Third
Long Island Sound Lobster Health
Symposium

Summary of Presentations

March 7, 2003

The Long Island Sound Lobster Research Initiative

A collaboration funded by the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service, NOAA Sea Grant Programs of Connecticut and New York, the Connecticut Department of Environmental Protection Long Island Sound Research Fund, and the U.S. Environmental Protection Agency, Long Island Sound Study Office, in collaboration with the Atlantic States Marine Fisheries Commission.In July 2000, Congress made $6.9 million available to support research into the causes of the 1999 lobster mortality event and to support assessment and monitoring of the Long Island Sound lobster resource.

Lobster Mortality Research Steering Committee

- Atlantic States Marine Fisheries Commission
- Connecticut Department of Environmental Protection
- New York State Department of Environmental Conservation
- NOAA, National Marine Fisheries Service
- NOAA, National, Connecticut, New York Sea Grant Programs
- U.S. Environmental Protection Agency, Long Island Sound Study Office
- Connecticut and New York lobster industry representatives

Connecticut Department of Environmental Protection Long Island Sound Research Fund

The Long Island Sound Research Fund, administered by the Connecticut Department of Environmental Protection, was established in 1989 to promote scientific research through in-state academic institutions directed toward priority environmental protection and management of the Long Island Sound estuary. In July 2000, Governor Rowland made one million dollars available to the fund to help determine the causes of recent lobster mortality and identify methods to prevent future declines.

Hosted by the NOAA, Sea Grant Programs in Connecticut and New York under the auspices of the Atlantic States Marine Fisheries Commission (ASMFC) Lobster Mortality Research Steering Committee.

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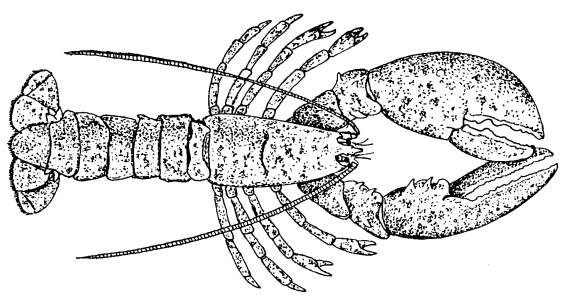

Compiled and edited by Nancy C. Balcom
NOAA, Connecticut Sea Grant College Program
University of Connecticut

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Bridgeport, Connecticut

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Background

During the fall of 1999, the Long Island Sound (LIS) lobster population, particularly in the westernmost part of the Sound, suffered a significant mortality event from which it has not yet begun to show signs of recovery. At the same time, the incidence and extent of shell disease affecting lobsters in the easternmost portions of the Sound, Narragansett Bay, Rhode Island, and Buzzards Bay, Massachusetts was also increasing significantly. The commercial lobster fishery in Long Island Sound has suffered and continues to suffer tremendous economic hardship as a result of this mortality event.

The Lobster Mortality Research Steering Committee was formed as a subcommittee of the Lobster Management Board of the Atlantic States Marine Fisheries Commission. The Committee is a collaboration funded by the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service, NOAA Sea Grant Programs of Connecticut and New York, the Connecticut Department of Environmental Protection (CT DEP) Long Island Sound Research Fund, and the U.S. Environmental Protection Agency, Long Island Sound Study Office, in collaboration with the Atlantic States Marine Fisheries Commission. The First Long Island Sound Lobster Health Symposium was held in April, 2000, bringing together scientists and lobster industry members to discuss the mortality event and identify potential factors that may have led to the die-off.

In July 2000, Congress made $6.9 million available to support research into the causes of the 1999 lobster mortality event and to support assessment and monitoring of the Long Island Sound lobster resource, and Governor Rowland of Connecticut made one million dollars available to the fund to help determine the causes of recent lobster mortality and identify methods to prevent future declines. Research proposals were sought, and currently there are 20 research initiatives underway addressing various aspects of the lobster mortality, funded by NOAA Sea Grant Programs in Connecticut and New York, CT DEP Long Island Sound Research Fund, NOAA Marine Fisheries, and the Environmental Protection Agency. Another research effort looking intothe cause of lobster deaths during the summer of 2002 is being undertaken by the Marine Disease Pathology and Research Consortium at Stony Brook University. The States of Connecticut and New York are conducting extensive lobster resource assessment and monitoring programs.

