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Evaluation of U.S. Turtle Protective Measures Under Existing TED Regulations, Including Estimates of Shrimp Trawler Related Mortality in the Wider Caribbean

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Southeast Fisheries Center

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EXECUTIVE SUMMARY

Sea turtle catch and mortality by U.S. shrimp trawlers under current sea turtle conservation regulations were evaluated. This required a rather complex analysis of shrimping effort, turtle catch rates, turtle mortality rates, effectiveness of TEDs and tow time restrictions, and compliance with existing regulations. Results of these analyses were used in determining whether changes in existing regulations to provide additional protection to endangered and threatened sea turtles were warranted.

Current TED regulations, assuming 100% compliance, have resulted in a 67% reduction in sea turtle mortalities by shrimp trawlers in U.S. waters. However, under current regulations an estimated 23,376 turtles are captured annually by shrimp trawlers and 4,360 of these turtles drown. Based upon a recent analysis by the National Academy of Sciences, these estimates may underestimate true mortality by a factor of four.

Sea turtle take by foreign shrimp trawlers operating throughout the wider Caribbean has never been quantified. Sea turtles are widely dispersed throughout the western North Atlantic and are known to migrate great distances between nesting and foraging habitat. It is likely that many of the same turtles that are protected in U.S. waters under TED regulations are subject to take by trawlers in foreign waters. To effectively recover sea turtle populations in the western Atlantic, protection throughout a species range is essential.

INTRODUCTION

Sea Turtle Conservation Regulations (Federal Register, Vol.52, No. 124, June 29,1987) commonly known as the Turtle Excluder Device (TED) Regulations, have been a major subject of fishery controversy in the southeastern U.S. for almost a decade. These regulations were vigorously opposed by the shrimping industry and have never been fully accepted as a reasonable solution to the shrimp trawler/sea turtle interaction problem. Opposition to TEDs has centered around the argument that shrimp loss always occurs in association with TEDs, that the economic burden on shrimpers is unfair, and that shrimpers do not catch a significant number of sea turtles in the first place.

Using data collected by observers aboard commercial trawlers from 1973 through 1984, Henwood and Stuntz (1987) estimated annual catch and mortality of sea turtles by shrimp trawlers in offshore waters of the southeastern United States. These analyses indicated that incidental catch and mortality of sea turtles by shrimp trawlers was a significant problem, with an estimated 11,000 turtles drowned annually in shrimp trawls. Based on these analyses and other supporting evidence, increased sea turtle protective measures were clearly warranted and the original TED regulations were implemented.

We undertook an extended reanalysis of sea turtle mortalities in U.S. waters to provide current estimates of turtle catch and mortality rates under existing TED regulations. These analyses facilitated a more complete evaluation of the recommendations of the National Academy of Sciences (National Research Council 1990) regarding the need to expand current TED regulations. The results of our analyses clearly support expansion of TED regulations in the southeast.

In addition to analyses of U.S. turtle mortalities under current U.S. regulations, we provide gross estimates of turtle catch and mortality for the wider Caribbean based on metric tons of shrimp harvested, and assuming turtle catch rates are comparable to those in U.S. waters. Because sea turtles are widely distributed and do not recognize international boundaries, it is likely that the same turtles protected in U.S. waters are subject to take in foreign waters. Therefore, the successful recovery of threatened and endangered sea turtle populations throughout their range may ultimately depend on reduction or elimination of foreign sources of mortality.

DESCRIPTION OF SOUTHEASTERN U.S. SHRIMP TRAWL FISHERY

Federal TED regulations were directed at protecting sea turtles from incidental capture and mortality by shrimp trawlers in the Gulf of Mexico and the southwestern North Atlantic. The southeast shrimp fishery targets shrimp in the family Penaeidae which inhabit the warm, temperate and tropical waters of the world, and are abundant in waters of the U.S. continental shelf, including estuaries, sounds and bays. Catches are dominated by three species; the white shrimp, Penaeus setiferus, the pink shrimp, Penaeus duorarum, and the brown shrimp, Penaeus aztecus. The most commonly employed gear is the otter trawl, but a variety of fishing gears and techniques are used in localized areas.

