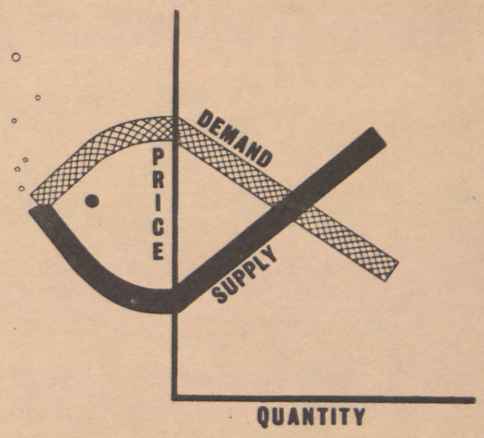

Cost and Earnings in the Boston Large Trawler Fleet

by

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and

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COSTS AND EARNINGS IN THE BOSTON LARGE-TRAWLER FLEET

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INTRODUCTION

The haddock fishery is one of the major New England fisheries and has historically been the mainstay of the New England groundfish industry. In spite of its favorable proximity to one of the world's major groundfish resource areas, however, this industry has failed to realize any appreciable expansion in recent years.

The present economic status of this phase of the domestic groundfish industry has raised much concern in the industry and in governmental agencies responsible for public administration of our sea food resources.

In order to improve the economic condition of this New England industry, it will be necessary to increase its relative efficiency and reduce costs. This cannot be accomplished, however, in a vacuum with respect to knowledge of the technological, biological and economic problems faced by the industry. Basic to the identification and understanding of these problems is an inventory of data relative to the performance of this industry.

Thus, the purpose of this study is to provide the industry and Government with detailed information on the economic performance of a selected group of fishing vessels engaged exclusively in the haddock fishery.

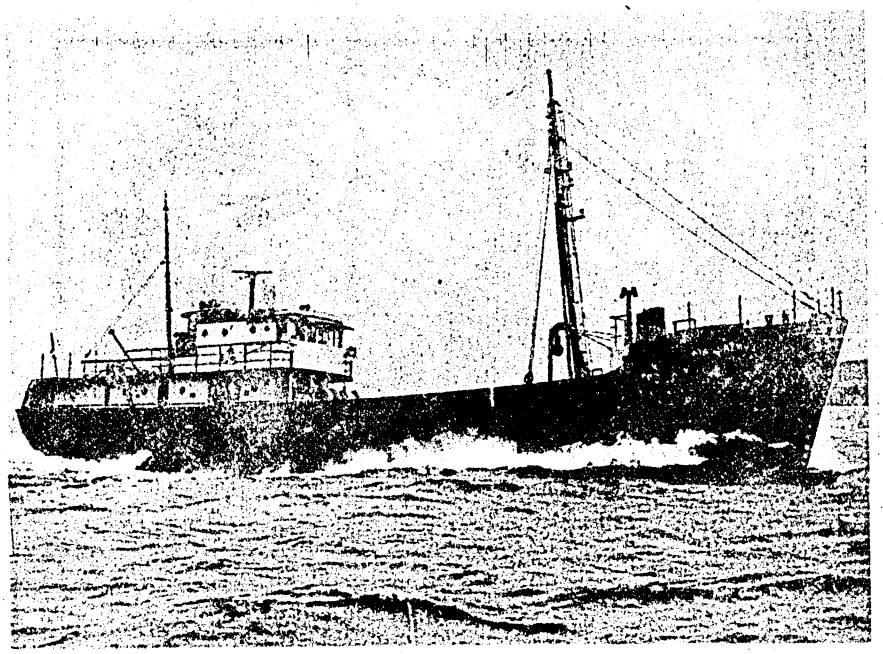
Scope of the Study

The intention of this study is to establish the operational characteristics of the large-offshore trawler haddock fleet based at the Boston port. In particular, the study is aimed at the determination of maintenance and operation costs and their relationship to such factors as: Gross tonnage of the vessel, horsepower of the main engine, number of crewmen, days absent, catch rate, and average fish price. Information on these relationships is useful in estimating costs and earnings for vessels operating under alternative conditions with respect to fishing effort, catch rate, and price of fish, and in making comparisons between vessels with different characteristics.

Source of Data

This study covers the large offshore trawler haddock fleet based in Boston (Figure 1). All crewmen on these vessels are members of the Atlantic Fishermen's Union. The contracts between vessel owners and the Union provide for a settlement sheet, supported by itemized bills, to be prepared and presented to the crew and the Union after each trip. Information from these settlement sheets for the 10-year period 1957-1966 was made available by the Atlantic Fishermen's Union, and formed the basic source of performance and cost data. Where necessary, these were supplemented with data from the Market News Service and the Branch of Fisheries Statistics, Bureau of Commercial Fisheries, U.S. Department of the Interior.

Figure 1. The Trawler "Massachusetts"--a typical vessel in the Boston Large-Trawler Fleet



Definition of Terms

Certain terms employed in this study are defined as follows:

Days absent (or days at sea): The total time spent at sea, expressed in 24 hour periods. This consists of time on the fishing grounds, time of steaming to and from port, and time of steaming between different fishing grounds.

Trip: The time spent at sea on a single voyage. Trip length is measured in terms of days at sea.

Days fishing: The total time of actual fishing activity, expressed in 24 hour periods.

Broker: A trip from which the gross proceeds are exceeded by the expenses and guaranteed crew salaries. "Brokers" are generally the result of bad weather, a breakdown, or an injury to a crewman which requires returning to port sooner than planned.

Landings: Unless otherwise stated "landings" mean the quantities of fish in eviscerated (gutted) form, unloaded at the dock.

Tons: Short tons (2000 pounds), unless otherwise stated.

DESCRIPTION OF THE FISHERY

The haddock fishing grounds are located in the area of the Northwest Atlantic called the Gulf of Maine. This area extends from Nantucket Shoals and Cape Cod on the west to Cape Sable (Nova Scotia) on the east, taking in the shorelines of Northern Massachusetts, New Hampshire, Maine, and parts of New Brunswick and Nova Scotia. The principal sector fished by the U.S. haddock fleet is known as Georges Bank, which lies some 150-200 miles east from Boston (Figure 2). Approximately 60 per cent of the fishing time of the large trawler fleet is spent on the more distant eastern parts of the Bank (Figure 3). Occassionally the trawlers fish on Browns Bank, south of Nova Scotia.

Figure 2. U.S. haddock catch on the principal New England fishing grounds, 1964

Figure 3. Distribution of fishing days, by grounds, of the Boston large-trawler fleet, 1966

The Fish Resources

In addition to haddock, cod and pollock are important species landed by the Boston large trawlers. The Boston port accounts for well over half of all U.S. landings of these species (Table 1).

Table 1. U.S. and Boston landings of haddock, cod and pollock (selected years)

The share of haddock, cod and pollock in total landings at the Boston Fish Pier is shown in Table 2.

Table 2. Composition of landings at the Boston Fish Pier (selected years)

Haddock: The majority of haddock landed by U.S. commercial vessels measure from 14 to 23 inches long and weigh between 1 and 5 pounds. Haddock reach commercial size in their third year of life.[1/]

[1/] The biological notes presented in this section are compiled from: Fishes of the Gulf of Maine by Henry B. Bigelow and William C. Shroeder, Fishery Bulletin of the Fish and Wildlife Service, Vol. 53, No. 74, U.S. Government Printing Office, Washington, D. C., 1953

Table 1. -- U.S. and Boston landings of haddock, cod and pollock (selected years)

Year	United States	Boston	Boston as % of U.S.
	Thousand pounds		
1950	249,643	162,084	65
1960	186,784	116,011	62
1965	191,949	107,491	56

Source: Fishery Statistics of the United States. U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries.

Table 2. -- Composition of landings at the Boston fish pier (selected years)

Species	Year	
	1960	1965
	Per cent	
Haddock: large	31.4	28.1
scrod	38.7	45.6
all haddock	70.1	73.7
Cod	13.9	12.4
Pollock	8.8	5.3
Other	7.2	8.6

Source: Market News Service, Bureau of Commercial Fisheries

Haddock mature sexually at 3 to 4 years of age at weights of 2 to 3 pounds. The primary spawning season is from late February to May. Spawning takes place in rather shallow water on Georges Bank (30 to 50 fathoms).

In the Gulf of Maine haddock average about 6 inches long at the end of their first year, and double their length during the second year. This rate of growth is almost maintained during the third year. The rate then drops to roughly 1 1/2 inches per year. Thus, 8-year-old haddockare about 25 inches long. The average relationship between length and weight is shown in Figure 4.

Figure 4. Relation between the length and weight of haddock

There are actually two more or less self-contained populations of haddock in the Gulf of Maine. One is on Georges Bank and the other on Browns Bank. The Fundial channel, between the two Banks, is more than 100 fathoms deep and is regarded as a natural barrier separating the two populations. It has been reported that there appear to be no important intermigrations between the two populations.[2/]

[2/] Comparison of haddock from Georges and Browns Banks, by Howard A. Schuck and Edgar L. Arnold, Jr., Fishery Bulletin of the Fish and Woldlife Service, Vol. 52, No. 67, U.S. Government Printing Office, Washington, D.C., 1951. Also: Definition of Haddock Stock of the Northwestern Atlantic, by John R. Clark and Vadin D. Vladykov. Fishery Bulletin of the Fish and Wildlife Service, Vol. 60, No. 169, U.S. Government Printing Office, Washington, D. C., 1960

Cod: The most productive cod grounds in the Gulf of Maine are: Georges Bank, South Channel - Nantucket Shoals Region, and Browns Bank. Most cod are caught in waters from 5 to 75 fathoms deep, in temperatures from 32° to 50-55° F.

Large catches of cod are made as they spawn on the eastern part of Georges Bank in depths of about 35 fathoms. Spawning season is from February to April. Ripe cod are in abundance from November to mid-February on Nantucket Shoals, east and south of Nantucket Island. In addition, great numbers of spawning fish congregate in Massachusetts Bay on grounds 3 to 10 miles offshore.

Pollock: American pollock is a cool water fish. Its general range is the continental waters on both sides of the North Atlantic in cool temperate and boreal latitudes. Within the Gulf of Maine, pollock concentrations seem greatest around the coastal belt of the Gulf, out to the 75 to 80 fathom line, and on the offshore banks.

Small pollock (8 to 10 inches long) weighing less than half a pound swarm inshore after early April, move out in June (evidently to avoid the rising temperatures) and return again in autumn. The larger fish tend to concentrate farther offshore.

Certain biological data for haddock, cod and pollock are summarized in tabular form in Table 3.

