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WITHDR...
ANNUAL SHELF

FISH CYCLES: a harmonic analysis

by

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FISH CYCLES: a harmonic analysis

by

Frederick V. Waugh
and
Morton M. Miller

Landings and prices of many species of fish follow fairly regular cycles. The most apparent are the 12-month or seasonal cycles, induced generally by a combination of natural factors, for example, weather and spawning cycles. There are also indications of longer cycles, although their causes are somewhat more obscure. Nonetheless, both the seasonal and the longer cycles can be measured with some precision with the use of harmonic analysis, which is especially suited to the study of rhythms and repetitions (whether in music or economics).

Cycles are, or should be, the concern of all connected with our fisheries--from the fishermen to the conservationist planner.

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As the pressures on our fishery resources mount, the need for rational management becomes more apparent. A good manager, among other things, must be able to anticipate cyclical changes. For this purpose, he can use harmonic analysis. It is an especially useful tool for confirming the existence of a cyclical pattern and determining the duration and amplitude of the cycle, or cycles.

Back in the 1920's and the 1930's, cycles received a great deal of attention from economists and statisticians. Agricultural economists found evidence of cycles in hogs and cattle. Henry L. Moore [7] believed that cosmic rhythms in the universe resulted in agricultural cycles on earth, which, in turn, caused cycles in business. Economic literature of the period, in fact, abounded with references to cycles.

Harmonic analysis was a favored method with many of the early workers in cyclical analysis. Some of the earliest (and best) textbooks on econometric methods [4, pp. 338-376; 9, pp. 216-238] explained the principles and the mechanics of harmonic analysis, and discussed its use in measuring economic cycles.

Nowadays, however, economic literature hardly mentions cycles, and harmonic analysis seems almost forgotten. Probably, this is mainly because the business cycle seems to have almost disappeared. Even agricultural cycles seem to have flattened out somewhat, although this is not the case with pronounced cycles exhibited in the landings and prices of many species of fish.

Effective management of fishery cycles may prove more formidable a task than efforts to control the business cycle, or to reduce agricultural fluctuations. The ocean is a resource common to all countries, and to manage its use requires the cooperation of divers political and economic interests. There are some current attempts at limited management of fisheries. For example, we are cooperating with other countries to regulate the catch of halibut and tuna in the eastern Pacific. A degree of international cooperation has also been achieved in the Atlantic fisheries. Thus, ongoing as well as future management schemes can benefit from more precise knowledge of cycles.

We summarize in this paper the statistical results of using harmonic analysis in the investigation of landings and price cycles for three species: market cod and large haddock that are landed at the Boston Fish Pier; and blackback (or lemon sole), landed at New Bedford, Massachusetts. We have computed similar results for several other species, but these three will illustrate the method. The same kind of analysis can be applied to other fisheries or to other industries (for example, to livestock).

These analyses cover only the seven years, 1962 through 1968. We chose this period because we had good monthly data on landings and prices of several New England species. Our initial interest was to measure seasonality (that is, 12-month cycles). But our analyses of the above three species suggested also a cycle of about five or six years, although a longer period would be needed to establish such a cycle. For that reason, we also present an analysis of the annual total catch of all food fish over the 42 year period, 1926 through 1967.

Market Cod at the Boston Fish Pier[1]

Cod has had a prominent place in the history of North America, since John Cabot, the 15th century New World explorer, reported that, "The sea is swarming with fish." Among the earliest colonizers of New England were fishermen seeking a climate more suitable for drying cod than that of Newfoundland. Nowadays, we import large quantities of frozen "blocks" of cod from Canada, and cod is no longer the mainstay of New England's commercial fisheries. But the species still ranks high at the important Boston Fish Pier, where cod landings in 1968 made up over 25 percent of the total landings of all fish.

Cod landings are marketed chiefly in two sizes: market cod, that weigh from 2½ to 10 pounds (and generally contribute about

[1] Those who want a fuller description of the several species of fish are referred to /1, 2, 3, 5, 7/.

