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POTENTIAL GAINS IN FLEET PROFITABILITY FROM LIMITING ENTRY INTO THE NORTHWESTERN HAWAIIAN ISLAND COMMERCIAL LOBSTER TRAP FISHERY

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PREFACE

This report was prepared by Karl C. Samples of the University of Hawaii and by John T. Sproul while under contract to the Western Pacific Regional Fishery Management Council (WESTPAC). It is the result of a cooperative research project on the economics of commercial lobster trapping in the Northwestern Hawaiian Islands. The cooperating agencies include WESTPAC, the Southwest Fisheries Center of the the National Marine Fisheries Service (NMFS) Honolulu Laboratory, and the Hawaii Institute of Tropical Agriculture and Human Resources, University of Hawaii. Karl C. Samples, associate professor of agricultural and resource economics, University of Hawaii is the principal investigator on the project.

Research findings stemming from this project have been documented in a series of separate reports. The first report describes the dynamics of the fishery since 1983 in terms of fleet composition and vessel fishing patterns (Gates and Samples). The second focuses on the post-harvest marketing of lobster products and analyzes the market situation and outlook for NWHI spiny and slipper lobsters (Samples and Gates). The third report in the series summarizes results of a cost-earnings study of three classes of lobster trapping vessels (Pooley and Clarke). Further reports are planned dealing with the economic implications of trap and trip limits, and area-season closures.

This report is being released as a Southwest Fisheries Center Administrative Report because the cost-earnings data which form the basis of the analysis were compiled from NMFS logbook files, and from the summarized results of a NMFS survey of vessel cost-earnings.

Because the report has been prepared by independent investigators, its statements, findings and conclusions do not necessarily reflect the views of WESTPAC or NMFS.

Samuel G. Pooley
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September 1987

INTRODUCTION

The Western Pacific Regional Fishery Management Council (WESTPAC) is currently considering a wide range of management measures for the Northwestern Hawaiian Island (NWHI) commercial lobster fishery. Limited entry has been proposed as one such measure. Little is understood, however, about the economic and biological consequences of such an action. The purpose of this research report is to predict the potential economic gains that could be realized through a limited entry program. Two general forms of entry management are analyzed: control over the types of vessels permitted to fish, and control of the total number of permitted traps. In both instances the focus is on estimating economic gains in terms of increased fleet profits.

As early as 1984, opinions were expressed in WESTPAC proceedings that the NWHI lobster fishery was overcapitalized. Suggestions also surfaced calling for tighter control over levels of trapping effort. Concern about the long-term economic health of the industry has since become more widespread in response to three trends that have become evident in the fishery. One trend is the expansion of fishing capacity during 1983-86 in terms of number of permitted vessels, average vessel size, and numbers of traps fished. Expansion of effort has had significant cost and revenue consequences, some of which have reduced the profitability of the fleet. For example, vessel operating costs have risen over time due to greater dispersion of trapping activities throughout the NWHI (Gates and Samples). The second trend is the decline in catch per unit of effort as measured by the harvested poundage of spiny and slipper lobster per trap fished (Clarke et al). Falling catch rates were specifically mentioned in a petition prepared by a number of lobster fishermen calling for tighter controls over the entry, and re-entry, of trapping vessels into the fishery A third relevant trend is the upward climb in ex-vessel prices for frozen and slipper lobster tails. While at the surface this appears to be good news for active NWHI lobster fishermen, it may well entice even more effort to be directed at reduced stocks (Samples and Gates).

In response to these trends, WESTPAC initiated minimum-size and escapement gap requirements in both the spiny and slipper lobster fisheries. The goal of both measures is stock conservation. This leaves the fishery still vulnerable to undesirable economic effects of overcapitalization because no limits have been placed on effective fishing effort either in terms of number of permitted vessels or traps.

Limited entry occurs in fisheries to <u>promote economically rational use of stocks</u>. In simple terms, use of stocks is considered "economically rational" when the difference between fleet production costs and returns is maximized. Maximization of fleet profits in turn implies that scarce productive resources are being used in a non-wasteful manner. Limited entry, therefore, is directed more at the conservation of capital and human labor rather than the conservation of a biological stock. This helps explain why it is justified based on economic rather than biological arguments.

Avoidance of actual or potential economic waste is the reason for limiting entry in the NWHI lobster fishery. Why then does waste occur in the first place? According to general theory, wastage occurs because fishermen as a group will devote increasing more effort towards exploiting a fish stock until a point is eventually reached where fleet production costs equal fleet revenues. Once this point is reached, fishermen as a group are breaking even financially. Collectively, fishermen are just earning enough revenues from selling fish to barely cover all production costs, including opportunity costs of capital and management inputs employed in fishing. Unbridled economic self-interest leads to this outcome for the following reason. When fishing is profitable, financial incentives exist that encourage fishermen to expand their collective fishing effort. Effort could expand either by current participants fishing more days and using more gear, or by the entrance of new boats into the fishery for the first time. Between 1983 and 1986, effort in the lobster fishery expanded through all of these avenues (Gates and Samples).

Associated with the expansion of effort is a biological feedback mechanism that has important economic effects. With each increment to effort, the average long-run productivity of effort already in place declines. In other words, sustainable catch per unit of effort falls. Translated into economic terms this means that each additional unit of effort imposes a cost on existing fishermen in the form of a reduced harvest revenue per unit of effort expended. It is this declining revenue per unit of effort, combined with rising fleet operating costs, that transforms a high profit fishery into one where fishermen as a group are barely able to make financial ends meet.

Well before this financial breakeven outcome has been reached, economic waste has occurred from a social perspective. Waste exists whenever productive resources (labor, capital, management skills, fuel and so forth) added to the fishery do not earn sufficient monetary return to cover: 1) out-of-pocket purchase costs, and 2) the external costs imposed on other fishermen due to declining catch rates. Such resources are being wasted, or misallocated, because society as a whole would be better off by having the resources employed in another productive activity where returns would fully cover all costs.

Limited entry is one way of preventing resource misallocation that arises from the unrestricted expansion in effort, such as exists in the NWHI lobster fishery. By constraining the number of fishermen, boats, gear or enterprises, an economically efficient fishery can be preserved before excessive effort is brought to bear on lobster stocks.

One way to think about limited entry is to imagine how a sole-owner of NWHI lobster stocks would go about managing effort to maximize his or her fishing profits. Suppose, for the sake of illustration, you were the owner and wanted to earn the maximum possible profits from harvesting lobsters over a twenty-year period. First, you would probably use only the most efficient boats and fishing methods so as to minimize the cost per unit harvested. Second, you would probably use only as many boats and traps that are necessary to maximize profit levels. One simple rule that can be applied to make sure you maximize profits is to verify, after adding another unit of effort to your fleet, that the additional fleet-wide revenues you earn are greater than the out-of-pocket costs of adding the new boat or additional traps. If revenues exceed costs, then the adding the unit of effort has increased your total profits. Otherwise, it is more profitable to withdraw that unit of effort. By following this simple control rule and paying attention to fleet-wide economic consequences of effort expansion, fishing profits will be maximized instead of being dissipated as in an uncontrolled fishing situation.

Limited entry is a legal means for society to effectively control effort in a manner similar to how a profit maximizing sole-owner would manage fleet activities. When society places controls on the amount of fishermen, vessels or gear allowed to fish, the inevitable process of expanding effort is checked and economic waste avoided before it occurs. The same principle applies in mature fisheries where excessive levels of effort are already being expended. Here, limited entry serves as a legal mechanism to remove effort, thereby reducing economic waste and increasing the aggregate level of profits shared by those who remain actively fishing.

Successful experiences in limiting entry have been documented in a number of crustacean trap fisheries located elsewhere. For example, effort in the Maine fishery for American lobster is regulated to a large extent by long-standing informal social agreements between participants (Acheson, 1972, 1975; Wilson). According to Wilson, fishermen's incomes are perceptibly higher in those areas where controls are most effective. Another example is the Australian rock lobster fishery where the government rigidly limits numbers of fishing permits and traps. This system has apparently resulted in profitable trapping operations, as evidenced by the high selling prices for lobster fishing permits (Meany).

Although these and other cases documented in the literature provide interesting insights into limited entry outcomes, they do not provide a clear indication of the possible economic gains that could be realized from a limited entry program in the NWHI lobster fishery. This is because of differences in target species sought, production technology and post-harvest marketing systems.