In providing a general overview of the southeast U.S. shrimp fishery, the offshore commercial fleet was separated from the inshore fleet. Offshore is defined as those waters seaward of the 72 COLREGS demarcation line (International Regulations for Preventing Collisions at Sea, 1972), as depicted or noted on nautical charts published by the National Oceanic and Atmospheric Administration. The offshore fleet consists of larger vessels with larger nets, that operate over wide geographical areas. Offshore vessels may target all three species of penaeid shrimp at different times of the year. Shifts in target species result in varying levels of effort over depths, seasons and areas.

The Gulf of Mexico offshore fleet consists of approximately 5,400 vessels, and the offshore southwestern North Atlantic fleet is composed of about 1,500 vessels (NMFS 1987). The majority of the southeast U.S. commercial shrimping effort occurs in the central and western Gulf of Mexico with approximately 4,000,000 trawling hours estimated annually. The annual southwestern North Atlantic effort is roughly 550,000 hours. Actual fishing strategies and preferred equipment of the offshore fleet (vessel size, vessel type, number of nets, types of nets, duration of tows, etc.) vary with geographical location, bottom topography, target species, time of the year, and other factors. The level of fishing effort expended in any given area is controlled by seasonal abundance of target species, i.e., the Key West fishery is primarily a winter fishery for pink shrimp; whereas, the northern Gulf fishery and the Atlantic fishery are primarily summer/fall fisheries for brown and white shrimp.

The inshore commercial shrimping fleet consists of approximately 11,000 boats, primarily of less than 25 feet in length. The otter trawl is the most commonly employed gear. In certain locations butterfly nets, beam trawls, and traps may

be used to capture shrimp. In addition to the commercial fleet, approximately 40,000-50,000 recreational shrimpers harvest shrimp in inshore waters. Under the existing TED regulations, boats under 25 feet in length are not required to use TEDs but must restrict their tow times to 90 minutes or less duration in specified areas and during specific seasons.

EFFECTIVENESS OF U.S. TURTLE CONSERVATION MEASURES IN SOUTHEASTERN SHRIMP FISHERIES

Background

Henwood and Stuntz (1987) provided preliminary estimates of incidental turtle catch and mortality rates by shrimp trawlers in offshore U.S. waters. These estimates were based on observer data collected aboard commercial trawlers. They indicated that approximately 48,000 turtles were captured annually, and 11,000 of these turtles were drowned in the trawls.

In promulgating the Federal TED regulations, all available information on turtle/trawler interactions, turtle strandings, and basic sea turtle biology was assembled and presented to a mediation team of shrimp industry and the environmental community representatives. The team negotiated and agreed to many of the seasonal and areal restrictions included in the final TED regulations. Therefore, the existing TED regulations were based partially upon what was known about sea turtle biology and turtle interactions with shrimp trawlers, and partially upon compromises that did not always consider the biology of the species. In assessing the effectiveness of existing regulations, it is clear that more sea turtles could be saved by expanding the TED requirements to year-round in both inshore and offshore waters.

No data on catch or mortality rates of sea turtles by inshore shrimp trawlers were available when the regulations were drafted. Because of this information gap, and as a result of agreements by the mediation team, TEDs were not required in inshore waters. A mandatory 90-minute tow time restriction was substituted for the TED requirement, but the effectiveness of this measure is difficult to evaluate without historic inshore catch and mortality data.

Assumptions

Estimating the average catch rates and mortality of sea turtles in U.S. shrimp fisheries under existing TED regulations is a complex procedure requiring a number of assumptions. In computing estimates of the effectiveness of existing TED regulations, the following was assumed:

(1) Turtle catch per unit of effort (CPUE) is a linear function of net size and length of tow, such that a 100 ft net will catch twice as many turtles as a 50 ft net over tows of equal length. (NOTE: All trawl measurements are reported in terms of headrope length, a measure of the distance across the top line of the net. For normalization purposes, a 100 ft. (30.5m) headrope length was used as a standard.)

The effect of this assumption is that quad rigs, twin trawls and single trawls are assumed to catch turtles at equal rates, and that the size of the net influences catch rates. Additionally, all net types are assumed to be equally effective in turtle capture. These assumptions may result in a bias, but it is not clear whether this bias would be positive or negative.