The Second Long Island Sound Lobster Health Symposium was held in Ronkonkoma, New York in November 2001. At this meeting, the newly-funded research projects were described, and an update on the lobster resource was provided.

The Third Long Island Sound Lobster Health Symposium provided a venue for university researchers to share preliminary results from their on-going projects, and for resource managers to provide an assessment of the current status of the LIS lobster population. The symposium was held at the Holiday Inn in Bridgeport, Connecticut, on Friday, March 7, 2003. Approximately 225 lobstermen, resource managers, researchers, environmentalists, and other interested individuals attended the daylong symposium to hear five integrated presentations: The Status of the Long Island Sound Lobster Resource, Environmental Stressors, Physiological Responses to Stress, Pesticides, and Infectious and Non-Infectious Diseases. A 79-page booklet of extended abstracts describing the individual projects was distributed at the symposium, and is available in PDF form on the LIS Lobster Research Initiative website www.seagrant.sunysb.edu/LILobsters. This document is a complementary publication summarizing the five presentations given at the symposium. Preliminary results are footnoted throughout this summary, referencing the different research teams and projects listed at the end of this document. For more information on the individual projects, please refer to the aforementioned abstract booklet, or contact the principal investigator directly.

Summary of Presentations

(1) The Status of the LIS Lobster Resource and Commercial Fishery

presented by *Carl LoBue, NYS DEC, and Penny Howell, CT DEP*

The States of Connecticut and New York are responsible for monitoring and assessing the LIS lobster resource. These efforts are carried out by the Connecticut Department of Environmental Protection (CT DEP) and the New York State Department of Environmental Conservation (NYS DEC), respectively. Currently, the outlook for the lobster resource remains gloomy, and there are few promising signs of resource and commercial fishery recovery.

Resource assessments can be made by analyzing fishery-dependent data[1]. The total number of lobster licenses for the Sound issued by Connecticut and New York in 2002 dropped to about half of nearly 1,800 issued in 1994. The number of traps in use has dropped from the high of 500,000 to about 300,000 in 2002, however the soak time (the time the traps remain in the water before they are fished and re-baited) has increased to as much as 60 days. The lobster harvest has decreased from a high of more than 11 million pounds in 1997 to about 8 million pounds in 1999 to 2.5 million pounds in 2002. When data from years of similar landings are compared (e.g., 1985-1986 and 2001-2002), the results show that the average number of pounds caught per trap has dropped from about 23 lbs. in 1985-1986 to about 7-8 lbs in 2001-2002, while nearly three times the number of traps were used. Over this 16-year time period, the average monthly ex-vessel price for lobsters has remained stable, making the cost of harvesting lobsters much higher[1].

Despite reductions in effort, the fishery remains overcapitalized, and exploitation on "surviving" adults remains at high levels. Shell disease data from the commercial catch show a continuing problem, particularly for reproductive females in the eastern portions of the Sound and southern New England[1].

Fishery-independent data show similar declining trends[2]. The annual Long Island Sound Trawl Survey (LISTS), conducted by CT DEP since 1984, shows a decline in lobster abundance (mean catch per tow) since 1998, with 2002 values slightly higher in the spring than in the fall. Indices of legal and sub-legal lobsters were at all-time lows in 2002. Preliminary results from CT DEP's on-going tagging study indicate that lobsters tend not to move far from their capture/release points, usually less than 5 km, although some have traveled more than 20 km. The net movement of the lobsters appears to be eastward[2].

Genetic studies of the LIS lobster population show that it functions as a distinct population, with the western LIS more genetically distinct than the rest of the Sound. Population rebuilding in the western parts of the Sound may have to rely on the lobsters that remain in western LIS[3].

A lobster habitat model is being developed using 1995 to 2000 LISTS data to determine lobster population "hot spots" and areas of preferred habitat by looking at various environmental factors. Overlays of stressors like dissolved oxygen levels, temperature, and pollutants will be added[4].

