Chile Litoral

DIÁLOGO CIENTÍFICO SOBRE LOS ECOSISTEMAS COSTEROS

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Estuarine Management Related to Human Needs: Meeting the Challenge

ROBERT NUZZI[1]

ABSTRACT

Pritchard's (1967) description of an estuary as "a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage" remains the operational definition. Human activity within estuarine watersheds can (and in some cases has) drastically change the land drainage component of an estuary. Such changes often affect the estuary's potential to satisfy nutritional (food source) and/or cultural (quality of life) needs. Increased understanding of estuarine dynamics developed under the U.S. National Estuary Program, established in 1987 as an outgrowth of the Federal Water Pollution Control Act Amendments of 1972 which, with its later amendment of 1977 became commonly known as the Clean Water Act, has resulted in the development of management programs aimed at maintaining estuarine qualities associated with both environmental preservation and human needs. Activities within the *tri-state estuary* (New York-New Jersey, Long Island Sound, and Peconic Estuaries, Fig. 1), including monitoring to determine water quality status and trends and the effects of land use on water quality, and the production of *Comprehensive Conservation and Management Plans* (CCMPs) are discussed. Lessons learned from these estuary programs have been applied to estuaries elsewhere, and are of special interest to IACERE relative to their potential application to the Chilean ecosystems.

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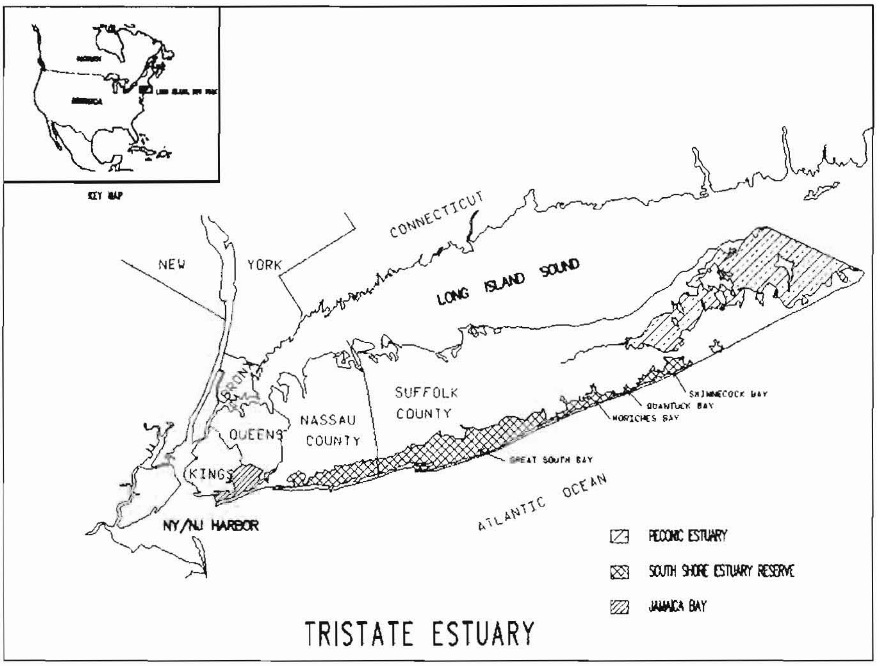
Figure 1
TRI-STATE ESTUARY



INTRODUCTION

While Chemists define water quality in terms of chemical constituents, and physical scientist in terms of temperature and density, the ecologist is more interested in the interactions of the chemical and physical parameters as they define the limits of the biological systems supported, and the ability to utilize the resources present.

Although estuarine systems may differ from region to region, the principles underlying what is considered "good" water quality remain pretty much constant. Those principles include the ability of the ecosystem in question to support a multiplicity of uses in concert with the maintenance of inherent qualities associated with estuaries: *primary and secondary productivity sustaining commercial and recreational fisheries, waterfowl, shore birds, and other wildlife.*

WATER QUALITY, WATERSHEDS, AND POLITICAL BOUNDARIES

The water quality that defines the health and productivity of estuaries is vulnerable to a variety of point and non-point source pollutant inputs from throughout the contributing watershed, which can include many thousands of hectares. In the U.S., the Chesapeake Bay watershed is estimated to be over 16 million hectares, and is distributed over several states. The Peconic Estuary's watershed, in contrast, is only about 45,000 hectares within six towns located within a single county. The importance of political boundaries lies in the relative ability, through land use planning, to control activities within the watershed that will ultimately affect water quality; control generally increasing in difficulty as the area and number of political jurisdictions increase. Control of activities surrounding estuaries whose watersheds extend beyond national boundaries (*e.g.*, the Tijuana estuary and the Laguna Madre in Mexico and the U.S.) is even more problematic.

