NOAA Ship Requirements for Fisheries Oceanography

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Introduction

This document describes my perspective as an ecologically oriented coastal physical oceanographer on the subject of research vessel usage for the next decade or two. Most of basic points I'll make are generally applicable to oceanographic research vessels, but some will be biased towards coastal ecological or fisheries objectives. This first page serves as a general summary and overview. Many of the more specific considerations are treated in detail in the UNOLS document titled "Scientific Research Requirements for Oceanographic Research Vessels."

I bring to this forum considerable experience as a field-oriented oceanographer and a modest amount of ship design and usage information I acquired as a scientific representative on the UNOLS Fleet Replacement Committee (for two years as a research faculty member at University of Southern California). I don't know all that much about specific vessel requirements associated with fisheries oceanography other than the fact that substantial net handling systems are usually desirable.

I view oceanographic research vessels first as data gathering platforms, then as a means of getting to where you want to be, and finally as a place to stay while you are working at sea. If you aren't getting good data, then one is wasting time and energy in transit and occupying stations, etc. In short, I feel strongly that we should focus most of our effort in this exercise on plans to upgrade NOAA's shipborne data acquisition capabilities. This involves capable and appropriate vessels and reasonably well-matched data acquisition technologies and vessel design.

The accelerated evolution of measurement technologies has revolutionized the way we observe the ocean. Appropriate application of acoustic and optical sensing technologies has dramatically increased data rates and volumes as well as the breadth of topics that might be addressed as part of a single oceanographic expedition. More precise navigation and ship motion specification combined with the above technologies has lead to some remarkable advances in the way oceanography is done at sea. In short, there is more potential these days for getting exceptional data sets using more modest vessels (if they are well-equipped) or for abusing the potential opportunities afforded by larger, better-equipped vessels, if critical components are "down" or inoperable during a particular cruise leg. The bottom line is bigger doesn't necessarily mean more capable with respect to data acquisition.

How will these vessels be used? What speed, endurance, and crew carrying characteristics are most desirable? What will the vessel of the 90's look like? Will each region of the U.S. have access to a range of vessel types? Is there a prototypical one-size-does-it-all vessel? I think we have to address all these questions in one form or another as part of this activity.

Here are some quick, general answers to the above questions that are difficult to refute. We need faster vessels (on average) to get from one data gathering point to another in less time, so we can gather essential data a greater percentage of the time (versus transit time). Vessels should be more efficient (in terms of fuel consumption) and require less crew to operate so that a greater percentage of the total ship operation expenditure can go towards data gathering. Endurance and crew-payload carrying capacity are paramount considerations for open ocean, trans-basin type vessels, but may be less important than speed or data acquisition capability for coastal vessels. There is no prototypical one-size-does-it-all-on-a-cost-effective-basis vessel, period! Each region will have to have access to a range of vessel types. Hopefully, all vessel types will be well-equipped in terms of data acquisition instrumentation.

Vessel Types

Vessel types usually break down by size (large, 200+ ft; medium, 130-200 ft; small, 70-130 ft), but there is considerable overlap in data acquisition capability as a function of size. There days a 100-ft vessel can acquire the same type and amount of data per unit time as a 300-ft vessel in many variable fields assuming comparable instrumentation. That is, the relationship between vessel size and data acquisition capability is changing with the advent of microprocessor-based, down-sized instrumentation systems.

With today's improved data acquisition equipment there is a greater need for precision navigation, tracking and station-keeping capabilities. This translates to modernized low speed propulsion units (Omnithrusters or Z-drives) and positioning systems which employ the best possible navigation electronics and control technology.

It is obvious that a small vessel must operate in coastal waters or at least within easy transit of a port which might be located in oceanic waters. No one would suggest that this vessel class should be used for pelagic work; just that they can be very cost-effective, capable platforms for coastal research efforts. SWATH (or catamaran) designs could be especially appropriate in this niche. Much of NOAA's currently planned research is sited in coastal waters as a result of the fact that most of man's activity and impact on the oceans is concentrated within 200 km of the coast. Even small "work boats" can play a significant role in this research context.

NOAA can probably count on the need for operating a minimum of one large vessel per ocean basin. These vessels should have an endurance of two months, accommodations for a scientific crew of 24 (minimum), cruising speed of 15 kts, range or 10,000 miles, and excellent low speed maneuverability and station-keeping capability. They should be equipped with the best possible navigation and data acquisition instrumentation which will probably require (for effective use) a permanent onboard instrumentation support team. These vessels typically cost 10K$/day (or more) to operate.

