THE EFFECTS OF BOTTOM TRAWLING ON AMERICAN LOBSTERS, *HOMARUS AMERICANUS*, IN LONG ISLAND SOUND

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ABSTRACT

American lobsters taken in the commercial trawl fishery in Long Island Sound, U.S.A., were inspected for incidence of damage and immediate mortality associated with bottom trawling. Similar sampling was conducted in the pot fishery. American lobsters from trawl and pot catches were held in controlled conditions for 14 days to determine the level of delayed mortality associated with the two fisheries. Trawl-caught lobsters were exposed to subfreezing (−9.5°C) temperatures for periods from 30 to 120 minutes and then returned to seawater to determine the rate of freeze-induced mortality. Major damage rates due to trawling ranged from 12.6-14.0% during molting periods to 0-5.6% during intermolt periods. Delayed mortality ranged from 19.2% during the July molt to 1% during August and appeared to be related to the incidence of damage, molt condition, and temperature. Mortality of American lobsters held in subfreezing temperatures occurred after 30-minute exposure and reached 100% at 120-minute exposure.

The American lobster, *Homarus americanus*, supports one of the most valuable commercial fisheries in the northwest Atlantic Ocean with landings of approximately 20,900 t per year valued at $115 million (Anonymous 1985). The fishery is conducted predominantly with traps or pots and, secondarily, with bottom trawl nets.

Long Island Sound is a 2,908 km^2 embayment of the Atlantic Ocean in southern New England, lying between Connecticut and New York at approximately lat. 41°N. The Sound supports a spawning stock of American lobsters and a valuable commercial lobster fishery, which, in 1985, generated landings of 1,134 t valued at $7.0 million for some 900 commercial fishermen. In Connecticut, over 90% of the commercial landings are taken by the pot fishery, and over 90% of Connecticut's commercial fishermen are lobster pot fishermen. Connecticut trawlers, who catch American lobsters in a mixed species bottom fishery, take <10% of Connecticut commercial landings and constitute about 10% of all commercial fishermen taking lobsters. Recreational lobstermen, both potters and scuba divers, totaled 2,440 in 1985 but only accounted for about 5% of total landings (CT DEP[2]).

The resource is heavily exploited with annual exploitation rates ranging from 85 to 95% (Briggs 1985; Blake 1986). Principal management measures include prohibitions on the taking of females bearing external eggs and the retention of any American lobster <81 mm carapace length (CL). These measures are intended to protect American lobsters from exploitation until they have reproduced at least once.

During late 1982, commercial catch per unit effort rates doubled from those of the previous 5 years (CT DEP fn. 2). This increase stimulated a shift in directed fishing by some trawlers from mixed finfish to lobsters. The redirection of effort also generated competition for lobsters and fishing space, and an extremely emotional controversy arose between potters and trawlers. This paper addresses the resource considerations of the controversy, that is, the impacts of mobile trawl gear on lobsters.

This study was designed to measure 1) the physical injury and immediate mortality incurred by American lobsters in the trawl fishery; 2) the potential level of trawl-induced delayed mortality of American lobsters less than the minimum length upon return to the water; and 3) the rate of mortality of American lobsters due to exposure to subfreezing air temperatures during winter fishing.

METHODS

Incidence of Damage

Biologists made 63 trips aboard commercial stern trawlers from 12 to 26 m and 12 trips on pot vessels from 12 to 14 m. Except during January

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[2]Connecticut Department of Environmental Protection (CT DEP) unpublished fishery statistics.

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1984, trawl samples were obtained each month from July 1983 through January 1985 during tows of 1-3 h duration. Similar observations of trawl catches were obtained from cruises made by the CT DEP's research vessel (a 13 m stern-rigged trawler) from May through November in 1983 and 1984 during tows of 0.5-2 h duration. Commercial pot fishery sampling was conducted intermittently during summer and fall in both years. All samples were obtained in Long Island Sound west of long. 72°52′W.

