Zooplankton and Micronekton Distribution and Interaction with Predators at the Northwest Atlantic Shelf Break and its Canyons

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LONG-TERM GOALS

Our long-term goal is to address the interaction of physical and biological processes determining the distribution, abundance, and community composition of zooplankton and micronekton and their association with predators (including marine mammals, seabirds, and fish) at the northwest Atlantic continental shelf break and its canyons, inclusive of the role of inter-annual variability and the effects of Gulf Stream warm-core rings. In the mid- to long-term, we anticipate addressing these topics via inter-disciplinary projects integrating our work on lower trophic levels with that of colleagues with expertise in top predator ecology, physical oceanography, ocean acoustics, and bio-physical modeling.

OBJECTIVES

In advance of such a broad, inter-disciplinary effort, we have multiple valuable datasets already available that can be mined to inform future fieldwork, including top predator visual survey data, depth-stratified net samples, and multi-frequency acoustic data collected at the New England shelf break and its canyons in 2005 and 2009-2013. These existing data were all collected under small awards internal to WHOI for pilot work or as unfunded add-ons to other cruises or ships-of-opportunity, and have thus remained largely un-analyzed.

The specific objective of this project is to work up these existing samples and datasets in order to provide a synthesis of spatial and inter-annual patterns of variability in zooplankton and micronekton distribution at New England shelf break canyons, and, where suitable data are also available, associations with marine mammals and other predators.

APPROACH

The datasets being examined in this project include:

1. Depth-stratified net samples from 1-m^2 MOCNESS tows (8 strata per tow) and multi-frequency acoustic and hydrographic data collected during a 10-day 2010 cruise on the R/V *Connecticut* to Atlantis and Veatch Canyons, and neighboring non-canyon regions. At the time a warm-core ring

was present influencing Atlantis Canyon (Figure 1), allowing for a comparison of canyon to non-canyon regions both influenced and not influenced by the ring.

2. Depth-stratified net samples from 1-m^2 MOCNESS tows and multi-frequency acoustic and hydrographic data collected during a 5-day 2005 cruise on the R/V *Endeavor* to Hudson Canyon aimed at examining the relative contributions to high-frequency volume backscattering of zooplankton vs. turbulent microstructure.
3. Depth-stratified Tucker trawl samples (2 strata per tow) collected each July during 2009 - 2013, at the head and mouth of Atlantis Canyon, by colleagues at the Sea Education Association (SEA) during annual cruises transiting across the shelf break on the SSV *Corwith Cramer*.
4. Visual survey data of the abundance and distribution of marine mammals, large surface-associated fish, and seabirds collected during the 10-day 2010 R/V *Connecticut* cruise to Atlantis and Veatch Canyons, and neighboring non-canyon regions.

Our approach has been to process net samples for the lengths, abundance, and biomass of different zooplankton taxa, with emphasis on euphausiids, in order first to examine zooplankton and micronekton distribution, abundance, and community composition within and between the three sampled canyons and time periods (2005, 2009-2012), paying particular attention to inter-annual variability, the influence of warm-core rings and hydrographic conditions, and differences between canyons. The results of net sample processing are being combined with analyses of the multi-frequency acoustic data (where available) in order to infer the taxonomic composition of scattering features and quantify the horizontal extent and vertical position of zooplankton and micronekton aggregations and layers. Finally, statistical analyses are being conducted of the distribution of top predators observed during the 2010 cruise, examining differences in the abundance of different taxa (especially marine mammals and seabirds) between survey sites and associations with environmental conditions, and estimates of the abundance and horizontal and vertical distribution of lower trophic levels derived from the combined analysis of acoustic and net data.