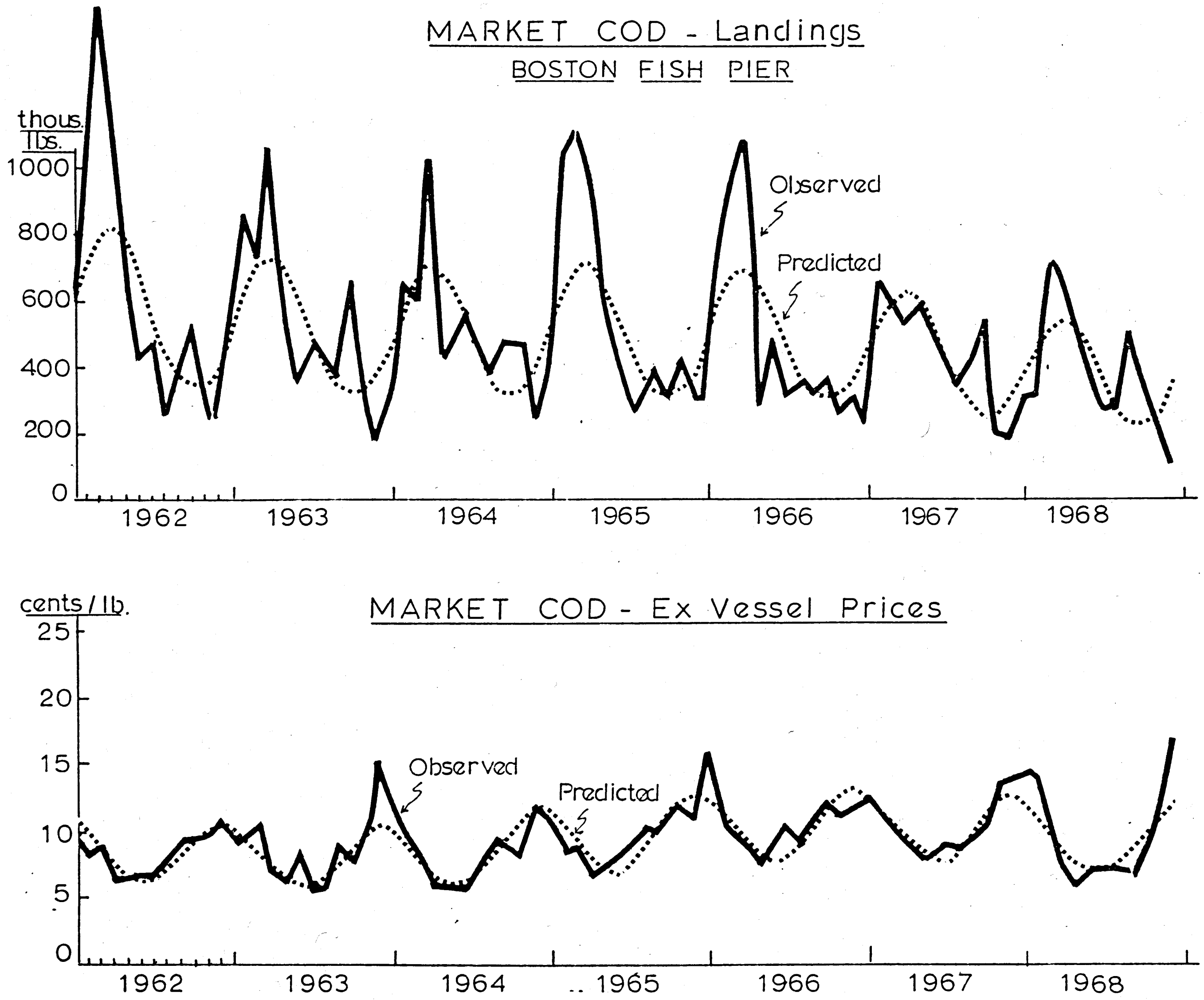
two-thirds or more of the catch), and large cod that run over 10 pounds. The market cod are preferred, as they are suitable for filleting, by machine or by hand, and they bring a somewhat higher price than the larger fish. Market cod brought an average of $9.02 a hundred pounds, dockside, in 1968, and the average for large cod was $8.15. Large cod are usually "steaked", and shipped to markets south of Boston, whereas fillets from the market cod are preferred by the local trade.

Figure 1 shows graphically the monthly landings and the monthly prices of market cod at the Boston Fish Pier. The solid lines show the actual landings and the actual prices. The dashed, oscillating curves are combinations of a linear trend, a 12-month cycle (seasonal), and a 5-year cycle. We chose a 5-year cycle mainly by inspection of the data shown in Figure 1. But we also checked our eyesight by computing 4-year and 6-year cycles.

The 12-month cycle (that is, the "seasonal movement") in landings rises from a low point in January to a peak in July. The 12-month cycle in price is the other way around. It starts from a high in December and January and reaches a low in June and July.

The prices used here were those received by fishermen. They were not deflated. Thus the upward trend in price

FIGURE 1.


MARKET COD - Landings
BOSTON FISH PIER
thous. lbs.
1000
800
600
400
200
0
Observed
Predicted
1962
1963
1964
1965
1966
1967
1968
MARKET COD - Ex Vessel Prices
cents/lb.
25
20
15
10
5
0
Observed
Predicted
1962
1963
1964
1965
1966
1967
1968

might be due to the rise in consumer income and in the general price level, from 1960-1968.

A simple cycle of 12 months is $y = a \cos 30t^{o} + b \sin 30t^{o}$. And a simple cycle of 5 years (60 months) is $y = a \cos 6t^{o} + b \sin 6t^{o}$. Here $\cos 30t^{o}$ means the cosine of an angle of 30t degrees, where t is the number of the month. And $\sin 30t^{o}$ means the sine of an angle of 30t degrees. (We allow 6 degrees a month, or 72 degrees a year for the 5-year cycle. The circle is completed in $5 \times 72^{o} = 360^{o}$). By including both the cosine and the sine, we allow for the "phase" of the cycle (allowing it to peak at the proper place).

We computed the following two equations:

$$\log \hat{q} = 2.8821 - \underset{(3.0)}{0.0021t} - \underset{(8.7)}{0.1969} \cos 30t^{o} - \underset{(6.1)}{0.1393} \sin 30t^{o} + \underset{(1.6)}{0.403} \cos 6t^{o} + \underset{(6.2)}{0.1437} \sin 6t^{o}. \quad R^2 = 0.68,\ DW = 1.25 \qquad (1)$$

$$\log \hat{p} = 1.9389 + \underset{(5.4)}{0.0015t} + \underset{(13.4)}{0.1185} \cos 30t^{o} + \underset{(3.5)}{0.0307} \sin 30t^{o} + \underset{(1.9)}{0.0186} \cos 6t^{o} - \underset{(4.8)}{0.0431} \sin 6t^{o}. \quad R^2 = 0.77,\ DW = 1.23 \qquad (2)$$

In (1) and (2), $\log \hat{q}$ is the estimated logarithm of monthly landings; $\log \hat{p}$ is the estimated logarithm of monthly prices. The numbers enclosed in parentheses are t values. The time trend and the two cycles account for 68 percent of the variance in landings, and for 77 percent of the variance in prices. The Durbin-Watsons indicate that there is significant serial correlation between the residuals. Thus, the t values noted above may overstate the significance of the regression coefficients.

