Exhibit 6

Responding to a Resource Disaster:

American Lobsters in Long Island Sound

1999 - 2004

Steering Committee for Lobster Disease Research

Chairman, 2005
Jack Mattice (2000-2005)
Director, New York Sea Grant Institute
Stony Brook University

Chairman, 2004
Emory Anderson (2000-2004)
NOAA Fisheries liaison to the
NOAA National Sea Grant Office (retired)

Chairman, 2000-2003
Anthony Calabrese (2000-2003)
Director, NOAA Fisheries
Milford Laboratory (retired)

Robert Beal (2005)
Atlantic States Marine Fisheries Commission

Ernest Beckwith (2000-2003)
Director, Marine Fisheries Division
CT Department of Environmental Protection

Gordon Colvin (2000-2005)
Chief, Bureau of Marine Resources
NYS Dept. of Environmental Conservation

Nick Crismale (2000-2005)
Connecticut Lobster Industry Representative

Andrew F.J. Draxler (2005)
NOAA Fisheries, Sandy Hook Laboratory

Joseph Finke (2000-2005)
New York Lobster Industry Representative

Lisa Kline (2000-2003)
Atlantic States Marine Fisheries Commission

Harry Mears (2000-2005)
NOAA Fisheries
Northeast Regional Office, Gloucester

Edward Monahan (2000-2005)
Director, Connecticut Sea Grant
University of Connecticut

Carrie Selberg (2003-2004)
Atlantic States Marine Fisheries Commission

Eric Smith (2003-2005)
Director, Marine Fisheries Division
CT Department of Environmental Protection

Terry Smith (2005)
NOAA Fisheries liaison to the
NOAA National Sea Grant Office

Mark Tedesco (2000-2005)
U.S Environmental Protection Agency
Long Island Sound Study

Other Interested Parties

Nancy Balcom (2000-2005)
Rapporteur, CT Sea Grant Extension
Program, University of Connecticut

Antoinette Clemetson (2001-2005)
Rapporteur, New York Sea Grant Institute /
Cornell Cooperative Extension

Ron Rozsa and Harry Yamalis (2000-2005)
CT Department of Environmental Protection
Office of Long Island Sound Programs

Cover photos by John Collins, formerly with University of Connecticut Center for Instructional Media and Technology, courtesy of Capt. Mike Theiler, Jeanette V Fisheries, Waterford, CT.

RESPONDING TO A RESOURCE DISASTER:

AMERICAN LOBSTERS IN LONG ISLAND SOUND

1999 - 2004

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CTSG-06-02

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As catches diminished and then disappeared altogether, more and more lobstermen hauled their traps and tied up their boats; some left the fishery for good. (Credit: John Collins)

Executive Summary

In the fall of 1999, the American lobster *(Homarus americanus)* resource in western Long Island Sound (Connecticut and New York) experienced a significant mortality event. State and federal landings data indicate that prior to the die-off, bi-state commercial lobster harvests ranged from 7 to 11.7 million lbs. annually, valued at $18 to $40 million. Twelve hundred resident commercial lobster licenses were issued in 1998; in 2002, fewer than 900 lobstermen remained licensed. Commercial harvests of LIS lobsters totaled about 1. 6 million lbs. in 2004, worth slightly less than $7 million.

Documentation supplied by the two state resource management agencies in collaboration with the commercial lobster industry resulted in a Department of Commerce declaration of a 'commercial fishery failure due to a resource disaster'. Strong bi-state Congressional support led to an appropriation of $13.9 million in disaster assistance: $7.3 million for economic relief and $6.6 million for resource monitoring and assessment, and to support a research initiative to investigate the potential causes of the mortality event. Connecticut and New York also contributed research support, as well as the U.S. Environmental Protection Agency, Long Island Sound Office (Table 1).

Sixty-five scientists at 30 institutions and agencies nationwide participated in the research initiative, investigating the effects of environmental factors, mosquito control pesticides, and disease on the physiology and health of American lobsters. The results indicate that the physiology of the lobsters was severely stressed by sustained, hostile environmental conditions, driven by above-average water temperatures. A new lobster disease, paramoebiasis, was identified as the proximate cause of death for the majority of lobsters examined by pathologists. Laboratory studies demonstrated that the pesticides used for mosquito control have sub-lethal or lethal effects on lobsters, based on concentration and time of exposure; however, modeling exercises indicate it is unlikely that the concentrations of individual pesticides in western Long Island Sound were high enough to cause the mortality event.

Table 1. Breakdown of federal and state funds applied to the research, resource monitoring, and outreach components of the 1999 lobster mortality event. 'Match' refers to non-federal monetary contributions required of federal grant recipients. For a breakdown of the economic relief expenditures, see Table 2, page 8.

	NOAA Fisheries	EPA	CTSG	NYSG	State of CT	State of NY	TOTAL $
Research	750,000	268,000	1,310,000	1,238,000	780,000	1,000,000	5,346,000
Monitoring	-----	-----	-----	-----	1,300,000	1,300,000	2,600,000
Outreach	15,000	-----	165,000	190,000	16,000	10,000	396,000
Match	-----	127,000	602,000	661,000	518,000	574,000	2,482,000
TOTAL $	765,000	395,000	2,077,000	2,089,000	2,614,000	2,884,000	10,824,000

Background

Lobsters and crabs pulled dead or dying from traps were an unwelcome but common sight during the fall of 1999 in western Long Island Sound. (Credit: CT DEP)

During the fall of 1999, the American lobster population in Long Island Sound (LIS) suffered a significant mortality event, particularly in the western and central Sound. Calls to the Connecticut Department of Environmental Protection (CT DEP) and the New York State Department of Environmental Conservation (NYS DEC) reporting unusually high numbers of dead and dying lobsters began in late August and early September. Bi-state (Connecticut and New York) commercial lobster landings from western LIS (west of Norwalk, CT and Huntington, NY) declined by as much as 99% from the previous year. Lobster landings at ports east of Norwalk and Huntington were reduced by as much as 64 to 91%. At the same time, lobstermen in eastern LIS (as well as Rhode Island and Massachusetts) continued to see a rise in the incidence and extent of shell disease in lobsters, which, while apparently unrelated to the mortality event, raised additional concerns about the status and health of the lobster resource and the Long Island Sound commercial fishery.

During the summer and fall of 1999, the mosquito-borne West Nile Virus (WNV) appeared for the first time in North America, in the New York/Connecticut region. By early September, seven human deaths had been attributed to WNV. Control programs were undertaken in both states to curb adult and larval mosquito populations, to protect public health. The application methods and pesticides used varied geographically and temporally, from early August to mid-October.

In late September, as the magnitude of the lobster die-off continued to grow, the CT DEP collected water samples for analysis and contracted with the University of Connecticut to test the samples for a range of materials including pesticides, herbicides, PCBs, semi-volatile organic compounds, volatile organic compounds, heavy metals, and cyanide. None of the materials were detected in the samples at concentrations above the detection limits of the equipment. Samples were also screened for toxic phytoplankton and bacteria by the NOAA Fisheries Laboratory in Milford, CT. None were found.

Lobster specimens were sent to the University of Connecticut for gross and histopathological examination in mid-October. Pathology reports indicated that most of the lobsters examined were infected with parasitic amoebae, or paramoebae. The parasitic amoebae infecting much of the lobsters' nervous tissue were considered by the pathologists to be the proximate cause of death of the lobsters, but it remained unclear whether other factors played a role in suppressing any possible immune response to the infection.

