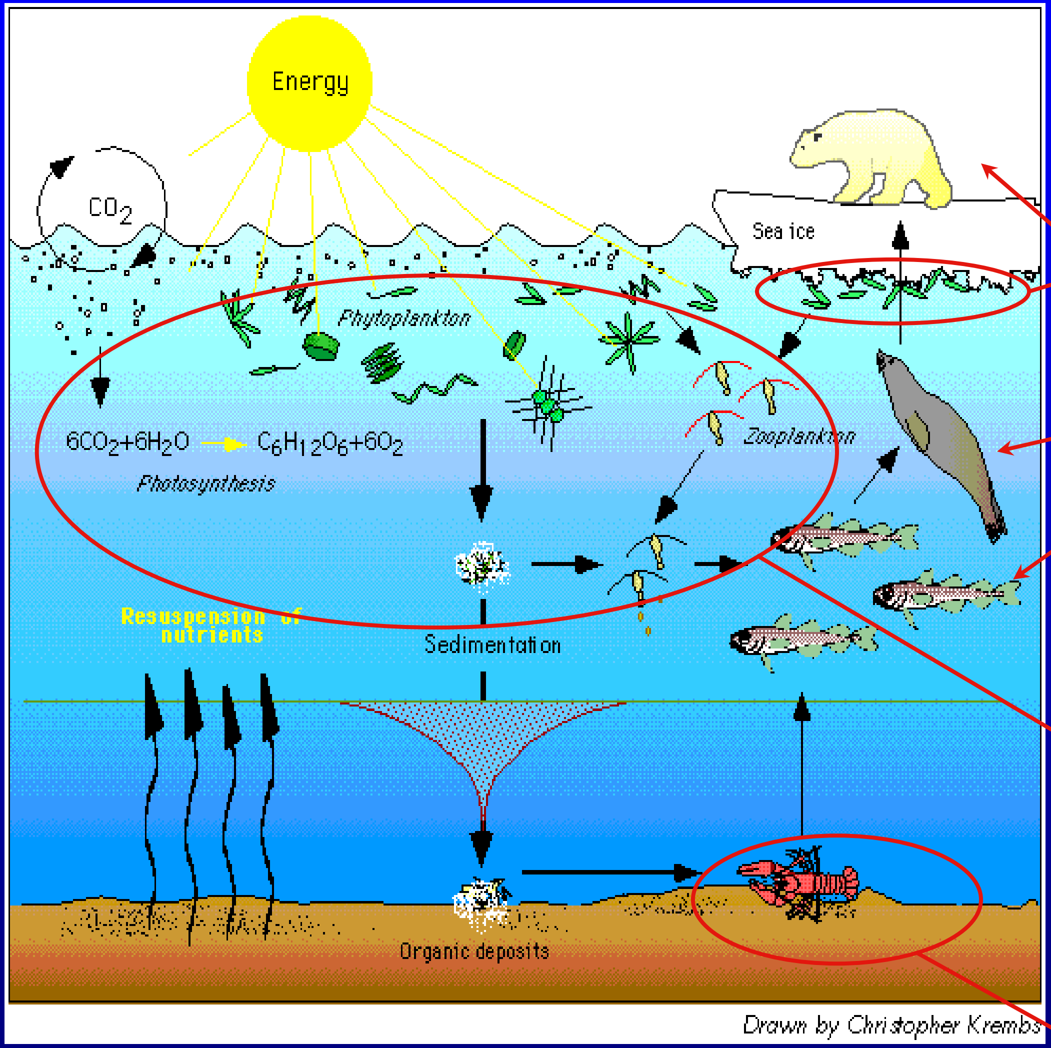
with suggestions from R. Gradinger, E. Sherr, S. Smith, D. Kirchman, S. Plourde

Overall Problem

- **Arctic plankton ecology is profoundly impacted by the seasonal variations in temperature, light, and ice cover.**
- **The ice that both constitutes a critical substrate and an integral environmental variable also presents logistic barriers to plankton ecology studies.**

