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Sewage Discharge by Recreational Boats in R.I. Coastal Waters

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THE REGULATION OF SEWAGE DISCHARGE BY RECREATIONAL BOATS

IN

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BY

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ABSTRACT

Federal legislation regulating sewage from recreational boats has existed since 1972 (The Clean Water Act). Since that time the regulations have failed to prevent untreated sewage from boats from being discharged into the Nation's waterways. This has caused conflicts over water quality, particularly in shellfish growing areas.

The regulatory system which exists to regulate sewage from recreational boats was analyzed for nine sources of possible regulatory failure. Seven of the nine were found to be operating. They include: lack of technology, lack of enforcement, lack of issue salience, negative attitudes on the part of the boaters, the economics of compliance, conflicting interest groups, and administrative errors.

At the time the regulations were promulgated several other regulatory options were available to the implementing agency. Seven of these options, ranging from no federal regulations to strict controls on boat numbers were analyzed for their potential effectiveness. To acheive the goal of improved water quality, mandating only type I marine sanitation devices, or only type III marine sanitation devices could have been more effective than the current regulations. Questions of implementation still must be addressed. Eliminating regulations for boats less than 65 feet in length would be the easiest to implement, but ignores water quality issues. Opting to use a strict formula method resolves some of the water quality issues and implementation problems. Other options, mixing state and federal responsibility, would be equally ineffective or worse than the current system in protecting water quality.

The lack of effective federal regulations resulted in the use of a standard formula (Food and Drug Administration) by state shellfish sanitation officials. This formula limits boat numbers based upon predicted sewage loads using several assumptions. Data from a mail-return survey and shoreside observations of Rhode Island boaters administered during the summer, 1988, were used to modify the occupancy rate assumptions of the standard formula. Occupancy rates ranging from 27% to 100% were used depending on boatlengths and the site in question. Two formula modifications were generated. Allowable boat numbers in three Rhode Island harbors were calculated. In Dutch Island harbor 74 boats would be allowed by the formula, 144 boats by modification one, and up to 245 by modification two. The maximum number generated by modification two can be used only when all boats are less than 25 feet in length. On a peak weekend 103 boats were observed in this harbor. Newport harbor has an allowable boat count of 1922, 3768 by modification one, and up to 6405 by modification two. There were 1592 boats present on a peak weekend. The Great Salt Pond (Block Island) would be allowed 445 boats by the formula, 872 by modification one, and up to 1482 by modification two. There were 1587 boats present. The modified formula uses more data on boat use and is thus more reflective of the sewage loads entering RI waters. Further information would increase its accuracy.

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1. The Regulation of Water Pollution

The 1972 Clean Water Act (CWA) amendments were comprehensive legislation that changed the character of water pollution laws. Prior to this act water quality was regulated based upon ambient standards, and only regulated at the federal level when there were interstate conflicts (Kneese and Schultze, 1975). No limits were set on discharge. The only requirement was that ambient water quality be maintained. If water quality was found to be below the ambient standards attempts were made to find and control the source. The difficulties with this type of regulation are obvious. When several sources are responsible for degrading water quality, proving responsibility and degree of responsibility is impractical at least.

The 1972 CWA amendments changed this method. Effluent standards, as opposed to ambient standards, were issued for many pollutant sources in the context of the act. The Environmental Protection Agency (EPA) was enjoined to issue standards for every point source of pollution. If the effluent standards were set properly the combined input of all sources would not be enough to degrade water quality. It was this change in standard setting that allowed recreational boats to come under federal control as a pollutant source. Prior to this act, the pollution load from boats would have been one of the last addressed in resolving an ambient water quality problem. Now the *relative* contribution of recreational boats was unimportant. They were a pollutant source and could be regulated "at the pipe".

Many states recognized and regulated boats as a pollutant source prior to 1972 (Robberson, 1964). However the ambient concept and the requirement of interstate conflict prevented comprehensive federal regulation. With the new effluent regulations came uniform federal regulations of boats that preempted state authority to regulate discharge from boats.

The change to effluent standards allowed regulation at the federal level that did not depend on the relative contribution of boats to water pollution, or even proof that boats did indeed degrade water quality. While it may be a given that a failing sewage treatment plant is a greater threat to water quality than a concentration of recreational boats, the effluent criteria allowed all sources to be regulated with equal measure. The enforceability of these standards vary, but the potential is there. The 1972 amendments to the CWA changed recreational boats from one of many sources which may have effected ambient water quality to a point source which can and was regulated.

2. The Clean Water Act and Boat Pollution

The Federal Water Pollution Control Act was first enacted in 1948 and amended subsequently. Although the WPCA had grown since 1948, the 1972 amendments were a massive response to growing environmental awareness in the United States. This awareness resulted in a great outpouring of federal environmental regulation. The Clean Water Act and the Clean Air Act were two of the major outcomes of this groundswell of environmental concern.

The goal of the 1972 CWA amendments (section 101) was to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (CWA, 1972, sec.101). The discharge of all pollutants into the navigable waters of the US was to be eliminated by 1985. Although a major focus of the CWA of 1972 was the construction grant program that provided funding for publicly owned treatment works (POTW), other pollution sources were also subject to regulation by this act. One of these was sewage from vessels. Debate existed then, and now, as to the actual degree of degradation created by the discharge of sewage from boats. However Congress had decided by 1972 that it was a significant enough source to be regulated (CWA, sec. 312, 1972). Clearly, other issues, such as POTW's, and hazardous and toxic wastes can be considered more critical to the health of the nations waterways. A priority schedule could be implied from the funding and strength of the legislation on these other issues. However, the CWA was intended, perhaps idealistically, to end pollution from all sources in one single legislative action. Sewage from boats was considered such a source.

The thrust for the inclusion of boat sewage regulations came from Midwestern representatives (Amson, 1989). Freshwater lakes, streams, and impoundments that may be slow to flush or are a source of drinking water may be more sensitive to sewage inputs from vessels. Especially in the Great Lakes regions, where boating is very popular, sewage from boats was deemed significant (Hearings, Seattle, 1977, Robberson, 1964).

The boat toilet regulations enacted in 1972 prohibit the discharge of untreated sewage from boats within the territorial sea. All boats with installed marine toilets are required to have a functioning marine sanitation device (MSD) to treat or contain the sewage. Since the time of the regulations, opposition from boaters has been great. Enforcement by the Coast Guard has been scant. Other means of regulation by shellfish sanitation authorities have developed to restrict boat numbers in harbors. The situation as it exists today with federal authorities not enforcing the marine sanitation device (MSD) regulations and boaters not complying with the law has created a user conflict with shellfishermen. This issue has finally come to a head as boater populations grow and pressures on the ocean resources increase.

B. User Conflicts

1. Water Quality and Shellfishing Conflicts

One basic mechanism forcing a regulatory response at the state or federal level is public outcry. This has been seen in the ocean dumping cases and in the entire anti-pollution efforts of the 1970's. The US government tends to regulate only in response to crises or perceived crises. In the 1970's pollution from recreational boats was regulated as part of the groundswell of environmentalism. Boats were just one more pollutant source that had to be dealt with. Since that time the controversy surrounding boat wastes has been relatively quiet. It is only recently that the headlines of the 1970's are being repeated (Sisson, 1988). MSD regulations were enacted but never enforced relieving the boating public of the need for effective protest. The issue was never considered important enough to illicit more than a passing comment from environmental groups, most often in the Great Lakes region. The current wave of environmental concern (ocean dumping, etc.) coupled with rising boat numbers and increasing pressures on the ocean resource has revived the boat waste issue.

Essentially there are two major user groups in conflict: boat owners/users and shellfishermen. The closure of shellfishing areas due to boat concentrations impacts the use of the resource by shellfishermen (McCagg, 1989, Baker, 1988). Using a formula method to limit boat numbers or restricting discharge generates opposition from boaters (Gaffet, 1986, Robberson, 1964, McCagg, 1989).

In addition to this use conflict there is a confusing and often contradictory regulatory structure that has developed at both the state and Federal level. In Rhode Island there are two permitting agencies, the RI Dept. of Environmental Management (RIDEM) and the Coastal Resources Management Council (CRMC). Each classifies water according to a different system. RIDEM classifies water according to biological standards. CRMC classifies water based on use, both actual and potential. Often there is direct conflict in the uses allowed under each system (Brillat, 1989). Water quality classifications under DEM, the agency responsible for 401 permits under the CWA, may not reflect the actual pollution levels present. The result of all this confusion is dissatisfaction on all sides.

2. Rhode Island Boaters and Shellfish

Recreational boating has long been a popular activity in Rhode Island. Over the last decade, the number of boats and boat owners has increased dramatically. There are currently 28,000 boats in Narragansett Bay (McCagg, 1989). Almost 32% of RI residents participate in boating (Ward et. al., 1987). Boaters contribute to economic development through marina sales and tourism. However, shellfishing is also an important industry in this state. When these two user groups come into direct conflict over water quality a balance must be struck.

Achieving this balance has been attempted through federal marine sanitation device regulations and through the Food and Drug Administrations (FDA) National Shellfish Sanitation Program (NSSP). The FDA requires that boat numbers be limited in areas where shellfishing occurs. Neither of these strategies has been popular with boaters nor very effective in eliminating user conflicts.

C. Hypotheses

This thesis examines the problem of recreational boats and sewage from two perspectives. It first looks at the regulatory system in place at the federal level. Federal regulations are analyzed for nine possible sources of regulatory failure. Other possible regulatory systems are also examined for their chances of success based on the same criteria. It is hypothesized that the greater the difficulty in enforcing the federal MSD regulations, the less likely that they will be effective in stopping untreated sewage discharge from vessels. A subsidiary hypothesis of this is that the smaller the degree of public support for and awareness of the regulations the less likely that they will be effective. Other sources of failure will also be considered.

Secondly this thesis examines a specific failure of the current strategy used to regulate boats in RI. Boats are regulated by RIDEM using a formula method to determine allowable boat numbers in harbors based on sewage loading. The formula used is a standard formula developed by the Food and Drug Administration in 1968. It is a simplified description of boat contribution to sewage pollution. The use of this formula may be too restrictive in determining boat numbers, intensifying opposition from boaters.

The FDA formula method is based on several assumptions, including a 100% occupancy rate and 2 persons per boat. It is hypothesized that there is a correlation of boat length with number of people aboard and the amount of time spent aboard. It is also hypothesized that the number of occupied boats in a harbor differs significantly from the assumed rate of 100%. Results from these tests can be used to modify the loading factors of the formula.

II. Background

A. The Contribution of Boats to Water Pollution

Recreational boats have the potential to degrade water quality through the discharge of raw or partially treated sewage. Sewage can be detrimental in two ways. Increased organic matter and nutrients can cause eutrophication of the receiving waters. The small amounts of sewage contributed by boats have not been well studied for their potential to cause eutrophication. The major concern has been the possibility of disease causing pathogens entering the water from untreated or partially treated sewage. It is this second concern that is addressed here.

The extent of the potential of boats to degrade water quality through the input of pathogens has been debated since the 1950's (Ingram, 1953). As yet, this debate has not been resolved and is complicated by the area specific nature of the problem. Several studies have correlated increased fecal and total coliform levels with boat use. Coliforms are bacterial indicators found in the human intestinal tract, and in birds and mammals. They are used to indicate the presence of sewage pollution. However, the relationship is sporadic and can be masked by coliform inputs from other sources.

Furfari (1969) studied the effect of recreational boats in Potter Cove, RI. A correlation was found on one of the survey days between increased boat number and elevated fecal coliform levels. However, the overall relationship between boats and coliform levels during the rest of the summer was sporadic and random. Other studies have shown a stronger correlation with boat number and coliform levels. Faust (1982) studied the effect of boat populations on fecal coliform (fc) and fecal streptococci (fs) levels in the Rhode River, a sub-estuary of Chesapeake Bay. Both fc and fs levels went up during a weekend of boat use. These effects were quantifiable because of dry weather. Faust reports that fc levels due to land runoff sources were 72 times higher than that from boating activity during a routine survey of water quality.

Seabloom (1969) compared total coliforms during the boating season and the non-boating season in two marinas: a fresh water and a saltwater marina. The freshwater study area showed elevated coliform levels due to boats. Coliform levels rose 11% during the boating season. The range of variation between sampling sites was extreme. A 73% decrease to a 140% increase was observed. In the saltwater marina the coliform levels actually declined during the boating season. This may be due to the known bactericidal effect of saltwater, but points out the difficulty in accurately assessing this problem.

Mack and D'Itri (1973) showed elevated coliform levels at the preferred slip space in a Lake Michigan marina. These levels increased further when the total number of yachts in the marina increased. Bacterial counts fluctuated greatly during the study, probably due to temperature, wind and wave action, and outside sources of coliforms. Garreis' et. al. (1979) study in Kent Island Narrows, Maryland, showed higher levels of total and fecal coliforms in marina waters as compared to a control. Three of the marinas studied had higher levels of fecal coliforms on the day after holidays and weekend than during the week. These marinas primarily catered to recreational boats.

The debate as to the effect of boats on water quality continues. One study concluded that boats numbers and coliform levels were correlated in Zach's Bay, New York (Cassin et.al., 1971). A later survey of the same bay concluded that boats were not a significant coliform source. In fact, the largest coliform increases occurred at a nearby bathing beach, and was probably due to the bathers themselves (Maher, 1977). The wide variation in results from these studies can be attributed to several factors. The indicator itself is questionable and can undergo growth and die-off, depending on conditions. For example, variations in flushing rates of different harbors will have a great effect on coliform densities. Boat use will vary, depending on the nature of the harbor. Background levels of coliforms may be great enough to mask the small contribution from boats. These factors and others will determine whether a correlation of boat number with coliform levels will be seen.

All of these studies stress the difficulty of separating various other sources from boat sources of fecal pollution. Most of the earlier studies relied on the total coliform to indicate sewage pollution. Furfari (1969) suggested the use of the fecal coliform indicator, as opposed to the total coliform indicator, as a better means of detecting recent fecal pollution. Total coliforms can be found more commonly and are not always of fecal origin. Studies which used only the total coliform indicator may have misconstrued the extent of contamination from boats. Even in areas of little development, runoff can be a major source of contamination (Faust, 1982).

Despite the variation in the studies on boat waste, the discharge of any untreated fecal matter remains a public health issue. Sewage can contain a wide variety of pathogens, including organisms responsible for dysentery, shigellosis, typhoid fever, gastroenteritis, and infectious hepatitis (Seabloom, 1969). The most common means of disease transmission is through direct bodily contact and through ingestion. Swimming in contaminated marine waters can result in gastrointestinal illness (EPA, 1986). However, the greater concern with sewage from recreational boats is the shellfish transmittal route. Shellfish are filter feeders and can concentrate pathogens to levels greater than that of the water column. Consumption of raw or partially cooked shellfish that have been contaminated has resulted in gastroenteritis, infectious hepatitis, and salmonellosis (Pipes, 1982). Traditional methods of evaluating water quality may be ineffectual in preventing a public health risk from shellfish. Some authors have suggested using analysis of shellfish meats as an alternative to testing the water column (Kay, 1982, Kassebaum, 1974). Although this would be a better method of evaluating the safety of shellfish harvesting, the correlation between coliform levels in shellfish and boat numbers is scientifically unclear (Kassebaum, 1974).

B. The Evaluation of Regulations

The federal MSD regulations were part of a general trend towards increased regulation at the federal level. These regulations, unlike price control and other economic regulations, were part of "social regulations" that were concerned with noneconomic issues (i.e. health, pollution, etc.) (Meier, 1985). Such type of regulation is often forced on the regulated population or industry by groups not directly economically impacted by the regulations (i.e. environmental groups). This means that social regulations face opposition from the affected groups and require more careful monitoring to be effective.

Evaluating the effectiveness of regulation is necessary both to determine if the regulation is operating to achieve its goals and also to determine future courses of action. An understanding of regulations' strengths and weaknesses can help to reform the regulatory process to create better regulations in the future (Meier, 1985). Examining specific regulations to see if they are achieving the desired outcome (i.e. changes in water quality, limiting sewage discharges), can expose failures in the regulations that can then be corrected. Regulations cannot be expected to function smoothly simply because they exist. Regulatory evaluation provides the necessary follow through to ensure that regulations are serving their purpose.

There are several ways to examine regulations and regulatory success (Meier, 1985). Both regulatory institutional structures and regulatory processes can be examined. Different facets of regulation can be analyzed. Economic analysis may focus on the efficiency of the regulations. Legal analysis focuses on the impact and fairness of regulations. There are many approaches because regulation is a multifaceted process that contains elements of all disciplines.

