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Fuel Efficiency Analysis of Trawl Nets in the Gulf of Mexico Shrimp Fisheries

Gary Graham and Dewayne Hollin

Shrimping is a fuel-intensive industry. More than one-third of the diesel fuel consumed in the U.S. fisheries is by Gulf of Mexico shrimp vessels, and more than 70 percent of this consumption is associated with trawling during shrimping operations. Eighty percent of the overall pull on the gear is distributed on the trawl nets. This project, conducted by the Texas Marine Advisory Service (MAS) and funded by the Texas Governor's Energy Office, evaluated new technology that permits more durable, but smaller, diameter twine to be used in shrimp net construction. Catch rates, trawl durability and increased fuel economy are parameters that were determined during testing by commercial fishermen under the direction of MAS. Initial results presented in this preliminary report are very promising for reducing fuel consumption as well as increasing shrimp production.

Two types of materials were compared to traditional nylon netting—KEVLAR, manufactured by DuPont, Inc., and SPECTRA, produced by Allied Fibers. KEVLAR, an Aramid, and SPECTRA, an ultra-high molecular weight polyethylene, are substantially stronger than nylon of equal twine diameter. This project sought to determine if high-tech materials of a smaller size, yet approximately equal strength, than nylon could be effectively used in trawl webbing.

Two sizes of SPECTRA and two diameters of KEVLAR were evaluated. Comparative trawls constructed of Number 18 nylon were used as controls. Engineering studies were performed aboard the RV GEORGIA BULLDOG off the Georgia coast to obtain comparative measurements of spread, speed, engine rpms and fuel consumption between a trawl constructed of the high-tech fibers and its nylon counterpart. Following these studies, the trawls were tested aboard commercial shrimp vessels in Texas. The trawls were placed aboard quad-rigged vessels for comparison, with two nets of the high-tech materials and two of traditional Number 18 nylon. Differences in production parameters of the nets were noted and the materials were observed closely to determine the abrasion resistance.

Early in the on-board tests, it became obvious that the KEVLAR abraded so much that it was uneconomical as trawl material in the Gulf fishery. The SPECTRA material, conversely yielded very positive results. Production increases of approximately 15 percent have been achieved regularly, while fuel consumption has been reduced as much as 20 percent. After a year of being towed, the SPECTRA material has also shown virtually no abrasion.

Today, there are vessels reporting conservative increases in shrimp production of 15 to 20 percent while decreases in fuel consumption by as much as 20 percent with SPECTRA fibers. Although the material costs considerably more per pound than traditional nylon, SPECTRA is much lighter in weight. A cost analysis of SPECTRA is important so industry participants are not subjected to "price tag shock."

Technical Data

Twine Comparisons

The specifications of the various twines tested are shown in Table 1.

Table 1. Twine Differences

Material	Approx. Diameter Inches	Approx. Feet per Pound	Strength Pounds
SPECTRA #7	.034	3,280	155
Nylon #15	.051	1,500	125
Nylon #18	.058	1,090	170
Nylon #21	.065	860	210
SPECTRA #11	.048	2,000	220

Gary Graham is a marine fisheries specialist and Dewayne Hollin is the marine business management specialist for the Texas Marine Advisory Service.

The important differences in the diameters and corresponding breaking strengths of several sizes of SPECTRA and nylon sizes are identified.

The #7 SPECTRA has a breaking strength of 155 pounds, which is midway between #15 and #18 nylon. Preliminary tests have indicated that this size of material may not be strong enough for the stresses imposed by deep water, brown shrimping grounds. Mudding and other rigorous conditions encountered in deep water may limit utilization of the smaller-sized high-tech fibers to the white shrimping grounds.

The larger sized-SPECTRA #11 has substantially greater breaking strength than #18 nylon and is slightly stronger than #21 nylon. It performed very well on the brown shrimping grounds.

The differences in weight of the various types and sizes of twines are shown in the column labeled **Feet per Pound**, which indicates that substantially more feet of twine are in a pound of SPECTRA than in nylon.

Twine Area Comparisons

Obvious benefits can be achieved through use of trawls with smaller twine surfaces. A net with a smaller surface area can be towed more efficiently through the water because of less drag. A reduction in drag may also result in greater horizontal spread and increased shrimp production. In order to increase efficiency through reduction of twine area, durability of the trawl, strength of the gear and catch efficiency must be maintained. These criteria were achieved using SPECTRA gear.

