

THEORETICAL AND ACTUAL BIOLOGICAL EFFECTS OF FISHING QUOTAS IN ALASKA'S FISHERIES

Heather V. Brandon, University of Washington

Rationalization of fisheries management (including IFQs, ITQs, and cooperatives) is utilized primarily to achieve economic and social objectives. The biological consequences of rationalization are largely theoretical and are based on predictions of the fisheries market and human fishing behavior. Very little analysis has been conducted to verify whether the anticipated biological effects have occurred or not.

The question central to my thesis is: Do rationalization programs produce the anticipated biological impacts? And are there additional biological effects from rationalization that were not predicted?

This poster will examine the five key biological assumptions made within two case study fisheries: Alaska pollock and halibut/sablefish. Additionally, this poster will highlight the findings of actual biological impacts from these two rationalized fishery programs. Additionally, I will acknowledge those assumptions that cannot be verified due to lack of information. Identifying gaps in data will allow me to recommend monitoring and research for future fishery rationalization programs.

Heather Victoria Brandon
School of Marine Affairs
University of Washington
brandon4@u.washington.edu

CITIZEN SCIENCE BEGETS COASTAL STEWARDSHIP: THE REEF ENVIRONMENTAL EDUCATION FOUNDATION FISH SURVEY PROJECT

Christy Pattengill-Semmens, Reef Environmental Education Foundation

Abstract

Effective conservation and management of marine resources requires a comprehensive understanding of ecosystem structure and function. Through concerted and persistent data collection, researchers and resource managers can gain an understanding of these ecosystem components. The monumental task of surveying and cataloging living marine resources can be daunting for managers who are typically constrained by limited budgets. Furthermore, establishing monitoring programs at a scale large enough to appropriately monitor marine communities is frequently cited as a stumbling block to effective management. One solution is to use volunteers to help collect information.

Volunteer data collection, or “citizen science”, has become a widespread alternative for scientists and resource agencies needing information but lacking sufficient resources to gather it. Since 1993 volunteer sport divers have been gathering data on fish assemblages as part of the Reef Environmental Education Foundation’s (REEF) Fish Survey Project. Survey data are recorded on preprinted data sheets, which are returned to REEF and optically digitized. Data are housed in a publicly accessible database on REEF’s Website (<http://www.reef.org>). To date, over 65,000 visual Roving Diver Technique surveys have been conducted at sites along North and Central America, throughout the Caribbean, and in the Hawaiian Islands. These data are useful for a variety of management applications, including evaluating the effects of harvest restrictions and zoning, identifying diversity hotspots, conducting fisheries-independent population assessments, evaluating the biogeography of fishes, and the discovery of rare, new, and non-native species.

A COMPARISON OF WATER QUALITY EFFECTS OF MONTHLY AND ANNUALLY BASED POINT SOURCE LOAD REDUCTIONS

Lewis C. Linker, U.S. EPA Chesapeake Bay Program Office
Ping Wang, University of Maryland Center for Environmental Studies

Abstract

Chesapeake Bay physical and biological processes can be viewed as ‘integrating’ variations of nutrient load magnitude over time. The integration of loads over time ameliorates intra-annual load fluctuation, with the Bay responding to overall loads on an annual scale, and showing little response to monthly variations within an annual load. This may be due in part to water residence times of more than several months, estimated by a given parcel of water discharged at the mouth of the Chesapeake. Also, the time that a given nutrient load influences water quality, including recycling of nutrients from the sediments, is estimated to be of the order of several years or less. Water quality model findings of insignificant difference between constant monthly and variable monthly point source loads are consistent with the estimates and observations of the literature. Based on the various lines of evidence, annually based point source reductions are considered to be sufficient to protect Chesapeake Bay water quality; this is an important consideration for establishing point source discharge permits.

Observations from the Literature

Residence times of water, estimated by an ‘age of water’ model analysis, are on the order of three to four months for waters in the upper Bay (CB1TF) or the tidal fresh Potomac (POTTF) (Wang, 2003). Waters of the lower Chesapeake tributaries, such as the headwaters of the York River, have a residence time of about two months. The age of water analysis estimate is based on hydrodynamic modeling of the Chesapeake using a Lagrangian subroutine to track a particular water source within a larger Eulerian hydrodynamic simulation. This gives a lower bound to the time that water and associated nutrient loads remain in the estuary, contributing in part to the Chesapeake Bay as an “integrator over time” of nutrient loads.

Nutrient residence times are longer than that of water. Nutrients are taken up by algae throughout the year, and once taken up, settle to the bottom to decay in the warmer summer waters, contributing to summer anoxia/hypoxia. Nutrient uptake in the winter and early spring is primarily by a concentric diatom phytoplankton community in the mesohaline region of the Bay. The annual peak of phytoplankton biomass, expressed as integrated water column chlorophyll *a* ($>1,000 \text{ mg/m}^2$), occurs in the early spring, driven by the high flows and nutrient loads of the spring freshet (Harding et al., 2002). “The

organic material of spring bloom origin subsequently provides the organic substrate for development of a robust microbial community whose metabolic activities deplete oxygen (O₂) while regenerating nutrients that support a summer phytoplankton community” (ibid.). Estimates of the magnitude of nutrient regeneration from bottom sediments expressed as a percentage of the annual terrestrial plus atmospheric inputs is given by Boynton et al. (1995) as 55% to 233%, and 44% to 214%, for nitrogen and phosphorus respectively.

Bottom nutrient releases come from organic nitrogen and phosphorus that have been deposited over a period of at least two years. Boynton et al. (1995) estimated “...annual mean pool sizes for nitrogen and phosphorus in the water column, sediments (top 5 cm of the sediment column), and biota ... for the 1985-1986 period ... to have 87% of the TN in the sediments, 12% in the water column, and <1% in the biota. Stocks of TP are similarly distributed, but sediment stocks are even more dominant.” Boynton et al. considered the upper 5 cm of the sediment to be as important as the first few millimeters because of mixing of the upper layers of sediment by bioturbation and resuspension.

From this, it is clear that summer anoxia is the result of organics, primarily from algal primary production, which deposit in sediments throughout the year, with peak algal biomass generated in the spring bloom. Organics from algal primary production are stored in Chesapeake sediments throughout the year and between years. “These results suggest that the coupling between nutrient loading, water column production of organic matter, and recycling of nutrients from sediments occurs over time scales of about several years or less” (Boynton et al., 1995).

Estimates from the Model

The complex movement of water within the Chesapeake Bay, particularly the density-driven vertical estuarine stratification, is simulated using a Chesapeake Bay hydrodynamic model (CH3D finite-difference hydrodynamic model) of more than 13,000 cells (Johnson et al., 1993). The Water Quality Model (CE-QUALICM finite-volume water quality model) is linked to the hydrodynamic model and uses complex nonlinear equations describing 26 state variables of relevance to the simulation of dissolved oxygen, water clarity and chlorophyll *a* (Cercio and Cole, 1994). Coupled with the Water Quality Model are simulations of settling organic material sediment and its subsequent decay and the flux of inorganic nutrients from the sediment, as well as a coupled simulation of underwater Bay grasses in the shallows. The model is run for 10 years using 1985-1994 hydrology, with 15-minute time-step and outputs of daily or monthly water quality. The 2002 version (13,000 cells) three-dimensional Chesapeake Bay Estuary Model (CBEM) is applied in this analysis.

A model run to examine the differences between a constant monthly load and a variable monthly nitrogen load, but each at the same annual load levels, was completed. The constant monthly discharge estimate is based on a management

scenario (Tier 3) which assumes a level of point source loads based on a constant 5 mg/l TN discharge applied against point source flow. The variable monthly load scenario is based on records of 54 Chesapeake Bay sewage treatment plants (STPs) which use Biological Nutrient Removal (BNR) treatment and have complete monthly records. The total nitrogen average concentration for each month of the 54 BNR STPs (which annually achieved about an 8 mg/l average concentration) was calculated and then converted to a concentration that would be at the same level of annual loads as the constant 5 mg/l case, yet still preserve the observed monthly variations. Monthly changes in flow were also taken into account. The variation in monthly concentrations calculated with this method varied from a low of 3.76 mg/l in August to a high of 8.46 mg/l in January. The derived monthly variation, equivalent on an annual basis to the constant 5 mg/l monthly loads, was applied to all point source dischargers in the Chesapeake watershed. To compare the two scenarios, recently developed water quality criteria were used. Water quality results of the two scenarios were indistinguishable. No difference was seen in the achievement of Chesapeake water quality criteria.