(2) CPUE does not vary seasonally; i.e. it remains constant throughout the year.

This assumption probably results in an overestimate of turtle captures during months of the year when temperatures are lowest. In the southwestern North Atlantic, for example, it is believed that some turtles migrate north and south along the coast as temperatures warm in the spring and cool in the fall. Therefore, turtles would not be subject to capture during some months of the year because they have moved out of the area. Conversely, CPUE rates could be higher than mean CPUE estimates provided in Henwood and Stuntz (1987) during summer months in certain areas.

(3) CPUE in inshore waters is the same as in offshore waters.

The effect of this assumption could be an overestimation or underestimation of CPUE in inshore waters. Inshore habitat probably supports different age/size/sex classes and different species composition of turtles than offshore waters. Thus, CPUE by species could differ greatly from that observed in offshore waters.

(4) Mortality rates are a direct function of tow time, and remain constant throughout the year.

This assumption is probably violated. Data suggest that turtles are more likely to survive forced submergence at cold water temperatures than in warm waters because of differences in metabolic rates. Therefore, turtles are probably at higher risk of drowning during summer months. Use of mean mortality rates may result in overestimation of deaths at some times of the year and underestimation at other times of the year.

(5) Compliance with the TED regulations and 90-minute tow time restrictions are 100%.

Given the NMFS enforcement capabilities, it is likely that total compliance with TED regulations will not be immediately achieved. The effect of violation of this assumption will be an underestimate of total captures and mortalities.

(6) In areas and seasons when regulations are not in effect, no TEDs or tow time restrictions are used.

The effect of this assumption could be an overestimate of turtle catch and mortalities. As fishermen become accustomed to use of TEDs, they may choose to leave them in nets year-round. Additionally, TEDs may be used at times and in areas where jellyfish or other by-catch are abundant, regardless of whether they are required by law.

(7) All TEDs are at least 97% effective in excluding sea turtles.

This assumption is supported by the TED certification process. However, if TEDs are improperly installed or the design is modified, effectiveness could be less than 97%. This assumption could result in an underestimate of turtle catch and mortality rates if fishermen alter certified TEDs in any manner.

(8) All comatose turtles are resuscitated; all will survive and be released alive.

The effect of this assumption is an underestimate of turtle mortalities. Existing data suggest that resuscitated turtles may suffer long-term damage from ingestion of water into the lungs. Also, turtles may be caught repeatedly over a short period and this likely contributes to mortality. Thus, an unknown number of turtles that have been revived and released probably die.

Computations

In deriving estimates of turtle catch and mortalities for offshore waters of the Gulf of Mexico under the existing TED regulations, an average effort/year for the period 1984-1988 of 5,117,021 hours was used (Galveston Laboratory, pers. comm., Table 1). Assuming that vessel rigging has not changed substantially since 1984 when the average vessel used 35.47 m of headrope, average effort/year was multiplied by 35.47/30.5 which resulted in an average normalized offshore effort of 5,935,744 (100 ft net hrs)/year. During seasons and in areas where TEDs are not required, mortality estimates were computed on the basis of effort, estimated turtle catch rates, and mortality rates reported in Henwood and Stuntz (1987). For areas and seasons with TED requirements, the same computations were used except that estimated turtle catch was assumed to be 3% of the estimated catch without TEDs (97% reduction in captures). Estimates were stratified geographically based on the NMFS Statistical Grid System developed for the shrimp fishery. Zones 1-7 approximately represent the west Florida coast; zones 8-17 include the Florida panhandle to Louisiana; and zones 18-21 include Texas (Fig. 1).

Offshore effort in the southwestern North Atlantic was estimated to be 19,748 days/year (average for years 1984-1987) based on NMFS data (Table 1). Assuming that vessels in the Atlantic offshore fleet are rigged similarly to the Gulf fleet, this value was normalized to 549,790 (100 ft net hrs)/year. In computing turtle catch and mortality estimates, it was assumed that 100% of the vessels used TEDs from May through August (except in Florida where TEDs are required year-round), and that no vessels used TEDs during the remaining months of the year.

