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ABSTRACT

We examined the contents of 21,309 lobster traps while aboard commercial fishing vessels during the 1993-94 spiny lobster (*Panulirus argus*) fishing season and found 6,972 of these traps contained species other than spiny lobster. We observed 15,536 individual fish and invertebrates comprising 172 species. Stone crabs, grunts, spider crabs, and sea urchins represented 65% of the bycatch. Legal-sized snapper and grouper were observed in approximately 0.5% of traps. Lobster catch rates were consistently lower and dead lobsters were more common in traps containing bycatch. Wood-slat traps were the predominate type of trap used in the fishery (90%). The remaining 10% of the traps were wire-reinforced wood (8%), wire (1%), or plastic (1%). Lobster catch rates from wood and wire-reinforced traps were not significantly different when fished in the same area, but wire-reinforced traps caught significantly more legal-sized fish and often caught more ornamental and unregulated species. Wire traps caught an average of 10 times more fish than other types of traps, but these traps were used exclusively in deep water. This precluded the direct comparison of the amount of bycatch caught in wire traps with other types of traps that were fished exclusively in shallow water. The number of plastic traps observed was too low to compare bycatch or lobster catch rates with other types of traps. In general, wood lobster traps usually do not contain bycatch and those animals that are captured were usually unharmed. There appears to be some potential to misuse or modify wire lobster traps to target commercially valuable fish, but using lobster traps in this way would likely reduce lobster catch rates.

INTRODUCTION

Bycatch in spiny lobster traps is an important consideration for fishery managers and commercial fishers. Fishery managers are concerned that lobster traps catch significant quantities of bycatch, particularly species in the snapper-grouper complex and other reef fish as specified by the Gulf of Mexico Fishery Management Council-Reef Fish Fishery Management Plan (1989) (Harper et al. 1990). Commercial lobster fishers in Florida value the occasional snapper or grouper they harvest, but in general they do not target any bycatch species with

