Observational Approaches To Distribution And Movement Of Marine Organisms In Relation To Physical /Chemical Structures

Background and context for observing approaches related.

Observations of animals movements provide data that are critical to a number of well defined societal needs. Fundamental is an understanding of how organisms are responding to the human forcing of the ocean, in terms of climate change, food security and ecosystem health? These society issues can be addressed by a series of science questions which include:

What will be the effects of Global Climate Change on populations of marine organisms?
- Can organisms adapt to changes in their environment?
  - If the environment changes, do they leave?
  - If they stay how do they adapt these to changes?
  - What is the time course of this changes (How fast can they adapt?)

How do we design and implement Marine Protected Areas
- Are they of sufficient size to protect populations of important marine organisms?
- Are they in the right places?
- Can they be defined in an adaptive manner?

How do seasonal animal migration patterns affect marine species protection efforts?
What are key marine ocean habitats and their extent allowing sustainable marine industry and securing human and marine animal food needs?

What are the drivers for marine animal migration - natural variability vs. anthropogenic change?
How healthy are ecosystems?

These science questions will help us to address issues that are critical to the IPCC Working group 2. This working group is currently working on AR5, and it is unlikely that any Ocean Observing system currently in the planning stages will be ready in time to provide input. However, if progress is made now the developing ocean observing system could provide critical data and time series for AR6. In addition to getting a better handle on the effects of global climate change, a biological ocean observing system will be important to differentiate ecosystem change due to climate, relative to other forcing factors such as pollutants and fisheries interactions. These data will provide the basis for Ecosystem Based Management, Development of Marine Protected Areas, and to better define Large Marine Ecosystems as many organisms move between ecosystems LME. Further, EBM will require an understanding of the oceanographic processes and features that create biological hotspots (regions of high biological diversity or animal abundance) and cold spots. Biological ocean observatories will also provide rigor to fisheries data, models & projections allowing for better management and assessment (Food security),

With respect to our ability to address these science questions within the framework of developing an ocean observing system, the models and empirical approaches needed to study the physics is well defined, whereas the biology has yet to be articulated. From this context it is important to insure that the physics and chemistry are appropriate/match for the biology. This is important because the currently available bio-physical models are not well coupled to the biology. The response of organism provides a “window” into long term processes and events. However, biology systems are non-linear as small changes can results in large effects, or there may be no effects until a certain thresholds are reached. In order to observe and document these changes and responses we need long time series that are 3 dimensional covering long time periods. Unfortunately very few such times-series exist and those that do are primarily 2 dimensional. However, there is a proven capability to measure long time and large spatial scales using mix of mobile and fixed platforms that include satellite remote sensing, moorings, cabled networks, mobile sensor platforms, AUVs, ROVs, Gliders, animals carrying natural and electronic tags, stable isotopic tracers and genomics.

Approaches

Marine organisms vary from microbes to whales and size matters! The approaches we employ to observe the movement patterns of will vary as a function of their size. For example, the measurement approaches used to study microorganisms are on the same scale and follow similar sampling regimes that are employed to measure the physical and chemical environment. Whereas the observational methods used to monitor the movements of large marine organisms like whales, or sharks can be quite different. There are two fundamental observational approaches, eulerian and lagrangian sampling methods. The currently available technology limits lagrangian observational approaches, where the movements of individuals are followed, to observations of arge marine organisms. Whereas the entire range of marine organisms can be studying using eulerian approaches. Eulerian approaches infer movements of organisms by monitoring changes in their distribution or presence/absence over gridded space. While in situ environmental data can be collected using both methods, tagging and tracking techniques (e.g biologging techniques) allow us to follow the organism where ever they go. With eulerian approaches the organism can only be observed within the predefined study area. In some cases this can lead to a significant bias in our understanding of the distribution of a species. For example, prior to the deployment of electronic tags, northern elephant seals were thought to range just offshore along the west coast of North America (Figure 1A). Whereas, tracking data shows that they travel across the entire North Eastern Pacific Ocean (Figure 1B). Tagging data provides a time series that can last from months to in some cases years and provides behavioral information that can be used to identify behaviors and associated habitats and depending on the type of tag deployed, data can acquired can range from a simple surface track (Figure 2A), to a surface track with a dive profile (Figure 2B) or a surface track and dive profile with associated environmental data (Figure 2C; temperature, salinity and or light level). Such behavioral data are important to identify differences in the movement patterns and habitat utilization of different species. However, lagrangian approaches can only be used with organisms that can be tagged.

