Effects of live-bait shrimp trawling on seagrass beds and fish bycatch in Tampa Bay, Florida

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The use of live shrimp for bait in recreational fishing has resulted in a controversial fishery for shrimp in Florida. In this fishery, night collections are conducted over seagrass beds with roller beam trawls to capture live shrimp, primarily pink shrimp, *Penaeus duorarum*. These shrimp are culled from the catch on sorting tables and placed in onboard aerated "live" wells. Beds of turtlegrass, *Thalassia testudinum*, a species that has highest growth rates and biomass during summer and lowest during the winter (Fonseca et al., 1996) are predominant areas for live-bait shrimp trawling (Tabb and Kenny, 1969). Because of their use in seagrass beds, roller trawls were designed to roll over the bottom to reduce gear penetration and debris collection. Because turtlegrass has an extensive root system, it is not likely to be uprooted by roller trawls, but the roller on the trawl has been noted to break off and collect old turtlegrass leaves (Woodburn et al. 1957). On the Gulf Coast of Florida, bait shrimp are generally collected from turtlegrass beds year-round, but most shrimp are taken October through February (Berkeley et al., 1985). Trawl and culling times for this fishery, including that of Tampa Bay, are typically short, 5–20 and 2–15 min, respectively, to reduce debris collection and both injury and mortality to shrimp. Although no data were collected, Berkeley et al. (1985) suggested that such trawling for shrimp may be destructive to seagrass beds and juvenile fishes, including spotted seatrout, *Cynoscion nebulosus*, snapper, *Lutjanus* spp., and pigfish, *Orthopristis chrysoptera*. However, the effects of this type of trawling on finfish bycatch mortality are unknown.

Numerous studies of fish bycatch mortality have used otter trawls. These include consideration of the effects otter trawling has on cod, *Gadus morhua*, and American plaice, *Hippoglossoides platessoides*, in the Gulf of St. Lawrence, Canada (Jean, 1963); on red snapper, *Lutjanus campechanus*, in the Gulf of Mexico (Gutherz and Pellegrin, 1988); and on bycatch in the Torres Strait, Australia (Wassenberg and Hill, 1989; Harris and Poiner, 1990; Hill and Wassenberg, 1990). In these studies fish mortality ranged from 10% (Jean, 1963) to 80% (Jean, 1963; Wassenberg and Hill, 1989), depending on culling times, animal size, and temperature. Trawl and culling times (30–60 minutes and 15–45 minutes, respectively) in these studies were typically longer than those used by the Florida live-bait shrimp fishery.

Our study objectives were 1) to determine effects of a roller beam trawl on turtlegrass biomass and morphometrics during intensive (up to 18 trawls over a turtlegrass bed), short-term (3-hour duration) use and 2) to examine the mortality of bycatch finfish following capture by a trawl.

Methods

Sampling was done in August and November 1990 in Tampa Bay, Florida (Fig. 1). A commercial bait shrimp boat towed two 3.38 m wide, 0.8 m high stainless steel roller beam trawls simultaneously, one

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from each side of the vessel. These consisted of a net attached to a stainless steel frame with a slotted roller along the entire lower portion of the frame. Stainless steel finger bars, 0.8 m long, were fastened vertically, 5 cm apart, along the front top of the frame to exclude seagrass and other debris (Berkeley et al., 1985). Each roller beam trawl weighed ~75 kg. Nets were constructed of 2.56-cm stretched mesh and had a 1.90-cm stretched mesh tail bag.

Turtlegrass

Nine trawl areas were selected in turtlegrass beds near Tarpon Key (Fig. 1). Each consisted of a marked 40-m × 3.38-m plot of continuous turtlegrass cover. Within each 40-m plot, a central 20-m × 3.38-m impact area was marked. During August, we sampled turtlegrass by removing cores of it within the impact area of each plot prior to trawling and after 1, 3, and 9 trawls. In November, new plots were marked and samples were collected prior to trawling and again after 9 and 18 trawls. Trawl levels were increased in November because preliminary analysis of the August data did not reveal a significant effect on turtlegrass at the maximum trawl level.