This study focuses on the implementation aspects of the federal MSD regulations. Many different factors have played a part in the success or failure of these regulations. Economic factors, legal authority, and social and political influences all combined to create the regulatory situation that exists. By examining separately the influences of several factors which may have affected the outcome of the federal MSD regulations, it is hoped to determine how and why the regulatory failure occurred.

Sources of regulatory failure may act at the initial promulgation stage or later during implementation and enforcement. It is important to examine possible sources of failure where they occur throughout the entire regulatory process. The presence or absence of several sources of regulatory failure may determine whether a specific regulation will be successful. If the possible action of these sources of failure can be determined prior to initiating the regulations, better, more effective regulations may be the result.

C. The History of Federal MSD Legislation and Regulation

The first mention of sewage pollution from boats in legislation occurs in the 1966 amendments of the Federal Water Pollution Control Act (P.L. 89-753). In section 17 of the amendments the Secretary of Interior is directed to study the "extent of pollution of all navigable waters of the US from litter and sewage discharged, dumped, or otherwise deposited into such waters from watercraft....". The Secretary was to report his findings and advise on the need for regulations by 1967. This report, issued on Aug. 7, 1967, determined that watercraft pollution can be a serious economic and health threat to US water-use areas. It recommended that federal regulations be implemented to control wastes from all vessels (Wastes from Watercraft, 1967).

Sewage from vessels is mentioned again in the FWPCA amendments of 1970 (P.L. 91-224, the Water and Environmental Quality Improvements Act). This act began the movement towards the marine sanitation device (MSD) regulations. The boat sewage provisions of this act were reiterated, almost in their entirety, in section 312 of the 1972 FWPCA amendments (the Clean Water Act).

By this point it is clear that, at least in the minds of the members of Congress, the issue of whether boats are a significant pollutant source that needs to be regulated has been resolved. The administrator (of EPA) is directed to devise regulations for MSD's, not to determine the extent of sewage pollution from vessels, as in the 1966 amendments. The 1972 CWA also directs the Coast Guard to develop regulations for the design and installation of MSD's and to be responsible for enforcing the regulations.

In 1972 the EPA issued regulations that prohibited the discharge of sewage into the navigable waters of the US (37 Federal Register 12391, 1976). The Coast Guard, in 1975, issued regulations that allowed for flow-through devices (40 Federal Register 4622, 1975), and in 1976, the EPA also promulgated revised regulations that allowed the discharge of treated sewage in coastal waters, the Great Lakes, and on navigable interstate waters (41 Federal Register 4452, 1976). The no-discharge requirements remained for landlocked bodies of water with no ingress or egress possible by the regulated vessels (Legislative History, CWA 1977). States could petition for other water bodies to be declared no-discharge zones after showing proof of having adequate pump-out facilities.

The 1972 amendments to the Clean Water Act preempted State authority to regulate sewage discharge from vessels. Although the boating population was in general opposed to boat toilet regulations, federal standards were supported. It was felt that a nationwide standard would be better than the wide variety of State requirements that existed. For example, Ohio and Wisconsin had no discharge requirements for marine toilets, while Minnesota allowed chlorinator treatments and Michigan had no regulations. Most of the coastal states, with the exception of New Hampshire, Florida, Georgia, and Hawaii, had no specific laws for boat toilets. Of the states with regulations, some had no discharge, and others had varying effluent limits (Robberson, 1964). Faced with this spectrum of regulations, boaters and MSD manufacturers preferred to deal with a single federal initiative.

The MSD issue came up again in the 1977 CWA amendments. Nationwide hearings on the proposed amendments show that while Congress may have concluded in 1972 that sewage from vessels was a pollution problem that required legislation to correct, the regulated population remained opposed. Opinions on the subject show a distinct geographical difference. Hearings in Minnesota generated responses from environmental groups that wanted stronger regulations, including no discharge in all of the Great Lakes, and possibly in estuarine waters. In addition, there was a push to limit graywater discharges (Hearings, Minnesota, 1977). The original push for boat toilet regulations came from the Midwestern representatives, so it is not surprising that the effort for more stringent regulations came from this area (Amson, 1989).

Hearings in Seattle, Washington generated quite different responses. The attitude there was that MSD regulations were an unnecessary burden on the boater. Coastal waters were perceived to be capable of assimilating the "miniscule" amounts of sewage produced by boats (Hearings, Seattle, 1977). A study was submitted that showed that boats have no detectable effect on bacterial water quality.

The polarization of opinion showed both the geographical difference in attitudes towards boat toilet regulations, and the continued opposition of the boaters. Neither side had a victory in the 1977 amendments. Only minor changes were made: to prohibit discharge in drinking water intake zones, and to require commercial vessels on the Great Lakes to treat sewage and graywater to secondary treatment levels.

The Clean Water Act has been amended several times since 1977 (1980, 1985, 1987), but no changes have been made in the MSD regulations. This is not due to a lack of interest by interest groups and Congressmen. Several unsuccessful attempts have been made to change the boat toilet regulations since 1977. In 1983 a bill was proposed by Representative Young (Alaska-H.R. 1421) that was designed to eliminate Coast Guard responsibility for MSD's on vessels less than 65 feet in length. In 1985, Senator Chafee (R.I.) introduced a similar bill (S. 793). This bill also eliminated the MSD requirements for vessels less than 65 feet long, but included more detailed regulations for what States may or may not require. Neither of these bills made it into the CWA amendments.

Currently the regulations as stated in the 1972 Clean Water Act remain, with minor changes. These regulations require that all vessels with installed toilets be equipped with either a type I, type II, or type III MSD (40CFR p.140). Type I MSD's are macerator-chlorinators that produce an effluent having a fecal coliform count not greater than 1000/100ml, and no visible floating solids. A type II device provides bacteriological breakdown of sewage and has an effluent of no greater than 200 fecal coliforms/100ml and no greater than 150mg/l suspended solids. Type III devices are designed to prevent the overboard discharge of treated or untreated sewage. For the purpose of this thesis, type III devices will be taken to mean holding tanks.

In freshwater lakes, reservoirs or impoundments where there is no egress or ingress possible by the regulated vessels, there is no discharge of any waste permitted. In areas where flow-through devices are permitted, the effluent must meet the standards listed above. States may apply for no discharge zones if they can prove they have adequate pump-out facilities. As of 1981 there were 15 no-discharge zones (EPA, 1981).

The original regulations had an incentive clause that allowed for type I devices if installed before January, 1980, and only type II and III devices after that date. However, due to lack of participation, this was dropped (43 Federal Register 29637, 1978, Amson, 1989). As the date of compliance neared, there was a demand for type I devices that exceeded supply. In addition, there were few type II devices available for small boats. This lead to a waiver in which type I and type III devices would be allowed for all vessels under 65 feet in length, until such time as type II devices adequate for small vessels were developed (43 Federal Register 29637, 1978).

Despite the fact that the MSD regulations have been on the books since 1972 a severe non-compliance problem exists. Opposition from the boating public has been continuous and strong (Hearings, Seattle, 1977, Ross, 1989). The initial incentive clause which would have allowed vessels which complied early (prior to 1980) with a type I device to be considered in compliance for the life of the vessel was abandoned due to lack of participation. Boaters felt that the incentive clause signalled a possible abandonment of all the MSD regulations and avoided complying (Amson, 1989). Presently a stalemate exists, in which Congress will not change the law, and boaters will not comply.

D. The Development of the FDA Formula

Concern over sewage from recreational boats has existed since 1940 (Vogt, 1966). The growth of boating since that time caused this concern to increase. By the early 1960's the push for some means of controlling boat wastes was already strong. Boating magazines and interstate conferences all debated the effectiveness and need for marine sanitation devices (Robberson, 1964; National Conference, 1966). The MSD controversy existed in the boating public, the industry, and among federal agencies. However, while this debate continued (and continues), and MSD's eventually became federally mandated (CWA, 1972 sec. 312), the public health service, specifically the shellfish sanitation branch, took an alternate route.

The public health service, under the Food and Drug Administration, is concerned with sewage pollution from recreational boats because of its potential to affect public health. Untreated sewage discharged in the vicinity of shellfish beds may contain pathogens which can be concentrated to infectious levels by the shellfish. The FDA does not approach the problem of sewage pollution from the same "fishable, swimmable" angle of the federal water pollution laws. Its primary goal is to ensure that the consumption of shellfish remains a safe activity. This requires control over the shellfish harvesting, processing, handling, and transport. All aspects of the shellfish industry must be prevented from contamination.

The FDA controls the quality of shellfish through the National Shellfish Sanitation Program (NSSP). The NSSP is a voluntary state program run by the public health service of the FDA. Membership in the program allows states to ship shellfish interstate. By becoming a member, states agree to comply by the manual of operations (NSSP Manual of Operations, 1988). This manual provides guidelines for the classification of the shellfish growing waters, and standards for the processing and handling aspects of the industry. The FDA publishes yearly progress reports on the status of individual states' shellfish sanitation programs. States with gross violations of the manual procedures, or having consistently poor reports are denied certification and may no longer ship shellfish to other states. The NSSP also publishes a bi-monthly listing of all certified shellfish dealers in the state.

Since the 1965 revisions of the manual of operations vessel source pollution has been considered as part of the evaluation of shellfish growing waters. Section C of the manual (1965 version) specifically mentions discharges from pleasure craft and other vessels as sources to be evaluated in the sanitary survey of growing waters. Even though water quality testing may reveal acceptable coliform levels, the mere presence of sources of fresh fecal material may justify an area closure. It is emphasized here, and in later NSSP documents (NE Technical Services Unit, 1972a), that *judgement* and not just the results of water quality testing must be used in determining the classification of an area. The recommendation has been made that states close marina areas, a priori, to shellfishing (NE Technical Services Unit, 1972b). In 1972, six states out of 20 surveyed automatically closed areas based on the presence of boats. The rest either based closure on bacterial counts or only had a marina in areas already polluted by another source (NE Technical Services Unit, 1972b).

In 1989 all states were required to close areas if a marina (as defined by the manual) is present (NSSP manual of operations, 1988). States which do not comply will lose the certification of its shellfish harvesters and interstate shellfish transportation capabilities. However, FDA is more likely to work with the state to develop an acceptable shellfish sanitation plan before it resorts to such sanctions (FDA, 1988). Only a few states have ever had their certification removed because of poor shellfish sanitation programs. The mere threat of such sanctions appears to be enough to generate co-operation in participating states. Unfortunately, because of illegal harvesting and statistical chance, following the NSSP manual is not always enough to ensure that shellfish do not become a vector for disease.

Preventing untreated sewage discharged from vessels from reaching shellfish growing areas is an obvious goal of the NSSP. However, the FDA does not have the regulatory authority to require boats to have functioning MSD's. Nor does it have the authority to keep boats from passing over shellfish beds. It does have the authority to require member states to comply with the manual of operations, or they will lose their certification to ship interstate. It is from these limits to the NSSP's authority that the formula method of determining allowable boat numbers developed. Although it is theoretically possible that the NSSP, instead of having growing area classifications, require massive bacteriological testing of every bushel of shellfish, the time, money, and manpower constraints of this option are obvious. Standards for growing areas, including the formula method for boat numbers, are a simple means of ensuring a modicum of public health safety.

The first published use of the formula appeared in the 1968 Proceedings of the National Shellfish Sanitation Workshop (US Dept. of HEW, 1968). In conjunction with a discussion on the NSSP position on boat wastes, MSD's, and courses of action for states, a brief mathematical application determining allowable boat numbers was given. Although some of the coliform contribution factors have been revised since then, the essential concept of number of boats, number of people, coliforms/person, and dilution volume has remained.

A 1972 position paper of the FDA essentially repeats Furfari (1968) in the classification of areas near concentrations of boats. This paper was not released for public distribution until 1983. In 1972 when it was written, the federal legislation requiring MSD's on recreational boats had just been passed (CWA, 1972 sec. 312). It is possible that it was felt that this legislation would be sufficient, and the position paper was not needed. Later release of this document may indicate the failure of the federal legislation. A 1976 draft position paper does not use the formula but states that the federal requirements for MSD's will not alleviate the need for judgement decisions on specific sites affected by marinas (Furfari, 1976).

The Environmental Protection Agency (EPA) picked up the formula method and included it in the Coastal Marinas Assessment Handbook (1985). This document, while having no regulatory power, serves as an advisory paper and can have a significant impact. The formula was used by several states in various forms in trying to develop appropriate buffer zones (S.C, N.C., R.I., MD,). However, it was not until the 1986 Interstate Shellfish Sanitation Commission (ISSC) and then the subsequent 1988 revisions of the NSSP manual of operations, that the use of the formula for determining allowable boat numbers became accepted policy for the NSSP. Prior to this the formula existed in technical papers circulated within the FDA as a recommended procedure. Inclusion of the formula in the NSSP manual of operations made it a required procedure for participating states.

The basic concept of the formula has not changed since its development in 1968. Four factors are considered in determining sewage loading: the number of boats, the number of people aboard, the number of coliforms per person, and the dilution volume available. The FDA's position has always been that site specific influences such as flushing and other hydrographic features may affect the water quality above shellfish beds (Furfari, 1976). However, a static volume method is used in the formula to create a generalized model. This method assumes that all the water in the marina area is completely mixed, both vertically and horizontally (Musselman, 1989).

The NSSP manual of operations (1988 revisions) requires participating states to close marina areas to shellfishing with a buffer zone determined by the formula (as modified by relevant information). However, the Clean Water Act of 1972 (and subsequent revisions) contains an antidegradation clause (sec. 101, 401) that prohibits the downgrading of water quality that would prevent an existing use. In class SA waters (RI-Department of Environmental Management DEM) a shellfish closure prevents a theoretically existing use and thus violates the CWA. Even in areas where the marina is in a lower quality water class (SB, SC), the dilution volume required for the buffer zone may cause a shellfish closure in adjacent SA waters. This is the bind that many state shellfish sanitation authorities find themselves in. By issuing water quality certifications as required by sec. 401 of the CWA shellfish sanitation officials are required to ensure that the water is not being degraded. The presence of a large number of boats in an area may make this certification impossible.

The NSSP cannot require the state officials to break federal law by closing areas. Due to the failure of the MSD regulations, the sanitation official in the state may have few options. If MSD regulations had been effective, then theoretically the conflicting use of recreational boats and shellfish harvesting would be resolved. Alternatively a state shellfish sanitation agent can restrict or prohibit boats, thus maintaining the integrity of the water. This is the actual effect of using the formula method and is often a political nightmare for state officials.

E. Use of the Standard FDA Formula

Because of the possible health risk from the discharge of untreated sewage from boats, state shellfish sanitation departments regulate boat numbers in harbors to maintain potential levels of coliforms below federal standards. This is done using a formula first developed in 1968 by the Food and Drug Administration (FDA) for the National Shellfish Sanitation Program (NSSP) (US Dept. of HEW, 1968). The formula regulates boat numbers based on several assumptions about sewage loading factors and the behavior of bacteria in water. It is a basic mathematical formula written as:

$$\text{fecal coliforms/100ml} = GPE/V$$

where G = number of boats

$P = 2x10^9$ fecal coliforms/person/day

E = population equivalent/boat

V = volume of dilution water available

Fecal coliform is used, as opposed to total coliforms, because it is more indicative of fresh fecal pollution. The maximum allowable level is 14 fecal coliforms/100ml at the end of the buffer zone around a marina (EPA, 1986). In the first use of the formula, it was thought that a count of 2 coliforms/100ml was more suitable for fresh fecal material than the standard of 70 coliforms/100ml. By the 1985 version of the formula, fecal coliforms were being used as opposed to total coliforms, and a standard of 14 fecal coliforms/100ml was set. However the EPA Coastal Marinas Assessment Handbook (1985) in rewriting the FDA formula, included the original tables based on 2 coliforms/100ml. These tables do not reflect the change in standards to 14 fecal coliforms/100ml, rendering the calculations of allowable boat numbers in that document inaccurate.

The formula is based on several assumptions which may be unfounded or invalid. These include:

--100% marina occupancy

--100% overboard discharge

--all occupied boats are discharging

--2×10^9 fecal coliforms/person/day

--2 persons per boat

--complete mixing of water in and around the marina; 24 hour flushing time

--no bacterial die-off or growth

--complete flushing of previous sewage load in one day
--no other sources of fecal coliforms
(Dept. of Environment, MD, 1987)

The 1986 Interstate Shellfish Sanitation Commission and the 1988 NSSP manual of operations (part I) restate this formula but recognize that the occupancy rate, the rate of discharge of untreated wastes, and flushing rates are variable. They recommend the use of all available technology to account for regional differences. Several states have developed marina policies that use a modified version of the standard (FDA, 1968) formula. Maryland has adopted a revised formula which used an occupancy rate of 13% to determine boat capacity in marinas (Dept. of Environment, MD, 1987). This occupancy rate was derived from a marina survey administered in a high use area during peak boating populations. Occupancy is defined as the number of occupied boats present out of the total number of boats present at the time of the survey. A different method of determining occupancy was also used. Occupancy is also defined as the number of days of the boating season someone was present on board. Both methods can be used to determine sewage loading.