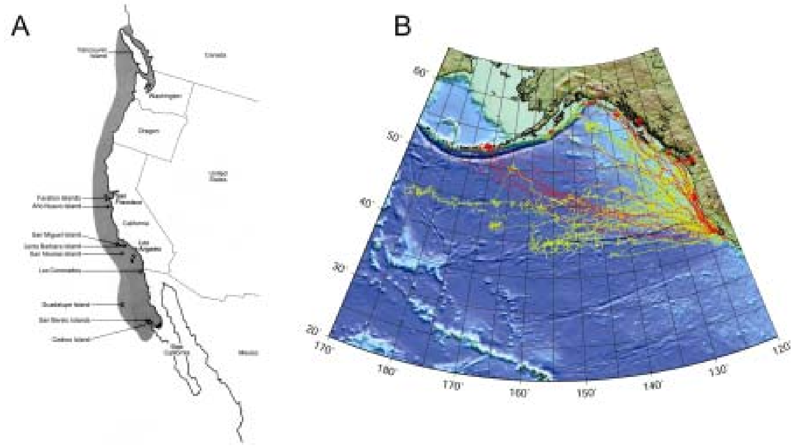
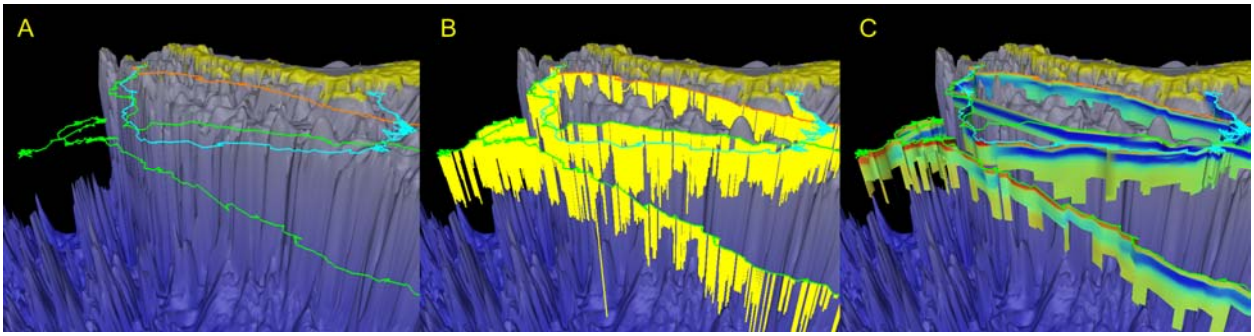


Figure 1. Distribution of northern elephant seals as determined using boat and plane based surveys (from Reidman 1990). B. Current distribution of northern elephant seals determined using satellite telemetry from Le Boeuf et al. 2000.

Figure 2. Track of southern elephant seals in the Western Antarctic Peninsula obtained using the SMRU CTD-SRDL 9000. A. shows just the surface track, B. shows the surface track along with diving behavior, and C. shows the temperature and salinity profiles that can be obtained to provide data on the physical environment the animals are moving through. Costa, Goebel, and McDonald Unpublished data.