The consequences of multiple stressors resulting from human influence include the decline of ecologically and economically valuable living resources, problems associated with low water column dissolved oxygen levels, and health advisories limiting the consumption of seafood.

THREATS TO WATER QUALITY

Cultural eutrophication, the anthropogenic acceleration of nutrient addition, is perhaps the best known, and most difficult to control threat to estuarine water quality. Nutrients, primarily nitrogen and phosphorus, find their way into estuaries through various non-point sources (including the agricultural use of fertilizers, and increased development resulting in, among other things, the introduction of landscape fertilizers and leaching from on-site waste treatment systems) and point sources such as sewage treatment plants. Non-point source pollutants are not limited to direct introduction over the land's surface, but in many areas may often involve pollution of groundwater that ultimately makes its way to the estuary. Urbanization, and the replacement of vegetation by impervious surfaces (buildings and associated infrastructure) result in the removal of terrestrial nutrient sinks, and accelerate the movement of nutrients to surface waters. Air pollution is often overlooked as a source of nutrients and other materials, but atmospheric deposition can comprise a significant percentage of nitrogen entering estuaries and surrounding watersheds. In the Peconic Estuary, atmospheric deposition of nitrogen across the entire estuary is estimated to be on the order of 3,200 kg/day, or about 25% of the total daily nitrogen load. The diffuse nature of its addition, however, makes it less problematic than other sources.

Aquaculture, involving large populations of fish or shellfish artificially maintained in estuarine areas, poses significant eutrophication problems as metabolic waste products and uneaten feed can become concentrated in the semi-enclosed coastal waters where culture is most likely to occur. Soto (2001), who suggests parallel culture of organisms able to use the waste products produced, artfully addresses this problem. Other problems associated with aquaculture include habitat loss, the introduction of exotic species (Naylor et al., 2001), loss of genetic diversity, and the introduction of chemicals used to accelerate growth rate (vitamins, hormones, and other growth factors), and to prevent or control disease (antibiotics and other pharmaceuticals) in densely populated growth pens. Although not specifically a water quality issue, the escape of farmed individuals, as occurred in southern Chile in 1994-95 (Soto et al., 2001), can affect natural ecosystem dynamics.

An overabundance of nutrients, particularly nitrogen, can lead to excessive planktonic and/or macroalgal growth resulting in a loss of esthetic value (discolored waters, clogged waterways, odors) and, often, low (hypoxia) or no (anoxia) oxygen, and the consequent deleterious effects on resident animal populations, including often clearly visible, and sometimes public health related fish kills.

Figure 2
EFFECT OF BROWN TIDES (1985-1987, 1995) ON BAY SCALLOP (*ARGOPECTEN IRRADIANS*) POPULATION IN THE PECONIC ESTUARY

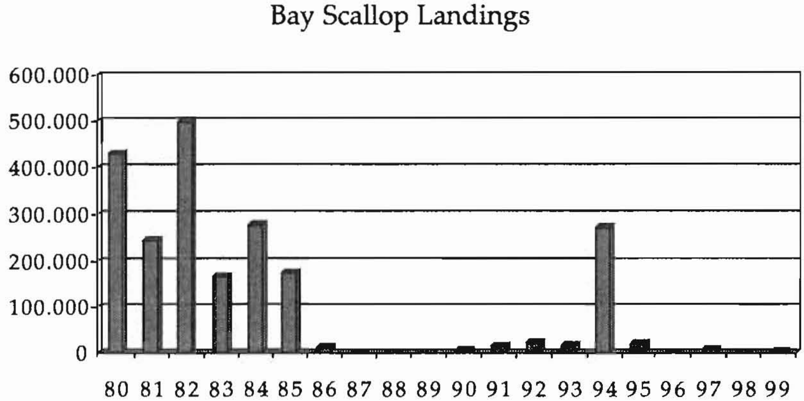
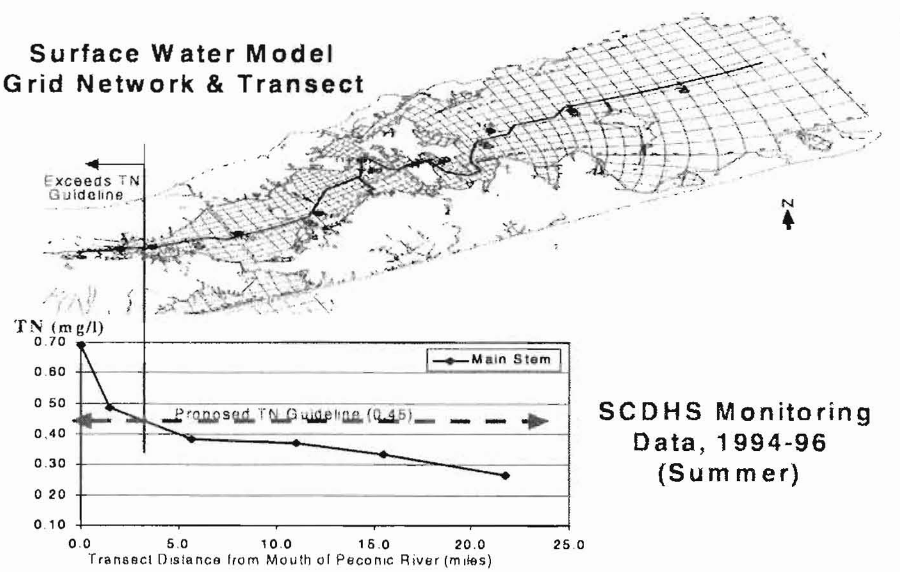