South Carolina has a marina policy which makes several modifications of the formula (S.C. Dept. of Health and Environmental Control, 1985). In its policy it is assumed that only 50% of the slips/moorings in a marina are physically occupied by a boat, with only 50% of those boats having people aboard, leading to an effective occupancy rate of 25%. In addition, a failure rate of 50% for marine sanitation devices (MSD's) is given.

In Rhode Island, the standard formula was modified in a Block Island case study. Dye testing of the Great Salt Pond showed that there was limited flushing. The water in the southern portion of the Pond, where the boats were to be moored, remained there, having relatively little impact on the northern portion of the Pond where the shellfish resources are. This hydrodynamic study resulted in a boat capacity of 712 as opposed to the 444 boats allowed by the standard formula (FDA, 1987). This capacity has yet to be approved by the R.I. Department of Environmental Management

The standard formula is only as reliable as its assumptions. Many of these assumptions can be considered invalid. This thesis attempts to correct only the occupancy rate assumptions. The other influencing factors must be kept in mind when using the formula.

1. The Fecal Coliform Indicator

One of the difficulties in predicting the health risk from sewage inputs from recreational boats is the reliability of the indicator used. Fecal coliform bacteria are a bacterial species found in the intestinal tract of humans and other mammals. The presence of these bacteria (specifically, e.coli) in seawater is used to indicate fresh fecal contamination of the water. Evidence of fecal contamination is considered presumptive evidence of pathogens which are often associated with fecal matter (fecal coliforms in themselves are not pathogenic). Untreated sewage may contain a wide variety of viral and bacterial pathogens. Polio, hepatitis, and salmonella are only a few of the pathogens which have been associated with sewage polluted water (Seabloom, 1969).

Although the pathogens are the major concern in determining water quality, they are not tested directly. This is due both to the difficulty of culturing these organisms, and the fact that they are often present in concentrations that are beyond the limits of detection (Pipes, 1982). The broad spectrum of pathogens which may be present make it difficult if not impossible to test for all contaminants. The fecal coliform is used to indicate the presence of sewage, and therefore the possible presence of pathogens.

There are several requirements of an indicator to be an accurate measure of water quality. It must be present in sewage and excreted by humans. It must be present in greater abundance than the pathogens, and should not proliferate in the receiving waters. Finally it must be more resistant to disinfection procedures than the pathogens (Kott, 1977). Total coliforms have been used as a test for sewage pollution, but the fecal coliform test is considered more accurate for the detection of fresh fecal pollution (FDA, 1969). The US Environmental Protection Agency (EPA) has set standards for the maximum allowable concentrations of either total or fecal coliforms, depending on the intended use of the water. For example, saltwater used for recreation involving bodily contact (swimming) cannot have a total coliform count greater than 200 coliforms per 100 ml of seawater. Shellfishing can occur only in areas with fecal coliform counts of less that 14 fecal coliforms per 100 ml of seawater (EPA, 1986). The standards are set to determine safe levels of risk. Waters with coliform counts within these levels are considered to be sufficiently pristine to allow safe use of the water and its resources, and will not threaten public health.

The fecal coliform indicator is used to assess and limit the impact from recreational boats. The federal regulations were written so that marine sanitation devices on boats could not emit sewage with coliform counts above 1000fc/100ml. This is an engineering type standard, such as used in regulating publicly owned treatment plants. State shellfish sanitation departments regulate boats based upon an expected fecal coliform load from each boat. This is an ambient type standard that was more common prior to the Clean Water Act of 1972 (Kneese and Schultze, 1975). The fecal coliform standard is used because boats are an intermittent source of sewage. Fecal coliforms are more indicative of recent fecal pollution than is the total coliform test.

The use of the fecal coliform indicator and the total coliform indicator as a measure of sewage pollution in general and from boats in particular is suspect. In some cases, the pathogenic organisms which we are attempting to detect through the use of an indicator can survive longer than the coliform organism (Lederc et.al., 1977). In other cases, the pathogen can be present, when there are no detectable levels of the indicator (Mack, 1977). Coliform indicators were used when bacterial diseases were the greatest concern. Current hygienic and antibiotic practice have decreased the abundance of these diseases (Cholera, etc.). Viruses are the major concern today. Fecal coliforms may be a poor indicator for viral disease (Musselman, 1989).

These types of failures of the indicator organism are due to both a lack of sensitivity in the testing procedure, and an incomplete correspondence of indicator level to pathogen levels. Other indicators besides the coliform group have been suggested as alternatives to the fecal coliform (Hoadly and Dukta, 1977). Some European countries have used these alternatives. However, the simplicity of the coliform test, and its longstanding use in the US have made the application of alternative indicators difficult to achieve. In addition, these alternatives suffer from many of the same problems as the coliform group.

A problem with the fecal coliform indicator that is specific to the recreational boat issue is a statistical problem (Cabelli, 1988). Safe levels of the indicator bacteria are set based upon the statistical probability of pathogens being present, given a certain concentration of fecal coliforms. The ratio is fairly accurate when there is a large source population, inputting over a continuous period. This situation exists in the operation of sewage treatment plants servicing a metropolitan area. This scenario is not accurate for recreational boats. The population contributing sewage from recreational boats is small in comparison to that of a city. The percentage of people using recreational boats who are ill is not necessarily the same as the percentage of ill people contributing to a city's sewage. In addition, the input from boats is very sporadic. Given these facts, the correspondence of fecal coliform levels to pathogen levels may not be as accurate when the contributing population is the boating population. The actual levels of pathogens may be more or less than is indicated by the fecal coliform test.

A final problem with the fecal coliform indicator is the inability to separate sources. Mammals and birds are all a source of fecal coliforms. Run-off from roads, combined sewer overflows, and leachates from private septic systems can also be a major contributor to coliform levels. Separating the impact from recreational boats from all other sources is impossible. Unfortunately, in the current model, background levels of fecal coliforms are not accounted for. Attempting to improve water quality in a given area by restricting recreational boats may be ineffective if other sources are more significant (Faust, 1982).

The use of the fecal coliform indicator at a fixed point in time does not address the issue of the behavior of bacteria and viruses in water. Die-off rates, propagation rates, temperature effects, sedimentation, and transportation are all factors that will affect the presence and abundance of both the indicator organism and the pathogens. When using an indicator organism it is assumed that its survivability in saltwater is the same or greater than that of the pathogenic organisms. However, as noted above, this is not always the case (Pipes, 1982).

Water temperature has a significant effect on the growth and survivability of most bacteria and viruses. It is assumed that the temperature will affect the indicator and the pathogen in the same manner, and to the same degree, but this may not be accurate. Many bacteria and viruses can encyst and remain in the sediment, long after the initial input. This is a potential pollution source which is not measured by water column sampling for the fecal coliform. Finally, boat numbers are regulated chiefly because of concern over shellfish contamination. Shellfish are filter feeders and can concentrate pathogens and other contaminants. The measure of fecal coliform levels in the water column may not be indicative of pathogen concentrations in shellfish (Kassebaum, 1974).

The use of the fecal coliform indicator has many problems, but at the moment it is the only reference point available for determining the possible pathogenic component of water quality. The allowable number of boats in an area is calculated based on the sewage load in terms of fecal coliforms. While the use of this indicator can result in either undetected public health risks or overly restrictive boat limits, it is the only option, and is better than no criteria at all.

2. The Hydrodynamic Regime

The NSSP marina policy states that while the simplified formula can be used, including all the assumptions about occupancy, static volume, etc., to make judgements about marina capacity, all relevant information should be considered. One fairly obvious consideration is the flushing rates of different marina sites. The EPA Coastal Marinas Assessment Handbook includes methods for a rough calculation of flushing rates based on the tidal prism (EPA, 1985). However, this is not often applied due to the difficulty in obtaining accurate information on river input.

The simple formula, without modification, uses the static volume assumption. This assumes that the dilution volume available for the sewage input is the total volume of the marina plus buffer zone. This water is considered to be completely mixed both vertically and horizontally, in and around the marina. It also assumes a 24 hour flushing time for all harbors. In most, if not all cases, this will not be true. Flushing time is usually longer.

Flushing rates -the amount of time it takes for water in an area to exchange with other water- vary in both space and time. The amount of mixing and the direction of flow may also vary. An enclosed basin type marina with little access to open water will not demonstrate the same behavior as a more open harbor. The circulation and exchange of water in a basin depends on three main factors, with several other factors having influence. The major forcing functions are tidal variation, freshwater inflow, and the geometry of the basin (Schulckter et.al., 1978). Other factors include windwaves, longshore currents, oceanic currents, and stratification because of salinity and temperature variation.

Circulation and exchange patterns can vary with season and with the time in the tidal cycle (Fisher, 1987). Fisher's study of two marinas, an enclosed basin and an open water marina, clearly shows the effect of flushing variation. During the ebb tide, the open water site showed flushing rates 10 times greater than the basin site. The flood tide results were more surprising. During the flood tide, the basin flushed more quickly than did the open water site. This was due to prevailing winds directed against the flood tide. Although this was a short term study with a single instantaneous dye injection, it does show that both tidal action and wind effects can be important influences on circulation patterns.

In some situations, where the water goes is as important as how quickly it goes there. FDA's (1987) study in Block Island, Rhode Island, demonstrated that the flushing rate in the Great Salt Pond was very slow. However, it also showed that the water mass tended to remain in the southern portion of the pond. This result allowed a harbor plan to be developed which permitted shellfishing under certain conditions in the northern portion of the Pond, and moorings in the southern portion.

The hydrodynamic regime is an important factor which can vary drastically between marina sites. The best means to protect water quality while preserving maximum use of the resource would be to test each marina or mooring site to determine its flushing rates and circulation patterns. This has been done more often, as pressure for marina sites grows.

Dye testing is the most common means of determining basin characteristics. Rhodamine WT is the dye used most often. It is loaded continuously over time, or injected at the beginning of each tidal cycle (Fisher, 1987, ASA, 1988). Fluorometers are used to record dye concentrations at various sites at various times. The specific methods of injection and monitoring vary. Dye testing is a good means of determining the general flushing characteristics of a basin and is relatively inexpensive. Although it is not biologically active, and will not exhibit the same behavior as bacteria and viruses (settling, degradation, etc.), it is an effective means of modeling effluent behavior.

An alternative method commonly used is either computer generated models or actual physical models of the site (Kator et.al., 1982, Schluckter et.al., 1978). These types of models can be useful but must be ground truthed to the field. Since it is not usually possible for a state agency to test all marina sites for flushing behavior, due to manpower, money, and time restrictions, a computer model that can be used for several sites would be highly useful. However, computer models can become inaccurate on a scale as small as a harbor because of side and bottom effects.

The contribution of recreational boats to bacterial water pollution is a highly localized problem. It is restricted to the coastal zone and further, only to particular basins and harbors in the coastal zone. If a marina has a great deal of flushing and is open to the sea, bacterial pollution from boats is not likely to be a problem. Even in enclosed or semi-enclosed marina, bacterial pollution may be restricted to only certain areas, depending on circulation patterns (FDA, 1987). Clearly the behavior of water in a basin is a critical factor in determining the possible impact of recreational boats on water quality. This aspect of the formula can be modified, but it requires effort and is costly.

3. Other Assumptions and Problems

Three of the major assumptions of the formula have been addressed here: the occupancy rate, the use of the fecal coliform indicator, and the hydrodynamic regime. Other assumptions remain that can have varying impact on the outcome of the formula. One of these is the assumption of zero background levels of fecal coliforms. Most marinas and mooring fields are found in coastal areas that have densely populated shorelines. Runoff from streets and individual sewage disposal systems (ISDS's) can contribute to the coliform levels of a harbor. Outfalls from sewage treatment plants and combined sewer overflows can have major impact. Most studies of marina contribution to bacterial water quality are hampered by high levels of background coliforms, especially after rain events (Faust, 1982). The small increases due to boats are masked by runoff from the land.

The fact that background levels of coliforms may be high does not mean that boats should be allowed to dump as much sewage as they wish. The problem of fresh fecal material verses "old" sewage remains. However, it seems inequitable to require boat numbers to be severely limited when the larger sources of pollution go unchecked. In addition, the implication that the water will be safe for shellfishing and other recreational activities simply because boat numbers have been restricted to allowable levels is unwise. To achieve the water quality desired by this nation, all sources of pollution must be corrected. The most efficient use of funds and time would be to eliminate those sources in which the greatest decrease in pollution is acheived at the lowest cost.

Another assumption is the 100% overboard discharge. It is assumed that all boats have heads and discharge untreated sewage. Although the MSD regulations have failed in their intent some changes have been made. Type I MSD's treat sewage to primary levels. Many people use port-a-potties as opposed to installed toilets and some boats are not equipped with any toilet facilities. These factors, if considered, would increase the allowable boat numbers.

The usefulness of the formula in determining sewage loading rates and therefore allowable boat numbers is dependent on the accuracy of the assumptions. In its unmodified form, the formula is a highly simplified description of the impact of sewage from recreational boats. Many, if not all, of the assumptions of the formula could be challenged with more information. However, gaining information is expensive and time consuming. Occupancy rates have been determined for many areas (Maryland, South Carolina, North Carolina) as it is a relatively simple task. Determining flushing rates, impacts from other sources, and actual pathogenic content of marina waters is considerably more difficult. If more information was available, boat quotas tailored to each harbor could be set. The amount of resources a state is willing to commit to obtaining this information depends on the importance of recreational boating to the community.

III. METHODS

Two approaches are used to assess the boat sewage problem. In the first method the regulatory structure is examined to determine why it failed in preventing the discharge of untreated sewage from boats. The second method examines the occupancy rate assumptions of the current FDA formula and suggests means of modification.

A. Regulatory Analysis

1. The Nine Sources of Regulatory Failure

The current federal regulatory system for controlling boat sewage was analyzed by determining which of the nine sources of regulatory failure applied to the program in place. Each source of failure was examined to see if it was in operation in the failure of the marine sanitation device regulations to generate compliance in boaters. Nine sources are considered, based on Meier (1985).

1) The first possible reason for regulatory failure is lack of technology. When the MSD regulations were promulgated, there may not have been adequate devices to enable boaters to comply. "Adequate" encompasses economic and practical factors, as well as the effectiveness of the devices to treat or contain sewage.

2) Lack of enforcement is another possible source of failure, and may be the major source. If regulations were not enforced due to lack of funding, lack of initiative, or the availability of sanctions, it is not likely that compliance would occur. Boater opposition to the

regulations has been shown. If no enforcement action occurred, the regulated population would not have complied voluntarily.

3) Proper authority, both to issue regulations and to enforce them, is required to have effective regulations. If the EPA and the Coast Guard did not have adequate authority in this area, then this could have caused regulatory failure.

4) Congress passes a great deal of legislation. Only those issues which are salient and can provide a Congressman with good publicity at little cost are kept in the forefront. Where agencies fail, Congressional oversight can provide a correcting influence. However, oversight may not occur if the issue is not considered important. If the general public (those not directly affected by the regulations) do not perceive the issue to be important than there will be no incentives for the political elite to focus on the issue. The issue salience of MSD regulations is considered as a possible source of regulatory failure.

5) How the regulated population perceives a regulation is important in determining whether compliance will occur. Regulations that all or many believe are beneficial will require little pressure to enact or enforce. However if there is strong opposition to a regulation it will be much more difficult to obtain compliance. The perception of the boating (regulated) population is examined. Two aspects, both the perception that the regulations are bad(good) and the perception that sewage from boats is not (is) a problem are considered as sources of regulatory failure.

6) The economics of compliance and noncompliance can play a major role in the effectiveness of a regulation. Clearly the greater

the costs of complying, the more likely that noncompliance will occur. The costs of compliance, the costs of noncompliance (penalties), and the probability of detection for noncompliance are examined to determine if these factors played a role in the failure of the regulations.

7) Interest groups are a powerful force in the structure of the US government. The action or inaction of environmental groups and boating organizations may have played a role in preventing the enforcement or the change of the MSD regulations.

8) The administrative process is an area in which many regulations falter. Between the original legislation, the promulgation of regulations by the agency, and the subsequent enforcement by the enforcement body, the intent of the law can be distorted or circumvented. The transfer from federal to state level is also a weak link. This process is examined for the MSD regulations to determine if the administrative process was a source of regulatory failure.

9) Finally, weakness in the original legislation is a source of regulatory failure. If the legislation is vague, confusing, or uncertain in its intent, then the subsequent regulations may be challenged. The MSD legislation of 1972 is examined for these types of weaknesses.

