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PRODUCTIVITY GAINS IN U.S. FISHERIES

by

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INTRODUCTION

The growth in productivity or annual landings per fisherman is an important determinant of the economic welfare for the U.S. fishing industry.[1] Small or negative productivity gains in a fishery are often associated with lagging profits, wages, and employment because U.S. fishermen must compete with foreign fishery imports and other protein substitutes where productivity is a main ingredient of competitive advantage. Moreover, rising productivity in the fishery sector has helped reduce inflationary tendencies that have been most prevalent in meat and fish products. Productivity gains, in the long run, raise standards of living or reduce the amount of time we must work to produce a pound of fish or a television set or an automobile.

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[1] Productivity is usually measured in terms of output per man-hour. These data are not available for the U.S. fishing industry; we must therefore rely on annual landings per fisherman as a rough measure.

Generally, gains in productivity are determined by the increasing efficiency of our vessels and gear; the education, training, experience, and morale of our fishermen; and, of course, the condition of the fishery stock and other environmental factors.

This article will survey the gains in productivity experienced by various U.S. fishing fleets over the last two decades. Comparisons will be made between gains in fishing productivity and that in competing sectors. We shall also explore some of the reasons behind the gains in productivity for selected fisheries.

LABOR PRODUCTIVITY TRENDS IN SELECTED U.S. FISHERIES

Before we discuss productivity trends in selected U.S. fisheries, it will be instructive to look at the statistical definition of labor productivity that will be employed in this article. Productivity or annual landings per fisherman is obtained by dividing aggregate landings (for a year) by the number of fishermen employed.[2] For any particular

[2]As economists define it, productivity is simply a ratio of physical output to physical input. Higher productivity means getting more output with the same effort or the same output with less effort. "Total-factor productivity" can be calculated by dividing

fishery, the accuracy of data on aggregate annual landings is fairly reliable. However, the number of fishermen reported by the National Marine Fisheries Service is not adjusted for the extent of utilization during the year. For example, the U.S. Bureau of Labor Statistics collects detailed data on hours worked for most industries in the economy. This makes it possible to compute productivity on the output per man-hour basis. No universally comparable data are available on the fishing industry. Hence, our statistical base is something less than perfect. Systematic variations in days and hours worked per year may be a biasing factor, but it is hoped that they are random. In addition, the reader should note

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output by a figure that represents all the resources used including plant and equipment, labor, and land. Theoretically, this is the true measure of efficiency, but statisticians have trouble constructing the index number that serves as the divisor. They have to combine unlike quantities--hours or work and units of capital investment--into a single index. And while statisticians never hesitate to add apples to oranges, the results are questionable. Economists, therefore, usually work with a simpler concept, "partial productivity." This is the ratio of physical output to a single input, usually labor. In most discussions, "productivity" means "labor productivity" or real output per hour, day, or year of work. It is a rough measure of the effectiveness with which we use our most important productive resource labor.

that we are comparing rates of growth in productivity among fisheries and other industries and not absolute differences in productivity.

Table 1 shows the compound annual growth rate of labor productivity for 17 of the nation's major fisheries over the 1950-69 period.[3] Notice that the Gulf of Mexico blue crab, Atlantic clam, and Gulf of Mexico menhaden fisheries all had rates of productivity advance over 5 percent. Unfortunately, some of our largest fisheries such as Gulf of Mexico shrimp, Atlantic sea scallop, Atlantic and Gulf of Mexico oysters, and Alaskan salmon exhibited negative trends in productivity.

One interesting aspect of the growth in labor productivity is its year to year fluctuation. This is important for a variety of reasons. Many fishermen are paid according to the "lay" agreement where fishermen and vessel owners share the value of the catch on some predetermined basis. Shortrun oscillations in labor productivity may contribute to an unstable

[3]The growth rate in labor productivity was computed by fitting a logarithmic function (i.e., fitting a linear time trend to the logarithm of output per fishermen). The 17 fisheries represent 68, 71, and 58 percent by landings, value, and employment, respectively, for the U.S.

Table 1.--Ranking of fisheries by the rate of growth in output per fisherman, 1950-69

Fishery		Rate of growth[1]
1.	Gulf of Mexico blue crab pot fishery	+7.8*
2.	North-Middle Atlantic and Chesapeake Bay dredge clam fishery	+7.0*
3.	Gulf of Mexico menhaden	+6.8*
4.	Pacific yellowfin-skipjack tuna	+4.5*
5.	Pacific halibut[2]	+3.8*
6.	North Pacific groundfish	+3.1*
7.	Atlantic menhaden	+2.4*
8.	Atlantic blue crab pot fishery	+1.3*
9.	Pacific albacore tuna	+0.8
10.	Atlantic shrimp	+0.7
11.	North Atlantic groundfish	+0.5
12.	Pacific (excluding Alaska) dungeness crab	-0.4
13.	Inshore northern lobster	-0.5
14.	Gulf of Mexico shrimp	-1.3*
15.	Atlantic sea scallop (subarea 5Z)	-1.5
16.	Atlantic and Gulf of Mexico oyster	-2.0*
17.	Alaska salmon	-3.1*

[1] Linear least squares trends of the logarithms of output per fisherman.

