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Shrimp Loss Associated with Turtle Excluder Devices: Are the Historical Estimates Statistically Biased?

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Abstract.—Estimates of penaeid shrimp losses associated with the use of turtle excluder devices (TEDs) in offshore waters of the southeastern USA are derived from a single study conducted from 1988 to 1990. The estimates were based on paired tows in which the inboard and outboard nets on one side of the vessel were equipped with TEDs while the nets on the other side were not. Comparison of the mean catch rates from the TED and control nets provided an estimate of shrimp loss. However, the net positions were not rotated by trip, the try net (i.e., a small shrimp trawl fished off one side of the vessel in front of the trailing inboard net) was fished in front of the inner standard net 70% of the time, and the data show that catches in the standard net trailing the try net were significantly reduced by operation of the try net. These findings warranted a new analysis excluding data from inner net pairs, as is done in the modern gear testing protocol. The reanalysis suggests that the shrimp loss rates for Georgia TEDs with and without accelerator funnels were 5.5% and 7.5%, respectively, and that the highest level of shrimp loss (15%) was associated with the "Super Shooter" TED with an accelerator funnel. The results of the historical study indicated that the shrimp loss rate associated with the Super Shooter design was only 1% and that the shrimp loss rates associated with the Georgia TED with and without accelerator funnels were 3.6% and 13.6%, respectively. Overall, we conclude that the historical estimates are biased. A reanalysis suggests that the shrimp loss rate associated with TED use in offshore waters of the southeastern USA is on the order of 6%. We also conclude that a new, well-designed National Marine Fisheries Service-approved study is needed.

Turtle excluder devices (TEDs) were first required in the penaeid shrimp trawl fisheries of the southeastern USA in 1987. However, widespread use of TEDs in offshore Gulf of Mexico waters and most of the southeastern Atlantic coast did not occur until about 1990 (for a review, see Crowder et al. 1995 and below). A TED generally consists of metal grids that have been installed in a trawl to enable endangered sea turtles (Cheloniidae and Dermochelyidae) to pass safely out of the net through a trapdoor without losing a large fraction of the shrimp catch. The shrimp, which are much smaller than sea turtles, pass through the grid to the cod end of the net, while the sea turtles are diverted out of the net by the grid. Previously, a small but unknown fraction of the fishing fleet also equipped their nets with accelerator funnels (i.e., a small mesh funnel sewn into the net directly in front of the TED grid to accelerate water flow through the TED and into the cod end of the net).

Some penaeid shrimp loss typically occurs in conjunction with TED use. Estimates of the magnitude of this loss in the penaeid shrimp fisheries of the southeastern USA come from a single study. Renaud et al. (1993) published the results of the 1988–1990 studies of TED shrimp loss conducted by the National Marine Fisheries Service (NMFS). The NMFS tested three types of TEDs: the Georgia TED (grid constructed of straight bars) equipped with an accelerator funnel, the same Georgia TED without an accelerator funnel, and the "Super Shooter" TED (grid constructed with a bent-bar design) equipped with an accelerator funnel (see Figure 2 in Renaud et al. 1993). The Georgia TEDs with and without accelerator funnels were reported to have shrimp loss rates of 3.6% and 13.6%, respectively, while the Super Shooter TED with an accelerator funnel had a shrimp loss rate of about 1% (Renaud et al. 1993).

The studies published by Renaud et al. (1993) constituted the original attempts to measure penaeid shrimp loss based on paired tows of nets with and without TEDs. In these studies, both of the inboard and outboard nets on one side of quad-rigged (two nets on each side) vessels were equipped with TEDs, while the inboard and outboard nets on the opposite side were

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TABLE 1.—Operational codes used to classify trawl tows selected by Renaud et al. (1993) for National Marine Fisheries Service (NMFS)-conducted studies versus the codes selected by the authors of this study.

Code	Frequency	NMFS	This study	Description
A	0	X		Nets not spread
B	9	X		Gear bogged into mud
C	7	X	X	Bag choked by object or large animal
E	0	X		Twisted bridle lines
F	33	X		Gear fouled on itself
L	3	X	X	Premature termination of tow by hang
M	123	X		Bags dumped together (i.e., catches not separated by net)
O	32	X	X	Log or other large object in net, but net was towed
S	33	X		Tickler chain fouled or tangled
Z	1,048	X	X	Good tow, no abnormalities
H	0		X	Rough weather