Rather than concentrate on the performance of existing limited entry programs, we adopt a different approach to predict potential economic gains from limited entry. To do this, we first estimate what fleet profits would be in a mature NWHI fishery without limited entry. Here we rely heavily on results of a recent cost-earnings study of the NWHI lobster fishery. Next, we calculate what fleet profits would be if an "ideal" limited entry program was instituted that rationalized the fishery. The analysis focuses on a hypothetical system which allows control over effort at two levels. This systems allows control of aggregate effort (trapnights) to maximize profits for any given fleet, and control over the types of boats permitted to fish so as to minimize the cost per pound of lobster landed. Finally, we interpret the difference between 1986 and maximum profit levels as the potential economic gains that could be realized through an effective limited entry program.

ESTIMATED PROFITABILITY OF THE NWHI LOBSTER TRAPPING FLEET WITHOUT LIMITED ENTRY

The first step in understanding the returns from a limited entry program for the NWHI lobster fishery is to determine the profitability of the NWHI lobster fleet in the absence of such a program. The question to be answered is "what amount of profits is the fleet expected to earn if effort continues to be uncontrolled as it currently is? Obtaining an answer to this question is important because the gains from limiting entry depend on the financial condition of the fishery before entry is restricted. If the fishery is economically healthy, then gains will be less than if the fishery has already reached a zero-profit level.

Estimating current economic net returns in the fishery is greatly simplified due to the work of Pooley and Clarke who analyzed the cost and returns of various sizes of lobster fishing boats. In their study, boats were differentiated into three classes: Class I (high-capacity, long-range boats); Class II (high-capacity, medium-range) and Class III (low-capacity, medium-range). Personal interviews were conducted over a 18-month period with a non-random sample of owners, operators and crew members of ten vessels from the three classes. The sample was non-random in the sense that it included only vessels that had fished in the NWHI for at least one season. Several of the vessels had fished for several years. The sample did not include other vessels in the fleet that were just entering the fishery in 1985-86. For this reason, the sample as a whole reflected the operating characteristics of mature, experienced trapping operations. Estimated average cost and returns based on interview data are summarized for the three vessel classes in Table 1.

Vessel profitability is calculated at two different levels, both of which are used in the analysis below. "OPERATING PROFIT" is the difference between annual lobster trapping revenues and out-of-pocket fixed and trip costs. This profit is the financial

TABLE 1

ESTIMATED ANNUAL AVERAGE PROFITABILITY OF LOBSTER FISHING VESSELS BY CLASS: BASED ON SAMPLE DATA

	- VESSEL CLASS -		
	CLASS I	CLASS II	CLASS III
REVENUE	$ 1,003,692	$ 590,136	$ 275,240
FIXED COSTS	$ 149,386	$ 58,622	$ 51,900
Annual repair	57,982	16,541	18,421
Insurance	81,302	24,032	29,507
Administration	10,102	18,049	3,972
TRIP COSTS	$ 516,705	$ 256,265	$ 163,146
Fuel and oil	77,562	25,489	26,776
Bait	55,706	19,932	22,711
Provisions	26,755	12,021	12,286
Medical	896	0	541
Supplies	4,851	4,894	2,486
Gear	29,520	16,216	14,299
Other	7,822	4,116	7,600
Crew share	313,593	173,597	76,447
OPERATING PROFIT	$ 337,601	$275,249	$ 60,194
NON-OPERATING COSTS	$ 319,618	$ 47,175	$ 84,141
Loan cost	97,842	5,509	45,436
Opportunity cost of capital	121,618	37,367	36,920
Selling costs	100,158	4,299	1,785
ECONOMIC PROFIT <LOSS>	$ 17,983	$ 228,074	$<23,947>

Source: Adapted from Pooley and Clarke

return that vessel owners earn to pay capital , selling and management costs Operating profits are a useful measure of the operating efficiency of a vessel.

The second profitability measure is reported in Table 1 as "ECONOMIC PROFIT <LOSS>." Economic profit accounts for all measurable costs of capital including interest charges on borrowed funds and a 10 percent return on equity investment. Selling (commission) costs are also accounted for. It does not include the opportunity cost of the vessel owner's labor and managerial skills expended to achieve enterprise objectives. Economic profitability more accurately reflects the social net return from fishing but it disguises actual operating efficiency levels. This is because it is conditional on a three factors that lie outside of the realm of actual vessel operations. These include the leverage position of the firm (the ratio of debt to equity capital), the total amount of capital invested, and the costs of post-harvest selling arrangements.

The average cost and return estimates given in Table 1 provide important insights into the actual 1986 profitability of experienced lobster trap vessels in the absence of limited entry. Legitimate questions arise, however, about whether the estimates adequately depict the expected profitability of the fleet over the next few years. Two near-term changes are particularly important to account for in the NWHI lobster fishery: 1) possible changes in fleet costs and returns that may arise as participants strive to reach peak production efficiency, and 2) likely declines in slipper lobster catch rates due to the non-sustainable nature of current catch rates. Regarding the first factor, if there are strong upward trends in operating efficiency evident in the fishery as measured by a declining average cost per trap fished, then vessel profitability may increase over the next few years, all other things remaining equal. This in turn would imply that the 1986 profit figures given in Table 1 would have to be adjusted upward to account for expected efficiency gains. Regarding the second factor, if slipper lobster catch rates are on the decline, then average projected profitability will expectedly be less than 1986 levels, in the absence of limited entry. We now turn to a brief digression on both of these factors.

Expected Changes in Operating Efficiency

Operations of the NWHI commercial lobster fishing fleet have evolved rapidly since 1983, the first year of WESTPAC management under a formal fishery management plan. Although some of these changes have been documented elsewhere (Gates and Samples, Clarke et al.), analyses conducted to date have not directly addressed the issue of dynamics in the efficiency of operations. Hence, it is difficult to judge whether vessels are operating in a manner that maximizes profits.

In order to better understand this important issue, a database of vessel operating characteristics (maintained by NMFS) was compiled for the years 1983-86 from two principal sources: 1) lobster fishing daily activity reports, and 2) trip sales and processing reports. Data were aggregated and analyzed according to vessel class. Attention focused on analyzing the time trends of three efficiency indicators: 1) average days fished per trip; 2) average trips taken per year, and 3) average number of traps hauled per day at sea. These data, even in aggregated form, are confidential due to small sample sizes and are not presented here.

Overall, the analysis suggests that operating efficiency of the fleet increased during 1983-86. This is true for all vessel classes, although rates of efficiency gains are not equal. Nevertheless, the available evidence indicates by 1986, vessels were being operated at, or very near, their peak production efficiency given available technology along with fuel and hold capacity constraints. The possible exception is the larger Class I boats which up until 1986 appeared to still be realizing some efficiency gains. Nevertheless, for purposes of this analysis, the 1986 cost and revenue figures given in Table 1 do in fact represent the financial performance of a mature fleet of vessels producing lobsters at minimum average cost.

Expected Changes in Lobster Catch Rates

NWHI boats began targeting on slipper lobsters as recently as 1984. Intense fishing mortality has since greatly reduced stocks but stocks in 1986 were still relatively high compared with equilibrium levels. According to Polovina et al. best estimates, 1986 catches of slipper lobsters were approximately twice maximum sustainable yield (MSY) levels. This implies that catch rates for slipper lobsters would be expected to fall even if effort remains at 1986 levels, but it is uncertain exactly how much because of the non-equilibrium nature of 1986 catches, combined with the uncertain effects of recently adopted minimum-size and escape gaps regulations.

Assuming catch rates decline in the manner projected by Clarke et al, there are important implications for the profitability associated with lobster fishing as shown in Table 2 where vessel costs and returns have been revised accordingly. To reflect the 50 percent reduction in slipper lobster catch rates, vessel revenues for each class have been reduced by subtracting one-half of the 1986 slipper lobster revenues earned by each class. This reduction is especially important for Class I boats which have tended to target more on slipper lobsters.

