An Economic Appraisal of Sail-Assisted Commercial Fishing Vessels in Hawaiian Waters

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Introduction

During the past decade, commercial fishermen in the United States experienced a rapid escalation in prices paid for motor fuel. This has revived an interest in using fishing boats propelled by a combination of sail and motor power.

It remains to be shown, however, whether investment in such vessels is economically justified as a means of reducing total operating costs associated with fishing. Positive indications of the cost-effectiveness of sail-assisted fishing vessels are evident in studies conducted by Shortall (1981) and Sorensen-Viale (1981). On the other hand, inquiries into the projected financial performance of sail-assisted cargo vessels have produced conflicting findings regarding their investment feasibility (Bergeson et al., 1981; Couper, 1979; Woodward et al., 1975).

ABSTRACT—This article investigates the projected cost-effectiveness of procuring and operating two sizes of multipurpose sail-assisted vessels for commercial fishing in Hawaiian waters. Investment in two comparable sized diesel-powered vessels is also analyzed for comparison. Annual operating cost and returns are projected over a 15-year time horizon. Sensitivity analysis of investment performance is conducted using alternative assumptions about fuel prices and key vessel financing parameters. Analysis of financial projections indicates that investment performance of sail-assisted fishing boats is inferior to conventional diesel-powered boats given current fuel prices, costs of borrowed capital, and vessel acquisition costs. This conclusion would not be altered if fuel prices were to double from their current levels. However, the relative financial performance of diesel and sail-assisted vessels does appear to be sensitive to perturbations in key financial parameters, particularly the purchase price of motorsailers.

The objective of this article is to provide a different and comparative line of analysis which is useful in further assessing the desirability of procuring and operating sail-assisted commercial fishing vessels in Hawaiian waters. Due to the limited range of vessel types and fishing operations under consideration, the analysis presented here is not intended to indicate actual investment prospects of sail-assisted vessels in all other fishing contexts. Nevertheless, a more complete understanding of the general potentials and limitations of sail-assisted technology will hopefully be achieved.

The discussion begins with a historical overview of the transition from sail to motor power by the U.S. commercial fishing fleet. Economic forces contributing to renewed interest in sailing technology are identified and alternate approaches to harnessing wind energy for commercial fishing are also briefly reviewed.

In the second section, attention is devoted to determining whether investment performance of motorsailing fishing boats is superior to that of conventional fishing boats. Within the framework of a case study of commercial fishing in Hawaiian waters, an appraisal is made of the projected contribution of sail-assisted vessels toward achieving reductions in total annual operating costs. Fifteen-year cost-earning projections are made for four sail-assisted and diesel-powered vessels, and sensitivity analyses of financial projections are discussed. Finally, conclusions are drawn regarding further adoption of sail-assisted vessel technology by the U.S. commercial fishing fleet.

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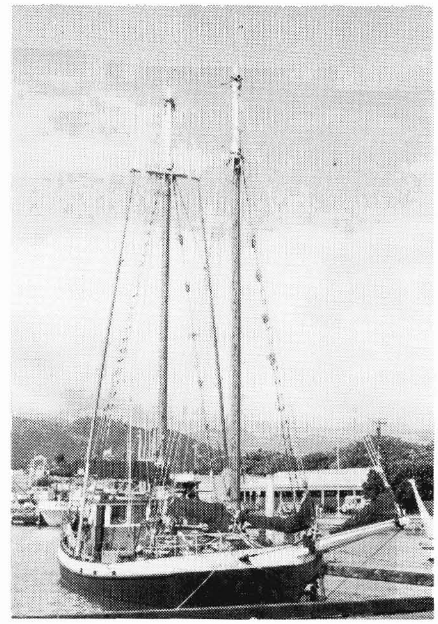

The *Cornucopia*, a sail-assisted vessel docked in Honolulu Photo by Rick Klemm, University of Hawaii Sea Grant Extension Service.

A Historical Perspective

As recently as 1920, most of the U.S. commercial fishing fleet was propelled by wind. Within three decades, however, economic changes created strong incentives for fishermen to abandon their sailing heritage. Particularly important was the increased availability of inexpensive fuels and reliable mass-produced marine engines. Altered market conditions, specifically a shift in consumer preferences toward fresh fish and away from salted and otherwise preserved fish products, also contributed to making speedier motor-powered vessels attractive investment alternatives.