Arctic Food web



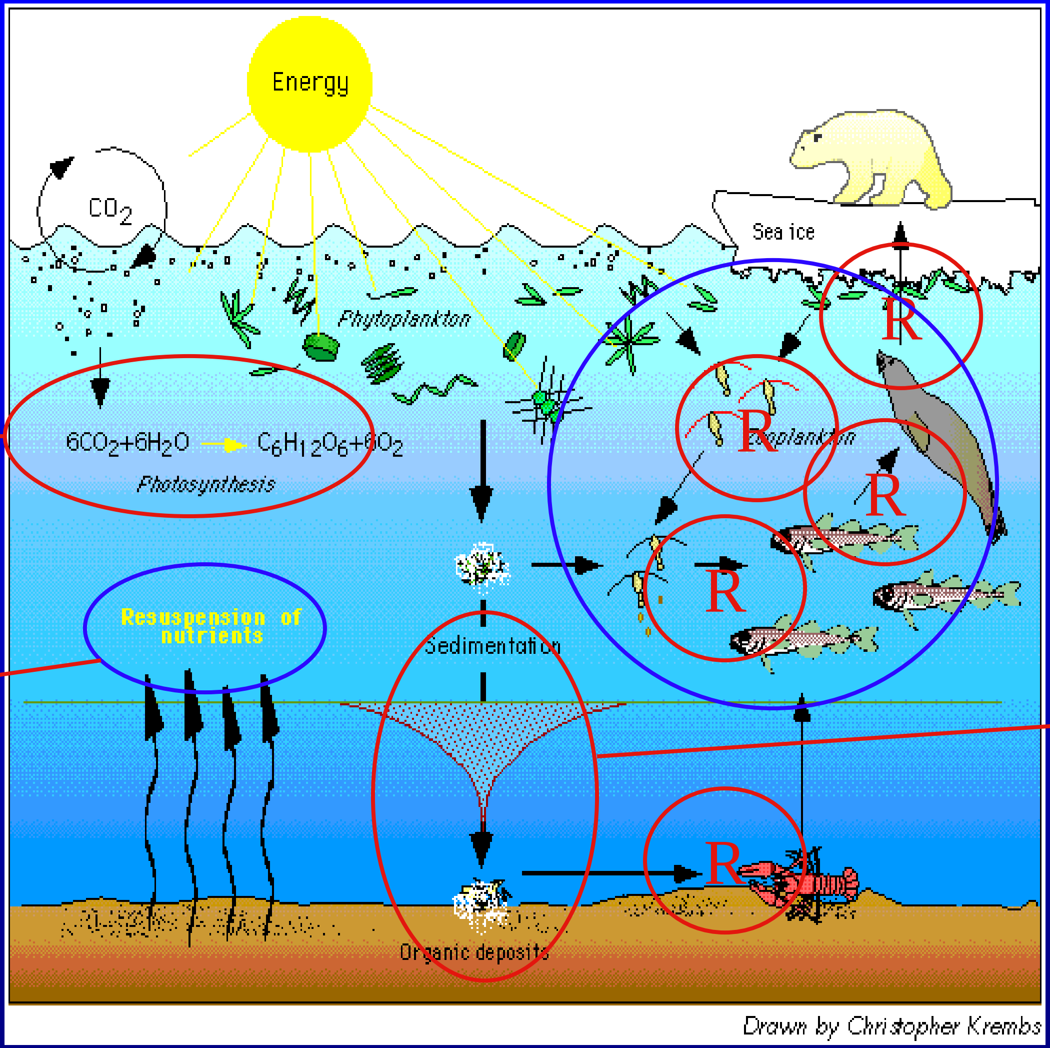
Sea Ice Community

Upper Trophic Levels

Plankton
-bacterio
-phyto
-microzoo.
-mesozoo.

Benthos

Some Transformations of Material associated with Food Web



R: Respiration of CO_2 during metabolism

Uptake of CO_2 to POC by photosynthesis

Repackaging of POC by grazing and consumption

Release and regeneration of nutrients and DOM

Flux of OM to depth is influenced by size/type of particle

All impact extent to which carbon is recycled and/or sequestered at depth

Physical processes (e.g., advection, stratification) impact transformations and flux

The Arctic is very sensitive to global climate change

- An understanding of biology is critical to understanding and modeling the Arctic response to climate variability because organisms:
  - Transform material (1^o and 2^o production, regeneration, repackaging)
  - Modulate fluxes (to/from sea floor, between shelf and basin)

How do biologists study this system?

- Observations
  - In-situ abundance, distribution, and behavior
  - Optical (e.g., photographic) and acoustic methods
  - In-situ sensors (e.g., flow cytometry, nutrient sensors, oxygen, fluoresecence)
- Collections
  - Abundance, taxonomic and species composition, distribution
  - Genetic analysis
  - Size (carbon content, morphometrics)
- Rate Determinations
  - Production and Respiration
  - Feeding
  - Reproduction
  - Growth

Examples of collection methods

CTD with Niskens
- Phytoplankton and Microzooplankton, Fluorescence, Hydrography

Plankton Nets
- Zooplankton

On-ice sampling (coring, sub-ice instrumentation and imaging, ice and snow thickness)