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[1] **NYS DEC Lobster Resource Monitoring and Assessment Project**
Kim McKown et al., NYS DEC, East Setauket, NY

[2-4] **CT DEP Lobster Resource Monitoring and Assessment Project**
[2] *Penny Howell et al.*, CT DEP, Old Lyme, CT
[3] ***Joseph Crivello,*** University of Connecticut
[4] *Roman Zajac*, University of New Haven

(2) Environmental Stressors

presented by *Carmela Cuomo, Yale University*

Several research projects[5,6,7,8] are looking at the environmental conditions that exist in the Sound and how they may have changed over time. The purpose of these projects is to assess what role environmental factors could have played in either directly or indirectly causing the lobster mortality event. These environmental factors include water temperature, dissolved oxygen levels, levels of ammonia and hydrogen sulfide, and concentrations of organic carbon, nitrogen, and biogenic silica. A review of historical data shows a trend towards higher water and air temperatures in recent decades[5,6,7]. During the summer of 2002, LIS water temperatures reached 22-23 ^{o}C in August.

Hypoxia and anoxia have been problematic in western LIS since the 1980s. Nutrient fluxes have increased in the Sound with increased population density and changes in land use patterns over the past 150 years. Records of organic carbon concentrations in sediment cores from central and western LIS show an increase beginning in 1850 of 1.2% - 2.5% and 4.5%, respectively[7]. Cores in western LIS also show an increase in nitrogen and biogenic silica, both indicators of eutrophication[7]. The warming of air and water temperatures results in a decrease in the renewal of oxygen in the water. The release of sulfides and ammonia from the sediments appears to be inversely correlated with water column hypoxia, meaning that they correlate not with oxygen levels in the upper water column, but with temperature and the amount of organic matter available in the sediments themselves[5].

REMOTS® sediment profile images taken in fall 1999 and 2000 showed the presence of an anoxic / sulfidic reduced sediment layer at the water/sediment interface underlying the majority of lobster fishing grounds in western LIS, reflecting that limited dissolved oxygen was present and mixing into the sediments[5]. Similar images of western LIS were taken in late 2002, showing little change from the previous years' findings. Ammonia levels in the bottom (sediment/water interface) and near bottom waters show an increase in October. Hydrogen sulfide was also present, with the levels peaking in May and October. Images of central and western LIS taken in August 2002 revealed the presence of a somewhat shallow reduced sediment layer in areas underlain by fine sediment, and deeper, well-oxygenated areas with feeding voids in areas underlain by sandier sediments[5].

Temperature has a strong structuring influence on Long Island Sound[6], while organic matter has a strong structuring influence on the bottom (sediment-water interface) waters of the Sound[5]. Above average, sustained water temperatures exert severe stress on lobsters. Exposure to hypoxic and reduced conditions (ammonia and sulfide) increases lobster mortality rates, especially among infected lobsters[8]. Environmental conditions (higher temperatures, lower dissolved oxygen levels, sulfide, and ammonia) present in western LIS in the fall of 1999, 2000, and in much of the Sound in 2002 were capable alone of causing lobster mortality, and at least were capable of having stressed infected lobsters to the point that could have resulted in a mass mortality[5].

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[5] **Monitoring of Bottom Water and Sediment Conditions at Critical Stations in Western Long Island Sound**
Carmela Cuomo et al., Yale University

[6] **Relationship Between American Lobster Mortality in LIS and Prevailing Water Column Conditions**
Robert E. Wilson et al., Stony Brook University

[7] **Environmental Change in LIS in the Recent Past**
Johan Varekamp et al., Wesleyan University

[8] **Effects of Environmental Stressors on Disease Susceptibility in Lobsters: A Controlled Laboratory Story**
Richard Robohm and Andrew Draxler, NOAA Fisheries Laboratory

(3) Physiological Response to Stress

presented by *Richard Robohm, NOAA Fisheries, Milford Laboratory*

Another series of projects[8,9,10,11,12,13] is looking at how stressful environmental conditions affect a lobster's physiology and immune system, at different life stages. This information will help scientists and resource managers more fully understand how a lobster reacts to its environment, as well as provide some tools for assessing the health of a lobster.

When lobsters infected with the bacterial pathogen, *Aerococcus viridans*, were exposed to environmental stressors in various combinations and levels of severity, it was determined[8] that:

1) higher temperature alone only moderately accelerates deaths in the infected lobsters;
2) at adequate oxygen levels, exposure to a combination of sulfide and ammonia strongly accelerates death in the infected lobsters; and
3) low oxygen alone accelerates death in the infected lobsters regardless of whether sulfide and ammonia are present.