The seasonal fluctuations in cod landings are due in large part to weather, as offshore fishing is much more difficult and expensive in the winter than in the summer. The seasonal fluctuations in prices are partly inverse reactions to the fluctuations in landings--but also reflect seasonal changes in demand, due to such institutional factors as Lent.

Each smooth curve in Figure 1 includes a linear time trend and two cycles. Each 12-month and 60-month cycle is shown separately in Figure 2. It may be observed in these graphs that in the seasonal (12-month) cycle, the peak of landings occurs about the middle of July: the low point of prices comes about July 1. The difference is probably due to seasonal changes in the demand for market cod. The peak of the 60-month cycle of landings falls at about the 12½ month - the 72½ month - etc.; that is, about January 1, 1963; January 1, 1968; - - -, etc.

The low point of prices occurs about July 15, 1963, July 15, 1968; - - -, etc. In other words, there is a lag of roughly 6½ months between the long-term cycle of landings and the corresponding cycle of prices. This may well be due to a degree of inertia in the market mechanism, and to uncertainties about how long an upward or downward movement is likely to persist.

In the 12-month cycle, the minimum of log p, as estimated from Figure 2, is about -0.12; the high point of log q is about +0.24. This indicates a price flexibility of about -1/2, based upon seasonal movements. Similarly, the 5-year cycle indicates a long-term flexibility of about -1/3.

(We shall later discuss a more precise measure of lags and flexibilities.)

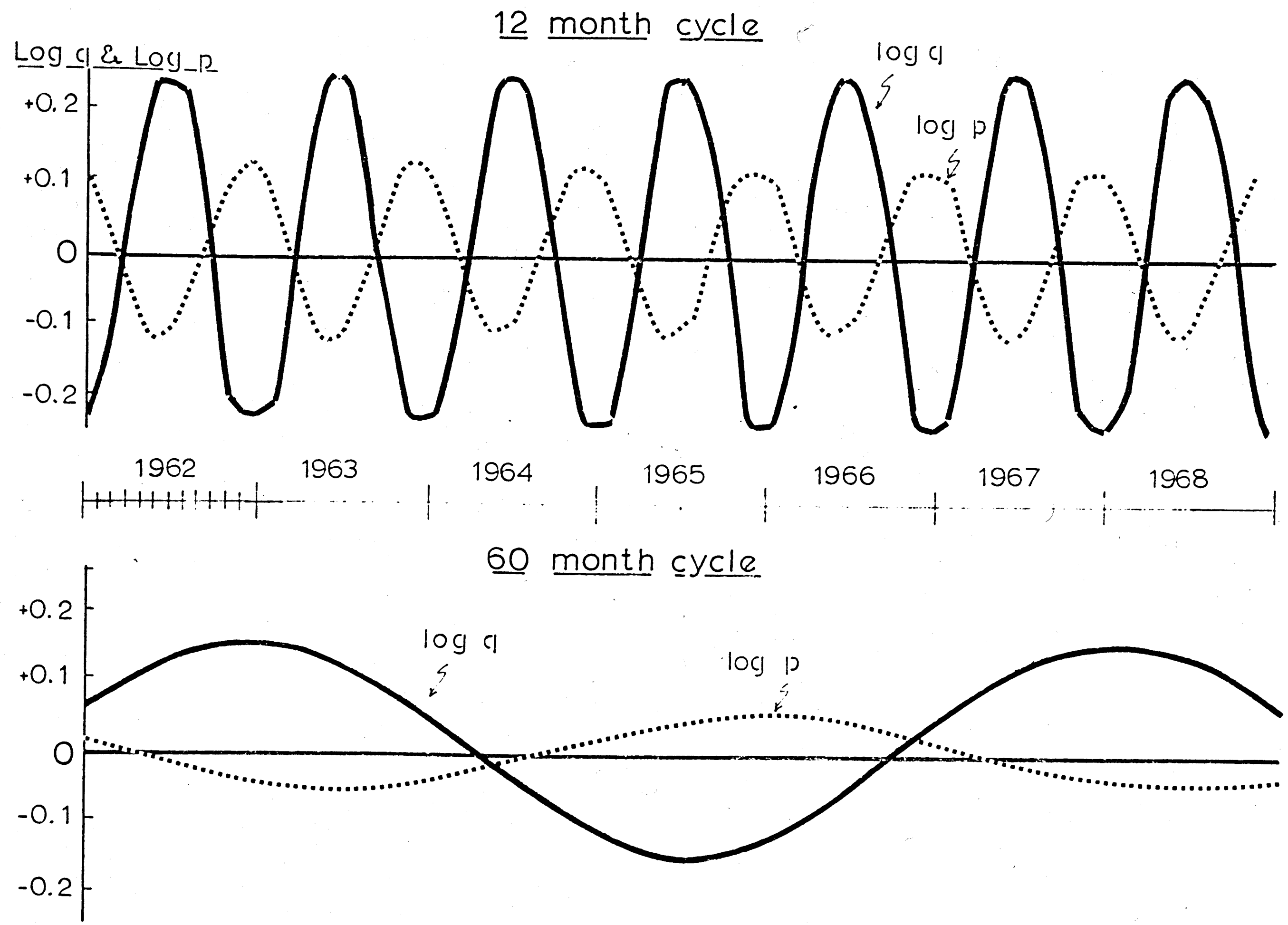
Note that, when the linear functions of the cosine and the sine curve are combined, they are simple cosine curves (or simple sine curves), with the phase adjusted to fit the data. If some of the t values in the regression equations like (1) and (2) are nonsignificant, we still need both the cosine and the sine function to get the phase properly. For example, in (2) the coefficient of $\cos 6t^{\circ}$ is less than 2.0. But we are primarily interested in the significance of the whole expression, $0.0186 \cos 6t^{\circ} - 0.0431 \sin 6t^{\circ}$.