Table 3. Biological data on haddock, cod and pollock

Table 3. --Biological data on haddock, cod and pollock

Species	Living Habits: Depth	Living Habits: Temperature	Living Habits: Salinity
	Fathoms	°F	Parts per thousand
Haddock	25 - 75	34 - 52	31.5 - 33.5
Cod	5 - 75	32 - 55	
Pollock	Surface to 100	32 - 52	32.0 - 32.8

Spawning

	Age at Maturity	Season	Grounds	Depths	Temperature
	Years			Fathoms	°F
Haddock	3 or 4	Feb.-May	Georges Bank	from 30	35 - 44
		Feb.-May	Browns Bank	30 - 50	
Cod	3	Nov.-April	Mass. Bay	12 - 25	
		Jan.-May	Ipswich Bay	5 - 25	36 - 47
		Feb.-April	Georges Bank	35	
		Nov.-Feb.	Nantucket Shoals	7 - 20	
Pollock	3	Nov.-Jan.	Mass. Bay Georges Bank Browns Bank	25 - 60	38 - 48

Source: The biological notes presented in this section are compiled from: Fishes of the Gulf of Maine by Henry B. Bigelow and William C. Shroeder, Fishery Bulletin of the Fish and Wildlife Service, Vol.53, No.74, U.S. Government Printing Office, Washington

International Regulations Affecting the Fishery

For conservation purposes the International Commission for the Northwest Atlantic Fisheries (ICNAF) has adopted regulatory measures related to net mesh sizes used in the haddock fishery in the Gulf of Maine. The Commission, in 1953, prescribed a mesh size of 4 1/2 inches.[3/] The regulation was adopted by the contracting governments on June 13, 1953.[4/]

[3/] International Commission for the Northwest Atlantic Fisheries, Second Annual Report for the Years 1951-52, St. Andrews, N.B., Canada, 1952.

These recommendations were based on results of experiments carried out on request of the Commission, by the Woods Hole Laboratory of the Branch of Fishery Biology, U.S. Fish and Wildlife Service, in June, 1952. (Compare: Experiments on the Escape of Undersized Haddock, by J. Clark, Commercial Fisheries Review, Vol. 14, No. 9, p. 1-7, Washington, D. C., 1952)

[4/] Contracting governments in 1953 included:

Canada, Denmark, France, Iceland, Italy, Norway, Portugal, Spain, United Kingdom, United States of America. New members since 1953 are: Germany, Poland, Rumania, Union of Soviet Socialist Republics.

In 1955 the mesh regulations were extended to include cod. This amendment also specified rules for exceptions concerning vessels that do not fish primarily for haddock or cod. The effects of the regulations on the fishery during the first year of implementation were reported by Graham and Premetz.[5/]

[5/] First Year of Mesh Regulations in the Georges Bank Haddock Fishery by Herbert W. Graham and Ernest D. Premetz. U.S. Fish and Wildlife Service, Special Scientific Report, Fisheries No. 142, 1955

Their investigations were continued by Clark,[6/] who estimated

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[6/] Effect of Mesh Regulations in Subarea 5, by John R. Clark, ICNAF, Annual Proceedings, Vol 5 for the year 1954-55, Halifax, Nova Scotia, Canada, 1955

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that nearly 3 million haddock were protected during a period of 9 months (from July, 1954 to March, 1955).

There are continuing efforts underway to develop an international regulation system for the North Atlantic area. These include an examination of various alternatives for management of the fishery resources in the area. Although these regulations are of great importance to the U.S. industry, they are not discussed further in this report.

DESCRIPTION OF THE LARGE TRAWLER FLEET

The United States haddock fishing fleet consists of small, medium and large trawlers.[7/]

[7/] The Bureau of Commercial Fisheries uses the following grouping of otter trawlers fishing from Boston:

small trawlers	-	under 50 gross tons
medium trawlers	-	from 50 to 150 gross tons
large trawlers	-	over 150 gross tons

Boston is the primary home port of the U.S. haddock fleet. This study covers the performance of only the large offshore haddock trawlers and includes data on 22 vessels which, in 1966, accounted for 49 per cent of the haddock landed at Boston and 23.5 per cent of total U.S. haddock landings.

Vessel Characteristics

The vessels in this study are large side trawlers. With a single exception they are constructed of steel. All are powered with diesel engines, use the same type of fishing gear (otter trawl), and share the common practice of storing the catch on ice in the vessel hold.

The vessels, however, differ considerably from each other with respect to gross tonnage, power of main engine, number of crewmen, and year built. These factors are the primary determinants of productivity of fishing vessels. Gross tonnage ranges from 153 to 458 tons and the vessels are powered by engines that range in size from 375 to 900 hp. Crewmen on the vessels may number 13, 15 or 17, depending on the size category of the vessel as determined by labor-management negotiations. The oldest trawlers in the fleet were built in 1934, whereas the newest one started fishing in 1965.

Because of these differing characteristics, some stratification was desirable for the purpose of this analysis. A preliminary evaluation of performance data for the fleet under study showed that it is sufficient to stratify this fleet into two gross tonnage classes: 150 to 199 gross tons, and 200 or more gross tons. It was also found that within the latter stratum (containing 17 trawlers) gross tonnage seems to have less effect in determining the productivity of a vessel than does propulsion power. Consequently, horsepower of the main engine was chosen as the substratum classification criterion. Within the substratum, a distinction was made between vessels with 15 men and 17 men crew.

Thus, the 22 large trawlers were divided into four vessel categories which will be referred to in the remainder of this paper as groups A, B, C and D. The main characteristics of each group are given in Tables 4 and 5.

Table 4. Main characteristics of Boston Large-trawlers

Table 5. Age distribution of Boston Large-trawlers (as of 1966)

Table 4. --Main Characteristics of Boston large trawlers

Vessel group	Vessels in group	Gross Tonnage Range	Gross Tonnage Median	Size of main engine Range	Size of main engine Median	Mean length	Crewmen
	No.			h.p.		feet	No.
A	5	153-170	163	375-437	420	99	13
B	3	213-251	218	500-550	500	98	15
C	7	203-264	241	520-575	525	111	17
D	7	226-458	238	735-900	800	120	17

Note: The length of vessels is given as registered length, which is between over-all length and length between perpendiculars.

Source: Merchant Vessels of the United States, 1965, United States Treasury Department, Bureau of Customs.

Table 5. --Age distribution of Boston large trawlers (as of 1966)

Vessel group	Age group (years)							Total
	1-5	6-10	11-15	16-20	21-25	26-30	31-35	
	No. of Vessels							
A	-	-	-	-	1	1	3	5
B	-	-	1	1	1	-	-	3
C	-	-	-	3	1	2	1	7
D	3	-	-	2	-	2	-	7
Totals	3	-	1	6	3	5	4	22

The Large Trawler Labor Force

A recent report on the Boston large trawler labor force indicates that in 1964 there were 582 fishermen employed on the trawlers, but the majority worked only part time.[8/]

[8/] Virgil J. Norton and Morton M. Miller - An Economic Study of the Boston Large-Trawler Labor Force. United States Department of the Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries. Circular 248, Washington, D.C., May, 1966. The statements presented in this section are compiled from that study.

The number of fishermen working full time in the fleet made up about 42 per cent of the total. The age distribution of the fleet's fishermen shows that about 3 out of every 5 were over 55 years of age in 1964.

With respect to education, the study pointed out that nearly two-thirds of the crewmen had not continued their formal education beyond the grade school level.

Full time fishermen in the fleet spent an average of 267 days at sea during 1964. This is about 22 days more than the typical U.S. worker spends on the job during a year. When converted into hours, the fishermen's time on the job contrasts even more sharply with the average in other industries, since the norm for offshore fishermen is a 12-hour work day at sea.

The study found that injury and sickness rates among the fishermen were high, bringing about a high incidence of job absence and inflated welfare costs.

VESSEL OPERATIONS

The average annual days at sea for the trawlers ranged from 231 for group A to 266 for group D. The over-all average was 248 days (Table 6). While there was a decline in days at sea for the first three groups over the 10-year period, the vessels in group D showed an increase. This latter results mainly from the addition of three new vessels to this group since 1963. The new vessels are able to spend more days at sea because of less mechanical failure and time spent for repairs. The annual days at sea by the older vessels in group D did not change significantly. The average trip length for all vessels ranged from 9.0 to 9.3 days, with 9.2 days as the weighted mean (Table 6).

Table 6 Days spent at sea by Boston large trawlers, 1957-1966

Table 6. --Days spent at sea by Boston large trawler, 1957-66

Year	Days per year					Days per trip				
	Vessel group					Vessel group				
	A	B	C	D	all vessels	A	B	C	D	all vessels
	Number of days									
1957	228	258	253	260	248	9.0	9.5	9.0	8.5	9.0
1958	243	247	263	261	255	9.2	9.4	9.0	8.7	9.1
1959	251	244	264	262	257	9.8	9.8	9.5	8.9	9.5
1960	215	221	257	248	238	9.5	9.8	9.6	9.1	9.5
1961	239	246	252	257	248	9.4	9.2	9.4	8.9	9.3
1962	250	247	256	254	252	8.8	8.9	9.1	8.5	8.8
1963	252	244	242	270	252	9.2	9.0	9.2	9.2	9.2
1964	225	235	262	274	253	9.2	9.3	9.5	9.1	9.3
1965	195	217	239	272	238	8.9	9.2	9.4	8.9	9.1
1966	213	145	234	271	235	8.8	8.5	9.0	9.2	9.0
Average: 1/										
1957-1966	231	233	252	266	248	9.2	9.3	9.3	9.0	9.2
1957-1959	241	249	260	261	253	9.3	9.6	9.2	8.7	9.2
1964-1966	211	204	246	272	242	9.0	9.1	9.3	9.1	9.1

1/ Weighted mean, to account for varying number of vessels in certain years.

The proportion of the days at sea spent on the fishing grounds by the four vessel groups was, 73.2 per cent, 70.6 per cent, 73.8 per cent, and 75.1 per cent for the groups A to D respectively. The variation among vessels in each group was smaller than that among groups indicating that the pattern of fishing for vessels within each group is quite similar.

Quantity and Composition of Landings

The annual quantities of fish landed per vessel in the groups under study varied considerably (Table 7). The table shows that the large vessels consistently landed greater quantities than the smaller vessels (group A). Size of the

Table 7. Average Annual Landing, per vessel, by size group, 1957-1966

vessels, horsepower, number of days spent at sea and on actual fishing are among the main factors responsible for higher landings by larger vessels. It is assumed that skill of the crew (especially of the captain) is also a contributing factor, since larger vessels tend to attract better crewmen.

The average annual quantities landed per vessel in two 3-year periods, 1957-59 and 1964-66, are the same. This, however, results from adding 3 new large vessels (group D) to the fleet in recent years. Comparison between these two time periods for identical groups of vessels (i.e. excluding new vessels) shows a drop in annual landings per vessel from 1297 tons in 1957-59 to 1164 tons in 1964-66.

