Simulated Economic Impact of TED Regulations on Selected Vessels in the Texas Shrimp Fishery

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Introduction

Shrimp fishermen trawling in the Gulf of Mexico and the south Atlantic inadvertently capture and kill sea turtles which are classified as endangered species. Recent Federal legislation requires the use of a Turtle Excluder Device (TED) which, when placed in the shrimp trawl, prevents turtle mortality. However, the shrimp industry has been concerned about the possible impact of the TED upon vessel shrimp catch.

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ABSTRACT—Shrimp fishermen trawling in the Gulf of Mexico and south Atlantic inadvertently capture and kill sea turtles which are classified as endangered species. Recent legislation requires the use of a Turtle Excluder Device (TED) which, when in place in the shrimp trawl, reduces sea turtle mortality. The impact of the TED on shrimp production is not known. This intermediate analysis of the TED regulations using an annual firm level simulation model indicated that the average Texas shrimp vessel had a low probability of being an economic success before regulations were enacted. An assumption that the TED regulations resulted in decreased production aggravated this condition and the change in Ending Net Worth and Net Present Value of Ending Net Worth before and after a TED was placed in the net was significant at the 5 percent level.

However, the difference in the Internal Rate of Return for the TED and non-TED simulations was not significant unless the TED caused a substantial change in catch. This analysis did not allow for interactions between the fishermen in the shrimp industry, an assumption which could significantly alter the impact of TED use on the catch and earnings of the individual shrimp vessel.

This analysis was designed to address this issue by evaluating the impact of the TED regulations upon the economic viability of representative shrimp vessels in the Texas shrimp fishery.

This analysis, however, does not explicitly consider the interactive aspects of the shrimp fishery, both among the vessels and between the vessel catch and remaining shrimp stock. An implicit assumption of this analysis is that the individual vessel's fishing behavior would not change as a result of the TED regulations, in response to either increases or decreases in catch per tow. Rather, this analysis is based on the resultant impact on the catch of the representative vessel in the Texas shrimp fishery given all the interactive effects. That is, after all other considerations, if the vessel catch has changed, what is the impact on the economic viability of the vessel? Finally, this is an intermediate analysis of the impact of the TED regulations. Future analysis should be directed at examining the interactive effects within the fishery.

History

In 1981 the National Marine Fisheries Service (NMFS), as the result of an ongoing research and development program, introduced a shrimping gear design aimed at reducing the capture of sea turtles. This device would be sewn into a shrimp trawl (Fig. 1) and was designed to provide a way for sea turtles to exit the trawl. Because of its proposed function, it was called a Turtle Excluder Device (TED) (Watson et al., 1985).

All sea turtles are listed as endangered or threatened by the Endangered Species Act. Under this Act it is illegal to import, export, take, possess, sell, or transport endangered species without a permit unless these activities are specifically allowed by regulation (USDC, 1978; Yaffee, 1982). Five species of sea turtles are caught in shrimp trawls in the waters of the southeast United States. They are the loggerhead, *Caretta caretta*; Kemp's ridley, *Lepidochelys kempi*; green, *Chelonia mydas*; leatherback, *Dermochelys coriacea*; and hawksbill, *Eretmochelys imbricata* (Dean and Steinbach, 1981; Anonymous[1]). In 1978, when the green and loggerhead sea turtles were listed under the Endangered Species Act (the other three species were listed in earlier rulemakings), the problem of incidental take of these species in the shrimp fishery was addressed in a Final Environmental Impact Statement (USDC, 1978). At that time, methods to reduce the incidental take were not available.

In 1983, NMFS began a formal program to encourage voluntary adoption of TED's by the shrimp industry. Through the voluntary program, TED's were constructed under contract and distributed to shrimpers who agreed to use them. Modification and evaluation of the TED continued, resulting in a smaller, lighter, collapsible NMFS TED, as well as other non-NMFS TED's. Despite numerous extension programs, publicity and train-

[1]Anonymous. 1983. Environmental assessment of a program to reduce the incidental take of sea turtles by the commercial shrimp fleet in the southeast United State. U.S. Dep. Commer., NOAA, NMFS Southeast Reg. Off., St. Petersburg, Fla., 20 p.

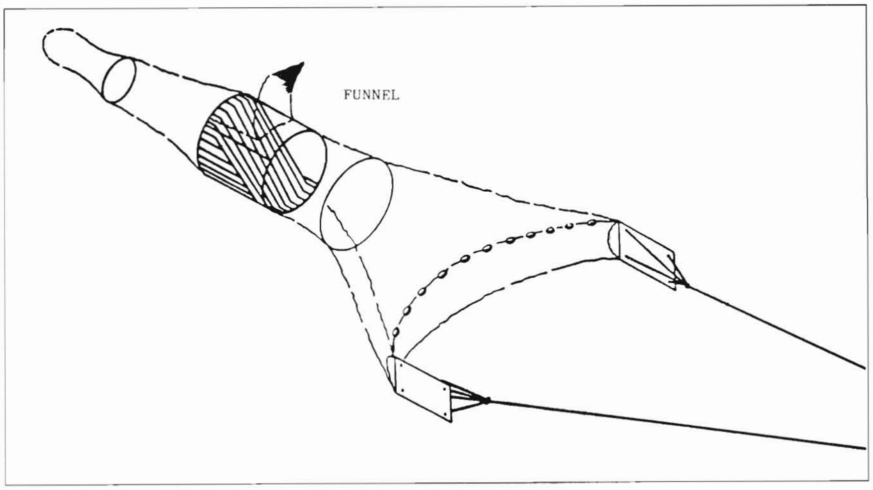

Figure 1.—Position of the TED in the shrimp trawl.

ing activities, the voluntary program was not effective (Anonymous[2]). As of late 1986, less than 3 percent of the shrimp fleet had used or continued to use a TED (Oravetz[3]).