Figure 3
MODEL GRID AND NITROGEN VALUES WITHIN THE PECONIC ESTUARY. NOTE THAT THE TOTAL NITROGEN GUIDELINE OF 0.45 MG/L IS EXCEEDED ONLY IN THE FAR WESTERN END OF THE ESTUARY



decomposition of moribund vegetation, raise public health, as well as quality of life issues. Hydrogen sulfide (H_2S) levels, resulting from the summertime decomposition of eelgrass (*Zostera marina)* in a dead-end canal within the South Shore Estuary Reserve exceeded 14 parts per million, well above acceptable ambient levels. This particular, more or less annual occurrence, is as much, or perhaps more, a result of poorly planned development and shoreline modification as it is of excessive nutrient input.

Even in the absence of oxygen depletion, changes in biotic composition caused by alterations of nutrient levels and/or ratios can result in food web dynamics whereby economically valuable species are replaced by less desirable ones. A prime example is the loss of the scallop (*Argopecten irradians*) population in the Peconic Estuary (Fig. 2) in 1986 as a result of the "brown tide" (Bricelj and Lonsdale, 1997) a bloom of a phytoplankton species not suitable for supporting shellfish growth. The resurgence of the scallop population in 1994, assisted by seed transplants, was terminated by another bloom occurrence in 1995.

Finally, there are those who argue that the apparent global increase in toxin producing harmful algal blooms (*Alexandrium* red tides responsible for "paralytic shellfish poisoning", *Karenia brevis* blooms causing fish-kills and human respiratory distress, *Pfiesteria* blooms that have been implicated in massive fish kills and human illness, *Dinophysis* blooms responsible for "diarrhetic shellfish poisoning", blooms of the diatom *Nitzschia* resulting in "amnesic shellfish poisoning, *etc.*) is the result of anthropogenic activities (Smayda, 1990). The detrimental economic impact of harmful algal blooms in Chile, relative to the exportation of Chilean seafood, has been discussed by Suárez-Isla, et al.(2002). A bloom of *Alexandrium catenella* in southern Chile during the summer of 2002 resulted in the intoxication of thirty people, one fatality, and a major impact on the economy (Rodriguez and Arancibia, 2002).

Water column nutrient levels often reflect nutrient use by the resident biota, surrounding wetlands, and coastal vegetation. Spartina marshes in the temperate Peconic Estuary in the northeastern United States, and mangrove forests in the subtropical Laguna Madre in Mexico may be nutrient sinks or nutrient sources. In either case, they undoubtedly help prevent the formation of detrimental algal blooms by modulating the introduction of nutrients. The loss of such species, or their replacement by less desirable ones, resulting from increased shoreline development, natural (storm) reconfiguration of barrier beaches and inlets, man-made changes in estuarine hydrology caused by inlet modification, dredging activities, shoreline hardening, or increased sediment deposition, could lead to further objectionable ecosystem changes, including the loss of food web links associated with commercially and recreationally valuable species. Estuaries in which erosion and sedimentation is exacerbated by activities taking place within the watershed include those of Chile (silviculture) and the Tijuana Estuary (cattle grazing).