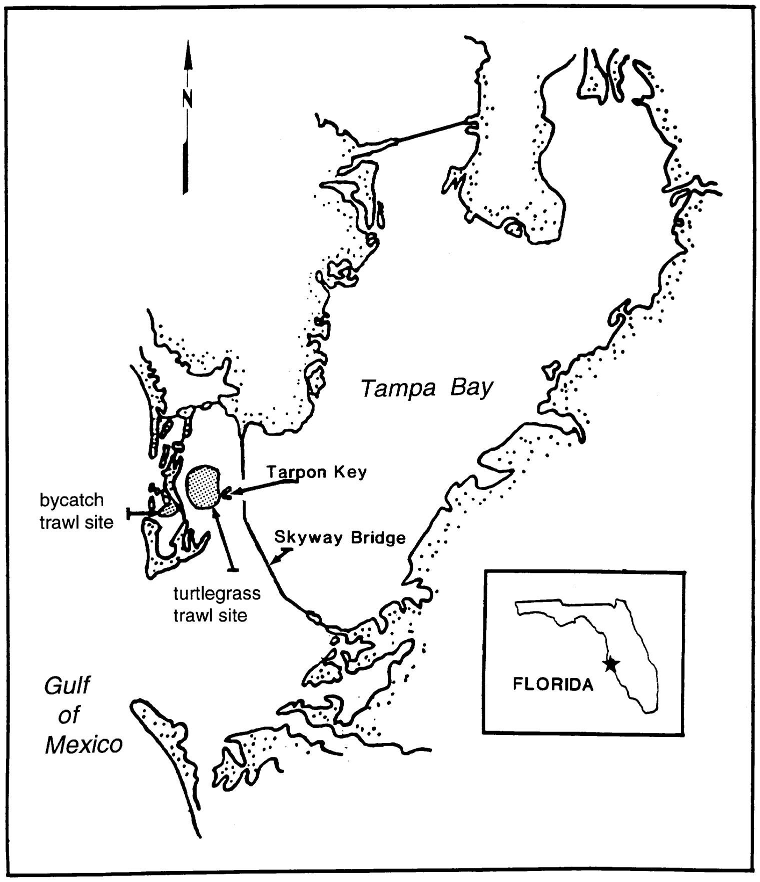

Figure 1

Location of bycatch and turtlegrass trawl sites within Tampa Bay, Florida, 27°40' North latitude, 82°27' West longitude.

Five 15-cm diameter × 20-cm deep substrate cores were taken randomly along a lengthwise midline transect within each impact area at each specified trawl level. For each core the shoot density, longest blade length, total blade length per shoot, and number of blades per shoot (from three randomly selected shoots) were recorded. The turtlegrass standing crop for each core was measured separately for above- and below-ground dry-weight biomass (dried at 60°C for at least 48 hours).

The sequential seagrass measurements within each replicate plot were used in regression analysis to detect rates of decrease for each of the different plant parameters as a function of trawl level. The regression slope (rate of decrease) for each plot was calculated for each plant parameter. Mean rate of decrease for each plant parameter was calculated for each month (all plots combined, n=9 for each month). T-tests were used to compare differences (P<0.05) in mean rate of decrease for each plant parameter for each month.

Mortality of bycatch fish

The bycatch collection site was southwest of Tierra Verde, near the mouth of Tampa Bay (Fig. 1). Each month 30 trawls of 5-min duration were made at this site over three consecutive nights. Trawl and culling times selected were based on observations of commercial live-bait shrimp fishing vessels and shortest times observed used to obtain conservative estimates of bycatch fish mortality. In August, the catch from one net of a trawl pair was allowed to sit on the culling table for 2 min prior to placement in the on-deck live well. The catch from the other trawl net was discarded. While the catch was sitting on the culling table, algae and detritus were removed to reduce subsequent fish entanglement. To reduce the effect of predation on mortality estimates, hardhead catfish, *Arius felis*, were removed from the catch. Bycatch for each trawl was placed in its own separate holding pen, which was held on deck inside an aerated 300-L live well until transferred to a final unvegetated holding site. Holding pens along with bycatch contents were transferred from the on-deck live well to the holding site in a 76-L seawater tank. On-deck holding times were 15 min, transport 5 min. Once at the holding site, pens were placed in the water at a low tide depth >1 m (the minimum) and anchored.

Holding pens were cubical, 1.25 m on each side, constructed of 6.4-mm mesh and had removable mesh tops. A 5-cm diameter polyvinylchloride collar was attached around the top sides of the pen to provide floatation. The mesh top and float collar prevented fish from escaping over the sides, and the top prevented avian predation. Lead-core line was sewn to the bottom seams of each pen to maintain pen volume. Loops attached to each corner of the pen enabled us to anchor the pens with conduit poles.