American lobsters were examined for evidence of physical damage, denoted as "new" (resulting from the current net tow or pot haul) or "old" (previously sustained). Old damage was inferred by the presence of discolored and healed tissue and by the absence of bleeding. New damage was further categorized as "major" and "minor". Major damage was defined as death, broken or crushed body parts or claw(s), and multiple injuries, even when each individual wound was minor. Minor injury included walking leg loss or damage, antenna damage, minor breakage to a claw or rostrum tip, and recently autotomized claw(s). Recent autotomy (reflex amputation) was defined as a fresh partition without discoloration of the covering membrane at the "breaking plane" (Herrick 1909). Additional data were recorded on length, sex, shell hardness, presence of eggs, and absence of claws. Soft, newshell, and hardshell condition generally followed stages A, B, and C, respectively, as described by Passano (1960). In this paper, the term "newshell" includes both soft and newshell lobsters (stages A and B).

In comparing damage rates between commercial and research vessels, we found that hardshell American lobsters <81 mm CL were damaged more frequently in research than in commercial samples ($\chi^2 = 6.143$). Since the research vessel used a smaller mesh (51 mm cod end) than commercial vessels (75-114 mm cod end), it caught a proportionately greater number of American lobsters <81 mm CL (86% research vs. 72% commercial). Therefore, only lobsters ≥81 mm CL were analyzed because the greater proportion of sublegal American lobsters and other biota in the small mesh sample might have resulted in an overestimate of damage relative to the commercial fishery, due both to intraspecific, agonistic behavior and to compacting of net contents.

The incidence of major damage, compared between pot and trawl gears, large and small trawl vessels, and commercial trawlers and research trawler were analyzed by chi-square goodness of fit (Sokal and Rohlf 1969).

Delayed Mortality

Damaged and undamaged American lobsters less than the minimum length were taken from the same area of Long Island Sound, on the same date, from commercial pot vessels and from either commercial trawl vessels or research vessel. Samples were obtained in November 1983 and May, July, and August 1984. They were transported in tanks with circulating seawater to a laboratory equipped with an open circulating seawater system and were observed twice daily for a period of 14 days. Lobsters were fed daily with assorted fish species. Dead lobsters were removed upon observation. Lobsters were selected nonrandomly from catches to ensure that damaged lobsters were adequately represented in the tests. Since damaged lobsters often made up only a small percentage of the total, our sample consisted of proportionally more damaged lobsters than their actual proportion in the catch.

American lobsters with minor damage were combined with undamaged ones for analysis because undamaged lobsters rarely experienced delayed mortality (2/309) and those with minor damage never did. To estimate total delayed mortality from each gear, the observed delayed mortality rate in each test category (undamaged hardshell, damaged hardshell, and newshell) was extrapolated to the corresponding trawl catches of undamaged, damaged, and newshell lobsters observed during the same months in 1984. The laboratory mortality rate for newshell lobsters was applied to all newshell lobsters in commercial catches rather than only damaged newshell lobsters since internal (unobserved) damage may have occurred. Field data from 1984 commercial catches were used to estimate total trawl-induced mortality because the proportion of newshell lobsters in commercial catches was highest during 1984, and we believe that that year's data most accurately represent the proportion of newshell lobsters taken in the fishery.

The chi-square goodness of fit (Sokal and Rohlf 1969) with Yates' correction for continuity (Zar 1974) was utilized to determine whether lobster mortality rates differed between large and small trawl vessels and between commercial and research trawl vessels. The effect of season and molt condition was examined using a log-likelihood ratio test (G-test; Sokal and Rohlf 1969). Seasonal changes were defined by water temperature variation whereas molt condition (newshell vs. hardshell) was based on the bimodal distribution of lobster molting (June-July and October-November) observed in Long Island Sound (Lund et al. 1973). The relationship between temperature and shell condition was evaluated by comparing data derived from postmolt periods following the summer (warming seawater temperature) vs. fall (cooling seawater temperature) molts. Postmolt lobsters recovered from the capture process in flowing seawater of 20°C in the July test and 15°-16°C in the November test. Intermolt lobsters in May recovered in 12°C seawater and, in August-September, at 22°C. In all cases, seawater temperatures reported here were elevated approximately 1°-2°C from passage through the circulation system.