Inlet modifications can directly affect changes in water quality, and the biological populations supported, by altering the exchange of estuarine water with generally less nutrient laden ocean water of higher salinity (as in the South Shore Estuary) or lower salinity (as in the hypersaline Laguna Madre). Estuarine salinity regimes are also subject to modification by the use of fresh water. Consumptive use within the watershed, or its exportation out of the watershed, tends to increase estuary salinity and encourage the landward movement of the freshwater-saltwater interface within the subsurface aquifer. In some areas, this has resulted in the intrusion of saltwater into freshwater wells. Conversely, the importation of water to support development (urban, agricultural or industrial) can result in decreased salinity and consequent ecosystem changes.

The introduction of toxic chemicals and/or pathogens is also associated with land use including agricultural (pesticides, herbicides, animal wastes, etc.), urban (petroleum products, pesticides, herbicides, household chemicals, paints, sewage, etc.) and industrial (industrial chemicals, petroleum products, thermal discharges, etc.). These pollutants not only affect the ability of the ecosystem to support biological populations, but also, from a public health standpoint, the ability to utilize the biological resources present.

Because water movement, and consequently the distribution of chemical, physical and biological properties, into, out of, and within an estuary is of such importance relative to its natural resources, the development of a hydrodynamic model of the system is generally considered an important first step in any effort to understand the total dynamic of the estuary, and to manage its resources. A model developed for the Peconic Estuary determined that removal of sewage treatment plant discharge from the mouth of the Peconic River at the western end of the estuary would reduce nitrogen concentrations to a level below that which would be expected to be detrimental (0.45 mg/l, Fig. 3).

An issue less easily addressed is the feeding of increasingly large coastal populations. In the U.S., this results in the net movement of nutrients from the center of the country to the coastlines, and ultimately to the estuaries and coastal waters. Clearly, such one-way transport cannot go on indefinitely.

Ultimately, epochal changes, including global warming, control the long-range fate of estuaries but, while there is disagreement as to the anthropogenic extent of global warming, it is the feeling of many that this phenomenon, and its effect on estuaries, and coastlines in general, is being accelerated by human activity.

In the final analysis it is human activity that poses the greatest *addressable* threat to estuarine water quality. The ability of estuaries to survive that activity, and to assimilate the byproducts of civilization while remaining desirable, productive ecosystems is finite, and the quest of the various estuary programs in progress is to determine the level to which specific activities, and byproducts, can be tolerated and assimilated. The potential to develop land use and natural resource management plans sensitive to estuary, and estuarine resource preservation depends on the extent to which this knowledge is, or becomes available. The actualization of such plans, however, requires the careful consideration of socioeconomic conditions, and the political will to carry them out.

THE U.S. ENVIRONMENTAL MOVEMENT

The environmental movement of the 1960's resulted in the passage of the National Environmental Policy Act (NEPA) in 1969. NEPA established the framework for environmental protection, requiring that all branches of government prior to undertaking any major action consider environmental issues. Those issues were to be described and discussed in "Environmental Assessments" and "Environmental Impact Statements".

The passage of the 1972 Federal Water Pollution Control Act (FWPCA) made it national policy to "restore and maintain the chemical, physical, and biological integrity of the nation's waters". A 1977 amendment of the FWPCA gave the U.S. Environmental Protection Agency (EPA) the authority to set effluent standards, and, through the National Pollutant Discharge Elimination System (NPDES), made it unlawful to discharge pollutants from a point source without a permit.

The law, at this point, became commonly known as the "Clean Water Act" (CWA).

Reauthorization of the CWA in 1987 provided, among other things, for citizen law suits against polluters and, in Section 320 established the "National Estuary Program" (NEP) for the development of a "Comprehensive Conservation and Management Plan" (CCMP) for "estuaries of national significance".

Currently 28 estuaries have been accepted into the NEP, three of which are under study by members of the IACERE team: New York-New Jersey Harbor, Long Island Sound, and the Peconic Estuary. A fourth estuary, the South Shore Estuary Reserve (SSER), as well as Jamaica Bay, while not part of the NEP are nonetheless important in the New York region, and are also being investigated (Fig. 1).

THE HUMAN ELEMENT: MANAGING THE MULTIPLE USES OF ESTUARIES

Do estuaries really matter if there is no human component associated with them? This, of course, is a rhetorical question akin to that asked about the sound made by a tree falling in a forest when no one is there to hear it. The fact is that all environmental management is done from an anthropocentric point of view. The term "management" encompasses both the ability to affect change, and the ability to direct change: one manages for "something".

The importance of Long Island Sound lobsters, South Shore Estuary clams, and Peconic Bay scallops derives from their desirability to the human component of the ecosystem. We like to eat them; some of us like to gather them. To some –the lobstermen, the baymen, the fishermen– they are a source of income, and for some of them, generations of harvesting have engendered a sense of belonging, or "heritage". And, of course, there are the quality of life issues associated with living near an estuary: swimming, boating, fishing, vistas, etc.

