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TESTS OF AN EXPANDED-MESH TRAWL NET TO REDUCE FUEL CONSUMPTION IN THE CALIFORNIA PINK SHRIMP FISHERY

N. Caruso[1], C. Toole[2], L. Massey[3], C. M. Dewees[2]

UCSGEP 89-8
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California Fishing Vessel Fuel Conservation Project

CEES Contract OPR-0127

University of California Cooperative Extension
Sea Grant Extension Program
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[1]Department of Naval Architecture, UC Berkeley

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Introduction

Improvement of fuel efficiency on trawlers can be achieved through modifications to the hull, power source, drive train, and propulsion system (e.g., Lamb 1981), as well as by decreasing the resistance of the towed fishing gear (Hopper 1981). For towed trawl gear, resistance is nearly equally distributed between the doors and the net itself (Kowalski and Giannotti 1974). A previous experiment of the California Fishing Vessel Fuel Conservation Project examined fuel savings resulting from use of a hydrodynamically designed trawl door (Bison© door) compared to a standard V-door (Dewees 1987, Perry 1987). Overall fuel savings averaging 6% were documented in at-sea trials. To investigate possible fuel savings resulting from changes in net design, the present study was initiated. A standard shrimp net was modified to decrease resistance, and fuel consumption and efficiency were examined under fishing conditions. Catch efficiency of the new design was also examined. A shrimp trawl was chosen, rather than a bottomfish trawl, because the smaller mesh size has greater resistance so changes in design should result in higher fuel savings.

Materials and Methods

Standard pink shrimp (*Pandalus jordani*) nets used on the Pacific coast are constructed of nominal 1 1/2-in mesh (1 3/8-in stretch mesh) throughout the body, wings, and cod end. A design popular in Oregon and central California (J&B©) was chosen as a standard net for comparison (Figure 1). The net had an 80-ft headrope and was constructed of #15 nylon mesh. The theoretical resistance of the net was calculated using Tauchi's formula (Koyama 1984), which considers twine diameter (d), bar mesh length (L), mesh opening angle (Γ), panel surface area (psa), and mesh attack angle (θ) as follows:

$$\text{Resistance} = \left[\frac{d}{L}\right] * \frac{1 - \cos^2\Gamma \cos^2\theta}{\sin\Gamma \cos\Gamma} * psa^2$$

Total twine surface area of the net was 1150 ft^2, while the theoretical resistance was 960 lbs.

A new 80-ft headrope net (Figure 2) was constructed by Pacific Trawl Co. of Eureka, based in part on a design developed by Duncan Amos of the University of Georgia Sea Grant Program. The Pacific Trawl net consisted of 6-in mesh of 4 mm poly twine in the jibs and top wings, grading to 3-in mesh of 3 mm poly twine in the wings and squares, and then 1 1/2-in mesh of #18 nylon throughout the remainder of the net. In addition to this, the net employed a fast taper in the intermediate section to reduce angle of attack and a very tight hanging ratio. Twine surface area was 725 ft^2 and theoretical resistance was 860 lbs.

Figure 1. Standard shrimp net (J&B©) used in field tests. TSA = twine surface area; numbers refer to meshes (M) in each section.