Specific regulations concerning use of TED's were developed in 1986 during mediation between members of the southeastern U.S. shrimp industry and interested members of the environmental community. Proposed regulations were published in the March 1987 Federal Register and final regulations were published in the July 1987 Federal Register. As summarized by the National Marine Fisheries Service (Anonymous[4]), as of 1 May 1989 in offshore waters, use of the TED was to be required of all vessels measuring 25 feet or longer. For vessels of less than 25 feet in length, the option of towing 90 minutes was available. There are seasonal requirements by region, with Canaveral and southwest Florida vessels required to pull the TED year-round, Gulf vessels required to pull the TED March though November, and Atlantic vessels from May through August. Inshore regulations have similar seasonal requirements but all shrimp trawls must either use a TED or limit tow time to 90 minutes.

Turtle Excluder Devices

Testing conducted off Cape Canaveral, Fla., prior to 1988 (Table 1) identified four TED's which satisfactorily excluded turtles from commercial shrimp nets: 1) The standard 30-inch opening and 25-inch opening NMFS TED's, 2) the "Georgia" TED, 3) the "Cameron" TED, and 4) the "Matagorda Bay" TED. In the time period subsequent to 1988, additional devices have been approved but they are not considered as part of this analysis.

The NMFS and Cameron TED's are three-dimensional, implying that a section of the net must be removed to install the device. The NMFS devices are rectangular in shape whereas the Cameron TED is circular (Fig. 2). The Georgia and Matagorda TED's are two-dimensional and are sewn directly into the net. The Georgia TED has a long oval shape with parallel bars creating a barrier across the surface of the device. The Matagorda TED is rectangular and also has parallel bars which function as a barrier to entry into the cod end of the trawl (Fig. 3). The positioning of the opening in the trawl, which allows turtles and other large organisms to escape, varies by TED. The NMFS and the Matagorda devices have top openings. The Georgia TED has a

Table 1.—Summary of testing conducted to determine capabilities of four Turtle Excluder Devices. Sources: Text footnotes 4, 5, 6, 8, and 10.

Test and type of TED	No. of tows	Turtles caught (no.)		Shrimp catch (lb.)		By-catch (lb.)	
		Control	TED	Control	TED	Control	TED
Cape Canaveral tests[1]							
NMFS TED	10	14	0	26.00	24.00	7,488	4,164
Cameron TED	10	21	0	26.75	26.50	4,551	3,026
Georgia TED	10	16	0	13.75	17.25	5,275	4,014
Matagorda TED	10	17	0	31.75	29.50	7,771	4,312
North Carolina Sea Grant							
NMFS TED with 45° grid angle	8			696[2]	291	158[3]	55.50
NMFS TED with 37° grid angle	10			1,393	1,513	73.10	42.65
St. Simon's Island							
NMFS TED	18			158.00	175.38		
Georgia TED	18			159.88	156.88		
Matagorda TED	18			143.25	194.75		
Cameron TED	18			175.88	200.75		
Texas testing[4]							
Std. NMFS TED	49			3,073	3,127	186.8	230.3
Mini NMFS TED	5			170	249	0	2.2
Georgia Jumper	14			753	793	29.6	40.1

[1]Data recorded for 7 tows w/TED, while 10 tows were recorded for control.
[2]Measured as number of shrimp rather than pounds of shrimp caught.
[3]Measured in kg.
[4]By-catch measured in bushels.

[2]Anonymous. 1986. Report from the turtle excluder device workshop. U.S. Dep. Commer., NOAA, NMFS, Southeast Fish. Cent., Pascagoula, Miss., 15 p.

[3]Chuck Oravetz, National Marine Fisheries Service, NOAA, Southeast Regional Office, St. Petersburg, Fla. Presentation at TED meetings in Pascagoula, Miss., Oct. 1986.

[4]Anonymous. 1989. Summary of TED/tow time regulation. U.S. Dep. Commer., NOAA, NMFS Southeast Reg. Off., St. Petersburg, Fla. 1 p.

bottom opening and the Cameron TED can be used with either a bottom or top opening.

Meanwhile, TED development and use has also been proceeding in other nations. In July 1986, following a publicity and coordination trip in March, a workshop and vessel demonstration was held in Mazatlan, Mex. In Indonesia, over 1,000 TED's are in use in the western area on joint-venture Japanese vessels. Indonesia has sent fishing gear experts for training at the NMFS Harvesting Systems Division, Mississippi Laboratories (USDC, 1985).

Tests for Shrimp Exclusion

NMFS Tests

As early as September 1983, NMFS was testing its new TED to determine the impact on shrimp catch and by-catch reduction. These tests were directed at evaluating the TED design modifications to improve finfish by-catch reduction rates. The TED used in these experiments was the original solid NMFS TED (Anonymous[5]).