However, the economy and the heritage associated with fishing and gathering, and even some of the quality of life issues, are not necessarily compatible with other uses, and other economies associated with estuaries and their surrounding lands (land development, agriculture, aquaculture, silviculture, ranching, industry, etc.). The management of coastal forests in Chile is a case in point, as their alteration can result in an increase in the delivery of nutrients to aquatic ecosystems, and the consequent problems associated with eutrophication, including a reduction in the capacity of those ecosystems to sustain other uses.

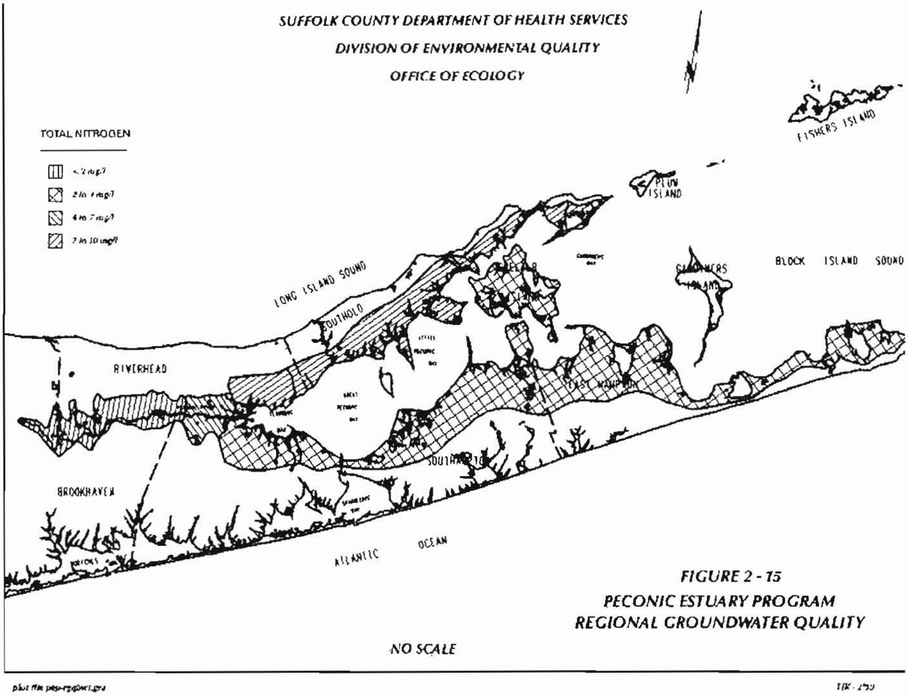
Moreover, in many instances it is not sufficient to consider only the estuary and its immediate watershed, as activities within this limited area may not necessarily be compatible with societal needs over a much wider (municipal, national, etc) area. Herein lies the problem. How can estuaries be managed in a manner that takes into account conflicting uses, natural and cultural, within and without the immediate area?

The Peconic Estuary, for instance, while considered relatively pristine, has experienced a serious decline in the population of bay scallops (*Argopecten irradians*), an economically and sociologically important part of that system. Similarly, Long Island Sound, and the South Shore Estuary have experienced problems with their fisheries: lobsters (*Homarus americanus*) and hard clams (*Mercenaria mercenaria*) respectively. That the economy has been affected is unquestionable. That the effect has not been catastrophic is due primarily to the fact that only a small percentage of the population was economically dependant on these resources, and these were natural (*i.e.*, not cultured) resources that could, to a degree, be replaced by other species. The situation might be quite different if a monoculture representing a significant portion of the economy was involved, as could be the case in Chile where salmonid culture is a major industry.

ESTUARINE MANAGEMENT WATER QUALITY AND LAND USE

Management of an estuary assumes that there is something being managed for (*e.g.* scallops, lobsters, hard clams, Salmon etc.). It is generally accepted that such management universally requires the preservation and maintenance of "good" water quality. Good water quality, which generally refers to nutrient composition (but also includes other issues such as sediment load, the presence of toxic chemicals, etc.), and which is often compromised by land use practices within the surrounding watershed, allows the estuary to support a *multiplicity of uses*, including preferred fisheries. Breitburg *et al*, speaking of a tributary of the Chesapeake Bay in the U.S., state that "because land use is such a major factor in restoring water quality in the Patuxent [river], understanding the factors that control land-use patterns and the conversion of land among uses is essential to designing effective policies". In areas that have yet to be urbanized, preservation is as much an issue as restoration.