On the cost side, it is assumed that the reduction in slipper lobster catch rates is exogenous to fishing vessels and does not affect profit maximizing levels of trapnights fished. Hence, all operating costs except crew shares remain constant. Since we assume that there is no change in the share system used to divide

TABLE 2

ESTIMATED ANNUAL AVERAGE PROFITABILITY OF LOBSTER FISHING VESSELS BY CLASS: MAXIMUM SUSTAINABLE YIELD CATCH LEVELS (a)

	- VESSEL CLASS -		
	CLASS I	CLASS II	CLASS III
REVENUE	$ 767,824	$ 504,566	$ 228,448
FIXED COSTS	$ 149,386	$ 58,622	$ 51,900
Annual repair	57,982	16,541	18,421
Insurance	81,302	24,032	29,507
Administration	10,102	18,049	3,972
TRIP COSTS	$ 422,234	$ 226,958	$ 144,116
Fuel and oil	77,562	25,489	26,776
Bait	55,706	19,932	22,711
Provisions	26,755	12,021	12,286
Medical	896	0	541
Supplies	4,851	4,894	2,486
Gear	29,520	16,216	14,299
Other	7,822	4,116	7,600
Crew share	219,122	144,290	57,417
OPERATING PROFIT	$196,204	$218,986	$ 32,432
NON-OPERATING COSTS	$296,081	$ 46,552	$ 83,838
Loan cost	97,842	5,509	45,436
Opportunity cost of capital	121,618	37,367	36,920
Selling costs	76,621	3,676	1,482
NET ECONOMIC PROFIT <LOSS>	$<99,876>	$ 172,434	$<51,406>

Note: (a) Estimated maximum sustainable yield landings are 176,131 pounds of slipper lobsters (mostly frozen tails), and 428,192 pounds of spiny lobsters (mostly frozen tails).

trip profits between vessel and crew, crew shares decline precipitously due to the reduction in revenues. As a result, the average share earned per crew member (based on average crew size for different vessels) drops to an estimated $19,771. Since this is probably the lowest possible wages that a crew member would accept, there appears to be no real "rent" earned by crew members at reduced catch rates. For this reason, we assume MSY crew shares represent the social opportunity cost of labor. In terms of economic costs, the reduction in slipper catches also reduces selling costs in proportion to the reduction in slipper revenue by class.

Estimated Fleet Profitability

In estimating fleet profits, we paid attention to two basic conditions: 1) the configuration of the fleet in terms of types of vessels, and 2) the aggregate slipper landings (1986 or MSY levels). The first condition has implications for the cost of landing lobsters, while the second determines the total operating revenue that can be realized by the fleet, regardless of the costs of effort. Four different fleet configurations were considered. The first was a fleet comprised of experienced vessels (with the cost characteristics given in Table 1) proportioned amongst the three vessel classes according to the actual composition of the fleet as it existed in 1986. This fleet configuration is hereinafter referred to as the "1986 fleet." The three other configurations were fleets comprised solely of Class I, Class II or Class III vessels.

Fleet profits were calculated as the difference between industry revenues and costs. Operating and economic profitability were both measured with the difference between the two arising from non-operating costs. The following general formula was used:

FLEET PROFIT = FLEET REVENUE - [AVERAGE COST OF EFFORT X EFFORT].

The first term in the right-hand side of the formula (FLEET REVENUE) is the gross operating revenue for the fleet. Two values were used for this variable depending on whether 1986 or MSY fleet profits were to be estimated: 1) the 1986 actual revenues equal to $ 5,969,000, or 2) estimated MSY revenues equal to $4,833,000. FLEET REVENUE also were varied depending on fleet composition. This is because the average ex-vessel prices received varied among vessel classes. For example, Class I and II boats received the highest ex-vessel prices for both spiny and slipper lobsters, while Class III boats generally received the lowest prices in the fleet (Table 3). In order to account for the fact that certain types of operations realize different average returns, FLEET REVENUES were calculated for each fleet configuration using two different price levels: 1) the weighted average ex-vessel prices received by the fleet as a whole in 1986, and 2) the average ex-vessel price received by a particular class.

TABLE 3

AVERAGE 1986 EX-VESSEL PRICES RECEIVED
FOR SPINY AND SLIPPER LOBSTERS BY CLASS

	-EX VESSEL PRICE PER POUND-	
VESSEL CLASS	SPINY	SLIPPER
Class I	$ 9.36	$ 6.66
Class II	9.30	6.67
Class III	7.88	6.28
All Classes	8.63	6.44

Source: Estimated using NMFS database of trip sales and processing reports

The cost side of the formula [AVERAGE COST OF EFFORT X EFFORT] was determined largely by fleet composition, although catch levels affected costs because of changes in crew shares. AVERAGE COST OF EFFORT took on 16 different values depending on: 1) whether the operating or economic fleet profits were to be calculated, 2) fleet composition, and 3) catch levels. EFFORT was defined in terms of trapnights, the standard measure of effort adopted by NMFS for this fishery. A trapnight represents the catching power of a single trap left to soak overnight. AVERAGE COST OF EFFORT was calculated for each class from the cost data given in Tables 1 and 2 using the formula:

AVERAGE COST OF EFFORT = [COST OF EFFORT] / TRAPS.

COST OF EFFORT in the formula was in turn defined in either of two ways. To calculate fleet operating profits, COST OF EFFORT was defined as the sum of fixed and operating costs. Alternatively, to calculate fleet economic profit, COST OF EFFORT was set equal to the sum of all costs including fixed, operating and non-operating costs. TRAPS was the annual average number of trapnights fished for a particular class of vessels, based on Pooley and Clarke sample data.

Estimated AVERAGE COST OF EFFORT based on 1986 catch levels for four vessel types and two levels of cost aggregation are given in the first column of Table 4. The cost estimates for the 1986 fleet as a whole were calculated as the weighted average of individual class average costs, where the weights were set equal to the proportion of total fleet trapnights fished by each class. Class II vessels were most efficient in terms of producing trapnights at minimum cost. By comparison, Class I vessels were the least efficient. This was true using both levels of costs. Estimated AVERAGE COST OF EFFORT based on MSY catch levels are given in the second column of Table 4. Since MSY catch levels are assumed to be less than 1986 levels, crew costs decline accordingly. Still, however, Class II boats produce effort at least cost relative to the fleet average, and compared with the other two vessel classes.

AVERAGE COST OF EFFORT estimates were then multiplied by EFFORT to arrive at fleet costs for different fleet configurations. EFFORT was defined as the amount of trapnights needed for a particular fleet of vessels to reach 1986 catch levels, given the catch per unit of effort (pounds per trapnight) experienced by a particular vessel class in 1986. For example, in 1986, Class I vessels fished a total of 840,904 trapnights and caught 482,959 pounds of lobsters. Class I vessels therefore experienced a catch per unit of effort of 0.574 pounds (482,959 / 840,904). At this catch rate, a fleet entirely composed of Class I vessels would need to fish 1,362,000 trapnights in order to catch the 1986 catch level of 781,654 pounds of slipper and spiny lobsters (781,654 / 0.574). EFFORT in this example would be 1,362,000. EFFORT for the 1986 fleet was set at 1,452,000, the actual number of trapnights fished.

TABLE 4

ESTIMATED AVERAGE COST OF EFFORT FOR THE NWHI LOBSTER FISHING VESSELS UNDER ALTERNATIVE COST AND CATCH SITUATIONS

	- ESTIMATED AVERAGE COST PER TRAPNIGHT -	
	BASED ON SAMPLE CATCH LEVELS	BASED ON MSY CATCH LEVELS (a)
BASED ON OPERATING COSTS (b)		
1986 average	$ 2.64	$ 2.31
Class I vessels	2.83	2.43
Class II vessels	2.22	2.01
Class III vessels	2.54	2.32
BASED ON ECONOMIC COSTS (c)		
1986 average	$ 3.73	$ 3.35
Class I vessels	4.18	3.68
Class II vessels	2.55	2.34
Class III vessels	3.54	3.31

Notes: (a) Estimated maximum sustainable yield landings are 176,131 pounds of slipper lobsters (mostly frozen tails), and 428,192 pounds of spiny lobsters (mostly frozen tails).
(b) Includes fixed and operating costs.
(c) Includes all costs (fixed, operating and non-operating).

EFFORT was held constant in order to calculate fleet profits at MSY catch levels. By doing so, it was implicitly assumed that the reduction in slipper landings between 1986 and MSY levels would result from a reduction in slipper lobster catch rates, and not from a reduction in trapnights fished. This assumption, while greatly simplifying the analysis, is contrary to standard theoretical predictions about the behavior of fishing firms facing reductions in catch rates. The normal expectation is that as catch rates decline, profit maximizing firms reduce the amount of fishing effort expended. One exception is when firms are operating at maximum capacity over the relevant range of catch rates.