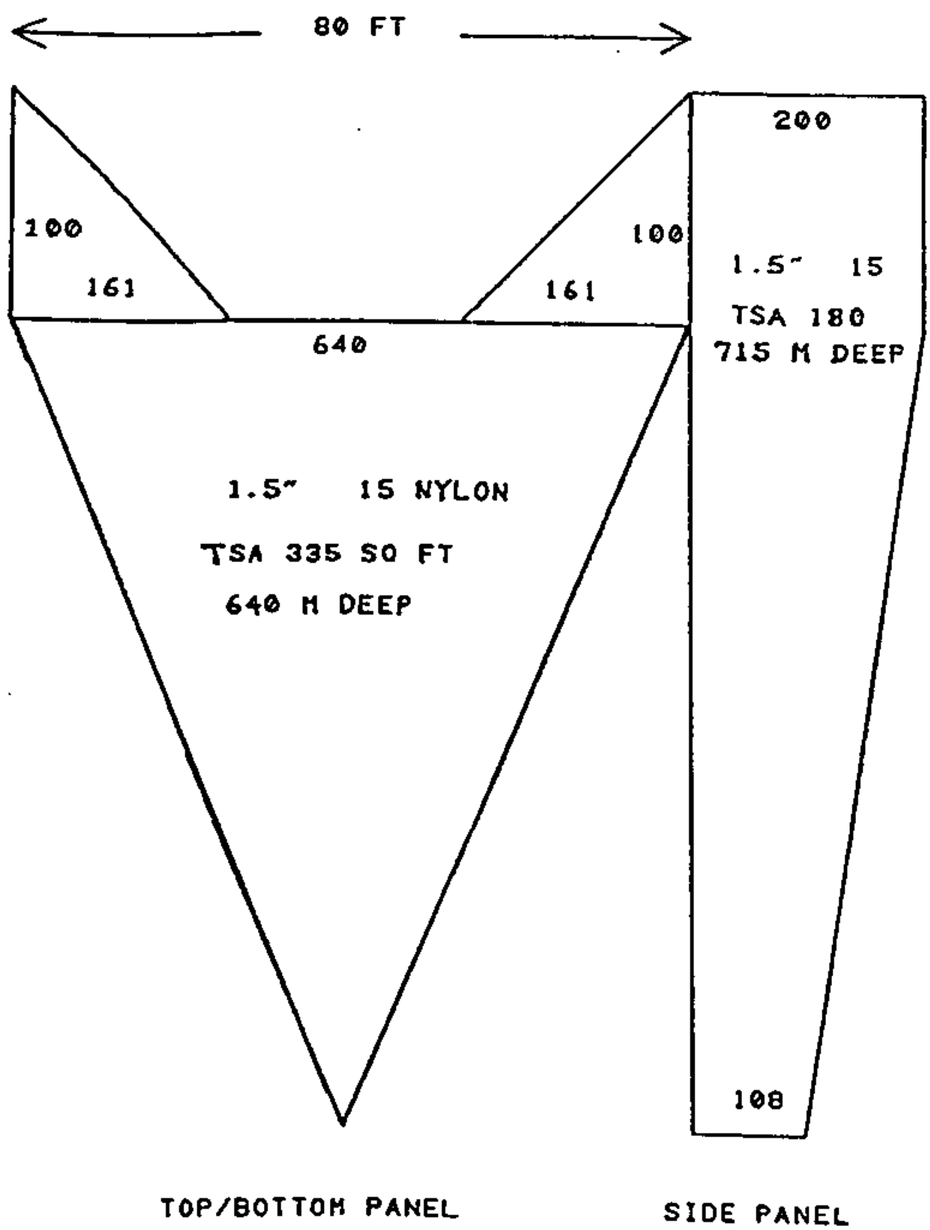