(We will discuss this later.)

At this point, we should point out that we do not insist that the cod cycle is exactly five years long. After all, we observed only seven years; that is, 1 2/5 cycles. But there is a clear indication of a cycle of several years duration.

FIGURE 2.

CYCLES FOR MARKET COD



Large Haddock at the Boston Fish Pier

Haddock is New England's leading commercial fishery resource. The species has been first ranking in the area, in both quantity landed and in value, since the advent of strong consumer demand for fresh and frozen packaged fillets in the mid 1920's. Haddock were found to be especially suited to the new market forms, because of convenient size and good keeping qualities. Prior to this period, haddock were less favored than cod, chiefly because, unlike cod, haddock were not suitable for salting.

Most of the New England haddock catch is landed at the Boston Fish Pier by a fleet of large offshore trawlers. These vessels principally fish in the Georges Bank area of the continental shelf, about 100-150 miles off the Massachusetts coast. Haddock is the primary item in their catch, and accounts for about 60 percent of all fish landed in Boston. In recent years, the U. S. haddock fleet has been joined on Georges Bank by vessels of many flags, and the intensive international fishing effort on the grounds has been accompanied by a sharp downtrend in total haddock landings.

Haddock have two market designations, according to size: scrod and large. "Scrod" haddock are the younger fish (2-3 years old) and weigh between $1\frac{1}{2}$ and $2\frac{1}{2}$ pounds. All haddock over $2\frac{1}{2}$ pounds are classified as "large". The average weight of large haddock landed is generally between 3 and $3\frac{1}{2}$ pounds.

Large haddock bring a somewhat higher price than scrod, principally for two reasons. It costs less per pound to hand fillet large haddock, and consumers prefer the larger fillet over scrod. The average price Boston vessels received for large haddock in 1968 was $16.08 a hundred-weight, compared with $15.10 for scrod.

We shall not present charts for haddock. They would be very like Figure 1 and 2. Seasonal variations, like cod, are attributable to the fact that fishing is easier, and less expensive, in summer than in winter.

We go directly to the regression equations,

$$\log \hat{q} = 2.4415 - \underset{(6.0)}{0.0032}\, t - \underset{(9.2)}{0.1431} \cos 30t^{\circ} + \underset{(5.7)}{0.0901} \sin 30t^{\circ} - \underset{(4.2)}{0.0692} \cos 5t^{\circ} + \underset{(6.0)}{0.1106} \sin 5t^{\circ}. \quad R^2 = 0.79,\ DW = 1.65 \tag{3}$$

$$\log \hat{p} = 2.0392 - \underset{(8.1)}{0.0024}\, t + \underset{(12.2)}{0.1038} \cos 30t^{\circ} - \underset{(2.7)}{0.0229} \sin 30t^{\circ} + \underset{(0.1)}{0.0005} \cos 5t^{\circ} - \underset{(3.3)}{0.0327} \sin 5t^{\circ}. \quad R^2 = 0.80,\ DW = 1.51 \tag{4}$$

Note in equation (4) that the t value for the coefficient of cos $5t^{\circ}$ is nonsignificant. As we noted in the section on market cod, this does not indicate that cos $5t^{\circ}$ should be dropped. We need both the cosine and the sine to get the phase correctly.

In this case, we got the best fit by using a long cycle of six years, in combination with the seasonal cycle.

The linear trend, the seasonal, and the 6-year cycle account for 79 percent of the variance in landings, and for 80 percent of the variance in prices. The DW test indicates no significant serial correlation in landings, but is inconclusive in the case of prices.

Blackback and Lemon Sole at New Bedford

Blackback and Lemon Sole are market designations for the same species, winter flounder. The classification is made by weight, blackback being fish under 3 pounds, and lemon sole those over 3 pounds. Winter flounder are taken on the offshore grounds, as well as in waters closer inshore. The principal habitat of the larger fish (lemon sole), however, is in the Georges Bank area of the continental shelf, while those taken closer to the coast are usually the smaller blackbacks.

Winter flounder are the meatiest of flatfishes (excluding halibut) that are common to the New England fisheries, and are said to be the best flavored among the East Coast flounders. They are landed principally at New Bedford, where they comprised about 10 percent of the total quantity of fish handled by the port in 1968. The size mix of the winter flounder catch is about 90 percent blackback and 10 percent lemon sole. The latter are the favored variety, especially by the restaurant trade, and brought an average of \$25.40 per hundred-weight, dockside, in 1968, compared with \$13.89 for blackbacks.