Average inshore effort in the Gulf of Mexico over the years 1984-1988 was estimated to be 2,190,822 hours. The mean footrope length of trawls was 11.81 m (Galveston Laboratory, pers. comm.). To convert this value to headrope, 2 m was added to this length resulting in a mean estimate of 13.81 m headrope length. To normalize effort, 13.81/30.5 was multiplied by 2,190,822 to estimate an average inshore effort of 991,973 (100 ft net hrs)/year (Table 1). Mortality rates were computed on the basis of offshore CPUE values and estimated mortality for 90-minute tows. The inshore Atlantic effort was computed based upon an estimate of 14,534 days/year (equivalent to 348,805 hours) which was normalized as above, to 157,934 (100 ft net hrs)/year. In areas and seasons

Table 1. Normalized shrimp fishing effort, mortality rates and catch per unit of effort (CPUE) used in calculating sea turtle mortalities for the Gulf of Mexico and the southern North Atlantic.

AREA	NORMALIZED EFFORT (100 FT NET HRS)	PERCENT MORTALITY	CPUE (TURTLES/ 100 FT NET HRS)
offshore			
zones 1-7	656,734	34	0.0046
zones 8-17	3,419,827	22	0.0030
zones 18-21	1,859,183	38	0.0026
Atlantic	549,790	21	0.0456[1]
	6,485,534		
inshore			
zones 1-7	14,053	12	0.0046
zones 8-17	732,244	12	0.0030
zones 18-21	245,676	12	0.0026
Atlantic	157,934	12	0.0456
	1,149,910		

[1]In statistical zone 28, an estimated CPUE of 0.12745 was used. This value was computed by assuming that a CPUE of 0.0487 (Atlantic mean) could be applied to 75% of the effort in this zone and a CPUE of 0.3643 (Canaveral mean) could be applied to the remaining 25% of the effort. Mortality estimates were taken from Henwood and Stuntz (1987). Figure 1 provides a description of the statistical zones.

Table 2. Estimated sea turtle capture with and without TED regulations for the offshore and inshore shrimp trawl fisheries in the Gulf of Mexico and southern North Atlantic.

	Offshore		Inshore	
Month	No Regs.- Estimated Number of turtles captured	Current TED Regs.- Estimated Number of turtles killed	No Regs.- Estimated Number of turtles captured	90-minute tow times Estimated Number of turtles killed
Gulf of Mexico				
JAN	927.20	173.74	34.11	5.17
FEB	944.13	165.18	9.55	0.52
MAR	873.73	7.79	21.65	1.54
APR	997.97	9.06	48.40	4.24
MAY	1786.69	14.77	368.98	42.65
JUN	1755.15	13.65	673.71	79.20
JUL	1732.64	15.25	284.61	33.27
AUG	1928.80	16.53	321.87	37.86
SEP	1769.80	14.67	380.12	44.91
OCT	2079.38	16.99	412.53	48.42
NOV	1748.40	14.57	255.88	29.64
DEC	1570.43	357.21	88.74	13.43
	18114.33	819.41	2900.14	340.85
Atlantic				
JAN	1635.44	136.80	13.76	1.20
FEB	654.40	10.90	2.45	0.02
MAR	353.07	6.61	19.91	2.60
APR	301.66	30.50	137.01	21.92
MAY	1227.57	7.73	415.25	49.21
JUN	3020.18	19.03	854.91	100.63
JUL	4010.91	25.27	2153.28	253.39
AUG	4072.53	25.65	1780.28	208.85
SEP	3661.34	590.46	1086.08	170.61
OCT	4075.94	616.22	787.17	122.99
NOV	3688.49	460.53	322.84	48.96
DEC	2651.93	274.69	118.57	15.19
	29353.47	2204.39	7691.51	995.57

Table 3. Summary of statistics of U.S. turtle catch and mortality rates with and without TED regulations.

