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EFFORT RESTRICTIONS IN THE NEW ENGLAND, SEA SCALLOP, DREDGE
FISHERY: A PRELIMINARY ANALYSIS

BY

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Introduction

Possibly recognizing that meat-count and shell-size restrictions have not controlled mortality in a particular manner, the New England Fisheries Management Council (NEFMC) has begun to explore alternative forms of regulations. In particular, restrictions on effort are being considered. Effort restrictions, however, while having advantages over meat-count and shell-size limitations, also have several problems. This is particularly true if age at capture and equity are of concern.

In this note, a preliminary overview of the use of effort restrictions is presented. The concept, as traditionally defined, is considered. Problems with the definition are subsequently discussed. Next, a preliminary analysis of changes in landings resulting from effort restrictions on New England sea scallop dredge vessels is presented. Last, problems of imposing effort restrictions on a fleet comprised of heterogeneous firms are discussed.

The Concepts of Effort and Effort Restrictions

Effort:

Effort may be defined as nominal, standardized, or effective. Nominal effort is a measure of fishing time or number of operating units (e.g., days-at-sea or fished or number of drags or trips made) (Treschev, 1975). Standardized effort is measured as the product of fishing power,

adjusted to a reference level, and fishing time or nominal effort; all measurements are expressed in terms of the same unit of measurement or base value. The purpose of standardization is to express effort over different types or sizes of operating units in terms of the same unit of measurement. Effective fishing effort is the percent of the mean population that is caught (Cunningham and Whitmarsh, 1980).

Thus, effort is a measure of the combination of all factors or activities by man which influence catch. That is, effort is a composite input (this is the same as adding or grouping together steak cod, market cod, cod scrod, and whale cod to simply cod). Consider, for example, a fishing firm which uses fuel, labor, electronics, ice, food, gear, machinery, and equipment to harvest and land fish. A measure of effort which allows for all these factors requires standardization to allow for the differences. The standardized measure of all the listed factors requires combining all the factors into a single composite measure of effort.

Kirkley and Strand (1988a, 1988b) and Squires (1987) have demonstrated, however, that it may not be possible to consider the influence of all factors in terms of a single measure. This does not rule out the possibility of using nominal effort or days at sea to analyze the effects of changes in catch resulting from changes in nominal effort. It does, though, require consideration of all factors in

any analysis.

In mathematical terms, the measure of effort as a composite input is specified as

$$(1) \text{ Effort} = g(\text{fuel, labor, electronics, ice, food, etc.})$$

This specification of effort requires that decisions about fuel, labor, electronics, ice, food, machinery, gear, and equipment be unrelated to the expected level of catch and the size of the fish stock. In addition, it is necessary that effort double if all inputs (e.g., fuel and labor) double. These conditions rarely apply to fishing firms (e.g., we typically observe an increase in the crew size when the fish stock or output price is very high).

Effort restrictions:

A major purpose of regulating effort is to control fishing mortality (i.e., the biomass or number of fish extracted by fishing expressed as a proportion of the mean population size). Effort restrictions can be either active (direct) or passive (indirect) (Sissenwine and Kirkley, 1982). Active controls directly control the level of effort (e.g., a restriction on days-at-sea). Passive controls affect or restrict the components of effort (e.g., type and size of gear and fishing practices).

In simple terms, effort restrictions are intended to reduce catch. Fishing mortality, in turn, should decrease. Overtime, the fish stock (numbers and/or biomass) should

increase. This is hypothesized to result in improved recruitment (number of fish or biomass added to the exploitable stock) and stock size in the future.

Unfortunately, the link between current levels of fishing and future stocks sizes is extremely difficult to determine. About all that can be shown is that a reduction in the rate of removal to very low levels will likely cause an increase in the size of future stocks, or a very large rate of removal will likely result in depressed fish stocks. The effects of controlling mortality or the rate of removal between the extremes is often uncertain.

Consider the following simplified example of how effort restrictions are intended to work. Let there be a catch-effort equation which explains how catch responds to changes in fishing effort:

$$(2) \quad C = q E N$$

where C is catch, q is a catchability coefficient, E is days at sea, and N is stock size. As effort (E) is restricted, catch should fall if stock size and q is held constant. Also, q E or F (fishing mortality) declines. As a result, the existing biomass and spawning stock size should increase in the future. The expected net result is an increased exploitable fish stock and biomass in the future:

(a) E decreases causing C to fall

- (b) C_t decreases causing N_{t+1} to rise
- (c) N_t increases causing N_{t+1} to rise
- (d) N_{t+1} increases causing C_{t+1} to rise

where t and $t+1$ represent the current and future time periods. The bottom line is that E_t decreases and C_{t+1} increases.