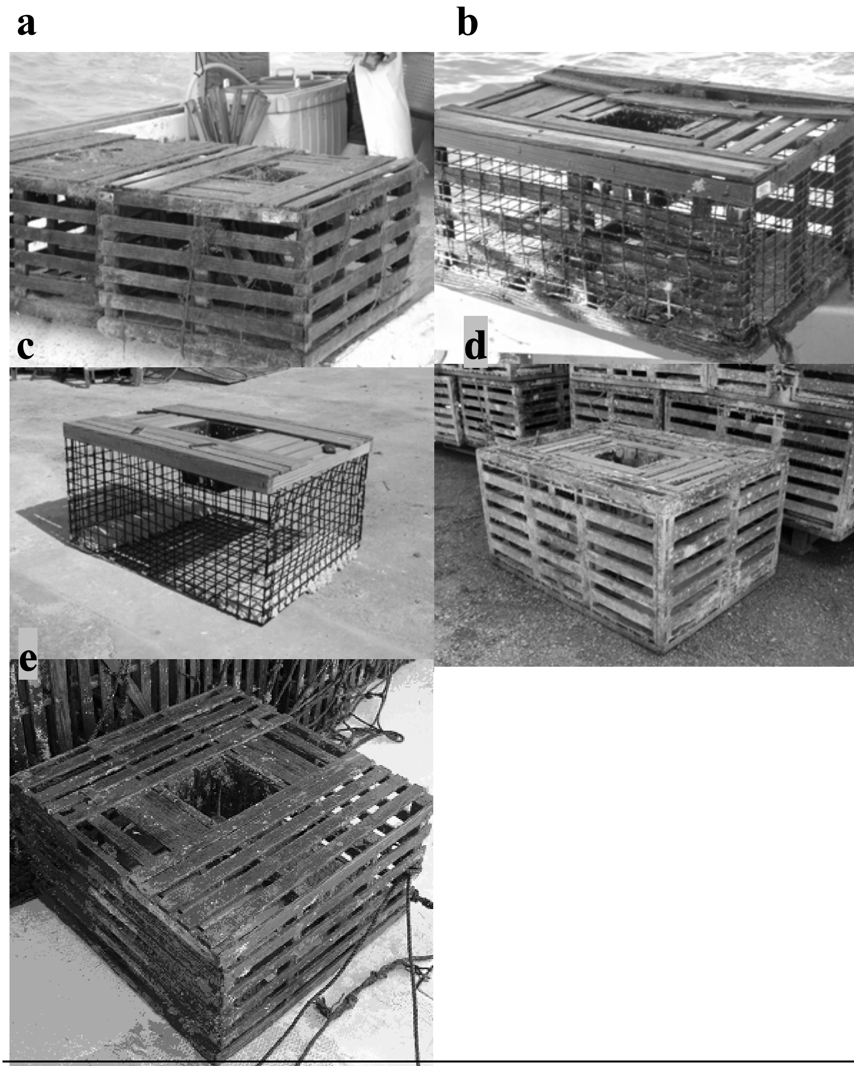

Figure 1. Types of lobster traps used in Florida. a) wood trap, b) wire-reinforced trap, c) wire trap, d) plastic trap, and e) large trap. Large traps are typically 90 cm x 120 cm or 90 cm x 90 cm (as shown). Other traps are typically 60 cm x 80 cm.

the exception of stone crabs, *Menippi* spp. Fishers consider some bycatch species competitors for space in lobster traps or potential lobster predators. Competition for space in traps is common between American lobsters, *Homarus americanus*, and spider crabs (Richards and Cobb 1987) and predation by octopus and several fish species on rock lobster, *Panulirus cygnus*, confined in traps is well documented (Joll 1977).

Fishery managers lack data on which species of fish are captured in lobster traps, and they are concerned that certain trap designs, particularly traps constructed with wire, capture a disproportionate number of fish. Fishery managers are also concerned that lobster traps can be modified to capture fish more effectively, and that these modified traps could be used to circumvent fish trap regulations. The traditional fishing gear for lobster is the wooden-slat trap(Figure 1a), but lobster fishers use a variety of lobster trap designs to fish in a wide range of habitats and depths. Wood traps reinforced with wire (Figure 1b) are used to prevent turtles from damaging the traps as they attempt to forage on lobsters in traps. Wire traps (Figure 1c) are used to facilitate trap retrieval from deep water or in areas subject to storm surge. Plastic traps (Figure 1d) are a more durable alternative to wood traps, and large traps (Figure 1e) are used in areas containing large lobsters or in areas where lobsters are caught at infrequent intervals but in great abundance.

This study was designed to observe current trap fishing practices and quantify the amount of bycatch associated with different types of traps used in the lobster fishery. Because these different types of traps are used in discrete areas that may have different fish communities, it is difficult to directly compare the amount of bycatch associated with a particular type of trap. We also quantified the number of dead lobsters and dead bycatch observed in traps. We were also able to compare of the amount of bycatch in wood and wire-reinforced traps in one region of the fishery where both types of traps were common. Breakage rate of wood and wire-reinforced traps were also examined to evaluate the need for wire-reinforced traps in some areas of the fishery.

METHODS

During the 1993-94 lobster fishing season (August 6 to March 31) we attempted to sample a total of 400 traps each month from at least three different fishers in each fishing area (Figure 2). These areas comprise over 90% of the landings. Fishers were chosen from a pool of volunteers obtained through a mail survey sent to every trap fisher. The mail survey was also used to ascertain how many wood, wire, wire-reinforced wood, and plastic traps were in the fishery.

We attempted to identify and measure the contents of 133 traps each fishing trip. We accomplished this by sampling the appropriate fraction of the traps based on the number of traps the fisher intended to retrieve that day. For example, if a fisher expected to pull 400 traps, we examined every third trap. Examination of each trap included recording the type of trap (wood, wire, wire-reinforced wood, or plastic), trap location (to the nearest minute of latitude and longitude), trap status (fishing, broken, robbed, or missing), soak duration (the number of days between successive trap pulls), type of bait, and the number of attractants. Attractants are live lobsters, usually sublegal-sized, that are intentionally transported between traps and placed in traps as live bait (Hunt et al. 1986, Heatwole et al. 1988).

Each lobster was sexed, measured to the nearest 1-mm carapace length (CL), and the reproductive condition of females was noted (presence of fresh or eroded spermatophores and eggs). Lobsters measuring 76-76.5 mm CL were recorded to the nearest 0.1 mm to retain information relative to the legal-size limit of 76.2 mm (3 inches).

