LONG ISLAND SOUND
Lobster Health News

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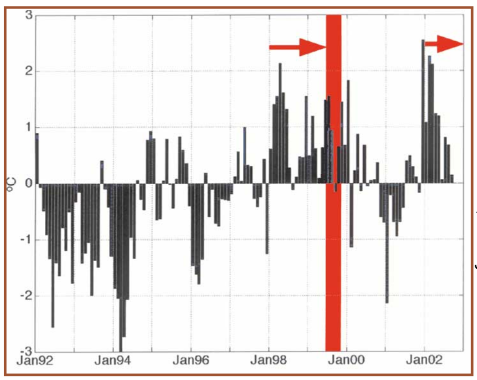
Highlights

Bottom water conditions can create problems for lobsters in Long Island Sound

Changes in various conditions in the surrounding environment such as temperature and sulfide content may affect lobster health. Researchers can predict approximate average temperature, salinity, and dissolved oxygen ranges for specific times of the year, based on historical data. Comprehensive Long Island Sound (LIS) hydrographic and water quality data sets for a number of years have enabled researchers to develop good descriptions of time and spatial scales of variability in temperature, dissolved oxygen, and salinity for LIS. Researchers have identified periods in which the bottom water



Temperature anomalies in LIS bottom waters for 1992-2002. Arrows indicate months in which lobster mortalities were reported.

temperatures consistently have remained above average. These unusual trends are referred to as *temperature anomalies*. Bottom water temperature anomalies are usually greatest during the winter and very early spring, and decline into the summer months. From 1998 to 2000, bottom water temperatures were anomalously warm, with maximum temperature anomalies exceeding 2°C higher than lobsters' ambient temperature tolerance limit (below 22°C). This means that lobsters were living for prolonged periods in conditions well above their warm water temperature tolerance limit. In some cases, this exposure may be over as many as three years.

In contrast, bottom water temperatures were anomalously cool from 1993 to 1996. The lowest natural mortality and highest recruitment values were recorded for American lobsters in LIS in 1996. The year 1999 was characterized by very warm winter and fall temperatures, and above average temperatures in July and August. Strong winds forced mixing of the water column in late August 1999, causing unusually warm surface waters to be mixed to the bottom, further elevating the bottom water temperature. Historical records of bottom water temperatures indicate that temperatures in 2001 were within the historical averages. However, bottom water temperatures in 2002 were higher than historical averages.

Analyses of historical datasets for six deep water channel stations distributed over the entire length of LIS show that temperature anomalies begin in winter, typically, and have integral time scales of several years, which makes for climate-induced variations. There are also other significant anomalies that occur in late summer and early fall that are known to be weather-induced. For example, summer-time bottom-water temperature anomalies can be greater in shallow mixed areas, and dissolved oxygen in the bottom waters can also be elevated at the same time.

Sediment-profile imaging techniques can be used to get sensitive measurements of environmental changes on the seafloor. One technique uses a specialized camera to retrieve undisturbed, vertical cross-section photographs (profiles) of the upper 15 to 20 cm of the seafloor. These measurements are used to characterize sediment types, evaluate benthic habitat quality, map disturbance gradients, and follow ecosystem recovery after

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The *adhoc* Steering Committee was established by the Atlantic States Marine Fisheries Commission to oversee research into the causes of the Long Island Sound lobster fishery disaster.

Letter from the Chair

The Atlantic States Marine Fisheries Commission's (ASMFC) American Lobster Management Board established an *ad hoc* ASMFC Lobster Steering Committee in August 2000, for lobster mortality research, with members appointed by the Chair of the Lobster Management Board. The Committee was charged to provide oversight and accountability for the expenditure of federal funds appropriated for research into the causes of Long Island Sound's lobster fishery disaster in 1999. In addition, the State of Connecticut and U.S. EPA provided funding to support research. We finished the first year of the full complement of research and monitoring programs in July, 2002. There are some preliminary results, but in many cases the first year was spent developing methods or techniques. The second year will be used to conduct replicate tests and refine these preliminary results. The results are slowly forthcoming, and the researchers made great strides in learning more about how the environment and man's activities may potentially affect the health of lobsters.