B. Modification of Occupancy Rate in the Standard FDA Formula

The current formula that is used by the Rhode Island DEM and other states' environmental departments under the National Shellfish Sanitation Program to regulate boat numbers was analyzed and modified. Although this formula contains many assumptions that may be inaccurate, only the occupancy rate assumption was modified here. The occupancy rate assumption assumes that all boats present in a harbor are occupied at all times by two persons. This assumption was challenged using a survey of boat use distributed to RI boaters and aerial photographs of Narragansett Bay. The basic hypothesis was that occupancy rate will be correlated with boat length and that this rate varies significantly from the assumed rate of 100%.

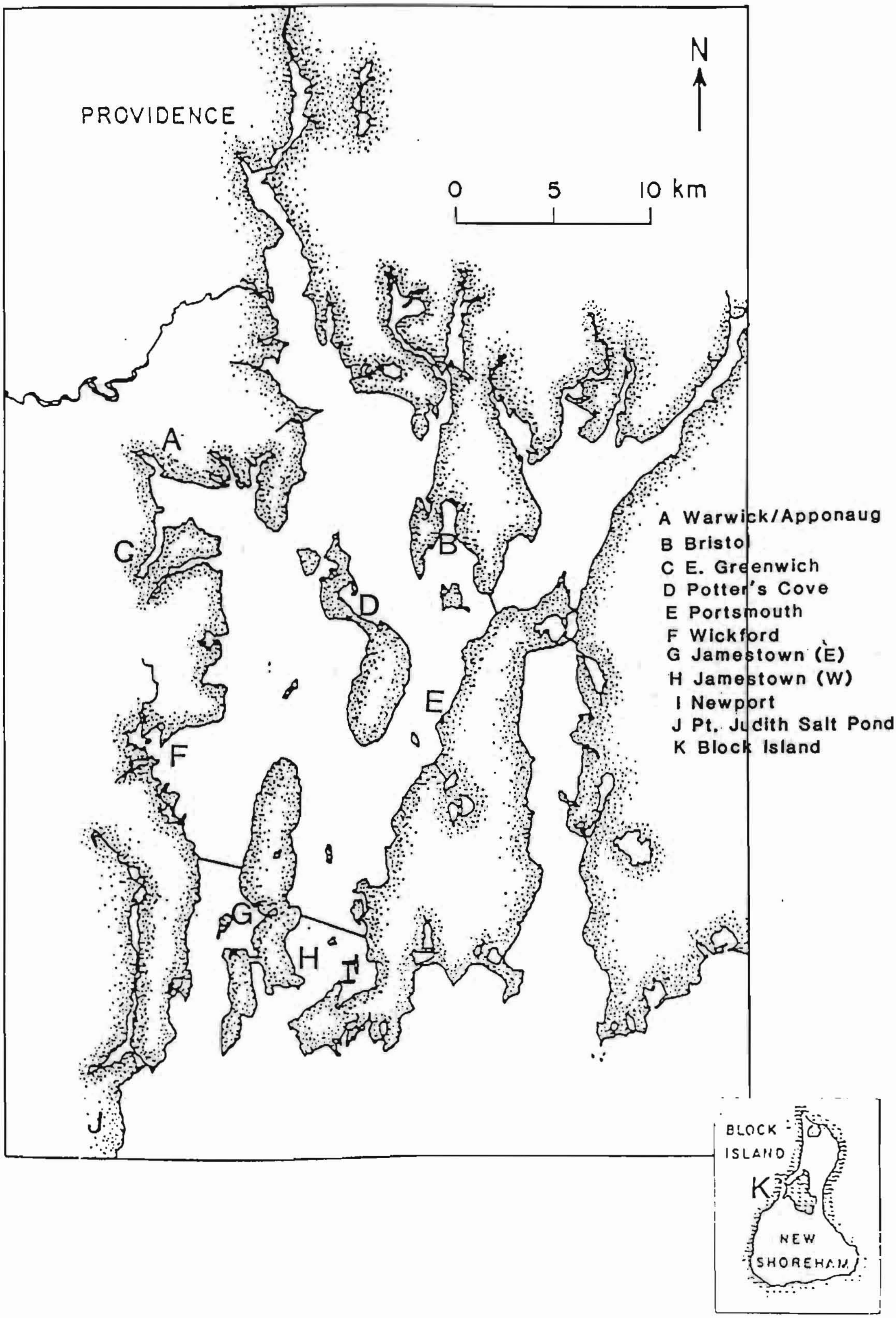
1. Survey Distribution and Questions

A mail return survey (Appendix A) was distributed to moored, anchored, and dockside boats during two high-use weekends over the summer of 1988. The first survey date was July 3rd, the Sunday of the holiday long weekend. Surveys were distributed shoreside to boats at slips in Newport, Portsmouth, and East Greenwich. Surveys were distributed from launches to moored and anchored boats in Newport Harbor, East Greenwich Cove, and Block Island (Great Salt Pond). The second set of surveys was distributed Sept. 4, the Sunday of the Labor Day long weekend. Surveys were distributed to boats at slips in Warwick/Apponaug, Wickford, and Wakefield (Pt. Judith Salt Pond). Moored and anchored boats were reached by launch in Jamestown (East and West harbors), Prudence Island (Potter's Cove), and Bristol Harbor. In total, 11 sites were reached over both survey dates (figure 1).

The surveys distributed on both dates were the same, one-sided survey form, with a pre-encoded mail return stamp and

Figure 1. Survey Distribution Sites, Narragansett Bay.

FIGURE 1
SURVEY SITES



address. The surveys were encoded so that the distribution site could be determined from the returned surveys. The chance for a prize of boating safety equipment was offered in the hopes of increasing survey response. Surveys were enclosed in plastic zip-lock bags to prevent water damage. Surveys were given directly to boaters if possible, or left in an obvious place if the boat was unoccupied. Surveys were distributed July 3rd between 4 pm and 7 pm, and between 8 am and 11 am on Sept. 4. The second set was distributed in the morning in the hopes of reaching more boats before they left to sail for the day.

Concurrently with survey distribution, shoreside data was collected from the boats at slips in Newport, East Greenwich, Portsmouth, Wickford, Warwick/Apponaug, and Wakefield. Information on the number of boats present, the number of people on each boat, and the number of empty slips at each marina was recorded. Only the data from Newport, E. Greenwich, and Portsmouth were analyzed. These data were collected on July 3rd during the afternoon, on a pleasant day. The other sites were observed in the morning, when many of the boat owners had not yet arrived or arisen, making estimates of persons aboard difficult. In addition, the weather on the Sept. 4 date was fair to poor. Since one goal of this project was to determine maximum occupancy rates, this second set of shoreside data was not included in the analysis.

The complete text of the survey can be found in Appendix A. The questions were aimed at determining how often R.I. boaters use their boats, how many people are usually aboard, and what correlation, if any, boat usage had with boat length. Further information gained from the survey can be used to determine characteristics of the Rhode Island boater.

Aerial photographs of Narragansett Bay were taken during the July 3rd survey. Inclement weather prevented photographs on Sept. 4. These photo's were taken to determine boat numbers, boat lengths, and type of boat (sail or motor) in the Bay. They were analyzed using a caliper to determine length and groundtruthed to a known length on land. Eleven photographs were analyzed, covering three harbors in Narragansett Bay (Newport, Block Island, and Jamestown).

2. Survey Data Analysis and Application

Survey responses from 290 boaters were analyzed using the SAS statistical package on the URI Prime Mainframe. The median number of days aboard, median number of people aboard, and median boat length was calculated for the total data set and for specific portions of it. Based on length frequency and discussions with industry contacts, boat size was divided into four size classes, boats less than 25 feet, between 25 and 35 feet, between 36 and 48 feet, and greater than 48 feet. The median values for days aboard, people aboard, and boat length, were calculated for each class. Occupancy rates were determined from the survey responses and from the shoreside data gathered at Newport, E. Greenwich, and Portsmouth. In the first method, occupancy rate was determined by dividing the number of occupied boats by the total number of boats present at the site. In the second method, occupancy was determined by dividing the number of days reported spent aboard by a 100 day boating season (Memorial Day to Labor Day).

The occupancy rates generated by the methods listed above were used to create two modifications of the formula for allowable boat numbers in harbors. These modified formulas were applied to three sites in Narragansett Bay. The modified formulas were used to determine what were the total possible numbers of boats allowed under DEM regulations, and what would be the predicted levels of fecal coliforms from the given number of boats (obtained from the aerial photographs).

IV. RESULTS

A. Regulatory Analysis

1. Failure of the Current Regulatory System

Nine sources of regulatory failure were examined for their applicability to the MSD regulations enacted in 1972. These nine are as follows:

1. lack of technology
2. lack of enforcement
   a. availability of sanctions
   b. effort
3. authority
4. issue salience
5. public perception
6. economics of compliance/noncompliance
7. interest group pressure
8. administrative process
9. weakness in original legislation

Of these nine, seven were found to be operating in the failure of the MSD regulations (table 1). The lack of adequate technology was a factor. Although equipment was available that treated wastes to the required levels, efficient, well-designed equipment was not. Type I devices treat sewage to primary levels, but require a power supply not generally available on sailboats. They also have a significant space requirement. There are no type II devices suitable for boats under 65 feet in length. Original regulations required type II or type III devices for all recreational boats by 1980. It was expected that manufacturers would develop devices suitable for recreational boats under 65 feet by this time. The failure of this development resulted in a waiver of these regulations (43 Federal Register 29637, 1978).

TABLE 1

SOURCES OF FAILURE

OPTIONS	SOURCE								
	technology	enforcement	authority	ssue salience	perception	economics	interest groups	administrative	legislation
CURRENT									
fed. msd regs	-	-	+	-	-	-	-	-	+
OPTIONS									
no fed. regs.	-	-	-	+	-	-	-	+	-
none for <65	+	+	+	-	+	+	+	+	+
fed.standards	-	-	-	-	-	-	-	-	-
type I only	-	+	+	-	-	-	-	+	+
type I +state	-	-	-	-	-	-	-	-	-
type 3 only	+	+	-	+	-	-	-	-	-
formula	+	+	+	+	-	+	+	-	-
Current msd regs.	-	-	+	-	-	-	-	-	+

n.b (+) positive force or not an obstacle
(-) negative force

Type III devices (holding tanks) have significant space requirements. These devices require on-shore counterparts, pump-out stations, to be effective. Pump-outs were never mandated in federal legislation. Where they are installed they have received infrequent use (Tanski, 1989, Rogers et.al., 1982, Strand et.al., 1988).

At the time of the first federal MSD regulations (1972) the technology that was available to prevent the discharge of untreated sewage was marginal. Since that time there has been little progress in improved types of devices. Technological difficulties continue to be an obstacle to compliance.

Lack of enforcement was a major reason for the failure of the MSD regulations. "Rules of conduct in the past when communities were cohesive groupings governed by convention- were enforced by habit, coercion and authority. Modern civilization has made convention lose its force, rules of conduct must be enforced by other means." (Lippman, 1929). To achieve the desired level of compliance, boaters needed to see that the laws were taken seriously by the enforcing agency (the Coast Guard). Since boaters were opposed to the regulations, voluntary compliance was not likely.

Enforcement can be divided into three categories: availability of sanctions, level of effort (i.e police per square mile, arrests per 1000, etc), and visibility of effort. The Coast Guard was given primary responsibility for enforcing the MSD regulations. This entailed both the inspection and certification of the devices themselves at the manufacturing level, and on the water enforcement of proper operation. The Coast Guard has the right to board vessels for the purpose of certifying compliance with the Clean

Water Act (USCG regulations, 1985). In the early 1970's some on the water enforcement occurred in conjunction with routine patrols and boardings for other reasons (Ellison, 1989). Funding for most of these patrols was cut in 1980.

Enforcing the MSD regulations has not had a high priority in the Coast Guard. Coast Guard responsibilities have grown over the last decade without concurrent growth in budget (Hearings, 1983, Oversight Report, 1981). Most of its pollution control effort has centered on the control and prevention of oil spills (budget reports, 1970-1988). A concerted effort to enforce MSD regulations was not made. In 1981, the Department of Transportation (DOT) reported to the Bush commission on regulatory relief that the MSD regulations were the most onerous regulations they had (Hearings, 1983). Given a limited budget and a wide variety of responsibilities the Coast Guard chose not to enforce a program that was opposed by the regulated population and of concern only in localized areas (Amson, 1989).

Enforcement would not necessarily have needed to be 100% efficient in catching violations. A few well publicized penalties can be effective in reducing violations. Seat belt laws are similar to the MSD regulations in their ease of avoidance and difficulties in detecting violations. Short term, high intensity enforcement programs for seat-belt use have caused significantly higher levels of compliance with the laws when enforcement efforts were well publicized. These programs increase both the probability that the driver will receive a ticket and the belief of the driver that s/he will be caught if the law is not obeyed (Jonah and Grant, 1985). Higher seat belt use has been shown in states with higher levels of enforcement (Campbell, 1988). Had similar programs been implemented for the MSD regulations more compliance may have been seen.

A final factor in enforcement is the availability of sanctions. The ability to levy stiff penalties for violations can change the behavior of the regulated population. Currently the only sanctions for operator violations is a fine of up to $2000.00. However this fine is rarely applied. Ontario, Canada, has fines of up to $10,000.00 for offenders (JRB, 1981). Although other factors play a role in Canada's high level of compliance, the high fines reinforce the seriousness of the offence. Avalon, CA has achieved a high level of compliance by combining a fine with expulsion from the harbor for one year (Harbormaster, Avalon, CA, 1989). Monetary penalties may be less important in this issue than restrictions on behavior. The lack of a wide variety of sufficiently stringent penalties contributed to the lack of compliance.

Lack of sufficient authority did not play a critical role in the MSD regulations. The Clean Water Act clearly gave the EPA authority to mandate MSD regulations of any type, and the Coast Guard the authority to enforce the EPA's regulations. If the issue had been a priority in either agency then they might have used their authority to regulate to the fullest extent. Since the issue was not a priority the regulations were largely ignored.

Issue salience encompasses two important factors: the value of the issue to the political elite, and the perception of the issue's importance to the general public (Meier, 1982). The general public is considered here to be a separate group than the regulated public (the boaters and manufacturers affected by the regulations). If a regulation is to be successful in its intent, issue salience is important. Regulations that have no support or are not followed by anyone with political clout are more easily circumvented by the regulated population. The general public, if they are aware of the MSD regulations, are disinterested (JRB, 1981). Sewage from boats lacks the crisis level necessary to generate a large scale public outcry. It may receive more attention on a local level in areas where high intensity boating conflicts with shellfishing (Gaffet, 1986, Stutz, 1985, Baker, 1988).

The boat sewage issue is also not a political rallying point. In areas where boating is popular the importance of the issue to the politician will more often be detrimental to implementation of MSD regulations. Congressmen from these areas will attempt to appease their boating constituents. Rep. Young (AK), Sen. Chafee (RI), and Rep. Holt (MD), all from areas where boating is popular, have attempted to pass bills and influence oversight hearings to remove the MSD requirement for smaller (<65') boats (H.R. 1421, S.793, Hearing, 1983). In areas where boating is not a major recreational activity the MSD regulations are not important enough to be followed by a Congressman. The benefits from becoming the leader in pushing MSD regulations are few. No legislator will gain political power from sponsoring this issue.

The perception of the regulated population is an extremely important factor in compliance in this issue. If a regulation is generally agreed to be good compliance will be high (Meier, 1985).

This has occurred to a greater extent in the Great Lakes than on either coast. The fact that the Great Lakes are enclosed, freshwater, engenders a greater feeling of the need to prevent water pollution. Boaters there are familiar with pumping out sewage to shoreside facilities. This is not the case in coastal waters. A 1980 survey of boating organizations reported that not one of them felt that MSD requirements were needed, nor desirable (JRB, 1981). Another survey reported 85% of boaters feel that pleasure boats do not make a significant contribution to water pollution, and finds that 73% feel they were a victim, rather than a willing partner, in the MSD regulations (Cruising World, 1979).

Attitudes have not altered significantly since this survey (Ross, 1989, Appendix B). Most boaters feel that the 1972 regulations were overkill and place unfair burdens on boaters (Amson, 1989, Sisson, 1989). Many of the survey responses from the summer 1988 survey in R.I. included comments that indicate boaters still feel victimized by anti-pollution laws that should be directed at industrial and municipal pollution sources (Appendix B). A user survey done for the Narragansett Bay Project also show that boaters feel themselves to minimal contributors to the sewage pollution (Ward et.al., 1987). Opposition to the MSD regulations existed when the regulations were first promulgated and has continued. In light of this, voluntary compliance is not likely.