Figure 4



Groundwater nitrogen levels within the Peconic Estuary watershed. Historical agricultural areas exhibit the highest levels. Areas along the north and south shores of the estuary have been undergoing recent development. Areas adjacent the Peconic River have not been farmed, and are mostly undeveloped.

Peconic Estuary

The Peconic Estuary does not present a typical case of accelerated eutrophication, but illustrates how land use practices can have a much more subtle, qualitative rather than quantitative, effect.

The use of agricultural fertilizers for many years, and the more recent introduction of nitrogen through lawn fertilization and on-site waste treatment systems resulted in a situation where, although the absolute value of nitrogen in the estuary is not extreme, its mode of addition to the estuary (through the groundwater) resulted in an unusual, and unexpected plankton bloom, the brown tide. Figure 4 illustrates the nitrogen levels in the groundwater surrounding the Peconic Estuary, clearly showing the relationship between land use and nitrogen content.

LaRoche et al. (1997) have suggested that a reduction in the introduction of groundwater containing high levels of nitrate nitrogen (dissolved inorganic nitrogen or DIN) during periods of reduced rainfall allowed the brown tide organism *Aureococcus anophagefferens* to out-compete the more typical phytoplankton species because of its ability to utilize dissolved organic nitrogen (DON) for growth.

Are agriculture and/or land development incompatible with the desired management objectives of this estuary? Potentially, if undertaken without serious forethought and planning. Weller et al. (2003) estimated the relationship between agriculture (cropland) and land development relative to nonpoint source nutrient discharge for the Patuxent River watershed to be 6:1. Put another way, nonpoint source discharge from one hectare of cropland is equivalent to the discharge from six hectares of developed land. On the other hand, development increased the amount of point source nitrogen entering the estuary. While these numbers may not hold true for other areas, this is nonetheless the type of information required for proper management.

This information provides a compelling reason to regulate land use, and the use of fertilizers, both agricultural and those used by homeowners, within the watershed.

South Shore Estuary

The South Shore Estuary is somewhat more typical in that certain areas have suffered from eutrophication, primarily from the addition of wastes from on-site waste treatment systems that proliferated with an increasing population. Sewering of the most populated areas within the watershed, and the discharge of the collected sewage into the coastal ocean rather than into the bay, has resulted in a decrease of nitrogen in the estuary adjacent to the sewered area, and a general overall improvement of water quality in the estuary (Nuzzi and Waters, submitted), and adjacent tributaries (Monte and Scorca, 2003).

Unfortunately, this has not yet translated to the recovery of the formerly economically valuable hard clam fishery. Indeed, the Bluepoints Company which has operated a shellfishery originally dependant on a natural population, initially of oysters and more recently hard clams, in Great South Bay has ceased operations after more than 100 years in existence. There is also evidence suggesting that the initial decline in hard clams in the bay may have been due, at least partially, to undetected "low level" brown tide blooms, and overharvesting, as opposed to poor water quality.

LONG ISLAND SOUND

Long Island Sound is perhaps most typical in that the enclosed western portion has been subject to significant nutrient additions from municipal sewage treatment plants serving the New York metropolitan area. This has resulted in algal blooms leading to diurnal depletion of oxygen, and periods of hypoxia and anoxia caused by nighttime algal respiration, and eventual decomposition in the bottom waters. As the major nutrient inputs occur as sewage treatment plant (STP) discharges into the western Sound and, because of the Sound's hydrography, the severity of the problem decreases from west to east. Implementation of the Long Island Sound Study (LISS) CCMP recommendations to reduce nitrogen input has been initiated with STP upgrades.

USE SCENARIOS

Estuaries, of course, do not exist in a vacuum. They are surrounded by often-desirable lands, desirable because of their beauty, because of their fertility, because of the availability of source water, etc. In order for an estuary to maintain its "desired" function(s) the development of those surrounding lands must be controlled. So, in addition to an intrinsic multiplicity of uses, extrinsic values and uses, which are often much more complex and difficult to control, must be considered in the development of a use-matrix.

A hypothetical use scenario will undoubtedly contain many desired uses. It is the function of natural science (biological, chemical, and physical) to determine what might occur given a specific use pattern. For instance, what might happen to the estuary if high-density land development were to be allowed in the watershed? Or agricultural activities? Or industry? All of these potential uses must be considered, and guidance must then be provided to the managers and decision-makers, the social scientists, so that decisions, which will include socio-economic considerations, can be made. It's the role of the natural scientist to provide the best possible prediction as to what might occur given a specific scenario. It's the role of the social scientist to compare scenarios, and to decide on a course of action best suited for present and future generations.