A similar model run was made with variable monthly total phosphorus loads from STPs. The variable monthly load was based on the variation seen in the 2002 discharged loads of phosphorus, which varied from a low of 0.86 of the Tier 3 constant STP load in January, to a high of 1.10 of the Tier 3 constant STP load in June. The monthly variable load scenario had the same annual load as the Tier 3 scenario. As with the scenario of variable monthly nitrogen loads, no difference was seen in the achievement of Chesapeake Water quality criteria between the scenarios of constant or variable TP monthly loads.

Application

The EPA has developed water quality criteria for DO, clarity, and chlorophyll designed to protect water quality in Chesapeake Bay and its tidal tributaries (U.S. EPA, 2003). The main cause of water quality impairment for these parameters in the main stem of the Bay is loading of nutrients, specifically nitrogen and phosphorus, from point and non-point sources throughout the entire Chesapeake Bay watershed. The EPA is in the process of developing wasteload allocations for point sources discharging into the Bay and its tributaries that are designed to protect water quality in the main stem of the Bay.

Establishing appropriate permit limits that implement these wasteload allocations for discharges that cause, have the reasonable potential to cause, or contribute to excursions of water quality criteria for the main stem of Chesapeake Bay is different from setting limits for other parameters such as toxic pollutants. This is due to: 1) the exposure period of concern for nutrients loadings to this part of the Bay is very long; 2) the area of concern is far-field (as opposed to the immediate vicinity of the discharge); and 3) the average pollutant load rather than the maximum pollutant load is of concern. Thus,

developing appropriate effluent limitations requires innovative implementation procedures.

The present paper does not address wasteload allocations to meet other water quality standards in areas outside of the major Chesapeake Bay segments. This approach also does not apply to parameters other than nitrogen and phosphorus that may exhibit an oxygen demand to other waters of the Bay, such as dissolved oxygen, biochemical oxygen demand, and ammonia among others.

Of course, all local water quality standards apply and must be met when evaluating appropriate point source permit effluent limits. State water quality standards for nutrients to be applied to local waters are being developed as stand-alone criteria. In any case, where the nutrient wasteload allocations for protection of water quality in a river, tributary, or other part of Chesapeake Bay are expressed as a shorter term criterion, i.e., seasonal, monthly, weekly or daily values, the permit limits that derive from and comply with that wasteload allocation designed to protect those criteria must be used. Shorter averaging periods might be appropriate and necessary to protect against local nutrient impacts in rivers or streams in the basin.

Additionally, it is important to note that the nutrient dynamics of the Bay may not be unique, so the establishment of an annual limit with a similar finding of “impracticability” (pursuant to 40 CFR 122.45(d)) may be appropriate for the implementation of other nutrient criteria in other watersheds where attainment of the criteria depends on long-term average loadings rather than short-term maximum loadings. Annual limits may be considered when technically supportable with robust data and modeling as they are in the Chesapeake Bay context, and appropriate safeguards to protect all other applicable water quality standards are employed.

The nutrient dynamics of Chesapeake Bay are complex. Unlike toxics and many conventional pollutants that have a direct and somewhat immediate effect on the aquatic system, nutrients have no direct effect, but instead are ‘processed’ in several discreet steps in the Bay ecosystem before their full effect is expressed. Each processing ‘step’ further delays and buffers the time between the time of nutrient discharge in an effluent and the resultant nutrient effect on the receiving water body. More specifically, nutrients are taken up by algae throughout the year, and once taken up, settle to the bottom to decay in the warmer summer waters, contributing to summer anoxia/hypoxia. Thus, summer anoxia is the result of organics, primarily from algal deposition, which accumulates throughout the year, with peak algal biomass generated in the bloom of early spring, and that these organics are stored in Chesapeake Bay sediments throughout the year and between years. Chesapeake Bay’s biological and physical processes can be viewed as ‘integrating’ variations of nutrient load magnitude over time. The integration of nutrient loads from all sources over time ameliorates intra-annual load fluctuations from individual sources, with the

Bay responding to overall loads on an annual scale, while showing little response to monthly variations within an annual load.

The NPDES regulations at 40 CFR 122.45(d) require that all permit limits be expressed, unless impracticable, as both average monthly limits (AMLs) and maximum daily limits (MDLs) for all dischargers other than publicly owned treatment works (POTWs), and as average weekly limits (AWLs) and AMLs for POTWs. For nutrient effects in the main stem of the Bay, the long-term average loading rather than short-term maximum loadings are of concern. As the results of the water quality modeling of point source loading of nutrients in the Chesapeake Bay indicated, effluent limitations for nitrogen and phosphorus expressed as daily, weekly or monthly averages would provide no additional value for the protection of water quality standards of the main Bay.

Conclusions

The literature is replete with descriptions of Chesapeake processes that integrate or ameliorate fluctuations of nutrient loads over relatively short periods of time, responding to the total load over time rather than short term variations. The Chesapeake integrates variable monthly loads over time, so that as long as a particular annual total load is met, constant or variable *intra-annual* load variations appear to be relatively inconsequential.

A cautionary note here is warranted. The integration of nutrient loads over time is seen at the scale of the model analysis of the water quality criteria which uses about seventy large-scale regions of the Bay to examine water quality effects. Smaller scales, such as embayments and smaller tributaries, were unexamined. Of course, all local water quality standards apply and must be met when evaluating point source annual permit limits.

Resident times of water based on 'age of water analysis' estimate that a parcel of water would take more than several months before being discharged at the Bay mouth. Nutrient mass balances of the Chesapeake estimate that coupling between nutrient loading, production of organic matter, and recycling of nutrients from the sediments occurs over time scales of several years or less. Model scenario findings of insignificant differences between constant monthly and variable monthly point source loads are consistent with the estimates and observations of the literature. Based on the various lines of evidence, and at the scales applied to examine Chesapeake water quality criteria, annually based point source nutrient reductions are sufficient to protect Chesapeake Bay water quality.

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Lewis C. Linker
Modeling Coordinator
U.S. EPA Chesapeake Bay Program Office
410 Severn Avenue
Annapolis, MD 21403
Ph (410) 267-5741
Fax (410) 267-5777
linker.lewis@epa.gov

**FUZZY JUDGMENT: THE PROCESS OF INCLUSION AND
EXCLUSION OF COASTAL RESOURCE USERS IN FISHERIES
CRITERIA-INDICATOR DEVELOPMENT**

Merlina N. Andalecio, Dalhousie University

Abstract

Coastal resource users play a significant role in the development of criteria and indicators for fisheries management. As direct recipients of management, they may be considered as the best evaluators of fisheries criteria and indicators. The judgment of coastal resource users on the importance of five criteria and twenty-four indicators in evaluating the impacts of fisheries management strategies in coastal municipalities of a Philippine bay was assessed using the Analytic Hierarchy Process (AHP). AHP, developed by Saaty (1980), determines the measure of importance of criteria and indicators through pairwise comparisons. The degree of consistency in the judgment was measured through a consistency ratio (i.e. a 10% or less consistency ratio is considered acceptable). What happens then when the judgment of resource users does not satisfy this acceptable level?

This paper discusses the process of selecting which measure of importance of the criteria and indicators from among the groups of resource users should be considered in the final evaluation of impacts when inconsistencies in judgment exist. Two approaches in dealing with this difficulty were recommended: 1) Select only the group or groups in each municipality whose consistency ratio is 10% or less in at least one of the criterion indicators and overall criteria, or 2) Application of a non-metric Multidimensional Scaling (MDS) technique.

**A WORLD OF LEARNING IN COASTAL MANAGEMENT:
CRAFTING NESTED GOVERNANCE SYSTEMS IN A CHANGING
WORLD**

Donald D. Robadue, Jr., University of Rhode Island
Lynne Z. Hale, The Nature Conservancy
Don Seville, The Sustainability Institute

Over the past 35 years, there have been more than 700 international, national and sub-national initiatives, programs and projects that attempt to more effectively govern the world's coastal and marine ecosystems. The need for communication and sharing knowledge among groups working to improve coastal governance is widely acknowledged, however a greater emphasis upon the dissemination, integration and analysis of this growing body of experience is required.

The Coastal Resources Center recently completed an exploration of its own experience through an international gathering in November, 2002. The World of Learning workshop brought together coastal managers to discuss work from seven countries: Ecuador, Kenya, Indonesia, Mexico, Sri Lanka, Tanzania, and Thailand over the period from 1985 – 2003. These Coastal Resources Management Project, CRMP, country case studies are described in more detail in *Crafting Coastal Governance*, (Olsen, S. ed., 2003).

The term “nested governance system” is used to refer to the situation where “management power and responsibility [are] shared cross-scale, among a hierarchy of management institutions, to match the cross-scale nature of management issues” (Folke, et. al., 1998). Each CRMP country has a hierarchy of authority, more or less centralized, more or less capable, and more or less democratic and open to the voices of stakeholders. What all CRMP programs have in common is success in working across and through these levels, usually at the same time, in a loosely coupled but nonetheless mutually supportive way. This key element is part of what the “I” means in integrated coastal management, (ICM).