The CT DEP and the NYS DEC conducted a mail survey of licensed lobstermen and seafood dealers in late 1999. The results indicated that the lobsters found dead in the traps were both legal and sub-legal in size, male and female. More small lobsters were reported dead in the western Sound than in the east, and only western lobstermen reported severe mortalities (25-100% of a day's catch). Most respondents reported other animals, such as crabs and bottom fish, dead in their traps. Additional observations included a 'rotten egg' smell, and healthy-looking lobsters dying in the tanks within a day or two after delivery to the dealer.

...The Long Island Sound lobster fishery experienced 'commercial fishery failure due to a resource disaster'...

The governors of Connecticut and New York contacted the U.S. Secretary of Commerce in December 1999 requesting disaster assistance under Section 312(a) of the Magnuson-Stevens Fishery Conservation and Management Act due to the widespread lobster die-off in LIS. Based on preliminary data submitted by the states and information supplied by the lobster industry, the Secretary declared that the LIS lobster fishery experienced 'commercial fishery failure due to a resource disaster' on January 26, 2000. This declaration, coupled with the support of the Connecticut and New York congressional delegations, paved the way for a Congressional authorization and subsequent appropriation of $13.9 million for the purposes of providing economic assistance to the lobstermen ($7.3 million) and supporting a comprehensive research effort investigating the potential cause(s) of the resource disaster ($6.6 million).

The first LIS Lobster Health Symposium was held in Stamford, Connecticut, in April 2000. Organized by the Sea Grant programs in Connecticut and New York on behalf of a bi-state advisory committee, the two-day meeting brought together lobstermen, researchers, resource managers and others to discuss the mortality event, review the results of preliminary assessments, share observations, and develop a comprehensive list of potential causative factors for further investigation. The research priorities identified included assessment of the lobster resource, disease, anthropogenic inputs (including pesticides), and oceanographic and environmental processes.

The Atlantic States Marine Fisheries Commission (ASMFC) formalized the bi-state advisory committee by establishing it as a sub-committee of its Lobster Management Board in August 2000. The primary responsibilities of the Steering Committee for Lobster Disease Research (SCLDR) were to guide the research initiative, recommend the allocation of the available federal funds, and report back to the ASMFC Lobster Management Board. Appointed members represented NOAA Fisheries, NOAA Sea Grant National Office, Connecticut and New York Sea Grant, the U.S. Environmental Protection Agency (EPA), ASMFC, CT DEP, NYS DEC, and the LIS lobster industry.

...$13.9 million in federal aid for economic relief and research...

Under the guidance of the SCLDR and through a subsequent research spending plan approved by Congress, NOAA Fisheries allocated $2.6 million to the States of Connecticut and New York to enhance and expand their lobster population monitoring and assessment programs (Table 1). The remaining funds were divided among NOAA Fisheries ($1 million) and the Connecticut and New York Sea Grant programs ($3 million)

to support research and extension work. These federal funds were matched by nearly $2.5 million in non-federal funds. The State of Connecticut, through its LIS Research Fund managed by the CT DEP Office of Long Island Sound Programs, offered an additional $1 million for research, of which $780,000 was used (Table 1).

The State of New York appropriated $1 million in 2000 for the creation and staffing of a pathology laboratory at the Marine Sciences Research Center, Stony Brook University (Table 1). The laboratory, a key element of a new Marine Disease Consortium established by the New York state legislature in response to the lobster die-off, is already facilitating the study of shellfish and finfish diseases.

A nationally-competitive request for proposals was issued by the Sea Grant programs and CT DEP in fall 2000. Researchers were asked to propose work in one of several areas: physical/chemical environment, disease, pesticides, and immunological responses to stress. Following a rigorous peer review process, 18 research projects were funded, involving more than 30 institutions and agencies nationwide, and more than 65 researchers and graduate students. These multi-year research projects, as well as several initiated in subsequent years, were supported by NOAA Fisheries, CT Sea Grant, NY Sea Grant, CT DEP, and the EPA. (See pages 18-20 for list of project titles and recipients.)

Given the nature of the problem being investigated, inter-disciplinary collaborations were strongly encouraged. Two working meetings of the entire research initiative community were held to share and discuss preliminary results. Additional LIS Lobster Health Symposia were held in Ronkonkoma, NY (2002) and Bridgeport, CT (2003) to provide updates on the research initiative to lobstermen, legislators, the press and the public.

In October 2004 at Stony Brook University (NY), the results of the research initiative were presented. A summary of the findings is presented, beginning on page 13.

Social and Economic Impacts

An initial assessment of the economic impact and human dimensions of the die-off, conducted by Human Ecology Associates in January 2000, found that approximately 70% of the western Sound lobstermen surveyed had lost 100% of their fishing income in the year after the die-off; the remainder lost 30-90% of their income. The study noted that because of the severity and suddenness of the die-off, these lobstermen found it hard to switch to other fisheries or to new vocations. The report also documented significant social and psychological damage to these fishing families and their communities.

...significant financial, social and psychological damage to the affected fishing families and their communities was documented...

Lobstermen, lobster dealers, and seafood restaurants in Connecticut and New York were surveyed by telephone in 2002 to assess the economic impact that the 1999 die-off had on various sectors of the lobster market. The results indicated that the lobster dealers and seafood restaurants were able to fill their supply demands with lobsters from northern New England and Canada. The socio-economic hardship resulting from the lobster mortality event was largely confined to local lobstermen and their families.

Lobster Resource Impacts

Pre-1999 LIS lobster mortality events

Small-scale lobster mortality events in the Sound during the fall are commonly reported to CT DEP and NYS DEC. One reason for this is that LIS is near the southern extent of the inshore range of this species. Even though lobsters are found as far south as North Carolina, they generally inhabit deeper, cooler, offshore waters south of Long Island. Lobsters living near the limit of their range are increasingly likely to be exposed to stressful environmental conditions, resulting in localized mortality events.

Periodic abnormally-high mortality events have also previously occurred in the LIS lobster population, including the late summer and fall in 1990 and 1991. Lobster tissues and water samples collected by CT DEP and NYS DEC were examined. Gaffkemia (*Aerococcus viridans homari*), also known as wasting or red tail disease, was determined as the probable cause. During the fall of 1993, gaffkemia was again the cause of an abnormally-high lobster mortality event. In the fall of 1997, CT DEP received reports of dead lobsters in the western Sound. However, no diagnosis could be made because the dead animals were not available for testing.

Incidences of mortality were also reported in the fall of 1998, with the highest percentage occurring in the western Sound, particularly in the Greenwich and Stamford (CT) areas. Tests for the presence of gaffkemia were negative. Lobstermen did not indicate the extent and severity of the 1998 mortality event until the problem became more severe in 1999.

The 1999 LIS lobster 'die-off'

Beginning in late summer and early fall of 1999, reports of large numbers of dead and dying lobsters of all sizes came in from lobstermen in the western Sound (Figure 1).