Lobster blood cells (hemocytes) can ingest and destroy pathogenic microorganisms using several mechanisms, one of which is by the production of cytotoxic hypochlorous acid (HOCl)[9]. A method to measure HOCl production by activated cells has been developed and this has been proposed as a way to quantify resistance to infectious disease in lobsters. A simple alternative method to measure disease resistance may be the level of protein in the blood, because HOCl production per hemocyte is directly correlated with serum protein concentration. In addition to the hemocytes, lobster serum was shown to contain at least two active antibacterial proteins that also function to control infections. Modulation of the above-mentioned cellular and humoral immune mechanisms by environmental stressors is under study[9]. Lobster hemocytes also have two types of receptors (TLR4 and CD14) commonly seen on the immune-system cells of other species, which are used to kill foreign cells[10].

The fact that the fixed phagocytes of the hepatopancreas represent an important part of the immune system of lobsters has not been previously recognized[11]. Once the methods are fully developed, it will be possible to quantify the uptake of foreign particles by the fixed phagocytes of live lobsters. This method will serve as a tool to help evaluate the ability of LIS lobsters to resist disease when exposed to various environmental stressors[11].

Normally, ecdysteroid titers (which measure the level of ecdysones, a family of steroid hormones that regulate molting) in lobster blood (hemolymph) rise significantly before molting[12]. However, titers in shell-diseased lobsters seem to be higher at other times as well, suggesting that ecdysone levels may be elevated in stressed animals, and as a result, they may undergo more molts[12]. This discovery complements the

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[8] **Effects of Environmental Stressors on Disease Susceptibility in Lobsters: A Controlled Laboratory Story**
Richard Robohm and Andrew Draxler, NOAA Fisheries Laboratory

[9] **Immunological Health of Lobsters: Assays and Applications**
Robert S. Anderson, University of Maryland

[10] **Development of Assays for the Evaluation of Immune Functions of the American Lobster (*Homarus americanus*) as a Tool for Health Assessment**
Sylvain DeGuise et al., University of Connecticut

[11] **Development of an Assay for Phagocytic Activity in the Immune System of Lobsters**
Jan Factor, Division of Natural Sciences, SUNY Purchase

[12] **Hormonal Responses of Lobsters to Stresses of Western LIS**
Hans Laufer et al., University of Connecticut

[13] **Stress Indicators in Lobsters: Hormones and Heat Shock Proteins**
Ernest S. Chang, University of California at Davis

fishery-dependent data that suggest that egg-bearing females are affected by shell disease, and lobstermen's observations that some egg-bearing females molt prematurely.

Thermal shock (created by a short-term rise in water temperature from 12 ^{o}C to 25 ^{o}C) causes an increase in the level of mRNA (messenger ribonucleic acid) for a general type of stress protein called HSP70 in lobster embryos, larvae, and juveniles[13]. While heat shock proteins have a half-life of several days, mRNA has a half-life of several hours, and can therefore be used to detect recent stress. Osmotic stress (a short-term exposure to 50% seawater or 150% seawater) in juvenile lobsters causes a significant increase in the mRNA for HSP90, another type of stress protein that may be involved in the regulation of the molting hormone. Just prior to molting, mRNA for HSP90, but not HSP70, increases in the lobster claw muscle[13].

(4) Pesticides

presented by *Sylvain De Guise, University of Connecticut*

Four research projects[12,14,15,16] are looking at the chronic and sub-lethal effects of various pesticides on lobsters of different life stages, in both static and flow-through laboratory experiments. The goals of the pesticide research are to: improve methods of detection so environmentally-relevant concentrations can be measured; detect concentrations of the mosquito control pesticides that can cause toxic (lethal and sub-lethal) effects; examine the diversity of effects in different life stages of lobsters; and determine if any or all mosquito control pesticides applied during 1999 may have contributed to health problems and death of the lobsters.

Methyl farnesoate, a hormone that affects metamorphosis in crustaceans, is similar in structure to methoprene, the larvacide used to control mosquitoes in fresh water. Laboratory studies show that survival of 2nd stage larvae is reduced in the presence of 1 ppm of both of these compounds[12].

