Could Barriers Protect New York City From Storm Surges?

The hypothesis of a team of New York Sea Grant funded researchers that strategically placed storm surge barriers could protect NYC from storm damage has gained the interest of some decision makers and attention of media.

New York metropolitan area increasingly at risk to storm damage

In an era of rising sea levels and more powerful storms, New York City and the metropolitan region may be increasingly subject to flooding. Much of the region is at a very low elevation, less than three meters above sea level, and the prospect of increased frequency of strong storms such as nor'easters and hurricanes heightens the need for local officials to place attention on the potential impacts of flooding, especially from storm surges. There are several options to protect the region's low lying infrastructure. Specific facilities like sewage or water treatment plants or power plants can be hardened against flooding, or sea walls or breakwaters can be built. Another option is to use storm surge barriers at strategic locations to block incoming storm surges. Would such a system work? Information about whether such barriers would actually prevent flooding would be useful for planning.

Stony Brook Storm Surge system: three choke points hold the key

A research team from the Marine Sciences Research Center at Stony Brook University tackled this question through modeling. The goal was to use existing modeling technology and methods, along with newly developed ones, to test whether storm surge barriers would protect the City from flooding. The working hypothesis for the project team was that storm surge barriers placed at certain "choke points" (the mouth of the Arthur Kill in Perth Amboy, The Narrows, and the upper East River near Whitestone) could prevent flooding of low-lying areas in New York City and nearby New Jersey by protecting them from unusually large storm surges generated by hurricanes and nor'easters.

The waterways surrounding New York City could potentially be protected from coastal flooding with three barriers (shown in white) located from west to east at Perth Amboy, NJ, the Narrows and the Upper East River.

After two years of intensive work and development, the project team developed a model system that demonstrated that storm surge barriers placed at certain choke points surrounding the metropolitan region would provide effective flood protection for low-lying areas in New York City and New Jersey during storm surge events. This model system, known as the Stony Brook Storm Surge system (SBSS), was developed by adapting two well established models: the Advanced Circulation Model for

Coastal Ocean Hydrodynamics (ADCIRC) and MM5, a regional weather forecasting model. To create this new model, the researchers created a regional database that combined bathymetric and topographic data.

This combined bathymetric-topographic database is a valuable tool that can be used for future modeling and is being updated as new data become available. With this database, calculations and simulations from both models can be used to create a model system that can simulate the impacts of storm surges from major storms and the effectiveness of various storm surge barriers in protecting coastal areas from storm surge flooding.

Project success leads to further funding and influence on decision makers

The project demonstrated the potential of storm surge barriers in protecting the metropolitan area from flooding. A sophisticated near real time modeling system was developed from work on this project. Given rising sea levels, vulnerable populations, and valuable real estate, this model is a valuable tool to aid in deciding whether to build storm surge barriers. In addition, this project has led to further funding for additional investigations, including two subsequent NYSG projects (totaling more than $170,000 in funding) that are studying additional aspects of implementing storm surge barriers for metropolitan New York.

Together, these projects have influenced the decisions of the NYC Department of Environmental Protection and other agencies to see this as an issue that needs addressing sooner rather than later. The work from this project and later projects is aiding in decision making regarding whether to pursue barriers or harden individual facilities. The model continues to evolve and be updated, and is available online (at http://stormy.msrc.sunysb.edu/) for research use. It has proven to be a useful tool to other researchers, the National Weather Service, and has even been used by Swiss Reinsurance to help with adjusting insurance rates. The work has generated media attention from city newspapers, the *New Yorker, New Scientist, Christian Science Monitor*, and the New York Academy of Sciences, which has helped increase the visibility of this issue to local residents and officials.

Students

Mr. Peng Cheng was supported as a Sea Grant Scholar on this project and graduated with a PhD in August 2006 from Stony Brook University.

Publications

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Sea Grant New York

Learning About Toxic Cyanobacteria to Keep New York State Drinking Water Safe

A state-of-the-art laboratory developed by NYSG researchers has pioneered the identification and monitoring of cyanobacteria toxins, analyzed these toxins for a variety of user groups, and accelerated the funding for related water quality research.

Cyanobacteria toxins

Cyanobacteria or blue-green algae are not algae at all. Cyanobacteria, which are found in most environments, are bacteria that photosynthesize, like plants, for energy. Some cyanobacteria convert nitrogen gas to usable ammonium or nitrate (nitrogen fixation) and play a vitally important role in the nitrogen cycle. Other cyanobacteria produce neurotoxins such as anatoxin-a or saxitoxin, both of which cause paralytic shellfish poisoning (PSP). Others produce hepatotoxins such as microcystin. The cyanobacteria toxins have been associated with taste and odor problems in drinking water and with the poisoning of birds, livestock and even human fatalities in other parts of the world. These toxins can also impact an entire lake's food web by affecting zooplankton feeding and reproduction. Freshwater mussels, a food source for water rats, mink and birds, can accumulate microcystins and saxitoxins. Despite these facts, background information on the levels of microcystins or other algal toxicants present in New York State's drinking water did not exist until this project.

The diversity of toxic species and the sheer number of these toxins is great; there are over 80 different types of microcystins alone. To confound this, a given species may or may not produce toxins; if it does produce toxins, it can produce multiple types of toxins. The diversity of species and complexity of toxins makes identifying and monitoring toxins problematic for resource managers and public health officials.

Sea Grant Scholar Xingye Yang collects algae with a pole sampler.
Photo by Greg Boyer

Existing detection methods fall into two general categories, activity-based tests (e.g., mouse bioassay, Protein phosphatase inhibition assay) and structure-based analysis (Enzyme-Linked ImmunoSorbent Assay, High Performance Liquid Chromatography, Liquid Chromatography Mass Spectrometry). Each method has its usefulness, but may be limited or require advanced laboratory training.

Intensive field study of NY lakes

Dr. Gregory Boyer from the Department of Chemistry and Dr. Neil Ringler from the Department of Environmental and Forest Biology both at the State University of New York – College of Environmental Science and Forestry teamed up to address these issues. To assess the current cyanobacterial toxin status in New York State drinking water, this team did a field study and surveyed more than 130 New York State lakes for the occurrence of cyanobacteria blooms and the presence of cyanotoxins. To advance the cyanobacterial toxin detection methodology, the team developed state-of-the-art analytical techniques to measure *in situ* concentrations of cyanobacterial toxins (e.g., microcystins, anatoxin-a and saxitoxin). The researchers have also developed a number of molecular probes that allow them to differentiate between toxic, potentially-toxic, and non-toxic organisms.