Industry-wide conversion to motor power came in several stages. An initial development of commercial motor/sail fishing occurred in England during the late 1870's with the introduction of steam-powered trawling (March, 1953). Somewhat earlier, sailing trawlers were towed to North Sea fishing grounds by steam-powered tugboats. Tugs would continue to tow the trawlers around the grounds during periods of calm. A natural outgrowth of this practice was to install coal-fired steam engines directly on the sailboats and dispense with the tugs. According to March (1953), this adaptation took place over a time span of 30 years.

In the United States, transition to motor power was pioneered by fishermen who retrofitted sailing vessels with low horsepower engines (Gardner, 1982; Traung, 1955). Experiments at finding an efficient combination of sail and motor power eventually gave way to a new generation of vessels designed to operate solely on diesel or gasoline engines. The competitive edge afforded by the new technology was substantial. Although motor-powered vessels required regular and costly engine maintenance, the need for labor-intensive handling and upkeep of sails and rigging was eliminated. A typical crew of three or four could thereby be reduced to one or two. Motor power afforded greater overall dependability, faster transit speeds, and roomier hold capacities and living accommodations. A wider repertoire of fishing gear could also be used.

Since 1950, commercial fishermen's reliance on motor power has become deeply rooted. A natural outgrowth was increased dependency on fuel as a primary production input. In part, this phenomenon was the result of widespread adoption of efficient but relatively fuel intensive fishing methods such as mid-water and deep-water trawling, purse seining, long lining, and open-water trolling (June, 1950; Broadhead, 1962). Furthermore, as fishing gear and vessels became more costly, transit speeds and fuel consumption increased to minimize unproductive travel time. Other contributing factors included use of fuel-inefficient hull and propeller designs, and high energy demands to service cold storage and living facilities (Norship, Inc., 1981).

Table 1.—Price indexes for gasoline, diesel fuel, and edible fish products, 1967-81.

Year	Wholesale diesel price index[1] (1967=100)	Regular retail gasoline price index[1] (1967=100)	Ex-vessel edible fish price index[2] (1967=100)
1967	100.0	100.0	100.0
1968	101.9	101.0	108.8
1969	102.4	105.7	124.5
1970	106.5	108.8	128.9
1971	110.0	111.5	141.9
1972	111.3	107.9	168.9
1973	139.7	119.0	223.8
1974	272.0	178.7	237.8
1975	309.4	201.3	240.7
1976	337.0	209.7	303.9
1977	383.8	224.3	343.7
1978	408.5	245.1	398.7
1979	573.9	388.1	454.9
1980	850.6	538.4	406.1
1981	1,058.1	618.5	439.9

[1]Source: USDC, 1970-82.
[2]Source: USDC, 1973-82. Data for 1981 is preliminary.

In the early 1970's, prevailing economic conditions warranted continued reliance on fuel. As shown in Table 1, ex-vessel fish prices were rising faster than fuel costs. This situation dramatically reversed itself following the oil embargo of 1973. Within 7 years, the wholesale diesel fuel price index increased by 1,000 points and the retail gasoline price index rose by 600 points. During the same time, the ex-vessel edible fish price index increased by just under 300 points.

Concern about the recent price trend for fuel relative to fish and other production inputs is one of the principal reasons underlying the renewed interest in sailing fishing vessels. Reintroduction of sailing technology has taken three distinct paths: 1) Retrofitting existing fishing vessels with sailing apparatus; 2) converting vessels with yacht hull designs into fishing boats, and 3) constructing new fishing vessels designed from the outset to be sail-assisted. While each of these approaches has its peculiar advantages and limitations, a common goal is to arrive at a cost-saving mixture of sail and motor power.

Retrofitting an existing fishing vessel with sailing apparatus is a relatively inexpensive way to take advantage of wind energy. The concept has been considered for the Florida snapper/grouper fishery (Kibert[1]; Shortall, 1981). Substantial fuel cost savings are reported to be achievable, especially on long-range trips where sails are utilized 40-50 percent of the time. To date, however, most retrofitting has been attempted on smaller fishing vessels working in nearshore waters. While this may appear to be a limitation of the technology, it is a distinct possibility that larger vessels up to 20,000 deadweight tons could also benefit from installation of sails as well (Close, 1978).