By combining FLEET REVENUE, AVERAGE COST OF EFFORT and EFFORT estimates into the fleet profit equation, the profitability of various fleet configurations under alternative cost and revenue assumptions were obtained (Tables 5 and 6). Looking first at Table 5, estimated operating profitability of the 1986 fleet is $2.1 million and the economic profitability is $554,000. The Class II fleet configuration yields the highest profits, regardless of price or cost circumstances.

Fleet profits are higher for Class I and Class II boats if class average prices are used to calculate revenues instead of fleet-wide prices. This is because the large and medium capacity vessels historically have received slightly higher average prices for their catch relative to the lower capacity Class III boats.

Estimated fleet profits are significantly lower, and often negative, when calculated at MSY catch levels (Table 6). The reduction is profits is a direct result of the revenue loss stemming from reduced slipper lobster catches. The 1986 fleet still manages to earn operating profit of $1,480,000. However, the fleet realizes a slight economic loss when all costs are considered. This outcome, combined with fact that crews are just earning opportunity wages, can be interpreted as the eventual outcome of uncontrolled fleet expansion in the NWHI lobster fishery. The Class II fleet is the only configuration that earns positive economic profits when calculated using fleet-wide average prices.

ESTIMATED PROFITABILITY OF THE NWHI LOBSTER TRAPPING FLEET WITH A LIMITED ENTRY PROGRAM

The second step in measuring the economic returns from a limited entry program for the NWHI lobster fishery is to predict the profitability of the fleet in a limited entry situation. The purpose of this step is to answer the basic question "what amount of profits will the fleet expectedly earn if trapping effort is managed in such a way to get the maximum possible economic return out of harvesting NWHI lobsters on a sustained basis?" Obtaining an answer to this question is important because the gains from a limited entry program depend on how much the fleet could potentially earn if an effective program was implemented.

TABLE 5

ESTIMATED ANNUAL OPERATING AND ECONOMIC PROFIT FOR THE NWHI LOBSTER FISHING FLEET BASED ON 1986 CATCH LEVELS (a)

	- ESTIMATED PROFITS -	
	CALCULATED USING 1986 FLEET WEIGHTED AVERAGE EX-VESSEL PRICES (b)	CALCULATED USING 1986 CLASS AVERAGE EX-VESSEL PRICES (c)
ANNUAL FLEET OPERATING PROFIT (d)		
1986 fleet (e)	$ 2,136,000	$ 2,136,000
Class I fleet (f)	2,118,000	2,510,000
Class II fleet (g)	2,747,000	3,117,000
Class III fleet (h)	1,641,000	1,265,000
ANNUAL FLEET ECONOMIC PROFIT OR <LOSS> (i)		
1986 fleet	$ 554,000	$ 554,000
Class I fleet	281,000	673,000
Class II fleet	2,268,000	2,638,000
Class III fleet	64,000	<439,000>

Notes:
- (a) 1986 NWHI landings were comprised of 353,462 pounds of slipper lobsters (mostly frozen tails), and 428,192 pounds of spiny lobsters (mostly frozen tails)
- (b) Calculated for both spiny and slipper lobster tails as the weighted average of ex-vessel prices ($ per pound) received by vessels across the three classes
- (c) Calculated for both spiny and slipper lobster tails as the average ex-vessel prices ($ per pound) received by vessels within each class
- (d) Revenues less fixed costs and operating costs
- (e) Actual 1986 fleet composition (15 vessels in total)
- (f) Hypothetical fleet comprised of 8 vessels with capacity to harvest 1986 landings
- (g) Hypothetical fleet comprised of 13 vessels with capacity to harvest 1986 landings
- (h) Hypothetical fleet comprised of 32 vessels with capacity to harvest 1986 landings
- (i) Revenues less all costs (fixed, operating and non-operating)

TABLE 6

ESTIMATED ANNUAL OPERATING AND ECONOMICS PROFIT FOR THE NWHI LOBSTER FISHING FLEET BASED ON MAXIMUM SUSTAINABLE YIELD (MSY) CATCH LEVELS (a)

	- ESTIMATED PROFITS -	
	CALCULATED USING 1986 FLEET WEIGHTED AVERAGE EX-VESSEL PRICES (b)	CALCULATED USING 1986 CLASS AVERAGE EX-VESSEL PRICES (c)
ANNUAL FLEET OPERATING PROFIT (d)		
1986 fleet (e)	$ 1,480,000	$ 1,480,000
Class I fleet (f)	1,526,000	1,878,000
Class II fleet (g)	1,916,000	2,243,000
Class III fleet (h)	880,000	530,000
ANNUAL FLEET ECONOMIC PROFIT OR <LOSS> (i)		
1986 fleet	$ <30,000>	$ <30,000>
Class I fleet	<175,000>	177,000
Class II fleet	1,437,000	1,764,000
Class III fleet	<808,000>	<1,157,000>

Notes:
(a) Estimated maximum sustainable yield landings are 176,131 pounds of slipper lobsters (mostly frozen tails), and 428,192 pounds of spiny lobsters (mostly frozen tails)
(b) Calculated for both spiny and slipper lobster tails as the weighted average of ex-vessel prices ($ per pound) received by vessels across the three classes
(c) Calculated for both spiny and slipper lobster tails as the average ex-vessel prices ($ per pound) received by vessels within each class
(d) Revenues less fixed costs and operating costs
(e) Actual 1986 fleet composition (15 vessels in total)
(f) Hypothetical fleet comprised of 8 vessels with capacity to harvest 1986 landings
(g) Hypothetical fleet comprised of 13 vessels with capacity to harvest 1986 landings
(h) Hypothetical fleet comprised of 32 vessels with capacity to harvest 1986 landings
(i) Revenues less all costs (fixed, operating and non-operating)

If a fishery has the potential for being highly profitable, then the social gains from limiting entry may be great. Conversely, some fisheries, because of high costs or low product prices, will never be profitable even if entry and effort is carefully managed. In fisheries such as these, the gains from a limited entry program may be not be worth the additional administrative costs, and the costs to displaced fishermen. Therefore, in order to assess the economic gains from limited entry, it is important to analyze fleet profitability after limited entry, just as it is to understand the financial condition of the fishery before entry restriction.

The major difficulty in estimating fleet profitability under limited entry is that profits levels depend to a large extent on the particular characteristics of the limited entry program. Limited entry can be instituted in countless ways, some of which are superior to others in terms of generating fleet profits. In the case of the NWHI lobster fishery, no specific limited entry program has been devised. This creates considerable uncertainty about program effectiveness.

We deal with this ambiguity by considering a hypothetical limited entry program designed to maximize sustained fleet profits by controlling both: 1) the aggregate level of effort (trapnights) engaged in harvesting, and 2) the types (classes) of vessels permitted to fish. In this scheme entry limitation is equated to control over fishing effort which is managed so as to generate the greatest profits on a sustained basis for any given fleet composition. The additional capability to control the type of vessels engaged in fishing allows for the use of only the most efficient harvesting operations. Analysis of this hypothetical situation with a high degree of control is useful because it sets the upper bound on the economic returns that the NWHI lobster fleet could potentially earn under any limited entry program.

Optimizing Effort Levels to Obtain Maximum Fleet Profits

In order to determine the "optimal" level of lobster fishing effort, there first must be a management goal. For purposes of this analysis, it is assumed that the sole objective in controlling effort (i.e. limiting entry) is to maximize sustained fleet profits, either operating or economic. By concentrating on fleet profitability, we rule out other plausible management goals, such as employment creation or harvest maximization, that presumably would also influence how effort is optimized. Note also that the objective is stated in terms of maximizing sustained fleet profits, as opposed to maximizing the present value of fleet profits over time. By doing so, we implicitly assume that fishermen and society at-large are not concerned about the timing of profit flows through time, but instead are concerned with making average annual profits as large as possible.

Following our earlier discussion, sustained fleet profits are maximized by selecting the optimal level of effort to fish on a sustained basis. According to standard economic arguments, effort is said to be at the profit maximizing level when there is no way to increase profits by adjusting the amount of effort upward or downward. This implies that at the optimal level, any increase in effort will generate just enough extra fleet revenues to pay for any additional fleet costs. The overall result is a no change in overall fleet profits.