Owing to low abundance of fish bycatch in November, collection methods were modified; the bycatch from both of the paired trawl nets was combined (only a single trawl net was processed in August), and placed into a single holding pen. Handling procedures were also changed to estimate fish bycatch mortality more conservatively by eliminating catch culling time. In November the catch was placed directly into an aerated 76-L transport tank and during transport to the hold site, algae, detritus, and hardhead catfish were removed. Thus, bycatch mortality results for the two months were not directly comparable. In addition, during November the holding pens were deployed prior to bycatch collection, and the trawl catch was subsequently transferred from the 76-L transport tank into individual holding pens.

Pens were checked for dead fish (no opercular movement) following initial placement at the hold site, and then at intervals of 2, 8, 12, 24, and 36 hours. Checks involved inspecting each holding pen by systematically lifting portions of the pen netting so that the entire volume, net sides, and bottom could be visually inspected for dead fish while allowing surviving fish to remain immersed. Dead fish were collected at each time check and preserved in 10% formalin. At 36 hours, all dead and live fish were separated and preserved. Fish were identified, and standard length and body depth were measured (to the nearest 0.5 mm). The number of individuals and weights of each species (to the nearest 0.01 g) were recorded for each trawl and holding pen time check. Fish with a body depth <7.5 mm were excluded from survival measurements because they were able to escape through the mesh and would cause an unrepresentative mortality estimate.

Because the number of individuals per species per trawl was generally <5, we pooled all 30 trawls for each month to assess survival. The more numerous fish species (spotted seatrout, *Cynoscion nebulosus*, pinfish, *Lagodon rhomboides*, and silver perch, *Bairdiella chrysoura)* were subdivided into small (25.0–65.0 mm standard length, SL) and large (65.5–125.0 mm SL) size classes for mortality comparisons. Mojarra, *Eucinostomus* spp. (including silver jenny, *Eucinostomus gula*), were smaller and were subdivided into small (25.0–55.0 mm) and large (55.5–95.0 mm) size classes so that we could examine size-related mortality. Determination of differential size-class mortality was tested with log-linear model analysis ($P<0.05$).

Salinity and air and water temperatures were measured hourly during bycatch trawling.

Results

Turtlegrass

Regression analysis to estimate mean rate of decrease showed no significant ($P>0.05$) reduction in mean shoot density, number of blades per shoot, longest blade length per shoot, total blade length per shoot, or above- and below-ground biomass with increased trawling during either month. Monthly vegetation measurements at each trawl level (all nine sites combined) are shown in Table 1.

Fish bycatch

We collected a total of 5901 fish representing 42 species; 3262 fish (29 species) in August, 2639 fish (36 species) in November. Mojarra (including silver jenny) were 79.3% (August) and 52.1% (November) of the total catch (Table 2). Most mojarra were smaller than 40 mm SL and were identified as *Eucinostomus* spp., whereas all larger Gerreidae could be identified as silver jenny. The unreliability of the identification of smaller Gerreidae (those smaller than 40 mm SL) precluded their definitive identification to species (Matheson and McEachran, 1984). Mojarra less than 40 mm composed 60.0% (August) and 24.7% (November) of all fish collected, and silver jenny represented 19.3% (August) and 27.4% (November) of all fish collected (Table 2).

Survival was variable (0–100%) among species and months (Table 2; Fig. 2). Among the abundant species (those with at least 20 individuals for each month), high survival was observed for gulf toadfish, *Opsanus beta*, pigfish, pinfish, and gray snapper, (Table 2; Fig. 2). Abundant species with low survival were silver perch, mojarra, silver jenny, and spotted seatrout. Greatest mortality in most species occurred within the first 8 or 12 hours after collection (Fig. 2).

Small fish were significantly ($P<0.05$) more susceptible to trawl-induced mortality than larger fish (Table 3). This was particularly evident for silver perch, spotted seatrout, pinfish, and mojarra (including silver jenny).

Species-specific survival was greater in November than August (Table 2; Fig. 2). For those species for which at least 20 individuals were collected each month, an average increase of 30.5% species-specific survival was observed in November compared with August. Silver perch (63.6%), gulf pipefish, *Syngnathus scovelli*, (48.1%), and gray snapper (35.0%) had the highest survival increases.