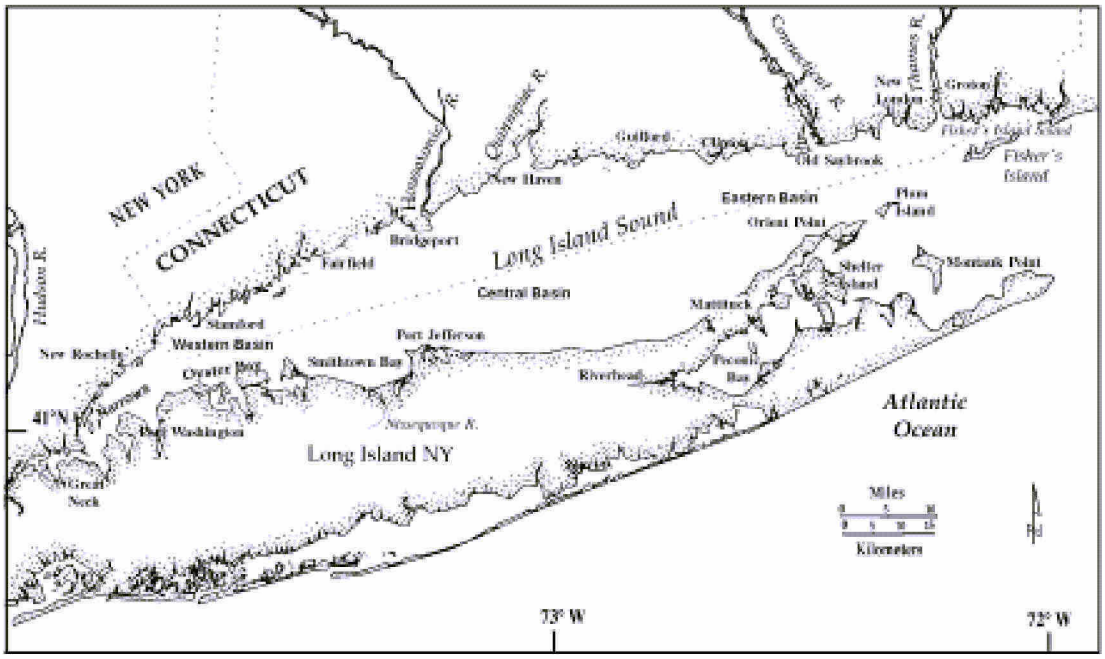


Figure 1. The western basin of LIS was the principal area affected by the lobster die-off in 1999. Although dead lobsters were also reported in the central basin, the waters west of Fairfield (CT) and Smithtown/Oyster Bay (NY) were the most severely affected. Lobsters in the eastern basin suffered an increase in the incidence of shell disease, which causes black pitting and lesions on the lobster carapace (shell).

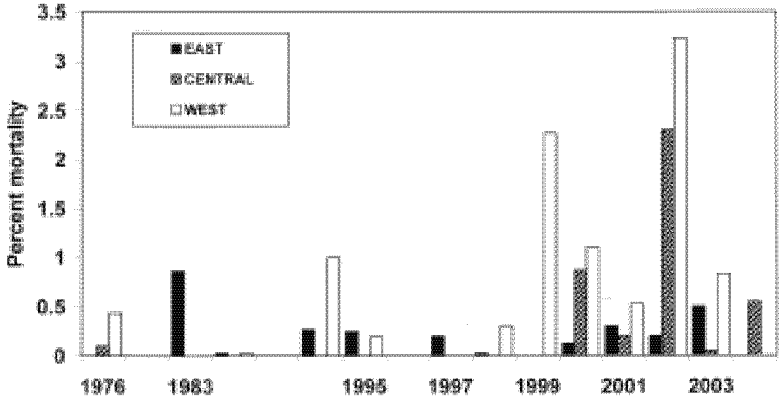


Figure 2. Average percentage of dead lobsters in commercial sea samples, July - September, 1976, 1983, 1985, and 1994-2004. Average number of ELIS lobsters examined annually = 2,264; range 293-5,954. Average number of CLIS lobsters examined in 1976, and from 2000-2004 = 2,981; range 806-6,262. Average number of WLIS lobsters examined = 2,936; range 483-5,617. Source: CT DEP and NYS DEC

Reports of dead or lethargic lobsters in central and eastern LIS increased significantly soon thereafter. These reports prompted CT DEP and NYS DEC to start investigating possible causes of this die-off, and to compile information documenting the impact on the lobster population and the commercial fishery.

Post-1999 LIS lobster mortality events

Since 1999, occurrences of dead and dying lobsters have been less widespread and more thoroughly documented. With the cooperation of lobstermen, CT DEP and NYS DEC staff sample commercial catches and have recorded seasonal mortalities primarily in the fall. Observations of commercial catches since 1976 show an increase in the incidence of dead lobsters in recent years, especially in the western basin (Figure 2). The incidence rate has increased from a very rare event (<0.5% of the observed catch) to a more common one (2-3% of the observed catch), with individual trips recording mortality rates as high as 14-46%.

One factor that explains an increase in mortality in recent years is a coast-wide increase in seawater temperature (see Status of Environmental Variables, page 10). When water temperature and observed mortality data were paired during NY DEC and CT DEP sea-sampling trips in the western basin, a statistically-significant linear relationship was evident (based upon averaged monthly data from August through October, 1996-2004).

A second possible factor affecting lobster mortality rate is an increase in the number of days lobster traps are left in the water (set) between hauls in the summer. For set times of fewer than 16 days, the number of dead lobsters observed during western LIS sample trips ranged from 0.2-3.8% of the catch, while observed mortality rates after set times in excess of 16 days averaged 8.4% in 1999, less than 1% in 2000 and 2001, and 5.7% in 2002 (Figure 3). These high-mortality trips all occurred during months of high water temperature. Extended high summer temperatures were recorded in 1999 and 2002, with cooler temperatures recorded in 2000 and 2001. This pattern suggests that the combination of high water temperature and long set time may be exacerbating some localized mortality events.

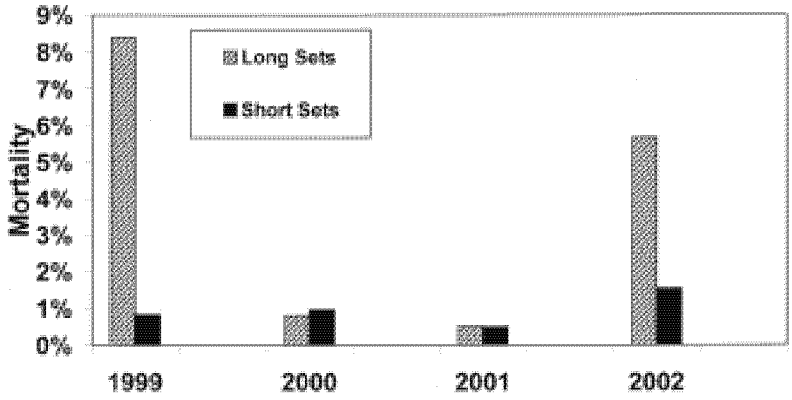


Figure 3. Observed percent mortality after long versus short set time in western Long Island Sound, 1999-2002 Sampling effort (total number of lobsters; number of long sets; number of short sets) was (8,123; 4; 10) in 1999, (3,364; 5; 11) in 2000; (12,158; 6; 27) in 2001 and (10,719; 6; 25) in 2002. Source: CT DEP and NYS DEC