NMFS continued testing and improving the TED, and additional tests were made in 1984. From July through September, the FRV *Jeanie* conducted tests off Florida, Alabama, and Mississippi. Initially, tests were directed at performance of several different designs of the NMFS TED. These included: Fiberglass frame and PVC joints, steel-frame collapsible, aluminum frame, and miniature-frame TED. PVC joints of the aluminum-frame TED's were found to be too weak to withstand normal shrimping operations.

Other cruises were made to compare shrimp retention rates of various TED's vs. a control net without a TED. These cruises were done both day and night and incorporated different types of finfish deflectors (Hummer wire, types A and H and solid bar, type D) (Anonymous[6]).

[5]Anonymous. 1983. Cruise Report for FRS OREGON II Cruise 137 - 9/6/83 - 9/21/83. Dep. Commer., NOAA, NMFS Southeast Fish. Cent., Pascagoula, Miss., 4 p.
[6]Anonymous. 1984. Cruise reports for FRV JEANIE. U.S. Dep. Commer., NOAA, NMFS Southeast Fish. Cent., Pascagoula, Miss., 4 p.

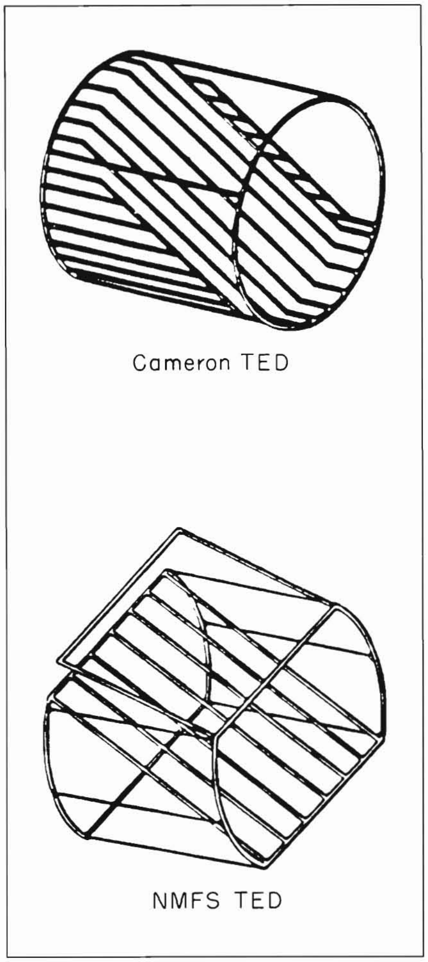

Figure 2.—General schematic of Cameron TED (circular) and NMFS TED (rectangular).

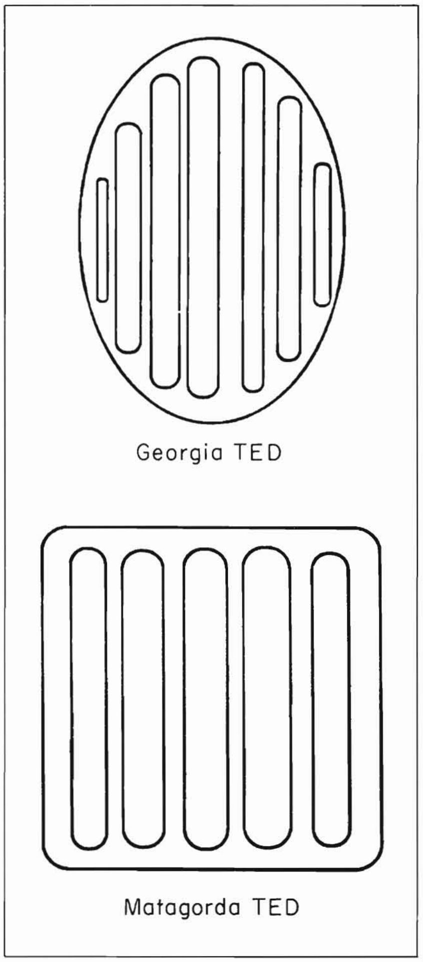

Figure 3.—General schematic of the Georgia TED (circular) and Matagorda TED (rectangular).

North Carolina Test

The University of North Carolina Sea Grant program was also involved in testing shrimp and finfish retention rates of the various TED's. In April and May 1986, two cruises were made aboard the *Carolina Coast* (Table 1) (Anonymous[7]). Of the two NMFS TED's tested, the one with the 37° grid angle appeared to be more effective at eliminating by-catch with no overall loss of shrimp. Although by-catch was measured in kilograms, shrimp catch was measure in numbers of individual shrimp. Large quantities of shrimp were not encountered, possibly due to the half-hour tow limitation. This made it difficult to measure the impact on shrimp catch.

In July 1986, under the auspices of the University of North Carolina Sea Grant Program, tests were conducted on the "Georgia Jumper" (Anonymous[8]). A total of 24 tows were made by the *Carolina Coast*. Nineteen tows were compared with a standard net and 5 tows were

[7]Anonymous. 1986. Cruise Report for CAROLINA COAST Cruises: TED Testing - April 28-30, 1986. Univ. N.C. Sea Grant, N.C. Mar. Resour. Cent., Atlantic Beach, N.C., 2 p.