When we plotted the data on landings, and on prices, of blackback and lemon sole (as in Figure 3), we saw clear evidence of two cycles in each year. This is likely accounted for by the inshore movements of winter flounder as water temperatures cool. (The species shuns shoal water in the summer). Therefore, the simple cosine and sine functions of $30t^o$ were inadequate. We decided to use functions of $30t^o$ and of $60t^o$ to estimate the seasonal. And we used functions of $6t^o$ to estimate a long cycle of five years.

The regressions were

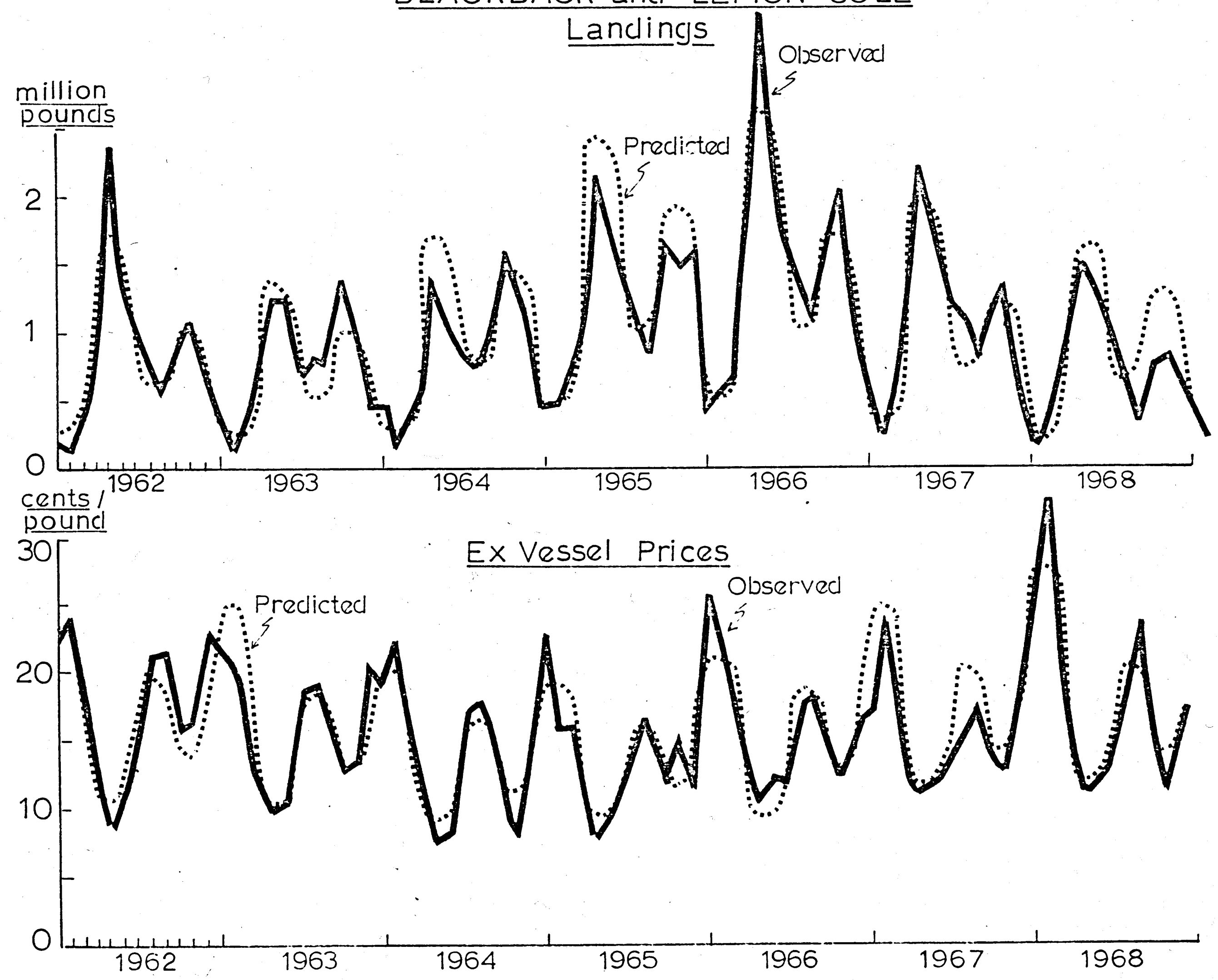
$$\log \hat{q} = \underset{(99.5)}{2.9027} + \underset{(1.3)}{0.0008}\, t + \underset{(7.2)}{0.1427} \cos 60t^o - \underset{(12.0)}{0.2375} \sin 60t^o$$
$$- \underset{(9.1)}{0.1809} \cos 30t^o - \underset{(7.6)}{0.1502} \sin 30t^o + \underset{(2.1)}{0.0047} \cos 6t^o \qquad (5)$$
$$- \underset{(6.5)}{0.1311} \sin 6t^o. \qquad R^2 = 0.83,\ DW = 1.56$$

$$\log \hat{p} = \underset{(147.4)}{2.1596} + \underset{(0.4)}{0.0001}\, t - \underset{(6.1)}{0.0607} \cos 60t^o + \underset{(12.9)}{0.1279} \sin 60t^o$$
$$+ \underset{(8.2)}{0.0818} \cos 30t^o + \underset{(0.9)}{0.0091} \sin 30t^o + \underset{(2.1)}{0.0235} \cos 6t^o \qquad (6)$$
$$+ \underset{(4.3)}{0.0447} \sin 6t^o. \qquad R^2 = 0.80,\ DW = 1.73$$

FIGURE 3.