Status of the Lobster Fishery

Trends in landings and effort

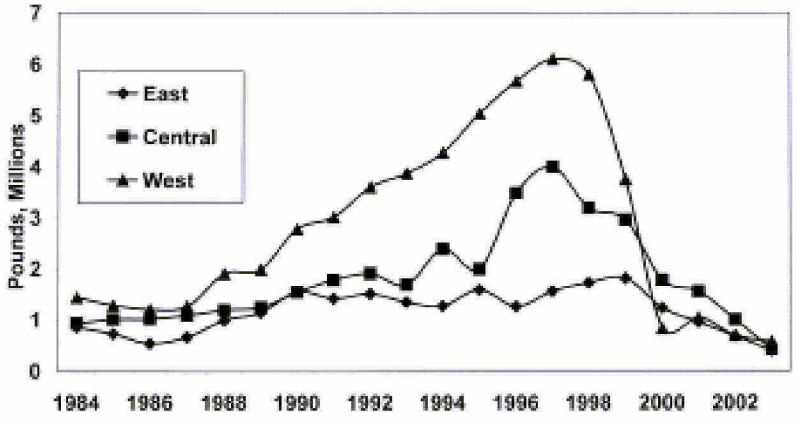
Total lobster landings reported in 2003 for Connecticut and New York ports dropped to its lowest figure in 25 years (1.58 million lbs.). The greatest increases and declines in the past decade were recorded in the western Sound (Figure 4). Total landings peaked in 1997 at a historic high of 11.7 million pounds, but dropped sharply to 2-4 million pounds in the following three years.

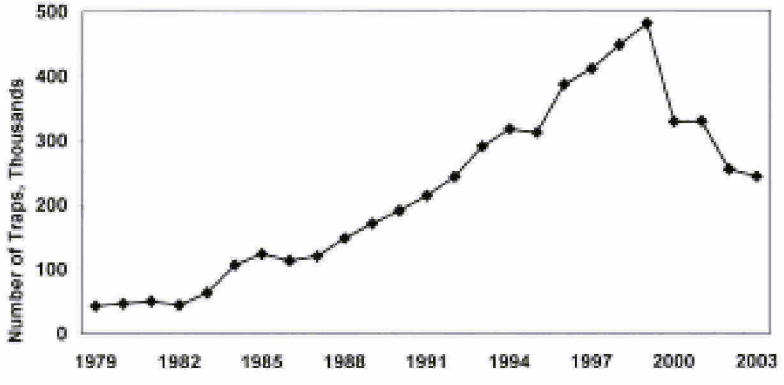
The total number of traps set in the Sound by New York and Connecticut lobstermen shows the same pattern (Figure 5). The decline is a reflection of a continuing downward trend in the number of license holders as well as a substantial drop in traps fished by each lobsterman since 1999. The number of license holders has been declining for more than a decade, but dropped by a third from 1999 to 2003 in both states (746 to 506 for resident NY licenses; 419 to 286 for CT licenses).

Lobster fishery disaster economic relief

Following the declaration that the Long Island Sound lobster fishery was a federal fishery disaster in January 2000, the U.S. Congress appropriated funds in July 2000 for disaster compensation. Through grants issued by NOAA Fisheries, the States of Connecticut and New York were each allocated $3.65 million in federal disaster relief funds. Both states also contributed 25% more in matching funds to the federal grants. The purpose of these funds was to:

- *compensate individuals for reductions in the number of lobsters caught in the 1999 LIS fishing season as compared to the 1998 fishing season, as a result of the resource disaster*
- *provide direct sustaining aid to lobstermen*
- *provide assistance to communities that are dependent on the lobster fishery and have suffered losses as a result of the 1999 disaster*





Upper left:
Figure 4. CT and NY landings in pounds by area. Source: CT DEP and NYS DEC

Lower left:
Figure 5. Total number of lobster traps set in LIS each year from 1979-2003 by NY and CT lobstermen. Source: CT DEP and NYS DEC

CT DECD direct assistance program

The Connecticut Department of Economic and Community Development (DECD), with assistance from CT DEP, prepared a grant application to NOAA Fisheries to provide direct assistance to Connecticut lobstermen affected by the lobster die-off. This program had three main components:

1) *direct payments for losses and sustaining aid to lobstermen impacted by the die-off,*

2) *an education and job re-training initiative for lobstermen interested in pursuing other opportunities, and*

3) *a trap allocation buy-back program.*

Matching the $3.65 million in federal funds was an additional $1.2 million in state funds. Direct payments to Connecticut lobstermen were made in two rounds (Table 2). In the first round, $3,018,000 was distributed to 109 lobstermen who had experienced a loss in landings value between 1998 and 1999 and had landed at least 1,500 pounds of lobster in 1998, according to their logbooks. In the second round of payments, $629,000 in additional funds were distributed to 152 lobstermen. Of these second round payments, 20% was used to supplement first round payments and 80% was used to provide sustaining aid to qualifying lobstermen who remained active in the fishery through 2003.

In addition, the DECD provided $119,000 to the Governor's Office of Workforce Competitiveness to support a job retraining program for lobstermen interested in making a career change. CT DEP also reduced fishing effort through a trap tag buy-back program totalling $1.1 million.

NYS ESD direct assistance program

New York State's Urban Development Corporation [d/b/a Empire State Development (ESD)], with assistance from NYS DEC,

Table 2. Compensation categories and allocations for federal and state funds allocated for economic relief of the Connecticut and New York lobstermen following the 1999 resource disaster.

	CT	NY
Direct Payment		
- initial round	$3,018,000	$2,804,000
- second round	629,000	739,000
Total Direct Payment	**3,647,000**	**3,543,000**
Interest subsidy		189,000
Retraining	119,000	133,000
Trap tag buy-back	1,096,000	1,000,000
TOTAL Assistance	**4,862,000**	**$4,865,000**

submitted a grant application to NOAA Fisheries for providing compensation to New York lobstermen adversely affected by the lobster die-off in 1999 as compared to their lobster income in 1998. ESD worked closely with the NYS DEC, the LIS Lobstermen's Association, the Western Lobstermen's Association, and the NY Seafood Council to ensure the relief program provided equitable and appropriate aid.

Relief assistance included compensation for lost income, interest subsidy, re-training and technical assistance, and trap tag buy-back (or effort reduction). The first three options had strict eligibility criteria while the last had broader eligibility.

The State of New York matched the $3.65 million in federal funds with $1.2 million. Originally, ESD allocated $3,017,000 of the total relief assistance appropriation toward direct compensation for lost income. Eligible applicants for this aid were NYS commercially-licensed lobstermen, lobster dealers, lobster bait dealers, or lobster gear dealers.

To receive aid, at least 50% of a New York lobsterman's gross income in 1998 and 1999 had to be derived from a LIS lobster business. Their 1999 loss had to equal at least 20% of their 1998 LIS lobster-derived income, and loss of income had to have been at least $5,000. A total of $2,804,000 was disbursed to eligible license holders (Table 2). The remaining

$213,000 was consolidated with unspent/ uncommitted funds and equitably disbursed to all license holders who had already been approved and awarded loss compensation in a second round of payments totaling $739,000.

Both Connecticut and New York lobstermen and dealers accumulated debt as they weathered the fishery disaster with reduced incomes. In New York, interest subsidy grants were made available, designed to subsidize interest costs on existing, eligible debt and lower interest costs by 3% per year. Although ESD allocated $500,000 for these grants, only $189,000 was committed. The balance was consolidated with unspent/ uncommitted funds and disbursed as indicated above.