With NYSG funding, Boyer and Ringler conducted the first statewide survey of the occurrence of cyanobacterial toxins in New York State. As part of this effort, a state-of-the-art analytical laboratory was established at SUNY-ESF for the analysis of all five major classes of cyanobacterial toxins (microcystins, anatoxin-a, anatoxin-a(S), PSP toxins and cylindrospermopsin). This laboratory and its techniques are now available to serve health and environmental monitoring agencies.

This research team compared three different techniques for analyzing microcystins. It was established that microcystins and anatoxin-a represent the greatest potential problem for New York waters. While the toxin levels are generally low, in several cases, toxicity was found to exceed the World Health Organization's threshold for safe drinking water. It was, therefore, recommended that a monitoring program be established for these toxins in New York State. Two other toxins, PSP toxins and anatoxin-a(S), were not found to be present in NYS waters and do not pose a serious problem. This study also identified anatoxin-a as the responsible agent for dog fatalities in Lake Champlain.

Novel toxin detection used by a variety of agencies and brings about further grants

Since Boyer's laboratory has been established, many organizations, agencies and institutes have used this laboratory for sample analysis including: California Department of Fish and Game, Maryland Department of Natural Resources, Metropolitan water District of Southern California, Phycotech, Stony Brook University, New York State Department of Environmental Conservation, Environmental Research Lab at the University of Arizona, Upstate Medical Center, Finger Lakes Institute, Environment Canada, and the Division of Water Supply Protection for the state of Massachusetts. Based on sample analyses performed in Boyer's laboratory, beaches were closed on northern Lake Champlain's Missisquoi Bay and Lake Neatahwanta in Fulton, New York protecting humans against cyanobacterial toxins.

In September 2005, the USEPA organized a review of cyanobacterial Harmful Algal Blooms (HABs) in the United States with respect to developing a national standard for these toxins in recreational and drinking water. The information from NYSG's project and subsequent NYSG research were an integral part of this review. This project provided key preliminary data for the successful submission of the first regional Monitoring and Event Response for Harmful Algal Blooms (MERHAB) project that will develop a tier-based monitoring system for cyanobacterial toxins in the lower Great Lakes. To date, the MERHAB project has funded 16 research investigators and 23 graduate students from eight universities (funding of $3.6M over five years).

In addition to the MERHAB grant, additional funds were leveraged by Boyer based on this NYSG project including grants from the following agencies: NOAA-Oceans and Human Health (total $750K), California Department of Water Resources (total $400K), National Science Foundation (total $28K), NYSTAR (total $200K), Environmental Protection Agency ($7K), Department of Defense (total $2.56M), NYSG (total $350K) for a grand total of over $7.8M in additional funds.

Equally as important, this project has increased the visibility of the potential problem of cyanobacteria toxins in the Great Lakes and led to increased funding for a number of other investigators. Research projects have been supported by NOAA Oceans and Human Health and several Ecology and Oceanography of Harmful Algal Blooms projects. Results from this project have now become an integral part of NOAA's Harmful Algal Research and Response National Environmental Science Strategy *(*HARRNESS) and are being leveraged in support of additional funding at the national and programmatic level.

Students

Working with Boyer on two NYSG projects including this one was Mr. Xingye Yang, a doctoral student in the Department of Chemistry, SUNY-ESF. Mr. Yang's thesis entitled "Occurrence and Stability of a Cyanobacterial Neurotoxin, Anatoxin-a, in New York State Waters" was completed in April 2007. In 2001, Mr. Yang won the Best Graduate Poster award during the North-East Algal Symposium for his work dealing with the identification of anatoxin-a in Lake Champlain.

Also assisting on this project was Amber Hotto. Her thesis project, entitled "Application of Molecular Techniques to Detection of Potential Microcystin-producing organisms in New York State waters," will be completed in summer 2007.

Boyer and an assistant take water samples. About 20 percent of water samples taken throughout NY waters tested positive for cyanobacteria toxins with microcystin being the most common.
Photo by Jamie Lescinski

Publications

Boyer, G.L., M.C. Watzin, A.D. Shambaugh, M.F. Satchwell, B.H. Rosen, and T. Mihuc. (2004). The occurrence of cyanobacterial toxins in Lake Champlain. Pages 241-257 in T.O. Manley, P.L. Manley, T.B. Mihuc, and Lake Champlain Research Consortium, editors. *Lake Champlain: Partnership and Research in the New Millennium.* Kluwer Academic Publishers.

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Presentations

The following list summarized invited presentations made by Dr. Boyer:

Boyer, G.L. 2000. Cyanobacteria Toxins and Drinking Water. Lake Champlain Research Institute. Plattsburgh, NY. 3 May 2000.

Boyer, G.L. 2000. Cyanobacteria Toxins and Drinking Water. International Atomic Energy Agency - Seminar. Marine Science Institute. Manila, Philippines. 8 June 2000.

Boyer, G.L. 2000. Harmful Algal Blooms: Are They Important in the Great Lakes? Shackleton Point Biological Station. Bridgeport, NY. 12 July 2000.

Boyer, G.L. 2001. Detection of Cyanobacteria Toxins in New York State Drinking Waters. In: Creating a Cyanotoxin Target List for the Unregulated Contaminant Monitoring Rule. EPA – Workshop, Cincinnati, OH. 17-18 May 2001.

Boyer, G.L. 2001. Current and Emerging Techniques Used to Identify Harmful Cyanobacteria. Workshop on Cyanotoxin Detection and Quantification Instrumentation. University of South Florida. Tampa, FL. 20-22 August 2001.

Boyer, G.L. 2001. Toxic Cyanobacteria in New York State Waters - Analytical Techniques and Current State of Affairs. Florida International University. Miami, FL. 4 Oct 2001.

Boyer, G.L. 2001. Toxic Cyanobacteria in New York State Waters - Are They a Threat to our Health? Skidmore College. Saratoga Springs, NY. 11 Oct 2001.

Boyer, G.L. 2001. Cyanobacteria Toxins in New York State Waters - An Overview from the 2000 and 2001 Field Survey. Seminar - Great Lakes Research Consortium. University of Buffalo. Buffalo, NY. 17 Oct 2001.

Boyer, G.L. 2001. Toxic Blue-Green Algae. Seminar in Applied Environmental Microbiology. Syracuse University. Syracuse, NY. 5 Oct 2001.