standard nets without TEDs (i.e., "naked" nets). All nets on a vessel were "tuned" by NMFS or Sea Grant gear specialists at the start of the experimental cruises. For each tow on a cruise, the shrimp catch per unit effort (CPUE), defined as heads-off weight (lb)/h per 100 ft of headrope towed, from the two TED-equipped nets was averaged and compared with the average shrimp CPUE of the two standard nets to provide one TED-standard net data pair per tow (Renaud et al. 1993). If one net on a side was excluded from analysis because of an unacceptable operation code (Table 1), the CPUE from the remaining net was paired with the average of the CPUEs from the other two nets. For vessels with only one net on a side, one net was equipped with a TED and the other was not. These data pairs were pooled with the data pairs from quad-rigged vessels. Paired *t*-tests were used to test the hypothesis of equal CPUE of shrimp for standard and TED-equipped trawls.

The experimental design of the Renaud et al. (1993) studies called for alternating the standard- and TED-equipped nets by side of vessel on each trip. This approach, combined with large sample sizes, was intended to offset potential try net effects on the penaeid shrimp loss estimates. A try net is a small shrimp trawl (e.g., 10–20 ft headrope) that is fished for short intervals off one side of the vessel in front of the trailing inboard net. In the experimental design, inner nets (with and without TEDs) would be exposed to the potential try net effects for equal amounts of time. However, more than 70% of the tows included in the Renaud et al. (1993) analyses were made with the try net in front of the standard net rather than the planned 50%. Adding the try net catches to the trailing inboard net increased the average catch rates for the affected net pair by 5–6% (Renaud et al. 1991). The analyses conducted by Renaud et al. (1993) did not include any adjustment for the observed try net effects on the inner nets despite the observation that the potential level of this effect was on the same order of magnitude as the estimated shrimp losses.

Renaud et al. (1991) acknowledged the problem of try net impacts and initially considered adding the try net catch to the trailing net as a potential solution. They concluded that "adding the entire try net catch to the trailing net confounds the data since all of the catch would probably not have ended up in the trailing net in the absence of a try net." Therefore, they reported results that excluded try net data. By taking this approach, however, they essentially assumed that none of the try net catch would have ended up in the trailing net, which is not very plausible. The simple solution is to restrict the analyses to data from outboard nets.

Given the potential bias in the Renaud et al. (1993) analysis due to try net effects, an expert panel of NMFS (one of us [J.M.N.] was a coauthor of the original paper), industry (Gulf and South Atlantic Fishery Foundation or GSAFF), and academic scientists (Texas A&M Sea Grant) was convened to determine whether a new analysis might be warranted. The panel (which included all coauthors of this study) conducted an analysis to determine whether try nets had a significant impact on the inner net catches. Next, following Mitchell and Foster (2004), we restricted the analysis to data pairs from TED-equipped and standard nets in the outboard position on quad-rigged vessels. This approach was intended to eliminate or minimize any potential try net effect on the penaeid shrimp loss estimates. The resulting estimates provide the best available data for estimating shrimp loss associated with the historical TEDs. The results of these analyses have taken on new importance because of changes in TED regulations that occurred in 2003, as will be discussed below.

Methods

A review of the historical TED data by the panel revealed that there were 126 paired tows during which both inner nets had been used as controls and try net position was also recorded. These data provided a basis for directly testing the impact of the try net on the trailing main-net catches by means of a paired *t*-test. The rationale of the panel was that if operation of the try net had a significant impact on the catch of the trailing inner main net, a new analysis of the historical data using only the data from the outer net pairs would be warranted.

The initial step in analyzing the data from the outboard nets was to review and select the operational codes associated with each net and tow combination that would be used in the analyses. Data from nets with 10 of the 22 possible operational codes were used in the original NMFS analyses (Renaud et al. 1990, 1991, 1993). The panel, by consensus, agreed to use four of these plus one additional code (Table 1). The operational codes accepted included "good" tows, tows made in rough weather, tows terminated prematurely by a hang-up, and tows in which large objects or animals were caught in the net and may have choked the bag or prevented the catch from getting into the cod end of the net or both. The panel did not include six of the codes used by Renaud et al. (1990, 1991, 1993) because (1) we did not believe that the problems reflected by these codes were TED related, (2) the codes designated circumstances that would alter the performance of the affected trawl and bias the comparisons, or (3) the code designated a circumstance where the catch in the outer net could not be separated from the catch in the inner net. However, we conducted a separate analysis using data from outboard nets only and the same operational codes selected by Renaud et al. (1993). A comparison of the two sets of outboard net analysis results enabled an evaluation of the impacts of using the reduced set of operational codes.