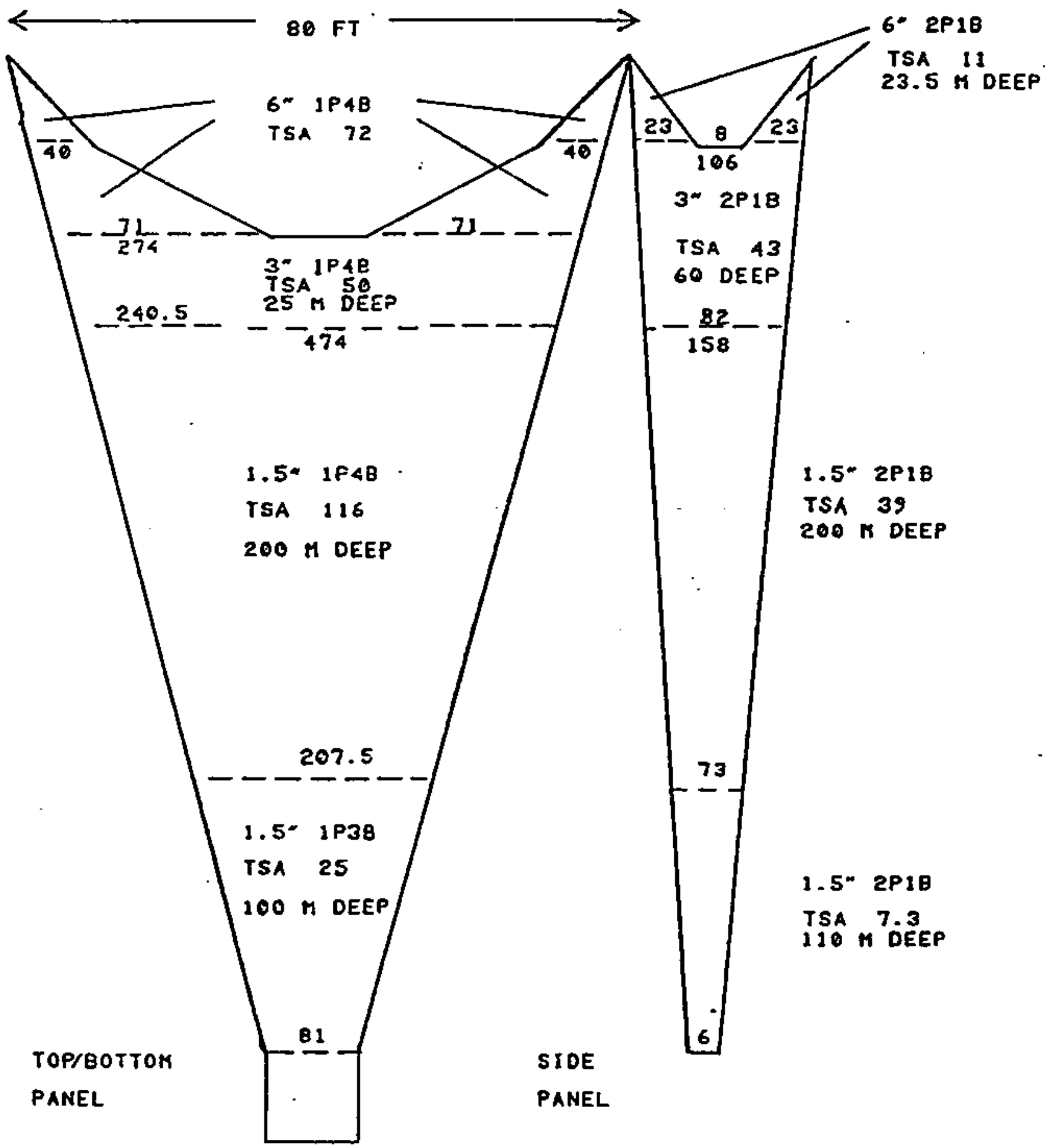