Boyer, G.L. 2001. Harmful Algal Blooms - Nature's Bioterrorists. Seminar, SUNY-ESF Emeriti Lunch. Syracuse University. Syracuse, NY. 5 Dec 2001.

Examining a Living Community: Hard Clams and Phytoplankton in Great South Bay

NYSG researchers have assessed the relationship among hard clams, phytoplankton and zooplankton, showing that hard clams are not the driving force they once were in Long Island bay food webs. A clam restoration program has been initiated based on the finding that clam filtration can shift phytoplankton populations to species that support strong juvenile clam growth.

Hard Clams: Historically a significant species

The hard clam (*Mercenaria mercenaria*) is an important economic and ecological species that has significantly declined in Great South Bay, NY. Hard clams are suspension feeders that obtain their nutrition by filtering plankton from the water. During the 1970s when the bivalves were much more abundant, they filtered a large fraction of the total volume of water in Great South Bay. Due to this intensive grazing activity, they most likely altered the composition of the plankton community. Researchers suspected that this community alteration had a positive benefit to the clams by actually improving the quality of their food.

Hard clams no longer dominate the benthic community and consequently, the phytoplankton composition, primary production, trophic structure and rate of nutrient cycling may have been altered. Additionally, recent evidence suggests that hard clams are growing slower in Great South Bay than they did in the past, potentially due to brown tides that can inhibit feeding, or changes in the plankton community due to variable plankton size and type. It is thought that these combined conditions could lead to poor hard clam production resulting in low fecundity, poor recruitment and longer exposure of juvenile hard clams to predation making it difficult for hard clam populations to recover.

Mercenaria mercenaria from Great South Bay examined in the laboratory. Photo by Steve Tettelbach

Looking at Trophic Interaction

Stony Brook University researchers Drs. Robert Cerrato, Glenn Lopez, Darcy Lonsdale, Roger Flood and Robert Armstrong from the Marine Sciences Research Center, and Dr. Jeffrey Levinton from the Department of Ecology and Evolution teamed up for this project. They examined the trophic interactions among phytoplankton, zooplankton, and hard clams to assess whether intensive grazing by hard clams shifts the composition of the plankton community toward species of different nutritional quality.

The team used a multi-beam echosounder to map three field sites along the Bay--Copiague, Babylon, and Patchogue--to identify sediment type and biotype. The team also characterized the existing biofiltration conditions and hard clam growth in the field. The focal point of this study was the experiments conducted in 400-liter tanks where adult clam and copepod abundance was manipulated in order to observe possible changes to the plankton community. Phytoplankton composition, zooplankton grazing, and hard clam growth were also measured.

Analysis of plankton samples showed that the composition of phytoplankton varied with the site, but most of the chlorophyll biomass was represented by the less than 5 μm size fraction. Dilution experiments showed that zooplankton grazing was capable of removing all the primary production most of the time at all three sites. Plankton characterization suggests that food quality was highest in Copiague and lowest in Patchogue. The observed juvenile hard clam response was consistent with this observation. Juvenile growth at Copiague was 7 times greater than at Patchogue. In Copiague, where growth under ambient conditions was high, juvenile growth declined by 57% in the treatment with high adult clam grazing, suggesting that juveniles were competing with adults for food.

In the other two locations, where growth under ambient conditions was moderate to poor, juvenile growth improved by 60 to 200% in treatments with high adult clam grazing. Examination of several physiological measures on a set of adult clams exposed to water from the treatments verified that observed increases in juvenile growth were related to food quality rather than quantity.

Manipulation of adult copepod densities was not successful since adult copepods in the tanks were protected from large grazers and increased in all treatments. Hard clams were effective phytoplankton predators on the eggs and early naupliar stages of copepods, suggesting that clams can also alter plankton structure indirectly by feeding on other grazers. Overall, these results suggest that intense grazing by hard clams can have a positive effect on the nutritional value of the plankton.

Based on these results, this research team believes that the reduction in clam abundance in Great South Bay has propelled the hard clam population and its associated ecosystem into a fundamentally different state. In the past, intense grazing by hard clams exerted enough control on the plankton assemblage to maintain a positive feedback loop. However, at present, zooplankton grazers are consuming most of the phytoplankton production in the Bay, and hard clams and other benthic suspension feeders exert little control.

Research results aid shellfish restoration efforts

These results have an important implication for hard clam restoration in Great South Bay. Restoration scenarios that involve planting small seed clams with low filtration capacity would not immediately alter the dynamics of the food web. As a result, processes now inhibiting the recovery of hard clams (e.g., low fecundity, poor growth, poor recruitment, high mortality) would also work against such restoration attempts. Instead, planting a large number of adult clams (and/or other benthic suspension feeders) might be a preferable strategy because it has the potential of restoring the plankton to an assemblage that promotes greater hard clam production.

Based on results from this, and other NYSG funded research, state and county organizations have included hard clams and other bivalve filter feeders in their management plans. New York State's Comprehensive Wildlife Conservation Plan added hard clams, blue mussels, ribbed mussels, oysters, and bay scallops to their list of species of greatest conservation need. The Peconic Estuary Program (PEP) and South Shore Estuary Reserve (SSER) management plans cite the importance of filter feeders in estuarine systems and recommend enhancing shellfish stocks "to fulfill ecological functions."

There are several restoration programs across Long Island that are benefiting from this work. The Nature Conservancy is sponsoring a large scale reseeding of chowder and other adult-sized clams in Great South Bay and Peconic Estuary. Suffolk County is running the largest scallop reseeding program attempted anywhere in the country. It is a four-year, $1.8 million dollar effort to restore bay scallop populations in the Peconic Estuary. In May 2005, Suffolk County announced a major aquaculture initiative to restore scallops, oysters and hard clams to the Peconic Estuary. In addition to the economic benefits of aquaculture, the County Executive justified the program because it "will augment spawning potential of natural populations of shellfish" and "will exert a positive influence on water quality by helping to prevent harmful brown tide blooms."

Students

Two scholars were supported on this project, both for their MS degrees. Ms. Amy Streck completed her degree in May of 2003 and is currently working for the National Marine Fisheries Service, Conservation and Education Division, in Silver Spring, MD.

Ms. Rebecca Marzeck completed her degree in August of 2003 and is currently working at Haskins Shellfish Laboratory, NJ.

Publications

Marzec, R. 2003. Predation on Early Life Stages of the Calanoid Copepod Acartia tonsa (Dana) by the Northern Quahog (*Mercenaria mercenaria* L.). MS Thesis, Stony Brook University, Stony Brook, NY. 72pp.