Once the operational codes were agreed upon, the panel then restricted the data pairs to those from outboard nets based on the above rationale. This same approach is routinely used today for evaluations of shrimp loss resulting from trawl modifications (e.g., Mitchell and Foster 2004). We then independently queried the data to determine the number of tows by TED type, statistical area, and phase (year). Paired *t*-tests and standard regressions of experimental net catch on control net catches were conducted for each gear type for both phase I (March 1988–July 1989) and phase II (September 1989–August 1990). Finally, paired *t*-tests were conducted for each gear type by phase and region. The regions defined by the panel were based on habitat and shrimp fishing differences and included the southeastern Atlantic seaboard, the eastern Gulf of Mexico, and the western Gulf of Mexico. The mouth of the Mississippi River was used as the dividing line between the eastern and western Gulf of Mexico.

Results and Discussion

Try Net Effect on Inner Nets

Standard nets were fished in the inner position on each side of the vessel during 126 tows. The mean catch in the inner net trailing the try net (7.6 lb of shrimp/h) was about 12% lower than the mean catch of the inner net on the opposite side of the vessel (8.6 lb of shrimp/h). The mean of the differences between the pairs was 1.0 lb of shrimp/h with a 95% confidence interval of 0.6–1.4 lb. The corresponding *P*-value was 0.00000031. Operation of the try net had significant impacts on the inner net catches. These findings provided direct evidence that the TED shrimp loss rates estimated by Renaud et al. (1993) were statistically biased and that the exclusion of data from inboard nets was warranted. The nature of the bias is described below.

Renaud et al. (1990) reported that the try net was fished in front of the standard net 76% of the time (664 of 877 tows) and was fished in front of the TED net only 24% of the time (214 of 877 tows). They reported that adding the try net catches to the trailing net increased the mean catch of the standard nets by 6% but had no effect on the mean TED net catch. They concluded that corrections based on try net catches to the trailing net increased the difference between the standard and TED nets in all cases. The imbalance in try net position relative to standard and TED nets continued in the second year of the study. Of the 403 paired tows used in the phase II analyses, the try net was in front of the standard net 57% (230 tows) of the time and in front of the TED net 43% (173 tows) of the time (Renaud et al. 1991). The mean CPUEs for the standard and TED nets trailing the try nets were increased by 5% and 6%, respectively, when the try net catches were added to the trailing nets.

Overall Shrimp Loss Estimates from Outer Net Comparisons

The total frequencies of the operational codes selected by Renaud et al. (1993) and by the authors of this study that occurred for the outer nets are shown in Table 1. The total frequency for the Renaud et al. (1993) codes was 1,288 versus a frequency of 1,090 for the codes used in this study. Approximately 85% of the samples were common to both studies. Of the 198 samples that we did not use, 123 were deleted because the two nets on a side were dumped together and the catch from the outer net could not be determined (operational code M). The one code we added that was not used by Renaud et al. (1993) did not occur. The