NOAA can probably count on the need for operating a minimum of two small vessels per coastal region. These vessels should have an endurance of at least two weeks, accommodations for a scientific crew of 10 (minimum), cruising speed of 15 kts, range of 3,000 miles, and excellent low-speed maneuverability and station-keeping capability. They should be equipped with the best possible navigation and data acquisition instrumentation which will probably require (for effective use) a permanent onboard instrumentation person. These vessels typically cost 4K$/day (or more) to operate.

Intermediate size vessels fall between these two categories and play an important role in benign oceanic regimes or more rigorous coastal regimes. In the former they can play a large ship role; in the latter, they are a necessary consistently perform successful coastal missions. Their operating cost is closer to that of a large ship. Small SWATH (or catamaran) vessels can overlap significantly with intermediate size vessels in many operational categories.

I favor a vessel with a more flexible, open-deck-type design that can effectively accommodate additional van storage or portable labs. Generally speaking, vessels seem to gravitate towards the other end of the design continuum with more permanent lab space at the expense of open fantail and versatility. In my opinion, that defeats some of the possible utility of large- and intermediate-size vessels. This is especially true of vessels for fisheries work in that plenty of open deck space is required for net handling and associated gear. Three characteristics seem to be part of designs which try to mold intermediate-size or large ships into do-it-all vessels. They tend to be beamy (to get more space per length) and thus are slow or inefficient, and ironically are less versatile than one might expect because of the emphasis put on permanent lab space (which is often just used for storage anyway). The former characteristics disallow the possibility of faster, longer-range, higher-endurance designs with open deck configurations (e.g., similar to modern-day tuna-fishing vessels).

How Will These Vessels Be Used?

I am presuming that these vessels will be primarily used for the purposes of oceanographic research) including fisheries oceanography). One needs to get on station efficiently, get the essential data with supporting environmental data, and get back to port. Hopefully this can be achieved with high odds of success, with adequate living quarters, and with moderate ship and scientific operational costs in that order. Too often operational costs are minimized first and foremost.

First, basically well-suited vessels and sound data acquisition systems must be selected and meticulously maintained and operated. These criteria sound straightforward, but are surprisingly difficult to achieve in a multiple-use environment with rigorous scheduling constraints and ever-present economic restrictions. Some of the data acquisition gear can come aboard with the scientific party, but many systems must be attached to the ship for effective shared use. Special purpose design requirements can make one group's well-suited vessel another group's working nightmare. Fisheries research vessels can suffer from this syndrome in that special features needed for efficient net handling may be incompatible with other research vessel requirements. This applies particularly to fantail design. It is my understanding that there are very few vessels in the U.S. research fleet that are appropriately rigged and configured for fisheries research activities. This is probably an indication of the fact that fisheries research vessels have a number of special design features that the rest of the research community has difficulty with.

What are these features and how might they be accommodated in innovative vessel designs? I'll appeal to my colleagues who work specifically in fisheries oceanography to address this question, but it is one that this working group needs to tackle.

Two special-purpose designs that can play an important role in many coastal environments are the small SWATH (or catamaran) vessels and the "work boat." Fully instrumented versions of either type of craft can acquire a tremendous amount of data per dollar and offer a high degree of versatility. The performance of such activities as NOAA's Coastal Ocean Program would be significantly enhanced by upgrading this vessel class in NOAA's fleet.

What Types of Sampling and Data Acquisition Systems Are Required for Fisheries Oceanography Research Vessels?

Research vessels should be very well suited for obtaining significant oceanographic data with the highest possible likelihood of success. This implies that appropriate data acquisition systems are an integral part of ship's equipment and are also given high priority for maintenance and periodic updates. Traditionally, most data acquisition systems have been brought aboard by scientific parties, installed and troubleshot on a real-time basis. This mode of operation often leads to a significant drop in efficiency if it is gauged in terms of critical data words acquired per ship day. There is a growing consensus in the research community that many of today's critical oceanographic research problems are interdisciplinary in character and demand thoughtful, well-balanced programs of study to further understanding in these areas. In contrast to disciplinary approaches, these interdisciplinary efforts require broader data bases and unique mixtures of variable fields. On a very basic level (dictated by fundamental sampling theorems) it is important to cosample diverse fields so that data grids are collocated in space and simultaneously in time. Otherwise it is impossible to establish covariability relationships. Shipboard data acquisition systems are one of a few technological approaches which currently allow such sampling schemes to be implemented on a practical basis. But doing it well on a demand basis requires careful planning and coordination of effort.