[8]Anonymous. 1986. Cruise Report for CAROLINA COAST Cruise: TED Testing - July 14-18, 1986. Univ. N.C. Sea Grant, N.C. Mar. Resour. Cent., Atlantic Beach, N.C., 2 p.

compared with the NMFS TED. Several adjustments were made to the TED before it was operating properly. When all 19 tows were considered, the TED experienced an 18 percent shrimp loss, however, for the 15 tows when the TED was operating properly there was only a 9 percent shrimp loss. The tested TED was very effective in reducing horseshoe crab, cannonball jellyfish, stingray, and tunicate catches, with an overall by-catch reduction of 24 percent (21 percent for the 15 tows above). For the 5 tows against the NMFS TED there was an overall 9 percent shrimp loss with 40 percent less by-catch (Anonymous[9]).

Georgia Test

The Marine Extension Service of the Georgia Sea Grant College Program conducted tests off Georgia on the four TED's tested at the Cape Canaveral channel: Georgia Jumper, Cameron TED, Matagorda TED, and NMFS Collapsible TED without funnel. The purpose of these tests was to determine shrimp exclusion rates of TED's (Anonymous[10]).

A total of 72 double-rig trawls were conducted with 9 port and 9 starboard tows conducted with each of the four different TED's (Table 1). Sampling was conducted 3-4 miles east of the south portion of St. Simon's Island, Ga., in 30 feet of water. The Georgia Jumper had a 1.9 percent gain compared with a standard trawl without a TED. The NMFS TED had a 9.9 percent loss, the Cameron TED a 12.4 percent loss, and the Matagorda TED a 26.4 percent loss (Anonymous[11]).

Texas Test

Tests with the four TED's presently certified for use were conducted in Texas waters using both bay and Gulf vessels to determine the impact of TED devices on Texas shrimp production (Graham[12]). Many of the tows done in Texas were faulty, for one reason or another, and thus, rigorous statistical analyses have not been carried out (Table 1). The results of this testing were useful in indicating the learning process which must occur when a TED is introduced into the trawl.

TED Impacts

When reviewing testing that has been completed on various TED's, a wide range of results is apparent. Tests have been conducted in different areas off the eastern and southern U.S. coasts using different types of vessels and different TED's. The approach to testing is consistent, i.e., simultaneous drags with a control net and a TED net, but the gear and nets vary across all experiments. As a result, it is not surprising to find that TED capabilities varied with the experiments.

Cape Canaveral testing certified four TED's as possessing the capability of "kicking out" sea turtles from the trawl. Further testing conducted by the NMFS determined finfish reduction capability of the TED and helped in refinement of the TED. Finfish reduction rates as high as 80 percent were recorded during the day although night reduction rates were lower. There was no significant reduction in shrimp catch during these tests (Anonymous[13]).

Testing by the University of North Carolina Sea Grant program resulted in extreme values for average shrimp loss (58 percent) over all tests. The TED was mounted in the net at a 45° angle; subsequent North Carolina testing showed this to be an inappropriate angle. In addition, the results were for experiments where the total number of shrimp encountered were small, and this makes any analysis suspect. Further testing with a 37° angle for TED installation gave a shrimp increase of 8.6 percent, and more shrimp were consistently encountered during these experiments.

Tests off St. Simon's Island, Ga., were the only ones to use all four certified TED's. The Georgia Jumper had a 1.9 percent production gain, whereas the other three TED's showed losses (NMFS a 9.9 percent loss, Cameron a 12.4 percent loss, and Matagorda a 26.4 percent loss). However, only 18 tows were made with each TED.

The final series of tests, off the Texas coast, are reported here. Again, the variety of vessels used and variation in equipment, as well as change in location, made accurate interpretation of this data difficult. In addition, a report by Byrne, et. al.[14] argues that the experimental design of the TED testing does not allow specific shrimp retention rates to be identified.

Economic Impact of TED's

Method of Analysis

The intent of this analysis was to examine the impact of TED regulations on the earning capacity of a single representative vessel. The method of analysis is to simulate conditions that are representative of a vessel in the Texas' Gulf shrimp fishery, using the firm-level simulation model FLEETSIM, under the proposed TED regulations (Clark et al[15]). FLEETSIM is a firm level, recursive, simulation model which simulates the annual production, costs, and income aspects of a fleet, by vessel, over a multi-year planning horizon.

FLEETSIM is capable of simulating a hypothetical fleet for 1-10 years. The model recursively simulates a typical fleet by using the ending financial position for year one as the beginning position for the second year, and so on. FLEETSIM does not include an overall objective function to be optimize, but rather analyzes the outcome of a given set of input data and assumptions for a typical fleet. Accounting equations and identities con-

[9]Anonymous. 1986. Cruise Report for CAROLINA COAST Cruises: TED Testing - April 28-30, 1986. Univ. N.C. Sea Grant, N.C. Mar. Resour. Cent., Atlantic Beach, N.C., 2 p.

[10]Anonymous. 1987. Preliminary results from shrimp retention studies on four different turtle excluder devices off the Georgia Coast. Univ. Ga. Sea Grant, Mar. Ext. Serv., Brunswick, 15 p.

[11]Anonymous. 1987. Preliminary results from shrimp retention studies on four different turtle excluder devices off the Georgia Coast. Univ. Ga. Sea Grant, Mar. Ext. Serv., Brunswick, 15 p.