Anthony Calabrese
Chair

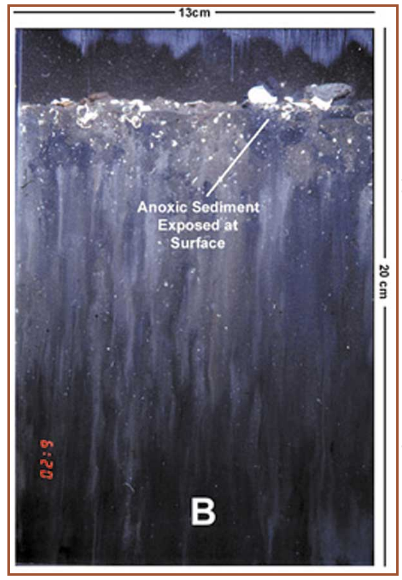
LIS Lobster Industry Speaks Out

A meeting was organized in Connecticut between lobstermen, state legislators and CT DEP, last fall, to discuss the difficulties being faced by the industry. The industry reiterated its belief that the problems are directly related to the use of mosquito control pesticides and their by-products. The lobstermen want to know if chlorine could magnify the by-products of Malathion, and, can these chemicals, or their derivatives, become incorporated into the sediments? Water temperature as a factor in the deaths of weak lobsters in 2002 was discussed. The industry observed that in 2002, weakened lobsters could be resuscitated for extended periods when kept in cold water. Whereas in 1999, weakened lobsters perished regardless of storage technique. Many lobstermen think that lobsters are being pushed to deeper waters in the Sound. Some lobstermen also stated that increased predation by growing stocks of black sea bass, scup, and striped bass may be taking a toll on juvenile abundance and 'short' lobsters. They are also concerned that interruptions in the lobster's life cycle could be playing a role in the continued diminished status of the stock.

Abstract from meetings with LIS Lobstermen

Bottom water conditions cont'd

disturbance abatement. This technique was first introduced under the name REMOTS® (Remote Ecological Monitoring Of The Seafloor). REMOTS® sediment profiling and water quality monitoring in western LIS show that sediments on the seafloor were low in oxygen (or anoxic) from August throughout November 2000.



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REMOTS® sediment profile image showing anoxic sediments in western LIS.

This was also accompanied by a build-up of organic particulate matter that eventually decomposed and caused a further reduction in the oxygen content at the sediment–water interface. Previous studies have documented similar compromises in the sediment in western LIS, and this problem is now believed to be chronic in this area. Profiles show that these benthic communities are dominated by organsims well-adapted to an anaerobic lifestyle in sediments with a high-sulfide content. Benthic communities usually change over time, but this cycle of annual hypoxia causes them to be in a chronic state of arrested development.

More sensitive measurements show that hypoxic events persisted in western LIS in summer 2000 for much longer periods than were previously believed. There were increases in the amounts of sulfide and ammonia during August to November 2000. This indicates that anaerobic processes (such as decomposition) were dominating over normally aerobic processes in the near-surface sediments. Research is ongoing to study the effects on lobster health of elevated ammonia, hydrogen sulfide, and chlorinated hydrocarbons in water and sediment.

The work of the following researchers and their co-investigators are included in the preliminary results and discussion described above in the "Physical & Chemical Environment" section: Carmela Cuomo (Yale Univ.), Robert Wilson (Stony Brook University)

Toxic effects of pesticides on lobster's health in Long Island Sound

Teams of researchers are investigating the effects of three pesticides on lobster health. The pesticides being tested include Malathion and pyrethroids (used on the shore to control adult mosquitoes), and methoprene (used in fresh water to control mosquito larvae). Both lethal and sublethal effects of the pesticides are being examined. Lethal doses, called LC_{50}, (the concentration necessary to kill half of a study sample), are being established for each to provide a measure of toxicity. In addition, scientists are exposing lobsters to small, environmentally-realistic, amounts of pesticides at varying concentrations and under various conditions to determine how the pesticides accumulate and the physiological impacts on organs, tissues, and shell biosynthesis.