Successful interdisciplinary sampling schemes can be promoted by shipboard data acquisition systems that can operate in parallel at comparable data rates. Historically, this goal has been frustrated by low data rate systems which demand dedicated "wire time" and are deployed and retrieved intermittently. In the absence of parallel winch configurations on winch-independent data acquisition systems, this class of technology disallows collocated, simultaneous sampling of complementary environmental data fields. We must advance beyond such technologies where possible and exploit designs which allow practical joint operations of parallel winch and A-frame configurations.

I envision ships as data acquisition platforms similar in many ways to satellites, but more practically adaptive and controllable. The ocean sciences community has fallen far short of the data acquisition benchmarks established by the atmospheric sciences and space research communities. It is up to us to "pick up the pace" and implement reasonable and consistent advances in the observational end of our science. A prime component of our resource base for this activity involves using ships as observational platforms.

Where can improvements be made? In my view, the big short-coming or blind spot is the implicit assumption that ships can be used efficiently as scientific tools regardless of how well instrumented they are. That is, give a scientific team ship time and they'll come back with lots of good data. It doesn't work that way, everyone knows it, and we're not doing much to improve our plight.

NOAA should commit to making the following shipboard measurements as a matter of routine:

1) Underway pumping system which measures near-surface temperature (T), salinity (S), optical properties (OP's), nutrients (NUTS), biological properties (BP's)
2) Profiling system which measures all the above
3) Dual frequency Acoustic Doppler Current Profiler (150 & 600 khz) to measure currents underway and on station as well as estimating profiles of "acoustic biomass" (backscatter intensity)
4) Meteorological variables (wind speed, direction, humidity, irradiance) at two standard heights
5) Precise navigation data (x, y coordinates and time)
6) Ship motion data (speed, heading, pitch, heave, roll)
7) Satellite remote-sensing data for the operating region should be available through data links in near real-time
8) Buoy data for the operating region should be available through data links in near real-time

All data should be archived using a single computing network (e.g., a local area network of PC's or a minicomputer cluster) at full data rate (~1 hz) to optical disk. Preprocessed average data (1 minute averages) should be available in real-time in both tabular and graphic formats. Daily preprocessed archives and summaries should also be available in near real-time. All data should reside on a PC interactive system hosted by a central data storage and processing node (which might also be a glorified PC or minicomputer).
One can envision modular integrated systems which would do most of the above (minus a few vessel mounted sensors and transponders). These units would

be of modest size and weight (and thus easily shipped). They would employ a standardized architecture (easily serviced or recalibrated at a central facility) and utilize "off-the-shelf" component elements (little prototype development).

Oceanographers spend a great deal of time and effort trying to acquire the above data fields aboard ship and are seldom able to realize this goal. If this data were available as a routinely acquired baseline set, we all could start concentrating upon more specific measurement objectives. This in itself would be a dramatic improvement in the scientific utilization of research vessels. The price would be a modest increment (perhaps 10%) in the future overall ship acquisition and operation budget. The scientific return, in terms of data acquired per ship day, would be dramatic (perhaps a 10–100-fold increase). The increased data return per extra dollar spent would be truly spectacular! We could do this now. Why wait to get this underway? Let's let our ideas and insight limit our understanding of this component of our environment, not a grossly inadequate observational data base.

What are the more specific measurement objectives associated with fisheries oceanography research? Evaluation of fish stocks is an important activity. Larval and juvenile survival studies are also significant components of this research area. Are there other distinct categories that can be named? The first category seems to be the one which requires specialized vessel and equipment configurations that may be at odds with more general usage requirements. How generic are these needs as a function of fishery type and oceanic environment? Will acoustic methods soon (within the next decade or so) supersede or partially replace more traditional methods of sock assessment?

The Great Lakes Environmental Research Laboratory does not have responsibility for research on exploited Living Marine Resources in the Great Lakes, but it does conduct ecosystem-oriented studies of nutrient and contaminant flux impacts on lower trophic levels including forage fish. Scientists at GLERL are currently conducting programs titled Coordinated Ecosystem Research, Pollutant Effects, Exotic Species, and Large Lake Climate and Global Change, in addition to other research activities. These programs all treat aspects of food web dynamics in relation to environmental variability and have substantial field components that must be supported by research vessels. In order to successfully reach our research goals in these areas, we require 150–300 ship days per year on a range of coastal and estuarine vessels. Approximately one half of this time must be supported by a larger coastal vessel (70–100 ft) with greater crew carrying capacity and seakindliness characteristics. The remainder of the ship days can be supported by smaller, higher-speed "work boats." Both vessel types should be fully instrumented with the best possible suites of oceanographic instruments, and should be relatively high speed (15 kts or greater). A premium should also be placed on minimizing operating and maintenance costs associated with these vessels.