[12]G. Graham. 1986. Summary of TED cruise reports #1 - #10 and individual cruise accountings. Tex. Agric. Ext. Serv., Tex. A&M Univ., Coll. Sta., Tex., 11 p.

[13]Anonymous. 1984. Cruise reports for FRV JEANIE. U.S. Dep. Commer., NOAA, NMFS Southeast Fish. Cent., Pascagoula, Miss., 4 p.

[14]R. Byrne, W. Griffin, and J. Clark. 1987. Four TED's analysis of variance. Nat. Resour. Work. Pap. Ser. Nat. Resour. Workgroup, Dep. Agric. Econ., Tex. A&M Univ., Coll. Sta., 15 p.

[15]J. L. Clark, J. W. Richardson, and C. J. Nixon. 1987. Description of FLEETSIM: A general firm level policy simulation model for a shrimp fleet. Nat. Resour. Work. Pap. Ser. Nat. Resour. Workgroup, Dep. Agric. Econ., Tex. A&M Univ., Coll. Sta., 50 p.

stitute most of the computational components of the model.

Procedure

Three separate simulations were conducted in an effort to analyze the impact of the TED regulations. These three models were: 1) Historical, 2) Baseline, and 3) TED Simulations.

The first FLEETSIM analysis examined the historical situation in the Gulf industry from 1978 to 1986. No analysis is included for bay vessels on the assumption that bay shrimpers will take advantage of the 90-minute tow time exception and will not be required to use TED's. This analysis was deterministic and was conducted to obtain a starting financial position for the baseline simulation. The program was run using actual values for changes in inflation, interest rates, landings and prices, and production costs for a representative vessel. In addition, the model began with a new vessel in 1978 and was run without considering income tax. Therefore, all values generated represent a before-tax situation.

The second FLEETSIM analysis involved the development of a baseline simulation model for the fishery. The first year of analysis for this model was 1987. The purpose of the baseline model was to predict what would occur in the industry without TED regulations. The result of the baseline simulations was later used to determine the impact of the TED regulations. The third step, following the development of the baseline simulation model and estimates of future costs and returns for the representative vessel, was to build effects of TED regulations into the model.

Data

Production and budget information for Gulf shrimpers was obtained from interviews conducted with members of the Texas Gulf shrimp industry (Anonymous[16]). This information included past production, costs and returns, and changes in number and size of vessels for the period 1969-86. Vessel size and construction varied considerably from 20- to 30-foot wood up to 90-foot steel ones. Some firms had vessels that were 20-30 years old, while others culled vessels after 10 years.

Baseline and TED simulation analyses were stochastic, as opposed to deterministic. In Baseline and TED policy analyses, pounds landed by the vessel were stochastically set about a mean value, based on a 5 year (1982-86) average of fishery landings. Prices were similarly set but included an adjustment based on changes in the Consumer Price Index. No attempt was made to account for any price changes which might occur if the use of a TED leads to a decline in total production of shrimp, Gulfwide. Price would likely increase if production declined, especially for large shrimp which are the mainstay of the Gulf shrimp fleet analyzed here.

In an effort to make stochastic variables a function of actual relationships in the industry, an analysis of historical price and landing trends for Gulf shrimp vessels was conducted. To generate random landings and prices, it was necessary to provide cumulative deviations around mean values for these variables. This was accomplished by regressing average annual landings and prices against time and taking resulting deviations and dividing them by the value for mean landings and prices. An additional explanation of this procedure can be found in the FLEETSIM user manual.

Values for future interest rates and inflations rates, associated with prices and production costs, were obtained from COMGEM[17], a macroeconomic simulation model developed by Penson, Hughes, and Romain. The "best" predictions available were annual predictions of inflation rates approximating 4 percent for 1987 through 1990 and, thereafter a constant of 4 percent. The cumulative deviations of these macroexogenous variables, i.e., interest rates and fuel prices, were generated based on historical data in much the same manner as those for landings and prices.

Assumptions

The impact of the TED on the production capability of the vessel is potentially manyfold. It is expected that initially there will be a negative impact while the fisherman learns how to use the device. This "learning period" will vary by vessel and captain and, therefore, a measurement of its impact is difficult.

Contributing to this measurement problem is the range of difficulty of use across various TED devices. The Georgia Jumper and Matagorda TED's are relatively simple devices, whereas the NMFS and Cameron TED's are bulky and more difficult to work with. Many vessel captains already employ some type of excluder device ("jellyball shooters") during certain portions of the year. This experience should make efficient use of a TED more likely. In this analysis, because of the inability to establish a reasonable estimate of the "learning period" impact of adopting a TED, no impact is included.

Another point is the widespread perception that some of the TED's are bulky and, therefore, unsafe to handle and may have an effect on insurance rates. Conversely, there may be positive benefits associated with the use of a TED. Improved fishing efficiency and fewer safety problems which arise from heavy bycatch, may result in favorable changes in insurance rates. No analysis is incorporated in this study because of an inability to establish a specific impact of the TED on insurance rates.

For similar reasons, issues dealing with possible improved shrimping efficiency associated with use of the TED are not dealt with in this analysis. This improved efficiency centers around possible higher percentage of shrimp in the catch when a TED is used, resulting in longer tow times, improved shrimp quality, and reduced sorting time.