A second approach is the so-called "yacht conversion" method. Here the strategy is to build a fishing vessel using an easily-driven yacht hull. Boats of this type are currently being built in several U.S. shipyards and are generally constructed in 35- to 80-foot lengths. The primary economic advantage of the yacht conversion method stems from an efficient hull design which allows for fuel savings even while operating under full motor power.

The disadvantages of converting a yacht into a fishing boat are four. First, initial acquisition costs can be high. Secondly, the hold capacity afforded by a sailing yacht hull is generally limited to less than 30 tons. Third, workspace on deck may be also restricted, a feature that can result in reduced selection of fishable gear as well as gear handling bottlenecks. Lastly, it can be difficult to find an experienced crew who can safely operate a sophisticated sailing vessel of this size and at the same time catch enough fish to make the operation profitable.

A third approach is to design and build a sail-assisted fishing vessel from the keel up. The few boats of this type fishing in U.S. waters today are generally at least 60 feet in length with hold

[1]Kibert, C. J. 1981. The economics of sailpower for snapper-grouper boats of the Florida west coast fleet. Florida Sea Grant College Marine Advisory Program, Univ. South Florida, Tampa. Unpubl manuscr., 23 p.

capacities exceeding 20 tons. Most are capable of fishing a wide assortment of gear within operating ranges of 2,000 miles. As with a converted yacht, an efficient hull design is used to trim fuel use while underway in either the motor or sail-assist propulsion mode. Primary disadvantages of a motorsailing fishing boat include high acquisition costs, deckspace shortage, and need for an experienced sailing crew.

Investment Analyses

Analysis here focuses on the economics of procuring and operating sailing-motor vessels to fish Hawaiian waters. The principal objective is to compare and contrast the lifetime financial performance of sail-assisted vessels vis-a-vis fishing boats that use conventional diesel engine propulsion.

Two representative sailing vessels will be evaluated. The first is a 47-foot converted yacht used to fish tuna (handline and troll) and bottomfish within an operating radius of 100 miles from home port. The second is a long-range craft capable of fishing for albacore and bottomfish in the Northwestern Hawaiian Islands, 1,500 miles from Honolulu. For comparison, investment in two comparably sized diesel-powered vessels is also analyzed.

Data on vessel design characteristics, fuel usage rates, catch rates, expenses, and fishing practices were obtained from four sources: 1) Personal interviews with owners and skippers of three Hawaii-based sail-assisted fishing vessels, 2) personal interviews with owners and skippers of comparable sized diesel-driven fishing boats, 3) telephone interviews with representatives of companies building sail-assisted and diesel fishing boats, and 4) vessel and engine manufacturer's published technical specifications. Characteristics of the four vessels under investigation are given in Table 2.

Table 2.—Comparative specifications for sail-assisted and diesel vessels.

Vessel characteristics	Sail-assisted (47-foot)	Diesel (45-foot)	Sail-assisted (65-foot)	Diesel (65-foot)
Hold capacity (tons)	10	15	30	40
Freezer/cold storage	Ice	Ice	Spraybrine/ blast	Spraybrine/ blast
Engines (brake horsepower)	Main. 100	Main 165	Main: 160 Aux: 100	Main: 340 Aux. 100
Fuel capacity (gallons)	700	1,500	4,000	7,000
Sail area (square feet)	850		1,600	
Purchase price[1] (1982 dollars)	$190,000 (new)	$150,000 (new) $80,000 (used)	$550,000 (new)	$480,000 (new) $250,000 (used)
Crew size (including captain)	3	3	4	4

[1]All vessels equipped with necessary fishing gear and standard communication/navigation electronics.

Apart from propulsion differences, sail-assisted and motor-driven vessels within each size category share many similarities. For example, both exhibit the same fish harvesting capabilities as measured in terms of catch per operating day, and total annual catch. Unfortunately, lack of published data on the fishing performance of motor-sailers makes it difficult to verify whether the catch data obtained for Hawaii sail-assisted vessels are typical of sail-assisted vessels in general. One might suspect that factors such as deck space limitations, reduced transit speeds, and gear handling deficiencies might reduce the relative fish catching power of a fishing motorsailer. Evidently, however, these factors do not impinge on the vessels under study here.

A second similarity is that all vessels are equipped with main engines. Although the motorsailers rely on relatively less powerful engines, they utilize main engines to operate hydraulic fishing equipment, increase speed and maneuverability when fishing and docking, and provide supplementary power when traveling against prevailing winds or in periods of slack winds. In addition to main engines, both larger boats are also equipped with auxiliary engines for electric power generation and to drive on-board freezing units.