Table 7. --Average Annual landings per vessel, by size group, 1957-66

Vessel Group	Years									
	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
	Tons									
A	907	877	877	813	967	1161	922	849	779	694
B	1188	929	943	995	1187	1365	1146	940	1050	375
C	1534	1407	1335	1445	1529	1580	1225	1347	1196	1105
D	2012	1736	1694	1836	1925	2056	1673	1800	1900	1710
All groups 1/	1393	1235	1202	1259	1382	1507	1249	1300	1318	1195

1/ Weighted mean

Note: 3-year averages for all groups:

1957-59	1275 tons
1964-66	1276 tons

Table 8 gives the landings of these vessels in the form of indices. The decline for groups A, B and C during the more

Table 8. Indices of average landings per vessel by vessel group, 1957-66

recent years reflects the decreased effort exerted by these vessels as well as a slightly downward catch rate (to be discussed in detail in a later section). The annual catch for group D has not changed significantly because the decreased catch rate has been offset by a 4 per cent increase in effort. It should be noted that this latter group contains all the vessels added to the fleet after 1962.

Haddock accounts for 70 per cent of the total landings of this fleet with the remaining 30 per cent being made up primarily of cod and pollock (Figure 5).

Figure 5. Composition of landings at the Boston Fish Pier, 1957-1966 (annual)

Table 8. --Indices of average landings per vessel, by vessel group, 1957-66

[1957 - 1959 = 100]

Vessel Group	Years									
	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
	Indices									
A	102.2	98.9	98.9	91.6	109.0	130.9	103.9	95.7	87.8	78.2
B	116.5	91.1	92.4	97.5	116.4	133.8	112.4	92.2	102.9	36.8
C	107.6	98.7	93.7	101.4	107.3	110.9	86.0	94.5	83.9	77.5
D	110.9	95.7	93.4	101.2	106.1	113.3	92.2	92.2	104.7	94.3
All groups	109.2	96.8	94.2	98.7	108.3	118.1	97.9	101.9	103.3	93.6

In accordance with the Massachusetts Culling and Weighing Regulations (effective September 9, 1957), haddock is sorted into two market sizes: Scrod haddock weighing from 1 1/2 to 2 1/2 pounds, and large haddock weighing over 2 1/2 pounds. Fish weighing less than 1 1/2 pounds are discarded at sea. Over the last decade there has been a remarkable shift in the proportion of large and scrod haddock landed by the large trawler fleet. This trend is evident not only for the fleet included in this study, but also for all vessels landing haddock at the Boston port (Figure 5). It is interesting to note that there is substantial variation in the composition of landings during any given year. Figure 6 shows, for example, that large haddock generally make up a much greater share of the total Boston landings in the spring season than in the late summer and fall.

Figure 6. Composition of landings at the Boston Fish Pier, 1957-1966 (monthly)

Analysis of the data in Figure 5 brings to light some important implications in that the increasing proportions of scrod haddock in the landings of recent years has resulted in additional labor requirements in the handling of fish. Schuck[9] gives the following average weights for

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[9] Studies of Georges Bank Haddock, Part I: Landings by Pounds, Numbers, and Sizes of Fish, by Howard A. Schuck. Fishery Bulletin 66, U.S. Department of the Interior, Fish and Wildlife Service.

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gutted haddock, based on sample measurements over a period of 18 years:

scrod haddock	1.691 pounds
large haddock	3.398 pounds

This means that, on the average, there would be 1,183 fish in one ton of landed scrod haddock, or 588 fish in one ton of landed large haddock. Considering the proportions of scrod and large haddock given in Figure 5, it is possible to set up an interesting comparison. In 1964, in each 100 tons of haddock, there were on the average:

scrod haddock--50.4 tons or 59,610 fish

large haddock--49.6 tons or 29,194 fish

total -100.0 tons or 88,774 fish

In 1966, in a load of 100 tons of haddock, there were:

scrod haddock--73.0 tons or 86,339 fish

large haddock--27.0 tons or 15,892 fish

total -100.0 tons or 102,231 fish.

This indicates that in order to land 100 tons of haddock 15 per cent more had to be handled on board vessels on the fishing grounds in 1966 than in 1964. Because current on board handling techniques require that each fish be processed individually, this meant a significant additional work load in 1966 for the crewmen.

Landings per Trip

The quantity of fish landed per trip[10/] has an important

[10/] As shown in Table 6, trip length has not varied significantly over the past decade.

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bearing on production costs per pound of fish. Days fishing, abundance and availability of fish and weather conditions are important among the factors that affect quantity landed per trip. An analysis of landings from 4,600 trips taken by this fleet from 1957-1965 revealed that although landings per trip ranged widely, the "usual" catches were within 14 to 20 tons of the mean catch (Figure 7). Further, Figure 8 shows that for 50 per cent of the trips, landings were at least 35, 40, 50 and 60 tons respectively for the four vessel groups A, B, C & D.

Figure 7. Relative frequency distribution of landings per trip, by vessel group.

Figure 8. Cumulative frequency distribution of landings per trip, by vessel group.

The average annual quantity of fish landed per trip was nearly constant over the 10-year period 1957-1966, although the average value of the landings per trip rose by nearly 19 percent during the same period (Table 9)[11/]. The graphs in Figure 9 present a comparison

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Table 9. Average quantity and value of landings per trip, by vessel group, 1957-1966.

11/ The comparison is made between two 3-year means: 1957-1959 and 1964-1966. For the analysis presented in this table all "broken" trips from which the trawlers landed less than 10 tons of fish have been disregarded. These trips accounted for about 1 percent of all trips, with an average catch and value of 5.2 tons and $1,363, respectively.

Figure 9. Landings per trip, for different vessel groups, 1957-1966.

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of landings for three different vessel groups.

The seasonality of landings per trip is shown in Figure 10.

Figure 10. Seasonal index of landings per trip

Table 9. --Average quantity and value of landings per trip, by vessel group, 1957-66

Vessel Group	Unit	Years									
		1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
A	tons	36.0	33.2	34.5	36.5	38.6	41.2	34.6	35.8	35.7	29.9
	1000 $	6.1	7.2	7.3	6.3	6.3	7.7	7.1	6.9	7.7	7.0
B	tons	44.0	36.0	37.7	44.5	45.6	49.8	43.4	37.1	45.6	--
	1000 $	6.8	7.4	7.2	7.3	7.4	8.6	8.4	7.1	10.1	--
C	tons	55.0	48.3	48.4	53.8	56.9	56.6	47.6	49.1	47.2	43.6
	1000 $	8.9	10.0	9.8	8.9	9.4	10.1	9.5	9.3	9.9	10.3
D	tons	65.6	57.9	58.3	67.2	66.4	68.5	57.3	60.0	62.7	57.8
	1000 $	10.8	12.0	11.3	11.4	11.0	12.4	11.8	11.9	13.8	13.7
Average for all groups 1/	tons	50.7	44.1	44.8	50.6	52.0	53.3	46.4	48.1	50.8	48.5
	1000 $	8.3	9.2	9.0	8.5	8.5	9.6	9.4	9.3	11.0	11.4

1/ Weighted mean

Catch per Day at Sea

Traditionally, catch per day fishing is used as an indication of changes in productivity (abundance and availability) of the fishing grounds. This is an appropriate index to use for biological purposes. However, for economic analyses, catch per day at sea and the associated expenses or revenue are more useful. As Green and Broadhead[12/] and Noetzel[13/] point out,

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12/ Roger E. Green and Gordon C. Broadhead: Cost and Earnings of Tropical Tuna Vessels Based in California. Fishery Industrial Research, Volume 3, No. 1, pp. 29-45. Bureau of Commercial Fisheries, 1965.

13/ Bruno Noetzel: Selected Problems on the Methodology of Planning of Catches in the Polish Sea Fisheries. Reports of the Sea Fisheries Institute in Gdynia. Volume 10/B, pp. 209-234. Gdynia, Poland, 1960.

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vessel expenses continue, and in fact differ only slightly, whether the vessel is fishing, searching, or steaming to the grounds or to port.

Based on the average catch per day at sea for the 4 vessel groups (Table 10) an analysis of variance shows that while there is a

Table 10. Catch per day at sea, by vessel group, 1957-1966.

significant difference among vessel groups in catch per day, there is not a significant difference for each vessel group over the 10-year period.[14]

14/ The resultant F value for among vessel groups is 51.89 with (3, 36) degrees of freedom ($F_{0.01} = 4.43$), while the F value for years is 0.58 with (9,30) degrees of freedom ($F_{0.01} = 3.07$)

This conclusion, however, appears to be in conflict with what can be expected in this fishery, where the fleet is getting older and increased effort by foreign vessels is exercised on the fishing grounds, especially in the last few years. These conflicting results of the analysis of variance seem to come from the fact that average catch rates for vessel groups, instead of invididual catch rates, were considered.

Therefore an alternative method for testing the hypothesis of decreasing catch rate was applied.

Table 10. --Catch per day at sea, by vessel group, 1957-66

Year	vessel group			
	A	B	C	D
	Tons			
1957	3.98	4.62	6.05	7.75
1958	3.60	3.76	5.35	6.64
1959	3.50	3.86	5.06	6.46
1960	3.79	4.50	5.62	7.39
1961	4.04	4.82	6.05	7.49
1962	4.65	5.54	6.16	8.09
1963	3.66	4.69	5.07	6.21
1964	3.77	4.00	5.14	6.57
1965	3.99	4.84	5.01	6.98
1966	3.18	2.59	4.71	6.30

In the multiple regression equation*

$$\hat{Y} = 1.38580 + \underset{(2.4)}{0.00190}\, X_2 + \underset{(12.646)}{0.00669}\, X_3 - \underset{(2.427)}{0.05957}\, X_4$$

where: Y = catch rate per day at sea, in tons

X_2 = gross tonnage of vessel

X_3 = horsepower of main engine

X_4 = time variable (1957 = 1, 1966 = 10),

with t values given in parentheses, the regression coefficient for the time variable is significantly different from zero.

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* This estimating equation is based on 178 observations of individual vessel catch rates over the 10-year period, 1957-1966. The coefficient of determination is equal to 0.57, the resultant F value is 77.07 with (3,174) degrees of freedom.

The value of the time variable coefficient indicates that the catch per day at sea was decreasing over the past ten years at a rate of about 120 pounds per annum. What part of this is attributable to biological changes on the fishing grounds (as the result of more effort) and to changes in operational effectiveness of the fleet caused by time (age of vessels) cannot be established from the data available.

Another indication of this regression equation is the high significance of the horsepower variable. Since all the Boston large trawlers use the same size trawls, vessels with more horsepower are capable of dragging the net at a greater speed, fishing in more severe weather, reaching the grounds or changing positions on the grounds in a shorter period of time. It can be argued, of course, that part of the success may be due to the human factor, since vessels with higher potential fishing capability may attract better crews.

The relative fishing effectiveness of the four vessel groups may be expressed by indices. A method used by Shimada and Schaefer[15/]

15/ Bell M. Shimada and Milner B. Schaefer. A Study of Changes in Fishing Effort, Abundance and Yield for Yellowfin and Skipjack Tuna in the Eastern Tropical Pacific Ocean. Inter-American Tropical Tuna Commission Bulletin, Volume 1, No. 7, La Jolla, California, 1956.