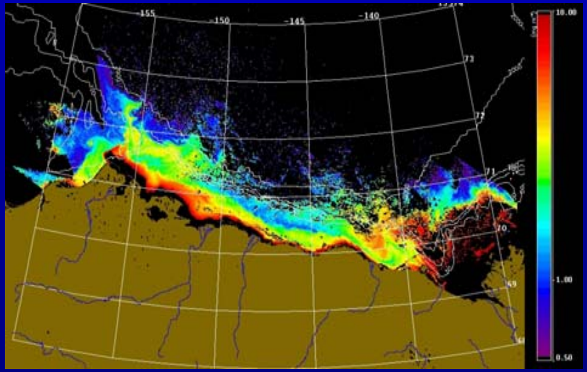
Benthic Sampling

Grabs, corers, dredges
- Benthos

Examples of in-situ observations

(Enumeration/High resolution sampling)

Optical Instruments (VPR, OPC, AC-9)

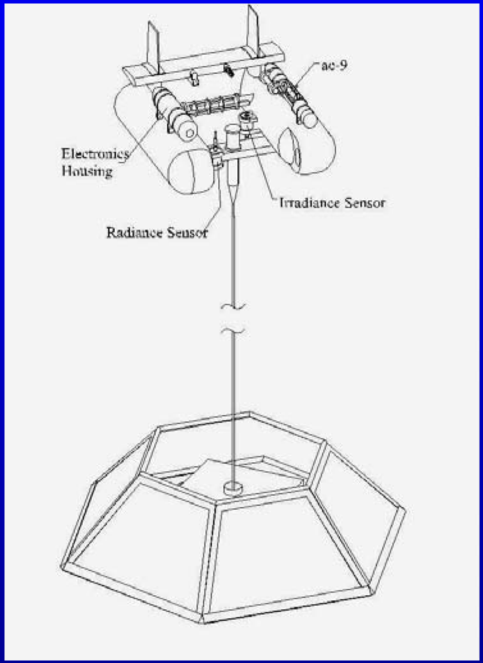


Ocean Color (SeaWIFS, Aug. 30, 2000)

Towed Instruments such as BIOMAPERII (Wiebe) - Acoustic, environmental, and optical (VPR, AC-9)

Examples of in-situ instrumentation

- Moored and autonomous instruments equipped with sensors such as optical sensors (AC-9, VPR), acoustics (ADCP, echosounders) and hydrographic/chemical (CTD, oxygen, nutrients), flow cytometers
- Submersibles?



Autonomous Vertically Profiling Plankton Observatory (AVPPO) equipped with optical (AC-9, VPR) and hydrographic sensors (Gallager et al., 1998; Thwaites et al., 1998). (Images from www.whoi.edu/science/B/sosiklab)

The WHOI REMUS AUV equipped with a VPR (Goldsborough, Davis, Gallager)

Determination of Rates

- Requires ambient temperatures and light conditions achieved with on-deck incubators or environmental chambers
  - Some experiments are conducted *in-situ* on buoys which alleviates the problems of trying to emulate *in-situ* light conditions

On-deck incubator/plankton wheel cooled by ambient seawater

Despite years of research, basic questions still remain

- Spatial and temporal variability in biological and physical environment - interannual variability appears to be high
- High resolution vertical distributions
- Basic rate processes: Primary production, reproduction/growth, grazing, respiration
- The food web and microbial loop
- Importance of macrozooplankton and fish (predators)
- Life cycles
- Seasonal cycles
- The ice as a substrate - variability in under-ice biological and physical environment
- The basin environment - easier to study the shelf but basin is also critical
- Link between atmospheric forcing and biological response

What has prevented greater understanding?

- Lack of access
  - Severe environment
  - Few suitable platforms (ships, ice camps)
  - Most access in summer only
- Lack of facilities
  - Ships and ice camps poorly equipped for most experimental work
- Lack of spatial and temporal coverage

Ice Camps

- Plankton Ecology at the SHEBA ice camp (year long study)
- Superior facilities permitted high quality experiments
- 2003 -2004 CASES program: Canadian year-long study, also ship based
- 2003 - Ice camp, some biological studies/collections