Figure 2. Experimental trawl (Pacific Trawl Co.©) used in field tests. TSA = twine surface area; M = meshes; P = mesh cut on point; B = mesh cut on bar (for determining mesh tapers).



The nets were fished on the F/V Gus D, a 73-ft wooden stern trawler similar to many of the older vessels in the fleet. Characteristics of the Gus D are presented in Table 1. One advantage of the vessel for the present experiment was the ability to fish in either a single or double-rigged configuration.

Table 1. Characteristics of the F.V Gus V.

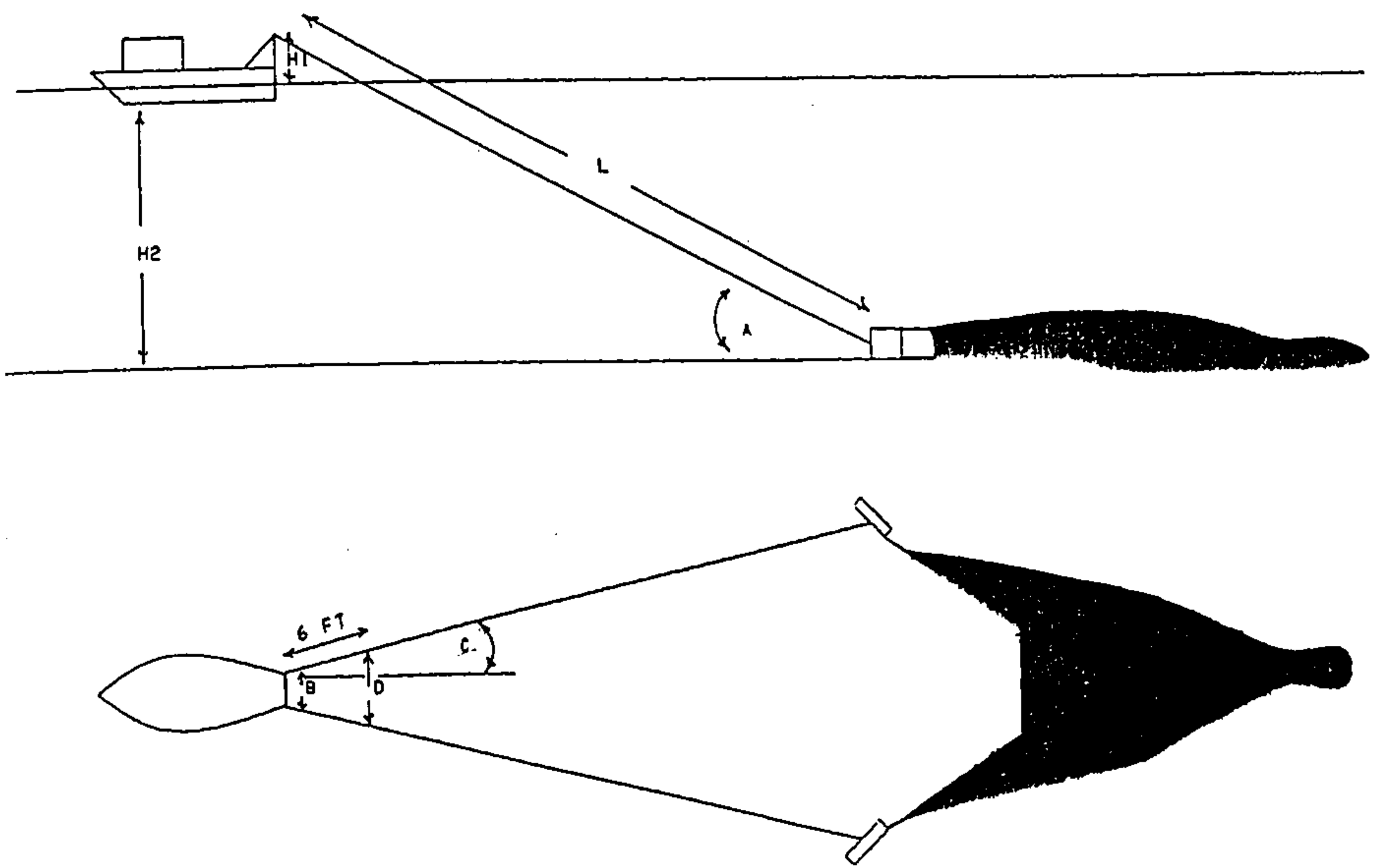
Length over-all	73 ft	Engine	Caterpillar 343 SHP
Beam	20 ft	Reduction gear	6:1
Draft	12 ft	Propeller	60 x 52, 4 blade
Tonnage	99 gross		

Two sets of tests were made. The first tests were conducted in July 1988 near Morro Bay and were designed to measure the efficiency of each net. During these tests the boat was single-rigged and the net towed off the stern so there would be no effects of ruddering. One set of 5 x 7-ft steel V-doors was used for all trials. Tows were made at a constant depth at a series of three RPMs. Tows were made both with and against the current and averaged together in an attempt to cancel out its effects. Vessel speed (speed over bottom) was determined to the nearest 0.1 nmile/hr using LORAN. Fuel consumption was measured to the nearest .01 gal using a MAX Machinery© positive displacement, radial piston flowmeter. Warp tension (total resistance of trawl gear) was measured with spring gauges to the nearest 100 lbs. Since tension fluctuated continuously, values are averages of several measurements taken during each tow.