Average air and water temperatures observed were 31 and 32°C, respectively, in August, 23 and 24°C, respectively, in November. Salinity averaged 35 ppt during both months.

Discussion

Because roller trawls were designed to reduce seagrass fragment collection, it has been assumed that they have minimal impact on seagrass habitat (Tabb and Kenny, 1969; Berkeley et al., 1985). We were unable to detect significant trawl impacts on shoot density, structure, or biomass of turtlegrass by intensive short-term (18 trawls within three hours) trawling. This finding supports conjectures by Woodburn et al. (1957) and Tabb and Kenny (1969) that roller trawls have minimal impact on turtlegrass habitat.

However, we did not test for effects of repetitive trawling over turtlegrass beds over a longer period of time. Trawling may cause elevated localized turbidity, which could chronically reduce the potential for seagrass to perform photosynthesis (Kenworthy and Haunert, 1991). In contrast, limited trawling in areas with substantial epiphytic growth and numerous senescent turtlegrass leaves may enhance light availability by removing old plant parts (Woodburn

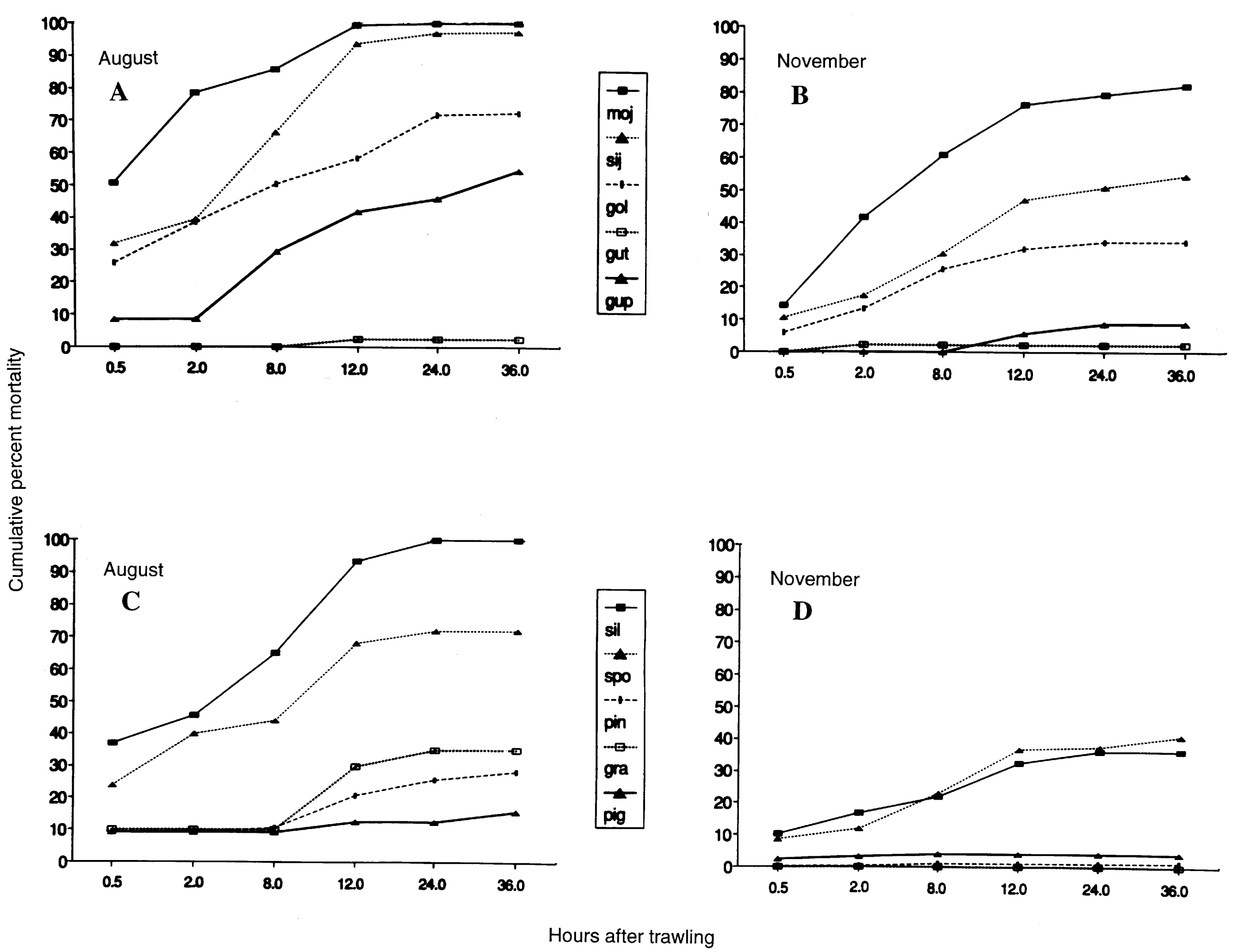

Figure 2

(**A–D**) Cumulative percent mortality in August and November of the abundant (at least 20 individuals per sample month) species collected with shrimp trawls and held in floating pens for 36 h. As noted in the text, handling procedures differed between the two collection periods. Species codes: moj = mojarra, sij = silver jenny, gol = goldspotted killifish, gut = gulf toadfish, gup = gulf pipefish, sil = silver perch, spo = spotted seatrout, pin = pinfish, gra = gray snapper, and pig = pigfish.

et al., 1957) and epiphytic growth from the plants (author's personal observation).