There are several interest groups involved in the MSD regulations. The relative strength of these groups will drive the success of the regulations. In this issue, it appears that the major lobbying groups involved, the environmental lobby and the boaters have functioned to counteract each other. The situation remains in which the regulations are not changed, but neither are they enforced.

Interest group strength can be broken down into several factors (Meier, 1987). Size, resources, dispersion, cohesion, intensity of commitment, prestige, number of groups, and coalition breadth will determine how well an interest group can convert regulations to serve themselves.

The boating public is well dispersed (East and West coasts, Great Lakes, other waterways), has cohesion on the MSD issue, is committed, and may have some elements of prestige. Most boating organizations have sufficient size for localized pressure, but may not be large enough to exert influence at the federal level. Boaters do not seem to have the resources or the willingness to mobilize those resources to be an effective lobby at the federal level. The fact that there are many boating organizations, divided by state and local boundaries, further decreases their power. Finally, the MSD issue lacks coalition breadth. Only boaters tend to care about it. A large number of different interest groups concerned about this one issue is not likely.

The environmental interest groups appear to have the resources necessary to push for stringent regulation and are more organized. In addition environmentalists are well dispersed throughout the country and have a wide variety of different interest groups that support the concept of clean water. This pressure is weakened by a lack of cohesion and intensity of commitment on this issue. Save the Bay, an environmental lobby in R.I., has only recently put sewage from boats on the agenda. Boater membership in this group is a likely factor in this delay. Other environmental groups mention boat sewage briefly or not at all (Hearings, Seattle, Minnesota, 1977). Environmental groups seeking to solve pollution problems are not likely to focus on boat sewage as a major source.

Shellfishermen do not seem to be organized sufficiently at the federal level to be a strong force for MSD regulations. They lack size, resources, dispersion, and coalition breadth. Shellfishermen are also not committed to stricter MSD requirements, but to preventing boats in shellfishing areas (Baker, 1988, Stutz, 1985). Shellfishermen in Rhode Island are concerned about recreational boats for boating safety reasons and because of competition for space on the water. Shellfishermen may be unaware of the conflict with boaters due to sewage pollution until the presence of boats are the direct cause of shellfish area closures (Ward et.al., 1987).

A factor to consider in any regulation is the costs of compliance. These costs include the initial cost of new treatment devices, annual operating costs, and the costs of non-compliance. The costs of non-compliance include the fines, lawyers fees, and time spent in court, that could ensue if the violation was detected. Therefore the probability of detection is also a factor.

For commercial vessels the costs of compliance are high, from $10,000 to $50,000 for installation. These costs can be passed on to clients and included in the costs of doing business. The costs of non-compliance are also high. The probability of detection of non-compliance is great since yearly Coast Guard inspections are required and unplanned boardings more likely. Loss of the ability to do business because of non-compliance is sufficient incentive to generate a 90-95% compliance rate among large, commercial vessels (EPA, 1981).

The costs of installation and annual operation is much less in total for recreational boats, but compliance is also less. The average cost per boat is $1000 for type I devices and $350 for type III devices. Average operating and maintenance costs range from $18-$43 for type I and type III, respectively (JRB, 1981). This assumes that pump-out stations are available for type III's and would be used. The price and maintenance costs of the devices varies somewhat with size. The total compliance costs if all effected boats had complied by 1979 would have ranged from 133 million to 333 million. This does not include costs of enforcement and education.

When considering the costs of purchase and upkeep of an average (~30 ft.) boat, the costs of MSD's do not seem significant. However investment and operating costs are only part of the picture. The fine for operating a boat without an approved, functioning MSD is no greater than $2000. This may be a sufficient penalty if the probability of detection were high. The probability of detection in the first year of installation would have to be 33% for the costs of compliance to balance the costs of non-compliance (Appendix C) for type I devices and 16% for type III devices. To ensure compliance at very low levels of enforcement (less than 1%) penalties would have to be greater than $400,000. Ontario, Canada has fines of up to $10,000 per violation. However, other factors such as inspections, public perception and enforcement levels may be more important. The costs of compliance in the US remain as a disincentive for proper implementation of the MSD regulations due to the low costs of non-compliance.

The administrative process involves both the number of groups and agencies involved in rule-making and the subsequent actions of the lead agency. Boaters, manufacturers, and environmentalists had input into the original legislation through lobbying efforts and public hearings. In the 1972 CWA and subsequent amendments boating organizations were ineffective in creating less stringent regulations, but did manage to gain control by other means than legislation.

The original regulations proposed by EPA in 1972 (June 23) prohibited all overboard discharge of treated or untreated sewage. In 1975 EPA reconsidered its original standards and proposed new ones. After receiving many comments, the final version was promulgated in 1976. These new standards prohibited type I devices by 1978 but contained an incentive clause allowing flow-through type I devices for vessels so equipped by 1980. Because of boaters' delays in compliance and the lack of adequate type II devices the Coast Guard issued a waiver in 1977 and another in 1978 for the installation of type I devices. The result of these waivers is that type I and type III devices are acceptable for vessels under 65 feet until adequate type II devices become available for smaller vessels.

Although the regulated group may not have had much say in the original legislation, the delays in the promulgation of the regulations and the changing requirements indicate that they did exercise some control. Had the EPA and the Coast Guard come out with regulations within reach of the available technology and maintained both the regulations and the time table, boaters may have realized the necessity of compliance. Delays in promulgation of the regulations and shifting compliance deadlines allowed boaters to stall enough to avoid more stringent regulations. In addition the shifting position of EPA from no-discharge to flow-through devices gave the impression that the final step to no regulations for smaller boats may be forthcoming. This attitude further delayed compliance.

The final source of regulatory failure to be examined is weakness in the original legislation. Legislation which is vague and confusing in intent will be easier to circumvent than specific legislation. This is not the case for the MSD legislation. It clearly directed the EPA and the Coast Guard to issue standards of performance to prevent the discharge of "untreated or inadequately treated sewage into or upon the navigable waters from new and existing vessels" (CWA, sec.312, 1972). Only vessels without installed toilets were exempt. The legislation gave specific time tables for compliance (two years for new vessels, five years for existing vessels). The sale or manufacture of a vessel without a certified MSD, the rendering of devices inoperable, and the operation of a vessel without an operating MSD were all declared illegal. Penalties and the enforcement authority were also spelled out. The directive to the implementing agencies was straightforward in the legislation. Other factors than weakness in legislation played a greater role in the failure of the regulations.

2. Other Regulatory Options

The failure of the MSD regulations to alleviate sewage pollution from recreational boats left a gap in pollution control. This gap was filled be the existing Shellfish Sanitation Program policy which regulated boat numbers according to EPA water quality criteria for shellfishing areas. However the MSD regulations as they exist were not the only option available to both the Congress and the implementing agency. A spectrum of options ranging from the most restrictive to the most lenient is examined for the possibility of success of failure based upon the nine criteria listed in chapter 3. These options are as follows:

1. no federal requirements
2. no fed. requirements for smaller boats (< 65ft.)
3. fed. standards, state programs if desired
4. fed. minimum of type I, no state
5. fed. minimum of type I, state greater if desired
6. fed. type III standards, mandate pump-outs, no Y-valves
7. no or fewer boats in certain harbors based on formula

1. No federal regulations. This describes the situation as it existed prior to 1972. At that time boaters were in favor of federal requirements to avoid the variation between states. Presently the push is in the opposite direction, for less or no federal regulations.

This option, from the federal standpoint, is the easiest because it requires no federal action. It essentially reverts to the pre-1970 situation giving state control. At that time there were 13 states with no-discharge regulations and 16 states with various lesser marine toilet restrictions (Robberson, 1964). Seven of the nine sources of failure would act if this option were implemented, although results will be variable between states (table 1).

Technology may be a significant factor against compliance with state regulations for boats that travel interstate. Enforcement would be up to the state and would probably be minimal in most coastal states due to lack of funding. Authority may be a problem if states have to write new legislation or if an implementation structure does not exist. Agencies within the state may squabble over control. Issue salience will vary with state. It may be a stronger force in local and state politics than at the federal level. The perception of the regulated population will remain opposed to regulation, but they may feel more capable of participating in the process at the state level than at the federal level, reducing the perception of victimization. However, boaters may feel more aggrieved if they have to comply with varying regulations across state lines. Compliance costs will remain the same as in the current situation. The economics of non-compliance will vary with state but will probably not change much without increased enforcement.

Interest group pressures will be a stronger force at the state level, but the effect will vary from the Great Lakes to the two coasts. Prior to the federal regulations Wisconsin and other Great Lakes states had more stringent regulations than the current ones (Hearings, Minnesota, 1977, Robberson, 1964). On the coasts, the strength of boating groups may be more significant. The administrative process may be more streamlined, depending on state. Weakness in legislation may be a greater problem since the lack of federal regulations will imply that the issue is not critical.

2. No federal regulations for smaller boats (less than 65 feet). This option would eliminate federal regulations for boats under 65 feet in length. Several bills to amend the Clean Water Act have proposed this option but none have been successful.

This option would be the best in terms of implementation of regulations, but may not address the pollution problem sufficiently. The greatest proportion of boats with toilets is smaller boats (99.9%, EPA, 1981). In this option, only two sources of failure, issue salience and interest group pressure, are present.

Technology is sufficient since type II devices for large boats have been available since the early 1970's. Enforcement would be much easier for several reasons. Most larger boats are commercial vessels that have yearly Coast Guard inspections. The number of boats greater than 65 feet are fewer, allowing for a greater possibility of chance boardings. The EPA and the Coast Guard would maintain authority. Since the Coast Guard already has authority to inspect commercial vessels on a regular basis, adding MSD requirements is fairly simple.

Issue salience would be poor. There are fewer large boats. Commercial vessels are more likely to be concerned with issues of commerce and shipping than in fighting boat toilet regulations. The perception of the regulated population will not necessarily improve, but will not be the obstacle that it is now. Owners of larger vessels may feel singled out by regulations that specifically address them. However, the argument that the wastes from one vessel is not a problem is less valid for large boats.

Costs of compliance for larger boats are greater but can be passed on to customers and depreciated with the value of the boat. The costs of non-compliance, being unable to do business if failing inspection, are significantly greater. The total costs of compliance to the nation will be less. Interest group pressures opposing compliance will decrease. Owners of large boats do not have a separate lobby or coalition. By eliminating regulations for small boats, the EPA eliminates a large membership of the interest group. Environmentalists may still push for regulations on smaller boats, but this will only help the regulation of the large class size.

The administrative process would be improved. Only one type of MSD would be acceptable, standards for which were set from the beginning in 1972. The regulated population is smaller, allowing more specific regulations to be written. It is not likely that weakness in legislation would occur in regulating large boats. The current legislation allows for variations depending on classes of boats. The requirements of preventing sewage pollution would remain the same.

3. Federal standards for MSD's; the state can implement its own program based on those standards. This would place the federal level in an advisory capacity only. States could use the standards to set up boat toilet regulations of their own.

This option has some good points in that it standardizes the MSD requirements making manufacturing and interstate sales easier. Legislative attempts (Young, H.R. 1421, Chafee, S. 793) and agency initiatives (Hearings, 1983) have tried to shift power to the state level with little success. All nine sources of failure could operate in this regulatory option.

Available technology would remain poor. Requiring MSD's at the federal level did not spur manufacturers to develop better devices; setting standards will not change this. Enforcement would be done at the state level. It would remain minimal, depending on state funding. Authority, that is, power to regulate would be worse than currently. EPA would only have the authority to set standards, with little authority to ensure that those standards were followed. It would have no authority to actually regulate boats. State authority would depend on legislation and may be circumvented by strong boater lobbies.

Issue salience at the federal level would be non-existent. There is no political prestige or power to be gained from forcing EPA to change standards when states can choose to ignore those standards. The perception of the boating population would still be poor. Costs of compliance may be worse, depending on the standards. It is doubtful that costs of non-compliance would be higher. Interest group pressures at the federal level would focus on gaining less or more stringent standards. At the state level, boating groups would push for no state programs. Interest group pressure will vary with state, but it is likely that in states with high intensity boating, they will be more effective in preventing MSD regulations.

The administrative process could conceivably worsen if the standard setting process at the federal level, and program implementation at the state level suffer the same delays as the current regulations. By dividing responsibilities, this option creates the possibility of twice the problems. Legislation is weakened by only setting standards because it implies that the issue is not important. State legislation will vary.

4. Federal minimum of type I; states may not have more stringent standards. This provides for across the board minimum treatment for all vessels with installed toilets, yet prevents stronger regulations in states like Minnesota, etc. which have pushed for no discharge zones. It prevents variation across state lines.

This option eliminates interstate compliance problems and provides for some water quality protection. Of the nine sources of failure, five are present here.

Technology remains a problem. Type I MSD's are effective for power boats but do present a significant power drainage for sailboats. Type I devices that require less energy would be needed to implement this option. Enforcement may be easier. A single type of device is required, that is not easily bypassed by Y-valves. Y-valves are devices which allow the sewage to bypass the MSD and be discharged directly without treatment. Malfunctioning devices will be more visible during on-board inspections. However, unless inspections are made, enforcement will remain a problem.

Authority under the EPA and Coast Guard would still be present. Issue salience remains a problem. Using this option does not alter the fact that MSD regulations are not a major federal consideration. The perception of boat owners as being victimized will not change. However, a simple regulation without numerous delays and waivers may have convinced boaters that they must comply.

It will be more expensive per boat to comply since type I devices are more expensive than type III. Interest group pressure would remain an obstacle to compliance as boaters push for decreased requirements. The administrative process would be less of an obstacle since EPA could promulgate a single requirement that all boats, regardless of size, must use. Legislative weakness would not be a factor.

5. Federal minimum of type I; states may have more stringent regulations. Again, this provides for an across the board minimum water quality protection. It retains the states right to have stricter controls, and sets up the possibility of variation between states.

This option combines all the failures of option 4 with those of option 3. All nine sources of failure would be present if this option were used. Technology would be a problem, further complicated by varying interstate regulations. Enforcement would be confused. Responsibilities would be divided as to who enforces where, and what regulation. Authority would be split between federal and state levels, causing a detrimental division of power. Issue salience would remain poor. At the state level, it may improve, but may swing to the boaters favor in some states.

The perception of boaters would be even worse for having to deal with both federal regulations and varying state regulations. Costs of compliance will be the same or greater if each state requires a more restrictive device. Pressure from boating groups will grow at the state level, while environmental lobbies may lose interest because of existing federal regulations.

The administrative process would be further confused by the necessity of two governmental agencies promulgating regulations. Legislation may be weakened if states have to fight consistency battles with the federal government, and boaters seek loopholes to state legislation. This option simply introduces too many players into the regulatory system.

6. Federal minimum of type III; pump-outs would be mandated; Y-valves are illegal. All waters, coastal and inland, would be no discharge zones. Pump-out service would be mandated to ensure that holding tanks could be properly maintained. For maximum compliance, Y-valves, which allow the holding tank to be by-passed, and therefore discharge beyond the territorial sea, would be illegal.

This option is by far the best in terms of improving water quality, but still retains six of the nine sources of regulatory failure. The technology needed for this option exists and is fairly effective. Holding tanks exist which function efficiently for most boat sizes and types. Pump-out facilities of varied type (shore-side, slip-side, on launches, etc.) also are available, even if they have not been built in most places. Enforcement would be improved if the no Y-valve regulation were enforced at the manufacture and sales level. Spot checking of boats for holding tanks, and shore-side counts of pump-out use could ensure compliance.

Authority would be a greater problem under this option. The authority to mandate pump-outs at the federal level is questionable. Attempts to make Y-valves illegal in the Mid-west have met with legal challenges (Sisson, 1989). Additional legislation may be required to give the EPA and the Coast Guard adequate authority. Issue salience will increase as more people (marina operators, manufacturers, dealers) become involved. The more attention paid to the issue will increase its chances of being watched by Congress for proper implementation. The perception of boaters as being victims in the regulatory process will remain. However, mandating pump-out stations will remove the complaint of lack of such facilities and make it easier to comply. The costs to the boater will remain constant, but increase in general because of costs of pump-outs, and increased loading of municipal treatment plants.

Interest group pressure from boaters will increase as boating organizations gain broader coalition breadth (marina operators, etc, will now be concerned). The administrative process is not likely to improve since more groups must now be regulated. Legislation will have to be rewritten to give the EPA and Coast Guard the proper authority. The current legislation is too weak to allow regulation of pump-outs and Y-valves.

7. No or fewer boats in certain harbors based on formula. This final option is the one in place today, due to the failure of the MSD regulations. It is the most restrictive in that it limits the use of the water resource by the boating public.

This option is being exercised today despite the existence of a federal program. It is not derived from the Clean Water Act, but from the administrative powers of the Food and Drug Administration. This agency has the authority to require states to classify waters based on boat numbers to ensure the protection of public health. This option has only three of the nine possible sources of failure opposing its success.