[2] Output per fisherman day.

* Trend was statistically significant at the 5 percent level.

earnings pattern.[4] Other industries have fixed wage aggrements that depend on secular rather than _short-run_ changes in productivity. To get some idea of which fisheries are more subject to oscillations in labor productivity, we constructed an index of instability which measures the percentage fluctuations around the longrun time trend in annual landings per fisherman.[5] Table 2 shows the 17 fisheries discussed earlier ranked according to cyclical instability in labor productivity. Using the most unstable as a base (i.e., Gulf of Mexico blue crab pot fishery) we see that 13 of the fisheries are less than one-half the instability of the base fishery.

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[4]Generally, a contraction in landings--due to a decline in productivity--will reduce income per fisherman in prices do not change appreciably. Prices may not increase if foreign imports are significant and/or price elasticity is large (i.e., a large percentage drop in landings results in a small percentage increase in price).

[5]The formula used to construct the index was

$$CV_y = \frac{\sum_{i=1}^{N} \left| 1 - \frac{Y_c}{Y_o} \right|}{N}$$

where CV_y = cyclical variation in labor productivity; Y_o = observed labor productivity; Y_c = computed labor productivity from the time trend; and N = number of years.

Table 2.--Ranking of fisheries by the cyclical variation in output per fisherman, 1950-69

Fishery	Cyclical variation in labor productivity	Percent of largest
1. Gulf of Mexico blue crab pot fishery	0.448	100.0
2. Atlantic sea scallop (subarea 5Z)	0.298	66.5
3. Pacific (excluding Alaska) dungeness crab	0.242	54.0
4. Pacific albacore tuna	0.234	52.2
5. Gulf of Mexico menhaden	0.204	45.5
6. Atlantic shrimp	0.188	42.0
7. Atlantic menhaden	0.157	35.0
8. North-Middle Atlantic and Chesapeake Bay dredge clam fishery	0.148	33.0
9. Alaska salmon	0.147	32.8
10. Atlantic blue crab pot fishery	0.104	23.2
11. Pacific yellowfin-skipjack tuna	0.104	23.2
12. North Pacific groundfish	0.100	22.3
13. Gulf of Mexico shrimp	0.095	21.2
14. Pacific halibut	0.093	20.8
15. North Atlantic groundfish	0.082	18.3
16. Atlantic and Gulf of Mexico oyster	0.081	18.1
17. Inshore northern lobster	0.055	12.3

Although the performance of individual fisheries is important, we do want some summary measure to tell us how the entire fishery sector is doing with respect to the rate of growth in labor productivity. If so, we can compare this summary measure to other important sectors in the U.S. economy. Fortunately, we can construct an aggregate index of labor productivity. The construction of this index is rather technical in nature and will not be discussed in detail here.[6] Suffice it to say we cannot add the total pounds of fish landed in the U.S. and divide by the number of fishermen employed when constructing an aggregate index over a period of time. This is true since there may be appreciable shifts in the production of various species with differing absolute productivity, thereby biasing the index. The constructed index controls product mix.

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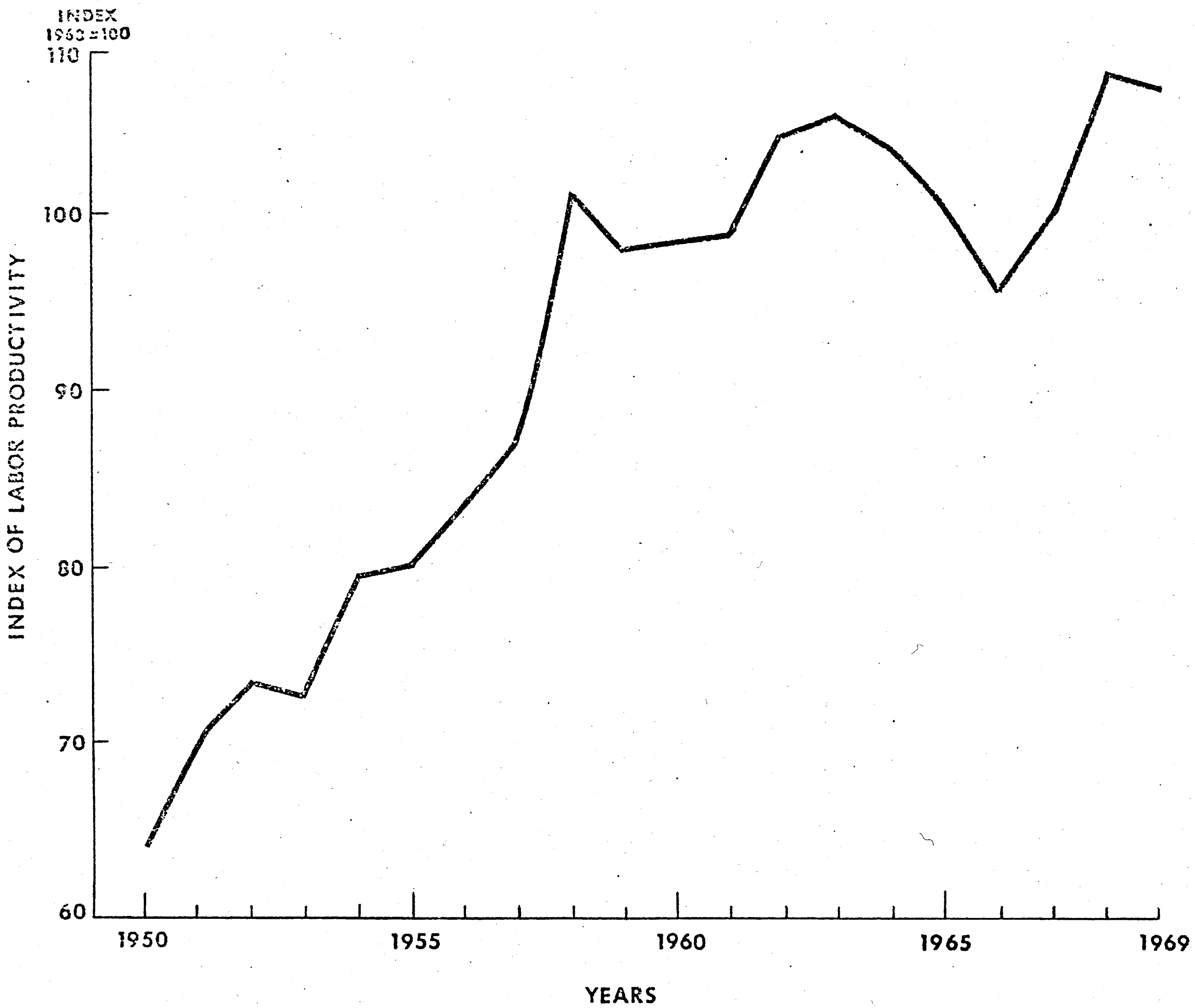
[6] See "Output Per Man-Hour Measures: Industries," (Bureau of Labor Statistics, 1966). Because of the problems with our data, it should be said that it was implicitly assumed that the work year is approximately the same for each fishery; a biasing factor may be introduced in the index to account for errors as a result of this assumption. However, as long as the difference in work years remains constant from fishery to fishery, this factor should not appreciably influence the time trend in the productivity index.