The trawl-caught sample included 74 lobsters taken from research vessel catches. Comparison of delayed mortality rates between research and commercial samples revealed no significant difference ($\chi^2 = 0.305$) so the samples were pooled. Delayed mortality rates from samples taken from small (12 m) and large (20 m) trawl vessels in November 1983 and August 1984 were not significantly different ($\chi^2 = 0.05$), therefore, large and small vessel data were also pooled. All damage observations were recorded in the same manner as reported above.

Mortality Due to Freezing

Seventy hardshell, undamaged, trawl-caught American lobsters <81 mm CL were held in an open circulating seawater system at 8°C. On 15 January 1985, three groups of 20 lobsters were exposed in a wooden box (2 m × 1 m × 0.3 m) to ambient air temperature of −9.5°C for periods of 30, 60, and 120 minutes. The remaining 10 lobsters were held without exposure as a control. After the prescribed time had elapsed, the test lobsters were returned to the holding system and observed several times during the following 48-h period for incidence of mortality.

RESULTS

Incidence of Damage Due to Trawling

Damage to American lobsters of all sizes caused by commercial trawling throughout the 19-mo sampling period is summarized in Table 1. The monthly incidence of major damage (including immediate mortality) varied seasonally, from 0 to 14.0% in the trawl fishery and from 0 to 3.5% in the pot fishery. Minor damage ranged from 0.9 to 8.1% in the trawl fishery and from 0 to 10.7% in the pot fishery. Differences between pot and trawl damage rates were compared only for months in which both gears were sampled. The incidence of major damage was significantly greater for trawl samples in July and October-November, but not in August or September (Table 2).

The incidence of damage due to the two gears

TABLE 1.—Incidence of damage to American lobsters taken by commercial otter trawl from July 1983 through January 1985.[1]

Month		Major damage			No major damage		
		Broken parts	Multiple injuries	Dead	Minor damage	Undamaged	Total (n)
Jan.	(n)	1	0	2	6	91	100
	(%)	1.0	0	2.0	6.0	91.0	
Feb.	(n)	0	0	0	1	14	15
	(%)	0	0	0	6.7	93.3	
Mar.	(n)	6	3	0	9	557	575
	(%)	1.0	0.5	0	1.6	96.9	
Apr.	(n)	19	8	4	25	1,461	1,517
	(%)	1.3	0.5	0.3	1.6	96.3	
May	(n)	22	7	0	21	1,087	1,137
	(%)	1.9	0.6	0	1.9	95.6	
June	(n)	1	1	4	2	216	224
	(%)	0.5	0.5	1.8	0.9	96.3	
July	(n)	72	44	16	57	854	1,043
	(%)	6.9	4.2	1.5	5.5	81.9	
Aug.	(n)	18	4	1	36	1,056	1,115
	(%)	1.6	0.4	0.1	3.2	94.7	
Sept.	(n)	49	4	23	36	1,242	1,354
	(%)	3.6	0.3	1.7	2.7	91.7	
Oct.	(n)	94	47	25	116	1,426	1,708
	(%)	5.5	2.7	1.5	6.8	83.5	
Nov.	(n)	133	128	50	181	1,738	2,230
	(%)	6.0	5.8	2.2	8.1	77.9	
Dec.	(n)	77	20	13	68	998	1,176
	(%)	6.5	1.7	1.1	5.8	84.9	

[1]Data from months in successive years are pooled.

TABLE 2.—Incidence of damage to American lobsters taken by commercial pot and otter trawl gears, 1983-84.

Month	Pot fishery		Trawl fishery		
	Major damage	N	Major damage	N	χ^2
July	0.9%	2,165	12.7%	1,043	212.2**
August	1.3%	1,512	2.1%	1,115	1.8
September[1]	3.5%	424	5.9%	1,344	2.4
Oct.-Nov.[1]	0.6%	661	14.4%	2,672	96.8**

**significantly different ($P < 0.001$).
[1]1983 data only (no pot fishery samples taken in 1984).

was analyzed with respect to shell hardness and carapace length (<81 mm vs. ≥81 mm). Size-specific damage to newshell American lobsters taken in the trawl fishery was significant with smaller lobsters incurring more damage (43% vs. 30%, $\chi^2 = 6.64$, $P = 0.01$). There were no size-specific differences in damage to newshell lobsters taken in the pot fishery or to hard-shelled ones in either fishery.