Dr. Sylvain De Guise conducting exposure experiments to observe the toxic effects of methoprene on the life stages in lobsters.

Malathion was found to have a LC_{50} of 33 parts per billion (ppb). This toxicity was observed after lobsters were treated with a single dose and exposed for 96 hours. This experiment does not investigate the combined effects of other factors, such as varying pesticide concentrations when the animals are stressed. Another critical question being addressed is to determine if Malathion compromises the immune system at lower doses, and researchers measure the amount of phagocytosis occurring in the lobster. Phagocytosis is the process by which immune cells fight disease by consuming foreign particles that have invaded cells. Results showed that phagocytosis in lobster blood cells was significantly reduced three days after a single exposure to only 5 ppb, indicating that transient exposure to tiny concentrations (6 times lower than the LC_{50}) of Malathion can have subtle sublethal effects on the defense mechanisms of lobsters. Malathion appears to degrade very rapidly; however, the rate depends on the initial concentration. In experiments so far, as much as 65 to 77% was lost one day after application; up to 98% was lost after three days.

Dr. Michael Horst studying how methoprene may affect shell formation in lobsters.

Researchers are also interested in whether methoprene, a larvicide that is usually used in a solid form akin to "briquettes", can interfere with lobster physiology. Methoprene is designed to mimic a juvenile hormone in insects, which is analogous to methyl farnesoate, the crustacean juvenile hormone that regulates growth, molting, and reproduction directly and indirectly. MF stimulates ecdysone, the hormone that induces molting. MF is normally synthesized by the lobster's mandibular organ, located in the jaws. Normal levels of MF and ecdysone have been determined for American lobsters, with juvenile and females having higher levels than males. MF levels can rise with increasing water temperature, and have been found in higher levels in animals infected with shell disease. Tests showed that low concentrations of methoprene applied to isolated mandibular organs increased MF synthesis, especially in lobsters not already producing it, such as older males. Since MF stimulates ecdysone, it is plausible that pesticide exposure may stimulate molting at inappropriate times under some circumstances.

Adult lobsters exposed to methoprene at 25 ppb for 24 hours showed an accumulation of the chemical in various tissues. Highest concentrations were seen in epithelial tissues (skin underneath the shell), hepatopancreas (liver), and the gonads (reproductive organs). There was almost no accumulation observed in tissue samples taken from the stomach or muscles. The effects of methoprene on protein synthesis in juvenile lobsters were examined by exposing them to a concentration of 10 ppb for 18 hours, and injecting them with radiolabelled sugar and amino acid compounds to determine protein synthesis. This resulted in a 91-94% reduction in protein synthesis in the hepatopancreas and a 40-50% reduction in the gills, but there was no measurable effect observed in muscle tissue.

There is interest in the possible toxic effects of methoprene on the larval stages of lobsters. A lobster goes through several transformations (stages I-III) during its planktonic phase, before it resembles a miniature adult (post-larval stage IV) and settles to the bottom. Post-molt adults succumbed to methoprene at concentrations of 25 ppb after only 12 hours of exposure. Preliminary results from exposure trials at concentrations up to 25 ppb did not have a marked effect on stage I larvae. However, toxicity was observed for stage II larvae at various concentrations.