Constructing an index based on the 17 fisheries shown in table 1, we find that aggregate productivity grew at an annual rate of 0.7 percent. To obtain a more representative figure for all fisheries, we added an 18th fishery which represents the group of remaining U.S. fisheries not included in the original 17. The aggregate index showed productivity growth at an annual rate of 2.5 percent over the 1950-69 period. However, there seems to be a noticeable tendency for the growth rate of fishermen's productivity to decline over the observed period; i.e., the annual growth rate over 1950-59 was 4.7, but it slacked to 0.5 in the last 10 years. This was probably a result of increasing fishing pressure in established fisheries (see section below on factors behind productivity advances). This index is plotted in figure 1. On the average, the American fisherman has been able to raise his productivity significantly over the last 19 years. This is especially encouraging when we realize that the fishermen, as opposed to their conterparts in manufacturing and service industries, must exploit a resource which has a fixed biological maximum that has a tendency to depress labor productivity (see discussion below).

Figure 1.--Index of labor productivity for the fishing sector, 1950-69



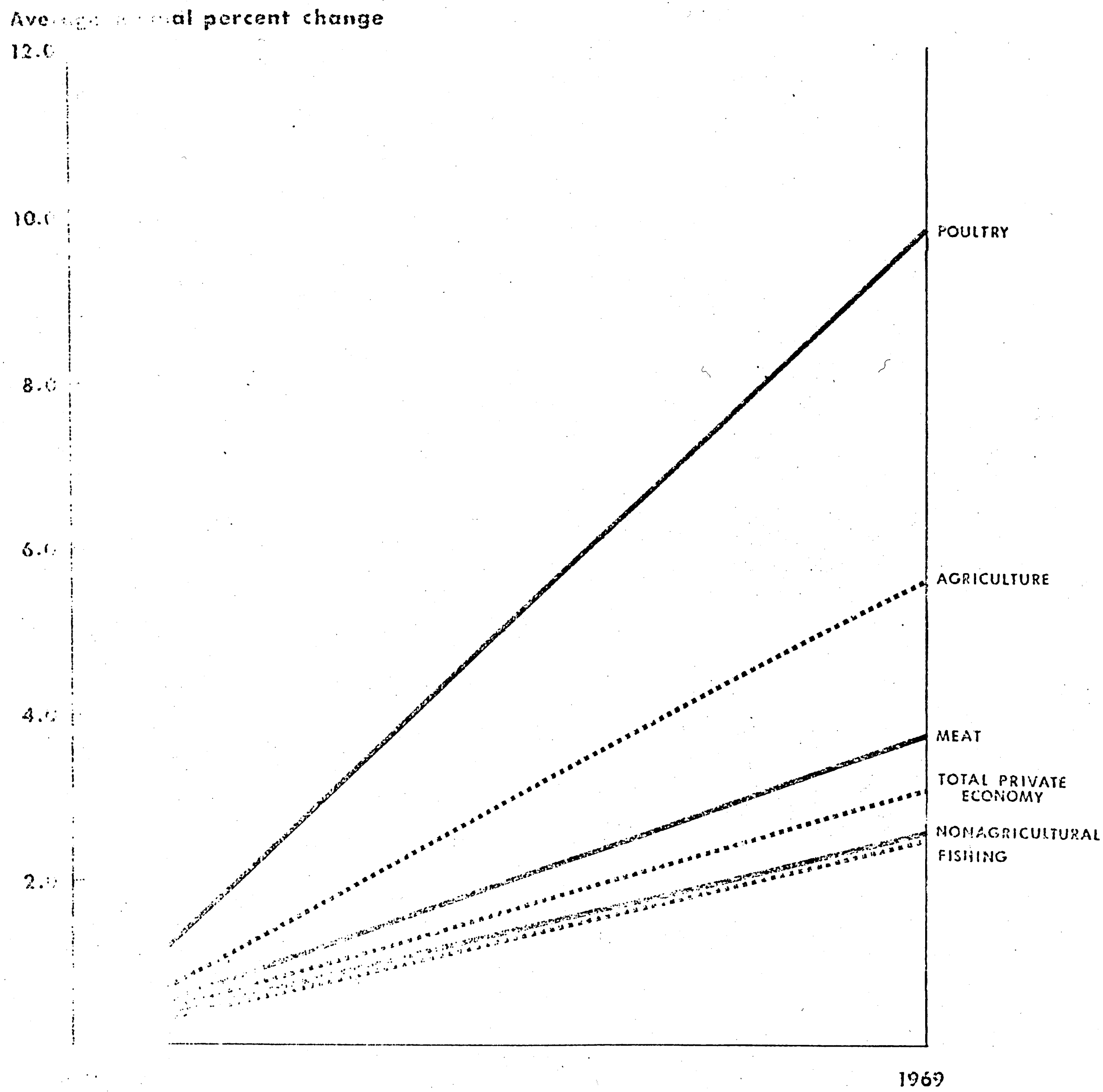
Note: Productivity index is based upon 17 individual fisheries and 18th residual category.