Trawled egg-bearing female American lobsters (always hard shelled) incurred 1.9% major damage, no immediate mortality, and 2.1% minor damage throughout the sampling period ($n = 909$). Eggbearers ≥81 mm CL ($n = 585$) exhibited 2.2% major damage and 2.4% minor damage while those <81 mm CL ($n = 306$, 18 size unspecified) incurred 1.3% major damage and 1.6% minor damage. Pot-caught eggbearers sustained 0.9% major, and 0.8% minor damage throughout the sampling period ($n = 1{,}926$). One of 1,926 pot-caught egg-bearers (0.05%) died on deck. These data suggest that the damage and immediate mortality to gravid American lobsters associated with both fisheries is minimal.

From September 1983 through December 1984, trips were made with both large (15-26 m) and small (12-14 m) trawl vessels during eight different months. In two of those months, damage rates were equal, in two they differed by <1%, and in four they ranged from 7.3% higher for small vessels to 13.7% higher for large vessels. The difference exhibited in the four months for which deviations of more than 1% were observed was not significant ($\chi^2 = 0.019$, $P < 0.5$) indicating that damage to trawled American lobsters is independent of vessel size.

Trawl-induced damage occurred at similar rates in cold-water vs. warm-water intermolt periods (2.2% January-June vs. 3.1% August-September) and between cooling and warming postmolt periods (11.5% October-December vs. 12.6% July; Table 1). This suggests that damage due to trawling is more a function of shell condition than water temperature.

Delayed Mortality

From November 1983 to August 1984, 526

TABLE 3.—Estimated mortality to American lobsters <81 mm CL (delayed and immediate) due to otter trawling in 1984. Actual delayed mortality is computed by multiplying the percent occurrence of each damage category in trawl catches by the laboratory delayed mortality rate for that category. Total mortality rate is the sum of the actual delayed mortality plus immediate mortality observed on deck.

Month	Trawl catches %	Laboratory delayed mortality rate %	Actual delayed mortality %	Observed immediate mortality %	Total mortality rate %
May (*N* = 608, trawler catches; *N* = 41, laboratory samples)					
Hardshell					
undamaged	96.5	0	0	0	0
damaged	2.0	85.7	1.7	0	1.7
Newshell	1.5	33.3	0.5	0	0.5
			2.2	0	2.2
July (*N* = 533, trawler catches; *N* = 40, laboratory samples)					
Hardshell					
undamaged	81.8	10.5	8.6	0	8.6
damaged	9.9	85.7	8.5	2.1	10.6
Newshell	6.2	33.3	2.1	0	2.1
			19.2	2.1	21.3
August (*N* = 456, trawler catches; *N* = 146, laboratory samples)					
Hardshell					
undamaged	98.2	0	0	0	0
damaged	0.7	85.7	0.6	0	0.6
Newshell	1.1	33.3	0.4	0	0.4
			1.0	0	1.0
November (*N* = 408, trawler catches; *N* = 147, laboratory samples)					
Hardshell					
undamaged	86.3	0	0	0	0
damaged	3.9	42.4	1.7	1.2	2.9
Newshell	7.8	33.3	2.6	0.8	3.4
			4.3	2.0	6.3

American lobsters <81 mm CL, taken from pot and trawl vessels, were held to estimate trawl-induced delayed mortality (Table 3). Of 374 trawl-caught lobsters held in the laboratory, 47 (12.6%) had sustained major damage. Eighteen were newshell and were treated as one category regardless of damage sustained. Two of 309 (0.6%) undamaged, hardshell trawl-caught lobsters died whereas 55.3% of damaged ones died within the 14-d period, most within the first 7 days. Six of 18 newshell lobsters died (33.3%). Of 153 pot-caught lobsters, 8 (5.2%) had major damage; none were newshell. No pot-caught lobsters experienced delayed mortality.

