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STUDY IN PROGRESS

Finfish By Catch Mortality in the Gulf of Maine Northern Shrimp Fishery

by

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Abstract

Short-term mortality experiments were conducted on Atlantic cod, pollock, American plaice, witch flounder, winter flounder, and yellowtail flounder discards in the Gulf of Maine northern shrimp small-mesh fishery. Discard mortality of gadids was generally higher than that of flounders. Substantial additional mortality due to avian predation was incurred when discards were returned to the water. Differences among species in predation-caused mortality were apparently due to differing abilities among the fish species to sink immediately upon hitting the water. Logistic regression analyses demonstrated that air temperature, time on deck, and length of fish were the factors that most influenced short-term mortality of winter flounder and American plaice. Differences in discard mortality rates between our study and those of large-mesh trawl fisheries indicate that mortality is specific to both species and the fishery in which the species are being captured.

Introduction

Fisheries resources of the Gulf of Maine are exploited by many fisheries, including a pot fishery for lobster, a dredge fishery for scallops, and trawl fisheries for both shrimp and demersal finfish species, known as groundfish. The trawl fishery for northern shrimp, *Pandalus borealis*, in the Gulf of Maine operates out of ports along the coast of Maine, New Hampshire, and the north shore of Massachusetts. The shrimp season is usually open from early December through mid-May, although this may vary from year to year. During this time the female shrimp move from deeper waters of the gulf to the shallower inshore waters to deposit their eggs (Haynes and Wigley 1969).

Bycatch within the small-mesh shrimp fishery includes many fish and shellfish, including: mid-water species such as pollock, sea herring, alewife, and blueback herring; demersal species such as lobster, various crab species, cod, haddock, red hake, white hake, silver hake, winter flounder, yellowtail flounder, American plaice, and witch flounder, as well as commercially-unexploited species such as long-horned sculpin. Many of the finfish caught in the shrimp fishery are of little commercial value, or are of sublegal size and cannot be landed. The weight of finfish discarded in the fishery may exceed the weight of shrimp landed (Clark and Power 1991; Howell and Langan 1992). Many sublegal discards are juvenile fish not yet contributing to fisheries or spawning stocks. Stocks may be impacted by the loss of juveniles discarded in the shrimp fishery. However, little is known concerning mortality rates of discarded groundfish in this fishery.

Studies done in large-mesh, directed fisheries on short-term mortality of plaice (Jean 1963; Powles 1969), cod (Jean 1963), Pacific halibut (Williams, et al. 1989), and in the small-mesh shrimp fishery on various New England groundfish (Howell and Langan 1992) indicate that time on deck, size, and temperature all affect mortality rates of discards. Several studies have also indicated that anatomical damage incurred during towing and physiological stress brought on by hyperactivity during the tow may increase mortality rates (Beamish 1966; Rogers 1986). Jean (1963), Powles (1969), Williams (1989), and Howell and Langan (1992) all concluded that, under normal deck conditions and normal sorting times, all or most discards die, although colder ambient temperatures and larger body size do increase survival.

We are studying the short-term mortality of six groundfish species discarded in the Gulf of Maine small-mesh northern shrimp fishery: the Atlantic cod (*Gadus morhua*), pollock (*Pollachius virens*), American plaice (*Hippoglossoides platessoides*), yellowtail flounder (*Pleuronectes ferrugineus*), winter flounder (*Pleuronectes americanus*), and witch flounder (*Glyptocephalus cynoglossus*). In this paper, we present data concerning the short-term mortality caused by capture and handling of these species on commercial vessels, and that by avian predation once fish are returned to the water after sorting of the catch. In addition, the relative influence that duration and depth of tow, time on deck, size of fish, temperature, and weight of catch have upon mortality of discarded winter flounder and American plaice will also be discussed.

Methods

Survival experiments were conducted on the R/V *Argo Maine* under contract to the Maine Department of Marine Resources and on cooperating commercial vessels from January through April, during the time the small-mesh

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fishery was open in 1993. Capture, sorting of the catch, and handling of discards were conducted under conditions typical of the fishery. Fish totes, which are plastic storage bins measuring 31.5 inches x 18.25 inches x 11.5 inches (80cm x 46.4cm x 29.2cm) and holding approximately 19 gallons (72.2 liters) when full, were used as holding tanks for the experiments. The tanks were filled with seawater at ambient (surface) temperature. Randomly selected fish of a species were placed in the holding tanks, with a maximum of 20 fish per tank. Tanks were flushed when needed to maintain adequate oxygen levels and minimize temperature fluctuations. Fish exhibited short term survival if they were alive at the end of a one- to two-hour time period in the holding tank. Multiple replicates were run for each species. The number of replicates run for each species was dependent upon weather, market conditions, down-time of boats, the fishing success of both boats and individual tows, and the availability of subject species in tows.

Test groups typically consisted of 10 to 20 individuals randomly selected from the catch independent of condition; the specific, number of fish per test depended upon availability in the catch and was limited by space in the holding tanks. Fish in each test or replication were classified according to the time spent on deck prior to being placed in the holding tanks (either 15, 30, 45, 60, or 75 minutes)

For the winter flounder and American plaice the variables length (size), time on deck, air temperature, tank temperature, duration of tow, maximum depth of tow, and weight of shrimp in tow (as an index of total catch of tow) were tested for significance ($P < 0.05$) using one-way analysis of variance. Stepwise logistic regression was used to determine which variables most influenced mortality rates caused by capture and handling.