It appears simple and obvious. Yet, it may not work. If it does work, what happens along the way? The economic benefits of today are being traded for hopeful increased economic benefits tomorrow. That is, the fisherman pays today for a product believed to be available tomorrow. However, the product may not be available. Also, since most fleets are comprised of different size vessels, it is quite possible that some vessels must pay more dearly for future products.

A Preliminary Analysis of Effort Restrictions

In this section, a preliminary analysis of controlling nominal effort in the New England, sea scallop, dredge fishery is presented. The analysis is based on data available from the Northeast Fisheries Center, National Marine Fisheries Service. First, an industry catch-effort model is specified and estimated. Then, catch-effort models for three vessel size groups are estimated, and their results are compared to those obtained from the industry analysis.

fishing more days).

The resultant estimate of the catch-effort model based on data for 1968-1985 is:

$$(5) \quad C_t = 111.27 \text{ Effort}^{.57} t^{-.11} C_{t-1}^{.11} C_{t-2}^{.74}$$

where effort is the composite input obtained in equation (4), t is time, and C_{t-1} and C_{t-2} are catches in the two preceding years. A positive coefficient implies that catch will increase as the value of the associated variable is increased and the values of all other variables are held constant; a negative coefficient implies that catch will decrease as the value of the associated variable increase.

Consider restricting total days-at-sea from the 1985 level of 17,837 days to the 1978 level of 9,927 days. The corresponding total effort decreases from 238.37 to 187.32 standardized days; catch declines from 35,812 metric tons of whole scallops to 30,612 tons or 14.5 percent. However, the same level of standardized effort can be maintained by substituting or augmenting labor for days; the required rate of increase is approximately one man per boat (i.e., going from an average crew size of 9 to 10 men per vessel).

Subfleet analysis:

Unfortunately, an effort restriction across the fleet ignores the potential impacts and different responses by individual vessels of different characteristics (Karpoff, 1987). That is, if a fleet is comprised of vessels

with different characteristics (e.g., vessel size), the effects of a uniform restriction will likely vary across vessels. This is illustrated by considering three vessel classes in which effort restrictions are uniformly imposed. The three classes are based on size: (1) 5-50 GRT, (2) 51-150 GRT, and (3) 151 + GRT.

In the preceding analysis, effort was restricted to its 1978 level of 9,927 days-at-sea. This works out to a uniform restrictions of 59.09 days-at-sea per vessel. In comparison, the number of days-at-sea per boat in 1985, without restrictions, was 106.17 days. Holding the number of vessels and tonnage constant and applying the 59.09 days to each vessel in the three size classes yields the following total levels of effort with restrictions: (1) 5-50 GRT--1181.79, (2) 51-150 GRT--3722.63, and (3) 151 + GRT--5022.59 days-at sea. The unrestricted number of days-at-sea during 1985 for the three tonnage classes were 423, 4891, and 12523 days, respectively. It is immediately evident that the small boat fleet will not be restricted by the effort restrictions while the large boat fleet will have effort reduced by more than 50-percent. In fact, the small boat fleet will not experience any restrictions until total days are restricted to less than 3,553 days or 21 days per vessel given uniform restrictions in terms of days per boat.

Similar to the industry analysis, it was determined that composite inputs could be formed for the three vessel

classes:

$$(6) \quad 5-50: \quad E_t = D_t^{1.056} (V_t \text{GRT}_t)^{-1.056}$$

$$(7) \quad 51-150: \quad E_t = L_t^{2.056} D_t^{-0.54} (V_t \text{GRT}_t)^{-2.056}$$

$$(8) \quad 161 +: \quad E_t = L_t^{2.29} D_t^{-0.29} (V_t \text{GRT}_t)^{-1.056}$$

The two larger vessel classes can increase labor to offset restrictions on days-at sea; the smaller vessels cannot augment other factors to maintain the same level of effort.

Given the restrictions of 3722.63 and 5022.59 days for the two larger vessel classes, the same level of effort can be achieved by increasing labor for 9 to 10 and 10 to 11 men per boat, respectively. Alternatively, a one-percent restriction on the unrestricted 1985 levels of days at sea will reduce the composite level of effort by 1.56, .54, and .29 percent, respectively, for the small, medium, and large boat fleets. This means that the same level of effort before the restrictions can be obtained by increasing labor; this will enable the two larger vessel classes to harvest the same level of catch realized before the restrictions. As will be subsequently shown, it is also possible for the small boat fleet to substitute labor to maintain the same level of catch; however, they cannot maintain the same level of effort.

