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The common property ocean fishery is often cited as an example of economic inefficiency in production. The usual recommendation is to restrict entry of fishermen so that incomes of those remaining are improved. Such logic would seem to indicate that the economic theory of common property natural resource use is not well developed. It was with this premise that the current investigation commenced.

A mathematical model of productive interdependence among firms in a common pool situation was developed. Following this, the concept of rising supply price for an industry exhibiting productive interdependence was introduced. The concept of a fishing-day was introduced and it was argued that the firm viewed a fishing-day as one of its variable inputs.

When the above concepts were combined with the biological

model presented, a bioeconomic model of the fishery evolved. The model permitted illustration of the impact upon industry output from changes in: (1) technology; (2) demand for the product; and (3) fish population; and the chain of ramifications which result when current production is something other than the sustained yield of the fish stock.

The usual charge that a common property fishery is "inevitably overexploited" was evaluated in the context of the bioeconomic model and seen to be false. The traditional recommendation to restrict entry such that fleet marginal cost equals fleet marginal revenue, so as to maximize "rent," was shown, instead, to merely create higher-than-competitive returns (profit) for remaining fishermen. The disregard for those fishermen excluded by such action was questioned on equity grounds, as well as on grounds of economic efficiency. It was also demonstrated that depending upon demand for the product and technology of the industry, equating fleet marginal cost with fleet marginal revenue was not sufficient proof that the fish stock would not be overfished.

The usual concern for the welfare of the resource under common property exploitation was discussed and in light of present regulations, deemed to be of little moment in the fishery.

A sole owner could, <u>perhaps</u>, achieve economies of large-scale production in the long run, but to do so would require access to a large number of fishing grounds. This being the case, extraction of monopoly profits would occur. Also to be weighed against possible gains from unified management would be the impact on those excluded from the fishery. Regard for regional employment, stability, and growth would seem to be ignored in the process of possibly reducing per unit production costs in the fishery.

The presence of productive interdependence was seen to provide no basis for the charge that externalities are present in a common property fishery. A distinction between interdependence and externalities exists which, up to now, has gone unrecognized. Thus, the recommendation for taxes to "internalize the externalities" was shown to be incorrect. Misallocation of fishing effort over grounds of different quality may exist, yet reallocation (costless) is more likely to create differential profits for vessels on the better grounds, than it is in realizing social savings.

The rudiments of resource allocation theory were presented, with particular reference to the fishery. It was concluded that the salvage value of commercial fishermen is lower than their acquisition cost and hence they may be receiving their "opportunity" income. This being the case, the usual conclusion that society would benefit if "excess" fishermen produced other goods and services, appears weak. It was further hypothesized that, contrary to traditional thought, fishermen are more mobile than those occupational groups which stand to gain from long-term asset (land) appreciation.

In conclusion, the presence of considerable uncertainty in a fishery, and the lack of perfect knowledge on the part of biologists and economists, renders the sweeping conclusions of traditional writers in fishery economics, and their subsequent policy recommendations, particularly vulnerable to incredulity.

Economic Efficiency in Common Property Natural Resource Use: A Case Study of the Ocean Fishery

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ECONOMIC EFFICIENCY IN COMMON PROPERTY NATURAL RESOURCE USE: A CASE STUDY OF THE OCEAN FISHERY

I. INTRODUCTION

Natural resources are utilized both in consumption and in production. When conditions make private ownership impractical, unique problems of management and use arise. The lack of private ownership also causes problems in the application of traditional economic analysis to questions of optimum rates of use over time, optimum rates of use in one time period, proper fee levels, and interdependence among users. Private ownership of natural resources is not a sufficient condition for socially desirable decisions concerning use; however, when it is lacking, the economist must improvise in his quest for conclusions regarding economic efficiency. Such is the nature of this investigation.

The advent of marine economics research at Oregon State University, in conjunction with the national Sea Grant program, places more than mere academic interest on the common property aspects of fisheries exploitation. Economists will be called upon at an increasing rate to pass judgement on various aspects of this country's use of the ocean resource, from recreation, to waste disposal, to food production. In order that the economist be equipped to provide the correct answers, he must first ask the right questions; that is, relevant, testable hypotheses must be deduced from his knowledge of economic theory, and its application to the unique problems associated with the common property exploitation of the ocean resource[1].

It is the primary goal of the present undertaking to synthesize a bioeconomic model of the common property fishery such that future research may focus upon those questions particularly germane to the achievement, and maintenance of economic efficiency. However, to justify such an endeavor, it must first be demonstrated that the present methods for analyzing the economic aspects of the ocean fishery are of such a nature that their derived conclusions are open to question. Thus, a critical review of the "state-of-the-arts" in common property theory as applied to the fishery will comprise a significant portion of the present investigation. Only after demonstrating that the models and their conclusions are questionable, will an attempt be made to develop an improved bioeconomic model.

Early writers in fishery management were concerned primarily with biological relations. The concept of maximum sustained yield prevailed as the sole criterion for decision making. The most widely known effort to combine economics and biology was that of

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[1]One should not conclude that the basic problems of commonality investigated herein are confined to ocean resources. Commonality is also encountered in ground water pools, oil pools, water and air pollution, highways, recreation, and public grazing lands.