Results

Mortality rates differed among species. Short-term mortality among gadids was generally higher than that of flounders. Within the gadids, cod experienced a 36.1% mortality, compared with 21.7% for pollock. Mortality among flounders varied from 29.4% for the witch flounder to 0.8% for the yellowtail (Table 1). A higher percentage of gadids than flounders appeared to suffer severe stress, which may have contributed to the higher mortality. Predation by birds was also higher on the gadids as a group than on the flounders (Table 2). Differences among flounder species in percentages of fish observed to be eaten by birds resulted from differences in behavior when returned to the sea. Winter flounder and yellowtail typically sank or swam down rapidly after hitting the water, while regardless of apparent condition, witch flounder and American plaice generally did not. The combined mortality due to capture, handling, and predation on the discarded fish is extremely high for both cod (77.2%) and pollock (70.1%). Flounders experienced less combined short-term mortality, but nonetheless, nearly one half of all American plaice (48.9%) and witch flounder (48.1%) tested died. In contrast, winter flounder experienced an 11% combined mortality and yellowtail only 3.3% (Table 3).

Of the 272 winter flounder tested, 14 (5.15%) died either on deck or while in live tanks. ANOVA demonstrated that air temperature, tank temperature, length of tow, maximum depth, and weight of shrimp as highly significant (all $P < 0.000$) and length ($P = 0.055$) as possibly significant. Based upon logistic regression analyses, length, air temperature, and time on deck had greatest influence upon mortality. Additional variables did not significantly improve the fit of the model. The model's acceptance of time on deck indicates that survival improves as time prior to being discarded increases (Table 4), which is counter to the expected relationship between survival and time on deck. This result occurred due to the interaction between air temperature and time on deck. Nearly all of the winter flounder that died during experiments were exposed to sub-freezing air temperatures. The same tows that captured these fishes were largely composed of shrimp with few finfish bycatch, allowing all sorting to be completed in short periods of time (thus short time on deck for the discards). Consequently, death was likely caused by temperature with time on deck being an incidental interaction with the temperature variable.

A total of 114 of 588 (19.39%) American plaice died. All variables were determined to be statistically significant by ANOVA ($P < 0.000$ for all). Regression analysis yielded a best reasonable fit of the model containing length, time on deck, and air temperature.

Discussion

Our studies indicate high rates of mortality for gadids caught in the shrimp fishery. The high initial mortality and great susceptibility to avian predation appear to be a direct result of the stressed condition of the gadids as they are brought on board, as exhibited by swollen eyes, bloated swim bladders, and loss of equilibrium. As a group, flounders appeared to experience less severe stress; this is reflected in lower initial mortality rates and less susceptibility to predation by birds.

Previous studies have suggested that discard mortality in trawl fisheries may approach 100% (Jean 1963; Powles 1969; Williams 1989; Howell and Langan 1992). Based upon limited information (Hokenson, unpublished data), mortality among redfish (*Sebastes* spp.) and haddock (*Melanogrammus aeglefinus*) was observed to be 100% in the Gulf of Maine shrimp fishery. Ultimate mortality of discards in the shrimp fishery may be higher than immediate mortality rates measured in our study due to potential prolonged effects of capture and handling. However our research indicates that there may be some survival of commercially important species in the fishery. Based upon similar short-term mortality experiments to those we employed, Jean (1963) and Powles (1969) indicated that mortality of Atlantic cod and American plaice discards is likely 100% in a Canadian large-mesh trawl fishery. We believe differences in survival of discards between the two fisheries may be due to the cooler temperatures typical of the winter shrimp fishery, and inherent differences in capture and handling between the two fisheries. Our data strongly suggests that discard mortality of particular species is specific to the fishery in which they are captured.

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Table 1. Percent fishes alive after holding in live tanks.

Species	Number	Percent Survival	95%C.I.
American plaice	588	80.6	77.4, 83.8
Winter flounder	272	94.9	92.2, 97.5
Witch flounder	327	70.6	65.7, 75.6
Yellowtail	125	99.2	97.6, 100
Pollock	401	78.3	74.3, 82.4
Cod	133	63.9	55.6, 72.2

Table 2. Percent fishes consumed by sea birds when returned to water alive.

Species	Number	Percent Eaten	95%C.I.
American plaice	295	36.6	31.1, 42.1
Winter flounder	229	6.1	3.0, 9.2
Witch flounder	151	26.5	19.4, 33.6
Yellowtail	78	2.6	0.0, 6.2
Pollock	291	62.6	57.0, 68.1
Cod	28	64.3	45.4, 83.2

Table 3. Combined immediate mortality due to capture and avian predation.

Species	Percent Mortality
American plaice	48.9
Winter flounder	11.0
Witch flounder	48.1
Yellowtail	3.3
Pollock	70.1
Cod	77.2

Table 4. Mean values of measured variables for fish that died and fish that survived capture and holding.

	Winter flounder		American plaice	
Variable	Dead (n=14)	Alive (n=258)	Dead (n=114)	Alive (n=474)
Length (cm)	15.07	19.07	16.89	24.79
Time-on-deck (min)	32.14	40.06	45.00	32.66
Air Temp. (deg. C.)	-2.29	1.31	4.90	4.69
Tank Temp. (deg. C.)	0.64	2.46	4.17	4.42
Length of tow (min)	158.35	144.86	112.6	159.8
Maximum depth (fathoms)	56.57	53.66	72.04	85.65
Weight of shrimp in tow (lbs)	411.07	435.68	279.5	283.8