One way to arrive at the optimal level of effort is by trial and error. Alternatively, it can be identified analytically by solving the following formula in terms of effort:

$$\frac{\text{CHANGE IN FLEET REVENUES}}{\text{CHANGE IN EFFORT}} = \frac{\text{CHANGE IN FLEET COSTS}}{\text{CHANGE IN EFFORT}}$$

In order to use this formula, however, it is necessary to first understand how changes in effort affect sustained fleet revenues (the right-hand side of the formula). Unfortunately, the empirical link between effort and revenue for fishing in the NWHI has not been studied in any detail. Nevertheless, it is no doubt governed an underlying relationship between trapping effort and sustainable lobster harvests. For purposes of this analysis, we assume this biological relationship takes the logistic form:

$$\text{YIELD} = \text{A} * \text{EFFORT} - \text{B} * \text{EFFORT}^2$$

where YIELD is sustainable lobster yield (spiny and slipper combined) in terms of numbers, EFFORT is number of trapnights fished on a sustained basis; and A,B are unknown constants that need to be estimated. By dividing both sides of the formula by EFFORT, an expression is obtained for catch rate (YIELD/EFFORT), measured in terms of the number of lobsters per trapnight:

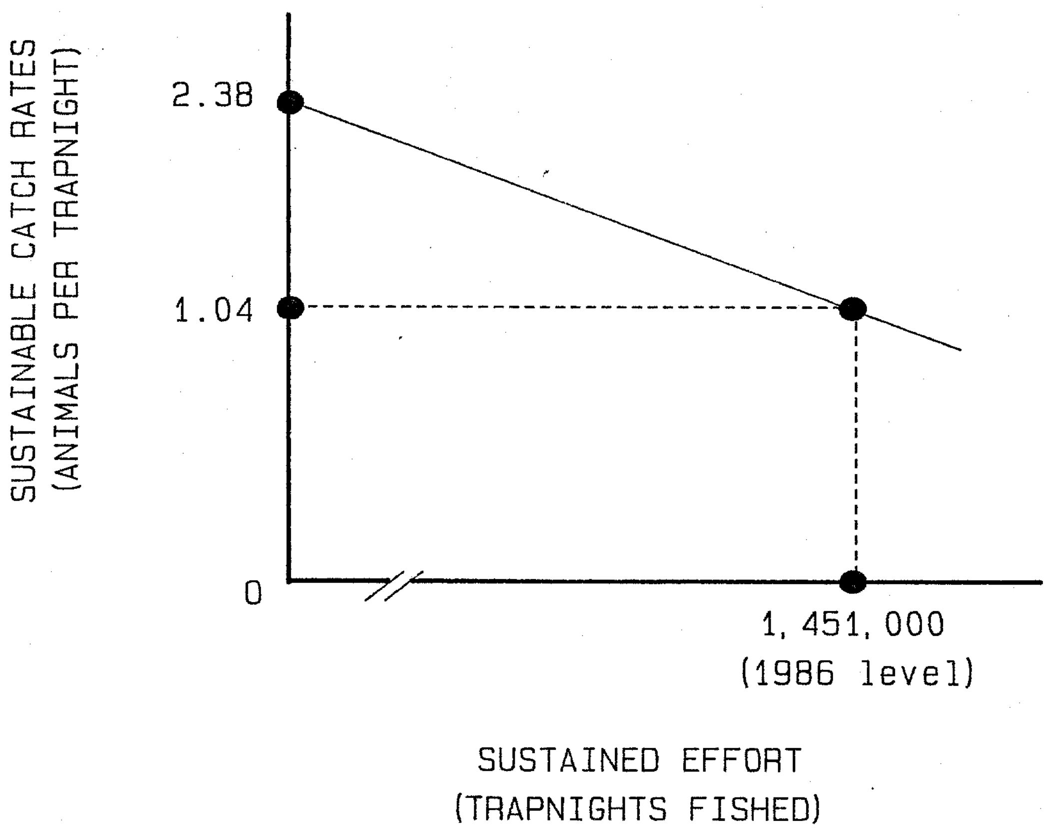
$$\text{YIELD/EFFORT} = \text{A} - \text{B} * \text{EFFORT}$$

This expression is useful because information is available about catch rates and effort levels that enables crude estimates to be obtained for the two unknown constants A and B. This includes historic data on catch rates and effort levels (Clarke <u>et al</u>.) along with MSY projections (Polovina <u>et al</u>.). We know from historic catch data that fishermen enjoyed a relatively high average catch rate of 2.38 lobsters (legal spiny and slipper combined) per trap back in 1983 when the fishery was just opening up and stocks were largely unexploited, Furthermore, based on the Clarke <u>et al.</u> estimate of MSY for lobsters (896,407 spiny and 618,794 slipper lobsters), we can calculate the expected lobster catch rate for the fishery operating at MSY levels. Assuming a MSY catch of 1,515,171 lobsters, and a corresponding effort level of 1,451,876 trapnights (the estimated 1986 effort level for the NWHI), we estimate a MSY catch rate of 1.04 animals per trap.

These two data points are graphically depicted in Figure 1. The equation connecting the two is:

FIGURE 1

ESTIMATED RELATIONSHIP BETWEEN SUSTAINABLE CATCH PER UNIT EFFORT AND SUSTAINED EFFORT IN THE NWHI LOBSTER FISHERY



$$YIELD/EFFORT = 2.38 - 0.000009\ EFFORT.$$

From this equation, the relationship between fleet revenues and effort can be obtained in two additional steps. The first step is to multiply both sides of the estimated YIELD/EFFORT equation by EFFORT. This generates a sustained yield-effort equation:

$$YIELD = 2.38\ EFFORT - 0.000009\ EFFORT^2$$

The second step is to convert sustained yield (measured in animals per year) to sustained revenues (measured in dollars per year). This is accomplished by multiplying both sides of the estimated yield-effort relationship by the estimated average dockside price per lobster landed (weighted according to species composition), which according to catch data reported by Clarke *et al.* amounted to $3.18 in 1986. This multiplication results in an expression relating sustained fleet revenue (FLEET REVENUE) and EFFORT:

$$FLEET\ REVENUE = 7.57 * EFFORT - 0.00000295 * EFFORT^2$$

The change in FLEET REVENUE associated with a change in EFFORT is therefore given by:

$$\frac{CHANGE\ IN\ FLEET\ REVENUE}{CHANGE\ IN\ EFFORT} = 7.57 - 0.00000585 * EFFORT$$

This equation captures the first part of the optimization problem of how to select the profit maximizing level of effort.

The second part of the problem is to relate changes in fleet fishing costs to changes in effort. A simple and reasonable approach to this is to assume that fleet costs increase or decrease in response to adjustments in effort according to the average cost of effort at the time the adjustment occurs. The assumption that the marginal cost of effort equals its average cost was adopted in this study. However, even after making this simplifying assumption, the matter is still somewhat complicated by the fact that the average cost of effort itself depends on EFFORT. This is because EFFORT affects fleet revenues which in turn influence selling costs which means that average costs are dependent on fleet effort.

Crew shares, like selling costs, would also normally be related to revenues, and therefore to effort levels. However, for purposes of this analysis we assume that MSY crew payments represent the social opportunity cost of labor and consequently labor costs are held fixed and independent of vessel catches. Anderson (1982) offers convincing arguments that when optimizing effort, labor should be valued at its opportunity cost. This assumption, however, does not rule out that eventually labor may share in the surplus profits earned by fleet. The level of sharing is conditional on many extraneous factors including the relative bargaining power of vessel owners and crews.
A computer simulation model was developed to solve for both the

optimal level of effort and corresponding fleet revenue in an recursive iterative fashion. Effort was selected to maximize fleet economic profits for the four fleet configurations previously discussed.

Profit maximizing levels of effort for four fleet configurations and two cost scenarios are given in Table 7. Differences in optimal effort levels between the fleets reflects differences in vessel costs per trapnight fished. Optimal effort in all instances is substantially below the 1986 (and MSY) levels of effort of nearly 1.45 million trapnights. A 50 percent reduction in effort from 1986 levels would be needed to reach levels that maximize fleet economic profits.

Estimated optimal effort levels were used to calculate optimal fleet size (Table 7). This was accomplished by dividing profit maximizing effort by the average number of trapnights fished by various vessel classes. Optimal fleet size represents the number of boats of certain classes needed to fish the proper level of effort so as to maximize fleet profits. Optimal fleet size was not calculated for the 1986 fleet because of complications in arriving at a satisfactory estimate for average trapnights fished.