Nets constructed of new, high-tech materials and those made of nylon webbing were measured at the National Marine Fisheries Service Laboratory in Pascagoula, Miss., to obtain differences in the surface area between trawls. Table 2 shows a comparison of trawls constructed of the two sizes of SPECTRA webbing and the corresponding net designs made from #18 nylon. As indicated, there was a 38 percent difference between the #7 SPECTRA 40-foot, two-seam balloon and its nylon counterpart. The #7 SPECTRA net had a twine area of 84.47 $ft.^2$, compared with a 118.5 $ft.^2$ surface area for the #18 nylon.

Because of its greater size, differences in twine area were not as large for the SPECTRA #11 flat net when compared with the nylon #18 trawl. The #11 SPECTRA net had a twine diameter of 120 $ft.^2$ as compared to 157 $ft.^2$ for the nylon trawl. This represents a difference of 24 percent.

Engineering Tests

Different parameters of efficiency were established during engineering tests aboard the RV GEORGIA BULLDOG. This research vessel operated by the University of Georgia Marine Extension Service is equipped with various equipment to measure trawl spread, towing speeds, precise engine rpm and total trawl pull. The differing measurements between the SPECTRA trawls and corresponding nylon nets are shown in Table 3. The various parameters of efficiency were taken at two different engine speeds—approximately 1100 rpm and 1200 rpm.

Several conditions were encountered during these tests that impacted tests results. Trawls evaluations initially began using 8'x40" trawl doors. Because of the spreading efficiency of the high-tech fibers, these trawl doors opened the nets to their maximum horizontal openings. This phenomenon precluded the possibility of obtaining comparatiave measurements between the SPECTRA and nylon trawls. For comparative purposes, small trawl doors, 6' x 36", were used to obtain data. It should be noted that the nets were towed with the bags open and with no chains to eliminate variability of catch.

Encounters with different concentrations of soft jellyfish were another problem during the test tows. Although the cod ends were left open, the jellyfish were often caught in the meshes of the webbing, which can create resistance and variability between drags.

Differences in spread, speed and pull are shown in Table 3. Increases in efficiency can be noted for each trawl type constructed of SPECTRA.

Otter Door/Trawl Evaluations

Comparative tests were performed to determine the potential for increasing energy efficiency by reducing trawl door sizes in conjunction with high technological netting. The trawler FV GOLDEN EAGLE, based in Freeport, Tex., participated in sea trials to determine if efficiency could be enhanced through use of smaller otter doors with SPECTRA nets. This vessel was equipped with a GM 12-71 engine with a 4.5-1 reduction gear. A 54-inch propeller with a 36-degree pitch was used on the vessel.

Three sizes of trawl doors were used in the evaluations and comparisons were made with two diameters of SPECTRA fibers and #18 nylon netting materials. Parameters of efficiency such as engine speed and vessel speed were documented. The results of these sea trials are shown in Table 4.

Obvious parameters of increased efficiency were achieved when size reduction of trawl doors was incorporated into the study. When compared with the traditional gear used aboard the vessel—35-foot trawls with 7-foot by 40-inch doors—substantial reductions in engine speeds were experienced. These reductions in engine revolutions related directly to fuel efficiency and engine life expentancy. The potential for fuel savings was confirmed by comparing graphs showing fuel consumption rates at various engine rpms. These graphs, printed by the engine manufacturer, indicated two and a half gallons per hour fuel reduction.

After extensive trials with the SPECTRA gear, the owner/captain of the FV GOLDEN EAGLE indicated that two and a half gallons of fuel per hour savings was a conservative estimate. Fuel capacity aboard his vessel had been a limiting factor regulating the length of fishing trips. Through incorporation of high technological fibers, he was able to extend his fishing trips by three to four days (25 to 30 percent longer). It should be noted that the 35-foot nylon trawls traditionally used aboard the vessel were compared to even larger SPECTRA trawls (40-foot headrope length).