In the development of an observational system it is important to consider the domain or region that is being studied. For example, the observational approaches employed for monitoring movements of organisms in the nearshore or coastal zone will have to be carried out at a higher spatial and temporal resolution than studies carried out in the open ocean. Such studies should follow the GOOS guidelines for these regions/domains. Further, as many of the processes of study cover a range of scales, and some organisms for example highly migratory top predators transit across ocean basins going from one coastal zone to another where resources are abundant (Shaffer et al 2006). In order to accommodate these movement patterns, it will be necessary to develop a nested observatory system, where high resolution sampling takes place in small coastal study areas, and these observing areas are then nested in larger regional or ocean basin scale regions where the sampling resolution is reduced. Finally, we recommend an approach that incorporates a combination of sampling procotols that provide the large scale synoptic context along with a more focused series of measurements that provides a higher resolution time series that provides a more process oriented view. One example of this is the "wind to whales" project in Monterey Bay (Croll et al 2005). In this study the mooring provided the information on biophysical coupling that brought blue whales into Monterey Bay, while satellite tracking showed that blue whales migrate to and from these highly productivity upwelling regions.

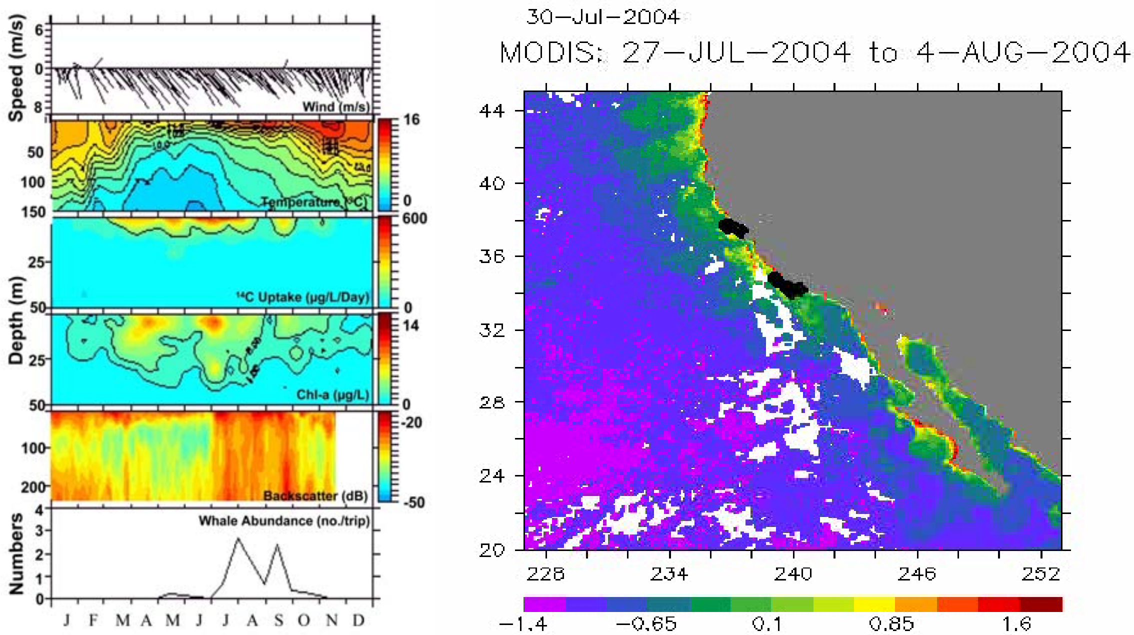


Figure 3. On left is the

Data Management:

Shift in importance of proper data and metadata handling.

Integrate data management and utilize data management systems/tools in daily research

Student up data handling, increase importance of sustained data acquisition and high quality data handling,

idea of meta data documentation and data usage statistics similar to tracking scientific paper results as a measure for impact and for scientific funding decisions.

Keep grand picture in view but don't ignore fundamental and local research which won't directly yield a Science or Nature paper.