Laboratory delayed mortality rates for damaged hardshell American lobsters were pooled in May, July, and August because of the small sample sizes (n = 14). Delayed mortality rates ranged from 50 to 100% in the three months. The mean (85.7%) was applied to the proportion of damaged hardshell lobsters in the commercial trawl fishery in each of those months. In November, a 42.4% delayed mortality rate (n = 33) was applied to the damaged lobster category in November commercial samples. Although only two undamaged hardshell lobsters died, both occurred in July (2 of 19). This proportion (10.5%) was applied to the proportion of undamaged hardshell lobsters in the July commercial catches. Since no delayed mortality occurred to undamaged hardshell lobsters in May, August, or November, no delayed mortality rate was applied to that category for those months. The delayed mortality rate for newshell lobsters (33.3%, n = 18) was applied to the proportion of newshell lobsters in commercial catches (1-8%). Immediate (on-deck) and delayed mortality rates for lobsters <81 mm CL and for each shell condition (undamaged hard, damaged hard, and newshell) were summed, resulting in an estimate of total mortality for each season (Table 3).

Estimated trawl-induced mortality rates for the four sample periods were tested to determine the relative importance of high seasonal water temperatures (July and August) and molting (November and July). November and July had significantly higher rates of mortality than May and August (Tables 3, 4), indicating that molt condition (July and November) is more important in determining the extent of mortality than water temperature. There was no significant difference between May and August delayed and immediate mortality estimates (Table 4) despite a 10°C difference in water temperature. However, warm temperatures appeared to increase the incidence of mortality after molting since the July rate was significantly higher than the November rate (21.3% vs. 6.3%, Table 4).

TABLE 4.—Log-likelihood ratio test of expected trawl-induced mortality to American lobsters <81 mm CL, by season. Underlining denotes no significant difference at $P = 0.05$. $\chi^2 = 178.4^*$ overall, 44.8* (July-November), 11.8* (November-May), and 1.8 (May-August).

	May	August	November	July
Water temperature	cold	warm	cold	warm
Molt condition	nonmolting		molting	
Estimated mortality	2.2%	1.0%	6.3%	21.3%

* = $P < 0.005$.

Mortality Due to Freezing

Exposing undamaged American lobsters to ambient air temperatures of −9.5°C produced no mortality at 30-min exposure, and 70% and 100% mortality at 60 minutes and 120 minutes, respectively. Damaged lobsters were not tested since they occur so infrequently during cold-water periods of the year (Table 1). Freezing temperatures may also induce reflex amputation (autotomy) of claws. One lobster of 20 in the 30-min sample and four American lobsters of 20 in the 60-min sample autotomized one claw.

DISCUSSION

Jamieson and Campbell (1985) found that sea scallop dragging in eastern Canada could damage American lobsters, but since the sea scallop and lobster fisheries generally were not simultaneous (lobsters tended to emigrate from the scalloping areas each season prior to the advent of the drag fishery), the use of scallop gear over beds that hold lobsters at other times posed no significant impact to the resource. Scarratt (1972) observed a similar situation in the eastern Canadian Irish moss rake fishery. Although American lobsters did suffer damage from the gear, most lobsters emigrated before the moss harvest season, so the damage associated with the gear was minimal. In western Long Island Sound, the lobster pot and mixed species trawl fisheries both operate throughout the year. Since the seabed in this area is relatively uniform and generally free of obstructions to trawling, lobsters can be taken simultaneously with both gears, raising concerns that trawl gear is detrimental to the resource.

In Narragansett Bay, RI, using a 13 m stern trawl-rigged research vessel, Ganz (1980) found low immediate mortality to trawl-caught American lobsters and low damage rates during intermolt periods, and higher damage rates immediately following molting. He observed that hardshell lobsters were not likely to sustain critical injuries but postulated that commercial-scale operations might produce higher damage rates than the research vessel because of net compaction. We found that major damage (including immediate mortality) was greatest during molting periods, ranging from 12.6% in July to 14.0% in November. Hardshell (intermolt) lobsters suffered little damage by commercial trawling, with the monthly incidence of major damage and immediate mortality <3% from January through June and in August. Minor damage, including autotomy of claws, ranged from 0.9 to 8.1% and was greatest in October-November. Minor damage was <2% from March through June.