Bioaccumulation studies showed that methoprene accumulated in adult lobster tissue after a 4 hour exposure at 50 ppb[14]. Concentrations measured included 6.17 ppm of methoprene in the epithelial cells, 5.18 ppm in the green gland, and 1.55 ppm in the hepatopancreas.

In static tests exposing adult lobsters to a single exposure of malathion, a pesticide sprayed aerially to control adult mosquitoes, the acute toxicity level (LC50) was determined to be 33 ppb[15]. In comparison, malathion is considered to be very highly toxic to walleye at 60 ppb. Sub-lethal effects on adult lobsters by malathion were measured at exposures of 5 ppb[15]. After a 72 hour exposure to methoprene, the LC50 of stage II larvae was 2 ppb[14].

Flow-through tests have been conducted exposing stage II lobster larvae to resmethrin at non-stressful temperatures (16 – 20 ^{o}C)[16]. The 24 hr LC50 was 300 ng/L (parts per trillion) whereas after 96 hours

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[12] **Hormonal Responses of Lobsters to Stresses of Western LIS**
Hans Laufer et al., University of Connecticut

[13] **Stress Indicators in Lobsters: Hormones and Heat Shock Proteins**
Ernest S. Chang, Bodega Marine Laboratory, University of California at Davis

[14] **Acute Effects of Methoprene on Survival, Cuticular Morphogenesis and Shell Biosynthesis in the American Lobster**
Michael N. Horst et al., Mercer University School of Medicine

[15] **Determination of the Toxicity and Sublethal Effects of Selected Pesticides on the American Lobster**
Sylvain De Guise et al., University of Connecticut

[16] **Effects of Pesticides of Lobster Health: Trace Level Measurements and Toxicological Assessment at Environmentally Realistic Concentrations**
Anne E. McElroy and Bruce Brownawell, Stony Brook University

of exposure, the LC50 was measured at 100 ng/L) indicating the highly toxic nature of this pesticide to crustaceans and the increased toxicity resulting from continuing exposure[16]. More tests will be conducted at stressful temperatures and with both methoprene and malathion.

The detection of toxicologically-significant pesticide levels in the environment post-application required the development of new trace analytical methods capable of detecting ng/L levels[16]. The methods available now are 1,000 times more sensitive than those used in 1999, and were able to detect pesticides (piperonyl butoxide, resmethrin and methoprene) in shallow water samples in 2002[16]. Environmental degradation of the pesticides appears to be rapid. In static, acute, single-exposure tests in the laboratory, malathion degraded rapidly, decreasing 65-77% after one day, and 83-96% after three days, and was not detectable in lobsters after five days[15]. However, an effect on phagocytosis was noted on day three of the test.

Lobsters appear to be more sensitive to lethal effects of malathion (adults) and methoprene and resmethrin (larvae) compared to other species. Adult lobsters also exhibit sub-lethal effects by much lower (at least 6 times) concentrations of malathion[15]. The effects on phagocytosis could explain the lobsters' reduced resistance to pathogens.

A key piece of missing information is the actual concentration of pesticides that lobsters could have been exposed to during the fall 1999. Pesticide application data are available from New York, however; it has not yet been determined if a comparable database of information can be compiled for Connecticut.

(5) Infectious Diseases (Paramoebiasis and Shell Disease) and Non-infectious Disease (Calcinosis)

presented by *Salvatore Frasca, University of Connecticut*

The final series of research projects[17,18,19,20,21] are seeking to better understand several infectious and non-infectious diseases: paramoebiasis, shell disease, and calcinosis. Paramoebiasis was discovered in lobsters in the fall of 1999. Simultaneously, shell disease has been affecting increasing numbers of lobsters, particularly in the more eastern parts of the Sound. Calcinosis was first diagnosed in lobsters in the summer of 2002.