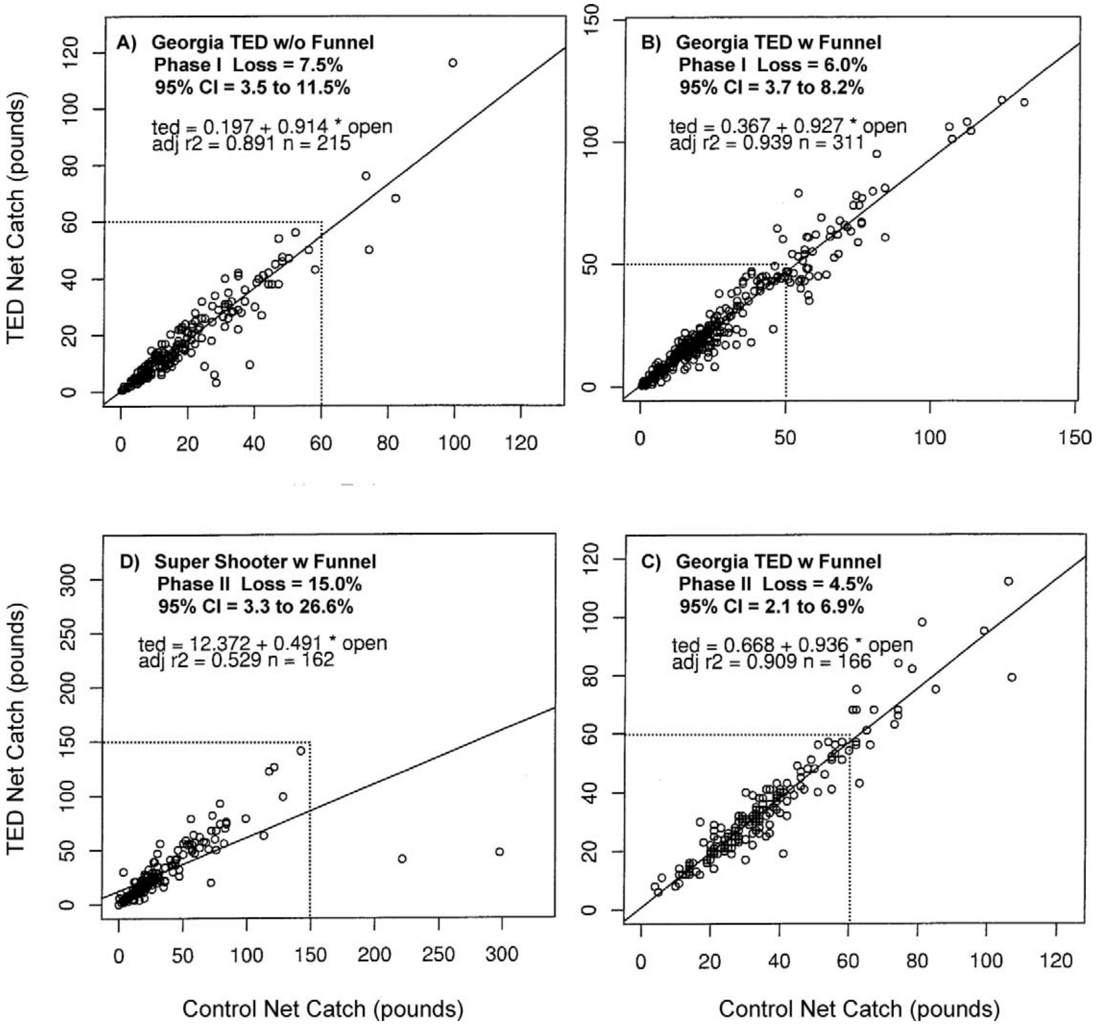

FIGURE 1.—**(A–D)** Data plots and estimated relationships for penaeid shrimp catches in control (open) nets versus catches in nets with various types of turtle excluder devices (TEDs) using the operational codes selected by the authors (see text). Phase I data were collected from March 1988 to July 1989, phase II data from September 1989 to August 1990. All the shrimp loss estimates were significant at $P < 0.05$.

remaining codes used by Renaud et al. (1993) but not by us included events in which one or both of the outer nets bogged into mud ($n = 9$) or became fouled with itself ($n = 33$), or the tickler chain became fouled or tangled ($n = 33$). The occurrence of these events in one or both outer nets would independently lower the catch in the affected net and consequently render any TED versus standard net comparison meaningless.

Ignoring regional effects, the highest level of overall shrimp loss (15.0%) was observed for the Super Shooter TED equipped with an accelerator funnel (Figure 1D). However, note that this result is influenced by two tows with high leverage. The shrimp loss for a Georgia TED without an accelerator funnel was 7.5% (Figure 1A) as compared with losses of 6.0% (Figure 1B) and 4.5% (Figure 1C) for Georgia TEDs equipped with accelerator funnels. All the observed differences were significant at $P \leq 0.05$. The overall loss for Georgia TEDs with accelerator funnels based on combining the data for both years of the study was 5.5%.

The results for the same analysis (i.e., using data from outboard nets only) but applying the Renaud et al. (1993) operational codes (except for code M, bags dumped together) yielded results for the Georgia and Super Shooter TEDs with accelerator funnels that were similar to the results obtained from the primary analysis (compare Figure 1B–D with Figure 2B–D). However,