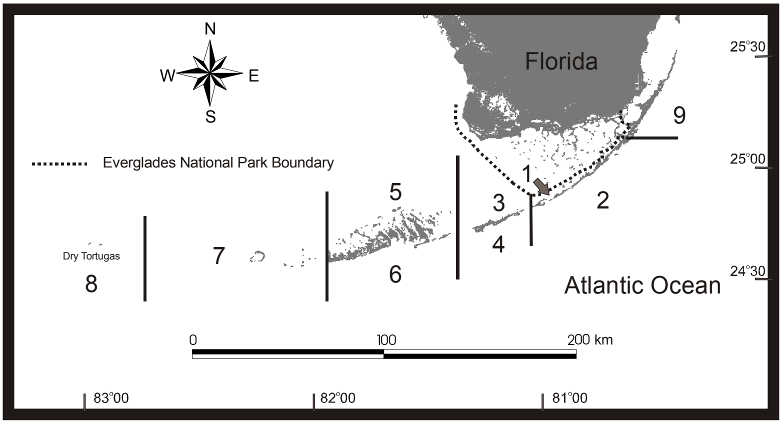

Figure 2. Study area differentiated into nine sampling areas.

Dead lobsters were sexed and measured when sufficient remains were present. Fish were identified, measured to the nearest 2.5 mm (1 inch), and classified as either legal or sublegal according to Florida fishery regulations. Stone crabs without legal-sized claws were counted as either the number of undersized claws or the number of individuals. This caused us to misrepresent the number of stone crabs without legal-sized claws. Other invertebrates were counted but not measured. Encrusting and fouling organisms were not counted.

A comparison of bycatch capture rates between wood and wire-reinforced wood traps was made for a subset of the data that included both types of traps from area 2 (Figure 1). Only traps that were distributed within adjacent 1-minute latitude or longitude of each other, which in South Florida is approximately 1.6 km, were included. A Wilcoxon two-sample test was used to compare if wood and wire-reinforced traps contained equal numbers of lobsters. The nonparametric test was chosen because of the negative-binomial distribution of lobsters in traps. After the assumptions of adjacent fishing areas for the traps and equal numbers of lobster in each type of trap were met, a Wilcoxon two-sample test was used to test for differences between the number of reef fish in wood and wire-reinforced traps. We defined reef fish as all snapper, grouper, hogfish, triggerfish, porgies, grunts, and parrotfish; with the exception of parrotfish, this group was consistent with the Gulf of Mexico Fishery Management Council-Reef Fish Fishery Management Plan (1989). Parrotfish were included in the reef fish category because they were routinely harvested in area 9 (near Miami). The number of snapper-grouper in wood and wire-reinforced traps was compared separately using the Wilcoxon two-sample test. We also reported the expected catch rates of reef fish and the snapper-grouper subset of that group separately for each type of trap. All analyses included both legal-sized and sublegal-sized lobsters and fish. A G-test (using Williams correction) was used to determine if the number of broken wood and wire-reinforced traps differed.

RESULTS

We accompanied 116 different commercial fishers on 192 fishing trips, during the 1993-94 fishing season. We sampled an average of 365 traps in each of seven of the fishing areas using at least three different fishers each month. We were unable to complete sampling trips in the Dry Tortugas (area 8) and only eight trips were completed in area 9 adjacent to Miami (Figure 2).

Mail survey returns from 351 fishers owning 319,066 of the 704,234 traps in the fishery, indicated that 90% of traps in the fishery were all wood, 8% were wire-reinforced wood, 1% were wire with wood tops, and 1% were plastic. Direct counts of trap types while aboard commercial fishing vessels corresponded with those estimates obtained by the mail survey: 88% wood, 9%, wire-reinforced wood, 2% wire with wood tops, and <1% plastic (Figure 1).

Wood traps were fished in all areas and depths; wire and wire-reinforced traps were observed exclusively in the Atlantic in a variety of depths and wire traps were observed water deeper than 20 m. Mail survey respondents indicated that some wire traps were used in deep water in the Gulf of Mexico north of area 3 outside of our sampling area. Most of the plastic traps were observed on a single sampling trip in area 3.