Fleet and Vessel Profitability at Optimal Effort Levels

Annual fleet operating and economic profits, corresponding to estimated optimal effort levels, are given in Table 7. Regardless of fleet configuration, operating profits exceed economic profits by 30 to 50 percent. The highest overall fleet profits are obtained by limiting effort to a fleet of six Class II vessels.

The sensitivity of fleet profit estimates to assumptions about the opportunity cost of labor is depicted in Figures 2 and 3. Although an inverse linear relationship exists between profits and the opportunity costs of labor, the relative profitability of various fleet configurations is generally independent of the price of labor.

Profitability for the fleet under limited entry translates into profits for participants. Table 8 summarizes the typical annual lobster fishing revenues and costs for three vessel classes operating in a limited entry environment where fleet operating profits are maximized. All vessel types are profitable, both in operational and economic terms. This is largely the result of increased revenues inflows associated with higher catch rates.

POTENTIAL GAINS IN FLEET PROFITABILITY FROM LIMITED ENTRY

The preceding discussion has set the stage for predicting the potential gains in fleet profitability due to limited entry. In theory, the gains are simply the mathematical difference between

FIGURE 2

RELATIONSHIP BETWEEN ESTIMATED ANNUAL FLEET OPERATING PROFIT AND OPPORTUNITY COST OF LABOR FOR VARIOUS FLEET CONFIGURATIONS

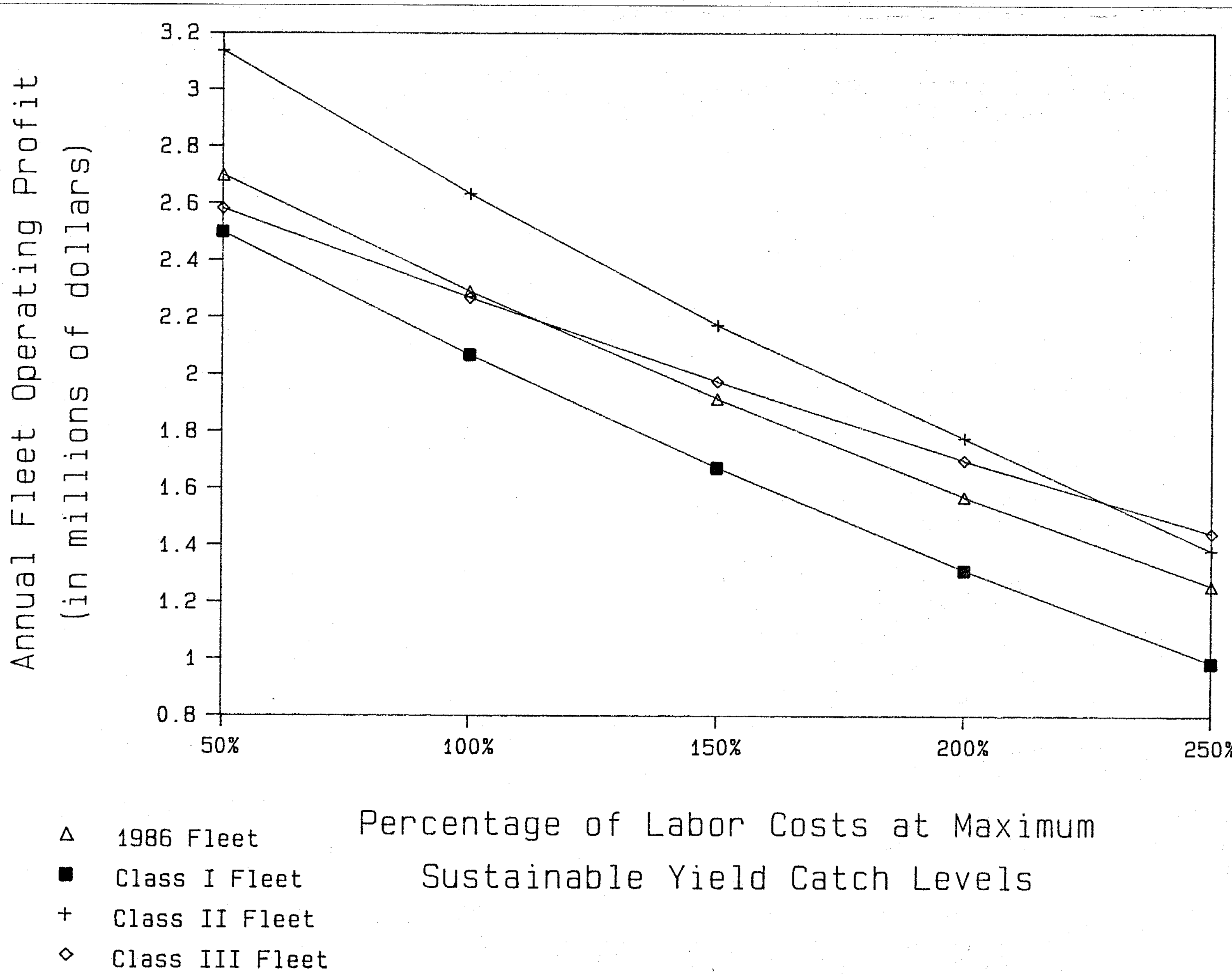


FIGURE 3

RELATIONSHIP BETWEEN ESTIMATED ANNUAL FLEET ECONOMIC PROFIT AND OPPORTUNITY COST OF LABOR FOR VARIOUS FLEET CONFIGURATIONS

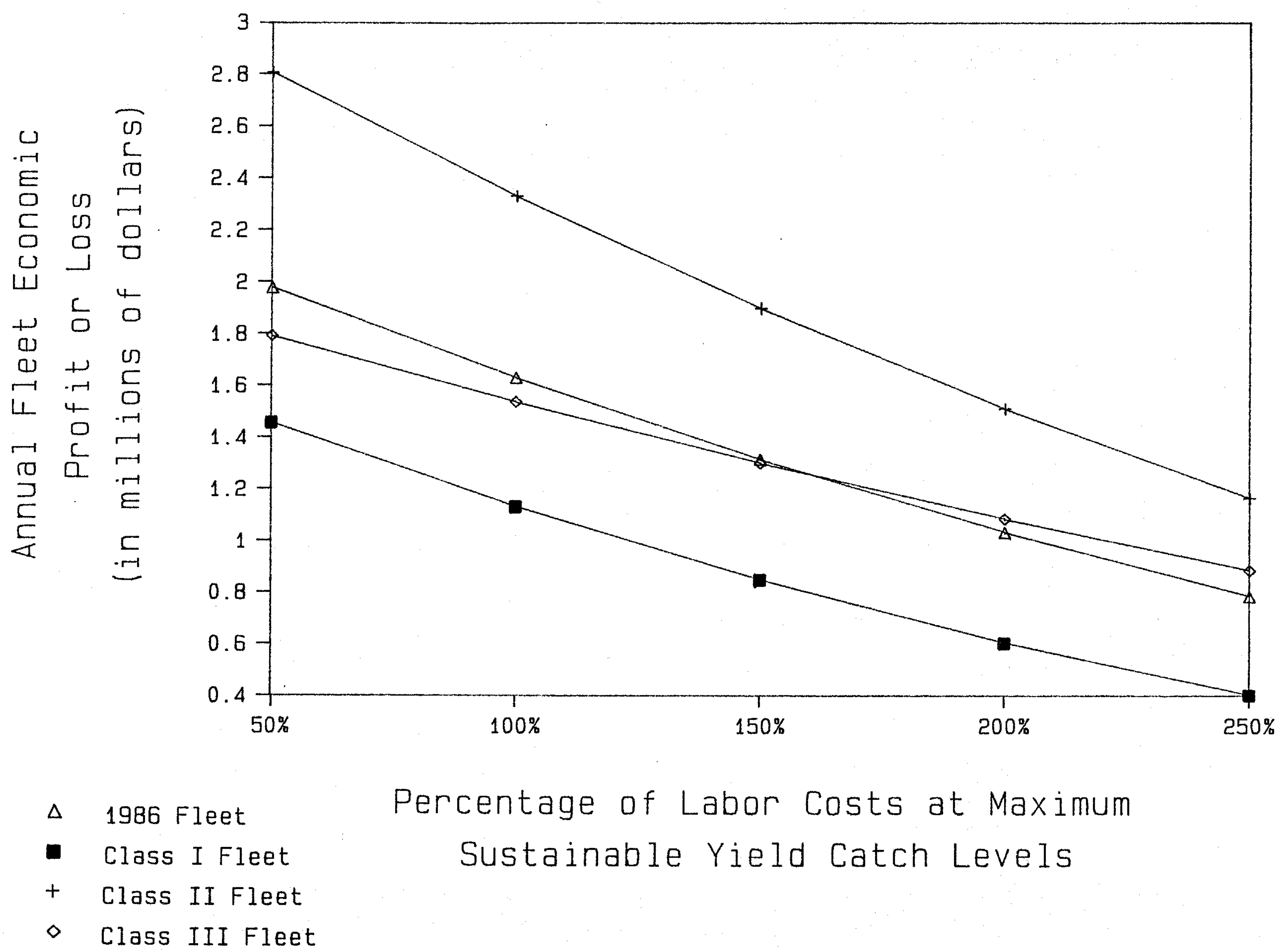


TABLE 7

ESTIMATED ANNUAL OPERATING AND ECONOMIC PROFIT FOR THE NWHI LOBSTER FISHING FLEET BASED ON MAXIMUM ECONOMIC YIELD (MEY) CATCH LEVELS