ESD subcontracted with Cornell Cooperative Extension of Suffolk County to manage training and technical assistance. ESD allocated $350,000 for training and technical assistance but only $133,000 was requested. The balance was consolidated with unspent/ uncommitted funds as indicated previously.

Effort reduction program

The purpose of the trap tag allocation buy-back program was two-fold: to provide additional compensation for lobstermen impacted by the lobster die-off, and to reduce potential fishing effort by lowering the number of traps that could be fished.

In New York, the ESD allocated $1 million toward the reduction of fishing effort in the LIS lobster fishery. A total of 83,333 trap tags were purchased, reaching ESD's goal to reduce overall lobster fishing effort by 25%. The program was managed in partnership with NYS DEC which licenses the trap tags.

In Connecticut, the CT DEP administered this program under a Memorandum of Understanding with the DECD. Through this program, 122 lobstermen relinquished 58,410 allocated traps for a total payment of $1,096,000, equating an 18.6% reduction in the total state allocation (Table 2).

Lobstermen prepare to deploy a string of baited traps. As a conservation measure, NY and CT lobstermen sold nearly 142,000 trap tags back to the states, to help reduce fishing effort for lobsters by 19 - 25%. (Credit: John Collins)

Status of Environmental Variables

Air and water temperature

Over the past 50 years, mean air temperature (measured in NY City) has risen while summer water temperature in LIS has become more volatile. Scientists at Stony Brook University found that the inter-annual variation in August water temperature has increased in both frequency and amplitude. Bottom water temperature data, recorded by CT DEP since 1991, indicate that 1999 was the warmest to date (Figure 6).

Dissolved oxygen levels

The increase in nutrients flowing into the Sound coincides with increasing human population and changes in land use patterns over the past 150 years. Records of organic carbon concentrations in sediment cores from the central and western Sound collected by scientists at Wesleyan University show an increase beginning around 1850. These nutrients fuel algal blooms in the spring and summer. When the algae die, they sink to the bottom and decompose. As decomposition occurs, the amount of oxygen in the bottom water declines, in some cases to less than 3 mg/l, causing hypoxic conditions. Hypoxia forces mobile organisms to move to more oxygenated waters, while immobile organisms endure or succumb to the stressful environment.

NYC DEP monitoring data show periods of reduced dissolved oxygen in the East River and western Sound since 1909; hypoxic areas were first clearly identified in the central Sound in the mid-1950s. Hypoxia has become a recurring phenomenon in the Sound west of Branford (CT) and Shoreham (NY) since the early 1980s. Hypoxic conditions typically begin in mid-July and end in late August or early September.

Precipitation and run-off

Rainfall has also exhibited an increasing trend since 1970. Freshwater run-off during rain events has also increased as Connecticut and New York landscapes have changed from farms and forests to paved urban areas. Large volumes of fresh water reduce vertical circulation in the Sound by acting as a cap on saltier bottom water. Run-off also transports a variety of non-point source pollutants into local water bodies and LIS, including pet waste, automobile fluids, fertilizers, herbicides, pesticides, and debris. These materials have a negative impact on water quality.

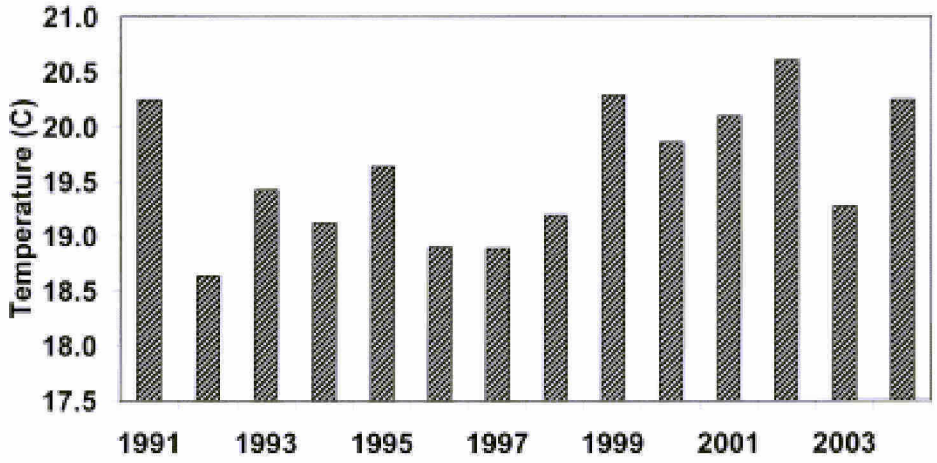


Figure 6. Annual LIS bottom water temperature averages, August - October. Source: CT DEP

Status of the Lobster Resource

Distribution by habitat type

Lobster catches from the CT DEP Trawl Survey were examined by a University of New Haven researcher before and after the 1999 die-off, who noted that lobster abundance in shallow waters declined sharply starting in 1998. Abundance in deeper waters increased in 1996 and 1997, due to greater survival and movement of lobsters just below legal size (carapace length = 50 to 80 mm) into these sites, then dropped sharply in 1999 and 2000. From 1996 to 2000, larger lobsters were found at all depths, although their abundance was greatest in deeper waters after the 1999 die-off. This pattern suggests that bottom water temperature may affect lobster distribution. The degree of this effect varies with lobster size.

A fishery-independent lobster trap survey conducted by NYS DEC in western Long Island Sound during 2003 revealed that lobster catches dropped sharply when bottom dissolved oxygen fell below 4 mg/l and water temperature exceeded 18^{0}C. This decline was noted particularly for egg-bearing females. Both the trap survey and the CT DEP trawl survey data indicated that the percentage of female lobsters decreased from east to west in the Sound. Between 2000 and 2004, few legal-size, egg-bearing females were recorded in the trawl survey catch from the Narrows region in western LIS (Figure 1; page 5).

Movement and Genetics

Mark/recapture studies over the past 40 years have shown that most lobsters in LIS remain within about a 6-mile radius (10 km) of their capture site. Results of the CT DEP tagging study conducted after the die-off concurred with these past studies. The net movement of 75% of 1,290 recaptured lobsters at large for more than 30 days was 3 miles (5 km) or less. Lobsters tagged in the western and central basins moved both east and west, but few left the basin where they were tagged. Similarly, few lobsters tagged in the eastern basin moved to the central Sound and none to the west.

Eastern LIS lobsters commonly moved in and out of the Race (far eastern end of the Sound; Figure 1) to and from Rhode Island waters. Although tagging study results indicate that the majority of the LIS lobster population is sedentary, about 14% are faster-moving "colonizers" who may be moving into newly-available habitats throughout the Sound.

Genetic analyses by a University of Connecticut researcher further support the view that lobsters in the western basin have limited contact with lobsters outside the Sound. More genetic similarity was found between lobsters from the eastern and central basins than between those two areas and the western basin. The genetic study also indicated limited contact between western basin lobsters and offshore Atlantic Ocean lobster populations.