The technology for this option is extremely simple. Boat numbers in harbors are counted, and based on dilution volumes, sewage loading is predicted. If the load is too great, state shellfish sanitation authorities can either close the area to shellfishing or reduce the number of boats. Enforcement is easy. States that do not close areas can be denied certification for interstate shellfish sales. State environmental departments can deny permits for new marinas based on the formula before compliance problems exist. The most difficult enforcement aspect is the removal of excess boats in existing marinas and mooring fields, and the problem of uncontrolled boat numbers in free anchorage areas. In free anchorage areas, state control over boat numbers is limited. However state officials still retain the ability to close these areas to shellfishing.

The authority of the state environmental departments to use the formula option comes from voluntary participation in the National Shellfish Sanitation Program. This program is administered by the FDA. States also gain authority from the CWA anti-degradation policy which prohibits the limitation of an existing resource use (such as shellfishing) by a pollutant source (such as boats). Thus there is sufficient authority for this option.

Issue salience can be strong in states with large numbers of boaters and shellfishermen. This option in particular addresses the shellfishing interests more directly than options generated by the CWA. The perception of boaters is poor as usual, and more adamantly opposed to restricting their use of the ocean resource. Costs are low in that boaters are not required to add any equipment to their boats or pay for operation and maintenance of MSD's. Costs in terms of lack of access to ocean uses and limits on development of marinas are less tangible and could be considerable.

Interest group pressures may be more in favor of this option due to the influence of shellfishermen. This option places boaters and shellfishermen in more direct opposition. Environmental groups generally concerned about the health of the water are replaced by commercial fishermen concerned about their economic livelihood. This gives the implementing agency (FDA, state agencies) a stronger supporting group to oppose the boater pressures.

The administrative process is still an impediment because of the larger number of agencies involved and the nature of the NSSP. The formula method is a policy, not a law, that has developed over two decades. The rules that the state must follow are not always clear, and final responsibility can be broken up among several groups (i.e., DEM and CRMC in R.I.). The lack of legislation requiring the use of the formula is a weakness that undermines the use of this option.

The current regulatory strategy is the use of the standard FDA formula. Although this formula does succeed in resolving more of the sources of regulatory failure than does the federal MSD regulatory system (table 1), it still generates a great deal of boater opposition. Modification of some of the more unrealistic aspects of the formula assumptions may make it more acceptable to the boating public, thus generating more cooperation. One such assumption is the occupancy rate. This was modified for RI boaters using a survey administered in the summer 1988 boating season.

B. Occupancy Survey Results

1. Boat Use Characteristics

The survey results and the shoreside data support the hypothesis that the occupancy rate differs from 100%. The survey results show that occupancy rate, as measured by the reported number of days aboard, varies from 30% to 100%, depending on the size class of the boat (table 2). The shoreside data show occupancy rates, as measured by the number of occupied boats out of the total number of boats at the site, ranging from 27% in East Greenwich harbor to 51% at Newport (table 3). The rate varies depending on the type and popularity of the marina site. Newport is a well known destination marina area where people will be more likely to be on their boats. E. Greenwich is a origination point. Marinas here are more likely to be used as "parking lots". Boaters tend to arrive in the morning, take the boat out, and then go home for the evening. At these type marinas there was a greater proportion of local residents among the survey respondents (table 4). A local resident was defined as one whose reported address in the survey was the same or very nearby the place of survey distribution. It is not surprising

TABLE 2

OCCUPANCY RATES FOR SURVEY DATA

Size Class	# People Aboard	# Days Aboard	Occupancy Rate
I (L<25')	1	30	30%
II (25'≤L≤35')	2	40	40%
III (36'≤L≤48')	2	60	60%
IV (L>48')	2	250	100%

Assume 100 day boating season: Memorial Day through Labor Day

TABLE 3

OCCUPANCY RATES FOR ON-SITE DATA

Site	# Occupied	# Unoccupied	Empty Slips	Occupancy Rate
Newport	127	121	26	51%
East Greenwich	46	120	111	27%
Portsmouth	49	124	144	28%
Total	222	365	281	38% (AVG)

TABLE 4

MARINA HARBOR TYPE BASED ON RESIDENCY

SITE	#RESIDENT	#NONRESIDENT	UNKNOWN	TOTAL	%RESIDENT OF TOTAL
E. Greenwich	13	1	2	16	81.25
Newport	12	21		33	36.36
Portsmouth	10	6		16	62.50
Block Island	0	41	1	42	0.00
Dutch Island	11	8		19	57.89
Jamestown(E)	20	5		25	80.00
Bristol	15	2		17	88.24
Wickford	26	5		31	83.87
Pt.Judith	28	1		29	96.55
Potter Cove	0	12		12	0.00
Warwick/ Apponaug	47	3		50	94.00

that different marinas will show wide ranging occupancy rates. In either case, the occupancy differs significantly from the assumed value of 100%.

The number of people aboard did not differ significantly from the assumed number of two per boat (figure 2). There was a slight trend towards more people with larger boats, but the median remained at two. Of the 290 surveys returned, 140 (48.3%) were from moored boats and 150 (51.7%) from boats at slips. There were 162 sailboats among the respondents, and 126 motorboats. The majority of the surveys came from local residents (62.6%) (table 5). Most of the respondents had some type of marine sanitation device if they had an installed toilet. Type II MSD's were the least common. Only 5.5% of all those with marine toilets had type II MSD's. Port-a-potties were more common (27.7% of all those with marine toilets). Only 11.7% of the survey respondents claimed to have no toilet facilities at all (table 6).

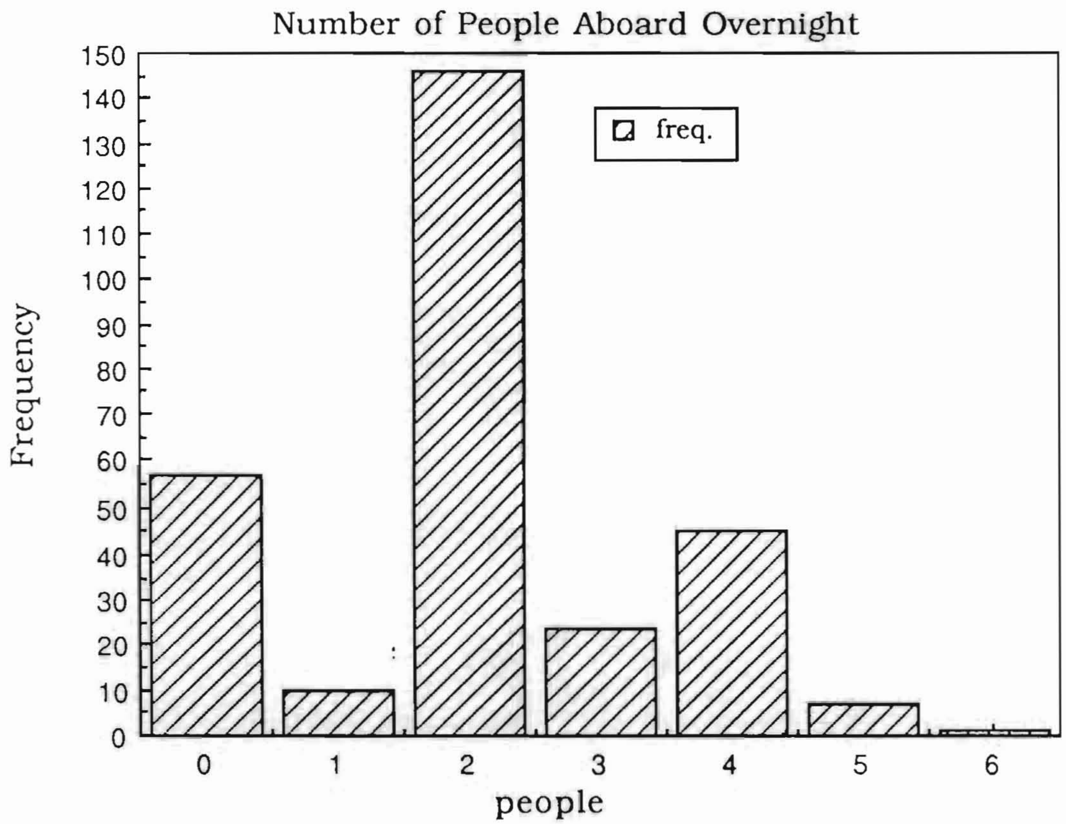
The median time spent aboard was 40 days and 10 nights. The median boat length was 28 feet (table 7). Median values were taken because the distribution was not a normal one. The median values for days aboard, nights aboard, and number of people aboard was determined separately for each size class (table 8).

2. Formula Modification

The results from the on-site data and the survey responses were used to create two modifications of the sewage loading rate formula. The on-site data resulted in an average occupancy rate of 38%, with a range from 27% to 51% (table 3). Empty slips at the site

Figure 2. Overnight occupancy. The median number of people aboard did not differ from the assumed number of two people per boat.

FIGURE 2



Number of People Aboard Overnight
Frequency
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
freq.
0
1
2
3
4
5
6
people

TABLE 5

SURVEY RESPONSES

CATAGORY	NUMBER RECEIVED	% OF TOTAL
Harbor Location		
moored	140	48.3
slips	150	51.7
Boat Type		
sailboats	162	56.3
motorboats	126	43.8
Residence		
local resident	178	62.6
non resident	106	37.3

TABLE 6

TYPE DISTRIBUTION OF MARINE TOILETS

Type of Head	Frequency	% of Total
no response	34	11.7
type I	61	23.4
type II	14	5.5
type III	94	36.7
porta-potty	71	27.7
other	17	6.6

TABLE 7

BOAT USE CHARACTERISTICS

variable	average value	median value	standard deviation
length	28.8	28	7.27
days aboard	51.2	40	47.6
nights aboard	24	10	47.9
people aboard	2.1	2	1.34

TABLE 8

SIZECLASS DATA

Length < 25 N=83

Variable	Average	Median	Standard deviatio	Spearman corr. coefficients
length	21.4	22	1.86	
days	38.9	30	26.8	-0.062
nights	6.29	1	11.1	0.352
people	1.07	1	1.1	0.329

25≤Length≤35 N=161

length	29	30	2.9	
days	46.4	40	26.8	0.085
nights	20.5	14	22.6	0.379
people	2.3	2	1.2	0.282

36≤Length≤48 N=43

length	39.9	39	3.4	
days	80.7	60	83	-0.082
nights	57.9	30	87.9	0.245
people	2.88	2	1.1	0.126

Length > 48 N=3

length	59.7	53	14.2	
days	220	250	162.1	-0.5
nights	220	250	162.1	-0.5
people	3	2	1.7	0.866

are discounted, as the boaters are not present to contribute to the sewage loading at the site. Using this data, a simple modified formula was developed. The occupancy rate 'X' depends on whether site-specific occupancy rates, and average for the Bay, or the highest occupancy rate is used. In this modification, the highest occupancy rate is used to estimate sewage loading rates at three sites: Newport, Jamestown, and Block Island. The highest occupancy rate is used as it represents the greatest potential sewage loading, and will give a more conservative estimate of allowable boat numbers.

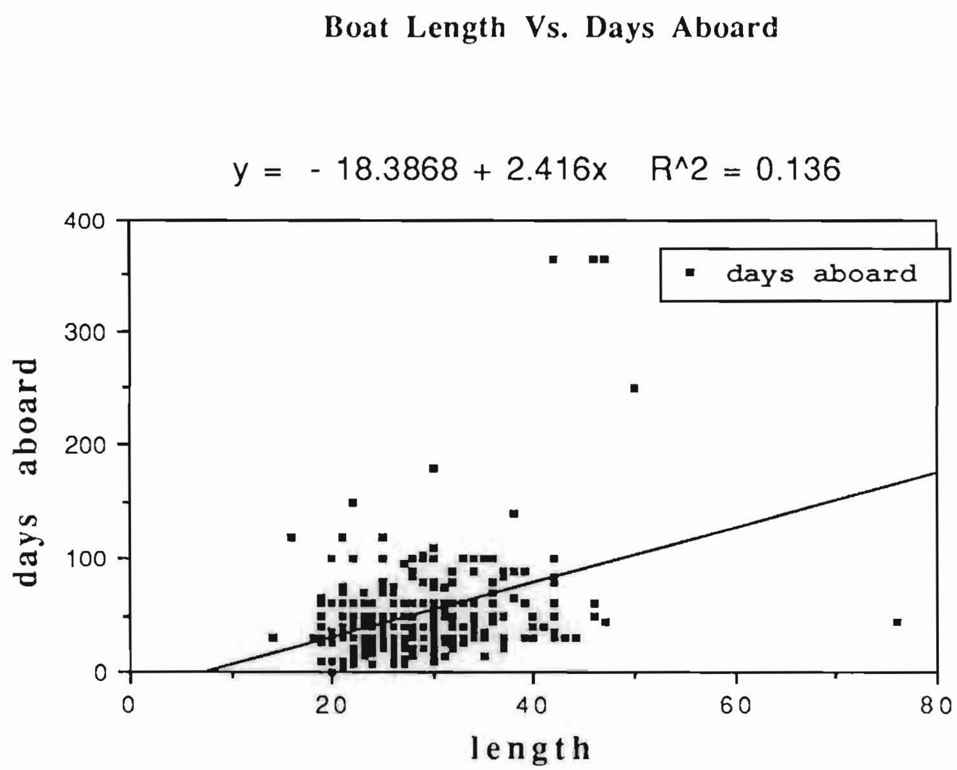
Modification 1

$$14 \text{ fc/100ml} = \frac{(G)*(2)*(2x10^9)*(X\%)}{V}$$

The mail return survey generated occupancy rates ranging from 30% for size class I to 100% for size class IV (table 8). For the purpose of the second modification, occupancy was defined as the number of days aboard divided by a 100 day boating season (Memorial Day to Labor Day). Length was found to be positively correlated with days aboard (R^2=0.136) (figure 3). Although there was a significant difference in days spent aboard between size classes (figure 4), within size classes, the correlation was not as strong (figure 5). A modification was developed which allows varying numbers of boats, depending on the size class of the boat.

Figure 3. Boat Length Versus Days Aboard. Boat length for all those surveyed was correlated with the number of days spent aboard.

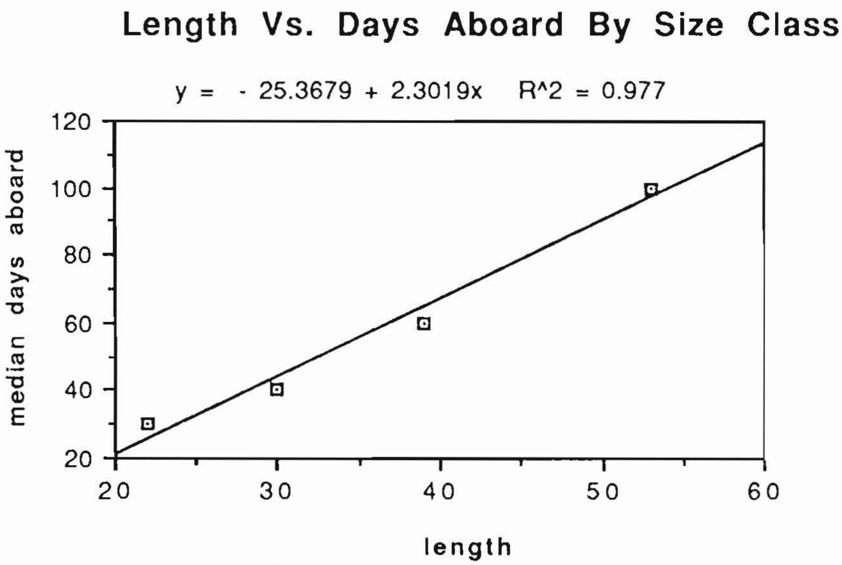
FIGURE 3



Boat Length Vs. Days Aboard
y = - 18.3868 + 2.416x R^2 = 0.136
days aboard
400
300
200
100
0
0
20
40
60
80
length
days aboard

Figure 4. Length Versus Days Aboard By Size Class. Boat length versus days aboard was strongly correlated when boats were broken down into the four size classes.