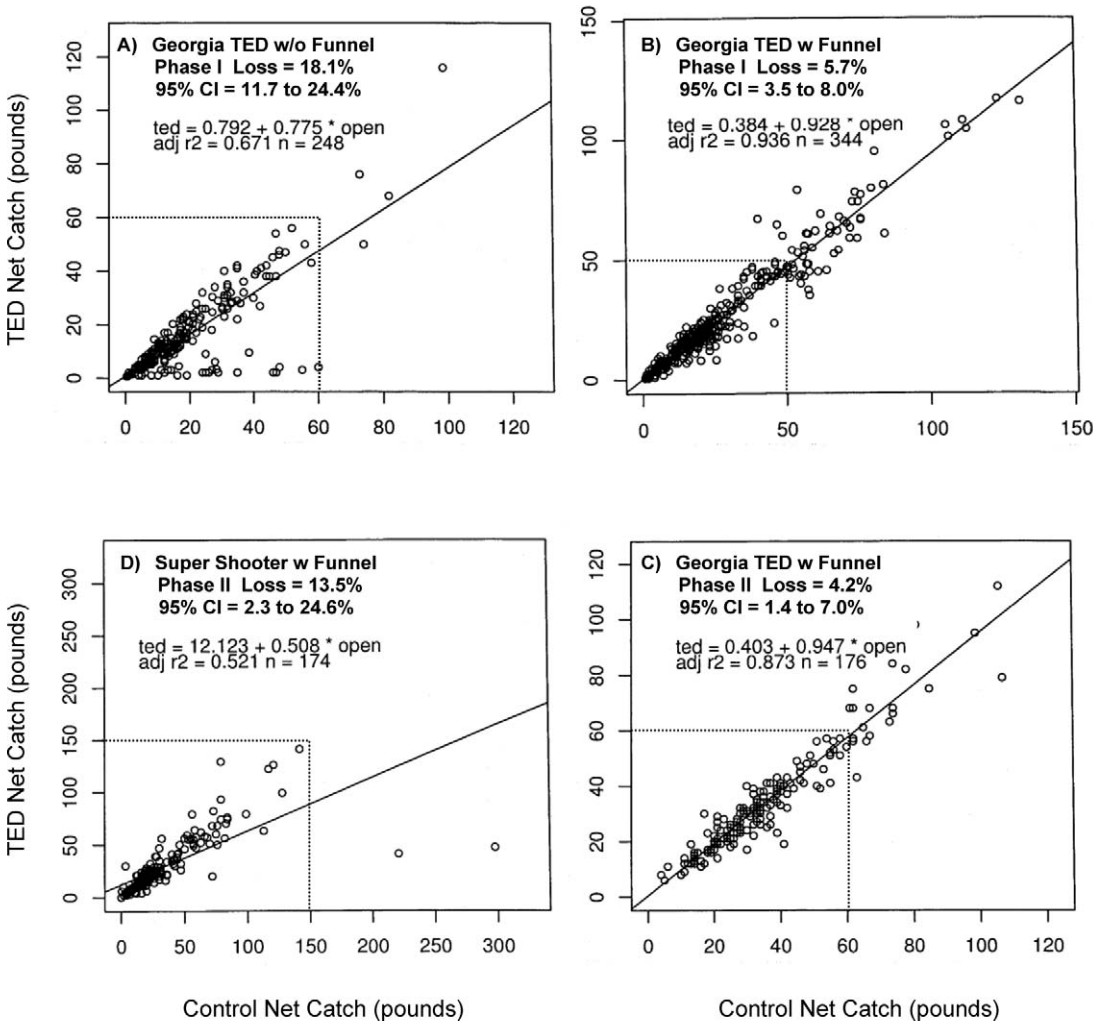

FIGURE 2.—**(A–D)** Data plots and estimated relationships for penaeid shrimp catches in control (open) nets versus catches in nets with various types of turtle excluder devices (TEDs) using the operational codes selected by Renaud et al. (1993). See Figure 1 for additional details.

the shrimp loss estimate obtained for the Georgia TED without an accelerator funnel based on the Renaud et al. (1993) operational codes was 18.1% (Figure 2A), nearly 2.5 times greater than the loss estimated using the panel-selected codes (see Figure 1A). We believe that the high shrimp loss estimate that results from using the Renaud et al. (1993) operational codes is attributable to factors other than TED performance.

The comparative loss values reported by Renaud et al. (1993) using data from both inboard and outboard nets were 1% for the Super Shooter TED with accelerator funnel ($P = 0.58$), 13.6% for the Georgia TED without an accelerator funnel ($P < 0.01$), and 3.6% for the Georgia TED with an accelerator funnel ($P = 0.02$). The reanalysis suggests that (1) the shrimp loss associated with the Super Shooter TED was much higher than originally estimated; (2) the Georgia TED without an accelerator funnel performed better than formerly estimated (shrimp loss of about 8.0% versus 14%); and (3) the shrimp loss for the Georgia TED with an accelerator funnel was 5.5%, about the same as the 4% loss estimated by Renaud et al. (1993). However, these overall analyses ignore regions.