	Offshore		Inshore		
	Atlantic	Gulf of Mexico	Atlantic	Gulf of Mexico	Total
Effort (hours/ 100 ft net)	549,790	5,935,744	157,934	991,973	7,635,441
CPUE (turtles/ 100 ft net hour)	0.0534[1]	0.0031	0.0487	0.0029	0.0076[2]
Turtle captures (No TED regulations)	29,353	18,114	7,692	2,900	58,059
Estimated mortality rate (% dead - No regs)	21	29	16	16	26.6[3]
Turtles killed (No TED regulations)	6,164	5,253	1,231	464	13,112
Turtle captures (current TED regulations)	10,495	2,925	7,114	2,842	23,376
Estimated mortality rate (% dead - current TED regs)	21	28	14	12	17.1
Turtles killed (current TED regulations)	2,204	819	996	341	4,360
Kill per unit of effort (No TED regulations)	0.01121	0.00088	0.00779	0.00047	0.00172
Kill per unit of effort (current TED regulations)	0.00401	0.00014	0.00631	0.00034	0.00057
Turtle captures with 100% TED coverage *	881	543	231	87	1742
Turtle mortality with 100% TED coverage **	185	152	32	10	379
Percent reduction in turtle mortalities under current TED regs	64	84	19	27	67
Percent reduction in turtle mortalities under proposed TED regs	97	97	97	97	97

* This entry assumes that TEDs are used at all times and in all areas (both inshore and offshore).
**Estimated mortality rate X turtles captures with 100% TED coverage.

[1]This estimate is based upon a weighted average computed as described in Table 1.

[2]Average CPUE calculated by dividing turtle captures by effort.

[3]Average mortality rate weighted by effort.