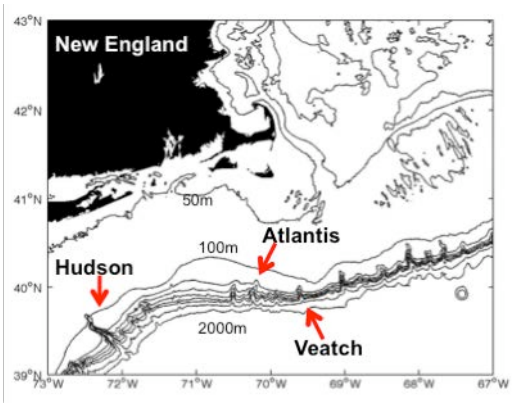

Figure 1 – Canyons of the New England shelf break. Arrows show the three canyons studied, for which existing data were available.

WORK COMPLETED

Processing of the various samples and datasets is complete. The euphausiid species composition, size, abundance, and biomass has been determined for the MOCNESS and Tucker trawl samples. Silhouette analyses of the size, abundance, and biomass of other zooplankton taxa (e.g., copepods, pteropods,

etc.) have also been carried out for the MOCNESS samples. Multi-frequency acoustic data have been post-processed and 'forward calculations' comparing observed backscattering levels to predictions based on MOCNESS net samples and taxon-specific scattering models have been used to infer sources of scattering. Top predator survey data from the 2010 R/V *Connecticut* cruise have similarly been cleaned up and binned at 1-km spatial scales appropriate for removal of auto-correlation.

Our efforts in the past year have focused on statistical analyses and integration of these various biological datasets with concurrent observations of environmental conditions, as described in the results section. Currently, we are focused on preparation of manuscripts based on these analyses.

RESULTS

Analysis of net samples collected with the MOCNESS system in 2005 and 2010 as well as with the Tucker trawl on the SEA cruises from 2009 through 2013 have indicated signficant variation in the biomass, abundance, and species composition of euphausiids between regions, notably including between shallow (especially canyon head) and deep (especially canyon mouth) sites (Figure 2). Differences between shallow and deep sites were especially pronounced for the cold water species *Meganyctiphanes norvegica*. A number of environmental correlates were considered in multi-variate analyses (e.g., bathymetry, temperature, salinity, chlorophyll-a, distance to the warm-core ring), of which bottom depth was the strongest correlate of abundance and biomass for all euphausiids combined and for each species. Cluster analysis based on Bray-Curtis dissimilarities found significant differences in community composition, with deep and shallow sites generally clustering separately. Strong inter-annual variability in euphausiid abundance, biomass, and species composition was observed over the five years of sampling at Atlantis Canyon (Figure 3). Abundance and biomass were not linearly correlated with temperature, although biomass at the canyon head was lowest in the warmest (sea surface temperature, SST, nearly 25°C) and coldest (SST ca. 19°C) years, and highest in years of moderate SST.

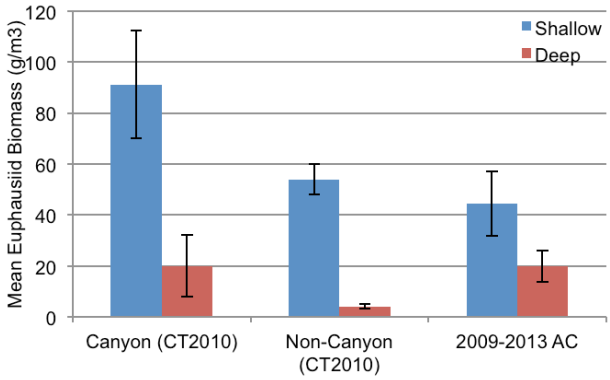

Figure 2 - Mean euphausiid biomass sampled at canyon heads (blue) and mouths (red) and at locations of comparable shallow and deep depths at sites away from canyons during the summer 2010 cruise and in Atlantis Canyon (AC) during summer 2009-2013.