One-third of larval lobsters in the Sound and the Race examined originated from offshore adults. It is speculated that these larvae were flushed into the Sound on flooding currents. Although this "offshore larval subsidy" may aid in stock recovery, the majority of larvae captured in all three basins of the Sound originate from the Sound's adults. Therefore, over the long term, stock rebuilding and stock stability will depend principally on an increase in the production and/or survival of local adult lobsters. Although the number of larval lobsters produced annually in the Sound is unknown, recent indices of abundance

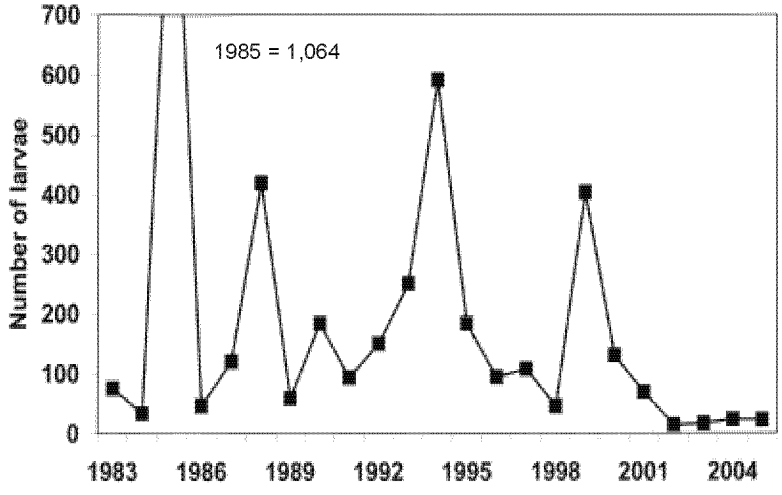


Figure 7. Larval lobster production in Long Island Sound, from 1983 - 2005. Source: CT DEP

generated by the CT DEP Larval Survey for the western basin are very low compared to indices measured during the past 22 years (Figure 7). The first time the indices consecutively measured negligible numbers of larvae annually was between 2002 and 2005.

Abundance Trends

Conditions throughout the Sound were favorable for recruitment in the early 1990s, allowing the lobster stock to increase to a historically-high abundance. This enhanced recruitment ended abruptly with the die-off. A similar trend was observed in Rhode Island waters and offshore canyons—catch surveys indicated that the abundance of small lobsters increased through the 1990s, then declined to record lows. These trends suggest that regional environmental factors were at first favorable and then very unfavorable for lobster production in the 1990s.

Fishing and Natural Mortality

Assessing the effect that the lobster fishery has on the LIS lobster stock is complicated by the recent increase in natural mortality losses made obvious during the 1999 die-off. Rhode Island Department of Environmental Management (RI DEM) and CT DEP trawl survey data indicate that natural mortality increased two to five times above average starting in 1997, and peaked in 2001 and 2002 (Figure 8). Since 1999, the lobster harvest (pounds landed) and fishing effort (number of traps fished and licenses sold) have both decreased substantially. Meanwhile, the average lobster caught for the market increased in size between 2001 and 2003 (compared to earlier years), as the loss of small, sub-legal-sized lobsters between 1999 and 2002 affected the entire population size structure.

Since 2001, indices of spawning stock abundance, recruit and harvest-size abundance have all declined well below the 1984 to 2003 median values for the entire Southern New England lobster stock. The ASMFC Lobster Technical Advisory Committee characterized this stock as 'depleted'. This depleted state is most pronounced for Long Island Sound. Fishing mortality is near the threshold of sustainability due to the current low stock abundance.

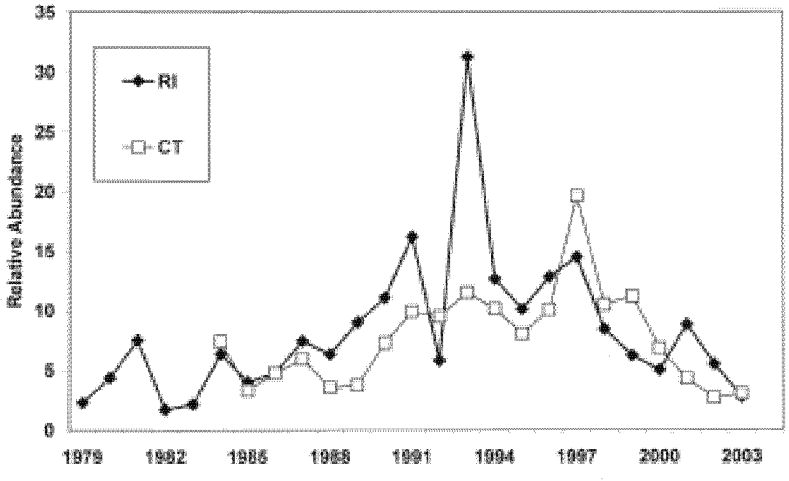


Figure 8. Relative lobster abundance in Rhode Island and Connecticut trawl survey catches. Source: CT DEP and RI DEM

Summary of the Research Findings

The extensive research initative undertaken to investigate the potential cause(s) of the 1999 lobster mortality event involved researchers from agencies and institutions across the country. The research projects were classified according to four general categories: physical/chemical environment, disease, pesticides and physiological responses to stress. While the first three categories investgiated actual events or conditions, the latter category investigated the response of lobsters to various stressors for the purpose of defining impact levels and to develop tools to help measure lobster health.

Physical/Chemical Environment

Scientists from Wesleyan, Yale, Stony Brook University, and NOAA Fisheries conducted several studies assessing physical and chemical environmental factors, looking at historical trends and changes, as well as actual conditions that existed in the Sound in 1999. Key findings that directly related to the die-off included sustained, above-average, stress-inducing water temperatures, hypoxia, and temperature stratification, followed by quick mixing of the water column caused by a rapidly moving weather front. Toxic sulfides and ammonium moving from the sediments into the near-bottom water column in late summer and early fall also acted as stressors. Driven by water temperature, these hostile environmental conditions placed undue stress upon the physiology of the lobsters, and may have been sufficient to have caused lobster deaths in absence of any other factors.

Paramoebiasis

At the height of the lobster mortality event in 1999 (late October to early November), pathologists at the University of Connecticut discovered that 94% (29 of 31) of the dead lobsters they examined were infected with microscopic parasitic paramoebae. The paramoebae invade and engulf nervous tissue, causing death. Later identified as *Neoparamoeba pemaquidensis* by scientists at the Bigelow Laboratory in Boothbay Harbor, Maine, Woods Hole Oceanographic Institution, George Mason University, and the University of Connecticut, this species was previously known to inhabit Long Island Sound, but not known to infect lobsters. At the time of the die-off, there was no evidence of other disease-causing infectious agents. Lobsters collected weeks later (mid-November to early December), exhibited only a 29% infection rate (11 of 38).

The infection rate of more than 800 lobsters collected systematically throughout the Sound over three years following the die-off by CT DEP staff ranged from 0-14%. It is possible that the growth and abundance of the paramoebae in LIS in 1999 may have been in response to the warmer water temperatures. The parasitic amoebae infecting the nervous tissues of the lobsters were considered to be the proximate cause of death, but other factors, such as the stressful environmental conditions and an all-time high lobster population size, likely played significant roles in determining the lobsters' susceptibility to disease in 1999. Much more remains to be discovered about paramoebiasis and its transmission into and between lobsters. Efforts to culture the paramoebae in the laboratory to study infectivity have been, so far, unsuccessful.