The dynamic interplay among local, regional and national levels is a common thread in each of the country program stories told during the World of Learning week. The flow of information and resources among and between layers of government, the economy and the social fabric of places is what sparks a village to create its own marine protected area (MPA), for example, in Blongko, North Sulawesi, Indonesia. It is also how the idea spread in just a few years to dozens of other villages in the province, and is now supported by a new provincial government law encouraging all of the 150 villages of North Sulawesi's Minahasa district to prepare a coastal management strategy.

What Drives Local Project Success?

CRMP program managers identified several key factors needed to change the behavior to achieve local success, as illustrated in Figure 1. These factors are:

- (A) It is important to work on problems that are of compelling importance or offer a potential benefit.
- (B) An engaged local team must be formed that is skilled enough to build a plan based on reliable knowledge. Capable local participation and capacity building to create local forums and leadership are also required.
- (C) The idea that a local action plan or strategy is needed might be based on perceived threats to an already good situation, or the perception, perhaps much delayed, that resources and quality are degraded to such a state that something must be done to prevent further loss, or to restore or otherwise improve conditions.
- (D) A project aimed at assisting a coastal village must inevitably promote behavior that is consistent with the plan and discourage behavior that is not.
- (E) Through changed behavior, a village or site can claim local project success—more healthy, productive lives for their residents, and the sustained flow of natural and economic goods and services. All this work takes time and is subject to delays, missteps, missed opportunities and the possibility that over time other forces will overwhelm even best efforts to establish a local vision for conservation or restoration. Success at the local level depends in part on building strength at other levels.

The Value of Outside Support

Projects depend on support from outside their immediate locale. This is true whether a project is comprised of site-based conservation in an area of critical concern, area-wide planning for a coastal ecosystem supporting a variety of uses, or a demonstration site that may be scaled up at a later time. Useful support can be in the provision of a catalyst role and leadership, contributions of funds, and sharing know-how, information, staff, and access to decision-makers. Outside support can also aid in removing political, legal or administrative obstacles.

CRMP project managers identified important enabling conditions for local success, as shown in Figure 2.

- (F) National leadership has made an important difference in CRMP projects. Sri Lanka, with one of the oldest coastal management programs in developing countries, has always maintained a strong national presence with experienced

leadership. It has assured the continuation of this by supporting the education, training and advancement of junior staff. As a regulatory program, its staff has always been involved in local decision-making. The need for local special area management plans was clearly recognized in the national coastal management plan. Thus, subsequent efforts to carry out this policy in Hikkaduwa and Rekawa Lagoons had the full support of the Coast Conservation Department staff.

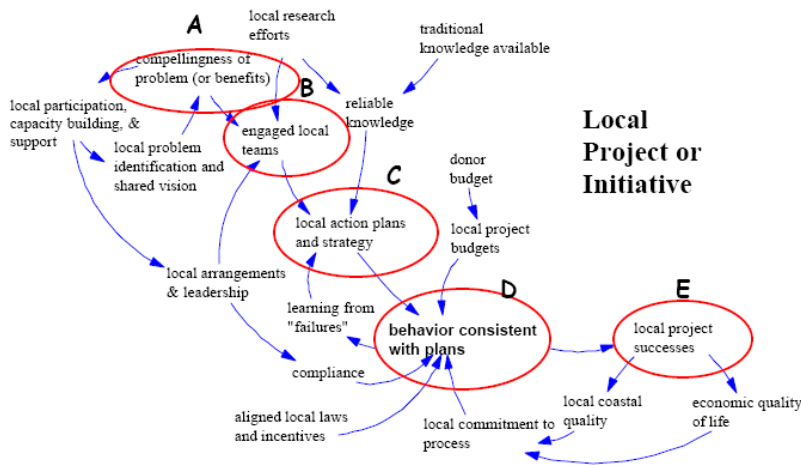


Figure 1. Factors that contribute to local success in coastal management

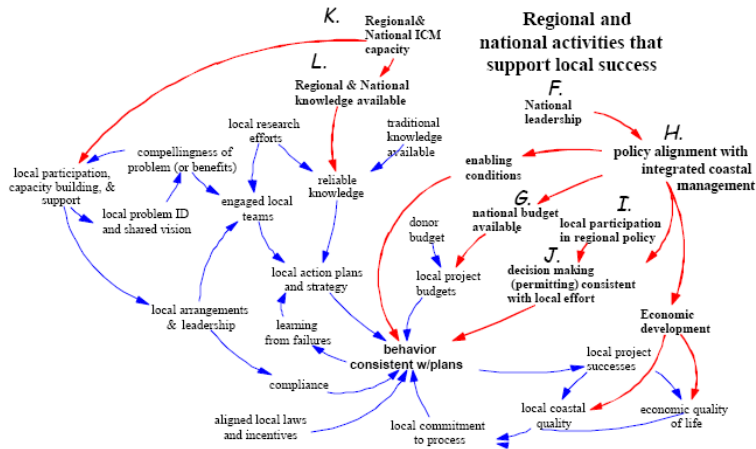


Figure 2. Regional and national activities that support local success

(G) Regional and national governments and organizations can play a key role in obtaining funding to start local initiatives and sustain larger programs that

provide resources for enhancing local success. In Mexico, international efforts to sustain the oversight committee meetings for the Costa Maya tourism corridor's environmental plan implementation were initially resisted by local, and state officials. They did not see why citizen groups should play a prominent role in official business. However, municipal elections brought in a new administration that supported citizen involvement, and initiated a complementary municipal shore management program.

(H) CRMP initiatives have taken many different approaches toward achieving a better connection between local, regional and national policy and public administrative frameworks. The National Coastal Management Strategy in Tanzania was approved in December 2002, providing a crucial strengthening of the district action planning already underway in Pangani, Bagamoyo, and Mkuranga. The district action plans are being carried out under guidelines established by the coastal partnership. These include substantive process and national consistency provisions along with financial support.

(I) Local participation is needed in regional policy-making. In some CRMP countries, national environmental policies and plans are complemented by more detailed programs at a state or regional level. Mexico's federal and state environmental laws require public involvement to formulate MPAs and land use ordinances at lower levels. These are the key governing policies for coastal development, as well as in the designation and management of marine and terrestrial protected areas. In the case of MPAs, a good example is the Xcalak Marine Park. The park was initiated locally and engaged the community in every subsequent stage of proposal preparation, management plan development, and oversight of park operations.

(J) National level decision-making (permitting) needs to be consistent with local policies. Many national governments are actively exploring how to place more decisions closer to the local level and reduce the costs of national bureaucracy. ICM often involves centralized national decision-making because coastal and marine resources are often common property resources held in public trust. CRMP projects illustrate very specific, practical measures being taken to foster decentralization. Tanzania has set national guidelines that made substantial progress in shaping future local decisions on mariculture and tourism—two key sectors capable of adversely changing local environmental quality, but which offer great economic potential.

(K) Regional and national-level commitment to training in ICM has made important contributions toward building local capability. This helps both site-based projects and future expansion of coastal management to other local areas. Indonesia's Proyek Pesisir has made an important investment in building the organizational capacity of the Ministry of Marine Affairs and Fisheries, which was formed out of bureaus from several different agencies. Universities and even private groups of stakeholders are attempting to fill the capacity gap.

(L) Traditionally, in most countries information flows upward to government or inward to academic researchers at a more rapid pace than it flows out. All CRMP programs have actively tried to counteract this direction of flow to relieve a major constraint on the ability of locally initiated programs to succeed. The Tanzania program recognized local efforts through its very popular annual Coastal Environmental Awards Scheme.

Are CRMP Countries Able to Build the Nested Systems they Need to Bring their Fledgling Pilot Projects to Full Programs?

The answer in a word is: Yes. All coastal management needs to show that a material difference is being made in resources and flows of benefits that are being conserved, protected and, where necessary, restored. Coastal managers need to look outside the immediate situation in a specific place for both potential beneficiaries and political, technical and financial ingredients of success. Bringing a group of practitioners to work closely together to sketch out a common road map from their various experiences, as happened during the World of Learning events, is a fruitful way to explore each country's experience for clues, hints, reminders, and insights into what might work to improve governance at home.