An anomoly seems to exist in these data. When comparing engine speeds required with 7-foot doors for the two SPECTRA sizes, the smaller, No. 7, required more engine rpms than the larger sized material. Similar results

Table 2. Twine Area Comparisons

40' Two Seam Balloon (Hollis Special) Trawl	
No. 18 Nylon	No. 7 SPECTRA
15.33 m^2	8.22 m^2
118.5 $ft.^2$	84.47 $ft.^2$
1.79 inch stretch	1.77 inch stretch
38 percent difference	
40' Flat Net	
No. 18 Nylon	No. 11 SPECTRA
14.59 m^2	11.16 m^2
157 $ft.^2$	120 $ft.^2$
1.79 inch stretched	1.82 inch stretched
24 percent difference	

Table 4. Efficiency Parameters Obtained from Various Trawl Door Sizes and Netting Types.

Door Size	Spectra #7	Spectra #11	Nylon #18
8'x40"	1580 rpm 2.2-2.3 nts	1580 rpm 2.5 nts	
7'x40"	1540 rpm 2.3-2.5 nts	1500 rpm 2.5-2.7 nts	1600 rpm* 2.5 nts
6' x 40"	1450-1500 rpm 2.6-2.7 nts		

*Note that #18 nets were 35-foot trawls as compared to 40-foot SPECTRA nets.

Table 3. Two 40-foot Flat Nets: SPECTRA #11 versus Nylon #18 with 6' x 36" Doors.

Material	RPM	Spread (Feet)	Speed	Pull (Pounds
NYLON	1104	61.8	2.65	2625
SPECTRA	1109	64.9	2.79	2500
DIFFERENCES		5%	5%	5%
NYLON	1211	60.9	2.90	3175
SPECTRA	1203	64.9	3.03	2625
DIFFERENCES		6%	4%	17%
Two 40-foot Two-Seam Balloons (Hollis Special) SPECTRA #7 versus Nylon #18 with 6' x 36" Doors.				
NYLON	1107	60.5	2.71	2625
SPECTRA	1104	67.0	2.8	2488
DIFFERENCES		10%	4%	5%
NYLON	1208	60.2	2.87	3175
SPECTRA	1205	66.5	3.02	2725
DIFFERENCES		9%	5%	14%

Table 5. Cost Comparisons on Trawl Nets (webbing only)

Type of Net	Material	Estimated Cost per Net*	Cost for Eight Nets
40' Balloon Net	#18 Nylon	$ 800	$ 6,400
40' Balloon Net	#7 SPECTRA	$1,180	$ 9,440
40' Balloon Net	#11 SPECTRA	$1,395	$11,160
40' Flat Net	#18 Nylon	$ 700	$ 5,600
40' Flat Net	#7 SPECTRA	$1,000	$ 8,000
40' Flat Net	#11 SPECTRA	$1,200	$ 9,600

* Costs do not include doors, TED's, tickler chain or other cordage.

were noted with comparisons between the SPECTRA sizes using 8-foot doors. The explanation for this relates to the angle of attack assumed by the trawl doors. The No. 7 SPECTRA nets yielded such low resistance that they were overspread by the 7- and 8-foot doors. As a result, the trawl doors assumed a greater angle of attack, which introduced abnormal requirements on engine speed. In later efforts under actual fishing conditions, the angle of attack was reduced in the 7-foot by 40-inch doors. This made the gear fish more efficiently. Currently the vessel is using the 7-foot doors rather than smaller 6-foot doors because of their superior performance on softer substrates encountered in the offshore waters of Texas. The larger doors have a tendency for less bogging of trawl into the seabed.

It is apparent that smaller sized trawl doors can be used with the SPECTRA netting materials. This will contribute to even greater efficiency in trawling activities. Because of reduced weight of smaller doors, on-board handling of gear can also be made easier.

Cost Analysis (SPECTRA versus Nylon Webbing)

SPECTRA is more expensive than nylon, but it is also much lighter. While SPECTRA costs $34.60 per pound, nylon costs only $3.50 per pound or about 1/10 the cost of SPECTRA. One bale of these materials is 3000 meshes X 200 1/2 meshes regardless of size of twine or material type. The weight per bale of each material is as follows:

SPECTRA # 7	82 pounds
SPECTRA #11	144 pounds
NYLON #18	260 pounds
NYLON #21	295 pounds

The important cost that should be evaluated is that of the nets built from either SPECTRA or nylon webbing. Two common sizes and types of shrimp nets — a 40-foot balloon net

Table 6. Cost Differential Based on Percent of Added Cost for SPECTRA Spare Nets

	Increased Costs (%)
1. Basic #18 Nylon 40' Flat Net ($700)	
a. #7 SPECTRA 40' Flat Net ($1,000)	+43%
b. #11 SPECTRA 40' Flat Net ($1,200)	+71%
2. Basic #18 Nylon 40' Balloon Net ($800)	
a. #7 SPECTRA 40' Flat Net ($1,180)	+47%
b. #11 SPECTRA 40' Flat Net ($1,395)	+74%

and a 40-foot flat net—will be evaluated in forthcoming cost analyses. Since each boat will pull four nets and probably carry replacement nets, we will be looking at the cost of a total of eight nets per boat. The #7 SPECTRA will probably be best used in the nearshore shrimp fishery that exists inside 15 fathoms of water, while the #11 SPECTRA should be used in deeper water.