NEW BEDFORD

BLACKBACK and LEMON SOLE



Price-estimating Equations

Equations (1) through (6) simply describe linear trends, seasonals and longer cycles. Suppose that the landings in the t^{th} month are known. Then our best estimates of prices are: for market cod at the Boston Fish Pier;

$$\log \hat{p} = \underset{(25.2)}{2.6121} - \underset{(6.5)}{0.2335} \log q + \underset{(4.2)}{0.0010}\, t + \underset{(7.3)}{0.0725} \cos 30t^{\circ} - \underset{(0.2)}{0.0019} \sin 30t^{\circ} + \underset{(3.4)}{0.0280} \cos 6t^{\circ} - \underset{(1.1)}{0.0096} \sin 6t^{\circ}. \tag{7}$$

$$R^2 = 0.85, \ DW = 1.33$$

for large haddock at the Boston Fish Pier,

$$\log \hat{p} = \underset{(11.6)}{5.4985} - \underset{(5.8)}{1.4220} \log q - \underset{(2.7)}{0.0270}\, t - \underset{(0.4)}{1.2700} \cos 30t^{\circ} - \underset{(1.1)}{0.0195} \sin 30t^{\circ} + \underset{(1.0)}{0.0190} \cos 5t^{\circ} - \underset{(6.8)}{0.1601} \sin 5t^{\circ}. \tag{8}$$

$$R^2 = 0.80, \ DW = 1.29$$

for blackback and lemon sole at New Bedford,

$$\log \hat{p} = \underset{(15.2)}{2.4972} - \underset{(2.1)}{0.1163} \log q + \underset{(0.7)}{0.0002}\, t - \underset{(3.5)}{0.0441} \cos 60t^{\circ} + \underset{(6.1)}{0.1002} \sin 60t^{\circ} + \underset{(4.3)}{0.0608} \cos 30t^{\circ} - \underset{(0.6)}{0.0083} \sin 30t^{\circ} + \underset{(2.6)}{0.0290} \cos 6t^{\circ} + \underset{(2.4)}{0.02945} \sin 6t^{\circ}. \tag{9}$$

$$R^2 = 0.81, \ DW = 1.47$$

Each of the above equations accounts for about 80 percent of the variance of prices, although each indicates significant serial correlation. Thus, the t values overstate the significance of the regression coefficients.

The regression coefficients for log price are price flexibilities; then reciprocals are sometimes taken as price elasticities (at the landings level). They are

	price flexibilities	reciprocals
for market cod	-0.23	-4.3
for large haddock	-1.42	-0.7
for blackback and lemon sole	-0.12	-8.3

These are extremely short-term flexibilities, based upon month-to-month changes. There may be some misunderstandings about this. For example, some economists apparently think that equations like (7), (8) and (9) provide longer-term elasticities than those we would get if we related deviation of prices from trend to deviation of quantities from trend. But, as shown by Frisch and Waugh [5], and by Tintner [9, pp. 301-308], the net regressions obtained from equations like (7), (8) and (9), are identical to the regression of deviations from the price equation upon deviations from the landings equation. To check this, we computed deviations from equations (1) and (2) for each month in the series. Say these deviations are

$(\log q - \log \hat{q})$ and $(\log p - \log \hat{p})$. Then we computed the regression

$$(\log p - \log \hat{p}) = -0.2335\ (\log q - \log \hat{q}). \tag{10}$$

Note that the -0.2335 is identical with the -0.2335 in (7). That is not all: equations (1), (2) and (10) together give the entire equation (7) except for differences due to rounding. (The computer gave us coefficients that were accurate to seven significant digits. But here we used figures rounded to four decimals.)

The above examples demonstrate that the "old-fashioned" method of relating deviations from trend gives the same results as the "modern" method of treating time as an additional variable in a multiple regression. Pure mathematics indicated that this is true, but some of us are reassured when a practical numerical example confirms it. Also, the older method gives more information than does the newer, in that it gives the trend of each variable. These separate trends are often useful.

<u>Measures of Lags and Flexibilities</u>

To estimate the cycles, we used both the cosine and the sine functions in equations such as (1) and (2). It is possible, however, to transform these equations into cosine functions alone, which makes it easier to measure lags and flexibilities. As Davis [4, pp. 346-347] and Tintner [9, 217-218] indicate,

$$a \cos x + b \sin x = \sqrt{a^2+b^2} \cos (x - \arctan b/a) \tag{11}$$

And we believe that the standard error of $\sqrt{a^2+b^2}$ is $\sqrt{s_a^2+s_b^2}$, where s_a and s_b are the standard errors of a and of b.