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Donald D. Robadue, Jr.
Associate Coastal Resources Manager,
Coastal Resources Center, Graduate School of Oceanography,
University of Rhode Island
South Ferry Road, Narragansett, RI 02882
Ph (401) 874-6128
Fax (401) 789-4670
e-mail: robadue@gso.uri.edu
<http://www.crc.uri.edu>

PANEL

MANAGING THE LOBSTER COMMONS: THE IMPORTANCE OF INFORMAL RULES

James M. Acheson, University of Maine

The Maine lobster industry is one of the world's most successful marine fisheries at present. The record high catches may be attributed in great part to state laws, which are effective in conserving the resource. Behind this successful management program is the existence of informal boundary rules and limited entry rules. These decentralized institutions make it possible for fishermen to monitor and sanction those who violate rules. They also give fishermen an incentive to support conservation rules by ensuring that those who sacrifice to maintain the resource will get most of the benefits. Boundary rules and limited entry rules are far more important for the management of common-pool resources than is generally recognized in the literature on common-pool resource management.

SPECIAL THEME SESSION

THE STATE OF SOCIAL SCIENCE AND MARINE PROTECTED AREAS

Sarah Lyons, National MPA Center Science Institute, Patrick Christie, University of Washington, Ana Spalding, National MPA Center Science Institute

Abstract

The human dimension plays a large role in the effectiveness of coral reef marine protected areas (MPAs). However, the social sciences are often overlooked in the planning, management and evaluation of these MPAs. There is a need for understanding the social, cultural, and economic contexts in which policy maker's conservation decisions will be applied. This session will focus on the current state of social science research as it relates to MPAs. Three presentations will address this topic from various perspectives. Patrick Christie, University of Washington, School of Marine Affairs, will present *Toward developing a complete understanding: A social science research agenda for marine protected area*, a paper recently published in *Fisheries*. Ana Spalding University of Miami, RSMAS/ National MPA Center Science Institute will present an analysis of the gaps and information needs identified to date in the MPA Center's regional social science workshop series. Sarah Lyons, National MPA Center Science Institute, will discuss current issues and efforts relating to the development of national and regional social science research capacities. The presentations will be followed by a facilitated, interactive discussion with the audience members about building the national capacity in respect to integrating social science research into the planning, management and evaluation of MPAs.

**USING SOCIAL ECOLOGY TO ENHANCE COASTAL RESOURCE
MANAGEMENT: ALIGNING COMMUNITY AND AGENCY
INTERESTS**

Kevin Preister, James A. Kent and Kristine Komar, James Kent Associates

Abstract

Social Ecology is the process of enhancing productive harmony between the human and physical environment, as called for in the National Environmental Policy Act (NEPA). This session explores well-developed methodologies for creating community support and consensus for coastal resource management. Used extensively by the Bureau of Land Management and the U.S. Forest Service in the West, social ecology gets below the polarization and the domination by extremist voices that are so common to environmental management. By focusing on informal levels of community, and the human geographic boundaries within which people organize their everyday lives, specific opportunities are identified for incorporating good science into local wisdom and for aligning community and agency interests. Such an approach requires a bio-social perspective in which both community and environmental health are equally important, and also requires that the proponents of public initiatives develop professional capacity for community-based approaches through mutual education and action with local residents. The session is designed in workshop format to be interactive and to include strategies to incorporate social ecological concepts back in the local settings of the participants.

WATER MASS AGES OF RHODE ISLAND COASTAL WATERS ESTIMATED USING ^{223}Ra AND ^{224}Ra AS TRACERS

Andrea L. Hougham, Graduate School of Oceanography,
University of Rhode Island
S. Bradley Moran and Roger P. Kelly, Graduate School of Oceanography,
University of Rhode Island

Abstract

The naturally occurring radium isotopes ^{223}Ra ($t_{1/2}=11.1$ days) and ^{224}Ra ($t_{1/2}=3.6$ days) are useful tracers of coastal water age due to their known sources and sinks. Surface and pore water samples were collected quarterly in five southern Rhode Island lagoons (Winnapaug, Quonochontaug, Ninigret, Green Hill, and Pt. Judith/Potter Ponds) from January 2002 through July 2003, and surface water samples were collected monthly in Narragansett Bay from October 2001 through January 2004. Measured ^{223}Ra and ^{224}Ra activities were combined with a simple box model to provide estimates of water mass age ranging from 1-20 days for the southern Rhode Island lagoons and Narragansett Bay. These results are within a factor of two of previously reported values for these coastal ponds and Narragansett Bay.

Introduction

Quantifying the residence time of Rhode Island's salt ponds and Narragansett Bay is important to understanding the sensitivity of these systems to contaminant inputs and planning future coastal land use. Tracer-based estimates of water mass residence time also provide independent constraints for numerical models of coastal water circulation and transport of dissolved materials across the land-sea margin (Nixon, Ammerman et al. 1996; Dettmann 2001; Kincaid, Pockalny et al. 2003).

Previously published residence times for Rhode Island waters include both models and direct flow measurements (Pilson 1985; Desbonnet and Lee 1996; Kincaid, Pockalny et al. 2003). A recent year-long study of the Pettaquamscutt River-Estuary indicated that radium isotopes are useful tracers of water movement in the shallow coastal waters of Rhode Island (Kelly and Moran 2002). In this study, dissolved radium activities were measured in the coastal surface and pore waters of southern Rhode Island for a period of 18 months in order to obtain estimates of water mass age on a seasonal and interannual basis.

Study Sites

The salt ponds of southern Rhode Island are shallow (less than 2 m), tidally flushed lagoons separated from the Atlantic Ocean by barrier beaches. The pond surface areas range from 1.5-6.4 km², and the watershed areas range from 11-75 km². Only three of the ponds have stream inputs (Ninigret, Green Hill, and Pt.

Judith Ponds). Narragansett Bay has an average depth of roughly 8 m, a surface area of 381 km², and a watershed area of 4,081 km². The three largest rivers entering Narragansett Bay are the Pawtuxet, Blackstone, and Taunton Rivers which enter at the northern half of the Bay.

Materials and Methods

Surface water samples (~100 L) and pore water samples (~10-20 L) were collected quarterly between January 2002 and August 2003 from Winnapaug, Quonochontaug, Ninigret, Green Hill, and Pt. Judith/Potter Ponds. Surface water samples were collected approximately every month between October 2001 and January 2004 from Narragansett Bay. Surface waters were collected using a bilge pump, stored in acid-washed cubitainers, and filtered using 1 µm polypropylene filter cartridges. Pore water was pumped to the surface through a 1 meter slotted, steel tube into acid-washed cubitainers, and filtered through 1 µm GF/B filters. Dissolved radium was quantitatively preconcentrated from the filtered samples by pumping the water through MnO₂ coated acrylic fiber at <1 L per minute (Moore 1976). ²²³Ra and ²²⁴Ra activities were determined to an average counting error of ±10% using a delayed coincidence counter (Moore and Arnold 1996).

Results

Surface water ²²³Ra and ²²⁴Ra activities in the salt ponds ranged from 1-51 dpm 100 L⁻¹ and from 6-406 dpm 100 L⁻¹ respectively. Pore water activities were 2-6 times greater than the surface water activities, ranging from 2-310 dpm 100 L⁻¹ and from 35-1,814 dpm 100 L⁻¹ for ²²³Ra and ²²⁴Ra respectively. Surface water ²²³Ra activities ranged from 1-7 dpm 100 L⁻¹, and ²²⁴Ra activities ranged from 3-50 dpm 100 L⁻¹. Seasonal variability was apparent in the ²²³Ra and ²²⁴Ra surface water activities with the highest values found during the spring and summer and the lowest values found during the fall and winter.

The activity ratios of ²²⁴Ra/²²³Ra for the salt pond surface waters were consistent through the study period (²²⁴Ra/²²³Ra = 1-20) with the exception of Winnapaug Pond, which showed greater variability (²²⁴Ra/²²³Ra = 1-65). The activity ratio for Narragansett Bay showed less variability (²²⁴Ra/²²³Ra = 3-10) with the exception being the 6/6/2002 samples (²²⁴Ra/²²³Ra = 10-20). Pore water activity ratios in the salt ponds remained constant through time (Green Hill ²²⁴Ra/²²³Ra=5-15; Quonochontaug ²²⁴Ra/²²³Ra=10-30; Pt. Judith ²²⁴Ra/²²³Ra=6-12), though there was considerable variability in these ratios for Ninigret (²²⁴Ra/²²³Ra=5-42) and Winnapaug Ponds (²²⁴Ra/²²³Ra=3-44).