	MEY EFFORT (TRAPNIGHTS)	OPTIMAL FLEET SIZE (a)	OPERATIONAL PROFITS (b)	ECONOMIC PROFITS (c)
1986 fleet (d)	751,000	(e)	$ 2,292,000	$ 1,632,000
Class I fleet	635,000	3	2,069,000	1,132,000
Class II fleet	893,000	6	2,632,000	2,331,000
Class III fleet	725,000	9	2,269,000	1,537,000

Notes:
(a) Rounded to nearest integer
(b) Revenues less fixed costs and operating costs
(c) Revenues less all costs (fixed, operating and non-operating)
(d) Represents a hypothetical fleet with the same average cost structure as the 1986 fleet (weighted in terms of level of effort)
(e) Not computed

TABLE 8

ESTIMATED ANNUAL AVERAGE PROFITABILITY OF LOBSTER FISHING VESSELS BY CLASS: MAXIMUM ECONOMIC YIELD CATCH LEVELS

	- VESSEL CLASS -		
	CLASS I	CLASS II	CLASS III
REVENUE	$ 1,355,266	$ 704,708	$ 460,550
FIXED COSTS	$ 149,386	$ 58,622	$ 51,900
Annual repair	57,982	16,541	18,421
Insurance	81,302	24,032	29,507
Administration	10,102	18,049	3,972
OPERATING COSTS	$ 422,234	$ 226,958	$ 144,116
Fuel and oil	77,562	25,489	26,776
Bait	55,706	19,932	22,711
Provisions	26,755	12,021	12,286
Medical	896	0	541
Supplies	4,851	4,894	2,486
Gear	29,520	16,216	14,299
Other	7,822	4,116	7,600
Crew share (b)	219,122	144,290	57,417
OPERATING PROFIT	$ 783,646	$ 419,128	$ 264,534
NON-OPERATING COSTS	$ 354,701	$ 48,010	$ 85,343
Loan cost	97,842	5,509	45,436
Opportunity cost of capital	121,618	37,367	36,920
Selling costs	135,241	5,134	2,987
ECONOMIC PROFIT <LOSS>	$ 428,945	$ 371,118	$<179,191>

Notes: (a) Effort selected to maximize fleet economic profits
(b) Assumed to equal crew shares based on maximum sustainable yield catch levels

fleet-wide profits with and without entry limitation. As a practical matter, however, estimating this difference is complicated because there are countless estimates of fleet profits depending on underlying assumptions about landings prices, labor costs, yield-effort relationships and a host of other influential factors. A related complication is that the potential gains depend to a significant extent on the characteristics of the limited entry program being evaluated.

To simplify matters, we project potential profit gains based on a selected set of fleet profit estimates presented above. To begin with, we confine attention to the MSY fishing situation as the baseline situation "before limited entry." Defining the baseline in terms of MSY catches rather than 1986 catches is justified in our opinion because of the non-equilibrium nature of slipper lobster catch rates that inflate 1986 catch rates above sustainable levels. Differences between classes in average ex-vessel lobster prices will be also ignored in favor of consistently using 1986 fleet average average prices to calculate revenues for all classes. This works against vessel classes I and II that received higher than fleet average prices for their lobsters in 1986. Third, we adopt a standard measure of labor costs. Specifically we assume that the opportunity cost of labor is captured by MSY fleet shares (approximately $20,000 per worker per year). This means that some of the gains in fleet profits from limited entry may in fact accrue to workers in the form of higher shares.

To further simplify the analysis, we estimate the gains in fleet profitability within the context of the hypothetical limited entry program which was previously discussed. Recall that this program has the feature that effort can be selectively controlled at either of two levels. The first and most basic level is control over fleet-wide effort in terms of aggregate trapnights fished. Following convention, we call this the "maximum economic yield" (MEY) effort level, and we abstract from the fundamental issue about how this effort level will be obtained and maintained through regulation. At this level of control, there is no mechanism to manipulate fleet composition, hence the relative composition of the 1986 fleet in terms of vessel classes is taken as given both before and after limited entry. If control is exercised only at this level, the gains from limiting entry are measured by comparing the profitability of the 1986 fleet (operating at MSY catch levels) with the profitability of a fleet with similar costs operating on a much restricted scale at maximum economic yield catch levels.

The second level of effort control in the hypothetical limited entry program is over the classes of vessels permitted to fish. When control is exercised at this level, the most efficient classes of vessels can be used exclusively. Although this type of limited entry program may not be a realistic alternative, the analysis of this option is useful because the estimated gains from being able to control both aggregate effort and types of permitted vessel classes is are sets an upper-bound on potential gains from limited entry. Gains from limiting entry at this level are measured by comparing the profitability of the 1986 fleet operating at MSY effort levels with the profitability of a fleet comprised of the most efficient vessels operating at MEY effort levels.

Gains From Limited Entry: Control of Aggregate Effort

A fleet of experienced vessels fishing 1,451,876 trapnights and harvesting MSY catches of slipper and spiny lobsters is estimated to earn $1,480,000 in operating profits (Figure 4). The fleet earns essentially zero economic profits (Figure 5). By limiting entry in such a way to allow only 751,000 trapnights to be fished, fleet operating profits increase by 55 percent to an estimated $2,292,000. Economic profitability increases from zero to $1,632,000. These gains are realized because control over aggregate effort results in higher average lobster catch rates, and lower fleet costs due to smaller fleet size.

Gains From Limited Entry: Control Over Effort and Vessel Type

Control over the types of vessels allowed to trap lobsters enables additional gains from limited entry to be realized. By restricting entry so that only Class II vessels can fish, and by further imposing an aggregate effort limit at 893,000 trapnights (the MEY effort level for Class II vessels), fleet operating profits reach an estimated $2,632,000 and economic profitability is $2,331,000. This situation is superior to the case where control is exercised only over aggregate effort without regard to the cost structure of the fleet. The added industry operating profits of being able to control vessel types amounts to $340,000 ($2,632,000 - $2,292,000), and additional economic profits are $699,000 ($2,331,000 - $1,632,000).

CONCLUSIONS

This report has analyzed the potential social gains from a hypothetical limited entry program in the NWHI lobster fishery. The analysis has been conducted largely from an economic perspective. We believe that this perspective is especially needed because limited entry, unlike almost all other fishery management tools, is largely justified on economic grounds.

We have equated the social gains from limited entry with increased fleet operating and economic profits. Of these two, increased in fleet economic profits is most important because social costs of fishing are more completely accounted for. We calculate that at best, a fully effective limited entry program, with control over aggregate effort and classes of vessels allowed to fish, would potentially increase annual fleet economic profit from nearly zero to $2,331,000. This sets an upper-bound on economic gains from a limited entry program in the NWHI.