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was applied by computing, for each vessel group, the ratio of the geometric mean of the catch-per-day-at-sea for the years 1957-66 to that of the standard group, specified arbitrarily as group C. Based on this method, the following Fishing Effectiveness Indices were calculated:

Vessel Category	Fishing Effectiveness Indices
A	0.711
B	0.800
C	1.000
D	1.290

Since the vessel groups are determined by size, with vessel size and horsepower of the main engine increasing from group A to group D, these indices indicate that in the fishery, fishing effectiveness generally increases as vessel size and engine horsepower increases. Figure 11 indicates the nature of this relationship.

Figure 11. Relationship between vessel size and landings

Vessel Capacity Utilization

The calculation of landings per day and per trip for the four vessel groups brought to light an extensive underutilization of vessel hold capacity. Although there is little that can be done with respect to vessel design for the present vessels, this underutilization of vessel hold capacity does imply the necessity of a full evaluation of economically efficient vessel types and sizes.

The vessel hold capacity utilization was calculated as the ratio of landings per trip to the fish hold capacity.[16/]

16/ The fishroom capacity of a vessel, expressed in tons of fish, was computed as the product of its net registered tonnage (one registered ton = 100 cu. ft. of space) and a constant factor, 3,000 pounds of fish. The latter is the average quantity of fish in ice that can be stowed bulked in 100 cu. ft. of space.

The average utilization of that capacity was:

Group A	27.2 percent
Group B	19.1 percent
Group C	24.6 percent
Group D	30.9 percent

Table 11 presents an evaluation of vessel hold capacity utilization.

Table 11 -- An evaluation of vessel hold capacity utilization

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Thus, for new vessels entering the fishery, it should be determined whether or not an alternative vessel design with less fish hold capacity might be economically more efficient.

Table 11 -- An evaluation of vessel hold capacity utilization

	Vessel groups			
	A	B	C	D
	tons			
Fish hold capacity	133.2	231.7	209.5	202.3
Mean landings per trip	36.2	44.3	51.5	62.5
Standard deviation in landings per trip	14.0	17.5	17.2	19.9
Expected upper limit on landings: 1/				
84.1 percent of the trips	50.2	61.8	68.7	82.4
	(37.7) 2/	(26.7)	(32.8)	(40.7)
97.7 percent of the trips	64.2	79.3	85.9	102.3
	(48.2)	(34.2)	(41.0)	(50.6)
99.9 percent of the trips	78.2	96.8	103.1	122.2
	(58.7)	(41.8)	(49.2)	(60.4)

1/ Based on figures 7 and 8 and assuming a normal distribution for each vessel group in figure 7.

2/ All figures in parentheses represent the percentages of capacity utilization.

An alternative implication of this discussion is that because of the tremendous amount of unutilized capacity in the existing fleet, it may be possible to develop a method of holding the fish in boxes rather than in bulk. Trials carried out with British trawlers confirmed that "fish properly boxed at sea is of significantly better quality at the time of landing than is fish caught at the same time and shallow-bulked or shelved."[17/] With the type of boxes and system of stowage pro-

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17/ A Progress Report on Trials of Boxing at Sea. White Fish Authority - BSP Industries, Hull, England, 1966

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posed by the White Fish Authority's Industrial Development Unit, the space requirements would rise to 95 cubic feet per ton of fish (long ton = 2240 pounds). This means that the weight to volume ratio would drop from 3000 to 2358 pounds of iced fish per 100 cubic feet of hold space. For example, the fish hold capacity of the trawlers in group D would be 159 tons of fish compared with 202.3 tons when bulking the catch. In spite of the increased stowage requirements with a boxing system, however, it is clear from Table 11 that for essentially all trips, present vessel hold capacity would be adequate to handle the expected catches. A thorough investigation of the feasibility of utilizing boxes for this fleet may be appropriate. This investigation should consider the possible gains from a boxing system as compared to additional costs such as box costs and possible additional labor requirements.

Revenue and Prices

Fish landed at the Boston fish pierare sold at auctions held at the New England Fish Exchange Selling Room.[18/]

18/ For a brief description of the Boston auction see: U.S. Department of the Interior, Bureau of Commercial Fisheries, Market News Service. Information and explanatory statement for daily New England Market News Services "Fishery products reports" issued at Boston, Mass., Apr. 1963 (rev.), 9 p.

Money received from these sales constitute the value of the landings or gross stock of a vessel from fishing operations. The sum of the gross stock from each trip in any year is the vessels gross revenue for that year. Table 12 shows the average annual gross revenue for the four vessel groups over the period 1957-66.

Table 12. Average annual gross revenue by vessel group, 1957-66

A comparison of averages for two 3-year periods, 1957-59 and 1964-66, and for the same group of vessels (48 vessel-years in each of the two periods) shows that the annual gross revenue per vessel remained at the same level of 246 thousand dollars. Within the same time span, the quantity landed by this group dropped from 1297 to 1164 tons per vessel-year, or 10.3 percent. This means an 11.4 percent increase in average price. Gross revenue for the whole fleet (including new vessels in recent years) increased by 12.2 percent (Table 12).

Table 12 - Average annual gross revenue by vessel group, 1957-66

Vessel Group	Years									
	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
	thousand dollars									
A	154.2	190.2	184.8	140.8	158.6	216.2	188.5	164.6	167.9	162.3
B	184.4	190.8	180.5	163.0	191.9	237.4	223.6	179.0	232.2	88.9
C	249.2	290.1	269.4	240.3	251.7	282.3	245.8	254.6	251.6	260.0
D	333.0	358.7	328.7	311.8	318.1	371.4	344.4	357.3	416.8	404.4
Average for all groups 1/	228.4	257.3	241.0	211.7	226.9	271.3	252.8	251.7	284.9	282.1

1/ Weighted mean.

Note: 3-year averages for all groups:

1957-59	242.5 thousand dollars
1964-66	272.2 thousand dollars

Prices for Main Species

Since haddock, cod and pollock account for most of the landings by the large trawler fleet, this discussion of prices is confined to these three species.

Over the ten year period 1957-66, landings at the Boston Fish Pier have been on a downward trend. Exvessel prices, however, generally show an upward trend. The upward trend of prices is most prevalent for large haddock (Figure 12 and Figure 13). Although the annual data presented in these figures appear to generate a rather consistant upward trend, it is apparent from Table 13 that the price variations within a given year are rather extreme. For example, the average monthly price for large haddock in January, 1966 was more than double the average May price. These fluctuations generally follow a seasonal pattern which is roughly inverse to the seasonal variations in landings (Figure 14). It can be seen from this figure that the expected inverse correlation between landings and ex-vessel price is most closely reflected in the case of large

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Figure 12. Trends of ex-vessel prices for haddock at the Boston Fish Pier

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Figure 13. Trends of ex-vessel prices for cod and pollock, at the Boston Fish Pier

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Table 13. Average monthly ex-vessel prices for haddock, cod and pollock at the Boston Fish Pier, 1966

Table 13 -- Average monthly ex-vessel prices for haddock, cod, and pollock at Boston Fish Pier, 1966

Species 1/	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Averag
	months												
	cents												
Haddock - large	22.06	16.75	13.05	13.58	10.77	12.34	17.73	17.62	18.70	21.12	17.37	18.01	15.4
Haddock - scrod	13.26	11.32	10.31	11.06	7.92	9.50	12.07	10.95	11.71	14.17	13.48	12.24	11.3
Cod - large	15.84	10.54	9.90	9.30	7.15	9.25	10.06	9.02	11.24	12.17	11.30	11.61	10.3
Cod - market	17.46	13.21	11.52	10.56	7.45	9.91	11.60	9.94	11.72	12.36	12.43	12.61	11.3
Pollock	8.64	12.42	8.82	8.44	7.81	11.37	10.08	5.48	9.26	7.98	5.20	5.68	7.29

Source: Market News Service, Bureau of Commercial Fisheries

1/ Large haddock -- over $2\frac{1}{2}$ pounds

scrod haddock -- $1\frac{1}{2}$ - $2\frac{1}{2}$ pounds

large cod -- 10 - 25 pounds

market cod -- over $2\frac{1}{2}$ - 10 pounds

haddock.[19]

Figure 14. Seasonal fluctuations in landings and prices of haddock, cod and pollock

[19] Obviously there are more factors which influence the ex-vessel price of large haddock. An even closer inverse correlation than the one mentioned above was found between the price of large haddock and landings plus inventories (compare: The Economics of Freezing Fish at Sea, by William H. Miernyk and Sumner M. Rosen, an unpublished report prepared for the U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries, under contract completed in 1956. A summary of this report has been published in Commercial Fisheries Review, Vol. 20, No. 11, November, 1958).

For further detailed price analysis see: Joseph F. Farrell and Harlan C. Lampe, "The New England Fishing Industry: Functional Markets for Finned Food Fish I," Bulletin 379, University of Rhode Island, 1966. Joseph F. Farrell and Harlan C. Lampe, "The New England Fishing Industry: Functional Markets for Finned Food Fish II," Bulletin 380, University of Rhode Island, 1966

Production Costs

Costs in this section are broken down into two general cost categories: Operating costs and owner costs. These two cost categories can generally be considered as variable and fixed costs of production.

Operating Costs

This group of costs comprises all the cost items that enter into the settlement of the proceeds from fishing between the crew and the vessel owner after each trip. In compliance with the wage system[20] presently in force, the owner's and crew's shares are

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20/ Details are stated in contracts between the vessel owners and the Atlantic Fishermen's Union, bargaining agent for the crewmen.

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computed as follows: After each trip the shared costs[21] are deducted from the gross revenue received, called "gross stock." The balance

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21/ Shared costs are: wharfage, scales, exchange fee, bonuses for two engineers and mate, sounding machine, watching, radar, fisherman's welfare, ice and lumpers.

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called "net stock," is then split into two parts, with 40 percent going to the owner (ship's share) and 60 percent to the crew (crew's share). The costs for fuel, lubricating oil, icing up, ice, groceries and provisions, cook's bonus, water, and lumpers are deducted from the crew's share. This then gives the net crew share from which each crewman receives an equal part. In addition to this, the captain receives 10 percent of the owner's share. Appendix A presents a copy of a typical settlement sheet.

Owner's Costs

This group of production costs contains cost items which the vessel owner has to cover out of his share from fishing operations, namely:

Vessel maintenance and repairs,

fishing gear,

insurance,

payroll taxes

management

office and other expenses,

depreciation,

broker payments.

Detailed information on operating costs and owner's costs are given in Appendix B.

In this Appendix a set of equations through which the various categories of operating costs may be estimated for the different sized vessels is also presented. This was achieved by relating costs to such factors as gross tonnage of the vessel, number of crewmen, days spent at sea, catch rate, price of fish landed, and others.