Despite likenesses in vessel physical configurations, procurement costs of the sail-assisted vessels are considerably higher than those reported for comparable motor-powered fishing boats. Two explanations for this phenomenon can be offered. One reason stems from the fact that sail-powered fishing vessels are a novelty in the U.S. diesel-dominated fishing boat market. High unit prices are probably attributable to short supply and the failure of builders to realize economies of scale in production. Another contributing factor is that the sail-assist concept entails installation of two propulsion systems and a consequent increase in production costs.

Annual fuel requirements for all vessels under study are given in Table 3. In arriving at these projections, no special restrictions have been imposed on vessel operations to minimize annual fuel demands. This is because the fuel consumption rates given here are largely based on actual reported 1980-81 fuel usage. It is assumed that the consumption amounts are consistent with achievement of overall vessel financial performance objectives. Reported amounts may, however, reflect some operational suboptimization, particularly with regard to transit speeds (Alderton, 1981; Digerness, 1980). Furthermore, actual fuel consumption will vary depending on where fishing occurs, the types of fishing activities conducted, and general weather conditions.

Based on projected fuel usage rates, it is anticipated that a 47-foot vessel equipped with sailing apparatus will realize a 37 percent savings on annual fuel use compared with its 45-foot diesel-powered counterpart. Overall annual fuel savings for the larger 65-foot sail-assist fishing vessel drop slightly to 36 percent despite the fact that it realizes a relatively higher fuel savings (53 per-

Table 3.—Projected annual fuel consumption by vessel type.

Vessel type	Transit time (gal./hour)	Transit time (hours/trip)	Transit time (trips/year)	Transit time (gal./year)	Fishing time (gal./hour)	Fishing time (hours/day)	Fishing time (days/year)	Fishing time (gal./year)	Other[1] (gal./year)	Total (gal./year)
Sail-assisted (47′)	2.0	18	25	900	1.0	18	225	4,050	100	5,050
Diesel (45′)	4.0	18	25	1,800	1.5	18	225	6,075	100	7,975
Sail-assisted (65′)	[2]4.0	340	6	8,160	4.5	18	160	12,960	500	21,620
Diesel (65′)	8.5	340	6	17,340	5.5	18	160	15,840	500	33,680

[1]Includes fuel use for engine warmup, dead drift, and port turnaround.
[2]Represents an average of fuel use rates on trips to the Northwestern Hawaiian Islands (3.0 gallons per hour) and return trips to Honolulu (5.0 gallons per hour). The difference is due to prevailing winds.

cent vs. 50 percent) during its transit operational mode. Annual fuel cost reductions of 35-37 percent are slightly higher than the 30-35 percent reductions projected elsewhere by Shortall (1981), and considerably lower than the 75 percent fuel savings calculated by Sorensen-Viale (1981).

Annual operating revenues, net of selling costs, are assumed to be identical for comparable-sized vessels. If, as mentioned earlier, sail-assisted vessels generally have relatively less fish catching power, then this assumption clearly biases the financial projections in favor of the motorsailer alternatives. The 45- and 47-foot boats are projected to generate $125,000 in revenues each year while the larger vessels each bring in $390,000 worth of fish annually. These annual revenues imply an average daily catch worth $555 and $2,440 dockside for the smaller- and larger-sized boats, respectively. It should be noted that daily catch rates of these amounts will, on average, result in less than full capacity hold utilization for all vessels under consideration.

Baseline financial parametric assumptions are detailed in Table 4. The assumptions apply to all vessel types with the exception of sail replacement costs which are borne only by motorsailers. In the baseline model, it is assumed that a 13 percent interest charge is assessed on the outstanding share of the vessel purchase price which is financed with borrowed capital (75 percent). However, since a 7 percent general inflation rate is presumed, the real inflation-adjusted loan interest rate is 6 percent. It is also anticipated that fuel prices will increase at the general inflation rate during the relevant 15-year investment period.

Insurance charges in the baseline model are calculated as a straight percentage of vessel purchase price. This linear relationship between insurance premiums and vessel value tends to work against sail-assisted vessels which are more costly to replace. Yet, it is consistent with the workings of Hawaii's marine insurance market (Samples, 1982). Admittedly some owners of motorsailers may incur reduced premium rates due to the lower risks of having to pay towing fees in the event of major engine breakdowns. This, however, does not appear to be the case for Hawaii-based sail-assisted fishing boats.

