OPTICAL AND ACOUSTIC ANALYSIS OF ARABIAN SEA EPIZOOPLANKTON

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LONG-TERM GOALS

Our research has been and will be directed at understanding the coupled biological and physical mechanisms controlling the fine-scale (1-10m) vertical distributions of epizooplankton, the ecological significance of these distributions and their effect upon other "particles" within the upper water column. This has lead to a focus upon the following set of inter-related questions:

a) Do physical gradients influence zooplankton distributions directly or indirectly?

b) Is the vertical distribution of zooplankton controlled by density gradients or loci of current shear situated within steep density gradients?

c) How strong a physical gradient must exist and how long must it persist to influence the zooplankton distribution?

d) How and under what circumstances does the fine-scale distribution of epizooplankton particle-grazers affect the fate of particles within the upper water column?

e) To what degree does local turbulence control fine-scale zooplankton distributions and how does this vary with the relative motility of different zooplankton taxa?

SCIENTIFIC OBJECTIVES

Among the strongest atmospheric forcing of the upper water column observable anywhere in the world ocean, recurs in the Arabian Sea. Seasonally reversing monsoonal winds drive strong currents, produce complex eddy fields, deepen the mixed layer and induce both coastal and open ocean upwelling. In much of the region a shallow oxygen minimum is found year round beneath the mixed layer. These physical features directly affect primary production processes but may also be expected to influence the abundance, distribution and diversity of the animals dependent upon that production. During the 1995 field season the NOAA Ship Malcolm Baldrige made two cruises (an intermonsoonal cruise in April/May and a late monsoon cruise in August) during which we collected direct (MOCNESS) and indirect (acoustic and optical) zooplankton data addressing the following questions:

1) How do zooplankton size class spectra, vertical distribution and biomass respond to seasonal mixing and consequent changes in food availability?

2) Do both coastal and oceanic zooplankton populations respond similarly?

3) Do the abundance and vertical distribution of mesopelagic organisms respond to seasonal mixing and consequent changes in food availability?

4) What are the relative biomasses of zooplankton and mesopelagic populations?

5) How are the vertical distributions and diel migration patterns of zooplankton and mesopelagic populations modulated by the oxygen minimum?

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APPROACH

The underlying rationale of our technical approach has been the conviction that to link physical and biological information into a dynamical understanding requires collecting data on fully comparable time and space scales. This assumption derives from the general observation that, while scales of biological and physical variation are often coupled, they are so in a complex and highly non-linear manner. Our field sampling is intended to provide information pre-requisite to dynamical understanding.

TASKS COMPLETED

The data specifically collected by our group on both cruises included:

1) diel series of MOC-1/150um mesh epizooplankton tows taken in the Omani basin and near the central mooring stations with a multifrequency acoustic subsystem mounted directly upon the net frame along with the standard temperature, salinity and oxygen sensors [31 tows - 248 samples]

2) acoustic backscatter data (12 and 100KHz) continuously collected by hull-mounted transducers [ca. 60dys] ;

3) current profile and acoustic backscatter data continuously collected by a hull-mounted 150kHz ADCP [60 dys]; and,

4) horizontal and towyo deployments of an integrated acoustic/optical sensor package consisting of a multifrequency (six frequencies ranging from 256KHz to 3MHz) acoustic subsystem, fluorometer, IR optical backscatter sensor, CTD, and an optical particle counter and integrated in-situ silhouette video “smart-sampler) mounted aboard an Aquashuttle tow vehicle [30 tows ca. 200 hours].

In regard to the above samples:

1) Over two thirds of the diel series MOCNESS samples have been analyzed. Analysis proceeds in three phases. First overall biomass is determined by displacement volume, then a functional type/size enumeration is made and last the individual copepod species are enumerated. All ancillary data with the exception of the multifrequency acoustic data has been processed and converted to standard data files for distribution to collaborating principals.
2) The hull-mounted transducers and associated electronics have been calibrated and a program written to analyze and display these data.
3) All ADCP data has been processed in regard to both currents and backscatter. The latter have been converted to zooplankton biomass calibrating against the MOCNESS displacement volumes. These data have been put in anonymous FTP directories for collaborating principals and will shortly be supplied to C. Flagg and S. Smith for inclusion in the overall atlas of ADCP data taken in the Arabian Sea during that field season.
4) Programs have been written to efficiently process optical particle counter data and integrate it with ancillary data and a subset (ca. 20% of the data) have been analyzed and quality controlled. Programs for more efficiently processing the multifrequency data (including that taken in conjunction with MOCNESS tows) are being prepared in collaboration with V. Holliday and will be finalized during a planned two week visit to San Diego this December. Analysis to date of the particle counter and multifrequency data has focused on the upwelling areas off Somalia and Oman.