ANNUAL EARNINGS

Before discussing the actual earnings of this trawler fleet we present an illustration of crew's and owner's earnings calculated for various levels of catch rates and at various ex-vessel prices.

First in Table 14 the annual landings per vessel and the

Table 14. Annual gross revenue, at various catch rates and prices.

corresponding gross revenue figures are shown. The landings were calculated at four different catch rates (from 3 to 6 tons per day at sea, for vessel group C), and the gross revenue values are the products of landings per vessel and ex-vessel price at four levels, from $180 to $240 per ton of fish landed. It should be mentioned that for the purpose of our illustration the relationship between catch rate (and thus landings) and the ex-vessel prices, as it was discussed earlier, has been disregarded.

The set of annual landings and gross revenues from Table 14 was then used for estimations of annual crew's and owner's earnings, which are presented in Table 15.

Table 15. Estimations of annual earnings, based on average effort (days at sea) and standardized catch rates

Table 14 -- Annual gross revenue, at various catch rates and prices

Vessel group	Days at sea	Catch rate standardized	Catch rate individual	Annual catch (landings)	Gross revenue at average ex-vessel price per ton $180	$200	$220	$240
	No.	tons			dollars			
A	231	3	2.133	492.7	88686	98540	108394	118248
B	233		2.400	559.2	100656	111840	123024	134208
C	252		3.000	756.0	136080	151200	166320	181440
D	266		3.870	1029.4	185292	205880	226468	247056
A	231	4	2.844	657.0	118260	131400	144540	157680
B	233		3.200	745.6	134208	149120	164032	178944
C	252		4.000	1008.0	181440	201600	221760	241920
D	266		5.160	1372.6	247068	274520	301972	329424
A	231	5	3.555	821.2	147816	164240	180664	197088
B	233		4.000	932.0	167760	186400	205040	223680
C	252		5.000	1260.0	226800	252000	277200	302400
D	266		6.450	1715.7	308826	343140	377454	411768
A	231	6	4.266	985.4	177372	197080	216788	236496
B	233		4.800	1118.4	201312	223680	246048	268416
C	252		6.000	1512.0	272160	302400	332640	362880
D	266		7.740	2058.8	370584	411760	452936	494112

Notes: 1) Days at sea (column 2) are averages for the period 1957-1966 (from table 6).

2) The four standardized catch rates of column 3 have been selected.

3) The individual catch rates (column 4) were computed by using the fishing effectiveness indices.

Table 15 -- Estimation of annual earnings, based on average effort (days at sea) and standardized catch rates*

Vessel group	Standard catch rate per day at sea	Earnings at average ex-vessel price per ton							
		$180		$200		$220		$240	
		Crew share	Profit or loss	Crew share	Profit or loss	Crew Share	Profit or loss	Crew share	Profit or loss
	tons	-Dollars-							
A)	3	1053	-28604	1496	-25155	1939	-21706	2382	-18257
B)		985	-37053	1421	-33139	1857	-29225	2293	-25310
C)		1724	-32300	2244	-27008	2764	-21716	3284	-16424
D)		2823	-29017	3532	-21811	4241	-14605	4950	- 7399
A)	4	2323	-18253	2914	-13654	3505	- 9055	4096	- 4456
B)		2234	-25310	2816	-20091	3398	-14872	3930	- 9653
C)		3184	-16424	3878	- 9368	4572	- 2312	5266	4744
D)		4821	- 7395	5766	2213	6711	11821	7656	21429
A)	5	3593	- 7908	4332	- 2160	5071	3588	5810	9337
B)		3483	-13567	4211	- 7043	4939	- 519	5667	6005
C)		4644	- 548	5512	8272	6380	17092	7248	25912
D)		6819	14220	8000	26230	9181	38240	10362	50250
A)	6	4863	2436	5750	9334	6637	16232	7524	23130
B)		4732	- 1824	5606	6005	6480	13834	7354	21663
C)		6104	15328	7146	25912	8188	36496	9230	47080
D)		8817	35835	10234	50247	11651	64659	13068	79070

Note: Individual crew share does not include broker payments. These payments are more likely to occur and be of larger amounts at the lower catch rates, than at the higher ones.

* From Table 14

In setting up this table, the individual crew share (i.e the crew's earnings per man) was derived by employing the appropriate equations from Appendix B. For calculations of fuel cost, which is one of the factors determining the net crew share, the following average gross tonnage figures were applied:

for vessel group A	162 GRT
for vessel group B	227 GRT
for vessel group C	237 GRT
for vessel group D	284 GRT

The owner's operating profit or loss (i.e. the owner's earnings) is the difference between owner's share and owner's costs. The owner's share is computed through deduction of total operating costs from gross stock. It was found that operating costs which include shared expenses and 64 percent of net stock (Appendix A), are closely related to gross revenue.

The regression based on vessel data for 1964-1966 (49 observations) is of the form: $C_o = 1900 + 0.65R$

where C_o = annual operating costs to the owner

R = annual gross revenue

The correlation coefficient is highly significant and essentially all of the variation in costs is accounted for by the equation ($r^2 = 0.999912$). From this regression, the owner's share was derived as: $S_{ns} = R - (1900 + 0.65\ R)$

$= 0.35\ R - 1900$

Owner's costs are listed in Appendix Table 2.

The minimum quantities of fish, which at given ex-vessel prices have to be landed in order to equalize gross revenue with the sum of operating and owner's costs, may be computed with the formula:[22/]

$$Q = \frac{F + 1900}{0.35\ p}$$

where: Q is the vessel's annual landings, in tons
F is the owner's annual costs (Appendix Table 2)
p is the average annual ex-vessel price, in $/ton.

[22/] This formula is derived from the required equality:
gross revenue = (operating costs) + (owner's costs)
or $R = 1900 + 0.65\ R + F$;
thus, $0.35\ R = F + 1900$ and $Q = \frac{F + 1900}{0.35\ p}$, since $R = Qp$.

Table 16 gives the break-even quantities for each vessel class, at various ex-vessel fish prices.

Table 16. Quantities of annual landings per vessel required to cover operating and owner's costs, at various price levels

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Table 16 -- Quantities of annual landings per vessel required to cover operating and owner's costs, at various price levels.

Ex-vessel price per ton	vessel group A	B	C	D
- -dollars- -	- - -landings in tons - - - -			
$ 180	947	1147	1269	1490
200	852	1033	1142	1341
220	774	939	1038	1219
240	710	860	952	1117

Estimates of operating profit (or loss) in Table 15 include allowances for depreciation as part of the owner's costs, although 18 trawlers out of 22 have already been depreciated. For some of these vessels, the public Certificates of Condition disclose the following book values:

3 trawlers of group A-----average value $ 2,884 (end of 1966)

2 trawlers of group B-----average value $ 3,738 (end of 1964)

3 trawlers of group C-----average value $ 13,031 (end of 1966)

2 trawlers of group D-----average value $ 14,958 (end of 1966)

Therefore, the actual profitability of the depreciated vessels in the fleet has been estimated as show in Table 17.

Table 17. Annual costs and earnings of Boston large trawler, 1964-66 average by size group

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Calculations are based on gross revenue data for 1964-1966, and no allowance for depreciation is made. The market value of the vessels is assumed to be equal to 15 per cent of the original construction costs.[23/] The last column in Table 17 presents average values for four new or renewed vessels (group D).

[23/] Miernyk (op. cit., page 74) gives the construction costs for six trawlers built after World War II as ranging from $200,000 to $250,000; these are vessels of groups B-D. Several large trawlers were built before the War, at much lower cost. For simplicity, the values shown in Appendix Table 1 (net investment by owner) were used for computation of market value.

The reason for including only three recent years in this presentation is to minimize the effects of changing prices for fish and supplies.

Table 17 -- Annual costs and earnings of Boston large trawlers, 1964-66 average, by size group

Item	Vessel Group 1/ A	B	C	D_a	D_b
	-dollars-				
1. Gross revenue	154117	135829	245766	404229	385360
2. Operating costs	102076	90189	161648	264649	252384
3. Owner's costs	50544	59483	66528	77569	91969
4. Total costs: 2 + 3	152620	149672	228176	342218	344353
5. Operating profit (or loss): 1 - 4	1497	-13843	17590	62011	41007
6. Vessel's market value 2/	19000	28800	30300	38200	236400
7. Working capital 3/	13100	12900	19600	29400	27600
8. Total investment	32100	41700	49900	67600	264000
9. Percent ratio 5:8	4.66	-33.20	35.25	91.7	15.53

1/ Vessels in groups A, B, C, and D_a are 100 percent depreciated, while group D_b contains new or renewed vessels.

2/ Fifteen percent of original construction costs for groups A, B, C, and D_a, and average book value, end of 1966, for vessels in group D_b.

3/ Working capital = 8 percent of total costs for vessels in the last column, and 8.6 percent for all other groups.

The large differences in the gross revenue values result from more days spent at sea by the larger vessels (compare table 6), and the higher catch rate per day at sea for these vessels (compare table 10).

In comparing only the depreciated vessels, every $100 of the invested capital created a product value of:

$480 on vessels of group A

$326 on vessels of group B

$492 on vessels of group C

$598 on vessels of group D_a

Although the efficiency of capital is of the same magnitude on the smallest trawlers and on those of group C, the latter group warrants an incomparably higher margin of operating profit (table 17). Vessels of group D_a and group B rank as the highest and lowest, respectively, with regard to efficiency and profitability.

The efficiency of labor can be compared from the following gross revenue values per crewman:

Vessel group	Dollars
A	11,855
B	9,055
C	14,457
D_a	24,955
D_b	22,668

Vessels in group A and B (as well as some of the vessels included in group C) produce very low or no return to invested capital. Some of these vessels have already left the fishery, and others are in the process of leaving.

For planning purposes, it is useful to consider the expected return on investment from new vessels of the various size categories. For this analysis, return on investment was calculated for a simulated operational situation, where:

1. New vessels are being operated, with an investment value as shown in Table 18 (built with 50 percent subsidy)
2. Working capital amounts to 8 percent of total costs of operation.[24/]

24/ Based on available accountants reports for a limited number of vessels.

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3. Fishing effort, expressed in days at sea, is taken at the level of the 10-year mean for each vessel group.
4. The standard catch rate per day at sea (i.e. the rate for vessel group C) is taken at the level of the 10-year mean, 5.4 tons of fish; the catch rates for the different groups are then derived by using the appropriate fishing effectiveness index.
5. The average price for landed fish is $220 per ton, the average value in 1966.

Under these assumptions, the return on investment ranges from 2.47 percent in vessel class B to 17.26 percent in vessel class D (Table 18).

Table 18. Estimation of Return on Investment, Boston large trawlers, under certain assumed operating conditions.