COMPARISON OF PRODUCTIVITY IN FISHING WITH OTHER SECTORS OF THE ECONOMY

Figure 2 shows a comparison of the growth in labor productivity over the 1950-69 period in the total economy, all agriculture, meat, poultry, nonagriculture, and fishing.[7] The rate of growth in fishing was less than that for the U.S. economy as a whole. However, the rate growth of labor productivity in agriculture was nearly twice that of the entire economy. Of special significance, productivity in fishing lagged considerably behind that in the poultry industry and over one percentage point (per annum) in the meat industry. Since labor productivity is a prime ingredient in relative price changes, it may be concluded that these trends were generally adverse to the fishing industry. That is, the more rapid advance in agriculture (including meat and pountry) lowered the price ratio of agricultural to fishery products. For example, the annual rate of growth (1950-69) in the wholesale price index of processed finfish was 3.9 percent while the wholesale price index for processed foods and feeds was 0.9 percent, partially reflecting the differential

[7]The aggregate productivity index based upon 18 fisheries will be used throughout the remainder of this article. Furthermore, we are comparing annual productivity in other sectors (as opposed to output per man-hour) with that in U.S. fisheries.

Figure 2.--A comparison of the rates of growth in labor productivity for the total economy, agriculture, meat, poultry, non-agriculture and fishing industries, 1950-69



: U.S. Dept. of Labor, Bureau of Labor Statistics; U.S. Dept. of Agriculture, Agricultural Statistics; and Economic Research Laboratory.

gains in productivity. The consumer may then substitute the less expensive agricultural products for fishery products, and the share of the total food markets will decline for fish. This is reflected in the data that show a 0.8 and 3.6 percent increase in per capita consumption of meat and pountry, respectively, while the per capita consumption of fish remained constant over the 1960-69 period.

Data are not readily available on fishing labor productivity in other countries. For illustrative purposes, however, we do have some information for the groundfish, menhaden, and lobsters as shown in table 3. For this limited sample, it is quite apparent that U.S. fishermen are not holding their own with their foreign counterparts in menhaden and groundfish. More research is needed in this area.

FACTORS BEHIND THE GROWTH IN LABOR PRODUCTIVITY IN FISHING

Why has labor productivity increased at a lower rate in fisheries than in competing sectors such as meat and poultry? Has it been because fishermen are technologically backward or are not working harder?

Table 3.--Comparisons of the growth rate in labor productivity for selected fisheries and countries

Fishery	U.S.	Other country	Period[1]
Menhaden (Atlantic and Gulf of Mexico)	-0.4	+2.8[2]	1960-68
Northeast Groundfish	-1.9	+4.0[3]	1959-69
Inshore American Lobsters	-0.3	-3.8[4]	1959-69

[1]Periods are different than shown in Table 1 because of lack of data in foreign countries for earlier periods.