Many species of fish and invertebrates were routinely observed in lobster traps during our sampling trips. Table 1 includes 43 taxa that, on average, were observed in more than 1% of traps. An additional 46 taxa were observed in 0.1% to 1% of traps (Table 2). Stone crabs (*Menippe* spp.) were the most abundant and valuable bycatch species. Excluding those captured prior to the opening of the stone crab season (October 15), we observed 1,024 medium, 913 large, and 481 jumbo or extra-large claws valued at approximately $4,645 (dollar values were calculated from ex-vessel prices in Marathon, Florida in March 1993) and approximately half as many sublegal-sized claws. Grunts (predominately white grunt, *Haemulon plumieri*) were the second most abundant group. Large grunts (> 12 inches) were rarely observed, except in the Marquesas, area 7. Legal-sized grouper (*Epinephelus morio* and *Mycteroperca bonaci*), hogfish (*Lachnolaimus maximus*), and snapper (*Lutjanus* spp. and *Ocyurus chrysurus*) were usually retained for sale or personal consumption. Spider crabs *(Mithrax spinosissimus*) were common, and the claws were occasionally harvested. Some bycatch species were harvested for the ornamental trade. These included urchins (predominately *Lytechinus variegatus*), angelfish (*Holocanthus* spp. and *Pomacanthus* spp.), and nurse sharks (*Ginglymostoma cirratum*). Cowfish (*Lactophrys quadricornis*), puffers (*Diodon* spp. and *Chilomycterus* spp.), and trunkfish (*Lactophrys bicaudalis*), were occasionally retained for use as stone crab bait. Octopus (*Octopus* spp.) and triggerfish (*Balistes capriscus*) were often killed and discarded because they were suspected lobster predators. Five of the observed bycatch species are protected and cannot be harvested. There were 30 long-spined sea urchins (*Diadema antillarum*), 5 jewfish (*Epinephelus itajara*), 3 Nassau grouper (*Epinephlus striatus*), 5 Bahama starfish (*Oreaster reticulatus*), and 1 loggerhead sea turtle (*Caretta caretta*). The loggerhead turtle was tangled in the trap rope. All protected species were released alive and apparently unharmed.

Twenty dead crabs, 8 dead fish, and 5 dead cormorants (*Phalacrocorax auritus*) were observed in traps. A small number of animals are also crushed on the deck or died of exposure during trap relocation and removal. This source of mortality was highly dependent on the behavior of the fisher and not an inherent source of mortality associated with the use of traps. Only confinement-induced mortality was reported in Table 1.

Table 1. Bycatch observed more than once per 1,000 traps in the 21,309 lobster traps observed during the 1993-94 lobster season. Species are listed in order of abundance. For those species regulated by size restrictions, the number of legal and sub-legal sized individuals are presented separately.

SPECIES	TOTAL	LEGAL	SUBLEGAL	DEAD
STONE CRAB	*	3,368[1]	1,514[2]	16
GRUNT	2,177	*	*	1
SPIDER CRAB	1,776	*	*	4
URCHINS	1,338	*	*	1
COWFISH	726	*	*	0
HERMIT CRAB[3]	538	*	*	0
PORGY	351	*	*	2
TRIGGERFISH	289	*	*	0
PUFFERS	262	*	*	0
PARROTFISH	263	*	*	0
ANGELFISH	233	131	101	1
TRUNKFISH	217	*	*	0
ARROW CRABS	161	*	*	0
SLIPPER LOBSTERS	155	*	*	0
OCTOPUS	146	*	*	0
FILEFISH	110	*	*	0
TULIP	96	*	*	0
BLUE CRAB	94	*	*	0
GROUPER[4]	87	7	79	1
MUTTON SNAPPER	81	45	36	0
HOGFISH	77	*	*	0
NURSE SHARK	76	*	*	0
SCORPIONFISH	73	*	*	0
CUBBYU	69	*	*	0
SEACUCUMBER	64	*	*	0
SURGEONFISH	59	*	*	0
OTHER CRABS	56	*	*	0
LANE SNAPPER	56	13	43	0
BIGEYE	48	*	*	0
HORSE CONCH	46	*	*	0
SAND PERCH	45	*	*	0
COWRIE	41	*	*	0
GREY SNAPPER	38	13	25	0
PEPPERMINT SHRIMP	36	*	*	0
CATFISH	35	*	*	0
JACKNIFE-FISH	32	*	*	0
JACK	32	*	*	0
SNAILS, VARIOUS	29	*	*	0
TOAD FISH	27	*	*	0
HIGH-HAT	27	*	*	0
BASKET STARFISH	25	*	*	0
YELLOWTAIL SNAPPER	25	19	5	1
MORAY	23	*	*	0