Thus, equations (1) and (2) are equivalent to

$$\log \hat{q} = \underset{(86.6)}{2.8821} - \underset{(3.0)}{0.0021}\, t - \underset{(10.7)}{0.2442} \cos (30t^{\circ} - 35^{\circ}\,16') + \underset{(4.3)}{0.1492} \cos (6t^{\circ} - 74^{\circ}\,20'). \tag{1a}$$

and

$$\log \hat{p} = \underset{(149.2)}{1.9389} + \underset{(5.4)}{0.0015}\, t + \underset{(3.2)}{0.1128} \cos (30t^{\circ} - 14^{\circ}\,31') - \underset{(3.5)}{0.0469} \cos (6t^{\circ} - 113^{\circ}\,39'). \tag{2a}$$

From the seasonal cycles, we can estimate lag and short-term price flexibility. The 12-month cycles in (1a) and (2a) --which deal with market cod at Boston--are

$$\log \hat{q} = \underset{(10.7)}{-0.2442} \cos (30t^{\circ} - 35^{\circ}\,16'), \text{ and}$$

$$\log \hat{p} = \underset{(4.3)}{+0.1128} \cos (30t^{\circ} - 14^{\circ}\,31').$$

Cod landings reach a minimum when $30t^{\circ} = 35^{\circ}\,16'$, i.e., $30t^{\circ} = 35.27^{\circ}$, i.e., when $t^{\circ} = 1.17$, i.e., about January 20. Price reaches a maximum when $30t^{\circ} = 14^{\circ}\,31'$, i.e., when $t \approx 1/2$, i.e., about January 1. Thus, price changes appear to lead the changes in cod landings by about 20 days. More precisely, there is a difference of $20^\circ 45'$; or 20.75 degrees, and the lag is 20.75/30 = 0.69 month. As already noted, this probably is due to seasonal changes in demand resulting from institutional factors.

The seasonal cycle indicates a price flexibility for cod of: 0.1128/-0.2442 = -.462. (This is approximately the result reached graphically in Figure 2.)

Turning now to the longer cycles, we observe that the 5-year cycles in (1a) and (1b) are

$$\log \hat{q} = \underset{(4.3)}{0.1492} \cos (6t^\circ - 74^\circ 20') \text{ and}$$
$$\log \hat{p} = \underset{(3.5)}{0.0469} \cos (6t^\circ - 113^\circ 39'). \qquad (12)$$

Maximum cod landings occur at months 12.39, 72.39, - - -. Minimum prices are at months 18.94, 78.94, - - -. Thus, price changes for cod at Boston lag 6.55 months behind changes in landings. The long-term price flexibility for the species is -469/1492 = -0.31.

From (3) and (4), the 5-year cycle for haddock at Boston can be written

$$\log \hat{q} = \underset{(5.3)}{0.1305} \cos (5t^\circ - 122^\circ 2'), \qquad (3a)$$

$$\log \hat{p} = \underset{(2.4)}{-0.0327} \cos (5t^\circ - 90^\circ 53'). \qquad (4a)$$

The lag between haddock prices and landings is (122.03 - 90.88)/5 = 6.23 months. In this case, price changes precede changes in landings. This may mean that the market anticipates changes in the landings cycle, so that prices start up before landings reach their maximum. The long-term price flexibility for haddock is -0.0327/0.1305 = -0.250.

Similarly, the long cycles in equations (5) and (6), for blackback and lemon sole at New Bedford, are equivalent to

$$\log \hat{q} = \underset{(4.7)}{-0.1397} \cos (6t^{\circ} - 110^{\circ}\ 4'), \qquad (5a)$$

$$\log \hat{p} = \underset{(3.3)}{0.0505} \cos (6t^{\circ} - 62^{\circ}\ 15'). \qquad (6a)$$

Again, price changes precede changes in landings. In this case, the lead is 47.81/6 = 7.97 months. The long-term price flexibility is 0.0505/-0.1397 = -0.361.