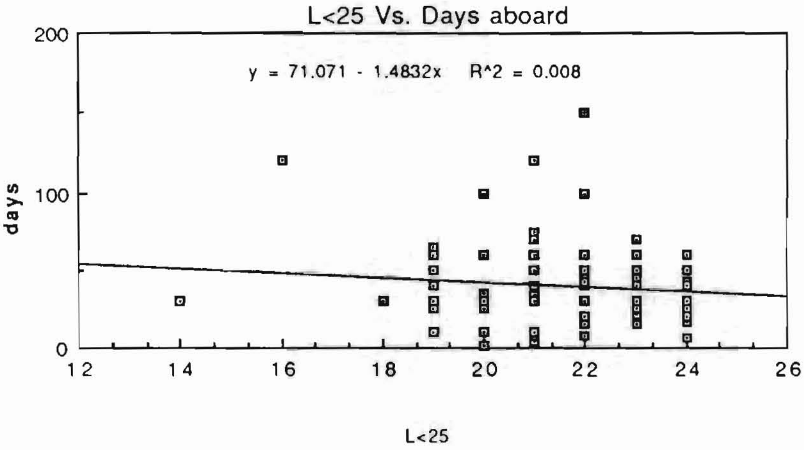
FIGURE 4

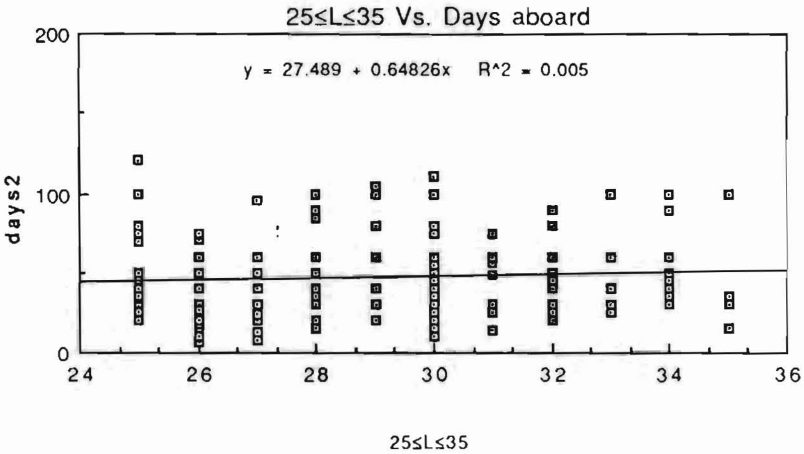


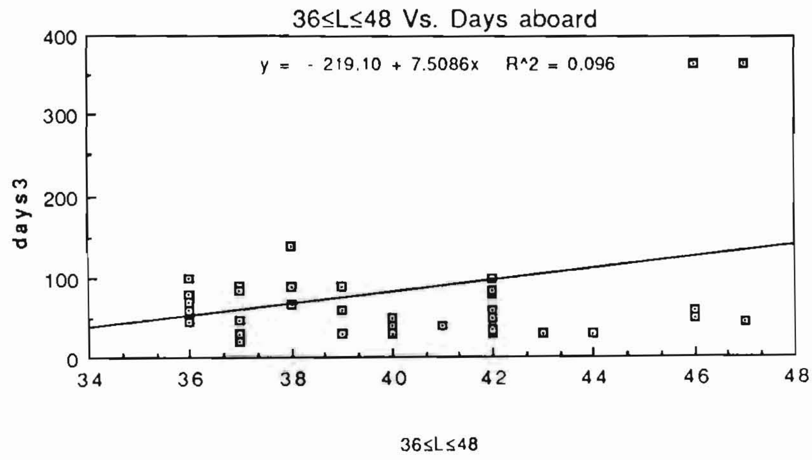
Length Vs. Days Aboard By Size Class
y = - 25.3679 + 2.3019x R^2 = 0.977
median days aboard
120
100
80
60
40
20
20
30
40
50
60
length

Figure 5. Length Versus Days Aboard Within Size Class. Boat length versus days aboard was not strongly correlated within each size class. The variability in boat use within size class limits the ability to predict sewage load by specific boat lengths. Only general size classes can be used.

FIGURE 5


L<25 Vs. Days aboard
y = 71.071 - 1.4832x R^2 = 0.008
200
100
0
days
12
14
16
18
20
22
24
26
L<25


25≤L≤35 Vs. Days aboard
y = 27.489 + 0.64826x R^2 = 0.005
200
100
0
days2
24
26
28
30
32
34
36
25≤L≤35


36≤L≤48 Vs. Days aboard
y = - 219.10 + 7.5086x R^2 = 0.096
400
300
200
100
0
days3
34
36
38
40
42
44
46
48
36≤L≤48

Modification 2

$$14fc/100ml = \frac{[(G_I)(30\%)+(G_{II})(40\%)+(G_{III})(60\%)+(G_{IV})(100\%)]*(2)*(2x10^9)}{V}$$

Where G = number of boats in that size class and the percentage is the occupancy rate for that size class.

Loading rates and allowable boat numbers have been calculated for 10 harbors in Narragansett Bay and for the entire Bay. The dilution volume for each area is calculated based upon nautical charts and depths in the area. Individual hydrodynamic factors are not considered. A flushing rate of 24 hours is assumed for all harbors.

Aerial photographs of sites in the Bay were analyzed for boat number and length. There were 1741 boats of size class I, 1054 of size class II, 366 of size class III, and 121 of size class IV in three harbors in the Bay. The breakdown by area and harbor is shown in table 9.

Appendix D shows the application of the two models to three harbors in Jamestown, Newport, and Block Island. Volumes and allowable boat numbers using the original formula and the first modification were determined for 10 harbors in Narragansett Bay (table 10). The dilution volumes were derived from two sources. The harbor volumes were calculated using a planimeter to determine area and a randomized grid sampling to determine average depth of the harbor (Migliori, 1989, p.c.). The volume of the Bay was taken from Chinman and Nixon (1985). Data from NOS/NOAA charts was

TABLE 9

OBSERVED BOAT NUMBERS AND SIZE CLASSES AT THREE HARBORS

SITE	CLASS I (<25 ft.)	CLASS II (25≤L≤35)	CLASS III (36≤L≤48)	CLASS IV (>48 ft.)	TOTAL
NEWPORT	761	508	217	106	1592
JAMESTOWN	78	24	1	0	103
BLOCK ISLAND	902	522	148	15	1587

TABLE 10

Boat Numbers and Harbor Volumes

Site	Volume (100ml units)	Boat # (CRMC)	Boat # (Photo's)	Boat # (FDA formula)	Boat # (Modification1)
Newport	5.49E+11	1457	1592	1921.50	3767.65
Dutch Island	2.1E+10	-	103	73.50	144.12
Great Salt Pond	1.27E+11	576	1587	444.50	871.57
Greenwich Cove	2.87E+10	876	716	100.45	196.96
Apponaug	7090000000	460	846	24.82	48.66
Westerly	6.4E+10	746	-	224.00	439.22
Little N.B.	2.16E+10	218	-	75.60	148.24
Bristol Harbor	1.05E+11	997	-	367.50	720.59
Kickamuit R.	3.43E+10	-	-	120.05	235.39
Sekonnet	640000000	231	-	2.24	4.39
Total, N.B.	2.13E+13	-	-	74550.00	146176.47

n.b. volumes for individual harbors from Migliori (p.c., 1989)
volumes for total, Narragansett Bay from Chinman and Nixon (1985)

digitized, using 4,500 shoreline points and 4000 bathymetry stations (Chinman and Nixon, 1985).

V. DISCUSSION

A. Regulatory Structure and Implications

1. The Failure of Regulations

In the last two decades there has been a significant increase in the number of regulations generated in government (Meier, 1985). Regulatory agencies were created to develop the technical details of new laws and to implement regulations. In addition to increases in regulation volume was also a change in the type of regulations generated. Regulations became part of most occupations, industries, and activities. Laws were written that gave more detailed directives to agencies as to what and whom were to be regulated.

More numerous regulations do not necessarily mean that the perceived problem to be regulated will be corrected. Implementation of regulations and follow through of results are critical factors. There is a great difference between output-the promulgation of regulations, the issuance of permits, etc., and outcome-an actual result in the environment or a change in the behavior of the regulated group (Burroughs and Lee, 1988).

There are several causes of implementation busts-the failure of regulations to achieve the desired effect. These have been examined for the MSD regulations. Clearly the MSD regulations are an example of regulatory failure. Several factors were predominant in causing this failure. The major sources were the lack of enforcement and more importantly, the opposition from the regulated population. Where this opposition did not exist or was not as strong, as in the program. It also would have provided a more consistent level of water quality protection. All sewage would at least receive primary treatment. There would be no discharge of untreated wastes as occurs now with holding tanks. This fact might have spurred FDA to re-evaluate its programs in the light of partial treatment of sewage from boats. A more balanced system of resource use could have developed from this option.

Having federal minimum requirements of type I devices but allowing states more stringent programs (option 5) would have been practically impossible to implement. However, this option would have provided for greater water quality protection where desired (i.e. the Great Lakes, states with a large shellfishing industry). The confusion and interstate conflicts would limit the usefulness of this option.

Mandating type III devices and pump-outs (option 6) would have been easier to implement than the current system and provide the highest level of water quality. If actually enforced, the concern over shellfishing areas would have been eliminated. The implementation possibilities of this option remain questionable, especially with the lack of authority to mandate pump-outs and make Y-valves illegal. If this option were not complied with, the results would be worse than the current situation, since all boats would have type III devices and could discharge untreated sewage.

3. Why the Formula Option Emerged

Of the possible options that could have been chosen to regulate boat numbers, option 2, no federal requirements for boats under 65 feet in length, would have been the easiest to implement. However, since the percentage of large boats (>65'), of all boats with installed toilets is small (.1%-EPA, 1981), federal authorities and environmental groups (Hearings, Minnesota, 1977), did not feel that exercising this option would have corrected the water pollution problem (Amson, 1989). Instead, the current system of regulating all boats with installed toilets was chosen. These regulations were never properly enforced and met sufficient opposition from the regulated opposition to be rendered ineffective. The regulations and legislation have never been changed, they simply have been ignored.

Into this regulatory vacuum came the use of the formula method (option 7). Use of this method was not a conscious choice by the authorizing agencies (EPA, Coast Guard), but came into being because of concerns over the sanitary quality of shellfishing areas. It is administered by a different agency, the FDA, separate from the Clean Water Act. In effect, a program set up in the late 1960's to resolve public health issue has remained operative even after federal legislation was passed to correct the problem. The priority of the FDA is not clean water for its own sake or even the regulation of boat sewage. Its priority is to ensure that shellfish consumed by humans will not cause illness. Since boats are a potential source of contamination a system was set up to address the problem of boats near shellfish beds. FDA does not require states to eliminate marina space but does require that areas near boats be closed to shellfishing.

The use of the formula is not codified in law and was not formally included in the NSSP until 1988. Since 1965 the presence of boats has been a consideration in the sanitary survey of shellfishing areas (NSSP Manual of Operations, 1965). The formula was first published in 1968 and has been a guideline since. After the CWA of 1972 many officials felt that the MSD regulations would negate the need for the use of the formula (EPA, 1985). This delayed the formal adoption of the formula method. As it became clear that the MSD regulations were not effective the formula method was revived and became formal policy in 1988. The use of this option has resulted from a public health need and not a conscious choice by the agencies involved. Its relative ease of implementation has allowed it to remain as the predominant regulation of boats and boats sewage.

4. Effects of Using the Formula Option

The use of the formula method to limit boat numbers in certain harbors has had the effect of worsening user conflicts without verifiable improvement in water quality. The focus on simply removing some sources of sewage, as opposed to requiring treatment of that sewage, implies that certain levels of pollution are acceptable. It in essence says that boats are a special source of pollution that can deposit untreated sewage into the nations waterways, where treatment plants and other sources (houses, etc.) cannot.

Determining the acceptable level of pollution from boats through the use of a highly simplified formula creates a situation where all users are dissatisfied. Boaters, unconvinced that they are a serious threat to the environment, feel aggrieved by the stringent application of a formula that may not reflect reality. Shellfishermen are equally dissatisfied. Shellfishing areas closed due to the presence of boats may not show contamination by conventional testing.

Revising the formula by obtaining additional information on boat use and hydrodynamics can correct some of these problems, but does not address the essential problem of regulations which are implemented without prior consideration of possible sources of failure.

A side effect of the formula method has been the limitation on new marinas and marina expansion. This effect may be considered a benefit or detriment, depending on the party involved. Limiting marina development limits public access to the water. A marina may not be permitted in an area due to water quality problems, but a condominium tied to town sewage lines may be allowed.

Using the formula method is the easiest option to implement. It eliminates the need to require specific equipment on boats and is easily monitored. However this option has some problems. The formula contains several assumptions which may be invalid. These can alter its adequacy in preventing threats to public health and in its assessment of harbor capacity.

Using the standard formula to determine harbor capacity severely limits the allowable number of boats. Block Island (Great Salt Pond), which presently supports a boat population of over 1500 boats would only be allowed 444 boats under the formula method, and only 872 boats using modification 1. The dye study done in Block Island would allow 712 boats (FDA, 1987). Greenwich Cove, which has a boat population of 716, would only be allowed 100 boats under the standard FDA formula (table 10). This is a restriction that boaters are unwilling to accept. On a realistic political level, restricting boat numbers to these limits is impossible.

The use of the formula has the potential to generate policy guidelines which are impractical if not impossible to follow. A state that is focused on its ocean resource and which has a longstanding boating tradition needs a more accurate means to balance use conflicts. Modifying the formula to reflect better boat usage can be helpful but is not the complete solution.

5. Use of the Formula Modifications

The modified formulas developed in this thesis use more information on actual boat use, but share many of the same problems as the original. As with most simplifications of reality, to use these models requires acceptance of the assumptions inherent in the models as well as the assumptions of the data collection methodology.

Once again, the revised formulas assume that all occupied boats in a harbor are discharging, and are discharging untreated sewage. This assumption is maintained despite survey results which show that at least a small percentage of the boats with installed heads have some treatment to primary levels (table 6). It also ignores the possibility of boaters using onshore facilities or discharging sewage only when out beyond three miles. These modified formulas further assume that all boats counted, regardless of size, have installed toilets, although discounting boats smaller than 25 feet is allowable under FDA policy.

These assumptions are used for several reasons. Firstly, the adequacy and maintenance of the type I systems for the boats are unknown. Second, the use of shoreside facilities and/or offshore discharge is unquantified and may be highly variable. It was desired with these modified formulas to provide a fairly simple means to determine allowable boat numbers. The determination of sewage loading is inexact at best. It is hoped that providing a margin of error by including boats which may not be contributing, yet using more information than the current method, will be in the best interests of both the boater and the public health.

The revised formulas consider all marina types to be equivalent, but they allow for varying occupancy rates after site specific studies. It was not possible with limited time and funding to do in depth studies of the use characteristics at all RI marinas. The survey work shown here gives reasonable parameters for the entire Bay which can be modified in turn if site specific studies are available. Samples were received from most marina areas, but the sample size for each would have been too small to make accurate judgements on use characteristics.

The formula method assumes that all marinas are alike in composition of boats and in the use of boats. This is not the case in most places (Fisher, 1987). Marinas in R.I. show distinct variations in occupancy depending on location (table 3). Some marinas, such as Block Island and Newport Harbor, are popular destination sites. Boaters come from Massachusetts, Connecticut, New York, and other parts of Rhode Island to spend the day in these harbors. Other areas, such as East Greenwich and Portsmouth, are origination points. Boaters use the marinas here in essentially the same manner as a parking garage. The boater drives to his/her boat, goes out for the day, and leaves again at night (table 4). Still other areas may have a mixture of these types of use. In addition, how an area is used may depend on the time of year and particular events (i.e. a yacht race, etc.)

Marinas also vary in composition. Some cater to larger vessels while others have a greater preponderance of small motor and sail boats. There are also variations in types of vessels. Galilee, RI, is mainly a fishing port that maintains a fishing fleet with drastically different use patterns than Newport marinas catering to yachts and pleasure boats.

The revised formulas retain several of the implicit factors of the original formula. These include background coliform levels of zero, no growth or die-off of the bacteria, and the static volume method of the original. As stated previously, assuming zero background levels is often blatantly incorrect. Marinas in the upper Bay, just below the Fields Point sewage treatment plant outfall, are definitely not discharging into pristine waters. However the intent of the formula and the modifications is to determine the allowable sewage load from boats that would theoretically be diluted sufficiently by the receiving waters so as not to exceed the 14fc/100ml maximum. From an overall water quality perspective all sources and the final quality of the water is important. The perspective of the administrator in charge of regulating boat numbers is restricted to limiting the pollution from this source. Other sources of pollution must be addressed if boat numbers do not exceed allowable levels and the waters remain polluted.

The behavior of bacteria in water is a concern both in terms of the pathogen and the indicator (Pipes, 1982). Fecal coliforms have been shown to have varying die-off rates depending on water temperature. These rates do not always correspond to those of the pathogens. This issue is a serious one that requires assessment of how we measure bacterial water quality and the effectiveness of current US programs.