The incidence of immediate mortality by month never exceeded 0.5% in the pot fishery or 2.2% in the trawl fishery. Moreover, we found that damage rates were independent of vessel size, whether in the commercial fishery or between 12 m commercial and 13 m research vessels (see below). Newly molted American lobsters were damaged by both trawl and pot gears but trawling caused greater damage.

Spurr (1978) found experimental otter trawl-induced injury in summer to be greater in July than in September; however, since he aggregated minor damage with major damage and did not provide sample sizes, quantitative comparison of major damage between the two studies is not possible. Spurr concluded that lobster damage due to trawling in winter would be minor, a conclusion supported by our data.

Ganz (1980) suggested that damaged, sublegal American lobsters might suffer mortality upon release, although he did not investigate this possibility. We found that delayed mortality appeared to be influenced by the condition (incidence of damage) of American lobsters. Only 2 of 309 undamaged, hardshell lobsters experienced delayed mortality after trawling, compared to 26 of 47 (55.3%) damaged, hardshell, trawl-caught lobsters. Delayed mortality never occurred to lobsters with minor damage or autotomized claws. Although the sample size was small ($n = 18$), only one-third of all trawled newshell American lobsters experienced delayed mortality.

While both trawl and pot gear damage lobsters, trawl-caught lobsters alone sustained delayed mortality. One of the initial concerns about trawling was that visibly undamaged American lobsters less than the minimum length, returned to the water after trawling, would suffer a high level of unobserved mortality. Our results indicate that such mortality rarely occurs to undamaged American lobsters; consequently, potential delayed mortality may be ascertained simply by inspection of the incidence of major damage in the catch.

Of the two molting periods in Long Island Sound, a higher rate of mortality was observed in July than in November, possibly related to the warmer postmolt water temperatures which occur in summer compared with late fall. Damage rates during postmolt periods were similar (12.6% July vs. 14.0% November) notwithstanding the difference in water temperature. These results suggest that the resistance of trawled postmolt American lobsters may be lowered by warm seawater temperatures and that such temperatures may increase the occurrence of delayed mortality independent of the incidence of damage. Mean values of immediate and delayed mortality for all samples taken during intermolt periods were negligible (<1.0% and <2.0%, respectively).

There appeared to be some variability in mortality depending on the type of damage sustained. Damage to the abdomen and carapace was almost always lethal (100% and 92%, respectively), while broken parts such as claws or rostrum resulted in 25% and 50% mortality, respectively. However, small sample sizes precluded definitive analysis.

Ganz (1980) speculated that the most significant impact of trawling might be related to the cumulative effect of trawling and damaging sublegal American lobsters, and subsequently releasing them to be taken again. In discussing this possibility, he reported an immediate claw loss (cull) rate of 3.5% and a prior cull rate of 8.8%. This is a valid concern, and one which should be considered in both trawl and pot fisheries. For example, Smith (1977) reported a cull rate of 26% in an area of Long Island Sound which had not been trawled during recent years and a rate of 23% in an area lightly fished with trawls, suggesting that a high cull rate can occur in the absence of trawling (both areas were heavily fished with pots). These observations, while higher than Ganz's, included both new and old claw loss as well as lobsters with regenerated claws. In the present study, minor damage (which included immediate claw loss) ranged from 0.9 to 8.1% per month in the trawl fishery and from 0 to 10.7% in the pot fishery.

While the mortality of trawled newshell American lobsters was high during the two molting periods, they represented such a small percentage of the total trawl catch (1-8%) that the estimated total mortality to the entire catch was little changed by their presence. Similarly, while damaged lobsters sustain a high rate of mortality, it is their proportion in the catch which determines the rate of additional mortality experienced by the population.

No truly soft American lobsters (stage A, after Passano 1960) were observed in the pot catches sampled for delayed mortality estimates, and they occurred rarely in other commercial pot samples (up to 3% in July 1984). They were observed infrequently in trawl catches as well (up to 7.8% in November 1984). The low incidence of soft lobsters in commercial catches is probably due to reduced mobility during the shell hardening process (Herrick 1909) when American lobsters are most vulnerable to damage and predation.