Regional Shrimp Loss Estimates from Outer Net Comparisons

Penaeid shrimp losses by phase, region, gear type, and operational code are shown in Table 2. With the

TABLE 2.—Comparison of penaeid shrimp loss estimates obtained using the gear operational codes chosen by this study and those chosen by Renaud et al. (1993) for the National Marine Fisheries Service-conducted studies. Phase I was March 1988–July 1989, and Phase II was September 1989–August 1990. Abbreviations are as follows: TED = turtle excluder device; GA TED/wo = Georgia TED without accelerator funnel; GA TED/w = Georgia TED with accelerator funnel; SS TED/w = Super Shooter TED with accelerator funnel; ATL = Atlantic Ocean; WGM = western Gulf of Mexico; EGM = eastern Gulf of Mexico. Values with plus signs indicate shrimp catch gains rather than losses.

			This study			Renaud et al. (1993)		
Phase	Gear	Region	Loss (%)	*n*	*P*	Loss (%)	*n*	*P*
I	GA TED/wo	ATL	8.50 (4.05–12.95)	186	0.00022	21.91 (14.19–29.63)	218	<0.00001
	GA TED/w	WGM	7.17 (2.80–11.54)	126	0.00150	6.22 (1.75–10.69)	139	0.06673
	GA TED/w	EGM	3.69 (0.49–6.89)	155	0.02430	3.88 (0.83–6.93)	173	0.01286
	GA TED/w	ATL	10.33 (5.98–14.67)	30	<0.00001	10.40 (6.08–14.72)	32	<0.00002
II	GA TED/w	ATL	6.36 (3.04–9.69)	63	0.00030	6.36 (3.04–9.69)	63	0.00030
	GA TED/w	WGM	3.47 (0.16–6.78)	103	0.03985	+3.09 (0.85–7.04)	113	0.12420
	SS TED/w	WGM	+32.94 (0.72–66.60)	43	0.5496	+32.41 (0.79–65.55)	45	0.05545
	SS TED/w	ATL	6.00 (0.88–11.12)	119	0.02220	+4.61 (0.85–10.08)	129	0.9810

exception of the results for the Georgia TED without an accelerator funnel fished in the Atlantic region during phase I, the selection of a reduced set of operational codes had little impact on the overall results compared with the results obtained using the Renaud et al. (1993) codes (Table 2). The following discussion is based on results obtained with the panel's operational codes. Studies in the Atlantic region during phase I included a comparison of the shrimp loss incurred using a Georgia TED with and without an accelerator funnel. Surprisingly, the shrimp loss from this TED with a funnel (10.33%) was greater than the loss associated with use of this TED without a funnel (8.5%). However, the samples for the Georgia TED without a funnel were collected from three areas spread between mid-Florida and South Carolina, whereas the samples for the Georgia TED with a funnel were taken in only one area off northern Florida. The observed differences between TEDs with and without an accelerator funnel may be confounded by the regional imbalance in sampling. The samples obtained for the Georgia TED with an accelerator funnel in the eastern and western Gulf of Mexico during the first year of the study suggested shrimp loss rates of 3.69% and 7.17%, respectively (Table 2).

In phase II, the Atlantic sampling by means of the Georgia TED with an accelerator funnel was conducted in the same region of northern Florida that had been sampled in year 1. The penaeid shrimp loss for this gear type during phase II was 6.36%, which was 25% lower than the 8.5% observed during phase I. Similarly, the loss associated with this gear type in the western Gulf of Mexico during phase II (3.47%) was lower than had been observed during phase I (7.17%). However, in this instance, the phase I sampling included observations from south Texas, an area that was not sampled during phase II. The observed decline could, once more, be a sampling artifact.

The Atlantic samples for the Super Shooter TED were restricted to the Pamlico Sound area of North Carolina, and much of the sampling was conducted inside the sound. The observed penaeid shrimp loss for this gear type in this setting was 6.0%. The representativeness of the samples from this inshore sound area for the offshore waters of the entire southeastern Atlantic seaboard is thus questionable.

The most surprising result of the reanalysis was the estimated penaeid shrimp loss of 32.9% found for the Super Shooter TED based on samples from the western Gulf of Mexico (Table 2). Although the sample size was small ($n = 43$), these results cannot be discounted. The loss is greatly influenced by the two samples taken in shallow coastal waters in the nearshore zone of western Louisiana (Statistical Area 17), where the control net catches were more than 200 lb, the highest recorded in the study. These two data pairs are plotted in Figure 1D, and these two data pairs are the main reason that the overall shrimp loss estimates for the Super Shooter TED were so high. Both the standard net and the TED nets in these pairs were determined to be operational code Z (good tow, no abnormalities). These data suggest that shrimp loss from TEDs might be greatest when catch rates are high.