A final issue is that research to date has been limited to tow-by-tow comparisons for one vessel and do not represent the situation when all vessels will pull a TED. For example, if an area of ocean bottom contains, at any one time, a fixed amount

[16]Anonymous. 1987. Regulatory impact review and regulatory flexibility analysis for regulations which require the use of turtle excluder devices by shrimpers to conserve sea turtles. U.S. Dep. Commer., NOAA, NMFS Southeast Reg. Off., St. Petersburg, Fla., 25 p.

[17]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

of shrimp, several passes through the area might catch a fixed proportion of available shrimp. If each net is catching less shrimp on the first pass (because of the TED), subsequent passes will be associated with larger remaining population level because less shrimp were taken on the previous tow. Thus, although catch per unit of effort might be reduced for a given tow because of the TED, the catch per unit of effort would not decrease as much as suggested by the sample data because more population remains for the next tow. The argument is perhaps best seen in reverse. Some of the research indicates that the use of a TED increases shrimp catch, yet it is not sensible to believe that the total shrimp catch Gulf-wide could increase annually by 5 percent if TED's are employed. The impact of TED's on the industry cannot be extrapolated from an isolated vessel pulling a TED, which has been the research to date.

The studies that have been conducted to date do not focus on the above issues and, therefore, data are limited. Although these issues are recognized as being important, they are not considered in this analysis.

It was assumed that the vessel was purchased new at the beginning of the historical simulation (1978). The vessel was of steel construction and 73 feet in length. In purchasing the vessel, it was assumed that 50 percent of the purchase price was paid down and the rest of the purchase price was financed over a 10 year period at 9 percent per annum.

To examine the impact of the TED regulations, assumptions had to be made about the impact of the TED on production capabilities of the vessels and cost of various TED devices. These assumptions were based on production impact analysis presented earlier as well as cost information obtained for the four TED devices.

Considerable differences exist in the studies that have been conducted about the impact of the TED on shrimp production. It is assumed that shrimpers will use those TED's that are most effective at retaining shrimp. The mean shrimp retention, however, has generally ranged from a small increase to about a 10 percent decrease when using a TED in those experiments where more than a few shrimp are encountered and technical difficulties are absent. Therefore, four scenarios are reported in this research: No change, a 5 percent decrease, a 10 percent decrease, and a 5 percent increase in shrimp production associated with the use of a TED. This range encompasses the mean retention of the most efficient TED's.

TED Costs

At the time of this study there were five certified TED's: the NMFS, Georgia Jumper, Cameron, Matagorda, and a "soft" TED. This paper was essentially complete before the soft TED was certified, and therefore, no economic analysis of this particular device is included. Highest estimates of acquisition costs were for the NMFS TED, with quotes between $375 and $475, whereas price estimates for the Georgia and the Cameron TED's ranged between $150 and $250 (Clark and Griffin[18]). For purposes of this analysis, each TED is assumed to cost $300 (a number between the lesser cost TED's and the NMFS TED).

Total cost of using a TED varied depending on type of vessel and type of TED. In the Gulf it is possible to see both double-trawl and twin-trawl rigs, indicating between three and six TED's could be required for a Gulf vessel. These numbers include a spare TED for each two TED's used. The expected life of the TED is assumed to be 2 years.

The model was run for a double-trawl rig which required an investment in three TED's at a cost of $300 per TED. This resulted in a total purchase cost for the Gulf vessel of $900 or an annual cost of $450.

An additional annual maintenance cost of $50 was assumed, resulting in an annual TED cost of $500. An accounting technique, which entered the TED cost on the cost side of the model and reduced initial cash by one-half the purchase price of the TED, forced the model to put cash aside for the purchase of a TED 2 years in the future.

[18]J. L. Clark and W. L. Griffin. 1987. Update of costs and returns for seven Texas shrimp vessels. Nat. Resour. Work. Pap. Ser. Nat. Resour. Workgroup, Dep. Agric. Econ., Tex. A&M Univ., Coll. Sta., 2 p.

Method of Evaluation

Variables used in evaluating the impact of TED regulations on the representative vessel were ending net worth in year 10, internal rate of return of the analysis, present value of ending net worth, equity-to-asset ratio and the probability net present value will be greater than zero. Net worth was determined by subtracting total liabilities from total assets. Ending net worth reflected owner's equity in the vessel and in other personal property at the end of the planning horizon. The internal rate of return is often referred to as "marginal efficiency of capital." By definition, internal rate of return is the discount rate that equates present value of benefits with the present value of costs. An investment is selected as long as internal rate of return exceeds cost of capital.

The present value technique puts the net worth at the end of the planning horizon in real dollars. The equity-to-asset ratio is one measure of solvency. A one-to-one ratio means a vessel/boat owner did not have any debt. A ratio less than one-to-one would indicate a business had not paid off all debt owed on assets (Osburn and Schneeberger, 1978).

Another issue when examining economic viability of the vessel is the probability that net present value of a stream of income during the period of analysis was greater than zero. The discount rate used for calculating net present value was set at 7 percent. It was not unreasonable to expect this rate of return on alternative investments outside the fleet. These five variables are obtained from stochastic simulations for the baseline and four TED scenarios.