Table 18 -- Estimation of Return on Investment, Boston large trawlers, under certain assumed operating conditions

	Vessel Class A	B	C	D
Days at sea	231	233	252	266
Catch/day at sea[1] - tons	3.84	4.32	5.40	6.97
Annual landings - tons	887	1006	1361	1854
Gross revenue[2] - dollars	195140	221320	299420	407880
Operating costs	128741	145758	196523	267022
Owner's costs	57744	70383	78028	91969
Total costs	186485	216141	274551	358991
Gross profit (before taxes)	8655	5179	24869	48889
Net investment in vessel and equipment	127000	192000	202000	254500
Working capital[3]	14900	17300	22000	28700
Total investment[4]	141900	209300	224000	283200
R. O. I. (percent)	6.10	2.47	11.10	17.26

1/ Standardized catch rate = 5.40 tons (for Class C)

2/ Assume an average price of $220 per ton of fish

3/ Working capital = 8 percent of total costs

4/ Total investment is equal to net worth, i.e., no borrowed capital is assumed.

SUMMARY, CONCLUSIONS, IMPLICATIONS

Summary

The purpose of this study is to provide information on the economic performance of the large trawler fleet, based in Boston, Massachusetts, and fishing for haddock on Georges Bank. This fleet, composed of 22 otter trawlers of over 150 gross tons, accounted for 49 percent of haddock landings at Boston in 1966. The analysis covers a ten year period, from 1957 to 1966.

The vessels are analyzed in four size categories with average gross tonnage and horsepower, respectively, of 163, 420 (group A), 218, 500 (group B), 241, 525 (group C), and 238, 800 (group D). As of 1966, about 82 percent of these vessels were over 15 years old. The vessels are manned by a crew of 13 (group A), 15 (group B), or 17 (groups C and D).

The 10-year average for days spent at sea by a vessel per year is 248 days. Of these, from 70.6 to 75.1 percent are reported as fishing days. The larger vessels regularly spend more days at sea per year than the smaller do, and, in addition, the proportion of days spent for actual fishing is higher for the larger than for the smaller trawlers.

The average length of a trip is 9.2 days at sea, whereas the average quantity of fish landed per trip is 36.2, 44.3, 51.5, and 62.5 tons, for vessels in groups A, B, C, and D, respectively. Landings per trip are highest in spring (March, April), and lowest at the end of the year (November, December).

Haddock, cod, and pollock constitute over 90 percent by weight in landings at the Boston port. Haddock alone makes up more than 70 percent. A significant shift in the proportion of large and scrod haddock, namely from large to scrod, has been noticed in the landings of recent years.

Fishing effectiveness, expressed in terms of quantity landed per day at sea, is positively correlated with the size of the vessel and, especially, with the installed horsepower, as indicated by the regression analysis. These two factors, combined with the level of effort (days at sea) and skills of the crews, are responsible for annual landings per vessel being more than twice as high on vessels in group D (1834 tons) than they are on vessels in group A (885 tons). The average annual landings for the whole fleet analyzed (4 groups combined) are the same in the two 3-year periods, 1957-59 and 1964-66, namely 1275 tons per vessel. This, however, includes new vessels added to the fleet in the latter period. On a comparative basis (the same vessels in each of the 2 periods), the landings per vessel-year are down from 1297 tons in 1957-59 to 1164 tons in 1964-66.

A fishing effectiveness index was calculated by relating the fishing effectiveness of a given group to that of a standard group (vessels in group C). This index is 0.71, 0.80, 1.00 and 1.29 for vessel groups A, B, C, and D, respectively.

The average utilization of vessel hold capacity was lowest on vessels of group B (19.1 percent) and highest on vessels of group D (30.9 percent).

Gross revenue per vessel-year (average for all 4 groups combined) increased from 242.5 thousand dollars in 1957-59 to 272.2 thousand dollars in 1964-66; i.e. by 12.2 percent. The 1964-66 figure, however, includes new vessels added to the fleet in this period of time. For the old vessels only (the same fleet in 1957-59 and in 1964-66) the average annual gross revenue remained unchanged, namely 246 thousand dollars in both periods. This means an 11.4 percent increase in average price, since the quantity landed by this group of vessels decreased by 10.3 percent (from 1297 tons per vessel in 1957-59 to 1164 tons in 1964-66).

Average annual ex-vessel prices for haddock (large and scrod), cod (market and large), and pollock show an upward trend. Fluctuations in average monthly prices follow a seasonal pattern, which is roughly inverse to the seasonal variations in landings.

Production costs are analyzed in two groups: operating costs and owner's costs. The first group comprises all the cost items that enter into the settlement of proceeds from fishing between the crew and the vessel owner, in compliance with the existing lay system. These costs on an annual basis are proportional to gross revenue. The second group contains cost items which the vessel owner has to cover out of his share from fishing operations. It includes all fixed costs and some of the variable costs (e.g., payroll taxes).

To minimize the effects of changing prices of fish and supplies, only 3 recent years (1964-66) are included in the analysis of earnings. The average annual operating profit (i.e., profit before taxes) or loss was: 1.5, (-13.8), 17.6, and 62.0 thousand dollars for a vessel in group A, B, C, and D, respectively (only old vessels included in group D).

For a group of new or renewed vessels (4 vessels in group D) the average annual profit before taxes was 41.0 thousand dollars per vessel. For the old vessels, no allowance was made for depreciation, since the vessels have already been depreciated, whereas for the new vessels depreciation was accounted for.

Return on investment is calculated as the ratio of profit before taxes to the sum of an estimated market value of the vessel and an estimated working capital. This ratio for old (depreciated) vessels is highest in group D (92 percent), and lowest in group B (-33 percent). For the new vessels in group D, the rate of R.O.I. is 15 percent. In this case the R.O.I. rate was calculated as the ratio of profit before taxes to the book value of the vessels plus working capital.

Efficiency of labor on a vessel of size group D is approximately twice as high as it is on a vessel in group A.

In a simulated situation, where:

a) new vessels of the four size categories are operated,

b) the vessels are built with a 50 percent construction subsidy,

c) no borrowed capital is employed,

d) an average catch rate, based on actual catch rates for the last 10 years, and an average price for fish based on 1966 prices are assumed,

the return on investment is 6.1, 2.5, 11.1, and 17.3 percent for vessels in groups A, B, C, and D, respectively. In this case the rate of R.O.I. was calculated as the ratio of profit before taxes to equity capital.

Conclusions

1. Within the group of Boston large side trawlers (over 150 gross tonnage) the fishing effectiveness, measured as the quantity of fish landed per day at sea, increases as the size and horsepower of the vessels are increased. Of these two factors, horsepower is the more influential one.

2. Because of the technical advantage, the larger and higher powered vessels are capable of spending more days at sea per year (expansion of production time).

3. Higher initial costs and operating costs on larger vessels are more than compensated for by adequately higher revenues. With the assumption that 50 percent of the vessels' construction costs are subsidized, the expected gross profit (before taxes) of the largest vessel is 5.6 times that of the smallest one.

4. Under the same construction subsidy assumption, a 17 percent rate of return on investment may be expected on a vessel of the type represented by the group of largest trawlers, as compared with a 6 percent rate on a vessel of the smallest category.

5. Besides the technical characteristics of a vessel, quality requirements for fresh fish landed by this fleet limit the time at sea on a single trip. With the given oceanographic conditions on the fishing grounds, and with the technology of preserving fish on board presently in use on these trawlers, the hold capacity is utilized to a low degree. Boxing of fish, instead of bulking, could be considered as one way of extending the time at sea per trip, and thus a way of improving the productivity of a vessel.

Implications

In recent years (1966-1968) about 45 percent of the fleet analyzed in this study ceased operations in the haddock fishery on Georges Bank. This withdrawal affected all size groups, except for group D. The addition of two old, remodeled trawlers to the fleet cannot make up the enormous losses. The fleet as a whole is old and there is an urgent need for new replacements.

The study shows that some vessels in this fleet can be operated with reasonable returns to capital and labor. The statement applies chiefly to vessels of 230-300 gross tonnage, with engines of 700-900 horsepower and with 17 crewmen. This, however, should not imply that side trawlers with such characteristics are the optimal vessels for the haddock fishery.

The determination of an optimal vessel for Georges Bank groundfish fishery should be the subject of a separate design study, which would also take under consideration different fishing technology (stern ramp trawler, midwater trawl), and different methods of preservation of fish on board (e.g., boxing).

The study also shows that a new vessel of the types discussed here, and built without any construction subsidy, could not be operated efficiently enough to secure a rate of return which would be sufficiently attractive for new capital. Even vessels with the highest rate of return on investment (17 percent, group D) would return only about 6 percent of the invested capital, if they were built without a subsidy (higher initial costs and higher depreciation).

The level of the construction subsidy can be argued upon. Therefore, in order to support the government in undertaking decisions with respect to the subsidy program, the proposed design study for the optimal vessel should be supplemented with a study on the effects of various subsidy levels on the rate of return and on the average cost of product.

Appendix A

Settlement Sheet

Vessel _____

Gross Sale of Fish

Less: - Wharfage
Scales
Exchange Fee
Chief Engineer
Second Engineer
Mate
Sounding Machine
Watching
Radar
Fisherman's Welfare
Ice 1/
Lumpers

Total Deductions

Net Stock to be divided

Ship's 40 percent

Crew's 60 percent

Less Expenses

Fuel
Lubricating Oil and Rags
Ice 2/
Icing up
Groceries and Provisions
Cook's Per
Water
Lumpers

Total Expenses

Balance

Shares Per Man

1/ in three summer months.

2/ in remaining nine months.

Appendix B

OPERATING COSTS AND OWNER'S COSTS

Information on operating costs is based on data from settlement sheets. In order to minimize the effects of inflation, data for recent years 1964-1966 were generally employed in calculating the individual cost items. Costs were adjusted with the appropriate price indexes where data from longer periods were utilized.

The operating costs are presented in the following discussion in the order they appear on the settlement sheets (Appendix A).

Information on owner's costs was not available for all vessels. However, estimates were made from:

a) Income statements from certain corporations

b) Certificates of Condition, for 1963-1966 1/

1/ These certificates are required by law of all corporations registered in the State of Massachusetts.

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c) Data available from other studies

Operating Costs

A. Expenses shared by owner and crew:

Wharfage: Based on the quantity of fish landed after each trip. The present rate is $1 for each ton of fish landed at the Boston Fish pier.

Scalage: A fixed charge in the amount of $9 for each unloading, regardless of the quantity of fish handled.

Exchange fee: Charged in the amount equal to 1 percent of the gross sales value of the catch, for services rendered by the New England Fish Exchange (auction room, records of all transactions, records of vessel expenses).

Bonuses: Paid on a per trip basis to the following crew members:

chief engineer	$25.00
second engineer	$15.00
mate	$20.00

Sounding machine: The cost of sounding machine amounts to $2.25 per day at sea on most of the vessels. Slight deviations from this rate in some cases are of very small significance to the overall calculations. However, in order to make the daily rate applicable to the fleet's performance data[2/], it should be raised to $2.50.

2/ The days spent by a vessel at sea, as they are shown in table 6, include only one-half of each of the day of departure and the day of arrival; whereas for the purpose of rental charges, these days were counted as two whole days.