Discussion

Water mass ages determined using ^{223}Ra and ^{224}Ra are the apparent ages calculated as the time elapsed since the water sample was isolated from the source (the sediment-water interface) (Moore 2000). Assumptions made using this method are: 1) the initial activity ratio in the pore water is both temporally and spatially constant; 2) there are no inputs or removals of radium, except for mixing or radioactive decay, once isolated from the source; and 3) shelf water contains negligible ^{223}Ra and ^{224}Ra . Using the isotopes ^{223}Ra and ^{224}Ra , water mass ages can be calculated using the following equation:

$$\left[\frac{^{224}\text{Ra}}{^{223}\text{Ra}} \right]_{\text{obs}} = \left[\frac{^{224}\text{Ra}}{^{223}\text{Ra}} \right]_i \frac{e^{-\lambda_{224}t}}{e^{-\lambda_{223}t}}$$

where $(^{224}\text{Ra}/^{223}\text{Ra})_{\text{obs}}$ is the activity ratio observed in the surface water sample corrected for shelf water inputs and $(^{224}\text{Ra}/^{223}\text{Ra})_i$ is the average initial pore water activity ratio. Solving this equation for t will provide the age of the water mass:

$$t = \frac{\ln \left[\frac{^{224}\text{Ra}}{^{223}\text{Ra}} \right]_{\text{obs}} - \ln \left[\frac{^{224}\text{Ra}}{^{223}\text{Ra}} \right]_i}{\lambda_{223} - \lambda_{224}}$$

The calculated water mass ages for each of the coastal basins studied are: Winnapaug = 3-9 days (avg = 6); Quonochontaug = 1-11 days (avg = 5); Ninigret = 1-20 days (avg = 12); Green Hill = 2-16 days (avg = 8); Pt. Judith/Potter = 1-11 days (avg = 7); Narragansett Bay = 1-20 days (avg = 8). The results indicate a separation in water mass age on a seasonal basis (Fig. 1). Calculated water mass ages were greater during 2003 than in 2002 for all sites.

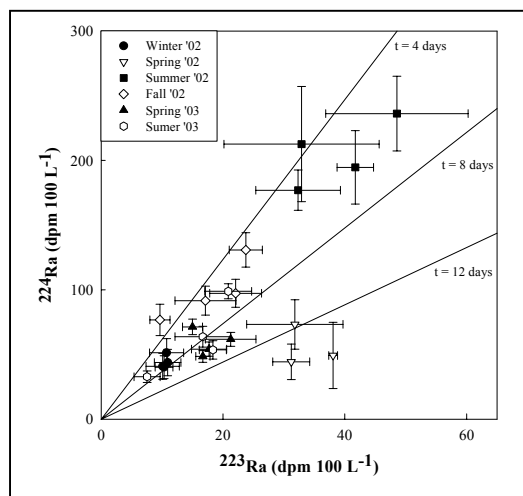


Fig. 1 Green Hill Pond surface water activities plotted as ^{224}Ra versus ^{223}Ra . Straight lines are modeled surface water ratios at time $t = 4, 8,$ and 12 days.

The radium-derived water mass ages calculated in this study are within a factor of two of previous studies (Fig. 2). Pilson (1985) calculated an average residence time for Narragansett Bay as 26 days with a range from 10-40 days depending on freshwater flow conditions. Kincaid et al (2003) used measured volume transports from the mouth of Narragansett Bay to estimate residence times for the bay ranging from 18-49 days in the summer and from 14-29 days in the winter. Desbonnet and Lee (1996) calculated tidal prism residence times for Ninigret Pond (5 days), Green Hill Pond (11 days), and Pt. Judith Pond (2 days).

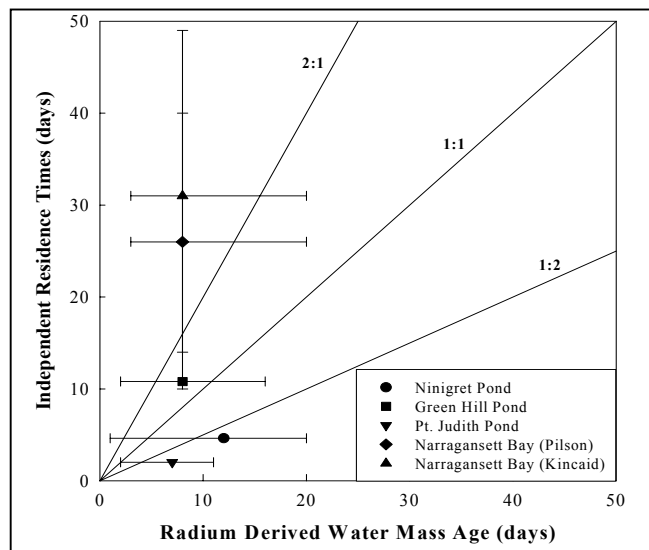


Fig. 2 Plot of independent residence times vs. radium derived water mass ages. The points represent the average values and the bars represent the range.

Conclusions

^{223}Ra and ^{224}Ra are useful tracers of water movement in the coastal zone due to their elevated activity in coastal waters and known sources and sinks. The results obtained in this study indicate that these radium isotopes can resolve age differences to within a few days. Radium-based water mass ages are within a factor of two of previously reported residence times.

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Andrea L. Hougham
Graduate School of Oceanography, University of Rhode Island
Marine Geochemistry Laboratory
URI Bay Campus Box 200
South Ferry Road
Narragansett, RI 02882 USA
Ph (401) 874-6259
Fax (401) 874-6811
ahougham@gso.uri.edu

**PANEL SESSION - THE INTEGRATED OCEAN OBSERVING SYSTEM
(IOOS): CONNECTING WITH COASTAL MANAGERS**

Geno Olmi, NOAA Coastal Services Center
Sandy Eslinger, South Carolina Sea Grant Consortium
Mike Hemsley, Ocean.US
Janice McDonnell, Rutgers University
Jan Newton, Washington State Department of Ecology

During the past few years, the National Oceanographic Partnership Program and the Ocean.US office have been developing a plan for implementation of an integrated national coastal and ocean observing system. The benefits of such a system are likely to include applications to address harmful algal blooms, coastal erosion, coastal storms, marine transportation and rescue, oil/pollution spill response, and fisheries management. While the data collected from ocean sensors may be applied to these and other issues, the potential value of an integrated ocean observing system will not be realized if the information is not applicable to the needs of various sectors in the coastal community and the information derived from ocean sensors is not delivered in appropriate (i.e., usable) forms.

Building on existing needs and assets, the Integrated Ocean Observing System (IOOS) is presently taking shape. It is important that members of the coastal community become involved in this development. This panel session at TCS19 will provide the audience with an update on the progress of designing and implementing the IOOS and provide examples where, on two fronts, people can become engaged in this development: ocean science education and the development of regional observing systems and regional associations. The panel session will conclude with an opportunity for questions and discussion.

The recent advent of coastal ocean observatories, and their ability to provide real-time oceanographic data, has created a unique opportunity to bring the ocean into classrooms around the world in a meaningful and effective way. This session will address efforts to design and deliver relevant ocean science education to diverse audiences, with an emphasis on translating data and information from coastal ocean observations into instructional materials and products for classroom educators and the public. Examples include educational projects that incorporate real-time oceanographic data, such as The C.O.O.L. Classroom, an online collection of interactive and interdisciplinary lessons based on the Rutgers University Coastal Ocean Observation Lab (C.O.O.L.) and the New Jersey Shelf Observing System (NJSOS), that was developed to bring cutting-edge oceanographic research, data, and technology directly to the classroom.

The panel session will also explore the rationale and status of emerging regional coastal and ocean observing systems and the Regional Associations that are designed to influence their direction and operation. Ocean.US has engaged coastal and ocean scientists and managers to develop an approach by which regional interests can be represented and merged with national needs for an integrated observing system. We will discuss results of a recent forum in which the formation and conduct of regional associations and a National Federation of Regional Associations was deliberated. The panel session will also highlight progress to date in two regions that are engaging scientists and members of the coastal community that have an interest in the information derived from observing systems in their region.

Geno Olmi
NOAA Coastal Services Center
2234 South Hobson Ave.
Charleston, SC 29405-2413
Ph (843) 740-1230
Fax (843) 740-1315
Geno.Olmi@noaa.gov

COASTAL RESOURCE ASSESSMENTS AT QUONSET-DAVISVILLE, RHODE ISLAND: LOBSTERS AND MARINE HABITAT

Tom Shinsky, Jeff Reidenauer, Bernward Hay, The Louis Berger Group, Inc.
Jeffrey Grybowski, Office of the Governor, State of Rhode Island

Introduction

Quonset-Davisville is a former U.S. Navy base located along the West Passage of Narragansett Bay, Rhode Island. The shallow depth of this part of the Bay required the dredging of a navigation channel between the deep Eastern Passage and the base in the early 1940's to provide access for aircraft carriers and other deep draft vessels. The base closed in 1992 and is now the property of the State of Rhode Island, which is reviewing various redevelopment options. Some port improvement alternatives may involve maintenance dredging or deepening of the existing channels. At present, active users of the marine facility include car import carriers and commercial fishing vessels. In order to assess potential impacts to marine resources at Quonset-Davisville resulting from port redevelopment, the joint venture of The Louis Berger Group, Inc. and the Maguire Group, Inc. (Berger/Maguire) was contracted to gather baseline data on these resources. Berger/Maguire conducted a remote video survey to characterize and map the seabed habitats potentially affected by port redevelopment. Berger/Maguire also performed a study of the American lobster (*Homarus americanus*) resource in the area.