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Disease pathogens in Long Island Sound's lobster populations

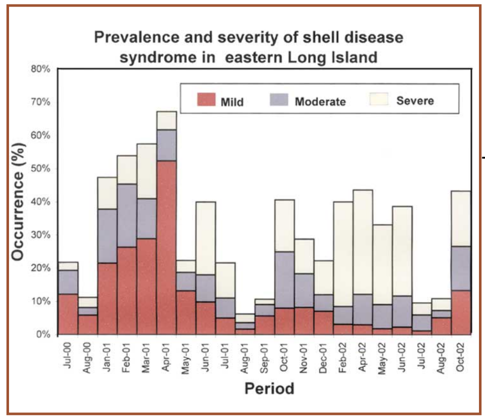
Disease has been of growing concern in the northeast lobster fishery for many years. Gaffkemia (or 'red tail' disease) was reported in the early 1990s, causing a decline in lobster production in Long Island Sound (LIS), but not to the extent observed between 1999 to 2000. This disease is caused by the bacterium *Aerococcus viridians var. homari*, which infects the circulatory system, impairs blood circulation, and may cause fatal hemorrhaging. *Vibrio* bacterium is also a common pathogen that infects lobsters and other crustaceans. Ciliate Disease (or 'Bumper Car Disease') is caused by a protozoan, *Anophryoides haemophila*. This disease has caused mortalities in places where lobsters are caged, such as Maine and various provinces in Canada, but there are no known reports of this disease in LIS to date.

Shell disease is an issue of concern in LIS's lobster fishery. Researchers are beginning to learn more about this disease that appears to be caused by bacteria. These bacteria are chitinolytic, meaning that they attack and break down the chitin that makes up the lobster's shell. Shell lesions are not caused by one bacterial species; an assemblage of several species (3-8 organisms) is involved. Bacterial samples isolated from shell lesions on infected lobsters caught in various areas of LIS, show that these assemblages are usually dominated by as many as four species. Preliminary results show similarities between the bacterial assemblages on infected lobsters from eastern LIS and Buzzard's Bay, but they differ from assemblages on lobsters from the Mount Sinai area in New York. There is some preliminary evidence that suggests shell disease may interfere with the molting cycle.

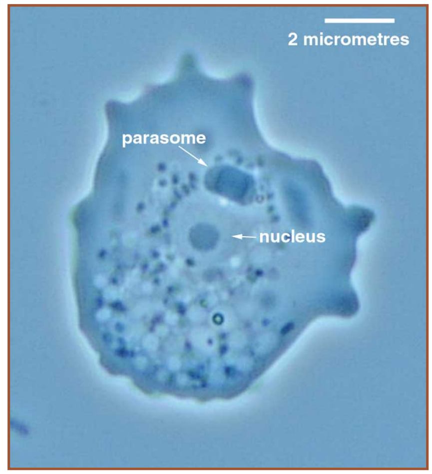
The state resource management agencies are also learning about the spread of shell disease in LIS, through at-sea sampling that is being done in cooperation with lobstermen. The data indicate that this disease affected as much as 70% of the lobster population in the eastern basin in winter 2000 and spring 2001. This incidence was reduced significantly, and never exceeded 3.5% after the summer molt, in the western and central basins. Although shell disease does not usually cause death in infected lobsters, (nor does it affect the lobster meat quality in any way), it affects the market value of the product.

While shell disease, is mostly a problem in eastern LIS, and it is easy to identify infected lobsters, another disease that killed lobsters in western LIS is paramoebiasis, which is much harder to spot. Paramoebae are tiny single-celled protozoa, similar to the amoebae introduced to students in their first biology class. Paramoebae can cause disease in crabs, sea urchins, and finfish. Paramoebiasis is the term for a paramoeba infection. Disease symptoms vary from one host to another; paramoebiasis in blue crabs (Grey Crab Disease) destroys nervous tissue and changes the crab's color to grey, while in finfish (Amoebic Gill Disease) the gills become inflamed. Researchers identified a paramoeba in the lobsters affected in the 1999 mass mortality in Long Island Sound. In the associated disease, sometimes called "limp lobster syndrome", lobsters become weakened, and infected animals die shortly after being landed. The amoeba invades the lobsters' nervous and connective tissue resulting in destruction of nerve tissue and inflammation. Re-searchers, using DNA sequencing techniques, now know that "paramoebae" parasites consist of the harmless *Paramoeba* and the potentially harmful *Neoparamoeba*. They believe that the lobster pathogen belongs to the species *Neoparamoeba pemaquidensis*, the one that is responsible for Amoebic Gill Disease. Potentially, all paramoebiasis is caused by strains of *N. pemaquidensis.* DNA