Resistance of the fishing gear as measured by warp tension is actually made up of three components: resistance in the opposite direction of the propeller thrust (opposing force), resistance lateral to the direction of propeller thrust (spreading force of the doors and net), and resistance downward due to weight of the fishing gear and the tendency for it to dig in (ground force). In an attempt to separate these forces the angle of the towing warps as they left the boat was measured, as was length of towing warps and depth of water (Figure 3). The force components were then determined as:

$$\text{Opposing Force} - W * \cos\left[\arcsin\left[\frac{H_1 + H_2 + T}{.9L}\right]\right] * \cos\left[\arcsin\frac{(D - B)}{12}\right]$$

Figure 3. Measurements used in calculating components of trawl gear resistance. See text for explanations.



$$\text{Spread Force} = W * \cos\left[\arcsin\left[\frac{H_1 + H_2 + T}{.9L}\right]\right] * \sin\left[\arcsin\frac{(D - B)}{12}\right]$$

$$\text{Ground Force} = W * \sin\left[\arcsin\left[\frac{H_1 + H_2 + T}{.9L}\right]\right]$$

Where H_2 = height of gallows above water (ft), H_2 = depth of water (ft), T = draft of boat (ft), L = length of warp cable (ft), B = distance between gallows (ft), D = distance between cables 6 ft behind gallows (ft), and W = warp tension (total of two cables) (lbs).

A second set of tests was made near Crescent City in October 1988 to compare the catch of shrimp with each net. For these tests, the boat was double-rigged from outriggers so that each net fished simultaneously. Tows were of 1-hour duration and alternate tows were made in opposite directions so that each net would be equally fished on inboard and outboard sides. Once nets were brought on deck all by-catch was sorted and the shrimp and by-catch were weighed to the nearest .05 kg. Warp tension was also recorded as a gross estimate of net resistance, since measurements included the effect of ruddering and component forces could not be separated when the boat was double-rigged.

Because only two measurements were made for each condition during the mechanical tests, no statistical analysis was possible. For biological tests, means associated with each net were compared using a t-test, modified to assume unequal variances (Elzey 1987). Differences were considered significant if the probability that they could have occurred by chance alone was 5% or less.

Results

Results of mechanical tests conducted while single-rigged are presented in Table 2 and Appendix 1. Fuel savings with the expanded-mesh net ranged from 3.4 to 5.7%, depending on RPM. The new net also pulled faster at two RPMs, although speed remained unchanged at 1550 RPM. Resistance of the expanded-mesh net was greater than for the standard net at 1450 RPM, but less at 1500 and 1550 RPM. Spreading force was much greater in the expanded-mesh net at lower speeds, but nearly identical to the standard net at 1550 RPM.

Table 2. Results of mechanical tests comparing standard shrimp net and expanded-mesh design. Percent change describes values for expanded-mesh net relative to standard net.

		STANDARD NET			EXPANDED-MESH NET			
	RPM	Against Current	With Current	Mean	Against Current	With Current	Mean	% Change
Gallons per hour	1450	8.75	8.84	8.80	8.52	8.48	8.50	−3.4
	1500	9.90	10.60	10.30	10.20	9.72	9.94	−3.5
	1550	11.00	10.30	10.60	10.30	9.72	10.00	−5.7
Speed (KT)	1450	1.75	2.00	1.85	1.90	1.75	1.87	+1.1
	1500	1.90	1.90	1.90	2.00	2.05	2.03	+6.8
	1550	2.10	2.20	2.15	2.15	2.15	2.15	0
Opposing Force (lb)	1450	3894	3741	3817	4044	4047	4045	+6.0
	1500	4261	4398	4330	4353	4280	4317	−0.3
	1550	4726	4680	4700	4659	4659	4614	−1.8
Spread Force (lb)	1450	149	104	126	155	155	155	+23.0
	1500	193	153	173	212	164	188	+8.7
	1550	214	158	186	211	159	185	−0.5

Table 3. Comparison of standard and expanded-mesh shrimp nets during biological sampling. Stnd = Standard shrimp net; Exp = Expanded-mesh shrimp net.