Proforma cost-earning statements were prepared for each year within the 15-year investment planning period. Calculated net present values (NPV) of before-tax net income streams were positive for all vessel types when calculated using a 6 percent real discount rate. NPV was consistently higher for the diesel vessels under study. Furthermore, diesel vessels yielded a higher average rate of return on owner's equity investment compared with the motorsailers. The 47-foot motorsailer returned 27 percent of owner's investment on average annually compared with a 54 percent annual return for its 45-foot diesel counterpart. Similar comparative average rates of return on owner's equity were evident with the larger 65-foot fishing vessels.

Table 4.—Baseline financial assumptions.

Item	Amount	Frequency of occurrence
1. Expected vessel useful life	15 years	
2. Salvage value	20% of vessel purchase price	Year 15
3. Maintenance on vessel and gear	10% of vessel purchase price	Annual
4. Engine rebuild	$6.00/b.h.p.	Years 5, 10
5. Sail replacement	$8.00/sq. ft.	Year 7
6. Insurance (hull and P&I)	4% of vessel purchase price	Annual
7. Moorage fees	$21.00/ft.	Annual
8. Diesel fuel	$1.10/gallon	
9. Ice	$22.00/ton	
10. Lay system	50% of net operating revenues to captain and crew, 50% to vessel	
11. Food and stores	$8.00/person	Daily
12. Equity share of financing	25%	
13. Loan duration	15 years	
14. Loan interest rate	13% of outstanding loan balance	Annual
15. Depreciation	Straight line	Annual
16. General inflation rate	7%	Annual
17. Fuel inflation rate	7%	Annual
18. Discount rate	13%	Annual

Annual cost-earnings (1982 dollars) averaged over the 15-year investment period are given in Table 5 for all vessels under investigation. These data help explain the relatively inferior financial performance of the motorsailers. In large part, the matter reduces to the fact that high purchase prices, and accompanying high maintenance and insurance costs, overwhelm operating cost savings afforded by sailing technology. Consequently, although a 47-foot sail-assisted fishing boat can save nearly 40 percent each year in fuel expense, this savings contributes little to overall total operating cost reductions relative to the additional overhead that the motorsailer creates. This is true because fuel expenses represent only 5 percent of total fishing costs for the 47-foot boat. Interest charges, maintenance, and insurance payments, on the other hand, together compose nearly 28 percent of total costs.

The fact that fuel expenses are a small portion of costs results in a situation where the relative financial performances of the four vessels are not significantly altered if a fuel price of $2.00 per gallon is used in the cost-earnings

Table 5.—Baseline proforma average annual cost-earnings (1982 dollars) for sail-assisted and diesel fishing vessel operations in Hawaii.

	Vessel type			
Item	Sail-assisted (47-foot)	Diesel (45-foot)	Sail-assisted (65-foot)	Diesel (65-foot)
Gross revenues	$125,000	$125,000	$390,000	$390,000
Fixed costs				
Maintenance	19,000	15,000	55,000	48,000
Insurance	7,600	6,000	22,000	19,200
Depreciation	10,133	8,000	29,333	25,600
Interest	4,443	3,703	18,284	11,849
Moorage	987	945	1,365	1,365
Other repairs[1]	533	132	1,061	352
Variable costs				
Fuel	5,555	8,773	23,782	37,048
Food	5,760	5,760	8,640	8,640
Ice and bait	2,550	2,550	—	—
Crew shares	55,568	53,959	178,789	172,156
Return to labor, management, and equity	12,871	20,178	51,746	65,790
Net present value	58,913	147,572	363,631	515,764
Average return on investment	27%	54%	38%	55%

[1]Amortized costs of engine rebuild and sail replacement.