[1]Legal claws [2]Approximate number [3]Underestimation [4]Excludes protected species

Table 2. Bycatch observed less than once per 1,000 traps in the 21,309 lobster traps observed during the 1993-94 lobster season.

SPECIES	SPECIES	SPECIES
WHELK	GOATFISH	TRUMPETFISH
PERMIT	ANEMONE	DOG SNAPPER
BLENNY	CUSK EEL	AMBERJACK
JEWFISH	PORKFISH	SPADEFISH
WRASSE	FROGFISH	LIZARDFISH
SEAHARE	SEAHORSE	NEON GOBY
BAHAMA STARFISH	FLOUNDER	STARFISH
HAMLET	STINGRAY	SHEEPSHEAD
LOGGERHEAD TURTLE	SOAPFISH	DAMSELFISH
VERMILION SNAPPER	PINFISH	ROCK SEA BASS
BANDED CORAL SHRIMP	MARGATE	CORAL SPIDER CRAB
CORMORANT(dead)	HIND	GOLDEN TILEFISH
SPOTTED LOBSTER	CALAPPA CRAB	SAND TILEFISH
CARDINALFISH	SQUIRRELFISH	SAND DOLLAR
BUTTERFLYFISH	ELECTRIC RAY	NASSAU GROUPER
SCHOOLMASTER SNAPPER		

The type of bycatch in different types of lobster traps was dependent on where the trap was fished and the number of lobsters in the trap. The number of attractants in traps was particularly important because those lobsters had been specifically placed in traps. The bycatch reported in specific trap types (Table 3) did not account for these effects. The bycatch reported for specific trap types was indicative of how the traps were used in the 1993-94 fishing season but should not be directly compared. A comparison of bycatch rates was possible, however, between the 1,276 wood traps and the 1,467 wire-reinforced traps in area 2. Both types of traps were dispersed through the entire area but always within adjacent 1-minute square latitude-longitude grids. The number of lobsters observed in each type of trap (3.94 and 3.93 lobster/trap for wood and wire-reinforced traps respectively) did not differ significantly (Wilcoxon two-sample test, p = 0.6343). Wire-reinforced traps caught significantly more snapper-grouper and significantly more reef fish than wood traps (Wilcoxon two-sample test, p = 0.0002 and 0.0001 respectively). Although the catch rates of snapper-grouper and reef fish were significantly different between different types of traps, on average only 1 wood and 3.2 wire-reinforced traps per 100 trap pulls contained snapper-grouper, and only 4.5 wood and 11 wire-reinforced traps per 100 trap pulls contained reef fish. Thirty-four percent of the snapper-grouper observed were above the minimum legal size. Wire-reinforced lobster traps captured an average of 1.1 legal-sized snapper and grouper per 100 trap pulls (Table 3).

The most abundant bycatch species were not evenly distributed among all traps. These taxa were more abundant in certain areas and aggregated in specific traps. For example, the mean 0.875 grunts/wire trap (Table 3) is more realistically reported as a mean of 3.39 grunts in 1 out of 4 wire traps that captured grunts. Snapper or grouper were observed in approximately 1% of traps and in 5% of those traps the fish were with conspecifics. Ninety-seven legal-sized snapper and grouper were observed in the 21,309 observations (0.5%) of traps during this study.

We observed significantly more damaged wood traps than wire-reinforced traps (Wilcoxon two-sample test, $p < 0.001$). Presumably, turtles damaged these traps as they attempted to forage on the confined lobsters. Approximately 6.8% (87/1,363) of the wood traps and 2.7% (40/1,507) wire-reinforced traps were damaged.