Lobster showing severe shell disease. Shell disease syndrome (SDS) is ranked according to the proportion of shell coverage (mild = 1-10%; moderate = 11-50%; severe = >50%).



Occurrence of shell disease in eastern Long Island Sound in recent years, observed in NYS DEC and CT DEP resource monitoring program.



Cultured *Neoparamoeba* obtained from Gulf of Maine sea urchins, showing nucleus and parasome.

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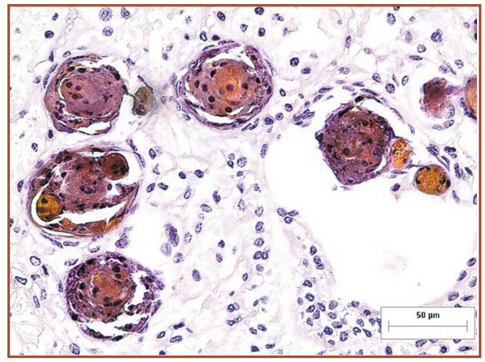
sequences are being used to develop diagnostic tests to detect *Neoparamoeba* in animal tissues, detect and monitor *Neoparamoeba* in the environment, and match strains cultured from environmental samples with amoebae observed in animals. Cultures can be used in experiments to determine how a strain of *N. pemaquidensis* becomes a pathogen.

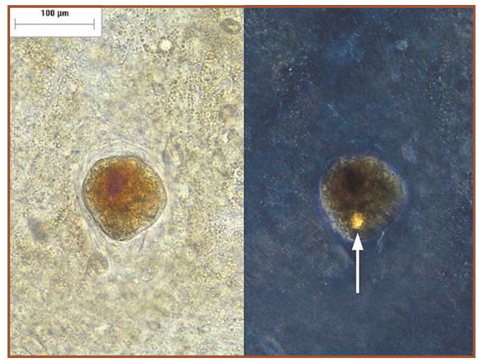
The research is also being supplemented by the work of staff in the states' resource monitoring agencies. More than 700 lobsters were collected by Connecticut Department of Environmental Protection (CT DEP) over 18 months as part of a study to assess the health of the current lobster population. Preliminary assessments have confirmed that the *Neoparamoeba* species was still present in mid-August 2001 in samples taken as far east as Niantic and Stonington, CT. Tests for other diseases carried by bacterial pathogens such as *Vibrio* and *Aerococcus* have shown them to be uncommon in LIS. No fungal pathogens have been found either.

Most recently, researchers have discovered a new disease in lobsters. Sick lobsters that were analyzed in summer 2002 were found to be suffering from calcinosis. This is a condition by which calcium accumulates in the soft tissues, forming kidney stones. The tissues in the antennal gland (the lobsters' 'kidney') and gills were affected, and infected lobsters showed a distinct orange coloration on the abdomen, among other physical symptoms. There were no other pathogens associated with the infected lobsters. It is a noninfectious disease that is believed to develop when lobsters experience prolonged exposure to prevailing high temperatures in the bottom waters.

The work of the following researchers and their co-investigators are included in the preliminary results and discussion described above in the "Shell Disease & Paramoeba" section: Andrei Chistoserdov (Louisiana State Univ.), Alistair Dove (Cornell Univ.), Salvatore Frasca (UConn), Richard French (UConn), Rebecca Gast (WHOI), Patrick Gillevet (George Mason Univ.), Penny Howell (CT DEP), Hans Laufer (UConn), Charles O'Kelly (Bigelow LOS), Peg Van Patten (CT Sea Grant).