Marine Habitat Mapping

The seabed around the Quonset-Davisville area consists primarily of soft sediments such as silt, clay, and sand (McMaster 1960). No cobble, gravel or other rocky bottom types occur in this area, and shell beds are the only hard substrate present. While the Rhode Island Department of Environmental Management has mapped ecologically significant marine habitats in Narragansett Bay such as eelgrass beds and winter flounder spawning areas, little is known about the types and distribution of seabed habitats in the Quonset-Davisville area. Earlier field studies in this area (Dzurenko 1998; Valente and Carey 1998; Pratt 1999) were limited to remote sampling programs consisting of benthic grabs, sediment profile imagery, and side-scan surveys, which are not able to characterize and provide the extent of macroalgal and macroinvertebrate habitats.

Berger/Maguire conducted a remote underwater video survey by towing a high-resolution color video camera along approximately 15 miles of transects through the study area. The video camera image was viewed in real-time by the camera operator and the vessel's position was imported onto the survey videotape. Dive lights were attached to the camera during the deeper transects, and two laser

pointers were also attached parallel to each other to provide a scale to the image. Habitats were evaluated by viewing the videotape and designating a habitat type based on the dominance of one of several sessile invertebrate species or the presence of distinct algal communities described below. Habitat types were designated at intervals of one to two minutes (over 700 locations) and the patterns of habitat distribution were used to create a habitat map of the seabed. The resulting habitat map was then laid over two-foot bathymetric data for the study area to discern correlations between habitat types and depth.

Macroalgae (green, red, and brown) are common in the study area from the shoreline generally out to a depth of 16 to 18 feet. The limit of macroalgal growth is shown by the red line in Figure 1. In this soft-bottom environment, most macroalgal growth is limited to beds of mollusk shells, which provide the only hard surface for attachment. In mid and outer Fry Cove and off of the Quonset Point bulkheads where shell beds occur, macroalgal diversity is high. Macroalgae which are common among these shell beds include *Codium fragile*, *Ulva latuca*, *Chondrus crispus*, and a variety of filamentous species. A habitat designated "brown algal complex" grows directly on the silt/sand seabed and on shells in areas of low wave energy, such as Fry Cove. This algal complex consists of fine filaments of a red/brown alga or algae and is found down to depths of approximately 12 feet.

A habitat type designated "algal mat" occurs off the bulkhead at the southern end of Fry Cove, in a valley reaching a depth of 26 feet; the valley was probably used as a borrow pit for construction of the adjacent airport. The seabed in this area is covered by a layer of what appears to be bluegreen algae. This layer consists of regularly spaced dark patches over a generally green background with occasional lightly colored patches, possibly of sulfide-producing bacteria. Silt-covered deposits of unattached macroalgae of numerous species are present, but neither invertebrates nor empty shells occur. Because this valley is much deeper than the maximum 13 foot depth of the natural contours of Fry Cove, this habitat likely has poor water circulation and low levels of dissolved oxygen. Currents and tides probably sweep detached bits of algae into this valley, where they slowly decompose. Pratt (1999) characterized the benthic community of this deep spot as "depauperate fauna". Analysis of sediment-profile imagery collected for this area (Valente and Carey 1998) showed that the depth of oxygen penetration here was only about 1/2 inch, and that there were indications of heavy organic loading.

In the soft seabed environment of the Quonset-Davisville area, slipper snails *Crepidula fornicata* commonly attach to empty clam shells and live mussels. This mollusk also occurs as dense beds consisting of masses composed of up to 10 or more individuals stacked on top of each other. *Crepidula* beds in the study area occur across the wide depth range from 4 to 28 feet, particularly in areas which are flat or only gently sloped. *Crepidula* beds cover much of the seabed in Fry Cove and along the airport bulkhead, and support considerable

macroalgal growth. Crustacean burrows, described below, are present among some of the deeper *Crepidula* beds.

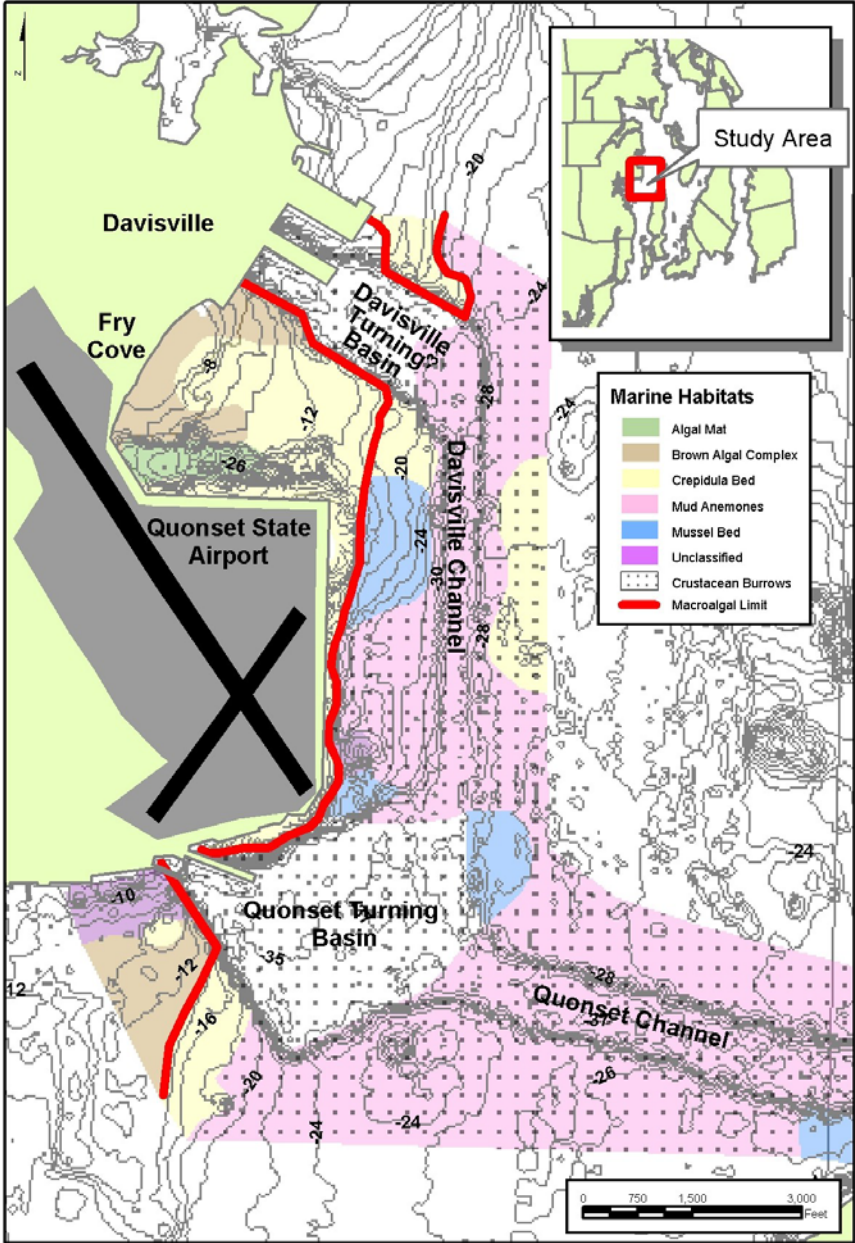


Figure 1. Seabed habitats in the Quonset-Davisville area.

Beds of the blue mussel *Mytilus edulis* are found in several exposed areas along the Davisville channel. These mussel beds occur from depths of 14 to 30 feet and are characterized by clumps of live mussels on the seabed, often on a background of empty mussel shells. Mussels are often covered with *Crepidula*, and in some spots, aggregations of sea stars and abundant scattered empty shells indicate high predation. Mussel beds occur deeper than the limit of most macroalgal growth in the study area. Spider and rock crabs are common among the clumps of mussels.

Most of the seabed in the Quonset-Davisville area deeper than 20 feet contains burrows excavated into the sediment by crustaceans. Burrow diameters range from one to three inches, and several burrow geometries were observed, all of which are found throughout the study area: vertical burrows penetrate perpendicularly into the seabed and have a circular opening from one to two inches in diameter; U-shaped burrows consist of two openings approximately an inch in diameter, which are usually located within a foot of each other; bank burrows enter the substrate at a near horizontal or gently inclined angle and have an irregular opening, and are generally have a diameter of two to three inches. During the survey, both mantis shrimp and lobster were seen in habitats with burrows, but no images were found to conclusively associate either species with a particular type of burrow.