Schlenk, C. 2004. New insights about south shore estuary hard clams. *Coastlines* 33(3): 8-9.

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Evolution of a Tidal Inlet

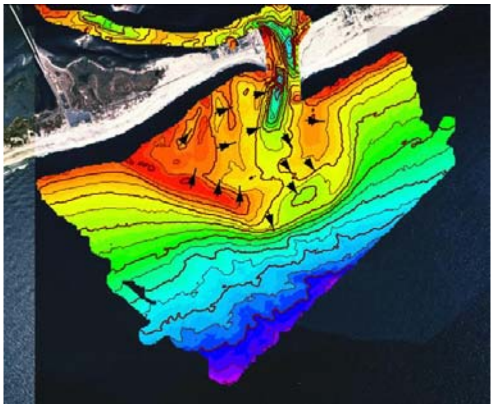
Because of the discoveries of New York Sea Grant researchers regarding sedimentation at a tidal inlet, state and federal officials are reassessing the management of Shinnecock Inlet, an economically and environmentally important waterway on the south shore of Long Island, NY.

A primer on dynamic tidal inlets

Along parts of the Atlantic coast, it has been estimated that as much as 80 percent of coastal erosion results from the interruption of longshore sediment transport at tidal inlets. The impacts of inlets can be exacerbated by attempts to stabilize these features for navigation purposes by dredging or building of structures if these activities are not implemented properly with a clear understanding of the important coastal processes and sediment transport pathways. Problems associated with maintaining navigation at inlets while minimizing erosion on adjacent shores are experienced worldwide.

Sediment transport near tidal inlets is quite complex. It involves the combination of waves and currents superimposed upon the dynamic water depth, or bathymetry, of the surrounding coastal area. Tidal inlets on open ocean coastlines provide a channel for sand movement into coastal bays, flood tidal deltas, and marshes. The net movement of sand into the back barrier lagoon or out the main inlet channel is controlled by flood- and ebb-tidal currents. In so doing, tidal inlets remove sediment from the longshore drift.

Unstabilized inlets often allow sand in the longshore transport system to bypass the feature and make it to the down drift shoreline. Bypassing at stabilized inlets is less well understood. There are two transport mechanisms currently theorized to be associated with natural sediment bypassing at tidal inlets; continuous or discontinuous.



A high-resolution bathymetric survey at Shinnecock Inlet, NY. Arrows indicate the direction of apparent sediment motion based on the movement of sand bodies. Map courtesy of D. Conley and R. Flood.

Continuous bypassing has been associated with ebb tidal shoals. Waves and tidal currents drive the longshore transport around the peripheral edge of the ebb tidal shoal and thus around the inlet. In this scenario, sand is transported to the down drift shoreline. Discontinuous inlet sediment bypassing occurs along a mixed energy shoreline (tidal and wave influences) and involves the episodic migration of sand bars formed on the down-drift side of the ebb tidal shoal. This results in the sporadic bypassing of discrete packets of sand.

Investigating Shinnecock Inlet

Recent research has shown how inlet bypassing on a tidal inlet with an ebb tidal shoal is predominantly of a continuous nature although discontinuous processes seem to exist. It is likely that the discontinuous processes may dominate in an area where the ebb tidal shoal is disturbed by dredging. Understanding if this is true and how bypassing occurs on such an inlet may provide management strategies to minimize impacts to down-drift shorelines. To investigate the sediment bypassing properties at such a manipulated tidal inlet, the research team of Daniel C. Conley and Roger D. Flood from the Marine Sciences

Research Center, Stony Brook University, used Shinnecock Inlet, located on the south shore of Long Island, NY. This team conducted detailed observations of the seabed evolution using a high-resolution multibeam bathymetry system. In order to perform numerical investigations of the sediment bypassing processes at Shinnecock Inlet, this team modified numerical models of near-shore circulation to be able to make detailed predictions of seabed evolution.

New survey techniques yield previously undetected dynamism in the Inlet

Sequential high-resolution bathymetric surveys at Shinnecock Inlet indicated that the ebb-tidal shoal accumulated sediment at a rate of about 440,000 m^3/yr with much of the material accumulating in deeper water. This observation differed from findings by the US Army Corps of Engineers (USACE) consultants who found that the volume of the ebb-tidal shoal had not changed in recent areas based on historic surveys. Based on that limited information, they had concluded the inlet had reached a dynamic equilibrium and was no longer disrupting the natural longshore transport of sand.

The discrepancy may be due to uncertainties in vertical datums for USACE surveys and the fact that USACE surveys generally did not survey the seaward face of the ebb-tidal shoal. The multibeam bathymetry studies suggest that about a quarter of the growth of the ebb-tidal shoal has been in water depths greater than about six meters on the seaward face of the shoal, and surveys that do not include this area will not correctly characterize the evolution of the ebb-tidal shoal. This detailed bathymetric change data will be used along with the revised flow and sediment transport models to ensure that model predictions agree with observed changes.

NYSG's coastal processes specialist, who is a member of the NYSDOS's State Inlet Advisory Committee and the US Army Corps of Engineers New York District Coastal Technical Advisory Committee, realized the data from the new surveys contradicted assumptions being made in the development of a comprehensive management plan for New York's ocean inlets. Through participation in these technical committees, NYSG was able to extend this information to state and federal officials who used it to make a decision to re-evaluate the $2 million inlet management planning effort. NYSG has been asked to assist in this reassessment.

Students

Two students worked on this research project. Ms. Charlene Sullivan graduated from the Marine Sciences Research Center, Stony Brook University, with a Master's degree in September of 2005. She then began work as an Oceanographer for Integrated Statistics located in Woods Hole, MA. Ms. Lijuan Huang graduated from the Marine Sciences Research Center, Stony Brook University with a Master's degree in September 2005. She worked with the multibeam data from the survey studies and is currently an intern at NOAA.

Publications

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Effects of Size-Selective Mortality on the Evolution of Growth Rate in Fishes

Congressional legislation that aims to apply ecosystem considerations to fisheries management may be due in some part to Sea Grant research that showed how fish in populations in which the largest fish are consistently removed will be, over some generations, slower growing, earlier maturing and smaller in average size.

Size selection in fish

There are many who have noticed that fish being caught seem to be getting smaller and smaller over the years. What is going on? There is also much concern over declining fisheries. Yet there have not been any definitive answers to explain these declines. The reason is that for every species-- even for every population-- there is a different mix of factors influencing population sizes and trends within various fisheries. Such variation creates a complex situation for scientists and managers to analyze. There is always a need for more research and greater understanding of such complex systems. One area of promising new research involves evolutionary response of fishes to size selection from fishing.