[2]Peruvian anchoveta

[3]Canada

[4]Canada

To answer these questions, we have selected three fisheries for examination. As indicated in the "Introduction," there are many factors that influence the trends in the productivity of fishermen. Probably, there are two important opposing forces. First, fishermen attempt to improve their technology, training, and experience so that their capability to catch fish will be enhanced. This tends to raise productivity. Second, the fishermen unlike their counterparts in agriculture are characterized by finite limitations to production. The buildup of aggregate fishing effort (i.e., vessels, gear and fishermen) tends to lower the productivity (catch per unit of effort) of those fishing the resource because more people share a fixed pie. This is a paradoxical result in that improvements in technology increase gear efficiency but also increase effective fishing effort, which in turn depresses the catch per unit of effort. Unless the level of effective fishing effort is controlled (e.g., through limited entry), the fisherman will remain on a constant treadmill attempting to balance changes in technology against the finite productivity of the resource. This is why fishery management is so important. In addition there are other factors that influence labor productivity in the fisheries such as changes in the environment and institutional changes (e.g., gear regulations).

In an attempt to quantify the influence of these important factors on labor productivity, for each fishery we computed the statistical relation between annual landings per fisherman and the following factors:

1. Aggregate fishing effort
2. Fishing effort per fisherman
3. Secular time trend
4. Environmental factors
5. Institutional or regulatory changes

It is hypothesized that increases in aggregate fishing will depress productivity; increases in fishing effort per worker (e. g., traps fished per fisherman, standard days fished per fisherman, or other gear used per fisherman) will increase productivity; a secular time trend represents all other factors such as changes in technology that may raise productivity; environmental change may either raise or lower productivity depending on individual factors;

and regulatory changes will hopefully raise productivity.

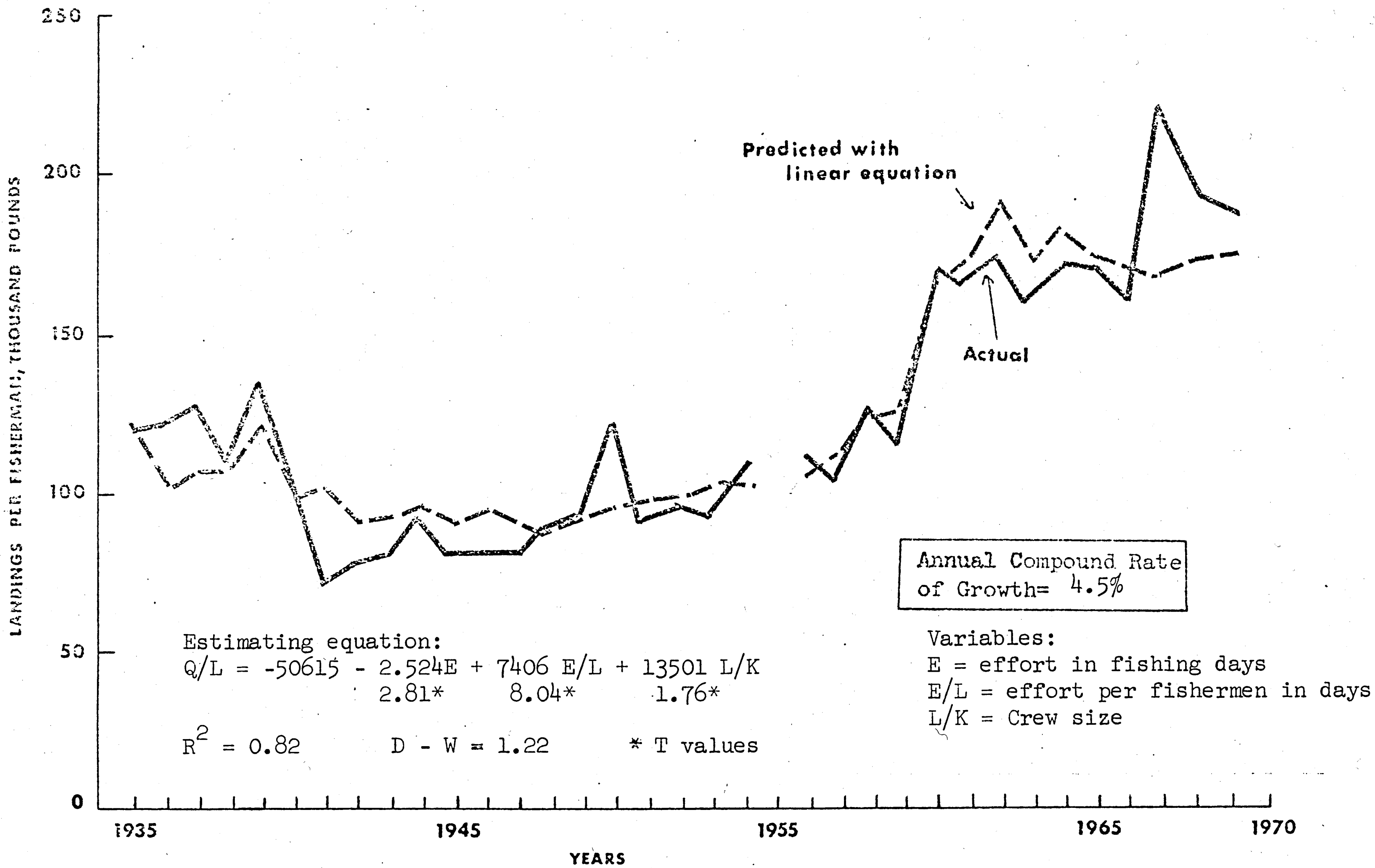
<u>Eastern tropical Pacific yellowfin and skipjack tuna:</u> The fishery for tropical tunas in the eastern Pacific Ocean developed shortly after the turn of the century. The degree of exploitation increased steadily as the United States fleet, which lands the major portion of the catch, grew, and as the fleets of Latin America and Japan developed. Prior to 1959, the catch of yellowfin and skipjack tunas from the eastern tropical Pacific Ocean was taken by bait fishing vessels that use live bait and pole. After 1959, many fishermen converted their bait vessels to purse seiners which have subsequently proved to be more efficient fishing vessels. Over the 1935-67 period annual landings per tuna fisherman showed an upward time trend, growing at a rate of 2.0 percent per year.[8]