Table 5 includes cost comparisons for trawl nets built from #18 nylon and #7 and #11 SPECTRA. The costs include the webbing only for each net constructed and for a total of eight nets from each type of material.

Table 6 shows the cost differential between both the 40-foot balloon net and the 40-foot flat net when using nylon and SPECTRA fibers. The cost differential between nylon and SPECTRA ranges between 43 percent more for #7 SPECTRA on a balloon net to 74 percent more for a balloon net using #11 SPECTRA.

An important factor in selecting any type fuel savings alternative, whether it is a vessel modification such as an engine changeout or gear modifications such as nets or doors, is to determine when the fuel-saving device or modification begins to contribute a profit to the operation of the vessel. Another way of looking at this is to determine how long it will take to "pay back" the cost of the equipment from vessel operations. The key to calculating payback is to have accurate cost estimates for purchase price, value of funds invested for the equipment or the cost of borrowing money for the purchase, accurate fuel consumption figures, and cost of fuel used in the vessel. Most of this cost information should come directly from the fishing industry.

Since most fishing is not conducted year round we base fuel consumption on annual averages for representative vessels used in the fishing fleet. The payback example in Table 6 uses conservative industry estimates of 15 percent reduction in fuel consumption while fishing with #7 SPECTRA webbing on a steel hull shrimp trawler with a 343 Caterpillar engine. The trawling was done while dropping rpm from 1,550 to 1,450, maintaining the same speed and reducing fuel consumption by 15 percent. Similar reductions in rpm were reported by industry participants in the project. A 3412 Caterpillar engine dropped its rpm's from 1,600 to 1,500 while lowering fuel consumption by 2 gallons per hour, or about 10 percent, and fishing with #11 SPECTRA webbing without a speed reduction. This drop in engine rpm's can significantly reduce the wear on engine parts and thereby increase engine life and lower maintenance costs. The cost savings on engine wear is variable by engine size and type. Due to these variables we have not included this very significant savings in our payback analysis.

Based on the assumptions shown in Table 7 we were able to calculate a payback period for the installation of eight #7 SPECTRA and eight #11 SPECTRA flat nets to be used on a shrimp trawler. The 5.9-month, or 177-day, payback period on the #7 and 14.8 months, or 444 days, on the #11 SPECTRA is based on year-round averages of fuel consumption and not heavy fishing periods. More intensive fishing would generate a shorter payback period as discussed later.

Table 7. Payback Period Based on Estimated Fuel Savings

Assumptions:

Fuel Savings — Estimated conservatively at 15% using #7 SPECTRA and 10% using #11 SPECTRA
Annual Diesel Fuel Consumption — 55,000 gallons
Cost of Diesel Fuel—65 cents per gallon
Cost of Invested Money — 10%

EXAMPLE ONE	EXAMPLE TWO
Eight #7 SPECTRA 40' Flat Nets	Eight #11 SPECTRA 40' Flat Nets
Cost—$8,000	Cost—$9,600
Incremental cost over #18 Nylon—$2,400	Incremental cost over #18 Nylon — $4,000
Annual Fuel Savings — 8,250 gal	Annual Fuel Savings—5,5000 gal
Cost — $5,363	Cost — $3,575
Payback period:	Payback period:
5.9 months	14.8 months
177 days	444 days

Table 8. Payback Period Based on Estimted Fuel Savings and Increased Production

Assumptions:

Fuel Savings—Estimated conservatively at 15% using #7 SPECTRA and 10% using #11 SPECTRA
Annual Diesel Fuel Consumption—55,000 gallons
Cost of Diesel Fuel—65 cents per gallon
Cost of Invested Money — 10%
Increased Shrimp Production—15% ($150 per day)
(Base: $1,000 per day production average)