Trawling may affect associated faunal communities by collecting and redistributing macroalgae and turtlegrass litter. Redistribution can reduce the habitat complexity of one area and increase that of another. The alteration of habitat can in turn influence species composition and abundance (Gore et al., 1981; Kulczycki et al., 1981; Leber, 1985).

Fish species were not equally susceptible to mortality by exposure or net injury. Regardless of handling procedures, mojarra were highly susceptible to mortality. At the other extreme, oyster toadfish and striped burrfish, *Chilomycterus schoepfi*, were much less susceptible to trawl-induced mortality. Because of differential species mortality, fish species diversity and composition may be altered in areas of intense or long-term trawling.

Mortality and size were inversely related for numerous species, also noted by Jean (1963) for cod and American plaice, and by Fritz and Johnson (1987) for freshwater drum, *Aplodinotus grunniens*. A pos-

Table 1

Mean (±1 SE) shoot density, morphometrics, and biomass of turtlegrass per 176.7 cm^2 at selected trawl levels during August and November. For each trawl level during a month $n = 9$.

Number of trawls	Shoot density	Number of blades per shoot	Longest blade per shoot (cm)	Total length all blades per shoot (cm)	Above-ground biomass (g)	Below-ground biomass (g)
August						
0	8.1 (0.8)	2.5 (0.1)	31.6 (3.0)	63.5 (7.4)	1.3 (0.1)	7.4 (0.6)
1	7.1 (1.1)	2.4 (0.1)	32.4 (2.0)	61.3 (3.7)	2.3 (0.4)	7.0 (1.1)
3	7.8 (0.9)	2.4 (0.1)	34.0 (2.6)	64.4 (6.4)	2.2 (0.2)	7.2 (1.0)
9	9.1 (0.9)	2.4 (0.1)	28.3 (1.6)	55.2 (3.3)	1.5 (0.1)	8.3 (0.8)
November						
0	10.2 (0.7)	2.3 (0.1)	24.1 (1.2)	41.4 (2.7)	1.1 (0.1)	7.1 (0.6)
9	10.4 (0.4)	2.3 (0.1)	23.7 (0.9)	40.2 (2.0)	1.2 (0.1)	7.5 (0.5)
18	10.4 (0.6)	2.2 (0.1)	23.3 (1.4)	38.3 (2.3)	1.1 (0.1)	7.3 (0.6)

Table 2

Fish collected during August and November live-bait shrimp trawling in Tampa Bay, Florida. Percent survival was determined 36 hours after collection.