[8] Catch quotas on yellowfin tuna were not a factor in productivity until 1969. The fishermen employed a series which was estimated by Bruno Noetzel of the Economic Research Laboratory with the help of material published in various years of the Annual Report of the Inter-American Tropical Tuna Commission.

To analyze the growth in labor productivity in the eastern tropical Pacific tuna fishery, we specified the following explanatory variables: fishing effort, or the aggregate number of standard fishing days; fishing effort per worker (i.e., standard units of fishing effort expended per worker); secular trend variables; crew size; a variable to reflect any residual increase in labor productivity because of the switch from bait fishing to purse seining. As expected, the statistical analysis revealed that the buildup in fishing effort displayed a negative impact on labor productivity; fishing effort per worker exhibited a positive influence on labor productivity; and the other factors were not statistically important. The Inter-American Tropical Tuna Commission apparently did a good job in adjusting their effort series for the switch in technology over the 1960-67 period. Therefore, it must be concluded that the switch in technology is primarily reflected in the effort per worker variable. A look at the effort per worker series reveals that it increased from approximately 13 to 20 standard units of effort per worker from 1959 to 1960. Prior to 1959, the standard unit of fishing effort per worker increased gradually due presumably to more efficient use of labor in searching and catching tuna. Although fishing effort increased appreciably over the period, its negative effect was greatly offset by increases in effort per fisherman resulting in an annual growth rate of 2.0 over 1935-69. The actual and computed (using a statistical equation) yellowfin landings per fisherman are shown in figure 3.

Pacific halibut: Early commercial fishing for Pacific halibut is considered to have commenced in 1888 when three sailing vessels from the New England States started to fish Cape Flattery on the northwest coast of Washington Territory. The rapid development of the Pacific halibut fishery did not occur until the 1920's. Initially, the fishery for the larger vessels was conducted over 12 months of the year. Because of the possibility of overfishing, the season was legally restricted by a three-month winter closure in 1924. Since then the season has been regulated by the International Pacific Halibut Commission (IPHC). The fishery is presently carried on by a mixture of Canadian and U.S. longline vessels.

Figure 3.--Observed and predicted labor productivity (annual landings per fisherman) for the Eastern Tropical Pacific tuna fishery, 1935-54 and 1956-69



Source: Inter-American Tropical Tuna Commission

Unlike other fisheries, an analysis of changes in labor productivity is complicated by institutional factors as well as economic and biological forces. Considering the entire fishery (areas 2 and 3), it is hypothesized that annual labor productivity is heavily influenced by the following factors: (1) the length of the fishing season, (2) aggregate fishing effort, (3) fishing effort per worker, (4) crew size on halibut vessels, and (5) secular time trend. In the Pacific halibut fishery, we used average landings per man-day at sea as a measure of labor productivity.[9] Over the 1927-66 period, landings per fisherman-day increased by 3.0 percent a year. The use of landings per fisherman-day eliminates the influence of shorter seasons due to regulations. According to the IPHC, an adjustment has already been made to the effort series to include improvement in technology. Therefore, the time trend will reflect any residual influence of secular improvement in labor productivity not specifically measured as part of the effort series. In addition, since