Discussion of Simulation Results

Deterministic Simulation 1978-1986

A representative Gulf vessel was simulated for 9 years. An outstanding balance on the vessel of $120,000 was financed during 10 years at a rate of 9 percent per annum. Beginning cash reserve was set at $26,000 and resulting beginning net worth (market value) was $117,692.

Table 2.—Annual production costs for a representative Gulf shrimp vessel (73 feet, steel hull).

Item	Cost (season total)
Ice	$ 3,106
Fuel	23,271
Repair and replacement	12,746
Other	14,063
Packing	$0.09/lb.
Dock rental	663
Insurance	7,738

Table 3.—Comparison of output variables at the end of a 10-year period across baseline and TED policy simulations for the Gulf of Mexico.

Simulation	Percent impact on shrimp production	Ending net worth	Internal rate of return	PV of ending net worth	Equity/ assets	Probability NPV>0
Baseline		$896,801	0.0372	$455,888	0.945	0.78
Scenario 1	0	886,062	0.0361	450,429	0.945	0.78
Scenario 2	−5	781,577	0.0231	397,314	0.936	0.74
Scenario 3	−10	680,316	0.0091	345,838	0.929	0.58
Scenario 4	+5	998,247	0.0500	507,458	0.960	0.82

These starting values are required by the model, but will not affect the comparative analysis of using a TED.

Annual values for those costs which varied with level of production are presented in Table 2. In addition to these costs, dock space was set at an annual rental of $663. Fixed costs, those which are set at the beginning of the year and do not vary during the period under consideration, included only vessel insurance at $7,738. Other costs, such as depreciation and interest, were calculated by FLEETSIM.

By simulating the model for the nine year period, 1978-86, the ending financial position for the vessel was obtained. The vessel ends the 9 years with $122,469 in cash on hand and vessel assets worth $211,692, giving total asset value of $334,161. The only liability associated with the vessel was an intermediate-term debt of $17,155. Net present value for 9 years was $54,739. Internal rate of return was 8 percent.

Baseline Simulation

The baseline simulation was set up to simulate what would occur to the Gulf vessel during 1987-97. This was accomplished without considering the impact of TED regulations and results were later used to compare against those analyses where the TED policy was simulated. The baseline simulation was run for 50 different iterations which allowed average values to be generated for the statistics of interest.

The vessel, purchased in 1978 had a market value in 1987 of $211,692 and a replacement value was $400,000. Average ending net worth in year 10 for baseline simulation was $898,801 (Table 3). Although the value for average internal rate of return is low (3.72 percent), the use of a representative vessel in the simulation model contributed to this low value. The practice by many Gulf shrimpers of spreading the cost of running a vessel across many different operations, allows the vessel to be run less efficiently and still remain solvent; hence, a low internal rate of return for the vessel. Many vessel operators, however, are very efficient and generated much higher rates of return.

Average present value of ending net worth was $455,888 and average equity to asset ratio was 0.945, indicating the operator had a low debt level. The baseline simulation model had a 78 percent chance of generating a net present value greater than zero (with a discount rate of 7 percent).

Simulation with TED

Four different simulations were run to examine impacts of TED regulations on a typical Gulf vessel. Again, 50 iterations of each simulation allowed average values for the statistics of interest to be generated. These different scenarios were run assuming no impact on shrimp catch (Scenario 1), a 5 percent decrease in catch (Scenario 2), a 10 percent decrease in catch (Scenario 3), and finally a 5 percent increase in catch (Scenario 4). These results were as expected in that all economic indicators declined for negative impacts on shrimp production and increased for the positive impact on shrimp production (Table 3).

The next step in the analysis of the simulation results was to determine if the decrease or increase in the economic indicators was a significant change from the baseline simulation. This was accomplished by a statistical comparison of the means. The hypothesis tested was

$$H_0: \mu^1 - \mu^2 = 0,$$

with an alternative hypothesis of

$$H_1: \mu^1 - \mu^2 \neq 0.$$

The test statistic used

$$z = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu^1 - \mu^2)}{\sqrt{\frac{s_1^{\,2}}{n_1} + \frac{s_2^{\,2}}{n_2}}}$$

which is an approximation of the Student t statistic, and can be used when sample sizes are sufficiently large (DeGroot, 1975). The sample sizes, n_1 and n_2, are equal to 50. This test statistic allows determination of significant differences from the baseline results but does not allow any comparisons to be made across all simulations. Since the primary purpose of this analysis was to determine if use of the TED resulted in a change in the economic well-being of the vessel, it was felt this test statistic would be sufficient.

The computed z-values for the various economic indicators are presented in Table 4. Each row examines the computed z-value for a TED scenario against the baseline scenario. Those test statistics which were significant at the 95 percent level are marked as footnote 2. It is apparent that all of the TED Scenarios where there is a change in the level of catch will cause a significant change in both Ending Net Worth in Year 10 as well as Present Value of Ending Net Worth. This is important because it indicates that even the discounted Net Worth is significantly different. However, Internal Rate of Return (IRR) is not significantly different from the baseline until Scenario 3. In Scenario 2, where the impact on the shrimp catch is a loss of 5 percent, the calculated z-value is significant at the 80 percent level. There is no significant difference in the values for the Equity/Asset ratio between the baseline and any of the TED scenarios.