Estuaries are quite resilient, having the ability to absorb insults while remaining viable, productive ecosystems. However, the degree to which insults can be absorbed without drastically, and perhaps irreversibly altering the *desired* characteristics of the system is often not known until damage has occurred.

While there is a generally accepted fact that estuaries are "productive", often there is a very specific idea of what we would like a specific estuary to produce. In the case of Chilean estuaries, it may be salmon, in other estuaries it may be hard clams (*Mercenaria mercenaria*), or scallops (*Argopecten irradians*). Of course, there are additional, and, hopefully, non-conflicting ideas of what else might be included in "production". For instance, the growth of a specific fish or shellfish, would hopefully not preclude the estuary from being a productive area for other shellfish, for environmentally important submerged aquatic vegetation, for finfish, etc., all of which may be (and often are) intimately associated with the target species. Unfortunately, this is not always the case, and decisions must be made that might favor one use over another.

Additionally, if an estuary must serve uses other than in terms of its intrinsic value, for instance, as a source of cooling water or industrial source water, or as a mode of transportation, decision-making becomes all-the-more more complex.

Regardless of decisions reached, it is the decision-maker's responsibility to insure that all required information, ecological social, and economic, is obtained and considered.

Comparative Estuaries

A quite preliminary contrasting of comparative estuaries being studied by the IACERE group reveals similarities as well as differences (Table 1). The estuaries range from shallow, well-mixed systems like the Peconic Estuary in the northeastern U.S., to the hypersaline Laguna Madre of Mexico, to the deeply stratified fiords of the Chilean Reloncavi. Their watersheds, the land area that influences water quality, also differ greatly, as do riverine inputs.

Nonetheless, in almost all cases nitrogen is thought to be the nutrient that limits production. The source of the nitrogen, however, varies among estuaries, from sewage treatment plants to individual septic systems, to agriculture and aquaculture operations. The introduction of toxics, from pesticides to petroleum products to industrial pollutants is also problematic in some estuaries.

CONCLUSION

The ability of an estuary to support a desired use, or multiplicity of uses, is influenced, to a greater or lesser degree, by land use along its immediate coastline and throughout its entire watershed. It is also affected by meteorologically mediated conditions from outside the watershed, and by seaward activities (*e.g.* shipping, oil rigs, etc.). Estuary management, therefore, requires a decision to be made regarding the desired use(s), the development of a complex, multiple-use matrix for consideration by decision-makers, and a model for predicting the consequences of any action (or inaction). The utility of such a model, *i.e.*, its ability to be used as a predictive tool, is directly proportional to the understanding of cause-effect relationships gleaned from investigations of ecosystem structure and function. The U.S. National Estuary Program requires the production of a Comprehensive Conservation and Management Plan (CCMP) in which recommendations regarding activities within and around the estuary are elicited. It is, however, recognized that, as estuaries are dynamic systems, knowledge of status and trends within them, especially as those trends are related to the realization of management plans, must be maintained in an effort to improve understanding of those dynamics, and to allow for management modification as required. This requires that monitoring be continued, albeit to a less intense degree, even after the completion of a CCMP.

Table N° 1
IACERE COMPARATIVE ESTUARIES

Sites	Main Geologic Features	Present water quality	Limiting Nutrient	Nutrient Sources	Key issues	Hydrology (e.g. Fresh-water inputs)	Climatic stressors
Jamaica Bay	Shallow Saline	Mesotrophic to Eutrophic	N	Sewage treatment plant (STP)	Toxics N inputs Remediation vs. preservation		
N.Y. Harbor	Deeper	Mesotrophic Moving to watershed approach	?	STP Dredging	Toxics, N inputs Dredging	Hudson River	
Peconic Estuary	Shallow	Mesotrophic Watershed approach	N	STP Septic tanks Agriculture Fertilizer Duck Farm	N inputs Brown tides Biodiversity losses Changes in land use Suburbanization Preservation & remediation Lost seagrasses Biodiversity losses	Rainfall Peconic River Groundwater	
Laguna Madre	Shallow	Mesotrophic to Eutrophic	N?	Agriculture Fertilizer	Brown tides Dredging Overfishing Preservation vs. remediation N inputs, SF effects Conflicts between	Hypersaline Riverine inputs	Hurricanes
Reloncavi	Deep channels Wish to move to watershed approach	Oligo to Mesotrophic but spatially variable	N	Agriculture Soil erosion Salmon farming (SF) Sewage	SF and tourism Fisheries decline Suburbanization Deforestation and Changes in land use Algal Blooms Overfishing Remediation vs. preservation	Large river inputs, Petrohue Cochamo Puelo	El Niño
Gulf of California		Oligo to Mesotrophic but spatially variable	P, N	Agriculture Food industry, Shrimp farming Sewage	N and P inputs Salt water intrusion Toxics (pesticides) Mangrove protection Fisheries decline (shrimp and other commercial fishe- ries, Port activities Preservation vs. remediation	Colorado River	Hurricanes

BIBLIOGRAPHY

PRITCHARD, D.W. 1967. What is an estuary: physical viewpoint. In *Estuaries*, Ed. G.H. Lauff. AAAS, Wash. D.C.