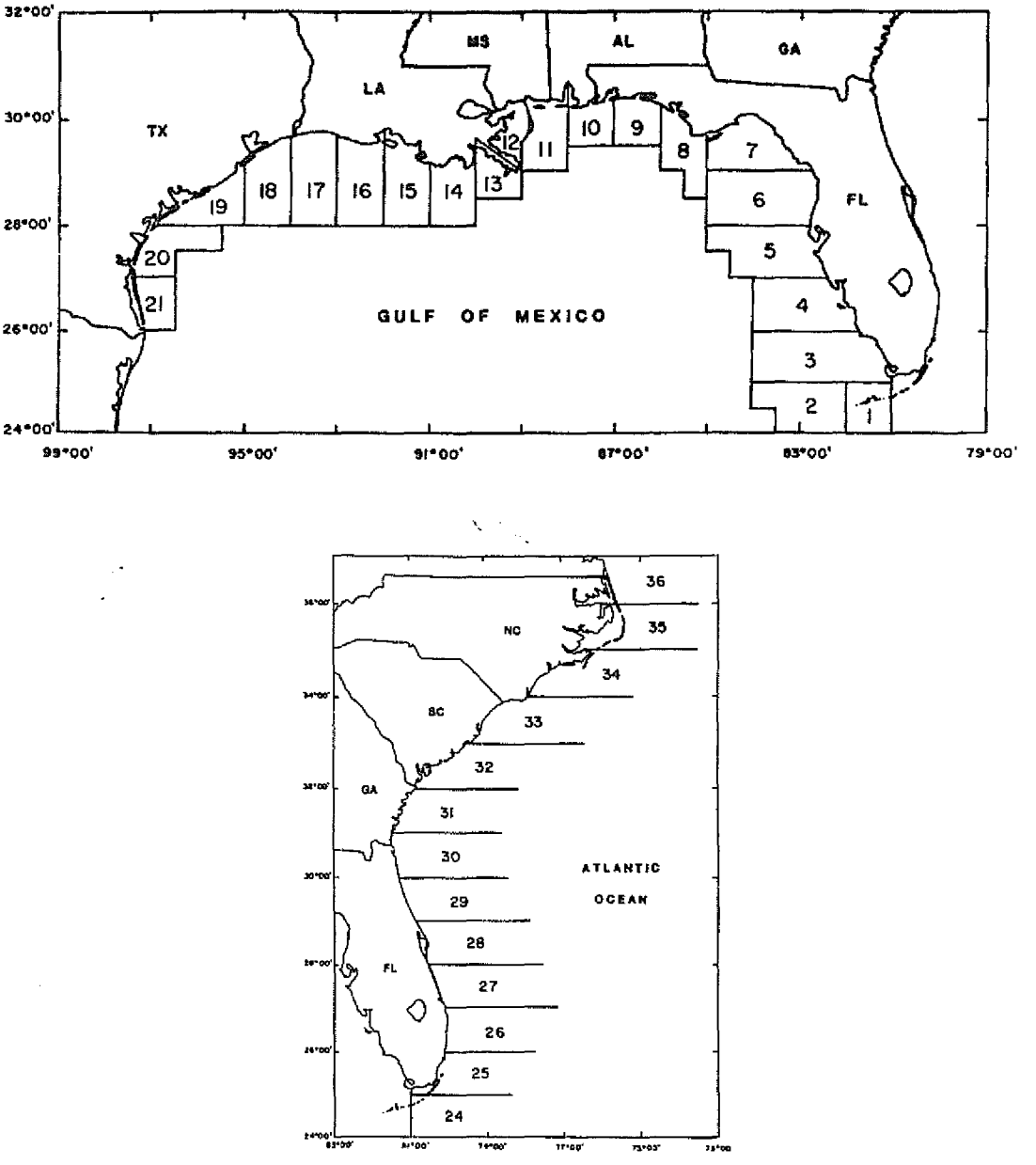

Figure 1. Statistical fishery effort reporting zones for the Gulf of Mexico, zones 1-21, and southwestern North Atlantic U.S. coast, zones 24-36.

where 90-minute tow times were not required, it was assumed that trawlers operate as they did prior to the regulations (Table 1).

TEDs are required year-round in Florida state waters, southwest Florida in zones 1-4, and along the east coast in zone 28 (Fig.1). For the remainder of the Gulf of Mexico, TEDs are required during all months except December, January, and February. In the Atlantic TEDs are required only for the months of May through August, except in Florida inshore waters and Canaveral where they are required year-round. Estimates of turtle mortality assume Florida and South Carolina TED regulations are in effect. For the inshore, it is assumed that all vessels are using 90-minute tow times when required as defined by the regulations, and are not restricting tows to 90-minutes during the remainder of the time. Estimated turtle mortalities when TEDs are required under current regulations are calculated by multiplying the number of captures with no regulations by 0.03 (assuming 97% exclusion) and multiplying this value by the applicable mortality rate taken from Henwood and Stuntz (1987). In inshore areas during periods when 90 minute tow times are not required, percent mortality was estimated to be 16% (Table 2).

FOREIGN SHRIMP FISHERY/MARINE TURTLE INTERACTIONS

A review of available information on the distributions of turtles and imports of penaeid shrimp into the U.S. and other countries suggests potential interactions between shrimp fisheries and turtles in many nations of the wider Caribbean. Since little reliable data exists on turtle CPUE in foreign shrimp fisheries, mortality rates associated with these fisheries, species composition of turtles incidentally taken in these fisheries, or other pertinent information needed to evaluate impacts on sea turtle populations, we attempted to estimate sea turtle mortalities on the basis of shrimp landings. Our analyses focused on wider Caribbean countries because the same turtles protected in U.S. waters are known to migrate through foreign waters and thus, might be adversely affected by foreign trawl fisheries.

World landings data for 1987 as reported by Vondruska (1991) were used in all computations. Data from 1987 were selected for analyses because the harvest data set is constantly being updated, and 1987 was considered the most complete and current set available (Vondruska pers. comm.). Applying what we know about U.S. penaeid shrimp fisheries to what might be expected in foreign fisheries throughout the wider Caribbean, we performed a cursory analysis assuming the following:

(1) Turtle distributions in the wider Caribbean are similar to those in U.S. waters.

(2) Shrimp trawl fisheries operate in the same way, and are composed of similarly rigged vessels fishing in the same manner as U.S. trawlers.

(3) Turtles in wider Caribbean waters behave the same once captured in a trawl as turtles in U.S. waters and trawls.

(4) Reported world harvests accurately reflect shrimping effort for selected countries addressed in this report.