		Total number caught		Percent of total catch		Percent survival	
Common name	Scientific name	August	November	August	November	August	November
Mojarra (<40 mm)	*Eucinostomus* spp.	1956	655	60.0	24.7	0.5	18.2
Silver jenny	*Eucinostomus gula*	629	725	19.3	27.4	3.2	45.7
Goldspotted killifish	*Floridichthys carpio*	182	82	5.6	3.1	36.8	65.0
Pinfish	*Lagodon rhomboides*	152	259	4.7	9.8	71.7	98.1
Scaled sardine	*Harengula jaguana*	52	11	1.6	0.4	15.8	54.6
Silver perch	*Bairdiella chrysoura*	46	77	1.4	2.9	0.0	63.6
Rainwater killifish	*Lucania parva*	42	9	1.3	0.3	28.6	44.4
Gulf toadfish	*Opsanus beta*	40	101	1.2	3.8	97.5	98.0
Pigfish	*Orthopristis chrysoptera*	32	122	1.0	4.6	84.4	95.9
Spotted seatrout	*Cynoscion nebulosus*	25	117	0.8	4.4	28.0	59.0
Gulf pipefish	*Syngnathus scovelli*	22	33	0.7	1.2	45.8	93.9
Gray snapper	*Lutjanus griseus*	20	46	0.6	1.7	65.0	100.0
Striped burrfish	*Chilomycterus schoepfi*	13	198	0.4	7.5	100.0	99.5
Blackcheek tonguefish	*Symphurus plagiusa*	11	21	0.3	0.8	63.6	90.5
Planehead filefish	*Monacanthus hispidus*	1	84	<0.1	3.2	0.0	95.2
Southern puffer	*Sphoeroides nephelus*	0	26	0.0	1.0		96.2
Others		39	73	1.2	2.8	33.3	82.2

sible explanation for perceived differences in trawl-induced mortality between small and large size-class fish may be attributed to larger fish having a greater proportion of muscle tissue and larger energy stores than smaller fish; the larger fish are thus able to avoid net contact during prolonged trawl tows, (Fritz and Johnson, 1987). This may cause small fish to be more susceptible than large fish to stress and mortality due to capture. Consequently, high mortality of small individuals, directly or indirectly due to trawling, could potentially reduce the local stock of juvenile fish. This reduction in juvenile fish in turn could reduce the reproductive potential of a species and alter species diversity and composition within affected areas (Wassenberg and Hill, 1989).

Greater survival during November was most evident for silver perch, gulf pipefish, and gray snapper. However, we were not able to assess whether observed increased survival was the result of changes in handling procedures that we instituted (culling versus no culling), or to seasonal factors, such as differences in water temperature as noted by Jean (1963), between our survey months. The 2-min culling time and high August air temperature may have substantially stressed the fish in our study. Also, the higher water temperature in August may have reduced the ability of fish to recuperate from handling because of increased respiratory demand (Alderdice, 1963; Bond, 1979) and lower ambient dissolved oxygen levels (Raymont, 1980). However, even with the changes in handling instituted in November to reduce stress, net injury alone appeared to cause substantial mortality in mojarra, spotted seatrout, silver perch, and goldspotted killifish, *Floridichthys carpio*. Mean size of fish caught was larger in November than in August; this too may have contributed to the higher survival observed.

Table 3

Percent fish mortality in relation to standard length (mm) for species with 20 or more individuals collected during each month. Parentheses indicate number of individuals in a size class. Asterisks (*) indicate significant differences $P<0.05$), based on log-linear model analysis, in mortality between size classes.

Species	Collection period	Size class (mm) 25.0–65.0	65.5–125.0
Silver perch	August	100.0 (42)	100.0 (4)
	November*	46.0 (50)	14.8 (27)
Spotted seatrout	August*	65.0 (20)	20.0 (5)
	November*	52.6 (78)	17.9 (39)
Pinfish	August*	47.1 (34)	22.9 (118)
	November		1.5 (259)
		25.0–55.0	55.5–95.0
Mojarra	August	99.1 (2435)	92.2 (153)
	November*	71.0 (1256)	28.0 (125)

Fish abundance per holding pen was not recorded until the end of the 36-h mortality observation period. Because of this, and the fact that predation of live and dead individuals within the pens was not measured, the mortality for smaller species or smaller individuals of a species may be conservative. However, the initial confinement may have also enhanced the survival of injured or disoriented fish by reducing predation that might have been experienced in an open system. Even if bycatch organisms survive trawling and culling they may be quite susceptible to predation. High postrelease predation on bycatch has been observed by prawn trawlers (Hill and Wassenberg, 1990), and this fate probably awaits much of the bycatch overboarded during bait-shrimp trawling. Many bait-shrimp boat captains have reported schools of hardhead catfish following boats and feeding on the bycatch as it is thrown overboard. We similarly observed numerous hardhead catfish and other predatory fish following our boats and feeding on bycatch, and numerous such predatory individuals were collected during our sampling.