Where slipper shell beds occur deeper than 20 feet, crustacean burrows may also be present. Most crustacean burrow habitats in the Quonset-Davisville area deeper than 25 feet also contain the mud anemone *Ceriantheopsis americanus*. This pale to reddish-purple anemone is one to two inches in diameter and constructs a tube of mucus, sand, and mud which it can withdraw into for protection. While anemones are common in the Davisville and Quonset channels and vicinity, they are not found in the turning basins, where the relatively steep basin walls may create a “dead end” effect of reduced water circulation along the bottom of the basins, resulting in conditions which do not support anemones. Pratt (1999) characterized both turning basins as “low diversity silt-clay fauna”.

Two areas surveyed lacked the characteristics of the macroalgal or macroinvertebrate habitats described above and so are portrayed as “Unclassified”. The largest unclassified area, west of the Quonset turning basin and adjacent to the shoreline, is exposed to strong southerly wave conditions.

Lobster Resource

The Quonset-Davisville area of Narragansett Bay supports a year-round commercial lobster fishery. The navigational channels in this area are approximately 10 feet deeper than the average 25 foot depth of the surrounding mid-West Passage and are the focus of much of the local lobster fishing effort. As dredging of these channels would likely impact the lobster resource, a

trapping study was conducted to characterize seasonal abundance trends and the use of channel habitat by lobsters. While both channels are approximately 35 feet deep, the Davisville channel is 500 feet wide and has a north-south alignment, whereas the Quonset channel is 1,000 feet wide and runs nearly east-west.

Local commercial lobster fishermen were chartered to set and haul lobster traps in the Davisville and Quonset channels and at reference stations located on the natural seabed in the study area. In order to catch juvenile lobsters, the regulatory escape vents of all traps were obstructed with trap wire panels. A Berger/Maguire scientist aboard the vessel conducted biological sampling on the catch. Information gathered included each trap's catch of legal, sublegal, and ovigerous (egg-bearing) lobsters as well as the incidence of shell disease. Approximately 110 lobster traps were set and hauled in the study area during each of seven sampling events conducted over a one year period. Over 1,600 lobsters were caught and sampled, revealing seasonal and spatial patterns of abundance, as well as trends in lobster sex ratios, reproduction, and shell disease. Comparisons of catches between the Quonset channel, the Davisville channel, and the reference stations were made using a single-factor analysis of variance. Comparisons between any two groups were made using a two-sample t-test.

Lobster abundance varied significantly between the seven sampling months in the study area, with peak catches occurring in late spring and summer and again in the fall. Total lobster catches in the Quonset channel and the reference stations were similar, and significantly higher than catches in the Davisville channel. Overall, lobster abundance in the study area showed a substantial increase between the summer of 2002 and the summer of 2003.

The average carapace length of lobsters caught during the survey was 74 mm, which is well below the legal size minimum (presently 86 mm), demonstrating the importance of the Quonset-Davisville area as juvenile lobster habitat. The size of lobsters in the Davisville channel, Quonset channel, and reference stations was not significantly different. During all sampling months, sublegal lobsters (defined as having a carapace length of 82 mm or less, which was the legal requirement at the start of the study) were significantly more abundant than legal lobsters in both of the channels and at the reference stations, comprising 84% percent of the overall catch.

The catches of sublegal lobsters in the Quonset channel and at the reference stations were similar, and significantly higher than sublegal catches in the Davisville channel. Likewise, the catch of legal lobsters in the Quonset channel and reference stations was similar, and significantly higher than that in the Davisville channel. Based on this, the Quonset channel and reference stations appear to represent similar lobster habitats, while the Davisville channel appears to be less productive lobster habitat.

Male lobsters dominated the catch in the Quonset-Davisville area, accounting for over two-thirds of the overall catch. Significantly more males were caught than females in both of the channels and at the reference stations. The proportion of males caught in each of these three areas was similar, as was the proportion of males caught during each sampling month.

Overall, 9% of female lobsters caught during the Quonset-Davisville survey were ovigerous (egg-bearing). Eighty-seven percent of ovigerous lobsters caught in the Quonset-Davisville area were sublegal, indicating the important role of sublegal lobsters in egg production in the area. The catch of ovigerous lobsters was not significantly different between sampling months or between the three study areas.

Shell disease affected 16% of lobsters in the Quonset-Davisville area. In September of 2002, shell disease was uncommon in all lobster categories, but it increased substantially throughout the winter and spring, and by May 2003, over 30% of lobsters were infected. By August 2003, most lobsters had molted out of the infected shells, reducing the incidence of disease to near levels seen a year earlier. Shell disease was especially high among ovigerous females, with 52% of this group infected overall during the study.

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Jeff Reidenauer
The Louis Berger Group, Inc.
Environmental Sciences Division
100 Halsted Street
East Orange, NJ 07018
Ph (973) 678-1960
jreiden@louisberger.com

CIRCULATION AND WATER QUALITY ASSESSMENT AT QUONSET-DAVISVILLE, RHODE ISLAND

Craig Swanson and Paul Hall, Applied Science Associates, Inc.
Malcolm Spaulding, University of Rhode Island
Bernward Hay, The Louis Berger Group, Inc.
David Tremblay, Office of the Governor, State of Rhode Island

Introduction

Quonset-Davisville is a former U.S. Navy facility located on the western shore of Narragansett Bay in Rhode Island. At present, active users of the marine facility include car import carriers and fishing vessels. Recently, deepening of the access channel in the bay was planned as part of a (now discontinued) plan to construct a container port at the facility. As part of this plan, baseline circulation and water quality data were collected in preparation for an Environmental Impact Statement (EIS), with the goal of minimizing potential impacts. This study characterizes circulation and water quality in the vicinity of Quonset-Davisville using an approach that combines an extensive hydrographic field survey with hydrodynamic modeling.

Field Survey

The field program was designed to provide a baseline set of environmental data to characterize the existing dynamics of the Quonset-Davisville channels and to supplement historical circulation and water quality data. Furthermore, data acquired from the field program were used to calibrate the hydrodynamic and water quality models. The field program consisted of three components: hydrographic moorings, vertical hydrographic profile survey, and Acoustic Doppler Current Profiler (ADCP) deployments (Figure 1).

Temporal variations in water properties were investigated using two hydrographic stations moored in the study area (Moorings A and B). The moorings were deployed between August 2002 and December 2003. Water level, water temperature, salinity, dissolved oxygen (DO), pH, turbidity and chlorophyll were recorded at 15-minute intervals throughout the deployments.

Spatial variations in water properties were investigated through a series of synoptic surveys in which vertical profiles of temperature, salinity, density, DO, pH, turbidity and chlorophyll were measured at 13 stations in the study area (Figure 1). A total of 22 vertical profile surveys were conducted between September 2002 and December 2003.