The number of legal and sublegal-sized lobster in traps containing bycatch was consistently less than that observed in traps that contained only lobsters. The number of dead lobsters in traps containing bycatch was generally higher than in traps without bycatch (Table 4). On average, 0.021 dead lobster (slightly over 2 dead per 100 trap pulls) were observed in traps without bycatch. Lobster mortality in traps containing triggerfish and octopus could be directly attributed to these animals because of the presence of bite marks on the eyes, legs, and carapace of the lobster. Lobster mortality associated with catfish, trunkfish, and tulip snails was not directly attributable to any source because overt signs of predation were seldom visible. The relationship between the number of dead lobsters and other notorious lobster predators (*e.g.* nurse sharks, grouper, and mutton snapper) was unclear because the number of dead lobsters did not consistently increase in the presence of these predators (Table 4).

The lobster mortality rates presented herein reflect only the number of dead lobsters observed. No attempt was made to extrapolate these observations to include deaths that may have occurred prior to the traps retrieval where the remains of the lobster carcass may have disappeared (Matthews 2001).

DISCUSSION

Fishery managers are concerned that lobster traps may be used to target fish. In this study, we measured the amount of bycatch in wood traps, wire-reinforced traps, wire traps with wood tops, and a limited number of plastic traps (Figure 1). Given that 0.5% of the wood lobster traps that we observed contained snapper or grouper, 1 or 2 legal-sized fish and an assortment of ornamental species would be captured per trip.

Traps with wire of any type consistently caught more fish, particularly grunts and porgies. Stone crab bycatch was a significant addition to the value of the catch in some areas. Bycatch capture rates in Tables 1 and 2 are indicative of current fishery practices, but we could not make direct comparisons of bycatch capture rates for all types of traps because each type of trap was used in particular habitats and depths.

Table 3. Comparison of the most numerous by-catch species by trap type. Numbers represent the mean per 1,000 traps. Different trap types were typically fished in different habitats; therefore, catch rates are not necessarily indicative of relative catch efficiency of each trap type. (n = number of traps observed).

SPECIES	TRAP TYPE WOOD n=18773	WIRE-REINFORCED n=1943	WIRE[1] n=496	PLASTIC n=100
SPINY LOBSTER[2]	3,253	3,770	875	1,160
STONE CRAB CLAWS[3]	166	116	4	160
STONE CRAB (small)[4]	69	115	0	150
GRUNT	94	195	875	150
SPIDER CRAB	72	14	4	0
URCHINS	67	35	4	20
COWFISH	17	40	673	30
HERMIT CRAB[5]	14	32	438	40
PORGY	4	20	486	10
TRIGGERFISH	10	21	109	30
PUFFERS	4	4	379	0
PARROTFISH	4	4	379	0
ANGELFISH	10	17	36	0
TRUNKFISH	9	17	16	0
SNAPPER	7	31	20	1
ARROW CRAB	2	8	214	0
SLIPPER LOBSTER	7	6	24	0
OCTOPUS	8	2	6	0
FILEFISH	3	7	87	10
TULIP SNAIL	5	5	4	0
BLUE CRAB	3	19	0	0
GROUPER[6]	4	4	26	10
HOGFISH	2	24	0	0
NURSE SHARK	3	8	0	0
SCORPIONFISH	2	6	69	0

[1]Wire traps have a wooden top [2]Includes all sizes [3]Legal claws [4]Approximate number [5]Underestimation [6] Excludes protected species

Table 4. Comparison of lobster catch rates and death rates in traps containing other species. A trap with multiple by-catch species is listed separately for each species (n =21,309 traps).