Histological section of antennal gland tissue showing granulomas.



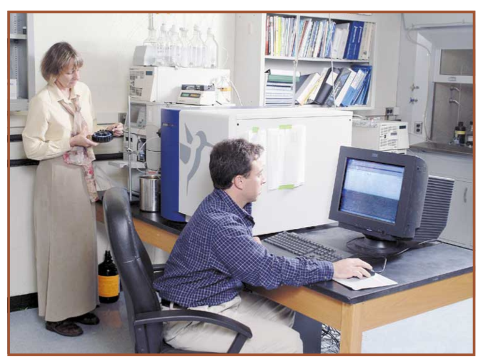
Granuloma in soft tissue. Arrow points to the calcium carbonate crystal.

Toxic effects of pesticides on lobster's health cont'd

Progress in developing a new probe to detect pesticide residues in a small blood sample has been made. This will allow researchers to conduct much more sensitive testing of blood samples and may even help detect the bacteria responsible for causing shell disease. Research is also continuing to measure trace levels of these pesticides and their breakdown products in the environment.

Chemical analysis of the lobster tissues obtained from monthly sampling in five zones in LIS is also underway. Results from the initial analyses of samples collected through mid-2001 showed that none of the samples contained detectable levels of the targeted pesticide compounds, at a detection level of 15 ppb.

The work of the following researchers and their co-investigators are included in the preliminary results and discussion above in the "Pesticides' section: Sylvain De Guise (UConn), Richard French (UConn), Michael Horst (Mercer Univ.).



Dr. Anne McElroy and assistant developing techniques to measure small concentrations of Scourge® and Anvil® in LIS's waters.

Fighting disease: The role of the lobster immune system

American lobster populations have long held tremendous commercial value in the northeastern United States. While that might imply that scientists have learned all the secrets about lobster, many questions raised following the 1999 mortality event indicate this is not the case. What constitutes a 'healthy' lobster? How does a lobster's immune system respond when the lobster is stressed by one or more factors? Which stressors are most harmful? These are some important questions being studied.

Researchers are currently working on ways to define how a lobster's immune system works, under the influence of various stressful conditions. The effects of temperature, salinity, low dissolved oxygen, ammonia, hydrogen sulfide, and the presence of microorganisms (lobster pathogens) are among the stressors being examined. Tests are being conducted on groups of lobsters in laboratory settings, exposing them to a range of these stressors, individually and in combinations, to determine how the lobster's immune system responds and under what conditions the immune system is overwhelmed. Different life stages of lobsters, ranging from larval to adult stages, are included in these experiments to see if some stages are more vulnerable to stress than others.

Dr. Ernest Chang measuring heat shock proteins produced when lobsters are under stress.

A number of immune system components are being measured to determine their role in fighting the effects of disease or other stressors. For example, the immune cells that fight infection and disease are called *phagocytes*, and the process of engulfing and ridding the body of foreign disease-causing organisms (pathogens) is called phagocytosis. Scientists can measure how effective the process of phagocytosis is in removing pathogens under both normal and stressful conditions, to see what, if any, outside factors negatively affect this critical immune system function. Other studies are measuring the presence of heat shock proteins or stress hormones in the blood. These are produced when a lobster is exposed to environmental conditions outside its normal tolerance range.

Lobster samples being collected for researchers to conduct experiments.

Several indicators of general lobster health status have been identified, including the number of blood cells or hemocytes present in the hemolymph (lobster blood). Immunologic data indicate a significant difference in hemocyte counts among healthy lobsters and sick lobsters. Another promising indicator appears to be the production of hypochlorous acid (HOCl) in the blood plasma. Hypochlorous acid is a powerful antimicrobial agent used by the hemocytes to fight disease, and its presence can be used as a signal when the lobster's immune system is fighting some kind of infection.