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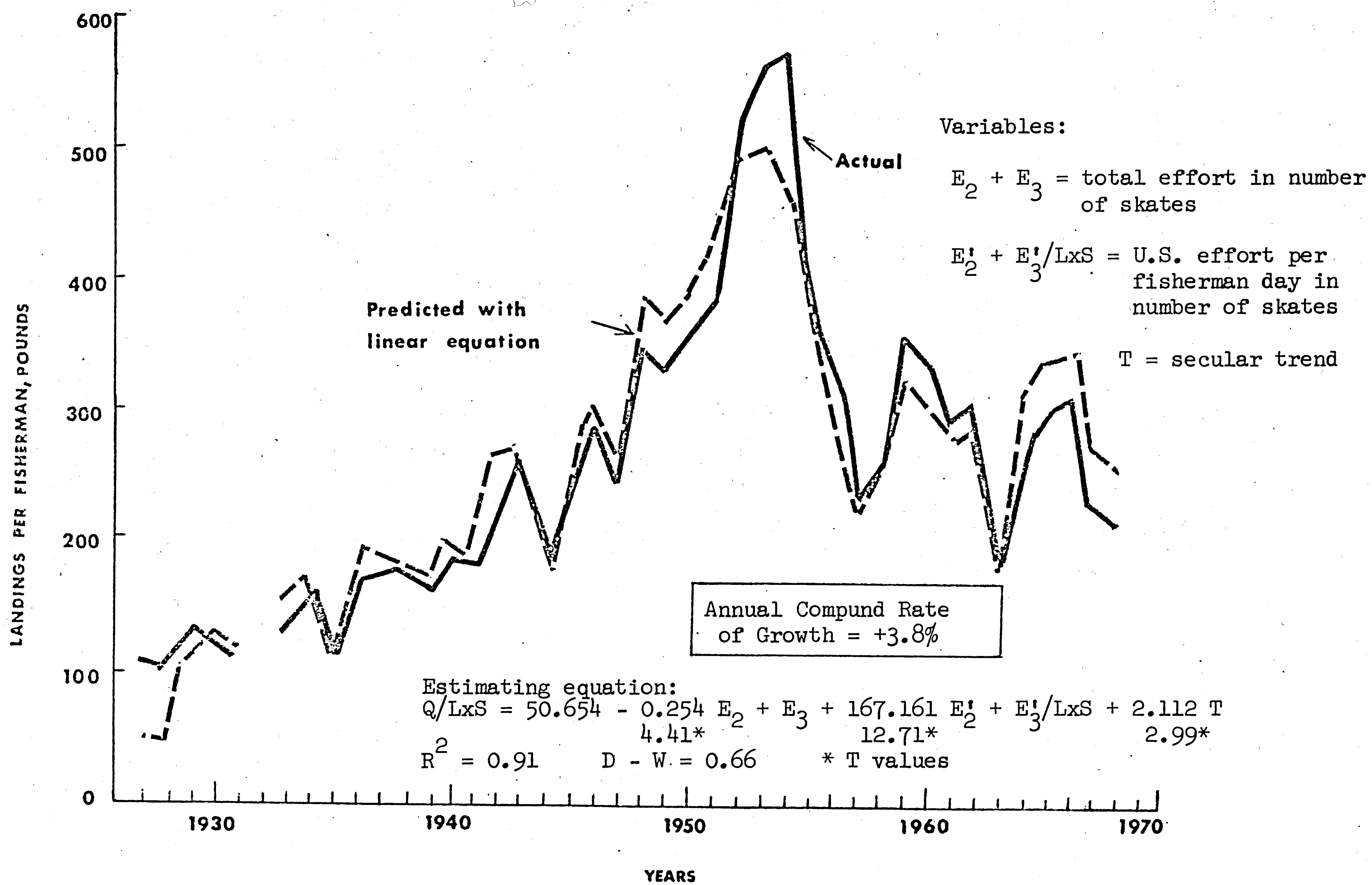
[9] This variable was formed by dividing the actual annual halibut catch by an estimate of the number of man-days expended in producing that catch. The estimate was derived by multiplying the halibut employment by the average number of days in a halibut season per annum.

the skates series[10] is really a skates per day series, we can create a fishing effort per worker series. This would measure the amount of fishing effort exerted per worker and should hava a positive influence on labor productivity holding other factors constant. The statistical results reveal that both fishing effort and gear used per worker are statistically important determinants of productivity and exhibit the hypothesized sign. Crew size and the time trend were not statistically important. Figure 4 shows the actual and computed annual landings per fisherman-day in the Pacific halibut fishery.

The inshore American lobster fishery: The inshore American lobster fishery in largely based upon fishing with wooden traps or pots; most lobsters are caught off the coast of Maine. Based upon previous studies