In 2000 Dr. David O. Conover at the Marine Sciences Research Center at Stony Brook University embarked on a study to look at the effects of size selective fishing. The project used the Atlantic Silverside (*Menidia menidia*) in a laboratory setting as a model of the effects of various forms of size-selective mortality on life history evolution over multiple generations. Populations of silversides were kept in aquaria and experiments were run where in each generation size selective culling occurred. The cullings were such that the researchers were testing what happened when only the smallest 10% survived, the largest 10% survived, or lastly, when fish of random sizes were left.

Size variation in Atlantic Silversides
Photo courtesy of David Conover

Size selectivity causes evolutionary response

The project demonstrated that size selective selection pressures can lead to genetically fixed changes in the population after just a few generations. The experiments showed that mortality that consistently removes the largest fish results, in a population that grows slower, matures earlier, and has a smaller average adult size. The implications for fishery harvests are that in cases where the largest individuals are typically harvested and the smaller ones thrown back, evolutionary changes could occur that result in populations with smaller fish and lower productivity. This is an undesirable outcome for economically important species.

Though these are laboratory based experiments with a single species, the results have garnered much attention in the management, research and public press, including a July 2002 article in *Science*. This work demonstrated that management of fisheries resources might need to take into account the evolutionary changes brought about by how fish populations are harvested.

This research--along with other NYSG funded research conducted by Dr. Timothy Essington on squid fish interactions--has helped stimulate discussion among fisheries managers and researchers and contributed to a fundamental rethinking about how fisheries have traditionally been managed. That is from a single species approach to an interacting multi-species and evolutionary approach that treats species as part of dynamic and evolving ecosystems. By demonstrating hypothetically that size selective harvesting can lead to evolutionary changes in populations of harvested species, life cycle changes can occur such as age and size at first reproduction that have impacts in the ecosystem. This work has played a role in the reauthorization the Magnuson-Stevens Fishery Conservation and Management Act. A bill, HR 5051, calls on the Secretary of Commerce to draft guidelines for applying ecosystem considerations to fishery management plans (FMPs) and gives fishery councils the discretion to prepare Fishery Ecosystem Plans (FEPs) based on these guidelines.

Conover participated in an informational presentation to Congress that was organized by SeaWeb's COMPASS (Communication Partnership for Science and the Sea) to inform legislators about the implications of his research results on fisheries. Conover assisted Hon. Wayne Gilchrest (R-MD), who introduced HR 5051, with a "Dear Colleague" letter to Congress Members. The letter cites Conover's research as support for the bill's key provision of applying ecosystem considerations into fishery management. The research is stimulating further research and fellowships have been funded by National Sea Grant in the area.

Students

Two Sea Grant Scholars were part of this project. Stephan B. Munch received his PhD in 2002 and is now an assistant professor at Marine Sciences Research Center at Stony Brook University. Matthew Walsh completed his master's degree in 2004 and is currently pursuing his PhD at the University of California Riverside.

Publications

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Evaluating the Ecological Effects of Cephalopod Fisheries

Sea Grant researchers have shown that squid play an important role in the food web of the Atlantic continental shelf--sometimes the predator, sometimes the prey. This multi-species approach has stimulated discussion among fisheries managers and researchers and helped in the reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act.

A trend beyond single species management

Management of coastal marine fisheries has traditionally been single species focused. With tremendous fishing pressure and declines in many fishery stocks there is a need for the most accurate information about the species managed by fisheries management councils. One aspect to consider is the impacts of the interactions between the species that are managed and how they affect the fish populations of interest. Clearly there is a need for research that adds to our knowledge of the many fisheries species of the Atlantic continental shelf.

Evaluating squid within its ecological context

In 2002 Dr. Timothy Essington, then at the Marine Sciences Research Center at Stony Brook University, embarked on a study to look at the role of squid in the Atlantic coastal food web. The study sought to understand the relationships between squid and what they eat as well as those between squid and the animals for which *they* are food.

The project results did provide a better understanding of the food web linkages between squid and finfish on the U.S. mid-Atlantic continental shelf ecosystem. An important finding was evidence for the importance of relative body size in mediating predator-prey interactions.

Longfin inshore squid, *Loligo pealeii* from the mid-Atlantic continental shelf
Photo courtesy of Timothy Essington

Squid mostly prey on juvenile fish after reaching a certain size. There is more squid predation on fish in winter and spring when there is an abundance of small fish. But in summer into fall there is much fish predation on squid when fish reach adult size. The research also found that most of the fish that are eaten by squid are eaten by squid smaller than those captured in the squid fishery. Another result was that squid comprise a major part of the diet of large bluefish and large whiting, and are important for all sizes of summer flounder. These results indicate that squid fishing might reduce the productivity of other fisheries by removing the food needed for those species to grow.

The project clearly shows that squid play an important role in the food web, acting as both predators and prey. These complex interactions have implications for management of both squid and finfish fisheries. Fisheries managers and researchers are beginning to discuss the implications of this work. It is contributing, along with other NYSG research done by David O. Conover, to fundamental rethinking of the ways in which we manage harvested marine resources.

This work has served as a reference in the process leading to Magnuson-Stevens Fishery Conservation and Management Act Reauthorization. Both Drs. Conover and

Essington participated in an informational presentation to Congress that was organized by SeaWeb's COMPASS (Communication Partnership for Science and the Sea) to educate legislators about the implications of the research results on fisheries management. Results from this research are influencing work by the North East Fisheries Science Center to assess silver hake. Dr. Essington is collaborating on multi-species modeling efforts involving silver hake and squid.

Students

Two Sea Grant Scholars were part of this project. Michelle Staudinger received a Master’s degree in 2004 and went on to pursue a doctorate at the University of Massachusetts Intercampus Graduate School of Marine Sciences and Technology (IGS).

Mary Hunsicker received her Master’s in 2004 and is now a Ph.D. student at the University of Washington.

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Endocrine Disrupting Compounds

In two related projects, Sea Grant researchers have found evidence that endocrine disrupting compounds in effluent from sewage treatment plants and in an urban estuary in the New York metro area have caused some level of feminization of resident winter flounder and striped bass.

Sources of endocrine disruption compounds (EDCs)

In the 1990s, the potential impact of contaminants altering hormonal status and reproductive success of wildlife species became a global environmental issue. Collectively these compounds are termed endocrine disruption compounds or EDCs. In some areas of Europe, widespread evidence of exposure to estrogenic EDCs has been documented. In the following decade increased availability of more sensitive analytical techniques demonstrated the presence of biologically significant concentrations of two groups of compounds with estrogenic activity.