More important, though, is how will total catch respond to the three different levels of effort. The corresponding estimated catch-effort models are as follows:

$$(9) \quad 5-50: C_t = .000000006L_t^{.69}E_t^{1.06}t^{3.30}C_{t-1}^{.11}C_{t-2}^{.01}$$

$$(10) \quad 51-150: C_t = 493906E_t^{.62}t^{1.74}C_{t-1}^{.14}C_{t-2}^{.05}$$

$$(11) \quad 151 +: C_t = 8.24E_t^{.69}t^{.95}C_{t-1}^{.24}C_{t-2}^{.04}$$

(Note that a restriction on days cannot be circumvented with respect to effort for the small boat fleet, but can be circumvented with respect to catch. That is, if the days-at-sea restriction is binding for the small boat fleet, they cannot increase labor to maintain the same level of effort, but they can increase labor to maintain the same level of catch).

Given no substitution to offset the restriction on days, total catch for each fleet is estimated to decrease by 0 (5-50), 8.8 (51-150), and 16.77 (151 +) percent. Thus, the effort restriction more severely affects the large boat fleet given no substitution.

The different effects of restricting days at sea can also be illustrated by examining the respective output elasticities or the percentage change in output resulting from a one-percent decrease in the existing levels of days at sea. Based on the industry specification, a one-percent decrease in the number of days, given no substitution and all other factors held constant, will result in a .23-percent decline in catch (table 1). In comparison, a one-percent decrease in days-at-sea will cause output to decline 1.66, .34, and .2 percent for the small, medium, and large boat fleet (table 1). These declines are based

on the condition that days at sea are restricted to less than their observed levels by one-percent.

Table 1. Estimated percentage change in catch for a one-percent reduction in days-at-sea, 1985

Fleet size	Days at sea		:	Catch ¹		
	Restrictions			Restrictions		
Number of vessels	None	1-% drop	:	None	1-% Days	%-change
5-50	423	419	:	560	551	-1.66
20						
51-150	4891	4842	:	9072	9041	-.34
63						
151 +	12523	12397	:	26180	26128	-.20
85						
Total	17837	17659	:	35812	35730*	-.23
168						

¹Metric ton weight--whole scallops.

*Based on aggregate model; not sum of three models.

Problems of Imposing Effort Restrictions

The preceding analysis indicates that effort restrictions imposed on a fleet with different characteristics will have different impacts on various groups of vessels. First, it is possible for a group of vessels to not be affected by the restrictions if a fleet restriction is uniformly applied to all vessels. Second, an across the board restriction on effort will impose a different level of burden for each vessel with different characteristics; smaller vessels are typically more adversely affected by these types of restrictions in which effort is uniformly restricted from its current levels for each vessel class.

Thus, a major problem of imposing effort restrictions is "How can they be fairly and equitably imposed?" The answer depends upon how fair is equitable is defined. This could be in terms of profit, revenue, costs, or access to the fish stocks. Economics would consider profitability, net benefits, and economic efficiency.

Another problem is that of factor substitution. That is, all three tonnage classes can mitigate the restrictive nature of days-at-sea restrictions by substituting labor. Alternatively, other factors such as electronics and machinery which were not considered in the example may be substituted. For example, the size of a dredge may be increased or the ring size decreased. It may be possible to increase the towing speed (fuel for days).

On-board capital or equipment may be increased. The actual substitution will depend upon the expected changes in revenues and costs from substitution.

Third, restrictions on days-at-sea are not the only form of effort restrictions and they may not adequately control mortality on juvenile scallops. It may be necessary to consider restrictions on days-at-sea, gear, area, and time of year (i.e, passive controls).

Last, overall effort restrictions may required additional limitations on the number and size of vessels. If entry is possible, it may be necessary to continuously adjust the effort restriction in response to possible increased overall effort. Alternatively, some vessels may be forced out of the fishery if new vessels are more efficient than the existing vessels.

Summary and Conclusions

The eventual objective of effort restrictions is to maintain or enhance the level of the exploitable fish stock. In simple terms, the present level of effort is restricted to either allow future stocks to be constant or to increase in size with respect to the present size of the fish stock. Active or direct restrictions, however, may fail to adequately control the age of capture, a major concern for the scallop fishery, unless accompanying passive, spatial, and/or temporal restrictions are also imposed. Moreover, implementation of effort restrictions may require

additional consideration of different classes of fishing vessels if equity is of concern. Last, restrictions on components of effort may require restrictions on other factors used to harvest fish if factor substitution is possible.

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