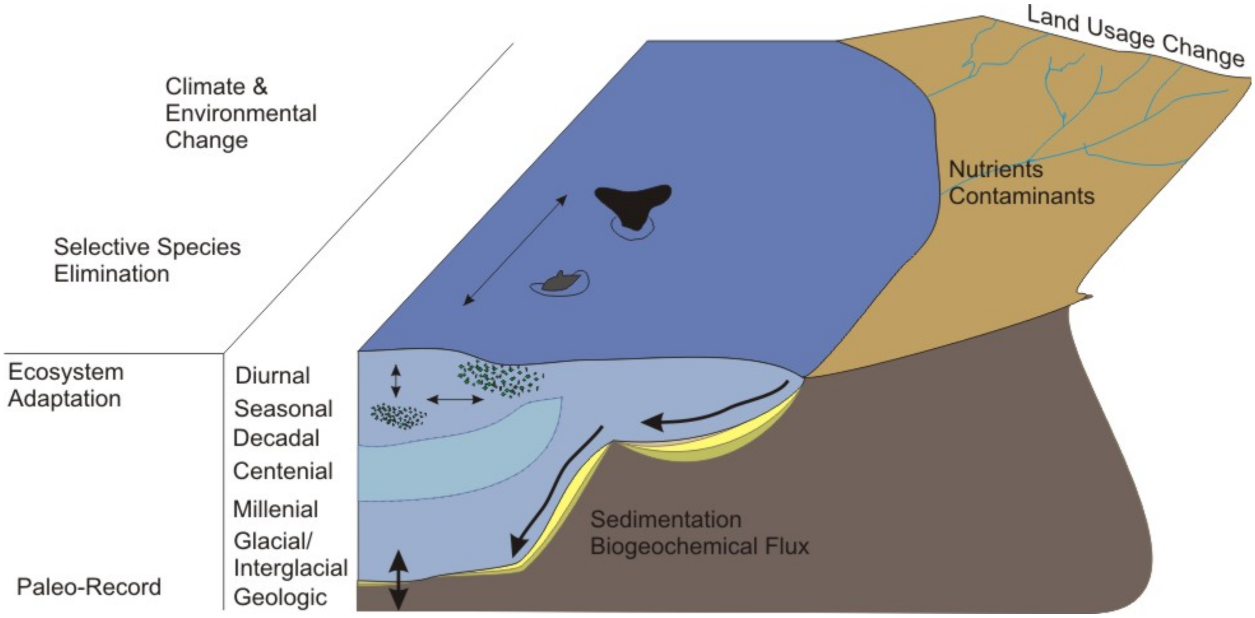
3: What are the priority observations to address this issue?

Long term observations (mobile, stationary, repeat), continuous - campaign

Vertical, horizontal and temporal variability

I	**Physical Structure and Changes**	seasonal – decadal – centennial changes
	moorings, profiler, autonomous + remote operated vehicles, atmospheric boundary conditions	

	CTD, current	
II	**Chemical Structure and Changes**	diurnal -seasonal changes
	moorings, profiler, autonomous + remote operated vehicles	
	Major and trace nutrients, O2, pH, CO2, contaminants	
III	**Trophic Structure and Changes**	active-passive migration adaptation to change effect of overfishing and contaminants
	moorings, profiler, autonomous + remote operated vehicles	
A	***Microbes***	
	nutrient availability	
B	***Phyto Plankton***	
	chlorophyll, speciation (genomics)	
C	***Zoo Plankton***	
	phyto-zoo relationship, speciation	
D	***Higher Trophic Structure***	
	speciation, population, distribution & movement,	



4: Where should the observations be made and at what frequency and duration?

Local versus global system/questions

Small scale processes/questions at high frequency

Large scale processes/questions at low frequency

On all scales continuous consistent long term measurements are needed to investigate dynamics and variability.

Consideration may be given to processes beyond the timescale of a single investigator life, especially for long lived organisms.

5: Observational technologies now available and on the horizon, and gaps in available sensors to address the need

Present day available:

i) ii) iii)

Currently in the refining to routine measurement stage, could be incorporated into system within the next 5 to 10 years:

i) ii) iii)
ii) oxygen
iii) chlorophyll

Ideas and technologies which can be adopted to measure certain parameters:

i) ii) iii)
ii) pH
iii) CO_2
iv)

Measurements currently not possible but would be of high value:

i) ii) iii)