No significant difference was observed in damage rates or delayed mortality based on sampling of vessels <15 m or >15 m. There was no difference in delayed mortality rate between 13 m research vessel samples and either 12 m commercial or 15-26 m commercial trawlers. Finally, there was no difference between damage rates to American lobsters ≥81 mm CL taken by research and commercial vessels in October-November 1984, the only period for which comparable data (tows of 2-h duration) were available for both vessel categories. The former results suggest that trawl-induced damage and mortality is independent of vessel size; the latter suggests that observations of fishery-induced damage made by biologists were representative of actual fishing conditions.

While American lobsters may succumb to subfreezing air temperatures, consideration of this source of mortality is a function of both temperature and exposure time and must be judged on the behavior of the fishery in question. Edwards and Bennett (1980) reported a survival rate of 42-85% for *Nephrops norvegicus* after 1-h exposure to air, noting that favorable weather conditions and the type of vessel used were factors contributing to higher survival. In the present study, American lobsters exposed to −9.5°C air temperatures for 30 minutes all survived. Those exposed for 120 minutes all succumbed. Intermediate exposure (60 minutes) produced intermediate results (30% survival). In Long Island Sound, field observations during a 19-mo period suggested that operators in the trawl fishery commonly sorted the catch within 15-45 minutes.

Our design tended to maximize the debilitating effect of freezing temperatures. Trawl net contents are commonly released onto the vessel deck in a pile. Consequently, organisms on the inside of the pile are protected from cold air temperatures. In our test, all American lobsters were placed on a flat table with 0.3 m high sides; thus, all lobsters were equally exposed to freezing temperatures and none were able to benefit from the "piling" of a normal catch. As a consequence, this experiment very likely overstated the impact of subfreezing air temperatures on commercially taken American lobsters.

An additional consideration beyond the directed fishery is the mortality to "sublegal" American lobsters (those <81 mm CL) and the damage to lobsters during molting periods which may result from a mixed species trawl fishery which includes a so-called incidental catch or "bycatch" of lobsters. As with freeze-induced mortality, this factor must be judged based on the performance of the fishery in question.

In Connecticut, trawlers reported <10% of the commercial American lobster landings reported by all fishermen during the period 1982-86 (CT DEP fn. 2). However, given the controversy surrounding trawling during this investigation and the weaknesses inherent in catch reporting systems during periods of controversy (Matlock 1986; Ferguson 1986), a number of independent methods of observation were used to determine the actual impact to the resource associated with trawling. Unannounced boardings by Connecticut Conservation Officers were utilized to estimate the true magnitude of lobster catches. Biologists made sampling trips on the vessels of commercial trawl fishermen fishing in Long Island Sound to document the fishery-induced incidence of damage. Research vessel sampling was used to estimate a fishery-independent rate of trawl-induced damage. The results of these observations suggested that the magnitude of American lobster catches per trip was about the same as those reported in mandatory logbooks and, except during molting periods, trawl-induced damage was minimal.

Observations in controlled laboratory conditions were utilized to estimate the delayed mortality which might be expected to occur to sublegal American lobsters returned to the water after trawling. These observations indicated that this source of mortality should only be a concern during molting periods. Since delayed mortality to sublegal American lobsters occurs to a significant degree only during molting periods, an incidental limit of some number of lobsters per day for trawlers during those periods represents an effective means to deter the directed fishery and protect sublegal American lobsters while allowing the finfish fishery to continue.

There has been considerable controversy in New England regarding the effects of trawling on the American lobster resource. This study provides three results of assistance to fishery managers dealing with this question. First, both pot and trawl gear damaged American lobsters, but trawl-induced damage occurred more frequently, and particularly during molting periods. However, damage was not always lethal and visibly undamaged lobsters virtually never sustained delayed mortality. Second, during molting periods, mortality caused by trawling reached 6-21%, depending on season. Delayed mortality was influenced most by the degree of damage sustained by the lobster. Therefore, while delayed mortality may be of considerable consequence to the resource during molting periods, it can be estimated by inspection of the condition of lobsters in the catch. Third, during intermolt periods, both immediate and delayed mortality due to trawling occurred infrequently (<1% and <2%, respectively). All these factors should be evaluated within the context of the biological and socioeconomic considerations inherent in the fishery management process.

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