-SHEBA Project Office

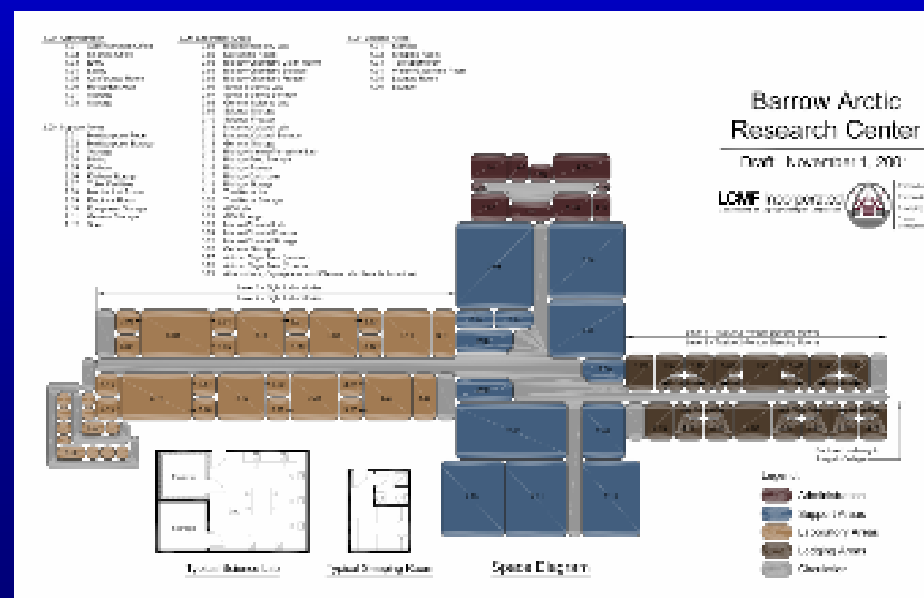
Recent Developments

- *USCGC Healy*
  - Excellent science facilities

C.A. Linder

- Proposed Global Climate Change Research Facility, Barrow, AK
  - 14 science labs
  - Accomodations

BASC Barrow Arctic Science Consortium



Ice, or the absence of ice, is a perpetual difficulty

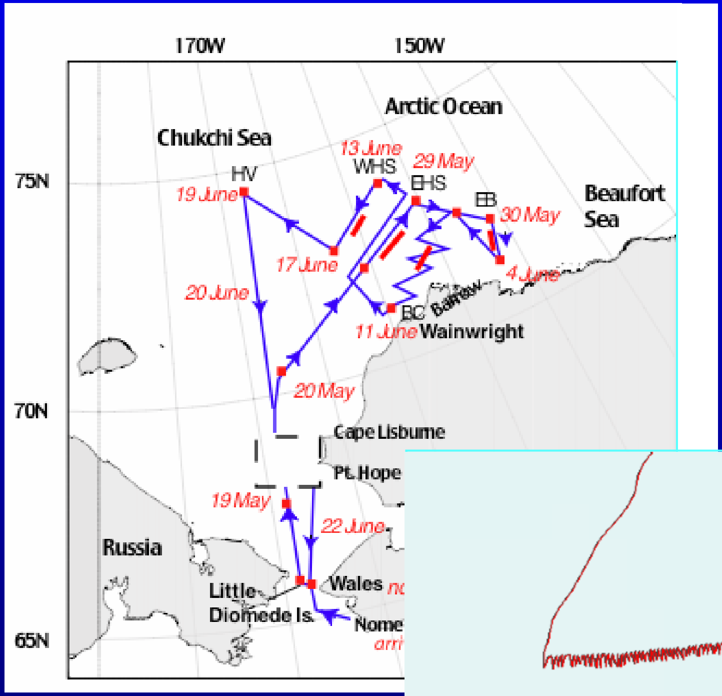
-SHEBA Project Office

Left: Pushing ice away from the wire on the *Healy*
Right: Ice melt at SHEBA in summer

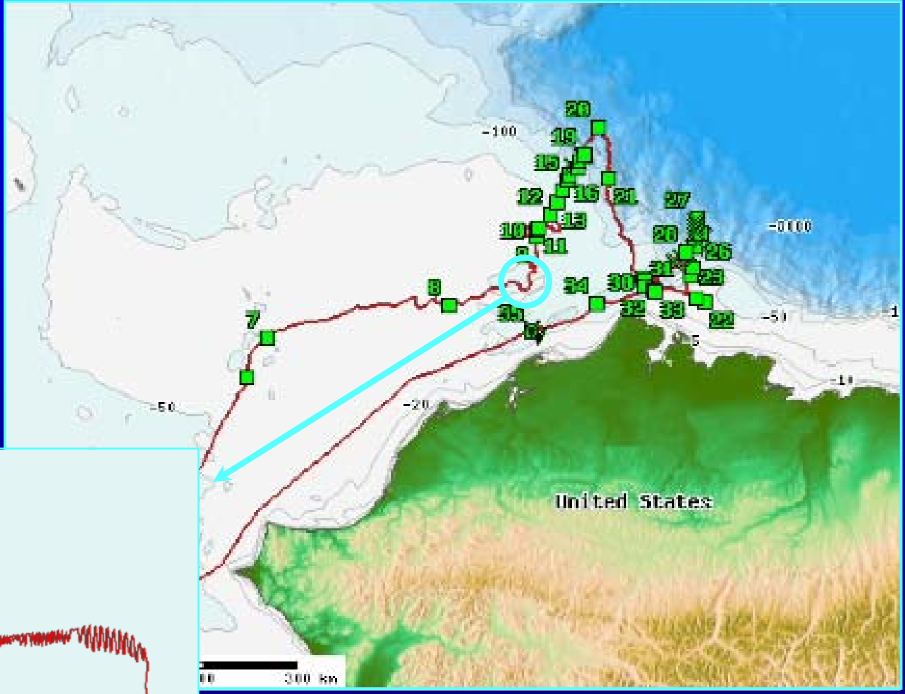
The problem with ships….