We have planned studies of physical–biological interactions and ecosystem variability that require colocated and simultaneous measurements of a broad range of physical, chemical, biological and optical variables guided by near-real-time satellite imagery and meteorological data. It is the concerted opinion of the scientific staff at GLERL that we are severely constrained by the operational characteristics of our research vessels and shipboard measurement capabilities. The success of our planned research efforts for the 1990's hinges upon revitalization of these infrastructural components.

Operating conditions vary significantly with season in the Great Lakes. Practically speaking, ship operations are not feasible (with our current vessels) in winter months due to severe weather conditions and ice cover. The remainder of the year tends to be fully scheduled and coincident, multi-lake ship operations are common in our laboratory research agenda. At present, we employ a second "work boat" with split crew to cover such requirements. The scientists in the Great Lakes community would welcome a modernized, more-capable research fleet.

Conclusions

In summary, my responses to specific questions posed in letter requesting input on this topic are:

1. Direction of Physical Oceanography in Coastal Ecosystem Research. NOAA can play a big role in longer-term ecosystem studies over the next few decades. No one entity will be able to shoulder all the responsibility for such studies, but NOAA is in a position to play an expanded leadership role with NSF, DOE, EPA, and MMS each contributing as their mandates dictate. It is my understanding that NOAA will play a central role in that its mandate includes the longer-term observation and stewardship of shelf/slope regions, estuaries and Great Lakes. Longer-term observations are required before the community can improve their understanding of the entire annual cycle, physically, biologically and geochemically, in various geographical regions. If we can't fully understand or predict "simple" fields like mass and heat, we will never be able to tackle the tougher vector fields (momentum) or biologically active fields (nutrients, plankton biomass, etc.). After we get the annual cycle under control (in numerous fields and geographical settings), then we are prepared to understand more subtle, gradual rectification of the more energetic annual cycle. These activities will all require longer–term interdisciplinary data sets. Let's note here that the phase "longer–term" is relative and for coastal ecosytems one independent episode or time step may take several years. In this context, our "longer–term measurement efforts" are really equivalent to "flash in the pan" experiments.

2. *Anticipated Rate of Growth.* Technologically and scientifically faster than we've ever experienced. Future shock! But I don't think we will see funding and "activity" keep pace with the technology and ideas generated by new observations and insights. One already has that sense at the close of the 80's. I think our science will progress at an unprecedented rate. Unfortunately, the ratio of what–we–could–do to what–we–are–doing will also grow at a high (and frustrating) rate. Right now we are putting a serious drain on the working community just planning what we hope to do. If these plans get funded at even a modest level, there won't be enough horsepower to get the work done effectively, especially if we take a brute–force approach (i.e., use old technology, labor–intensive methodology, untrained personnel, etc.).

3. *Changes in Mixes of Technology.* Traditional shipboard observations will gradually be replaced by advanced shipboard technologies (including acoustic remote–sensing techniques). We all have some homework to do first so we can establish and come to a consensus on what can or can't be done with technologies or various sorts. I don't think ships are going to be replaced by satellites any time soon, especially in interdisciplinary studies. I do think that shipboard data acquisition could easily become more "robotic" in character. I grimace every time I recall scenes from past cruises...senior scientists (500$/day each after overhead and benefits) on the fantail of a 10K$/day ship patching up some ancient piece of sampling gear while other senior scientists, engineers, technicians, etc. await their turn to occupy the fantail.

4. *Monitoring.* I think short–term versus long–term is a matter of perspective. A sixty year time sequence is statistically equivalent to a one–hour laboratory study if the processes of interest have time scales of one year and one minute respectively. It will take us another 50–100 years (if we start today with a serious effort) to sort out some of these interannual and climate variability issues. After we leave this exploratory, pilot–study phase, the intellectual progeny of our grandstudents can worry about whether or not it will be worthwhile "monitoring" such processes.

5. *Regional Needs.* The coastal regions of the U.S. can be split up into 14–20 relatively distinct regimes (viewed from a physical perspective). They all have their own set of characteristics, interesting phenomena, and problems. I don't think we can discount any of them in terms of ecosystem studies. The same goes for the major ocean basins.

6. *Anticipated Changes in Real–time Data Analysis and Integration of Data from Other Sources in Near Real–time.* Members of the community are already doing this integration. It pays off scientifically and economically so we need to do it better (more appropriate technology, and better prepared scientists, engineers and technicians) and more consistently (do the stuff we can do now, on a pilot basis, all the time) while continuously upgrading our capabilities.

NOAA'S OCEAN FLEET MODERNIZATION STUDY

Phase 1: Mission Requirements

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