Natural and synthetic estrogens and nonylphenol, a breakdown product belonging to a common class of surfactants, are used in many products including industrial detergents. Regulatory agencies in the U.S. and Europe scrambled to develop procedures for evaluating endocrine disruptive capabilities for new compounds as well as those already licensed for use. A major source of EDC exposure within aquatic and estuarine environments comes from sewage treatment plants (STPs). Although EDCs are metabolized during secondary (biological) sewage treatment, the resulting products can be more toxic and persistent in the environment than their parent compounds. At the time these projects started, little was known about the degree of EDC contamination or effects on native fish populations in the New York metropolitan region.

Sea Grant Scholar Lourdes Mena dissecting a winter flounder aboard *R/V Seawolf*. Photo courtesy of Anne McElroy

Landmark research in NYC waste treatment plants and Jamaica Bay

The first of two EDC projects teamed Drs. Anne McElroy, Bruce Brownawell & Charles Iden of Stony Brook University with Dr. Adria Elskus from the University of Kentucky and Dr. Daniel Schlenk from the University of Mississippi. This team of researchers examined three New York City STPs looking at estrogenic effects on striped bass and the concentrations of compounds known to be estrogenic in sewage effluent. This provided the first chemical and toxicological data from NYC area STPs to managers and environmental groups.

The second project paired Dr. Anne McElroy from Stony Brook University with Dr. Martin Schreibman from Brooklyn College – CUNY. This effort expanded on the previous project to study the effects of chronic exposure to environmental estrogen mimics using a resident benthic fish, winter flounder, as a model species of exposure in the field. Specifically, the researchers looked to see if winter flounder were being feminized or impaired reproductively and to see if the metabolite nonylphenol could be implicated in any adverse effects observed in winter flounder in Jamaica Bay, NY.

Results show endocrine disruption in wild fish

Application of newly developed, extremely sensitive, liquid chromatography- mass spectroscopy (LC-MS) methods indicated levels of the natural estrogens, estradiol and estrone to range from 5 to 18 parts per trillion (ng/L) in sewage from the three STPs. Levels of the estrogenic detergent breakdown products, nonylphenol and its 1,2, and 3 ethoxylate metabolites (collectively termed NPEOs) were thousands to tens of thousand times higher, ranging from 100 to 600 parts per billion (µg/L). Effluent from the largest, oldest, and least effective STP, Newtown Creek, proved to be highly estrogenic to juvenile striped bass. The effluent increased levels of the egg yolk precursor protein vitellogenin, normally elevated only in ripe female fish, by up to 200 times over levels observed in fish not exposed to effluent.

Young flounder throughout Jamaica Bay showed biochemical signs of exposure to estrogenic compounds in their environment. High levels of vitellogenin were observed and the young winter flounder also showed signs of female reproductive tissues within the testes of male fish. Altered sex ratios were observed in Jamaica Bay winter flounder with many more females caught than males as compared to the reference site, Shinnecock Bay, NY. Preliminary evidence also indicated that healthy winter flounder embryos exposed to sediment from Jamaica Bay showed delayed development and reduced hatching success. Winter flounder exposed to sediments dosed with nonylphenol showed some of the same responses seen in fish collected from Jamaica Bay, indicating that this estrogenic contaminant could be responsible for the effects observed.

The high levels of NPEOs in the least effective sewage treatment plant demonstrates the importance of treatment level in the ability of sewage treatment plants to remove polar compounds such as the nonylphenol exthoxylates (NPEOs) from effluent. It also provides some of the first direct evidence of endocrine disruption in wild fish (striped bass and winter flounder) exposed to sewage-derived endocrine disruptors, particularly nonylphenol, in New York waters. This information could support legislation to limit their use and release into the coastal environment.

Aspects of this work have been picked up by the popular scientific press, appearing in the *Amicus Journal:* Rivlin, M.A. 2000, “The Next Big, Bad Thing.” McElroy was invited to speak on the subject at a special session on emerging issues at the Society of Environmental Journalists. Additionally, multiple publications have resulted from applying methods developed as part of this project.

The results of this work have led to several additional major funded research projects, totaling over $1.2 million, in McElroy and Brownawell’s laboratory. These leveraged funds led to the development of an environmental mass spectrometry facility housed at the Marine Sciences Research Center, Stony Brook University that brings in between $70,000 to $100,000 per year. Orange County, California has used these methods to test out new treatment technologies for removing estrogen from sewage effluent.

Students

Three students successfully completed their degree programs from these two projects. In 2002, Patrick Ferguson received his PhD from Stony Brook University for his dissertation entitled: Analysis and Fate of Sewage-Derived Polar Organic Contaminants in the Marine Environment. For his highly significant efforts, he received the President’s Award for Distinguished Doctoral Student from Stony Brook University in 2002. He is currently an assistant professor in the Department of Chemistry and Biochemistry at the University of South Carolina.

Luke Roy received his Master’s degree in 2002 for his thesis entitled: Assessing Sediment Quality Using Biomarkers in Various Flatfish Species Off the Coast of Southern California. He has since entered the doctoral program at Auburn University in Alabama.

Lourdes Mena received her Master's from Stony Brook University in 2004 for her thesis entitled: Endocrine Disruption in Winter Flounder (*Pseudopleuronectes americanus*): In Jamaica Bay, NY.

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R/CTP-25 Estrogenicity of Municipal Sewage Treatment Plant Effluents: Vitellogenic and Estrogen Receptor Responses in Striped Bass

R/CTP-28 Endocrine Disruption in Jamaica Bay: Are Winter Flounder Being Affected?

(May 2007)

Effects of Pesticides on Lobster Health: Simulating Realistic Concentrations

Sea Grant researchers measured the toxicity of pesticides that may have been implicated in the 1999 lobster die off in Long Island Sound. Techniques developed to measure the pesticides are now sought after nationwide.

A coordinated research effort addresses cause of lobster mortalities

The massive Long Island Sound lobster die off in 1999-2000 led to a lobster research initiative by NY and CT Sea Grant and other state and federal groups to determine the factors involved with the event. Many research projects were funded that looked at different aspects of lobster biology, physiology and the Long Island Sound environment at the time of the die off. Information was needed on the state of the environment and the lobster population and potential factors at play that could have led to such a sudden and economically damaging outcome. Many approaches were used by the research effort including modeling, laboratory experiments, and environmental sampling. Together the various research teams and approaches developed a picture of how and why the event happened. This was one project of the initiative that looked at one piece of the puzzle, the possible role that pesticides might have had in the lobster mortalities.