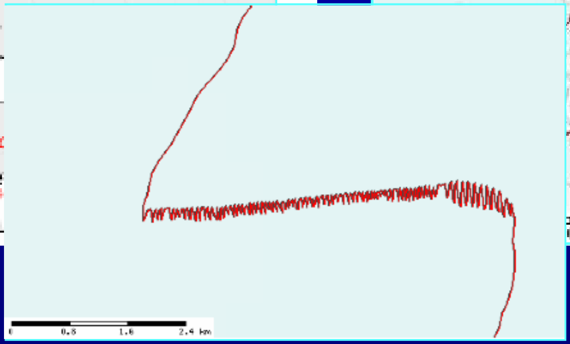
Spring 2004 SBI Cruise on *Healy*

Planned Cruise Track



Actual Cruise Track





Where are we going in the 21st Century?

- Access: Improved because of the *Healy* and BASC BUT still limited
  - *Healy* cannot realistically operate over an entire year
  - Studies originating in Barrow can only address questions regarding near-shore ecology
  - Ice camps: Usually opportunistic, difficulties in funding opportunistic research

- Spatial and temporal coverage: Improved because of the Healy BUT still limited

- Facilities: Improved quality BUT still limited

Solutions

- Another ship
- More ice camps
- Better ways of dealing with ice from ship
- Use of remote or autonomous equipment:
  - Moorings
  - AUVs
  - ROVs

This requires considerable instrument development

Instrumentation

- Needs to observe and quantify abundance and vertical distribution (vertically profiling)
- Needs to collect organisms and measure key components
- Needs to be affordable so that spatial coverage is broad
- Needs to be energetically efficient so that deployment periods can be long
- Needs to be small enough to be deployed
- Needs to survive the environment
- Remote access to data would be helpful, especially if instrument is not retrieved

Some instrumentation directions

- Existing sensors: nutrients, fluorescence (including multi-spectral), oxygen, particulates, acoustic, optical (VPR, OPC), plankton pumps (requires retrieval)

- Developing sensors:
  - New Optical - in-situ plankton, roving under-ice and benthic imaging vehicles
  - In-situ flow cytometry (e.g., Sosik, Olson)
  - In-situ genetic analysis - good for bacterio- and phytoplankton, less useful for mesozooplankton

Limitations

- Instruments are a single point in a usually very dilute environment (plankton are patchy)
- Very difficult to identify life stages of larger plankton using instrumentation- this is key to understanding life cycles
- We still lack the technology to identify and enumerate many taxa and trophic levels (e.g., bacteria)
- Rate processes very difficult to measure using instrumentation

Possible peril to ice-tethered instruments

Conclusions

- Our understanding of Arctic biology is still very limited
- Our ability to study Arctic biology has been compromised by technical difficulties imposed by the harshness and unique nature of the environment
- Now, with new technology, we are poised to achieve a new understanding
- Ice-tethered instrumentation can increase our understanding of seasonal and interannual variations in biology, particularly for abundances and distributions.

Plankton Ecology in SBI

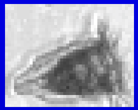
- Primary Production/Phytoplankton (Cota)
- Zooplankton Distributions/Abundance (Smith)
- Mesozooplankton/microzooplankton food webs (Ashjian, Campbell, Sherr, Sherr)
- Shelf-Basin Exchange of Plankton and Particulates (Ashjian, Benfield, Gallager)
- Sea - ice primary production (Gradinger and Eiken)
- Plus other studies of the chemical and hydrographic environment
- http://www.bio.utk.edu/SBI.nsf

Who are the Plankton?

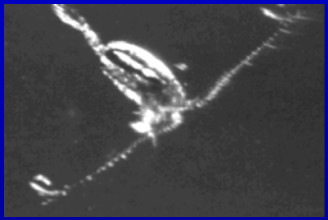
(Flowcam)

Phytoplankton
(e.g. diatoms)

Microzooplankton
(e.g.,protists)



(Flowcam)



(VPR)