Of these three assumptions, the use of the static volume to determine dilution is the easiest to correct and perhaps the most critical. Sewage from recreational boats became a concern when boat numbers in small enclosed harbors reached high concentrations. It is precisely these enclosed areas with little flushing that require the most protection from excess sewage loading. Dye testing to determine the flushing capacity of major marina sites in the Bay would be a first step in preserving water quality. Across the board application of the static volume method hurts both marinas where there is good flushing and water quality in areas that are more stagnant.

The use of the formula modifications requires that the assumptions of the data collection are accepted. A 10% survey response rate was achieved, resulting in 290 surveys. The results from these are assumed to be representative of the use patterns for all similar boaters in RI waters. It is assumed, as must be in all surveys, that the act of surveying the boaters did not influence their responses. This may be incorrect since some boaters may have been aware of the illegal nature of dumping sewage within three miles and responded accordingly.

Shoreside data were obtained from a total of 587 boats. If no one was present on board at the time of the survey, then the boat was counted as unoccupied. This "instantaneous" occupancy rate discounts people who may have arrived later (or left earlier). However, it is assumed that this snapshot picture of occupancy is representative of the occupancy throughout the day. That is, the fluctuations in people remains constant.

Clearly it would be impractical to devise a formula that accounts for all the possible variations in boat use. It is important to remember that these variations exist. The formula is a highly simplified method of determining allowable boat numbers. The use of this method is understandable given time and budget restraints. State agencies can classify buffer zones without a great deal of information. However this simple method becomes objectionable when it limits the use of a resource based upon scanty information.

A major problem that remains both with the modified formulas and with the original formula is the inability to predict and control the sewage load in free anchorage areas. Many towns in RI, in receiving Army Corps of Engineers funds for harbor maintenance, agree to provide a free anchorage area in the harbor. Neither boat number nor size can easily be regulated. Since they have limited access to shoreside facilities, anchored boats may be a greater contributor to sewage loading than boats at slips or moored. The use of the formula and the modifications is predicated on the ability to control and predict the number of boats in an area. This can be done in most harbors by limiting slip space and moorings. In harbors with free anchorage space boat numbers can be highly variable. Predicting and controlling the sewage loading in these harbors will be difficult.

VI. CONCLUSION

The regulation of boats occurred because it was felt in 1972 that boats were a pollutant source that needed to be controlled. These regulations have failed for several reasons. There was a lack of adequate technology, a lack of enforcement, a lack of issue salience, negative perceptions by boaters, low costs of non-compliance, competing interest group pressures, and administrative errors. Of the nine sources of regulatory failure listed on page 37, only two, legislative weakness and lack of authority, were not operating in the federal MSD regulations. It was hypothesized that difficulties in enforcement and lack of public support for regulations would make them more likely to fail. This analysis has proven this hypothesis, but also includes other sources of failure. Had more of these sources of failure been corrected, either through greater enforcement or a firmer administrative stance, the MSD regulations may have succeeded. Where boater perception of the need for regulations is better, as in the Great Lakes and in Canada, the problems of non-compliance are much less.

The Environmental Protection Agency, in promulgating the MSD regulations, had other options available to it. These options include but are not limited to:

1. no federal requirements
2. no federal requirements for smaller boats (< 65ft.)
3. federal standards, state programs if desired
4. federal minimum of type I, no state program

5. federal minimum of type I, state requirements greater if desired
6. federal type III standards, mandate pump-outs, no Y-valves
7. no or fewer boats in certain harbors based on formula

Of these options, having no federal regulations for boats less than 65 feet (option 2) would have been the easiest to implement but may not have resolved the water quality issue. Requiring type III devices and pump out facilities (option 6) would have been one of the most difficult to implement but would have provided the greatest level of water quality protection.

All the options available have difficulties in both implementation effectiveness and in their ability to protect water quality. A closer look at the probability of the success of the regulations, prior to their promulgation, might have eliminated some of the regulatory confusion that exists now.

The formula method of limiting boat numbers has been used because of the regulatory vacuum created by the failure of regulations at the federal level. This formula, while not perfect, can be used to regulate effectively boat numbers provided sufficient information is available.

Boat use data for Narragansett Bay was collected during the summer boating season, 1988, to obtain information to modify the formula for Rhode Island. Occupancy rates (the amount of time spent aboard) was found to be correlated with length (figure 3), proving the hypothesis that these variables would be correlated. However, no significant correlation was found between boat length and the number of people aboard. Therefore. that hypothesis is rejected. In addition, it was hypothesized that occupancy rate would differ from the assumed rate of 100%. This was proven by the results of the survey (tables 2 & 3), which show occupancy rates ranging from 27% to 100%.

Occupancy rates from the surveys were used to generate two formula modifications to calculate sewage loading rates and thus allowable boat numbers. These modified formulas contain more information about boat use and thus will be more reflective of the actual contribution of boats to the sewage load. However, the modifications, like the standard FDA formula, are only as good as the assumptions. These modifications still retain the static method of determining dilution volume. Using the static volume method overly limits boat numbers in areas with good flushing and may allow too many boats in more stagnant harbors. More information on the hydrodynamic regime of the harbors would increase the applicability of the formula. Site specific occupancy rates would also be an improvement. Finally, the problem of free anchorage areas still exists. Since it is difficult to limit boat number and size in these areas, the ability to control the sewage load will be curtailed.

Although the modified formulas may retain several of the problems associated with the standard formula, they are an improvement. Using a standard formula that overly limits boaters' use of the resource without improving water quality worsens user conflicts. The contribution of boats to water pollution is a variable and highly localized problem. Severely limiting boat numbers, especially if larger sources of pollution are present is inequitable and generates a great deal of hostility. Conversely, the implication that the water is safe for shellfishing and other recreational activities when boat numbers have been limited is flawed. Water quality may remain poor due to other sources. Needlessly antagonizing a user group without proven benefits is poor strategy for regulation.

The modified formulas can correct some of the use conflict by more accurately depicting boater contribution to pollution. Under the present standard FDA formula, Block Island would be allowed only 444 boats. The modified formulas allow for twice or greater this amount, depending on boat length. These numbers still would not reach the present number of boats found in Great Salt Pond on high use weekends (upwards of 1500 boats). Clearly there is a need both for more information to include in the formula and for a marina policy that equitably balances resource use.

The formula method was but one of several regulatory options. It may not be the best option in terms of improving water quality while retaining free use of the resource. However, other options may have been more difficult to implement (table 1). Revising the formula may correct some of the problems of regulatory implementation. If boaters feel that a revised formula will be more fair, more cooperation may result. Presently Rhode Island is moving towards option 6, requiring pump out facilities, although it does not have the authority to require holding tanks or a ban on Y-valves. If Rhode Island had sufficient pump-out capacity, it could apply to EPA for no-discharge status for its waters. Then it would have the authority to require either holding tanks or that flow through marine toilets be sealed while in RI waters. While increasing boater use of pump out facilities would improve water quality and *perhaps* open more areas to shellfishing, it is an extremely difficult option to implement. If absolute compliance with pump out regulations cannot be ensured, the use of the formula may continue.

The use of a revised formula does not address the essential problem of regulatory implementation. Policies initiated without careful consideration of the possible sources of regulatory failure will be ineffective in solving the problem. For example, of the nine sources of regulatory failure examined here (pg 37), it is clear that in Rhode Island, boater perception of the need for regulations was negative (Appendix B, Ward, 1987). The eight remaining sources of failure also could have been operating in Rhode Island, but they have not been well examined.

If a state truly wishes to formulate an effective strategy of regulation, it must take the time to examine the sources of regulatory failure applicable to the situation. By discovering which sources of failure could operate to render regulations ineffective, measures can be taken to alleviate these sources. This could involve, in the Rhode Island example, better boater education programs to convince boaters of the need for regulations, or more funding for enforcement efforts. Focusing on single issue details, such as the use of the FDA formula, ignores the larger system in which regulations function. Had a more careful analysis of the factors involved in the boat sewage pollution situation been done prior to initiating regulations, more sources of regulatory failure may have been avoided.

RHODE ISLAND SEA GRANT MARINE ADVISORY SERVICE

BOAT USE SURVEY

Boat length__________feet [ ] sail [ ] motor [ ] sail w/motor

Homeport-Town______________________________State________________

How often will you use your boat this season?________days

How often will you remain aboard overnight?________nights

How many people usually remain aboard overnight?_______people

Is there a head aboard your boat? [ ] yes [ ] no

If so, please indicate type of head, or marine sanitation device (MSD), below

[ ] port-a-potty [ ] MSD Type 1 [ ] MSD Type 2 [ ] MSD Type 3 [ ] other________

MSD Type 1 provides **chemical treatment** of sewage prior to discharge to waterways
MSD Type 2 provides **chemical treatment and** maceration of sewage prior to discharge
MSD Type 3 is a **holding tank (no discharge to waterways)**, and requires pump-out

If you **do have a holding tank** (MSD Type 3), how often do you pump out?

[ ] after a weekend's use [ ] after a week's use [ ] monthly [ ] other______________

What is the brand name of the chemical additive in your holding tank?______________

If you **do not have a holding tank**, please indicate below those factors that influence most your decision not to purchase or use a holding tank and/or pump-out facility

[ ] boat too small for holding tank [ ] holding tank too expensive
[ ] pump-out service not available [ ] cost of pump-out too expensive
[ ] pump-out service available only in congested areas

[ ] other____ 3B

Your response to this survey qualifies you for a chance at $200.00 of boating safety equipment. If you wish to have your name entered in the drawing for this equipment, please provide your name and address in the space below. Thanks again for providing information that will help improve boating on Narragansett Bay.

Name____

Address____

Town______________________ State________________ Zip__________

Appendix B

Boater Attitudes

Comments from Recreational Boaters in Rhode Island

"holding tank is a nuisance"

"I pump out the same way the fish, whales, and birds do!"

"(I) do not dump in harbor"

"(I) use on-shore facilities preferentially"

"Recreational boating on Block Island, the US East Coast, is miniscule as a source of pollution. Stop industrial and municipal dumping"

"Badly designed and improperly functioning community sewerage systems are the single largest source of pollution, aquatic animals and birds ....generate far more fecal waste than do boaters"

"Holding tanks are unsanitary and smell bad"

"I believe that human wastes is less harmful than the chemicals. This is the last area you should bother with. Concentrate on cities, towns, navy ships and commercial (ships)."

"it is a damned nuisance"

"(I) don't believe it causes the pollution"

"chemicals are more detrimental to marine environment than raw sewage"

"discharge in non-enclosed areas without chemicals probably not a serious problem compared to sewage treatment plant and industry discharges"

" a holding tank makes your boat smell...."

"I see people pumping holding tanks into harbor and it's disgusting. I think the water was cleaner in the harbor before holding tanks"

"(I) do not believe boating is a noticeable contributor to water pollution"

"(I) do not see where effluent from pleasure boats is (a) major threat to our environment"

Appendix C

This is a highly simplified analysis of possible penalties needed. Many other factors, both economic and social, are not included and could act to decrease or increase the required level of enforcement. The numbers given here should be taken as representative of possible orders of magnitude, and not as exact values.

Costs of Compliance

$$E = (1-P)(B) - (P)(C)$$

P= Probability of detection for violations
1-P= Probability of avoiding detection
B= Benefits from noncompliance
C= Penalties (on detection)
E= Expected Value (+)-no compliance, (-)-compliance.

Case I. Probability of Detection Needed at Current Costs and Penalties

B=$1018 (cost of type I device plus maintenance)
C=$2000 (highest possible fine)

$$0 = (1-P)(1018) - (P)(2000)$$

P= .33 (33%) minimum probability of detection needed for compliance

Case II. Penalty Needed at Current Levels of Detection and Costs

B=$1018
P= .002

$$0 = (1-.002)(1018) - (.002)(C)$$

C= $400,000 Penalty needed at very low enforcement levels.

n.b. This analysis assumes that individuals are not risk averse and are only concerned with their expected value.

Appendix D

Allowable Boat Numbers in 3 Harbors Using the Modified Formulas

Jamestown (Dutch Island Harbor)

I. Modification 1

-depth of harbor 15ft.
-surface area $4.94x10^6$ ft^2
-occupancy rate 51%
-maximum coliform value 14fc/100ml
-people per boat 2

1. Volume of harbor

$(15ft)*(4.94x10^6\ ft^2)*(283\ 100ml\ units/ft^3) = 2.1x10^{10}\ 100ml\ units$

2. Allowable number of boats

$$14fc/100ml = \frac{(G)*(2)*(2x10^9)*(51\%)}{(2.1x10^{10}\ 100ml\ units)} = 144\ boats$$

II. Modification 2

1. Volume of harbor = $2.1x10^{10}$ 100ml units

2. Allowable number of boats

$$14fc/100ml = \frac{[(.3G_I)+(.4G_{II})+(.6G_{III})+(G_{IV})]*(2)*(2x10^9)}{(2.1x10^{10}\ 100ml\ units)}$$

If all class I: G = 245

$$14fc/100ml = \frac{(.3G)*(2)*(2x10^9)}{(2.1x10^{10}\ 100ml\ units)} \qquad G = 245$$

If all class II: G = 184
If all class III: G = 123
If all class IV: G = 73

III. Actual Boat Counts, Aerial Photographs, July 3, 1988

- -class I = 78
- -class II = 24
- -class III = 1
- -class IV = 0

$$\frac{[(.3)(78)+(.4)(24)+(.6)(1)+(1)(0)]*(2)*(2x10^9)}{(2.1x10^{10} \text{ 100ml units})} = 6.4fc/100ml$$

6.4fc/100ml < 14fc/100ml 103 boats of the size distribution above are allowable

Newport Harbor

I. Modification 1

- -depth of harbor 19ft.
- -surface area $10.2x10^7$ ft^2
- -occupancy rate 51%
- -maximum coliform value 14fc/100ml
- -people per boat 2

1. Volume of harbor

$(19ft)*(10.2x10^7 ft^2)*(283 \text{ 100ml units}/ft^3) = 5.49x10^{11}$ 100ml units

2. Allowable number of boats

$$14fc/100ml = \frac{(G)*(2)*(2x10^9)*(51\%)}{(5.49x10^{11} \text{ 100ml units})} = 3768 \text{ boats}$$

II. Modification 2

1. Volume of harbor = $5.49x10^{11}$ 100ml units

2. Allowable number of boats

$$14fc/100ml = \frac{[(.3G_I)+(.4G_{II})+(.6G_{III})+(G_{IV})]*(2)*(2x10^9)}{(5.49x10^{11} \text{ 100ml units})}$$

If all class I: G = 6405

$$14fc/100ml = \frac{(.3G)*(2)*(2x10^9)}{(5.49x10^{11} 100ml\ \ units)} \qquad G = 6405$$

If all class II: G = 4804
If all class III: G = 3203
If all class IV: G = 1921

III. Actual Boat Counts, Aerial Photographs, July 3, 1988

-class I = 761
-class II = 508
-class III = 217
-class IV = 106

$$\frac{[(.3)(761)+(.4)(508)+(.6)(217)+(1)(106)]*(2)*(2x10^9)}{(5.49x10^{11}\ 100ml\ \ units)} = 4.86fc/100ml$$

4.86fc/100ml < 14fc/100ml therefore 1592 boats of the size distribution above are allowable

Block Island

I. Modification 1

-depth of harbor 16ft.
-surface area $2.8x10^7\ ft^2$
-occupancy rate 51%
-maximum coliform value 14fc/100ml
-people per boat 2

1. Volume of harbor
$(16ft)*(2.8x10^7\ ft^2)*(283\ \ 100ml\ \ units/ft^3)\ =1.27x10^{11}\ \ 100ml\ \ units$

2. Allowable number of boats

$$14fc/100ml = \frac{(G)*(2)*(2x10^9)*(51\%)}{(1.27x10^{11}\ \ 100ml\ \ units)} = 872 \text{ boats}$$

II. Modification 2

1. Volume of harbor = $1.27x10^{11}$ 100ml units

2. Allowable number of boats

$$14fc/100ml = \frac{[(.3G_{I})+(.4G_{II})+(.6G_{III})+(G_{IV})]*(2)*(2x10^{9})}{(1.27x10^{11}\ 100ml\ units)}$$

If all class I: G = 1482

$$14fc/100ml = \frac{(.3G)*(2)*(2x10^{9})}{(1.27x10^{11}\ 100ml\ units)} \qquad G = 1482$$

If all class II: G = 1111
If all class III: G = 741
If all class IV: G = 444

III. Actual Boat Counts, Aerial Photographs, July 3, 1988

-class I = 902
-class II = 522
-class III = 148
-class IV = 15

$$\frac{[(.3)(902)+(.4)(522)+(.6)(148)+(1)(15)]*(2)*(2x10^{9})}{(1.27x10^{11}\ 100ml\ units)} = 18.4fc/100ml$$

18.4fc/100ml > 14fc/100ml therefore 1587 boats of the size distribution above are not allowable

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