Radar: The rental figure for radar was $50 per trip until the end of March 1966. After that date no charges in this respect are made in the settlement sheets. Thus, it is now entirely an owner's expense.

Watchman cost: The cost of watching depends primarily on the number of days a vessel stays in port between two consecutive trips. The daily cost rate is about $7 on vessels of group A (150-199 gross tons), and about $10 on all other vessels.

For a given vessel, the number of trips made during a year and the number of days in port are inversely correlated. Thus, the costs of watching appear as a function of the annual number of trips which the vessel is able to complete under normal circumstances. To base the calculations of annual costs on this relationship is a much more convenient way than to apply the number of days in port which is not readily available. For trawlers of all groups, except for group A, the relationship between the cost of watching and the number of trips per year is of the form presented in Appendix figure 1.

Appendix figure 1 Regression of watchman costs per trip on annual number of trips

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Our interest for this regression is confined to that range of the independent variable which is reasonable for operation of this fleet.[3/] Thus the lower limit of the regression

3/ Over the time period analyzed in our study (1957-1966) the highest number of trips ever made by a trawler in a single year was 33.

line is about $20 because the trawlers stay in port at least 2 days between trips.

The form of relation as shown above does not hold for vessels of group A. For these the average watchman cost per trip over the last 5 years is relatively constant, showing little variation. Thus for this group the mean value of $25 should be used as the average watchman cost per trip.

Welfare and pension funds: Certain benefits are provided to hospitalized fishermen of the Boston offshore fleet under the "Boston Fishermen's Welfare Plan."[4/] The funds for this plan are

4/ For details see: Norton and Miller, op. cit., Appendix C, page 31.

supported by deductions of 1 percent of the gross sales.

Another deduction, in the amount of 0.5 percent of the gross sales is made to provide funds for the "Pension Plan." This plan was initiated in April 1966.

Ice: The quantity of ice used on each trip depends mainly on the quantity of fish caught during that trip. This quantity used is not necessarily the same as the quantity purchased for a given trip.

During 3 summer months (roughly from June through August) 5/ relatively more ice is used than during the remaining 9 months.

5/ For those trips the cost of ice is shared by the vessel owner and by the crew, while over the rest of the year the crew alone pays the bill.

The ratio of ice to fish is usually higher when fishing is poor; that is, when the crew anticipates a longer stay at sea.

A good approximation of the yearly cost of ice is obtained by applying the formula:

$$\text{Cost of ice} = .55\ Q\ c_I$$

The coefficient 0.55 reflects the average ratio of ice to fish,[6/] Q is tons of fish landed per year and c_I is price of ice (currently at $8.80 per ton).

6/ The calculation of this coefficient has been based on data for 544 trips. The coefficient is equal to 0.69 for summer months and 0.50 for the remaining 9 months. The summer months comprise about 28 percent of the annual number of trips. It has been assumed that these coefficients do not vary significantly from year to year.

A check of accuracy of this estimation formula showed that for all vessels which fished in 1966, the cost of ice predicted by the equation was within 5 percent of the actual cost.

Lumpers: The cost of lumper service (unloading fish from vessels) is primarily a function of the vessel's crew size and the quantity of fish landed from each trip. In 1965 and 1966, on vessels with 17 crewmen (groups C and D), a team of six lumpers was required. This number generally increases with the decreasing number of crewmen. There was, however, some variation in the number of lumpers employed on vessels with the same crew number (this applies to vessels with 13 and 15 crewmen).

The amount paid to the lumpers when unloading up to 50 tons of fish is $72, $96, and $150 for vessels with 17, 15, and 13 crewmen respectively. This amount increases proportionally for every additional 5 tons of fish unloaded over the initial base of 50 tons.

It is important to note that the method of sharing the lumper cost varies with the crew size of the vessels. For vessel with 17 crewmen, the entire lumper cost is a part of the crew expenses. On vessels with 15 crewmen, 25 percent of the lumper cost is deducted from the gross stock and the balance is charged to the crew expenses. For those vessels with 13 crewmen, 48 percent of the lumper cost is deducted from the gross stock, the remainder being a crew expense.

It would be inconvenient to calculate the annual lumpers cost by applying the appropriate cost rates to the various quantities of fish landed from each trip.[7] Instead the regression shown in

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7/ Compare the distribution of catch per trip (figure 7) and the seasonal variations (figure 10).

Appendix figure 2 may be used to estimate the annual lumpers cost

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Appendix figure 2 Regression of annual lumper costs on quantity of fish landed per trip

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for trawlers with 17 crewmen, and fishing over the whole year (from 26 to 33 trips). The linear correlation between the variables is significant.[8] This regression is valid within the range of

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8/ Some statistics for this regression, not shown in Appendix figure 2: $\bar{x} = 55.0$, $\bar{y} = 2520.54$, $r^2 = 0.96$, $t_b = 14.7$, $p < 0.001$, $S_E = \$84.67$, $38.32 < b < 52.28$ (95 percent confidence interval).

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the explanatory variable from 40 to 70 tons of fish per trip (annual averages).

Trawlers with smaller crews seldom unload more than 50 tons of fish from a single trip. Thus, the lowest cost rate is applicable in almost all cases. To estimate the annual cost, the following "rule of thumb" may be employed:

Group	Dollars per trip
A	150 (160 in 1966)
B	100 (115 in 1966)

B. Expenses covered by the crew:

Fuel cost: The regression of fuel cost per day at sea on h.p. of the main engine is shown in Appendix figure 3. The fuel

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Appendix figure 3 Regression of fuel cost per day at sea on h.p. of the main engine.

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costs are based on data for 9 years (1957-1965), adjusted to the 1966 level by employing an appropriate price index. For this regression $r^2 = .64$; the value of $t_b = 6.52$, $p < 0.001$; the standard error of estimate $S_E = \$10.74$ per day; and the confidence interval for the regression coefficient at 0.95 level is $b \pm 0.0313$.

A higher correlation was found between fuel cost and size of vessel expressed in gross tonnage than between fuel cost and horsepower. In this regression (Appendix figure 4) the second degree polynomial is found to fit the data.

Appendix figure 4 Regression of fuel cost per day at sea on gross tonnage

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The coefficient of determination r^2 is equal to 0.96 and the standard error of estimate S_E = \$3.80 per day. The range of gross tonnage in this regression is approximately 120 to 300.[9/]

9/ Observations for one vessel, with an exceptionally high ratio of hp/gross tonnage, have been excluded from computation of this regression.

A test of significance of departure from linear regression showed that the second degree term is significant in explaining the deviations from regression ($F = 13.16$, with (1, 17) degrees of freedom.)

Fuel cost in these regressions includes the cost of lubricating oil since in many cases the data for fuel and oil costs were combined.

Ice: Described in part A, Appendix B.

Icing up: According to the present labor-management agreement, the cost of icing up (loading the ice on the vessel) is $40 per trip, regardless of the size of the vessel and the quantity of ice purchased.

Groceries and provisions: The variation of costs per man per day among vessel groups for groceries,and provisions was not significant. Based on 1965 and 1966 data, the average cost per man per day for all vessel groups was about $4.20.

Cook's allowance: Is $15 per trip.

Cost of water: Since August 1966 has been $12 per trip, regardless of vessel size. For the purpose of this analysis, however, the cost of water has been included in the cost of groceries and provisions ($4.20 per man and per day).

Cost of lumpers: Has been described in part A.

Net crew share: Arrived at by deducting the expenses listed in part B from the crew's 60 percent share of net stock (see Appendix A), is than divided equally among the crewmen. In addition to his share, the captain is paid a bonus in the amount of 10 percent of the owner's share in net stock.

Depending on the time spent at sea, the abundance and availability of fish on the fishing grounds, and the price of fish landed, the net crew's share varies considerably from trip to trip. In the 3 years 1964-1966, the average percentage of the gross sales paid to the crew as net share, was:

Vessel group	Percent
A	39.4
B	36.4
C	39.6
D	42.8

These figures represent 3-year mean values for the given groups. The standard deviations of each vessel's annual means from these group means are: 1.88 percent, 2.37 percent, 1.51 percent, and 1.4 percent for the groups A, B, C, D, respectively.

"Brokers" are not included in the above calculations. 10/

10/ Contracts between the vessel owners and the Atlantic Fishermen's Union provide for a minimum guarantee of the net crew's share, which is: $13 for an officer, and $12 for a deckhand - per day at sea. When the individual net crew shares from a given trip are less than this minimum, the trip is delcared a "broker" and the difference is made up by the owner.

C. Mathematical calculation of gross revenue, ships share and crews share.

From the review of operating costs (part A and B above) it can be seen that for a given vessel the number of trips, the number of days at sea, and the quantity and value of catch are the only performance data required for calculation of costs. The data on average trip duration (table 6) may be used to express the number of trips in terms of days at sea. Furthermore, the amount of catch may be regarded as the product of days absent and catch rate per day absent. The value of catch is obtained from multiplication of the amount of catch by the average price of fish. It is assumed that:

1. The vessels are operated the whole year around, without any abnormal interruptions,
2. There is no "broker" trip, and
3. The average number of days absent per trip is equal to 9.1.[11/]

11/ This is the 3-year mean for the whole analyzed fleet, as shown in table 6. For a specific group of trawlers (size class) the respective value for days absent per trip could be applied as well.