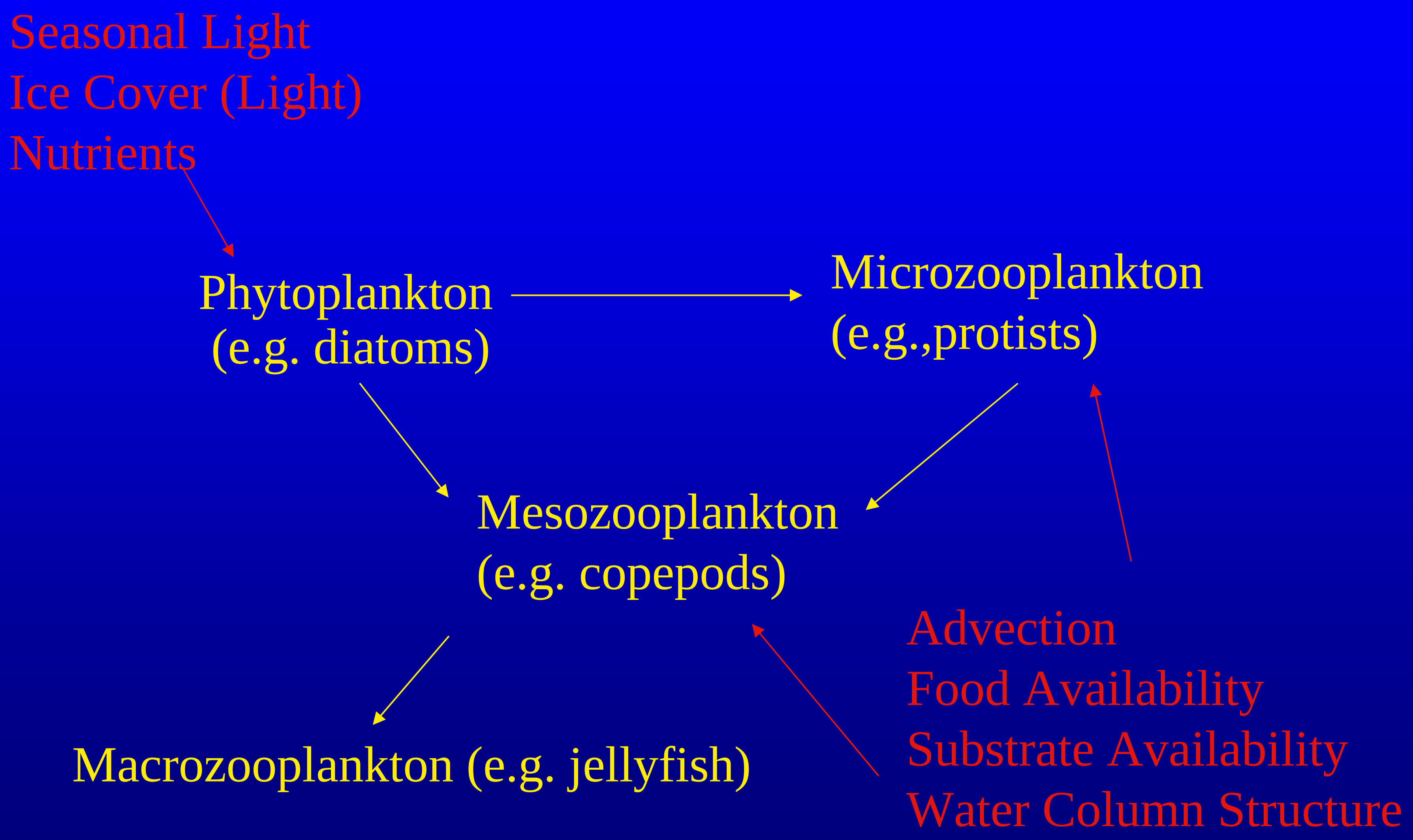
Mesozooplankton
(e.g. copepods)

Macrozooplankton (e.g. jellyfish)

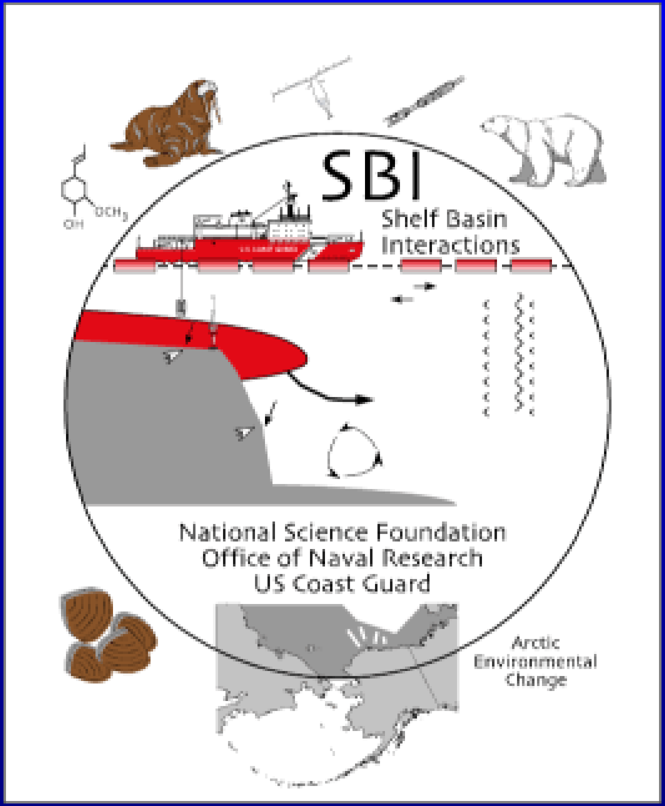
(WHOI OLI)