SPECIES	NUMBER OF TRAPS	LEGAL LOBSTERS per trap	SUBLEGAL LOBSTERS per trap	DEAD LOBSTERS per trap
LOBSTER	14453	0.87	2.72	0.021
STONE CRAB	3114	0.44	1.81	0.018
GRUNT	755	0.60	1.76	0.024
SPIDER CRAB	1216	0.48	3.24	0.039
URCHINS	659	0.35	1.48	0.016
COWFISH	493	0.22	0.67	0.023
HERMIT CRAB	344	0.54	1.46	0.012
PORGY	172	0.23	1.27	0.006
TRIGGERFISH	262	0.45	1.89	0.102
PUFFERS	188	0.16	0.65	0.027
PARROT	158	0.31	0.80	0.006
ANGELFISH	217	0.62	2.19	0.032
TRUNKFISH	172	0.35	0.62	0.058
ARROW CRABS	104	0.67	1.83	0.010
SLIPPER LOBSTER	146	0.78	2.69	0.021
OCTOPUS	147	0.24	1.15	0.063
FILEFISH	104	0.33	1.12	0.010
TULIP SNAIL	88	0.37	1.63	0.080
BLUE CRAB	78	0.55	1.00	0.013
GROUPER[1]	86	0.35	1.91	0.059
MUTTON SNAPPER	75	0.28	1.20	0.013
HOGFISH	66	0.30	1.38	0.030
NURSE SHARK	75	0.56	1.48	0.027
SCORPIONFISH	60	0.44	1.08	0.034
SEACUCUMBER	62	0.53	2.47	0.000
SURGEONFISH	58	0.39	1.64	0.036
GREY SNAPPER	33	0.33	1.52	0.030
CATFISH	33	0.0	0.84	0.091
MORAY	23	0.30	1.26	0.044

[1]Excludes protected species

Different locations potentially supported different fish populations, and we could not determine if the catch rates observed between different types of traps was an effect of the type of trap or variable fish abundance between different habitats and depths. The direct comparison of amount of bycatch in wood and wire-reinforced traps in area 2 was possible because both types of traps were interspersed and had similar lobster capture rates. These wire-reinforced traps caught more snapper and grouper than wood traps. Although wire traps tended to catch an order of magnitude more fish than other types of traps, few fish were commercially valuable snapper and grouper.

Lobster traps containing bycatch of any species usually contained fewer lobsters. It was not possible to determine if bycatch excluded lobsters from traps or if bycatch preferentially entered traps with fewer lobsters. Similarly, we could not determine whether bycatch species entered traps to kill lobsters or to scavenge dead lobsters. We are limited to reporting that bycatch was often associated with dead lobsters and we could not separate confinement-induced mortality (*sensu* Hunt et al. 1986) from predator-induced mortality. The apparent antagonistic relationship between lobsters and most bycatch species also complicated our attempts to compare the amount of bycatch in different types of traps. If more attractants were placed in a trap, the abundance of bycatch may have varied in response the use of attractants instead of the type of trap.

There were four major causes of bycatch mortality observed during this study, 1) bycatch wais retained for consumption, 2) bycatch was used as bait, 3) bycatch died in traps because of confinement or predation, and 4) bycatch was crushed during trap handling or died of exposure during trap transport. The number of fish retained for consumption or that died in traps was small. The largest source of mortality was among the unregulated species that were used as bait. This source of fish mortality was the result of a choice by the fisher to keep certain species as bait, not an unavoidable source of bycatch mortality associated with the fishery.

Wire-reinforced traps were more durable and required fewer repairs than wood traps. The number of traps damaged and the severity of the damage were significantly higher for wood traps than for wire-reinforced traps. The number of lobsters in each type of trap was not significantly different, but the decreased fishing effort associated with a 6.8% damage rate for wood traps would reduce the total lobster harvest per trip. Wire traps were also lost less often than wood traps because they maintained their position in strong currents and during storms. There may be additional factors unrelated to catch rates, such as trap loss, that influence which type of trap was used in a particular area. This study only addressed catch rates of lobsters and bycatch. We did not examine how other factors might influence fishing effectiveness.

There appears to be some potential for the misuse of wire lobster traps to target bycatch. Wire lobster traps (Figure 1c) are essentially small versions of fish traps and regulations that allow larger versions of these wire lobster traps may increase fish mortality. Fish traps are currently an illegal fishing gear in most of South Florida, but a large-wire lobster trap could be used to circumvent the fish trap prohibition. Normal-sized wire and wire-reinforced lobster traps could also be used to circumvent current fish trapping regulations if used improperly. The selective placement or baiting of wire lobster traps might increase the amount of bycatch. However, typical lobster trap fishing practices, which attempt to maximize the catch of lobsters, would reduce the amount of bycatch in any type of trap.

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