Pesticides

The concentrations of pesticides that induced sub-lethal and lethal effects in lobsters was determined experimentally for adults, juveniles and larvae by researchers at Mercer University, the University of Connecticut, the University of California at Davis, and Stony Brook University. Three classes of pesticides were examined: methoprene, a larvacide;

malathion, a commonly-used pesticide targeting adult mosquitos; and resmethrin, a newer pyrethroid pesticide targeting adults that is more toxic but very short-lived. All three pesticides were used to combat the West Nile virus outbreak in the summer and fall of 1999, and all were found to have the potential to adversely affect lobsters.

Lab studies revealed that while lobsters are relatively unaffected by methoprene, they are considerably more sensitive to the effects of malathion than any other freshwater fish and aquatic invertebrates previously tested. Other laboratory studies showed that sub-lethal effects (impairment of immune response, stress hormone production) occur at much smaller concentrations than lethal effects. All effects occurred at concentrations in parts per billion.

While it is evident that certain concentrations of these pesticides can kill lobsters, one important question was whether enough of the pesticides got into the LIS water column to cause illness or death in the lobsters. The dispersion of the individual pesticides over time was examined using two independent modeling techniques (carried out by Hydroqual, Inc. and at Stony Brook University) and very conservative assumptions (e.g., 100% of each pesticide applied entered the water before beginning to break down). The results indicated that only a few areas of the far western Sound could have had pesticide concentrations high enough to cause sub-lethal effects in lobsters.

Physiological Responses to Stress

Scientists at Stony Brook University, the University of Connecticut, the University of California at Davis, the University of Maryland, Cornell University, SUNY Purchase, and NOAA Fisheries provided more answers to the question, "What is a healthy lobster?" The resulting extensive toolbox of new techniques and tools will help biologists better understand how stressful conditions affect lobster health, such as how lobster blood cells (hemocytes) recognize and react to the presence of pathogens, what hormones are produced in response to stress, and what changes to lobster blood chemistry are induced by stress.

Shell Disease

Complementing the extensive research effort to investigate the western LIS lobster die-off, researchers at Stony Brook University, the University of Louisiana, and the Marine Biological Laboratory (Woods Hole, MA) studied the shell disease affecting lobsters in eastern LIS. Shell disease is caused by external bacteria that digest the minerals in the shell (carapace) of a lobster. This particular epizootic shell disease causes severe lesions and pitting on the carapace. Since lobsters routinely clean themselves, the disease often shows up on the back of the carapace and claws, areas they have difficulty reaching. Sea sampling data indicate that an increasing proportion of lobsters in eastern LIS, Rhode Island, and Massachusetts waters have shell disease, and that individual lobsters are more severely affected than previously observed.

Lobsters temporarily rid themselves of shell disease when they molt, shedding the diseased outer shells and replacing them with new healthy ones. However, if the disease bacteria become abundant enough to digest holes completely through a lobster shell, then internal lesions leading to death may occur. Preliminary data from a University of Connecticut researcher show that female lobsters have a higher rate of incidence of shell disease, and that affected females carrying fertilized eggs under their tails may molt prematurely, before the eggs are released into the water column.

Wrapping Up the 1999 Mortality Event

As a result of extensive research and data collection by many academic, federal, and state agencies, substantial evidence exists that a confluence and succession of factors pushed the Sound's lobster population far out of equilibrium with its environment in the fall of 1999. Responding to the stress induced by sustained and increasingly hostile environmental conditions, the immune systems of the lobsters were unable to compensate, and many lobsters succumbed to disease. While the main mortality event occurred in 1999, the problem may have been building over several previous years. There is no way to determine now when the lobsters began to become infected with paramoebae, or whether the environmental conditions and crowding due to the above-average abundance of lobsters fostered the infection, or simply exacerbated an existing problem.

Adverse environmental conditions have existed previously in the Sound, but not in such a sustained, severe and joint fashion. Based on the available information and the collective research results to date, the presumed sequence of events that culminated in the lobster mortality event in 1999 is as follows.

...responding to the stress induced by sustained, hostile environmental conditions, the immune systems of the lobsters were unable to compensate, and many succumbed to disease...

Scattered reports of atypical lobster mortality began as early as 1997. No samples were collected for examination, so it is unknown if lobsters were infected with paramoebiasis. In 1999, sustained, above-average water temperature was the driving force behind a snowball effect of environmental and oceanographic factors that stressed lobsters to the point at which their physiology could not cope with the inhospitable environmental conditions nor mount an immune defense against the paramoebae.

...sustained, above-average water temperature was the driving force...

Under drought conditions, bottom water temperatures were 1-2^{0}C warmer than average for many months during 1998 and 1999. Although this temperature increase seems small, it exceeded the upper thermal tolerance threshold for lobsters (20^{0}C or 68^{0}F), causing an increase in respiration rate. LIS lobsters are near the southern end of their inshore range in LIS, and a sustained increase in temperature is stressful.

From mid-July through early September, western LIS commonly experiences hypoxic conditions (an unfavorably low concentration of dissolved oxygen). Temperatures recorded in deepwater areas of the Sound were 21^{0}C (70^{0}F) or greater by late summer 1999; in some shallow areas, recorded temperatures exceeded 23^{0}C (73^{0}F). As the waters warmed, the amount of dissolved oxygen in the waters lessened. Hypoxic conditions existed for about 50 days in 1999, which is typical. The most severe period occurred the first week of August and most of the hypoxia had dissipated by the third week of August, before the mortalities occurred.

Lobsters have been observed moving into deeper cooler waters when nearshore waters get too warm. They are also known to "herd" or crowd in high numbers near margins of

hypoxic zones where the dissolved oxygen concentration is greater than 2 mg/l, avoiding those areas where oxygen is below this threshold. Because of these two factors—water temperature and hypoxia—it may be assumed that an already dense population of lobsters crowded into areas of the western Sound cool enough and oxygenated enough to sustain them. Crowded conditions such as these increase the likelihood of spread of pathogens among or between animals.

By August 1999, temperature and salinity were stratified in the water column. Late in the month, winds from a front moving through the region completely mixed the water column in a matter of hours. Warm surface waters were brought to the bottom, and caused an additional rise in temperature. Although lobsters can endure abrupt temperature changes, these lobsters were likely already physically weakened.

...studies showed that mosquito control pesticides can have both sub-lethal and lethal effects on lobsters...

Pesticides were being applied in both states to combat the spread of the West Nile virus, which had caused seven human deaths by early September. Lab studies showed that these pesticides can have sub-lethal or lethal effects on the various life stages of lobsters, depending on the exposure time and concentration.

The modeling efforts to date suggest that the amount of each individual pesticide applied is unlikely to have reached the concentration in the Sound that laboratory studies indicate is lethal to lobsters. However, it cannot be ruled out that in limited areas of the far western Sound, exposure to pesticides may have further weakened adult lobsters, making them even more susceptible to disease or the inhospitable environmental conditions. Lobster larvae, if they were present in these same areas at the time of exposure, may also have suffered. According to CT DEP sampling, larval abundance in the western Sound peaked in early July, while most pesticide applications occurred later in the summer and fall.

The Sound also experiences increased fluxes of ammonium and sulfide from bottom sediments into the lower water column in late summer. These substances can create hostile conditions for lobsters and other burrowing invertebrates in the narrow zone where the sediment and water meet, especially at high temperatures.

The fate of the LIS lobsters in the western Sound was sealed by paramoebiasis. Either the energy required to mount a sustained immune response to the disease took its toll on the lobsters, or the lobsters were unable to mount an adequate defense to the disease as they were already physically stressed due to the hostile environmental conditions. Many lobsters died as a result, and the population in the western Sound collapsed.