Analyzing pesticide toxicity on lobsters at likely concentrations

One of the projects that involved both laboratory experiments and environmental sampling was led by Dr. Anne McElroy and Dr. Bruce Brownawell at Stony Brook University Marine Sciences Research Center. The project addressed the controversial role pesticides might have played in the lobster die-off. Recent spraying for control of West Nile infected mosquitoes was believed by some to have played an important role in the lobster die-off. Those parties believed that through runoff from sprayed areas, pesticides entered the

Researcher Anne McElroy demonstrates the highly sensitive spectrometer used to measure minute quantities of pesticides.
Photo by Bob Strovink

Sound in concentrations high enough to be toxic to lobsters. This study analyzed the toxicity of commercially applied pesticides (i.e., active ingredients resmithrin, sumithrin, and methoprene) on stage I-II larval, and juvenile (1.5 to more than 2 year old) lobsters (which would have been prevalent around the time of the die-off), at concentrations realistically expected to be present in the water. The project also measured pesticide levels in receiving waters adjacent to areas sprayed.

Innovations in technique go far beyond measuring lobster sensitivity to pesticides

Results of the study show that Stages I-II larvae seem to be extremely sensitive to continuous exposure from resmithrin at low concentrations (0.26-0.95 µg per liter). Other pesticides used (malathion, methoprene) were much less toxic to lobster larvae. Juvenile (1.5 to more than 2 year old) lobsters appeared to be less sensitive to resmethrin and malathion than larval lobsters, but more sensitive to elevated temperatures. The results of the environmental sampling indicated that the concentrations of the applied pesticides were at much lower levels than found to be acutely toxic to larval and juvenile lobsters in the laboratory tests except in some enclosed bays in the very western end of LIS.

In order to detect the levels of pesticides found in the environment at the levels that might be present, the project team needed to develop more highly sensitive methods of measurement. The methods developed in this study use liquid chromatography coupled to time of flight mass spectrometry (LC-TOF-MS) and are more sensitive and robust than available in other laboratories. Also, the use of alkali metal adducts to simultaneously ionize important classes of pesticides are a new and powerful innovation in pesticide residue analysis. This innovative method is simple and can be easily extended to a wide range of different instruments in current use. It also can be applied to the analysis of other polar contaminants. The key aspects of these methods are now being assessed by state-of-the art analytical laboratories such as those of the USGS. Hydroqual Inc. has used data from this project for its modeling work on pesticides in Long Island Sound.

Development of these methods has led to further funding from EPA and NIEHS, and has contributed to the building of a new environmental mass spectrometry facility at Marine Sciences Research Center that was turned into a University Service Center. That facility is bringing in approximately $70,000-$100,000 per year in support for running research level analyses of estrogens, pharmaceuticals, pesticides and other trace organic contaminants.

One of the first sets of analyses conducted by the facility was the determination of pharmaceuticals and estrogens in wastewaters treated by a reverse-osmosis pilot plant study conducted by Montgomery-Watson at the Sonoma County Wastewater Treatment Plant. Work was also conducted for Suffolk County Vector Control caging study.

This research provided an important piece to the lobster mortality puzzle being addressed by the lobster research initiative. This work showed that the pesticides used during spraying events at the time were unlikely to have caused the mortalities at the concentrations likely present in the environment.

Students

The one scholar for this project, Ann Zulkosky, is currently a Knauss Fellow with the Senate Committee on Commerce, Science & Transportation. She is scheduled to complete her PhD in the spring of 2010.

Publications

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Culturing Hard Clams with Greater Success: A Cooperative Approach

In a Sea Grant-funded project using an unprecedented cooperative approach, scientists and resource managers experimented with the timing of hard clam seeding to improve yield and bring more clams to market.

Bolstering Long Island's declining hard clam industry

Despite being an economic and ecological cornerstone of Long Island's South Shore Estuary, the hard clam, *Mercenaria mercenaria,* has witnessed a precipitous harvest drop-off since the 1970s. Hard clam landings peaked in 1976 with a record harvest of 750,000 bushels valued at $14,600,000 (1976 dollars). By 2005, landings fell to 133,738 bushels with a dock-side wholesale value of $12,655,000 (2005 dollars, based on data compiled by New York Department of Environmental Conservation).

In response to the decline in wild hard clam stock, towns across Long Island have developed shellfish management programs that include municipal shellfish hatcheries and annual hard clam "seed" planting programs. These programs were implemented to help stabilize the declining trend of the shellfish population and rebuild stocks to levels that would provide optimum yields for commercial as well as residential shellfish harvesters.

Commonly, seed is dispersed in the fall after it has been cultured in the hatchery and nursery to about 15 millimeters in shell length. Once the seed has been planted in the field, it is susceptible to predation and changing environmental factors. These two factors also influence the clam's survival into the second growing season. The larger the seed clam, the less susceptible it is to crab predation and the greater the survival of a season's plantings.

Mercenaria mercenaria seed clams.
Photo courtesy of Gregg Rivara

The condition of stored energy reserves of the animal at the onset of winter also influences survival to the second growing season. During the winter, hard clams depend on stored energy reserves accumulated during the summer and fall. Current research suggests that seed planted early in the season grow faster or are in better condition by the end of the growing season.

Improving overall harvest yields is central to the continuing support of public enhancement programs. If earlier plantings of smaller seed show no worse survival than later plantings of larger seed, shellfish enhancement programs could modify their practices by planting smaller seed beginning earlier in the season. This ability would prolong the time frame over which field plantings would occur and maximize the use of finite culture space in upwelling and other nursery systems. Consequently, more seed could be produced throughout the season, which would ultimately lead to an overall increase in yield of seeded product at harvest. This would be of benefit to the Long Island programs as well as commercial clam farms and the larger hard clam enhancement community in the northeastern U.S.

A cooperative approach to find more effective seeding techniques

In an unprecedented cooperative approach, Gregg Rivara from Cornell Cooperative Extension (CCE) of Suffolk County led and coordinated research team participants from seven towns, a university and a state agency during 2002 and 2003. The research team members included: Dr. Robert Cerrato from the Marine Sciences Research Center, Stony Brook University, Debra Barnes from the New York State Department of Environmental Conservation, John Aldred from the Town of East Hampton, Thomas Carrano from the Town of Brookhaven, Craig Hassler from the Town of Town of East Hampton Shellfish Hatchery, Glen Hulse from the town of Huntington, Michael Litwa from the Town of Babylon, Kathleen McShane from the Town of Smithtown, and William Nazzaro from the Town of Southampton.