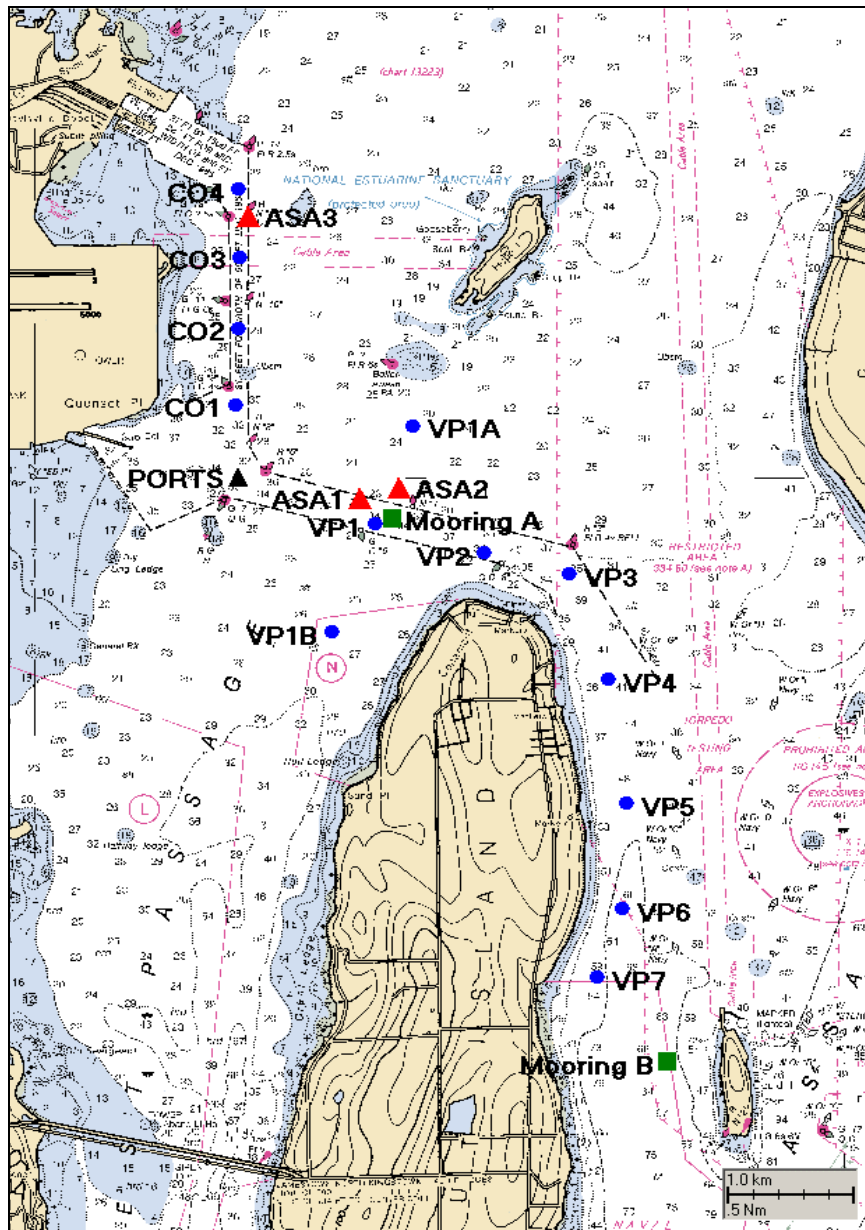


Figure 1. Map showing locations of instruments and sampling stations. Green squares are moorings, blue circles are vertical profiling stations, and red triangles are ADCP deployment sites. The Quonset-Davisville channels and turning basins are outlined by the dashed lines.

Spatial and temporal variations in currents were investigated through three deployments of a 600 kHz RD Instruments ADCP current meter. Deployments took place from 12 Nov – 19 Dec 2002 (ASA1), 10 – 29 March 2003 (ASA2) and 4 Sep – 5 Oct 2003 (ASA3). Additional data were obtained from a second ADCP located within the Quonset turning basin, and operated as part of the National Oceanographic and Atmospheric Administration PORTS system.

Analysis of data from the field survey revealed that tidal currents at the semidiurnal frequencies and their harmonics provide most of the energy in the current record. Tidal flow is typically ebb-dominant, with shorter ebb tide times but higher velocities. Little variation is seen in the magnitude of the tidal currents with depth. Near-surface currents move largely in response to the wind at subtidal timescales. The magnitude of this non-tidal current decreases and its direction rotates clockwise with depth.

Salinity increased both with depth and with distance down the bay from Quonset-Davisville. On average, the difference in salinity throughout the water column in the Quonset channel was 2.3 ppt. This difference varied seasonally, with a larger salinity gradient existing during the summer and a smaller gradient in the winter, consistent with higher degrees of stratification in the summer and more mixing in the winter. Because there was no strong gradient in salinity or density along the length of the channel, baroclinic flows in the channel bottom waters were weak or absent.

DO concentrations exhibited seasonal variations, with relatively high values registered in the winter while concentrations were relatively low in the summer, largely reflecting the inverse relationship between the solubility of oxygen in water and temperature (Figure 2). A small seasonal signal remained in the percent saturation representation, with DO values falling significantly below saturation values during the summer months at all depths. This decrease in DO was related to increased biological activity during the summer months and the stable stratification of the water column. These conditions prevented surface water, which is in equilibrium with the atmosphere and therefore generally rich in oxygen, from mixing downward into the water column. Very low levels of DO were observed during two periods in the summer of 2003 (4 – 18 July, 11 Aug – 3 Sep). During these events, Rhode Island Sound water entering the bay along the bottom of the main shipping channel, as observed at Mooring B, was more oxygenated than either surface or mid-depth waters. It is possible that this deep, relatively oxygen-rich water may actually mitigate some of the effects of low DO higher up in the water column.

Values of turbidity were typically low with slightly higher values measured near the bottom. In general, the low turbidity values indicate that there is little sediment transport in the Quonset-Davisville channels, consistent with studies indicating channel sedimentation averaged 13 to 25 mm/yr over the last 50 years (Berger/Maquire, 2003).

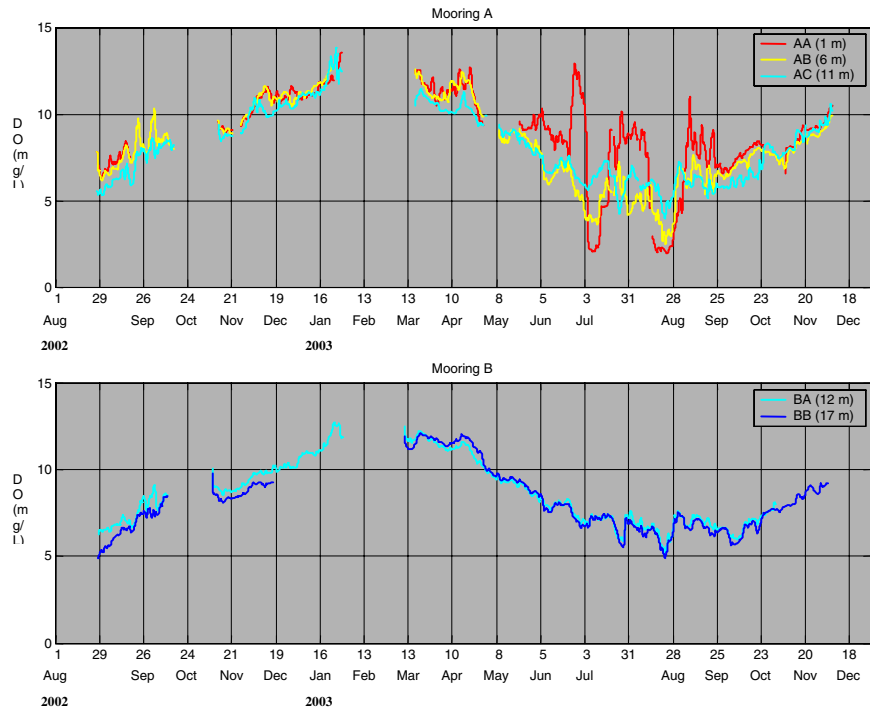


Figure 2. Dissolved oxygen (DO) concentration recorded at Moorings A and B at different water depths during the field survey. Data has been low-pass filtered at 40 hours to remove the tidal signal.

Modeling Study

A computer modeling study was undertaken to predict changes in circulation and water quality if the present Quonset-Davisville channels and turning basins were deepened. ASA's WQMAP system, an integrated series of hydrodynamic, eutrophication and sediment transport computer models (Spaulding et al., 1999), were used to predict currents, salinity, DO, and sedimentation in the study area. These models were calibrated and verified to the data collected during the field program. The calibration and verification process were conducted to ensure a good fit between model predictions and observations. The results were within established guidance criteria.

Simulations for the deepened channel geometry predict that tidal currents, expressed as the M2 current amplitude, decrease by about 2.8 cm/s (20% reduction) near the surface and about 0.4 cm/s (4% reduction) at the bottom compared to the present channel. These differences are small and indicate that

channel deepening would have little effect on tidal circulation. The difference in tidal velocities between the present and the dredged channel decreased with increasing distance from the channel. However, the mean of the total current speed at the channel bottom increases from approximately 5 cm/s in the present configuration to 8 cm/s when the channel is deepened.

The mean salinity in the deepened channel increases by approximately 0.5 ppt (less than 2%) relative to the salinity in the present channel. The predicted salinity difference outside of the dredged channels is less than 0.05 ppt (less than 0.2%).

Both the calibration and verification periods were used to estimate the effect of deepening the channel on DO. The results indicate a small reduction of DO, between 0.1 and 0.5 mg/L (less than 10%), due to deepening of the channel. The greatest reductions occur where the present channels and turning basins are shallowest.

Computer simulations show that the sedimentation rate in the deepened channel is reduced by between 2 and 8% compared to the present channel geometry. This is due to the fact that the mean of the total current speed in both the Davisville channel and the Quonset channel increases when they are deepened. The decrease in sedimentation rate is not significant because current sedimentation rates in the channels are low.

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Craig Swanson, Ph.D.
Applied Science Associates, Inc.
70 Dean Knauss Drive
Narragansett, RI 02882
Ph. 401-789-6224
Email: cswanson@appsci.com