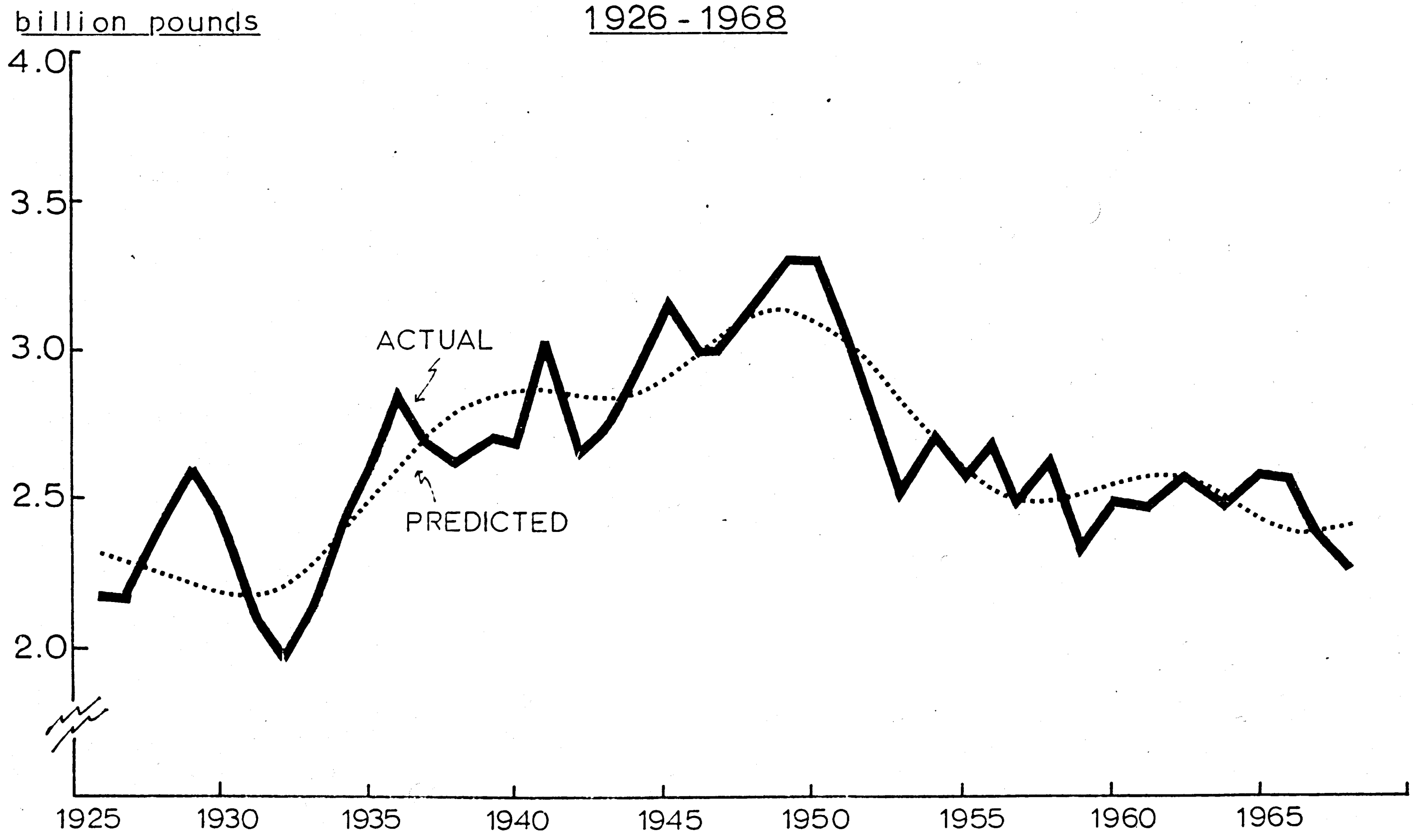
Annual Catch of All Food Fish

Thus far, we have discussed monthly data covering a 7-year period. The analyses suggest cycles of from 5 to 6 years, but, obviously, we would need a longer period to confirm this. To explore this matter, we analyzed the data on the annual U. S. catch of all food fish (that is, leaving out industrial fish) over the 43-year period, 1926 through 1968. The actual annual catch is shown by the solid line in Figure 4. The dotted line is computed from the regression equation,

$$\log \hat{q} = \underset{(39.3)}{0.4009} + \underset{(2.7)}{0.0011t} - \underset{(7.3)}{0.0501} \cos 10t^{\circ} - \underset{(4.0)}{0.0285} \sin 10t^{\circ} + \underset{(2.9)}{0.0184} \cos 30t^{\circ} + \underset{(1.4)}{0.0089} \sin 30t^{\circ}. \quad R^2 = 0.73,\ DW = 1.29 \qquad (13)$$

FIGURE 4.

U.S. CATCH OF ALL FOODFISH
1926 - 1968



Equation (13) is equivalent to

$$\log \hat{q} = \underset{(39.3)}{0.4009} + \underset{(2.7)}{0.0011t} - \underset{(5.8)}{0.0576} \cos (10t^\circ - 29^\circ\, 39') + \underset{(2.2)}{0.0204} \cos (30t^\circ - 25^\circ\, 47'). \qquad (13a)$$

The function of $10t^\circ$ is a 36-year cycle; it is clearly significant, but again we would need a longer period to confirm it. The function of $30t^\circ$ is a 12-year cycle; this is just significant, and we have more confidence in this because we observed over 3½ repetitions of this cycle in our 43 years. Unfortunately, we did not have available a 43-year series of prices of all food fish. Nonetheless, we consider that these results confirm the existence of other than seasonal cycles in the fisheries. Figure 4 shows visually that the fit is good. Equations (13) and (13a) are sophisticated measures of what we can see easily by eye. The same remark, of course, applies to the other diagrams and equations in this paper.

Epilogue

We have tried to demonstrate the utility of harmonic analysis (cosine and sine functions) as applied to investigating cyclical patterns in fish landings and prices. Our limited inquiry shows that the landings and prices of most species of fish exhibit strong seasonal fluctuations, and tend to follow fairly definite longer cycles, as well.

This kind of analysis can be valuable in making short-term forecasts and long-term projections, which are essential for developing sound conservation programs and policies. A too common practice is to assume that all economic series follow linear time trends. This is a questionable assumption--whether in fisheries, in agriculture, or elsewhere--and may lead to large errors in forecasting and projecting the future.

Where the growth rate is fairly steady (as that in human population) one can forecast at least a few years in advance by assuming that the rate will continue. But, if there are significant cycles, we obviously need to know where we stand in the cycle before we forecast even a few years ahead.

We also need to refine our estimates of long-term demand changes. When we make long-term projections (to the year 2,000 for example), we commonly expect large changes in population, in income, in production, and in other important variables. What should we take for price flexibility, or for the price-elasticity of demand? Almost all our statistical studies give us only short-term flexibilities and elasticities. We know very little about long-term flexibilities and elasticities. Yet these are precisely what we need for the purpose of making long-term projections. We have shown above how we think cyclical analysis can be used to estimate long-term flexibilities and elasticities.

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In the process of working towards these goals an array of written materials has been generated representing items ranging from interim discussion papers to contract reports. These items are available to interested professionals in limited quantities of offset reproduction. These "Working Papers" are not to be construed as official BCF publications and the analytical techniques used and conclusions reached in no way represent a final policy determination endorsed by the U. S. Bureau of Commercial Fisheries.