Calcinosis, a non-infectious disease of lobsters, was determined to be the cause of death of some lobsters that were lethargic and had a poor shelf life during the summer of 2002[17]. (Unlike with paramoebiasis, the lobsters "perked up" when placed in cold water tanks.) The main characteristics are an orange belly

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[15] **Determination of the Toxicity and Sublethal Effects of Selected Pesticides on the American Lobster**
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[16] **Effects of Pesticides of Lobster Health: Trace Level Measurements and Toxicological Assessment at Environmentally Realistic Concentrations**
Anne E. McElroy and Bruce Brownawell, Stony Brook University

[17] **Calcinosis in LIS Lobsters During Summer 2002**
Alistair Dove et al., Marine Disease Pathology and Research Consortium, SUNY Stony Brook

[18] **Bacterial Assemblages Involved in the Development and Progression of Shell Disease in the American Lobster**
Andrei Chistoserdov and Rozanna Smolowitz, University of Louisiana

[19] **Development of Polymerase Chain Reaction- and *in situ* Hybridization-based Tests for Specific Detection of Paramoeba Associated with Epizootic Lobster Mortality by Determination of Molecular Systematics of Genus *Paramoeba***
Salvatore Frasca, Jr. et al., University of Connecticut

[20] **Phenotypic and Molecular Identification of Environmental Specimens of the Genus [20] Phenotypic and Molecular Identification of Environmental Specimens of the Genus *Paramoeba* Associated with Lobster Mortality Events**
Patrick M. Gillevet et al., George Mason University

[21] **Oligonucleotide-based Detection of Pathogenic *Paramoeba* Species**
Rebecca J. Gast, Woods Hole Oceanographic Institution

and orange-colored hemolymph, "rusty" gills with grossly apparent granulomas, covered with heavy epibiotic growth. Normally green antennal glands are brown. A form of calcium crystal called aragonite is found at the centers of the granulomas.

This fatal metabolic disease was likely caused by the anomalously hot bottom water temperatures during the spring and summer 2002; high temperatures change the lobster's metabolism to favor deposition of calcium[17].

Epizootic shell disease, an infectious disease, is raising concerns in eastern Long Island Sound, Rhode Island, and Massachusetts[18]. It is similar to shell disease in other locations, but it is:

- localized to a large area of the Northeast coast;
- characterized by more severe and extensive lesions than seen in decades;
- the result of bacterial invasions of the cuticular pores, followed by erosion of the cuticle and resulting in chitin matrix pillars, melanization of the surrounding cuticle, inflammation accumulation both underlying and between the cuticle layers, hyperplasia of the cuticular epithelium, and local proliferation of new cuticle;
- correlated with bacterial infection of the pores (3 to 7 bacterial strains have been isolated, but so far investigators have been unable to prove Koch's Postulates through infectivity studies) and may be correlated with protozoal expansion of the lesions[18].

Lobsters can molt out of the affected carapaces. There is no correlation between shell disease and hemolymph infection.

Paramoebiasis was found in the lobsters in the fall of 1999[19]. Amoebae were found in the nervous, glandular, connective, and branchial tissues. These amoebae possess small, round paranuclear bodies. The goals of the projects looking at paramoebiasis are to: determine its phylogenetic relationship to others known to be free-living or parasitic to commercially relevant aquatic animals[20]; to develop DNA-based tests to detect the paramoeba in lobster tissues[19]; and to develop assays to detect the paramoeba in water and sediment samples to determine its environmental distribution[21].

Comparisons of the lobster paramoeba were made with those causing gray crab disease, sea urchin nerve ring, and salmon gill disease, as well as to free-living amoebae[20]. It has been determined to be most closely related to *Neoparamoeba* species[20]. Comparisons to other species of *Neoparamoeba* continue.

Using *Neoparamoeba* specific primers, detection methods are under way to detect the lobster paramoeba in water and sediment samples taken from LIS[21]. So far, three different neoparamoeba / paramoeba isolates from the Sound have been detected, from both water and sediment samples, *Neoparamoeba pemaquidensis, Neoparamoeba aestuarina*, and *Paramoeba eilhardi* (the latter was found in all samples and at all stations)[21].

Koch's Postulates have not been met through infectivity studies of paramoebiasis, due to the inability to culture this organism thus far. A new project is underway to attempt to acquire this key information[24].