www.bigelow.org/flowcam
www.whoi.edu/institutes/oli

Plankton and the Physical and Chemical Environments



Shelf-Basin Interactions Program (Phase II)

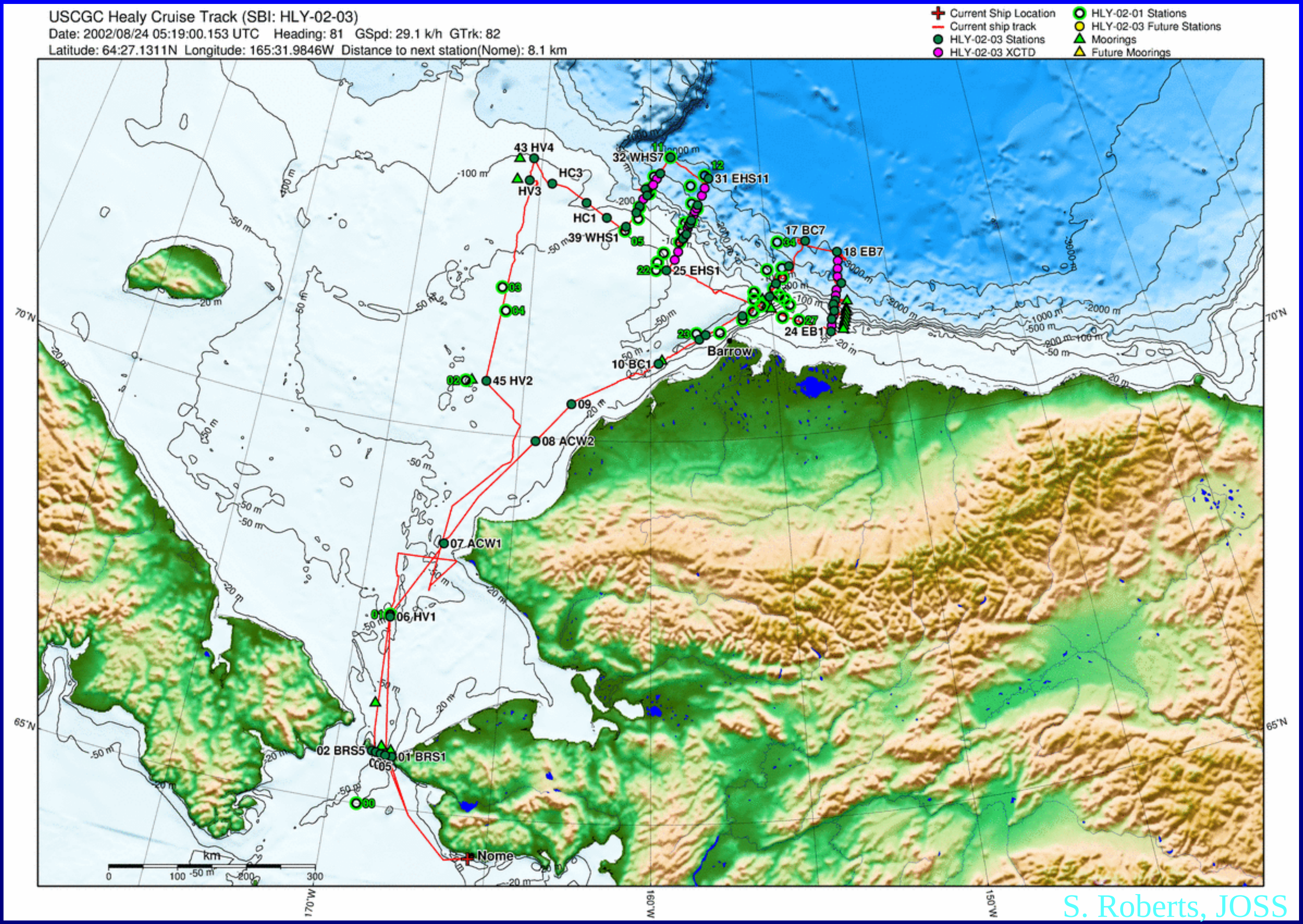


"The fundamental goal … is to understand the physical and biogeochemical processes that link the arctic shelves, slopes, and deep basins …. These processes strongly influence the biology, chemistry, and physics of the Arctic Ocean and its associated ecosystems."