Across Long Island, this cooperative research team conducted multiple field plot and predator exclusion experiments using hatchery reared seed clams. In general, the towns involved with this project were interested in increasing survival of hatchery-reared hard clam seed once planted in the field. Overall, they looked at the survival of hatchery produced hard clam seed planted at different times through the growing season across Long Island, NY. Specifically, the team tested whether small seed planted early in the growing season would grow faster and be in better condition at the end of the growing season than large seed planted late; whether these same seed would suffer higher predation losses than larger late planted seed; and using these results develop a practical early small seed planting strategy.

Coordinated experiments yield significant practical results

Analyses of field plantings suggested that while clams planted late in the growing season (October) survived at a much higher rate than those planted early in the growing season (June and August), the surviving June-planted clams were significantly larger. Survival in field plots ranged from 1 to 32%. Survival in predator-protected boxes was very high (20 to 100%), indicating that predation was the principal source of mortality.

Seed clams from predator exclusion experiments planted in June and August survived better that those planted in October. This latter result suggests that the condition of June and August planted clams was better going into the winter than October planted clams. The better winter survival of predator-protected June and August planted clams does hold out the possibility that earlier planting is feasible.

Towns and companies growing hard clams would do best to protect clams until the first winter either by using bottom nets, protecting the seed in some sort of container, or developing better culturing techniques. This would constitute a shift away from hatchery/nursery work towards field preparation and predator reduction at planting sites. An alternative that could increase survival would be identifying sites with low predator abundances and planting on those sites.

The results were useful to those that plant hard clam seed (including commercial shellfish farmers) as it confirmed the practice of planting late in the season to minimize crab predation as compared with planting smaller clams earlier. Survival of small seed planted early in the season can be significantly increased if protected from predators and that the timing of planting in the fall may be a critical factor as temperature controls crab activity.

Cornell Cooperative Extension of Suffolk operates a shellfish hatchery and nursery system for three towns at the Suffolk County Marine Environmental Learning Center. Based on these results, in 2006, CCE used mesh-covered bottom nursery plots in a shallow, non-navigable creek in Southold. These plots were stocked with small clams early in the season in order to relieve overcrowding in other nursery systems. They were then harvested in the fall for planting along with production from the other nurseries. The East Hampton Town Shellfish Hatchery used these findings to minimize clam seeding before the fall. Mesh bag over wintering was increased by 50% in 2005/2006; these clams would otherwise have been kicked out of the system by seeding them earlier in the season. It is anticipated that changes made by East Hampton and CCE should result in increased production of hard clams without a significant increase in cost.

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Genetic Characteristics of Great Lakes and Atlantic Coast Sea Lamprey

Sea Grant researchers have opened up the discussion about the parasitic sea lamprey which negatively impacts the economically important Great Lakes salmonid fishery. Their genetic evidence shows that sea lamprey populations appeared in the region soon after glaciation and their lack of homing fidelity precludes use of some management and control practices.

The parasitic sea lamprey: native or invasive?

The sea lamprey, *Petromyzon marinus*, is an anadromous parasitic fish native to North Atlantic coasts. Its range in North America extends from Newfoundland to Florida. The sea lamprey has expanded its range into the Great Lakes from the Atlantic through the St. Lawrence River, Hudson River, Erie Canal and Welland Canal. Its impact on the Great Lakes economically valuable salmonid fishery has been great, contributing to large declines of all salmonid species throughout the Great Lakes. Because of its damaging impacts, management practices have been used to control sea lamprey numbers and thus reduce harm to the fishery, but they are costly.

Effective control may be helped with detailed information of the biology and ecology of sea lamprey including knowledge of sea lamprey population genetics. An important question to answer was: Does the sea lamprey have any homing ability, and if so, could that be exploited as a control method? Another question dealt with the exact invasion history of sea lamprey into the Great Lakes. Some believed that the sea lamprey is native to the St. Lawrence and Lake Ontario. The question of the native status in Lake Ontario is controversial and needed definitive evidence to say one way or the other. Some speculate that if the sea lamprey is native, that perhaps weakens the case for lamprey control.

The sea lamprey is parasitic and its powerful mouth parts keep it firmly attached its host, in this case a lake trout.
Photo courtesy of the Great Lakes Sea Grant Network

A look at lamprey genetics reveals a native species with no homing fidelity

In 2000 to 2001 scientists Isaac Wirgin (New York University) and John Waldman (formerly of Hudson River Foundation) conducted a study into the genetic characteristics of Great Lakes and Atlantic Coast sea lamprey populations. Through examining mitochondrial DNA (mtDNA), the project goals were to estimate the genetic distance between Great Lakes and Atlantic coast populations; test whether sea lamprey show homing fidelity; and compare the genotypic frequencies among regions to help determine whether the sea lamprey is native to Lake Ontario.

The project results showed that there are fixed genetic differences between North American and European populations of sea lamprey. Genetic work from the project supports the hypothesis that sea lamprey do not exhibit strong homing fidelity. The genetic data studied provides evidence that sea lamprey are not recent migrants from the Atlantic as previously thought and are likely native to Lake Ontario. Sea lamprey could have colonized Lake Ontario after the retreat of the glaciers possibly through the St. Lawrence River.

These results have implications for both research and management. There has been an ongoing debate among people about the native status of sea lamprey. This study was the first to show genetic evidence for considering sea lamprey as native to Lake Ontario. Since this project, another lab at Michigan State University also provided evidence that sea lamprey are native to Lake Ontario. Thus there is now greater genetic evidence to consider sea lamprey native to Lake Ontario.

This scientific evidence has resulted in a change in thinking among many that previously thought sea lamprey do not belong in the Great Lakes at all to a recognition that sea lamprey are part of the native fauna that are now out of balance with the ecosystem.

There is recognition that a desirable goal is to keep sea lampreys at a low population level. The finding that sea lampreys do not have strong homing fidelity is unique among anadromous species, most of which return to their natal streams. Because of their parasitic nature, they would disperse randomly depending upon what fish host they were on. This information is useful for management since it rules out any control plans that would seek to take advantage of any homing ability thus saving valuable resources for other methods.

Because of the findings from this study and the Michigan State work, the Great Lakes Fishery Commission is considering the possibility of setting up an independent panel to review the research and make recommendations for new management and control practices.

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