What this suggests is that the impact of the TED is significant if the vessel owner is primarily interested in vessel earnings. However, if alternative enterprises are to be considered then there is no appreciable difference in the rate of return associated with the decision to operate a shrimp boat or an alternative enterprise until the impact upon the shrimp catch is very large. It is also notable that the impact upon shrimp catch and therefore earnings, does not result in significant increases in debt levels in the TED scenarios. Because of the way the FLEETSIM model generates Probability of Net Present Value greater than Zero, it was not possible to use the above test to determine significant differences from the Baseline scenario.

Table 4.—Calculated z-values for output variables used in determining if TED scenario values are significantly different from baseline values.

Simulation	Percent impact on shrimp production	Ending net worth	Internal rate of return	PV of ending net worth	Equity/ assets
Scenario 1	0	1.517[1]	0.100	0.48	0.01
Scenario 2	−5	19.433[2]	1.365[1]	6.146[2]	0.281
Scenario 3	−10	18.289[2]	2.797[2]	12.168[2]	0.774
Scenario 4	+5	−15.155[2]	−1.18	−4.792[2]	0.645

[1]Indicates difference is significant at the 20 percent level.
[2]Indicates difference is significant at the 5 percent level.

Summary, Discussion, and Conclusion

This analysis is an intermediate analysis of the impact of the TED regulations. It does not explicitly consider the interactive aspects of the shrimp fishery both among vessels and between vessel catch and the remaining shrimp stock. This analysis is based on the resultant impact on the catch of a representative vessel in the Texas shrimp fishery given all interactive effects.

Four scenarios were analyzed for the effect of the TED on shrimp production. These were, no change, a 5 percent decrease, a 10 percent decrease and a 5 percent increase. The results were as expected in that all economic indicators declined for negative impacts on shrimp production and increased for the positive impact on shrimp production. A statistical analysis of the economic indicators pointed out that in Scenario 2 and 4, both of which represented a 5 percent impact upon shrimp catch, Ending Net Worth and Present Value of Ending Net Worth were significantly different from the baseline at a 5 percent level. Only in Scenario 3 (10 percent decline in catch) were Ending Net Worth in Year 10, IRR, and Present Value of Ending Net Worth all significantly different from the Baseline Scenario at a 5 percent level. Research to date, however, indicates that there are TED's, specifically the Georgia TED, which have experimental results consistently better than a 10 percent shrimp loss. In fact, the Georgia TED (or Georgia Jumper) has increased shrimp retention in all experiments reported here. If there is no effect upon shrimp landings as a result of pulling the TED, the only economic effect will be the cost of purchasing and maintaining the TED. These costs will have only a very minor impact on the shrimp industry.

It is important to note that no research has been undertaken on other impacts a TED may have on shrimping operations. For example, in addition to the impact which by-catch reduction may have on shrimp catch, the TED may also impact quality, onboard safety, and onboard handling of gear and shrimp fleet catches when all vessels are pulling a TED. None of these potentially significant impacts have been studied here or elsewhere.

As discussed, no conclusive statements could be made about the impact of the TED upon shrimp retention using the existing data. A first step in the analysis of the impact of TED regulations on the shrimp industry should be to analyze the combined effects of shrimp gain or loss by an individual vessel with biomass changes when all vessels in the industry use a TED and the individual vessel impacts from reduced by-catch. These combined effects entail looking at the impacts, in the limit, of shrimp gain or loss when tows are successively applied to a fixed biomass of shrimp over time. If the combined effect leads to shrimp loss to all vessels, then further statistically valid side-by-side tests of a TED or TED's on shrimp retention need to be done. The other issues of shrimp quality, safety and deck handling procedures could possibly be included in these further tests. However, if there is no significant shrimp loss to all vessels when considering the above combined effects, then further expensive side-by-side retention tests of TED's is not warranted.

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Literature Cited

Dean, R., and D. W. Steinbach. 1981. Endangered marine turtles of the Gulf coast. Tex. Agric. Ext. Serv., Tech. Rep. L-1867, 5 p.

DeGroot, M. 1975. Probability and statistics. Addison-Wesley Press, Reading, Mass., ch. 8.

Osburn, D. D., and K. C. Schneeberger. 1978. Modern agriculture management. Reston Publ. Co., Inc., Reston, Va., p. 81-113.

Penson, J.P. Jr., D. W. Hughes, and R. F. J. Romain. 1984. An overview of COMGEM: A macroeconomic model emphasizing agriculture. Tex. Agric. Exp. Sta., Dep. of Agric. Econ. Inform. Rep., DIR 84-1, DP-12, 25 p.

USDC. 1978. Final Environmental Impact Statement on Listing and Protecting the Green Sea Turtle, Loggerhead Sea Turtle, and Pacific Ridley Sea Turtle Under the Endangered Species Act of 1973. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., St. Petersburg, FLa., 25 p.

________. 1985. Annual report FY85 - trawling efficiency device project. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southest Reg. Off., St. Petersburg, Fla., 10 p.

Watson, J. W., J. F. Mitchell, and A. K. Shah. 1985. Trawling Efficiency Device, a new concept for selective shrimp trawling gear. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southeast Fish. Cent., Pascagoula, Miss.

Yaffee, S. L. 1982. Prohibitive policy: Implementing the Federal Endangered Species Act. MIT Press, Cambridge, Mass.