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[17] **Calcinosis in LIS Lobsters During Summer 2002**
Alistair Dove et al., Marine Disease Pathology and Research Consortium, SUNY Stony Brook

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[21] **Oligonucleotide-based Detection of Pathogenic *Paramoeba* Species**
Rebecca J. Gast, Woods Hole Oceanographic Institution

[24] **Infectivity of Parasitic Amoebae in Lobsters: Testing of Koch's Postulates**
*Richard Robohm,*NOAA Fisheries Laboratory

Looking Ahead

The research initiatives should all be completed by June 2004. A fourth LIS lobster health symposium is scheduled for late spring 2004. The Lobster Mortality Research Steering Committee is currently evaluating a number of options by which to peer review and integrate the final research results. The research is currently on four tracks:

• looking at the role environmental conditions may have played in causing or facilitating the mortality event by stressing the lobsters;

• looking at what effects, if any, exposure to different concentrations of mosquito control pesticides under varying conditions has on the life stages of American lobsters;

• looking at a number of diseases that are affecting the LIS lobster resource and under what conditions; and

• developing tools to evaluate lobster health and its immune response to the presence of various stressors.

The ultimate goal is to use the results, coupled with current resource assessments, to develop a suite of management options that, if implemented, may foster the recovery of the LIS lobster resource. Given the difficulties now being experienced by the lobster fisheries in Rhode Island and Massachusetts, and the on-going problems in Long Island Sound, these research results hold even greater signficance, and are eagerly awaited by lobstermen and resource managers alike.

Lobster Resource Monitoring and Assessment Projects

[1] New York State Department of Environmental Conservation Lobster Resource Monitoring and Assessment Project

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[2-4] Connecticut Department of Environmental Protection Lobster Resource Monitoring and Assessment Project

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Research Initiative Projects

[5] Monitoring of Bottom Water and Sediment Conditions at Critical Stations in Western Long Island Sound

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[6] Relationship Between American Lobster Mortality in LIS and Prevailing Water Column Conditions

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[7] Environmental Change in LIS in the Recent Past

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Marilyn Buchholtz ten Brink, US Geological Survey, Phone: (508) 457-2392 E-mail: mtenbrink@usgs.gov

[8] **Effects of Environmental Stressors on Disease Susceptibility in Lobsters: A Controlled Laboratory Story**
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[9] **Immunological Health of Lobsters: Assays and Applications**
Robert S. Anderson, Chesapeake Biological Laboratory, Center for Environmental Sciences, University of Maryland.
Phone: (410) 326-7247; E-mail: anderson@cbl.umces.edu

[10] **Development of Assays for the Evaluation of Immune Functions of the American Lobster (*Homarus americanus*) as a Tool for Health Assessment**
Sylvain DeGuise, Dept. of Pathobiology, University of Connecticut, Storrs
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[11] **Development of an Assay for Phagocytic Activity in the Immune System of Lobsters**
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[12] **Hormonal Responses of Lobsters to Stresses of Western LIS**
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[13] **Stress Indicators in Lobsters: Hormones and Heat Shock Proteins**
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[14] **Acute Effects of Methoprene on Survival, Cuticular Morphogenesis and Shell Biosynthesis in the American Lobster, *Homarus americanus***
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[15] Determination of the Toxicity and Sublethal Effects of Selected Pesticides on the American Lobster (*Homarus americanus*)

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[16] Effects of Pesticides of Lobster Health: Trace Level Measurements and Toxicological Assessment at Environmentally Realistic Concentrations

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[17] Calcinosis in LIS Lobsters During Summer 2002

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[18] Bacterial Assemblages Involved in the Development and Progression of Shell Disease in the American Lobster, *Homarus americanus*

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[19] Development of Polymerase Chain Reaction- and *in situ* Hybridization-based Tests for the Specific Detection of the *Paramoeba* Associated with Epizootic Lobster Mortality by Determination of the Molecular Systematics of the Genus *Paramoeba*

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[20] Phenotypic and Molecular Identification of Environmental Specimens of the Genus *Paramoeba* Associated with Lobster Mortality Events

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[21] Oligonucleotide-based Detection of Pathogenic *Paramoeba* Species

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[22] Effects of Temperature and Body Size on Metabolic Stress in LIS Lobsters

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[23] Exposure of Lobsters to the Varied Chemical and Biological Environment of Long Island Sound

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[24] Infectivity of Parasitic Amoebae in Lobsters: Testing of Koch's Postulates

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