These analyses of euphausiids from net samples constituted the basis of the thesis research of a Master's student from Cornell University, Mr. Robert Levine. Mr. Levine was recruited to the project after his participating in the ONR-funded Friday Harbor Labs Bio-acoustics 2011 workshop, at which PIs Lawson and Wiebe were guest lecturers. Mr. Levine was hosted at WHOI through a new Cornell-WHOI program, and was responsible for the taxonomic analysis of net samples as well as subsequent

statistical analyses. Mr. Levine successfully defended his M.Sc. thesis in May 2014 and a manuscript based on the thesis is in development, targeted for journal submission in late 2014. In the past year, Mr. Levine's work has led to two products, a conference poster and his thesis:

Levine RM, Lawson GL, Wiebe PH, Lavery AC, Greene CH. 2014. Temporal and spatial variability in euphausiid abundance and species composition at the northwest Atlantic shelf break and its canyons. ASLO-AGU Ocean Sciences Meeting, Honolulu, Hawaii. Poster.

Levine RM. 2014. Temporal and spatial variability in euphausiid abundance, biomass, and species composition at the northwest Atlantic shelf break and its canyons. Master's of Science thesis. Cornell University.

Acoustic data indicated extensive and dense scattering layers especially present at canyon heads, both in the summer R/V *Connecticut* 2010 and winter R/V *Endeavor* 2005 cruises. During 2010, backscattering consistent with zooplankton was greatest near the 300 m isobath at the head of Veatch Canyon, which was outside of the warm-core ring. Backscattering consistent with fish was greatest in Atlantis Canyon, at the edge of the warm-core ring. MOCNESS tows conducted concurrent to acoustic data collection sampled large numbers of copepods and lesser numbers of euphausiids; taxon- and size-specific scattering models, coupled with net samples of animal size and abundance, however, suggested that euphausiids were the dominant scatterer in these acoustic layers. Scattering levels predicted based on net catches were lower than those observed until corrections were applied to account for the avoidance behavior of the larger euphausiids; sensitivity analyses also indicated a strong dependence on the assumed acoustic material properties (i.e., the sound speed and density contrast of the euphausiids). Shallow non-migratory layers were also evident, particularly at the edge of the warm-core ring in Atlantis Canyon, consistent with large abundances of meso-pelagic fishes. A manuscript examining the distribution of backscattering between study sites and its likely sources for the 2010 summer cruise is currently in development.

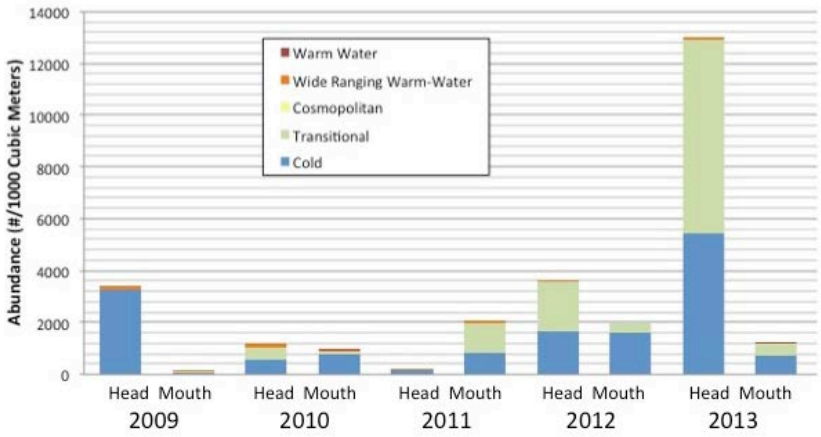

Figure 3 - Euphausiid abundance grouped by water mass type from SEA net tows targeting the head and mouth of Atlantis Canyon in 2009-2013.

Ongoing statistical analyses are examining the distribution of top predators observed during the 2010 R/V *Connecticut* cruise. Odontocetes (mostly dolphins) were more abundant at the canyon heads than at canyon mouths or non-canyon sites (Figure 4). The density of seabirds did not differ as clearly between study sites, but did show strong patchiness and indicator species analysis found shearwaters to

be most concentrated at the mouth of Veatch Canyon (Figure 4). Currently we are conducting multi-variate modeling, relating odontocete, shearwater, and storm petrel abundance to environmental conditions, including acoustically-derived indices of prey. Initial analyses suggest an association of odontocetes and seabirds with fronts in the area, particularly the edge of the warm-core ring and the shelf-slope front (Figure 4). These analyses are led by Dr. Timothy White, a postdoctoral research associate at the City University of New York who participated in the 2010 cruise as part of the top predator observing team. Dr. White is leading the development of a manuscript based on these analyses, anticipated for submission in late 2014.