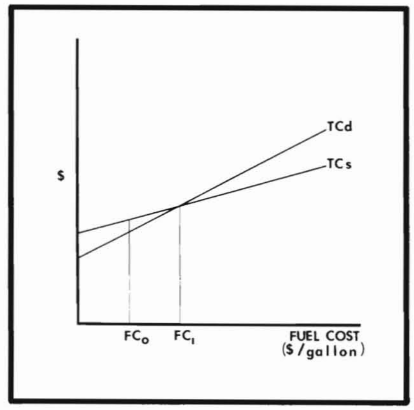

Figure 1.—Breakeven fuel costs for sail-assisted and conventional commercial fishing vessels.

projections. A price increase from $1.10 to $2.00 per gallon (an 81 percent increase) will add only an additional $7,177, or 7 percent, to the annual total costs of operating a 45-foot diesel boat. It would take a larger fuel price increase before the diesel vessel would be more costly to operate compared with the sail-assisted boat. This phenomenon is illustrated in Figure 1. Here, the total annual costs of operating a sail-assisted vessel (TCs) and a diesel vessel (TCd) are compared at various fuel cost (FC) levels. Starting with current fuel costs FC_0, it is clear that TCs exceeds TCd. This is attributed to the higher fixed costs of the motorsailer. The relative cost differential persists until fuel prices reach FC_1. Above this price, sail-assisted vessels are more cost-effective. In the case of the 45-foot diesel and 47-foot sail-assisted boats, FC_1 is calculated to be $6.10 per gallon. At this fuel price, the average annual total costs of operating both vessels are equalized, all other costs remaining constant. For the larger vessels under study, breakeven fuel price equals $3.43 per gallon. It is important to be cognizant of the fact, however, that at these higher breakeven fuel prices, total costs of vessel operations are high enough to make investment in either the sail-assisted or diesel vessels unattractive.

In view of the sizable contribution which debt service charges make to total annual costs of operating a sail-assisted fishing boat, sensitivity analyses were conducted by varying the following financial parameters: 1) Interest rates; 2) owner's equity share of vessel financing; 3) original purchase price; 4) discount rate; 5) insurance rate, and 6) maintenance costs.

Variations of 50 percent in individual parameters from baseline values have no discernable impact on the relative lifetime financial performance of the four vessels under study as long as the parametric changes are assumed to apply across the board to all boats. However, favorable changes in selected parameters affecting only a single boat can result in noticeable shifts in relative financial outcomes. This is particularly true for assumptions regarding sail-assisted vessel acquisition cost due to the linearities which exist in the finance model between vessel purchase price and insurance, maintenance, and depreciation expenses. For example, a 10 percent reduction in the acquisition costs of the sail-assisted vessels (holding all other parameters at baseline values) improves their relative financial performance just enough so that the present value of operating costs of the motorsailers is slightly less than their diesel powered counterparts.

Conclusions

The purpose of this article is to provide a further indication of the near-term desirability of owning and operating sail-assisted fishing vessels. Results from the case study of fishing in Hawaiian waters strongly suggest that at current fuel costs, interest rates, and acquisition costs, investment in sail-assisted vessels vis-a-vis conventionally powered boats is not economically prudent. In comparing the relative financial performance of the two vessel types, it appears that the fuel cost savings afforded by sailing technology are not great enough to offset greater fixed costs associated with financing, insuring, and maintaining the more expensive motorsailers. This conclusion would not be significantly altered if the price of fuel was to increase threefold from its current level. Furthermore, the competitive edge presently afforded by the diesel powered boats is even more pronounced if the fish catching of sail-assisted vessels turns out to be generally inferior.

Under what circumstances would sail-assisted vessels be an attractive means of reducing reliance on motor fuels? A sizable reduction in the real price of acquiring the technology would be an important prerequisite. Conceivably this might be accomplished several ways. One alternative not analyzed in this article is to focus efforts on retrofitting existing vessels with sailing gear. Admittedly this avenue is not available to all boat owners but it may yet prove to be the most economical path to reintroduce sail-power to U.S. fishermen. Further engineering and economic studies are needed to explore this possibility.

A second option available to some fishermen (but not to the industry as a whole) is to wait until the relative prices of motorsailers drop as vessel construction activity unfolds and as more used sail-assisted vessels appear on the market. If, in addition, these vessels could be financed at a reduced future interest rate, vessel operating costs would become more reasonable.

Finally, it is important to mention that this case study has focused on a narrow range of vessel types and fishing activities. In particular, the boats under study typically have an operating cost structure where fuel is a relatively small cost component. Cost savings generated by installation of sails are consequently correspondingly small. This situation may not hold true in other U.S. fisheries, such as Texas' Gulf shrimp fishery, where fuel costs are a relatively large cost item. In instances where fuel represents 30-50 percent of total operating costs, it may be the case that sail-assisted fishing boats are a cost-effective investment alternative. Investigation of the expected financial performance of motorsailers for such fisheries should be encouraged.

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