EXAMPLE ONE	EXAMPLE TWO
Eight #7 SPECTRA 40' Flat Net	Eight #11 SPECTRA 40' Flat Nets
Cost - $8,000	Cost - $9,600
Incremental cost over #18 Nylon—$2,400	Incremental cost over #18 Nylon—$4,000
Annual Fuel Savings (based on 360 days):	Annual Fuel Savings(based on 360 days):
8,250 gallons (22.9 gal./day)	5,000 gallons(15.3 gal./day)
$5,363 ($14.90 /day)	$3,575 ($9.93/day)
Payback Period in Months (days) with Estimated Fuel Savings Only:	
5.9 months (177 days)	14.8 months (444 days)
Payback Period based on Estimated 15% Fuel Savings on #7 SPECTRA and 10% on #11 SPECTRA and Increased Production of 15% overall for both:	
16 days	27.5 days

Table 9. Payback Period Based on Fishing Season Estimated Fuel Savings and Increased Production

Assumptions:

Estimated Fuel Savings per hour of trawling — 3 gals./hr. (#7 SPECTRA) and 2 gals./hr. (#11 SPECTRA)
Number of hours trawling per day — 10 hours
Cost of Diesel Fuel — 65 cents per gallon
Cost of Invested Money — 10%
Increased production per day — 15% ($150 per day)
(Base: $1,000 per day average production)

EXAMPLE ONE	EXAMPLE TWO
Eight #7 SPECTRA 40' Flat Nets	Eight #11 SPECTRA 40' Flat Nets
Total Cost — $8,000	Total Cost — $9,600
Incremental cost over #18 Nylon - $2,400	Incremental cost over #18 Nylon - $4,000
Daily Fuel Savings:	Daily Fuel Savings:
30 gallons	20 gallons
$19.50	$13.00
Payback Period Based on Estimated Fuel Savings and Increased Production:	
15.6 days	27 days

Payback Period Calculations

Industry participants in this trawl efficiency project have attempted to estimate changes in shrimp harvest production utilizing the #7 SPECTRA and #11 SPECTRA nets. Preliminary production data show that an increase of 15 to 20 percent was not uncommon. Since shrimp production varies so much by area and by type and quality of product harvested, we selected a base of $1,000 average daily shrimp production for the payback period analysis. Table 8 provides an estimate of payback based not only on fuel savings, but also on increased production. The projected increased production of 15 percent dramatically speeds up the payback period.

Theoretical payback period calculations have been based on annual fuel consumption data, but, in reality, if new SPECTRA nets become a vessel's standard gear, the real payback period begins with the next fishing trip. Tables 9 and 10 examine the payback period when the vessel starts fishing with the new nets. These data indicate a vessel could easily pay for the new nets on one trip, particularly the #7 SPECTRA 40-foot flat nets.

Conclusions from Cost Analysis

Based on the assumptions made in our payback period computations and the fuel savings estimates provided by our industry participants, it appears that SPECTRA webbing used in both the 40-foot balloon nets and the 40-foot flat nets is economically sound. Assuming that the technical specifications, cost of net production and projected shrimp production are within the estimates we have obtained from our industry participants, the cost of the nets could easily be recouped from one to two trips offshore or within a few weeks of nearshore shrimping. Once the payback period has been completed the fuel savings and increased production can contribute significantly to the profitability of the vessel's operation.

Table 9. Payback Period Based on Fishing Season Estimated Fuel Savings and Increased Production

Assumptions:

Estimated Fuel Savings per hour of trawling—3 gals./hr. on #7 SPECTRA and 2 gals./hr. on #11 SPECTRA

Number of hours trawling per day—10 hours

Cost of Diesel Fuel —65 cents per gallon

Cost of Invested Money —10%

Increased Production per day —15% ($150 per day)

(Base: $1,000 per day average production)

EXAMPLE ONE	**EXAMPLE TWO**
Eight #7 SPECTRA Balloon Nets	Eight #11 SPECTRA Balloon Nets
Incremental cost over #18 Nylon—$3,040	Incremental cost over #18 Nylon—$4,760
Total Cost — $9,440	Total Cost — $11,160
Daily Estimated Fuel Savings:	Daily Estimated Fuel Savings:
30 gallons	20 gallons
$19.50	$13.00
Payback Period Based on Estimated Fuel Savings and Increased Production:	
17.9 days	29.2 days

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Texas A&M University
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