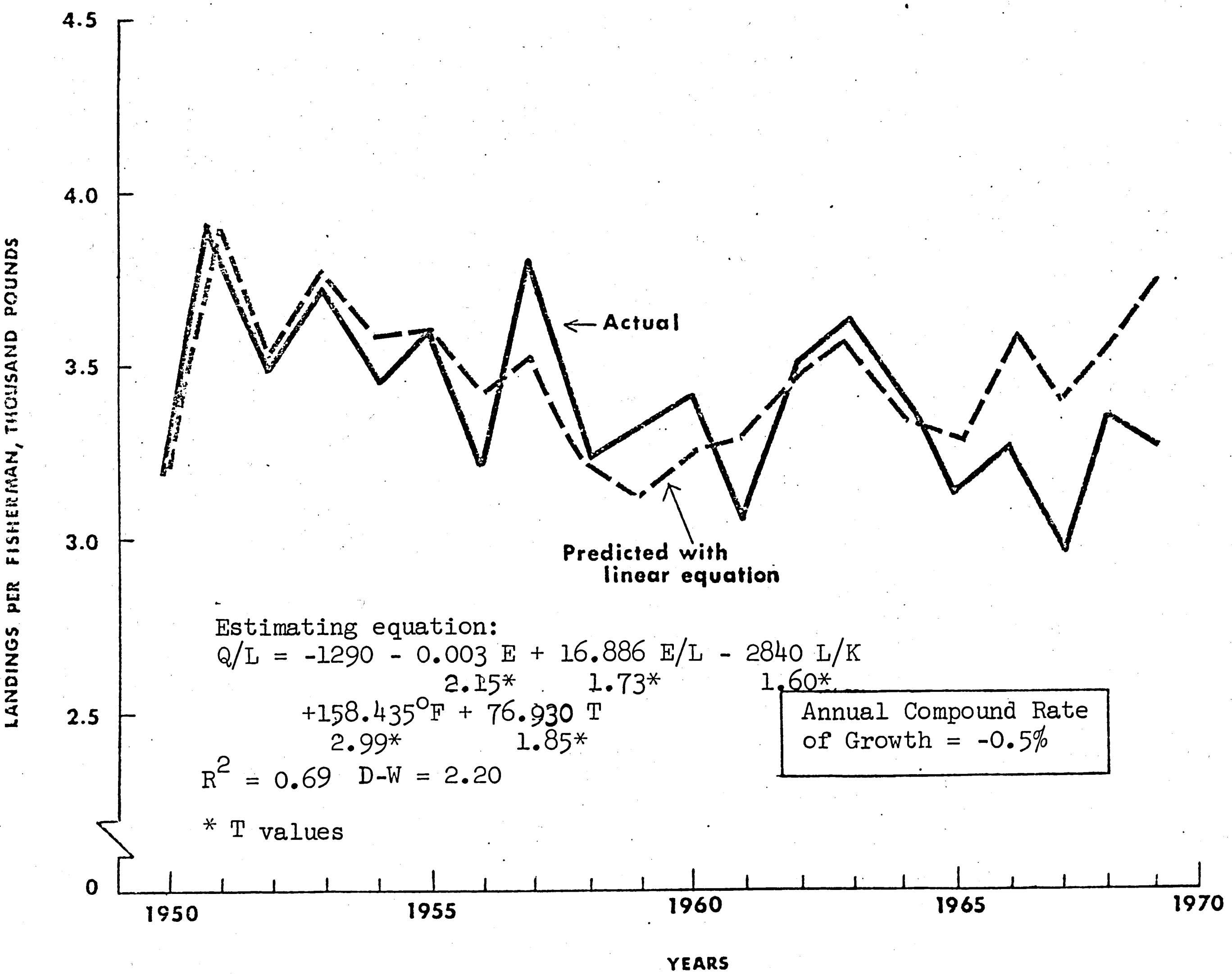
[10] In Pacific halibut fishing pressure is measured in terms of a skate of setline gear. "The groundline in a skate of gear is usually 250 to 300 fathoms long. Short lines called gangions are attached to the groundline at regular intervals and each gangion carries a hook." (Skud, 1972, p. 5)

Figure 4.--Observed and predicted labor productivity (landings per fisherman day) for the Pacific halibut fishery, 1927-31 and 1933-68



Source: International Pacific Halibut Commission such as that done by Dow (1961), it was hypothesized that changes in lobster productivity are due to the following factors: total number of traps fished per annum; traps fished per fisherman; crew size, mean annual seawater temperature, Boothbay Harbor, Maine; and secular time trend. According to our statistical analysis, the secular decline in sea-water temperature and increase in aggregate fishing effort produced a decided negative effect on labor productivity. The computed and actual labor productivities are shown in figure 5. Holding all other factors constant, the increase in fishing effort and secular decline in seawater temperature lowered annual landings per fisherman. However, increases in fishing effort per fisherman and the secular trend offset the negative factors, thereby producing a negligible downward trend in lobsterman productivity. In conclusion, despite drastic changes in fishing effort and seawater temperature in the inshore American lobster fishery, labor productivity did not change appreciably over the 1950-66 period.

Figure 5.--Observed and predicted labor productivity (annual landings per fisherman) for the American inshore lobster fishery, 1950-69



Variables:
E = number of trips fished
E/L = traps fished per fisherman
L/K = crew size
°F = seawater temperature
T = secular trend

Source: Fishery Statistics of the United States

MAJOR FINDINGS

1. Of the 17 fisheries studied, 11 exhibited positive time trends in output (landings) per fisherman. Based upon available data, therefore, it is quite apparent that many sectors of the fishing industry experienced substantial increases in labor productivity over the 1950-69 period. Also, the annual fluctuation of labor productivity varied significantly among the fisheries from the Gulf of Mexico blue crab to the North Atlantic groundfish fisheries.

2. The construction of a productivity index for all fisheries indicated that, for U.S. fisheries as a whole, labor productivity increased by approximately 2.5 percent per year over 1950-69. The growth rate slackened, however, in recent periods.

3. Of great importance, labor productivity in the U.S. fishing sector grew at a lower rate (i.e., 2.5 percent) than the entire U.S. economy. However, it was significantly below levels of labor productivity advances in poultry (9.8 percent) and meat (3.8 percent), which are fish's chief competitors for the consumer's protein dollar. Preliminary international comparisons revealed that U.S. advances have not been keeping pace with labor productivity advances in other countries for the groundfish and menhaden fisheries.

4. In our detailed study of three selected fisheries, it was generally found that two forces were at work: (a) increasing pressure on the resource base and (b) attempts to increase the fishing effort per worker. We were successful in isolating the quantitative effect of each factor. Generally, it was found that increases in fishing effort per worker offset the negative impact of rising aggregate fishing effort on the resource, thereby producing a rise in output per fisherman over the period of analysis. We were also quite successful in identifying the quantitative impact of such other productivity determinants as environmental, technological, and regulatory factors. The productivity function developed to explain changes in output per fisherman were quite successful in explaining the trend in the actual data.

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