FIGURE 4

FLEET OPERATING PROFITS BASED ON MAXIMUM SUSTAINABLE YIELD AND MAXIMUM ECONOMIC YIELD CATCH LEVELS

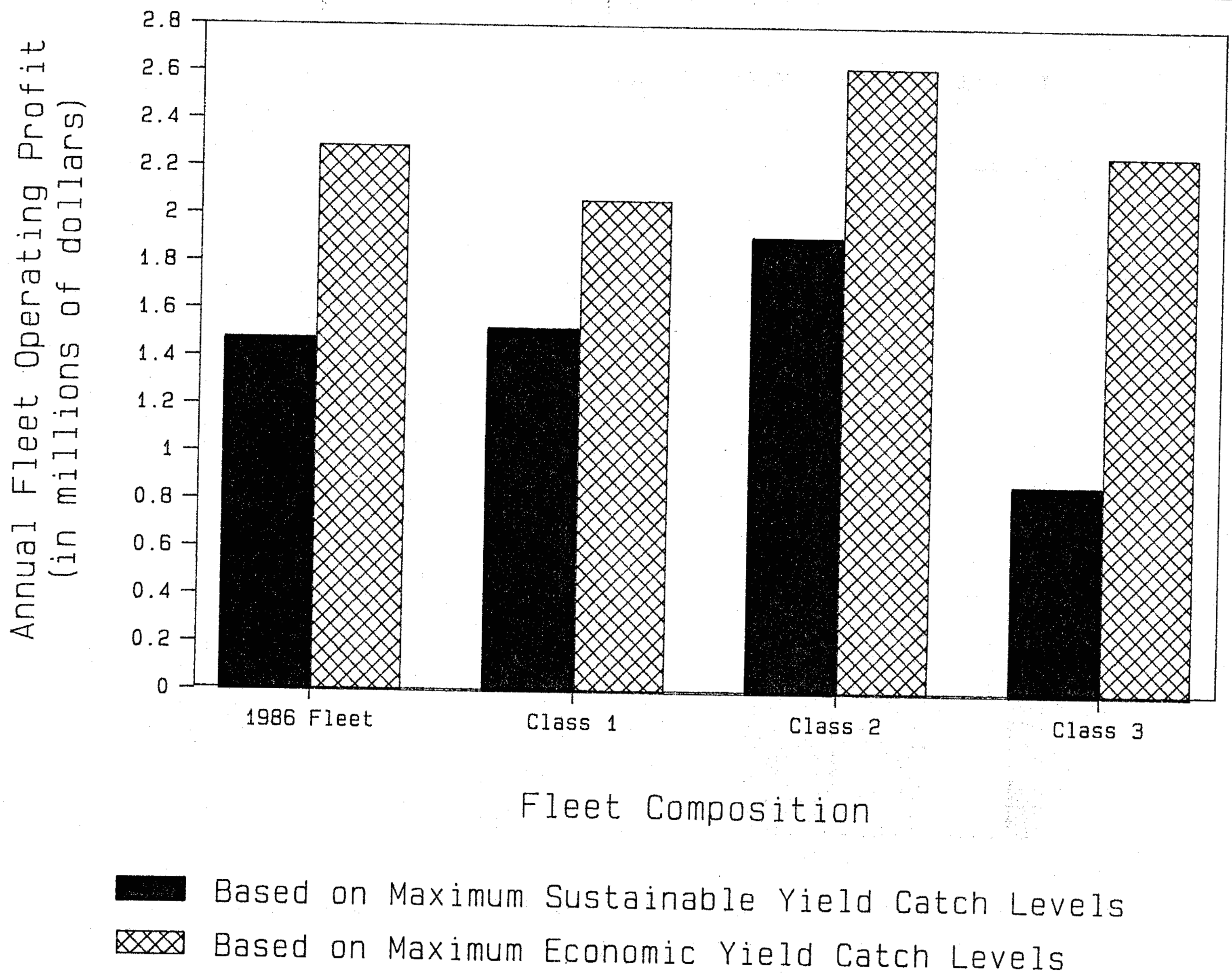
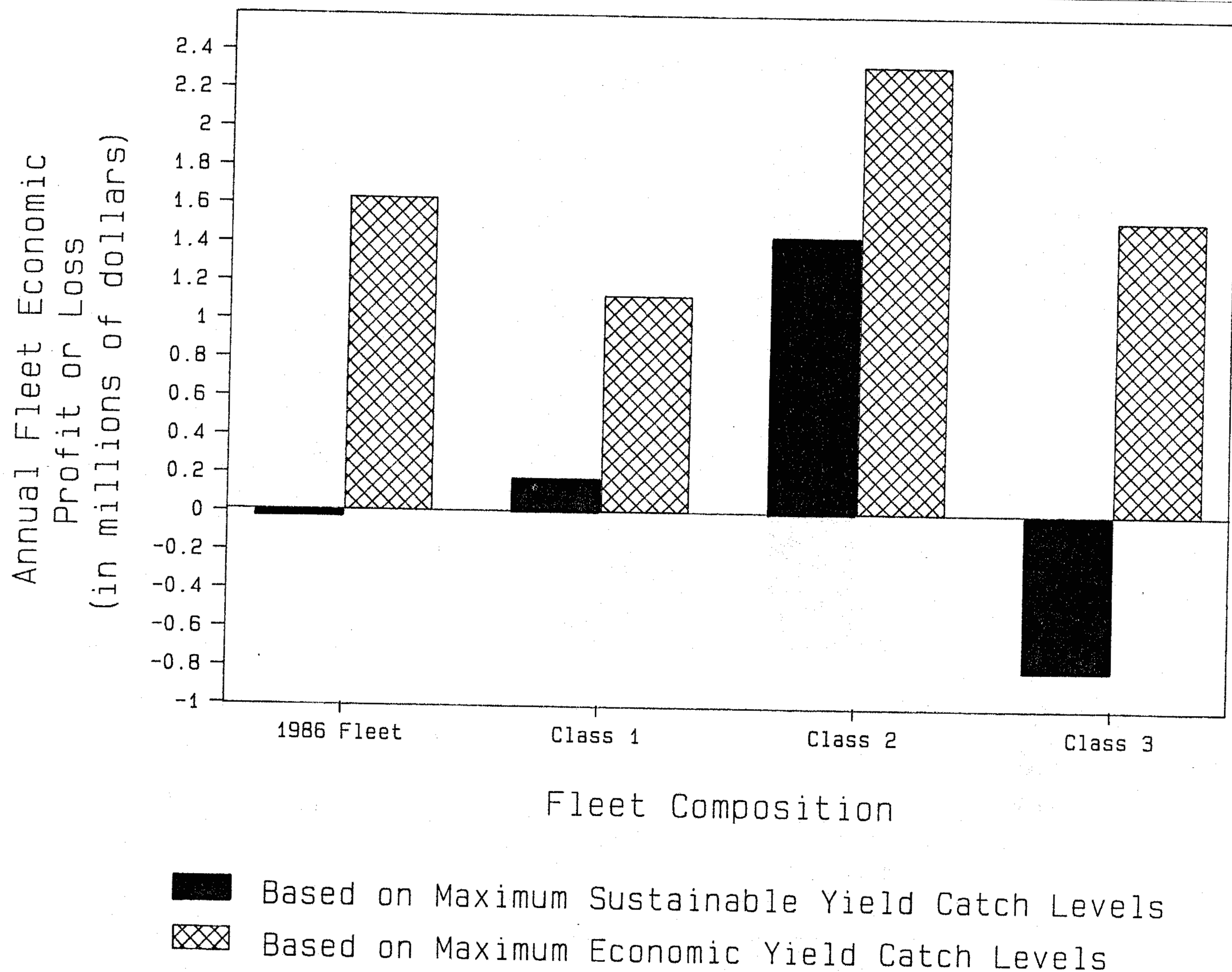


FIGURE 5

FLEET ECONOMIC PROFITS BASED ON MAXIMUM SUSTAINABLE YIELD AND MAXIMUM ECONOMIC YIELD CATCH LEVELS



There are numerous reasons why gains from an actual limited entry program may not reach this upper limit. Aside from increases in fishing costs and reductions in ex-vessel lobster prices, the foremost constraint is the manner in which entry is limited. If there is no provision for controlling the types of vessels allowed to fish and the amount of effective fishing effort per vessel, then gains will likely be less than our estimated upper-bound. Actual gains will depend on the composition of the fleet fishing under the limited entry regime, and the associated average cost per unit of effort.

Net gains from limiting entry may also be less than measured here because we have ignored a host of costs associated with achieving effective effort management. These additional costs tend to be specific to the the particular limited entry program being implemented. For example, the extra expense of implementing, operating and enforcing the program should be accounted for. These costs must be deducted from any gains in fleet economic profits. At the extreme, if it costs more to put the program in place than is earned by controlling effort, then the program has little economic justification. Accounting should also be given to the monetary and psychic costs borne by fishermen who are obliged to exit the fishery due to effort limitations.

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