Event Tow Effects

Based on these results, the penaeid shrimp loss estimates were examined by the operational codes listed for both the TED and control nets. The results of these comparisons are shown in Table 3. Typically, when the TED net exhibited an operational code of Z the loss was small—on the order of 2.6–3.8%. However, when an event occurred (e.g., operational code C, H, L, or O), the loss rates ranged from about

TABLE 3.—Penaeid shrimp losses by study phase, gear type, and turtle excluder device (TED)-net operational code. Operational codes are defined in Table 1 and TED types in Table 2. Values with plus signs indicate shrimp catch gains rather than losses.

			TED net		Control net	
Phase	Gear type	Code	Frequency	Loss (%)	Frequency	Loss (%)
I	GA TED/wo	C	1	88.8	0	
		H	0		0	
		L	0		0	
		O	1	32.5	0	
		Z	213	3.7	213	3.7
I	GA TED/w	C	1	33.3	0	
		H	0		0	
		L	0		1	0
		O	7	27.6	4	+10.3
		Z	296	3.9	296	3.9
II	GA TED/w	C	0		0	
		H	0		0	
		L	1	19.2	0	
		O	5	19.0	2	+9.7
		Z	156	2.6	156	2.6
II	SS TED/w	C	1	54.3	0	
		H	0		0	
		L	0		0	
		O	9	18.8	0	
		Z	148	+12.6%	148	+12.6

19% to 89% (Table 3). Although event tows were infrequent, the magnitude of the corresponding losses was high. These results suggest that the shrimp losses resulting from TEDs are typically small unless an event occurs that causes the shrimp catch to be shunted out of the TED opening for a substantial portion of the tow.

Conversely, when an event occurred in the control net, TED penaeid shrimp loss rates were either negligible or the TED net caught more shrimp than the impacted control net (Table 3). Although sample sizes were again small, the results show that infrequent problematic tows were probably the primary cause of shrimp loss in trawls.

Evaluations of Larger-Opening TEDs

In 2003, larger-opening TEDs were required in the penaeid shrimp fisheries of the southeastern USA (U.S. Office of the Federal Register 2003). The purpose of this change was to better protect the loggerhead turtle *Caretta caretta* and leatherback turtle *Dermochelys coriacea* based on concerns raised by Epperly and Teas (2002). Shrimp loss associated with the new TEDs was estimated by Mitchell and Foster (2004) as a basis for conducting an economic analysis of proposed TED alternatives. Potential changes in shrimp loss were based on comparisons of shrimp catches in nets with the new, larger-opening TEDs equipped with larger-than-required grids to shrimp catches in control nets equipped with previously legal, smaller-opening TEDs with minimum-sized grids of a bent-bar or Super Shooter design. These TEDs were believed to be most representative of the modern TED used immediately before the rule change. Neither the experimental nor the control TEDs were equipped with accelerator funnels because accelerator funnels are seldom used in today's fishery. Mitchell and Foster (2004) found no significant differences in shrimp catches in nets equipped with the new, larger-opening TEDs without accelerator funnels as compared with shrimp catches in nets using the smaller, hard-grid, bent-bar TEDs without accelerator funnels.

The only hard-grid TED without an accelerator funnel that was tested by Renaud et al. (1993) was the Georgia TED which, based on this study, had an overall penaeid shrimp loss of 7.5%. The TED configuration used as a control by Mitchell and Foster (2004) was not evaluated by Renaud et al. (1993). The Environmental Assessment/Regulatory Impact Review economic analysis for the new TED rule (NMFS 2002) used a status quo shrimp loss rate of 3.6%, the result reported by Renaud et al. (1993) for a Georgia TED with an accelerator funnel. No basis for this selection was provided. More reasonable alternatives would have been either to use the shrimp loss rate observed for the only hard-grid/no-funnel TED tested, the Georgia TED, or the Renaud et al. (1993) results for the same Super Shooter TED design that was used as a control by Mitchell and Foster (2004), even though it was used with an accelerator funnel.

Management Implications

The status quo penaeid shrimp loss for the TEDs in use immediately before the recent (2003) TED rule change is unknown. The level of this loss rate affects not only the economic assessments for the various TED alternatives described in NMFS (2002) but also the economic assessment of other technologies, such as bycatch reduction devices (BRDs). The shrimp loss for the "Fisheye BRD" was estimated to range between 3% and 7%, depending on its location in the trawl (GMFMC 1997).