Trawl-induced mortality may occur past our 36-h observation period. Numerous fish still alive after the 36-h observation period had missing caudal fins or ulcers, or both. Such fish are were susceptible to subsequent mortality through predation or infection, or both. Moreover, individuals recaptured and culled again in heavily exploited areas could suffer high mortality rates because of cumulative stress. To understand better the effects of this fishery on the resident fauna, we need additional evaluation of the effects of temperature on mortality; the consequences of postrelease predation, delayed mortality due to initial sublethal damage, and subsequent infection; and finally an evaluation of the potential for recapture of bycatch fish.

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Literature cited

Alderdice, D. F.
1963. Some effects of simultaneous variation in salinity, temperature and dissolved oxygen on the resistance of young coho salmon to a toxic substance. J. Fish. Res. Board Can. 20:525–550.

Berkeley, S. A., D. W. Pybas, and W. L. Campos.
1985. Live bait shrimp fishery of Biscayne Bay. Florida Sea Grant Ext. Prog. Tech. Pap. 40, 16 p.

Bond, C. E.
1979. Biology of fishes. Saunders Inc., Philadelphia, PA, 514 p.

Fonseca, M. S., W. J. Kenworthy, and F. X. Courtney.
1996. Development of planted seagrass beds in Tampa Bay, Florida, USA. I. Plant components. Mar. Ecol. Prog. Ser. 132:127–139.

Fritz, K. R., and D. L. Johnson.
1987. Survival of freshwater drums released from Lake Erie commercial shore seines. N. Am. J. Fish. Manage. 7:293–298.

Gore, R. H., E. E. Gallaher, L. E. Scotto, and K. A. Wilson.
1981. Studies on decapod crustacea from the Indian River Region of Florida: XI. Community composition, structure, biomass and species-areal relationships of seagrass and drift algae-associated macrocrustaceans. Estuarine Coastal Shelf Sci. 12:485–508.

Gutherz, E. J., and G. J. Pellegrin.
1988. Estimate of the catch of red snapper, *Lutjanus campechanus*, by shrimp trawlers in the U. S. Gulf of Mexico. Fish. Rev. 50(1):17–25.

Harris, A. N., and I. R. Poiner.
1990. Bycatch of the prawn fishery of Torres Strait; composition and partitioning of the discards into components that float or sink. Aust. J. Mar. Freshwater Res. 41:37–52.

Hill, B. J., and T. J. Wassenberg.
1990. Fate of discards from prawn trawlers in Torres Strait. Aust. J. Mar. Freshwater Res. 41:53–64.

Jean, Y.
1963. Discards of fish at sea by northern New Brunswick draggers. J. Fish. Res. Board Can. 20:497–525.

Kenworthy, W. J., and D. Haunert (eds.).
1991. The light requirements of seagrasses: proceedings of a workshop to examine the capability of water quality criteria, standards and monitoring programs to protect seagrasses. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFC-287, 181 p.

Kulczycki, G. R., R. W. Virnstein, and W. G. Nelson.
1981. The relationship between fish abundance and algal biomass in a seagrass-drift algae community. Estuarine Coast. Shelf Sci. 12:341–347.

Leber, K. M.
1985. The influence of predatory decapods, refuge, and microhabitat selection on seagrass communities. Ecology 66:1951–1964.

Matheson, R. E., and J. D. McEachran.
1984. Taxonomic studies of the *Eucinostomus argenteus* complex (Pisces: Gerreidae): preliminary studies of the external morphology. Copeia 4:893–902.

Raymont, J. E.
1980. Plankton and productivity in the oceans. 2nd ed., vol. 1, Phytoplankton. Pergamon, Oxford, 489 p.

Tabb, D. C., and N. Kenny.
1969. A brief history of Florida's live bait shrimp fishery with description of fishing gear and methods. FAO Fish Rep. 57:1119–1134.

Wassenberg, T. J., and B. J. Hill.
1989. The effects of trawling and subsequent handling on the survival rates of the bycatch of prawn trawlers in Moreton Bay, Australia. Fish. Res. 7:99–110.

Woodburn, K. D., B. Eddred, E. Clark, R. F. Hutton, and R. M. Ingle.
1957. The live bait shrimp industry of the west coast of Florida. Florida State Board Conserv. Tech. Ser. 21, 33 p.