(http://www.bio.utk.edu/SBI.nsf)

(NSF/ONR Funding)

Summer 2002 SBI process cruise on *USCGC Healy*



S. Roberts, JOSS

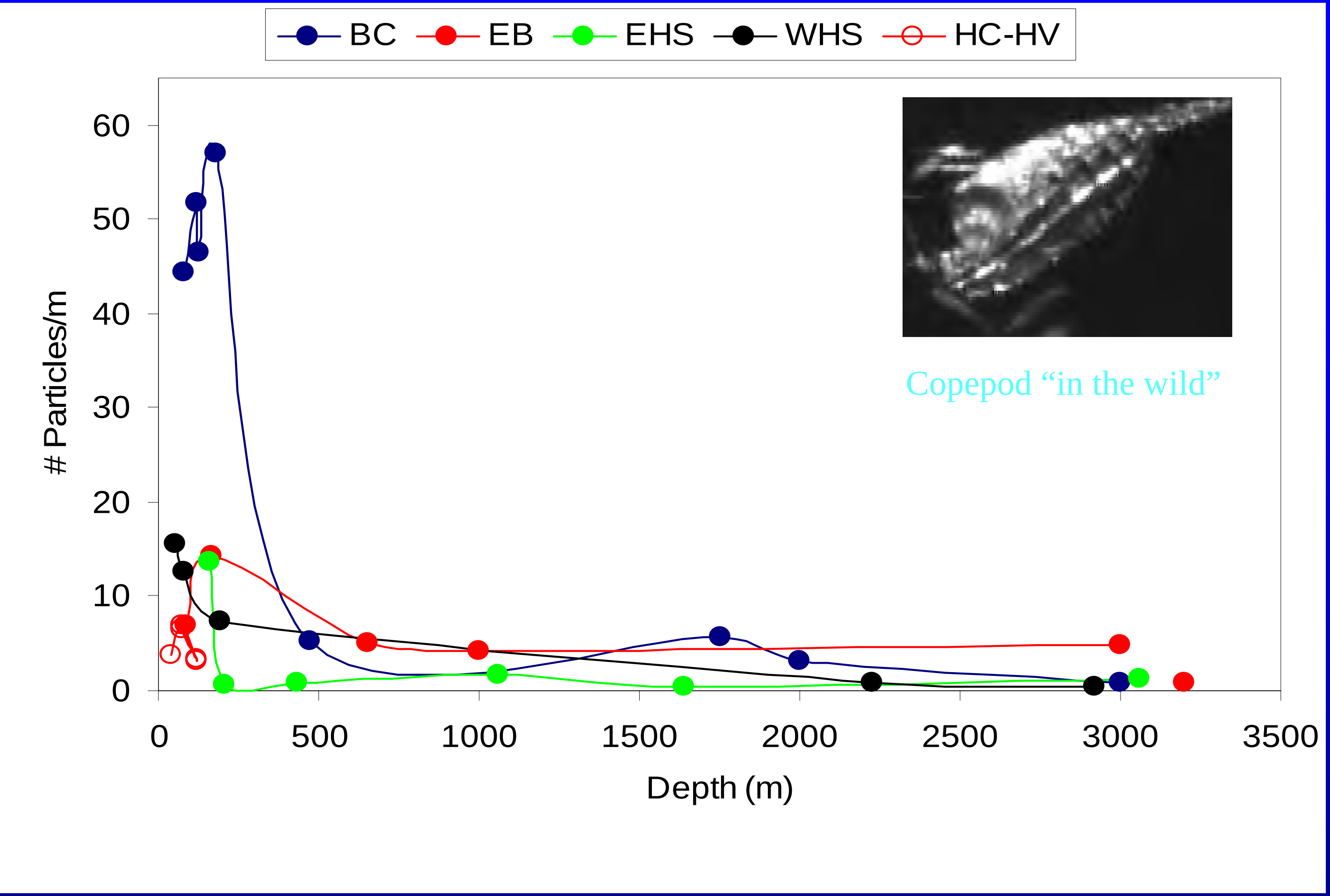
Transport of Plankton and Particles between Shelf and Basin

Carin Ashjian, Mark Benfield, Scott Gallager, Stéphane Plourde

Goal: To describe the transport of plankton and particles between the two regions

- We did 33 casts with the Video Plankton Recorder at 31 stations
- We will identify the images and couple particle/plankton distributions to hydrographic distributions and to ADCP velocities to describe which way material is moving

Preliminary Results



- Most particles in Barrow Canyon
- Particle concentration as high as seen in temperate regions
- Declining particle concentration moving offshore