Hours	Depth (fm)	Av. Speed	Lbs. Shrimp Per Tow (lbs per hr)		Count Per Pound		Percent By-catch		Av. Warp Tension	
			Stnd	Exp	Stnd	Exp	Stnd	Exp	Stnd	Exp
3.00	60	2.0	203 (68)	197 (66)	-	-	-	-	3250	3000
1.08	71	2.1	222 (206)	133 (123)	73	61	7	10	3000	2000
1.92	73	1.5	385 (201)	411 (214)	87	89	6	5	3300	3000
1.83	70	1.9	214 (117)	287 (157)	85	82	33	27	3000	2500
1.75	70	2.0	311 (178)	355 (203)	90	88	8	17	3150	2750
		Mean	268 (154)	277 (153)	84	80	14	15	3140	2650

Results of biological sampling are presented in Table 3 and Appendix 2. A total of 10 tows was made, but five were considered invalid due to obvious fouling of one net or the other (2 tows) and excessive chain on the footrope of the expanded-mesh net (3 tows), which resulted in a higher catch of shrimp but also an unacceptably high by-catch. During the five valid tows there was no significant difference between the two nets, in catch ($t=-.156$, $df=9$), catch per hour ($t=.037$, $df=10$), count per pound ($t=.53$, $df=6$), or percent bycatch ($t=-.11$, $df=7$). Average warp tension of the expanded-mesh net was significantly less (average of 15.6%) than the standard net ($t=2.5$, $df=5$, $p=<.05$), giving an approximate indication of towing efficiency.

Fish by-catch consisted primarily of smelt (mainly *Thaleichthys pacificus*), herring (*Clupea harengus pallasi*), juvenile hake (*Merluccius productus*), small flatfish (mainly slender sole, *Lyopsetta exilis*), juvenile rockfish (*Sebastes* spp.), adult rex sole (*Glyptocephalus zachirus*), adult arrowtooth founder (*Atherestes stomias*), eelpout (*Atheresthes cortezianus*), skate (*Raja binoculata*), and hagfish (*Eptatretus stouti*). Invertebrates included seastars (mainly *Petalaster*), brittle stars (ophiuroids), heart urchins (spatangoids), sea pens (*Ptilosarcus gurneyi*), comb jellies (ctenophores), jellyfish (*Aurelia* ?), squid (*Loligo opalescens*), polychaetes, and isopods.

Conclusions

Results of these tests indicate that the expanded-mesh shrimp net caught shrimp as efficiently as a net with 1 1/2-in mesh throughout, while requiring less towing power and fuel. Fuel efficiency varied with towing speed, with savings ranging from 3.4 to 5.7 percent. For a shrimp trawler burning 20,000 gallons per year while fishing, this would represent an annual savings of 680 to 1140 gallons of fuel.

Results indicate that the greatest savings with the expanded-mesh net occur at faster speeds. Spreading force is much greater with the expanded-mesh net compared to the standard net at low speeds. Although not measured in this experiment, a decreased headrope height is probably associated with the increased horizontal spread (Duncan Amos, University of Georgia, personal communication). The reason for this characteristic of the expanded-mesh net's performance is not completely understood and future tests would be valuable for exploring this further.

While catch rate results indicate that the two nets fish identically, it should be noted that these results only apply to the moderate fishing conditions encountered in this survey. The average catch of both nets was 307 lbs/hr; however, the average catch for all double-rigged boats in that area for the month of October 1988 was 510 lbs/hr (P. Collier, CDF&G, personal communication) and average catches can reach 600 to 700 lbs/hr during peak fishing periods. It is possible that performance of the nets could be different under these conditions.