Analyses of two years of data collected by CT DEP staff, by UConn researchers, show a significant difference in hemocyte counts and phagocytosis between inshore and offshore animals in specific areas of the Sound. The immune system seems to be stronger in lobsters from the area south of the Connecticut River to New Haven compared to animals in the rest of the Sound, and researchers do not know the reason for this, however, further evaluation of these data is underway.

CT DEP staff working with the lobster industry on a scheduled at-sea data collection trip.

The work of the following researchers and their co-investigators are included in the preliminary results and discussion described above in the "Immunology & Endocrinology" section: Robert Anderson (Univ. of Maryland), Ernest Chang (Univ. of California Davis), Sylvain De Guise (UConn), Jan Factor (SUNY Purchase), Richard French (UConn), Penny Howell (CT DEP).

Lobster resource status in Long Island Sound

The mortality events that occurred in 1999 demonstrated the importance of having access to good data to quantify the impacts of natural resource disasters. The States of Connecticut and New York expanded their resource monitoring and assessment programs for the lobster population in Long Island Sound. These new data will facilitate more accurate estimates of annual harvest, and they will be used to assess the overall population status of the lobster fishery. The expanded programs include sampling trips made in cooperation with commercial lobstermen, a semiannual trawl survey, a tagging study, and a young-of-the-year study, all with the objective of assessing the current status of the lobster stock in comparison to previous years. For example, the researchers are better able to compare changes in overall abundance of juvenile lobsters and measure the spread of shell disease in Long Island Sound.

Changes in Abundance

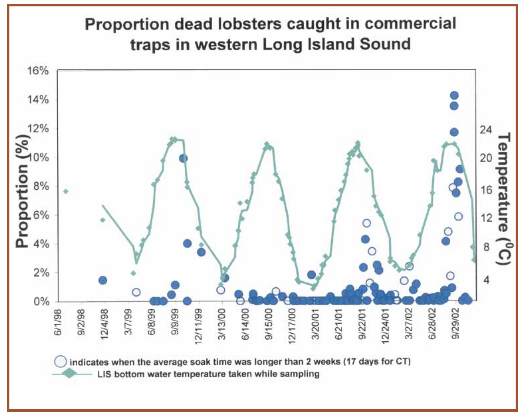
CT DEP conducts an abundance survey for lobster larvae each year; however, the results for 2002 were notably low. These annual surveys first started in 1983, and the indices help resource managers to assess the future of the lobster stock by comparing the index for each year with a long-term average. In 2002, the index was calculated as 2, which represents 10% of the long-term average.

In the 30 tows taken in the Narrows (western portion of the Sound) during the CT DEP's trawl survey in 2002, the size composition of the lobsters was similar to the rest of the Sound, as were the sex ratios for legal and sub-legal sizes, proportion of egg-bearing females, and proportion of hard shell lobsters. Fouling occurs when plants and animals colonize and grow on a lobster's shell; this incidence was found to occur 10-12% more frequently in the Narrows. Overall diversity of the species caught in the Narrows (30 finfish species and 22 invertebrate species) was lower than in the rest of the Sound. Horseshoe crabs (44%) and lobsters (32%) dominated the invertebrates.

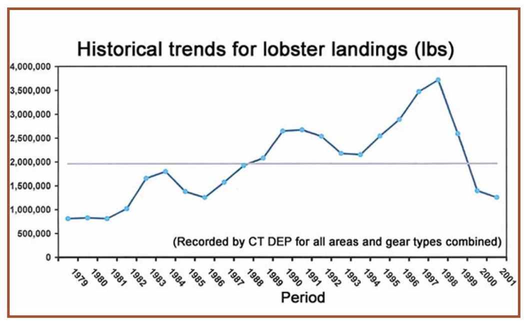
The spring 2002 mean catch from CT DEP's trawl survey was 6.31 lobsters/tow, which is consistent with its downward trend over the past two years. Historically, the trawl survey abundance indices in the 1980s fluctuated without any noticeable trends; however, indices between 1990 to 1998 showed an upward trend before its decline in 1999 when there was the lobster mass mortality. The 2002 abundance index is a continuation of the downward trend from the peak (19.6 lobsters) which was observed in 1997.