The number of turtles captured and killed by the U.S. fleet per metric ton (mt) of shrimp landed was estimated. An average of 103,339 mt of penaeid shrimp (heads-on weight) were landed annually during the period of 1980-1984 (Vondruska 1991). Using our estimates from observer data collected from 1973-1984, the average number of turtles captured per year per 103,339 mt shrimp with no TED Regulations was over 58,000 with approximately 13,000 killed (Table 3). Thus, the U.S. catch and mortality rates of sea turtles per mt of heads-on shrimp landed are 0.56 and 0.13, respectively.

Mexico

Of the foreign nations exporting shrimp and shrimp products to the U.S., the Mexican shrimp fishery and turtle occurrence in their waters is probably best known. In the past, the U.S. has cooperated with Mexico in several fisheries ventures in the Gulf of Mexico, and has worked closely with the Mexican government on fisheries related problems. Despite our close working relationship with Mexico, information on sea turtle species composition, distribution and rates of capture in shrimp trawls remains poor.

In 1987, approximately 87,106 mt of live weight shrimp were harvested in Mexico, including fresh water shrimp and a small but unknown amount of farmed shrimp. Using Mexico's total harvest, not just trawl-caught marine shrimp, will result in an overestimate of turtle take if fresh water and farmed shrimp are major components of the total harvest. However, in our analyses we assumed that fresh water and farmed shrimp were insignificant components of the total harvest. We estimated that Mexican shrimpers probably captured 48,779 turtles (0.56 X 87,106), of which 11,324 turtles (0.13 X 87,106) may have been killed. If the above assumptions and calculations are reasonable, the total

mortality of turtles by the Mexican shrimp fleet (11,324) is approximately equal to that of the U.S. fleet (13,000 turtles) before the implementation of TED Regulations.

This analysis is biased because we know certain things about the Mexican shrimp fishery that violate at least two of our assumptions. First, most captured turtles probably do not survive. Mexican fishermen reportedly do not release turtles; they either eat or sell them. Second, Mexican turtle CPUE rates may be much higher than U.S. rates because of turtle distribution patterns, proximity of nesting beaches, and possible directed fisheries. Thus, a more accurate estimate of turtle mortalities in Mexican shrimp fisheries may be closer to 48,779 turtles per year.

Central America

Very little information on the shrimp fisheries of Central American countries was available, but all export shrimp to the U.S. and other countries. There is good information describing the shrimp trawl fishery in Ecuador and for this reason, we used a description of the Ecuadoran offshore shrimp trawling industry to represent that of Central American countries. This assumes that fisheries in Central America are similar in operation to the Ecuadoran fleet which according to E. Klima(pers. comm.) is not an unreasonable assumption. Total harvest of shrimp from Ecuador in 1987 was 79,468 mt, of which the commercial shrimp trawl fishery accounted for about 11,000 mt (Vondruska 1991). Approximately 250 vessels from 50 to 70 feet in length are involved in this fishery. All are double rigged with otter trawls, most are refrigerated, and the average trip is 15-22 days. About 90% of the shrimp caught are white shrimp found in waters less than 15 fathoms depth. Thus, for example, if 11,000 mt of shrimp are produced from 250 Ecuadorian vessels, the Panamanian fishery which produced about 7,810 mt of shrimp is of similar size as the Ecuadorian fishery.

The figures for turtle captures and mortalities in the U.S. penaeid shrimp fishery (0.56 and 0.13 turtles/mt of shrimp landed) were used for estimation purposes. By Central American country the estimated 1987 catch and mortality of turtles is:

	Metric Tons (shrimp)	Turtles Caught	Turtles Killed
Belize	274	153	36
Costa Rica	8,776	4,915	1,141
El Salvador	2,871	1,608	373
Guatemala	1,135	636	148
Honduras	5,176	2,899	673
Nicaragua	1,090	610	142
Panama	7,810	4,374	1,015
TOTALS	27,132	15,195	3,528

Here again, turtle catch and mortality estimates are inflated if fresh water or farmed shrimp comprise a significant portion of the harvest. Mortality estimates are low if live captured turtles are not released, and the number of turtles caught may be a better indicator of true mortality.