Acknowledgements

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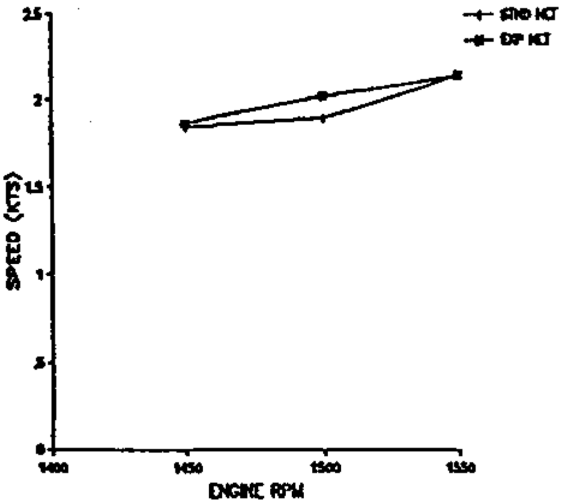
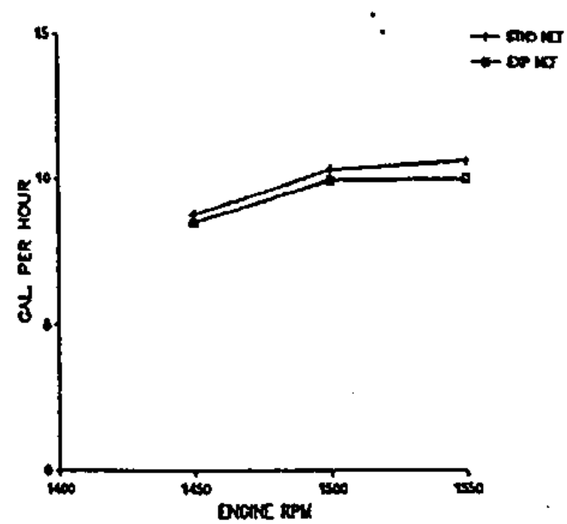
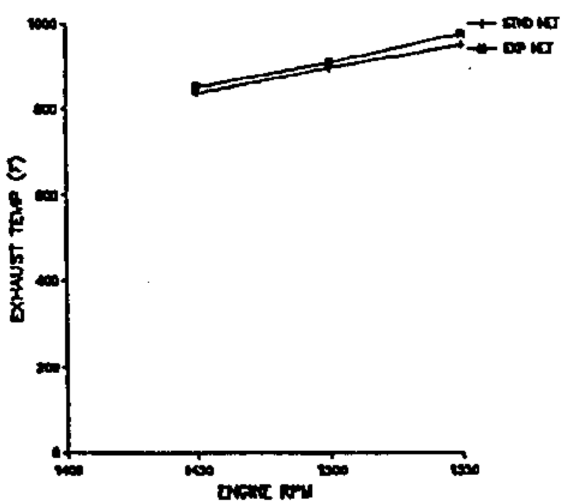
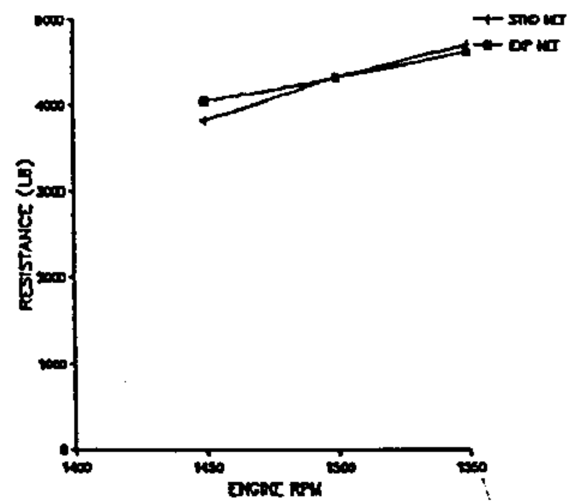
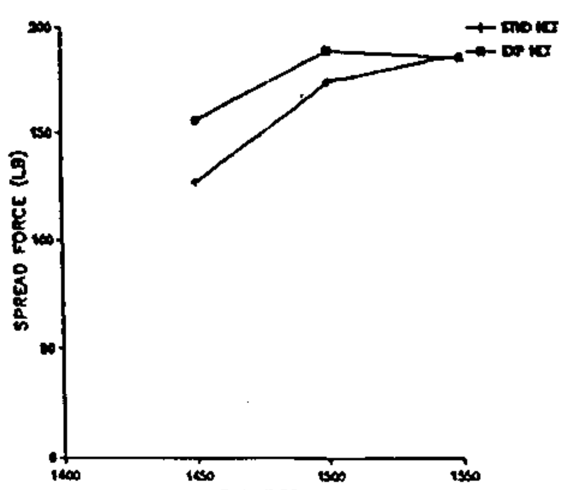
Appendix 1. Comparison of performance of standard and expanded-mesh shrimp nets at three RPM's.











Appendix 2. Comparison of shrimp catch, by-catch, and total resistance of standard and expanded-mesh shrimp nets by tow.