A tagging study began in August 2001, with enormous help from the industry. NYS DEC will begin to participate in this survey in 2003. As many as 6,148 lobsters were tagged by the end of October 2002. The initial return data indicate that the average time between release and recapture was 56 days. More than 50% of the lobsters moved less than 1 km from their release point, and only 2% travelled more than 10 km. There was no difference in movement among males, females, and egg-bearing females, and no correlation between time-at-large and distance traveled.

CT DEP is currently supporting two additional lobster resource studies at the University of Connecticut and the University of New Haven, respectively. The first is a genetic study of adult egg-bearing females collected in the eastern, central, and western basins of the Sound, as well as from Hudson Canyon offshore area. The preliminary results are helping researchers to identify how lobsters may have different genetic composition.



Proportion dead lobsters caught in traps in the state agencies' resource monitoring program. Dead lobsters correlate to high bottom water temperature.



Historical landing trends for lobsters caught in Long Island Sound (all areas). Volume of the landings since 1999 is comparable to the mid 1980s.

CT DEP staff tagging specimens to study lobster movement and migration in Long Island Sound.

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Lobster resource status in Long Island Sound cont'd

The genetic difference between the eastern and central basin lobsters is much less than the others, and all lobsters from LIS were found to be significantly different from the lobsters in Hudson Canyon. Preliminary results suggest that lobsters from the western basin are genetically different from the other areas. The order of magnitide of this difference is somewhat like comparing the genetic composition of lobsters from the western basin versus offshore. This means that there may be several different stocks being fished in LIS. The second project is an ongoing effort to develop a computerized lobster habitat model, incorporating physical and environmental data, as well as landings data. This new model will allow resource managers to predict the effects that habitat changes may have on lobster populations in Long Island Sound.

NYS DEC expanded its lobster resource monitoring program, and they conducted 106 sampling trips with commercial lobster vessels since September 1999. More than 5% of the lobsters caught were dead. This mortality was found to have coincided with long soak time (greater than 2 weeks) and above average bottom water temperatures. Both state agencies will work together on the tagging study in 2003.

A young-of-the-year study piloted in 2001 was repeated in 2002, where collector trays are deployed into the water in spring and retrieved in the fall. Small lobsters were found in a few sites only, this past fall, primarily in sites located in deeper waters directly south of Branford and around Fishers Island. Data loggers are collecting bottom temperature readings hourly, and additional data loggers will be deployed in 2003, using US Coast Guard Department navigational buoys.

The work of the following researchers and their co-investigators are included in the preliminary results and discussion described above in the "Resource Monitoring" section: Joseph Crivello (UConn), Penny Howell (CT DEP), Carl LoBue (NYS DEC), Roman Zajac (Univ. of New Haven).

Lobster Health Symposium

The 3rd Annual Lobster Health Symposium will be hosted by Connecticut Sea Grant College Program on Thursday March 7 at the Holiday Inn, 1070 Main Street, Bridgeport, CT 06604. Telephone 203.334.1234. This hotel is within close proximity to the ferry and train stations.

This will be the first opportunity for the Sea Grant-funded researchers to present some of the preliminary results for the research conducted in 2002. The state agencies in Connecticut and New York will also provide insight on the future of the lobster fishery based on the results of the monitoring programs.

Please check our website at www.seagrant.sunysb.edu/LILobsters for additional information, or contact one of the Outreach Coordinators to place your name on the mailing list:-

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