5) Programs to process the video records have been developed and tested. A subset (ca. 10%) of the records have been processed.

In addition to these samples all the 0-200m MOCNESS samples obtained by S. Smith et al. during her deep (0-1500m) Baldridge cruise tows have been processed by our group as described above for comparison with the diel series. These data have been supplied to S. Smith et al.

IMPACTS

The data obtained are proving an essential addition to the overall Arabian Sea program given the emphasis of the Baldrige cruises upon animal populations including the larger mesopelagic forms not sampled by any other participating vessel. The cruises not only make overall temporal coverage more complete but in addition markedly increase spatial coverage by including the coastal areas of the lower Arabian penninsula and Somalia. They will be an invaluable supplement to the Thompson data.

RESULTS

The data analyzed to date represent only a fraction of the optical and acoustic data collected but in general confirm the dramatic seasonal difference in plankton abundance and vertical distribution as well as the local (and surprisingly distant) apparent consequence of the coastal upwelling events.

There also appears to be reasonably good correspondence between optical and acoustic assessment of epizooplankton biomass and size structure including (much to my own surprise) much of the ADCP data. We anticipated that interpretation of the ADCP backscatter data would be confounded by the presence of mesopelagic fishes with swim-bladders but that was rarely the case. Apparently we simply did not sample in those areas dominated by mesopelagic scatterers. This was confirmed in the MOC-10 samples all of which have been enumerated by Madin et al.

TRANSITIONS

For the remainder of this contract period we anticipate devoting all resources to completing sample and data analysis from the Arabian Sea cruise. The hardware and software developed provide and efficient mechanism for studying mesoscale and submesoscale processes in plankton communities and we are assessing the suitability of various sites to continue these investigations. The most promising appears to be seaward of the Florida Keys where exploratory sampling has revealed the regular generation of submesoscale baroclinically unstable eddies that markedly redistribute resident plankton communites. Using other project funds we have deployed an in-situ optical/acoustic mooring in this region to obtain time series data that will permit us to better evaluate the plausibility of this hypothesis. Last the integrated video system/optical particle counter developed under this project may be commercialized by Focal Technology Inc. under a CRADA agreement being currently negotiated. Representatives of the company have visited the laboratory, examined the equipment and engineering drawings.

RELATED PROJECTS

The Thompson and Baldrige data sets partially overlap but in general provide complementary spatial and temporal coverage. The various methods and instruments used aboard the Baldrige are intended to complement each other in providing a more complete assessment of the animal communties. In order to address the research questions posed we are collaboarating with Thompson and Baldridge investigators as enumerated below:

1) Zooplankton biomass assessment by backscatter difference, low frequency hull transducer and ADCP backscatter versus multifrequency and MOC-1 sample biomass and size distribution. Net tow and multifrequency data are needed given the inherent potential sources of error in single-frequency acoustic biomass assessment (with V. Holliday and S. Smith);

2) Mesopelagic biomass and size frequency assessment from the MOC-10 and the low frequency hull transducers. Although 62 MOC10 tows were obtained the continuous acoustic data are needed to extend spatial and temporal coverage in particular determining if extensive schools of mesopelagic organisms were missed by the discrete net tows (with V. Holliday and L. Madin);

3) Multifrequency and Optical Particle Count epizooplankton size frequency distribution versus in situ video assessment of taxonomic composition and size frequency and MOCNESS and vertical net tow samples. These "technical" comparisons are needed to properly interpret shuttle data prior to addressing the following question;

4) Integrated optical/acoustic data across littoral upwelling jets versus continous pump sampling, drifter data and continous hull-mounted acoustic data (with M. Baars, G. Hitchcock and V. Holliday).

5) Taxonomic composition of MOCNESS samples at the Omani Basin, along the Omani and Somali coasts and near the mooring site. These data will be pooled with Thompson MOCNESS data and markedly extend their spatial and temporal coverage (with M. Roman, K. Wishner and S. Smith);

6) Multifrequency acoustic data from the MOCNESS mounted unit versus similar data with MOCNESS and SEASOR mounted units from the Thompson (with S. Smith and V. Holliday)