Symbols used:

R	gross revenue
P	proceeds to share
C_j	joint expenses (deductions from gross revenue)
C_t	trip expenses (deductions from crew's share)
S_s	ship's share
S_{sn}	net ship's share
S_c	crew's share
S_{cn}	net crew's share
q	average catch rate, in tons/day at sea
d	number of days at sea, per year
p	average ex-vessel price of fish, in dollars/ton
c_I	average price of ice, in dollars per ton

The following relations may be set up:

$$R = qdp \tag{4}$$

$$P = R - C_j = qdp - C_j \tag{5}$$

$$S_s = 0.4\,(qdp - C_j), \text{ i.e., 40 percent of proceeds to share.} \tag{6}$$

$$S_{sn} = 0.36\,(qdp - C_j), \text{ after captain's bonus is paid.} \tag{7}$$

$$S_c = 0.6\,(qdp - C_j), \text{ i.e., 60 percent of proceeds to share.} \tag{8}$$

$$S_{cn} = 0.6\,(qdp - C_j) - C_t \tag{9}$$

C_j is the sum of the following cost items:

C_{j1}	wharfage
C_{j2}	exchange fee, welfare and pension funds
C_{j3}	rental of sounding machine
C_{j4}	ice during 3 summer months
C_{j5}	watchman
C_{j6}	scales, bonuses for engineers and mate
C_{j7}	lumpers on vessels with less than 17 crewmen

Under assumptions 1, 2, and 3, the C_j items may be expressed in terms of q, d, and p as follows:

$$C_{j1} = \text{(tons of fish landed) (\$1)}$$
$$= dq$$

$$C_{j2} = \text{2.5 percent of gross revenue}$$
$$= 0.025\ qdp$$

$$C_{j3} = \$2.50 \text{ per day at sea}$$
$$= 2.5\ d$$

$$C_{j4} = (\text{tons of ice in summer months}).\ c_I$$
$$= 0.69\ (0.28\ \frac{d}{9.1})\ (0.96\,dq.\ \frac{9.1}{d})\ c_I$$ 12/
$$= 0.185\,dq\ c_I$$

12/ In these calculations, $\frac{d}{9.1}$ is the annual number of trips, 0.69 is the ratio of ice to fish during summer months, 0.28 is the proportion of annual number of trips made in summer months, 0.96 is the average seasonal index of landings per trip for 3 summer months.

$$C_{j5} = \$25.00\ (\text{number of trips})$$
$$= 25\ \frac{d}{9.1}$$
$$= 2.75\ d \quad (\text{for vessels of group A})$$

or
$$C_{j5} = 1593.24 - 23.64\ (\text{trips per year})$$
$$= 1593.24 - 23.64\ \frac{d}{9.1}$$
$$= 1593.24 - 2.6d \quad (\text{for all other vessels})$$

$$C_{j6} = (9 + 25 + 15 + 20)\ \frac{d}{9.1}$$
$$= 7.58\ d$$

$$C_{j7} = 0.48\ (160\ \frac{d}{9.1})$$
$$= 8.44\ d \quad (\text{for vessels with 13 crewmen})$$

or
$$C_{j7} = 0.25\ (115\ \frac{d}{9.1})$$
$$= 3.16\ d \quad (\text{for vessels with 15 crewmen})$$

Thus, $C_j = C_{j1} + C_{j2} + C_{j3} + C_{j4} + C_{j5} + C_{j6} + C_{j7}$

$= 21.27d + 2.632\ dq + 0.025\ qdp$ (for vessels of group A)[13]

or $C_j = 1593 + 10.64d + 2.632dq + 0.025\ qdp$ (for vessels[13] of group B)

or $C_j = 1593 + 7.48d + 2.632\ dq + 0.025\ qdp$ (for vessels of[13] groups C and D)

13/ For these calculations the 1965-66 average price of ice (c_I) of $8.80 was used.

C_t is the sum of the following cost items:

C_{t1}	fuel and oil
C_{t2}	ice during the remaining 9 months
C_{t3}	icing up
C_{t4}	groceries and provisions, water
C_{t5}	cook's bonus
C_{t6}	lumpers

These cost items may be expressed in terms of d and q as follows:

$C_{t1} = vd$, where $v = f(T)$ is a function of gross tonnage T

$C_{t2} = 0.55\ dq\ (c_I) - 0.185\ dqc_I$

$= 0.365\ dqc_I$

$C_{t3} = (\$40)\ \frac{d}{9.1}$

$= 4.40\ d$

$C_{t4} = 13\ (4.20d) = 54.6d$ (13 crewmen)

or

$C_{t4} = 15\ (4.20d) = 63.0d$ (15 crewmen)

or

$C_{t4} = 17\ (4.20d) = 71.4d$ (17 crewmen)

$C_{t5} = (\$15)\ \frac{d}{9.1} = 1.65d$

$C_{t6} = 0.52\ (160\ \frac{d}{9.1}) = 9.14d$ (13 crewmen)

or

$C_{t6} = 0.75\ (115\ \frac{d}{9.1}) = 9.48d$ (15 crewmen)

or

$C_{t6} = 29 + 45.3\ (9.1q) = 29 + 412.23q$ (17 crewmen)

Thus, $C_t = C_{t1} + C_{t2} + C_{t3} + C_{t4} + C_{t5} + C_{t6}$

$= 69.79d + 3.208\ dq + vd$ (for vessels of group A) 14/

or $C_t = 78.53d + 3.208dq + vd$ (for vessels of group B) 14/

or $C_t = 29 + 77.45d + 412.23 + 3.208dq + vd$ (for vessels of groups C and D) 14/

14/ For these calculations the 1965-66 average price of ice (c_I) of \$8.80 was used.

Now the net ship's share and the net crew's share can be estimated:

From (7) we have:

$$S_{sn} = 0.36\ (qdp - C_j)$$

$$= 0.351qdp - 7.657d - 0.948dq$$
(for vessels of group A)

$$\text{or}\quad S_{sn} = 0.351qdp - 573 - 3.83d - 0.948dq$$
(for vessels of group B)

$$\text{or}\quad S_{sn} = 0.351qdp - 573 - 2.693d - 0.948dq$$
(for vessels of groups C and D)

From (9) we have:

$$S_{cn} = 0.6\ (qdp - C_j) - C_t$$

$$= 0.585qdp - 82.552d - 4.787dq - vd$$
(for vessels of group A)

$$\text{or}\quad S_{cn} = 0.585qdp - 956 - 84.914d - 4.787dq - vd$$
(for vessels of group B)

$$\text{or}\quad S_{cn} = 0.585qdp - 985 - 81.938d - 412.23q - 4.787dq - vd$$
(for vessels of groups C and D)

Owner's Costs

Vessel maintenance and repairs: These costs have been approximated by using the regression of annual repair costs on vessel capacity in the tuna fleet[15/]: $\hat{Y} = 26,011 \log X - 36,040$.

15/ Roger E. Green and Gordon C. Broadhead, op. cit.

Since the explanatory variable in this regression is tuna vessel capacity, it was necessary to convert this to gross tonnage. For this, the regression of vessel capacity on gross tonnage of the form: $Y = -0.89 + 0.75 X$ was employed.[16/]

16/ Shimada and Schaefer, op. cit.

To allow for the different equipment on the Boston large trawlers compared to tuna seiners (tuna vessels have refrigerated fish holds), and for the difference in prices between 1962 and 1966 a correction factor based on limited information available of 0.80 was applied to the calculated figures.

The estimated maintenance and repair costs for a vessel in each of the groups are:

In group A	$14,500
" " B	$17,500
" " C	$17,900
" " D	$19,300

Fishing gear: The cost of fishing gear is assumed to be proportional to the quantity of fish landed. For the years for which data were available, fishing gear costs ranged from $7.22 to $10.36 with a mean of $9.05 per ton of fish landed. The cost for 1966 alone is close to the upper limit of the range shown. Thus the amount of $10 per ton is assumed to be the best current approximation.

Insurance: Rates for hull and engine insurance of steel trawlers are in the range from 3.5 - 4.0 percent (vessels of 0-5 years of age) to 7.0 - 8.0 percent (vessels over 20 years of age), of their market value. Protection and indemnity insurance amounts to $400 per crewman, annually[17/].

17/ Frederick W. Bell, The Economics of the New England Fishing Industry: The Role of Technological Change and Government Aid. Research Report to the Federal Reserve Bank of Boston. No. 31. 1966

In the absence of information on the market value of all vessels the regression of annual insurance costs on vessel capacity for tuna purse seiners[18/] has been employed for estimation

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18/ R. E. Green and G. C. Broadhead, op. cit. The regression is of the form: $\hat{Y} = 34{,}198 \log X - 60{,}779$.

Insurance costs are:

Vessel of group A - $10,432

Vessel of group B - $15,426

Vessel of group C - $16,015

Vessel of group D - $18,331

They are well in line with actual cost data available and with values shown in other studies.[19/]

19/ Frederick W. Bell, op. cit.

Edward J. Lynch, Richard M. Doherty, George P. Draheim: The Groundfish Industries of New England and Canada. A Comparative Economic Analysis. United States Fish and Wildlife Service, Circular 121, Washington, D. C. July 1961.

Payroll taxes: This item covers social security and unemployment taxes, and was assumed to be 6 percent of total payments to crews (net crews share plus bonuses).

Management and office costs: For vessels with 17 crewmen these costs are based on actual outlays shown in available accountants' reports. For other vessels these costs have been approximated in proportion to the number of crewmen.

Depreciation: With the exception of three newer trawlers (1 - 5 years of age), all the older vessels which have not changed their owners are already depreciated to salvage value. At the end of the year 1966 their book values, as shown in the Certificates of Condition, range from $2,884 (average for vessels of group A) to $14,958 (average for vessels of group D). Various methods of depreciation are actually applied. For the purpose of this analysis the annual depreciation, as shown in Appendix table 1, has been calculated by applying a straight-line depreciation over 15 years to the replacement costs, assuming a 50 percent Government subsidy, and retaining a 15 percent salvage value.

Appendix table 1 -- Annual depreciation of trawlers, by vessel category

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Appendix table 1 -- Annual depreciation of trawlers, by vessel groups.

Vessel group	Average construction costs 1/	Net investment by owner	Depreciation
	- - - - - - - - - - - - - -	-dollars-	- - - - - - - - - - - - -
A	254,000	127,000	7,200
B	384,000	192,000	10,900
C	404,000	202,000	11,500
D	509,000	254,500	14,400

1/ Construction costs for each vessel were calculated from the regression: Construction costs = 485 (GRT) $^{1.23}$. Reference: A Systems Analysis of Specified Trawlers. A report prepared under contract by Marine Technology, Inc., a Division of Litton Industries, for the Marine Sciences Council, Executive Office of the President, October 1967.

Broker payments: The amount paid by owners to the crews for "broker" trips varies considerably from year to year and from vessel to vessel, irrespective of the vessel's size. To give an idea on the magnitude of these payments and their variability, the extreme values for one recent year are presented below:

	Broker payments in dollars:	
Vessel group	lowest vessel	highest vessel
A	201	10,775
B	3,245	4,225
C	420	6,441
D	0	4,768

The year to year changes for given vessels are presented below:

	Broker payments in dollars:	
Vessel	in 1964	in 1965
1	4,768	0
2	5,166	989
3	4,425	8,760
4	6,404	1,342

While there is no distinct pattern in the occurrence of broker trips and in the amounts paid, it can be stated that, in general, the higher powered vessels (group D) tend to experience fewer "broker" trips than other vessels. The following figures, give general approximations for broker payments by vessel size group (in dollars per year).

Vessel category	Amount
A	$4,000
B	3,800
C	3,800
D	1,200

The owner's costs are summarized in Appendix table 2.

Appendix table 2 -- Average annual owner's costs, by vessel groups

Appendix table 2 -- Average annual owner's costs, by vessel group

Cost item	Vessel Group A	B	C	D
	- - - - - - - dollars - - - - - - -			
Vessel maintenance and repairs	14,500	17,500	17,900	19,300
Fishing gear	9,310	9,660	12,530	18,000
Insurance	10,432	15,426	16,015	18,331
Payroll taxes	4,983	4,652	6,697	11,152
Management	3,874	4,470	5,076	5,076
Office and other expenses	3,445	3,975	4,510	4,510
Depreciation	7,200	10,900	11,500	14,400
Broker payments	4,000	3,800	3,800	1,200
Total	57,744	70,383	78,028	91,969

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(continued from inside front cover)

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