BREITBURG, D.L., JORDAN, T.E. and D. LIPTON. 2003. Preface—From ecology to economics: Tracing human influence in the Patuxent River Estuary and its watershed. Estuaries 3(2A), 167-170.

NAYLOR, R.L., WILLIAMS, S.L. and D.R. STRONG. 2001. Aquaculture—a gateway for exotic species. Science, 294, 1655-1656.

SOTO, D., JARA, J. and C. MORENO. 2001. Escaped salmon in the inner seas, southern Chile: facing ecological and social conflicts.

BRICELJ, V.M. and D.J. LONSDALE. 1997. *Aureococcus anophagefferens*: Causes and ecological consequences of "brown tides" in U.S. mid-Atlantic coastal waters. Limnol. & Oceanogr.

SMAYDA, T.J. 1990. Novel and Nuisance phytoplankton blooms in the sea: evidence for a global epidemic. *In* Granelli, E., Sundstrom, B., Edler, L. and D.M. Anderson (Ed) *Toxic Marine Phytoplankton*. Elsevier, N.Y., pp. 29-40.

SUÁREZ-ISLA, B.A., LÓPEZ, A., HERNÁNDEZ, C., CLEMENT, A. and L. GUZMÁN. 2002. Impacto económico de las floraciones de microalgas nocivas en Chile y datos recientes sobre la ocurrencia de veneno amnésico de los mariscos. *In* Sar, E.A., Ferrario, M.E. and B. Reguera (Ed) *Floraciones algales nocivas en el cono Sur Americano*. Instituto Español de Oceanografía, Madrid.

RODRIGUEZ, C.V. and J. ARANCIBIA. 2002. Application of remote sensing of ocean colour to forecast HAB events in Chile. Harmful Algae News, No. 23 (UNESCO).

SOCIEDAD DE BIOLOGÍA DE CHILE. 1996. La nueva legislación forestal y el manejo sustentable de los bosques nativos Chilenos, Documento de trabajo. Panel Científico Sobre Bosques Nativos, Santiago, Chile.

SOTO, D. and H. CAMPOS 1996. Los lagos oligotróficos del bosque templado del sur de Chile. En "Ecología de los Bosques Nativos de Chile", Armesto, J.J., Villagran, C. and M.T.K. Arroyo, eds. pp.317-334. Editorial Universitaria S.A., Santiago, Chile.

LAROCHE, J, NUZZI, R., WATERS, R., WYMAN, K., FALKOWSKI, P.G. and D.W.R. WALLACE 1997. Brown tide blooms in Long Island's coastal waters linked to interannual variability in groundwater flow. Global Change Biology 3, 397-410.

TAYLOR, G.T., SAÑUDO-WILHELMY, S.A., and C.J. GOBLER. Speciation and concentration of dissolved nitrogen as determinants of brown

tide (*Aureococcus anophagefferens*, Pelagophyceae) initiation: an experimental evaluation. J. Phycology, in press.
BERG, G.M., REPETA, D.J., and J. LAROCHE 2002. Dissolved organic nitrogen hydrolysis rates in axenic cultures of *Aureococcus anophagefferens* (Pelagophyceae): comparison with heterotrophic bacteria. Appl. Environ. Microbiol. 68, 401-404.
MULHOLLAND, M.R., GOBLER, C.J. and C. LEE. 2002. Peptide hydrolysis, amino acid oxidation and N uptake in communities seasonally dominated by *Aureococcus anophagefferens*. Limnol. Oceangr. 47, 1094-1108.
GOBLER, C.J. and S.A. SAÑUDO-WILHELMY. 2001. Temporal variability of groundwater seepage and brown tide blooms in a Long Island embayment. Mar. Ecol. Prog. Ser. 217, 299-309
WELLER, D.E., JORDAN, T.E., CORRELL, D.L. and ZHI-JUN LIU. 2003. Effects of land-use change on nutrient discharges from the Patuxent River watershed. Estuaries 3(2A), 167-170.