Whether BRDs are practicable depends, in part, on not only the BRD penaeid shrimp loss per se but also the combined TED plus BRD shrimp loss. Renaud et al. (1993) noted that the overall level of shrimp landings would not be reduced by TED shrimp loss, mainly because of overcapitalization of the fishing fleet. However, the individual fisherman does experience an income loss proportional to the estimated shrimp loss. At present, the average profit for vessels in the Gulf of Mexico offshore shrimp fishery has declined substantially since the early 1990s. Profits are currently near the break-even point or even negative, and the fishery is no longer overcapitalized (Nance et al. 2006). Therefore, in today's economic climate, it matters a great deal whether the base or status quo TED shrimp loss is on the order of 7.5% or on the order of 3.6%. An increase in shrimp loss of a few percentage points could threaten the viability of the southeastern USA shrimp fishery if the base TED shrimp loss is on the order of 7.5% and BRDs having shrimp losses between 3% and 7% continue to be required.

In contrast, TEDs can result in positive impacts (e.g., reduced drag, fewer haulbacks, reduced sorting time, increased product quality) that decrease costs and increase product quality in some trawl fisheries, as reported by Brewer et al. (1998) for tropical Australia. However, in the cited instance, the bycatch : shrimp ratios are on the order of 16:1 to 19:1, and the bycatch includes an abundance of animals larger than 5 kg in the catches (Brewer et al. 1998). In the Gulf of Mexico, animals larger than 5 kg are not abundant in the catch, and the overall bycatch : shrimp ratio is on the order of 5:1 (NMFS 1995). More than 80% of the total southeastern USA shrimp fishing effort occurs in the Gulf of Mexico (Epperly et al. 2002; Nance et al. 2006). Under these conditions, the positive impacts of TEDs are minimized. About 20% of the total penaeid shrimp fishing effort in the USA occurs along the southeastern Atlantic seaboard. In this region, the overall bycatch : shrimp ratio is about 4:1 (NMFS 1995). However, catches of large elasmobranchs (mostly rays) and sea turtles are more frequent in this region than in the Gulf of Mexico. Furthermore, TEDs exclude the horseshoe crab *Limulus polyphemus*, which is a problematic species in the trawl fisheries of this region. Thus, TEDs may have more positive effects in the southeastern USA Atlantic trawl fishery than in the Gulf of Mexico fishery.

We believe it is unlikely that the penaeid shrimp loss rate observed in the late 1980s and early 1990s for a hard-grid TED without a funnel is applicable today because fishers have learned how to tune and configure TED grids and openings more efficiently. For example, the only TED used in both phases of the Renaud et al. (1993) study was the Georgia TED with an accelerator funnel. The shrimp loss in phase II (4.5%) reflected a 25% decrease as compared with the observed loss in phase I (6.0%). Further reduction may have occurred since that time. However, there are no data to support this premise. We suggest, based on the reanalysis of the historical data, that the most defensible point estimate of TED shrimp loss is on the order of 6% ($0.75 \times 7.5\% = 5.6\%$), a level approximately 1.5 times as large as the value used in present-day economic assessments (NMFS 2002).

Brewer et al. (2006) reported that, in Australia, total prawn loss associated with the use of a hard-grid TED was 5.8%. The loss rate for the green tiger prawn *Penaeus semisulcatus* and tiger prawn *P. esculentus* component of the catch was 6.8% as compared with no appreciable loss for the blue endeavor prawn *Metapenaeus endeavori* and endeavor prawn *M. ensis* component of the catch. Using a TED plus a BRD was estimated to reduce the total prawn catch by 6%, ranging from 6.5% for tiger prawns to 5% for endeavor prawns. Our TED shrimp loss estimate of 5.6% for the shrimp fishery in the southeastern USA during the late 1980s and early 1990s corresponds closely to the 5.8% TED shrimp loss estimate for the Australian shrimp fishery in 2001.

The Renaud et al. (1993) study was a voluntary program in which industry volunteers controlled TED type, area, sampling season, and adherence to the experimental design. Data came from virtually any vessel whose owner or captain would allow NMFS observers onboard (Renaud et al. 1993). As a result, there were marked imbalances in the data by area, season, and TED type. Thus, despite the improvements provided by the penaeid shrimp loss estimates reported herein, the data analyzed are representative of a study fleet that may or may not have been representative of the fishery at that time or of today's fishery. The most straightforward way to obtain shrimp loss estimates for the new, larger-opening TEDs would be to test them against standard nets, both with and without BRDs, in a well-designed, representative study. Our overall conclusion is that a new, NMFS-approved study is needed.

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