South America

All of these countries probably operate fisheries in the same manner as Mexico since all are important shrimp producers from an offshore shrimp trawling industry (E. Klima, pers. comm.). Thus, based upon the previously described assumptions and computations, the estimated catch and mortality of turtles by country using 1987 harvest data are:

	Metric tons (shrimp)	Turtles Caught	Turtles Killed
Brazil	62,666	35,093	8,147
Venezuela	6,074	3,401	729

Colombia	6,667	3,734	867
Guyana	2,893	1,620	376
French Guiana	2,810	1,574	365
Surinam	1,107	620	144
TOTALS	82,217	46,042	10,628

Four of the five species impacted by the U.S. TED regulations are found in coastal waters of South America where shrimp trawling occurs. Significant nesting and foraging of hawksbill, green and leatherback turtles occurs along tropical coasts, and loggerhead turtles are predominant in subtropical waters. In addition to these four species, the olive ridley has a largely complementary and non-overlapping range, with olive ridleys occupying this niche in tropical waters and the loggerhead in subtropical waters.

DISCUSSION AND CONCLUSIONS

Our principal objective in conducting these analyses was to evaluate the effectiveness of current TED regulations in the protection of sea turtles. This required a rather complex analysis of the best available information on sea turtle capture and mortality by shrimp trawlers. While a number of assumptions which could bias results were required in the analyses, it is unclear whether these biases resulted in overestimation or underestimation of actual turtle mortalities. Despite these uncertainties, we are confident that our estimate of 4,360 shrimp trawler related sea turtle mortalities annually under current TED regulations is a conservative estimate and actual mortalities could be much higher.

The National Academy of Sciences (National Research Council 1990) concluded that mortality to sea turtles from shrimp trawling was at least an order of magnitude greater than all other known man-induced sources of mortality. This study also concluded that the original estimates provided by Henwood and Stuntz (1987) could underestimate true mortality by a factor of four. Given the conservative nature of the Henwood and Stuntz analysis and the fact that the present analyses employed the same assumptions, the Academy would probably conclude that actual mortalities under current TED regulations are also underestimated in this analysis.

While sea turtle mortality estimates presented herein remain unacceptably high in terms of ensuring recovery of the species, the current TED regulations have resulted in a 67% reduction in annual turtle mortalities. This is a significant improvement over past conditions and should be viewed positively in terms of overall U.S. sea turtle conservation efforts. Compliance rates with TED regulations appear to be high, and annual shrimp landings have not changed despite alleged high shrimp loss rates associated with TED utilization.

On the basis of our analyses, we conclude that expansion of TED requirements to all areas at all times of the year would result in a total reduction in shrimp trawler related sea turtle mortalities of 97%. Given the fact that most mortality is preventable if TEDs are used and are functioning properly, there would appear to be no valid reason for not expanding TED requirements. Allegations of high shrimp loss rates and associated economic hardships have not been supported by landings statistics or studies of shrimp loss rates with TEDs (Renaud et. al 1991; Renaud et. al. 1990).

Our analysis of foreign sea turtle capture and mortality by shrimp trawlers is admittedly crude. However, our purpose in providing these estimates was to illustrate the point that U.S. protective measures may not, in themselves, be sufficient to recover species of concern. If we assume that turtles protected in U.S. waters are ultimately impacted by shrimp trawlers in foreign waters, saving turtles in U.S. waters may simply result in higher sea turtle catch and mortality rates in foreign waters and do little to improve survival of the species. Using our gross estimates of sea turtle catch and mortality for the wider Caribbean countries addressed in our analysis, we estimate 110,016 captures and 25,480 mortalities annually. These estimates are approximately double those in U.S. waters prior to implementation of TED regulations.

Given the extensive use of otter trawls in U.S. and foreign waters throughout the wider Caribbean and given the known adverse effects of trawling gear on sea turtle populations, significant improvements in survival of turtles could be achieved by mandatory use of TEDs in all U.S. and foreign waters. However, without foreign cooperation in efforts to conserve sea turtles, U.S. efforts may not be sufficient to achieve recovery of these species. Therefore based on our analyses, we recommend that U.S. TED regulations be expanded to require TEDs in all areas at all times, and that foreign nations within the wider Caribbean be urged to adopt similar turtle conservation regulations.

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