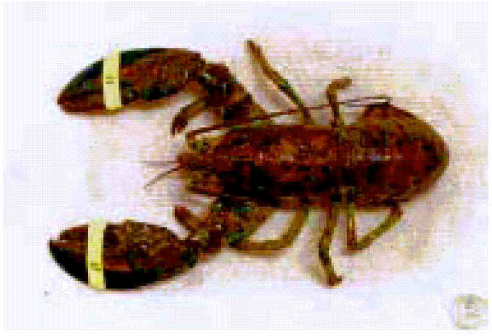
To help study the movements of lobsters within, and in and out of Long Island Sound, lobsters were tagged and released. Lobstermen were encouraged to report the tag number, location, and date for any tagged lobster caught, and return the lobster to the water. (Credit: CT DEP)

Future Work

At the request of the lobster industry, additional water quality modeling 'runs' are planned to try and answer some additional questions regarding the potential exposure concentrations and influence of pesticides in the mortality event. The pesticide sumithrin, a pyrethroid,was not studied as part of the research initiative because no research proposals were submitted to study its effects. Sumithrin should be investigated in future studies, in a manner similar to the studies on the effects of malathion, methoprene, and resmethrin. Further, additional work has been initiated to investigate shell disease, as it is affecting larger numbers of lobsters in the waters off the Northeast states, raising concerns among resource managers and industry members alike.

Under the auspices of the ASMFC's Lobster Fishery Management Plan, the lobster resource in southern New England has recently been described as 'depleted'. The stock assessment report recommended that abundance be rebuilt to the long-term average. A peer review of the stock assessment further recommended that the fishery mortality rate be reduced. These recommendations will be the basis of ASMFC action in early 2006. The ASMFC has further approved an expansion of the Steering Committee for Lobster Disease Research to provide for a coordinated coastwide response to lobster health issues.

While shell disease was not found to be the cause of the 1999 LIS lobster mortality event, research and monitoring show that eastern LIS lobsters, as well as lobsters in Rhode Island and Massachusetts waters, are experiencing increasingly adverse affects from shell disease. A meeting at the Millstone Environmental Laboratory (Waterford, CT) in 2001 brought together scientists and resource managers from throughout New England to discuss shell disease and develop a standardized method for monitoring shell disease on affected lobsters. In fall 2005, Congress appropriated $3 million for investigation of the epizootic shell disease affecting lobster stocks throughout New England. Rhode Island Sea Grant has convened an Executive Committee of state and federal resource managers, lobster industry members, scientists, and Sea Grant extension agents to oversee this new lobster disease research program, which will be initiated sometime during 2006.



A lobster severely affected by shell disease. The extent of the disease is ranked by sea samplers according to the proportion of shell coverage (mild, 1-10%; moderate, 11-50%; severe, > 50%). © Photo by Roxanna Smolowitz, MBL.

Research Project Titles and Investigators

The following research projects were funded by NOAA Fisheries, the CT and NY Sea Grant programs, the EPA, and the State of CT through the CT DEP Office of Long Island Sound Programs and Marine Fisheries Division.

Lobster Resource Monitoring and Assessment Projects

Connecticut Department of Environmental Protection (CT DEP) Lobster Resource Monitoring and Assessment Project

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New York State Department of Environmental Conservation (NYS DEC) Lobster Resource Monitoring and Assessment Project

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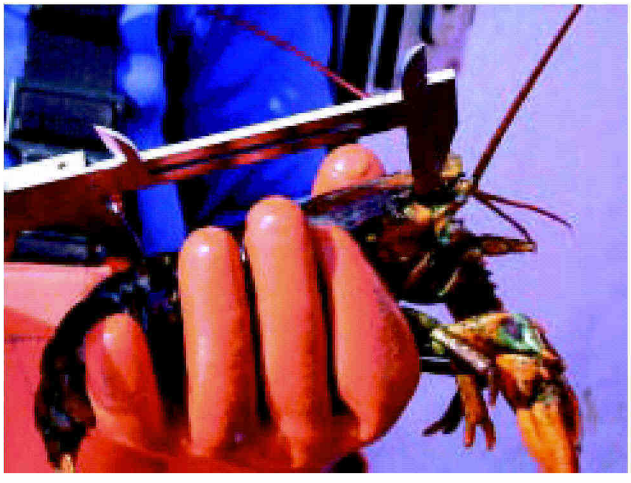

In addition to the data collected during independent trawl surveys of LIS, New York and Connecticut lobster biologists collect data on lobsters trapped by commercial lobstermen, including size, sex, and whether or not the females are carrying eggs. (Credit: CT DEP)

Research Initiative Projects

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

Carmela Cuomo, Yale University
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Relationship Between American Lobster Mortality in LIS and Prevailing Water Column Conditions

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Environmental Change in LIS in the Recent Past

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Effects of Environmental Stressors on Disease Susceptibility in Lobsters: A Controlled Laboratory Story

Richard Robohm, NOAA Fisheries Laboratory, Milford, CT (retired)
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Immunological Health of Lobsters: Assays and Applications

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Development of Assays for the Evaluation of Immune Functions of the American Lobster as a Tool for Health Assessment

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Development of an Assay for Phagocytic Activity in the Immune System of Lobsters

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Hormonal Responses of Lobsters to Stresses of Western LIS

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Stress Indicators in Lobsters: Hormones and Heat Shock Proteins

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Calcinosus in LIS Lobsters During Summer 2002

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Acute Effects of Methoprene on Survival, Cuticular Morphogenesis and Shell Biosynthesis in the American Lobster

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Determination of the Toxicity and Sublethal Effects of Selected Pesticides on the American Lobster

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

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Bacterial Assemblages Involved in the Development and Progression of Shell Disease in the American Lobster

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Oligonucleotide-based Detection of Pathogenic *Paramoeba* Species

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

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

Richard Robohm, NOAA Fisheries Laboratory, Milford, CT (retired)

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

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

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Co-investigator: *Ashok Deshpande* and *Anthony Paulson*, NOAA Fisheries, Howard Laboratory

Application of Water Quality Modeling Technology to the Investigation of the Decline in Long Island Sound Lobsters during the Summer of 1999

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Description of Transport and Dispersion within Long Island Sound during August and September 1999

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Maintenance of a *Paramoeba* Culture and Exploration of a Mitochondrial Cytochrome *b* Genetic Marker

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The Comparative Pathology of Shell Disease in the American and Caribbean Spiny Lobsters: Characterization of Gross, Light Microscopic and Ultrastructural Pathology

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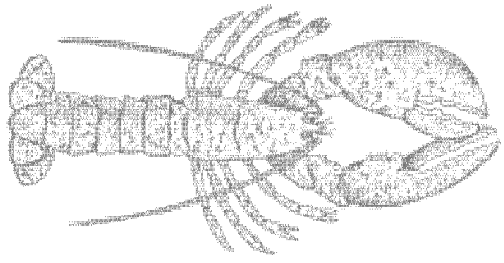

List Of Published Manuscripts

**Manuscripts are included in the LIS Lobster Research Initiative's special issue of Journal of Shellfish Research, 24(3): October 2005. The remaining manuscripts are ones that have been published and reported to date by the researchers involved in the initiative.*

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