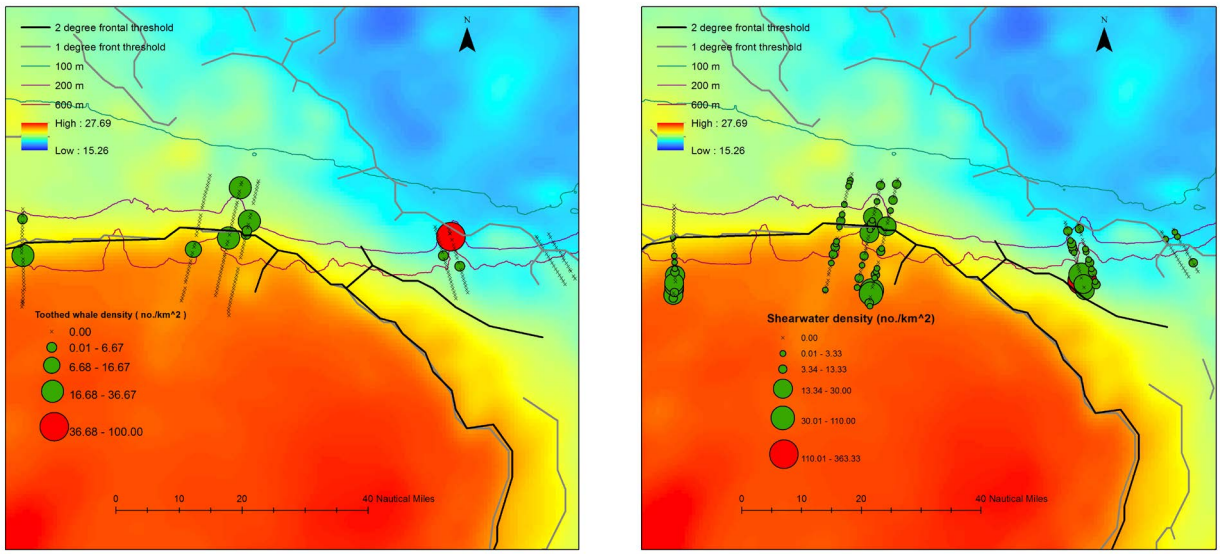

Figure 4 – Distribution of odontocetes (left panel) and shearwaters (right) observed during the 2010 R/VConnecticut shelf break survey plotted relative to bathymetry, satellite observations of sea surface temperature, and derived estimates of the location of temperature fronts. Four sites were surveyed: Atlantis Canyon (influenced by the warm-core ring), Veatch Canyon (outside of the ring to the east), a non-canyon site upstream (east) of Veatch, and a non-canyon site downstream (west) of Atlantis.

IMPACT/APPLICATIONS

As noted above, in the longer term, we anticipate developing an inter-disciplinary research effort to address ecosystem dynamics at shelf break canyons. We envisage linking such an effort to both the ONR Ocean Acoustics Shelf Break/Slope/Canyon Field Experiment planned for 2016-2017 and to the NSF Ocean Observatory Initiative's Pioneer Array scheduled to be commissioned in late 2014. The present project and resulting synthesis of patterns of variability in zooplankton and micronekton distribution at New England shelf break canyons and associations with higher predators will provide key information to generate future hypotheses and guide the development and field sampling design of such a broader effort.

RELATED PROJECTS

The top predator survey data to be analyzed here were collected as an unfunded add-on to a Woods Hole Sea Grant award to the present PIs from the 2010-2012 omnibus. The net sample and acoustic data were collected under a series of small projects through funds internal to WHOI.