H. Scott Gordon (1954). This work was essentially a "proof" that the level of fishing effort which would maximize "net economic yield" was always less than that which would maximize sustained yield. With this, Gordon was able to state unequivocally that fishing effort in all common property fisheries should be reduced. Gordon's work has provided the foundation for all subsequent investigations into the common property exploitation of an ocean fishery.

The normative aspects of such a general and sweeping argument have had considerable impact in the area of public policy; a "grandfather clause"[2] has been recommended for parts of the Alaskan salmon fishery by the Alaska Board of Fish and Game. Current literature in fishery economics unanimously calls for restricting the number of vessels allowed in a given fishery, or an elaborate system of taxes to "correct the inefficiencies." Thus, while a purely theoretical investigation of the ocean fishery might be thought too abstract for usefulness in public decision making, it is maintained that policy recommendations are currently being advanced on the basis of a theoretical model which may be misleading and incorrect. If the current investigation is successful in determining the correctness of these policy proposals, or raising doubts about some of them, a contribution

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[2]This is where only fishermen who have had licenses in the family for long periods of time can fish. Overtime, death reduces the number of vessels. It meets with little opposition from fishermen because they, or their descendents are not excluded, but "profit seekers" are.

will have been made.

Objectives

As stated, the primary objective of the present undertaking is to develop an economic model which, when combined with a biological model, will provide a realistic, yet operational framework for analyzing the state of economic efficiency in a common property context. Such a model should also provide a framework for analyzing some of the conclusions of the traditional writers in fishery economics. In addition to the primary objective, a secondary objective is to discuss and analyze some of the traditional conclusions, not only in the framework of the model developed here, but through reference to such issues as conventional resource allocation theory. These secondary objectives are listed below:

(1) To explore the relationship between the maximands advocated in the traditional models--net economic yield, rent to the resource, industry profits--and net social benefits.

(2) To evaluate the charge that labor in the fishery receives its average value product instead of its marginal value product. And, related to this charge, to explore the conclusion of Gordon (1954) and others that fishermen are poor and receive less than their opportunity wage.

(3) To explore the general conclusion that the production of goods and

services elsewhere in the economy could be enhanced by restricting vessels from the fishery.

(4) To discuss the possibility that the traditional models may not include enough relevant information to provide an adequate basis for policy recommendations in the fishery.

(5) To explore the nature of the variable input mix in the fishery--primarily the "right-to-fish"--and discuss the possibilities of factor misallocation.

(6) To investigate the charge that unrestricted entry "inevitably leads to overfishing, higher costs, and lower sustained yield."

(7) To evaluate the charge that externalities are present in the fishery and that restrictions, or taxes on vessels and fish caught, are needed to "correct" the situation.

(8) To explore the possibility that a misallocation of fishing effort over grounds of differing quality exists.

Procedure

To meet the objectives outlined in the previous section, the report of the investigation is organized in the following manner:

Chapter II provides a brief review of the essential findings of several of the more prominent researchers in fishery economics.

Chapter III, entitled "Rent, Resource Allocation, and Economic Efficiency," consists of an investigation of some of the conclusions of traditional fishery economists. Its purpose is to fulfill objectives (1) through (4) enumerated above. The conclusions of this discussion provide justification for undertaking the primary objective--that is, development of a more explicit and comprehensive bioeconomic model of the fishery.

A necessary part of a meaningful economic model is that of the biological aspects. Chapter IV presents, very briefly, the rudiments of fishery population dynamics. While abbreviated, it presents the essential ecological principles involved.

Chapter V contains the development of an economic model of fishery use under conditions of productive interdependence. It is the presence of interdependence which complicates traditional production theory and makes for interesting relationships within the industry. These relationships are made explicit and the equilibrium position of the industry is derived. Also included is a treatment of the "right-to-fish" as a factor of production. This latter discussion pertains to objective (5).

Chapter VI, entitled "Economic Efficiency in a Common Property Context," presents the bioeconomic model. The latter portion of the chapter is devoted to analyzing the traditional conclusion that unrestricted entry "inevitably" leads to overfishing, higher costs, and lower sustained yield. Also discussed is the charge that certain taxes are required to "internalize the externalities" in the common property fishery. An investigation of misallocation of fishing effort over grounds of differing quality is also included in this chapter.

Chapter VII, "Conclusions and Implications," is a drawing together not only of the findings of the present research, but the conclusions of such theoreticians as Ronald Coase, in an attempt to derive general summary statements about the relationship between common property exploitation of a fishery and: (1) resource allocation; (2) conservation; and (3) economies of large-scale production. In closing, some ideas are presented concerning the kinds of information which is yet required before unequivocal conclusions can be drawn as regards economic efficiency, or the supposed lack thereof, in ocean fishery exploitation.

II. THE TRADITIONAL APPROACH

Economic efficiency is a frequently used guide for comparing different institutional situations and is a useful criterion in assessing the performance of the industry, or market, under scrutiny. The fishing industry is frequently mentioned as one in which suboptimal conditions prevail.[3] Inefficiency on the production side implies that the industry as a whole is incapable of achieving the ultimate production possibilities frontier. It would also imply that excessive resources devoted to fishing prevents society as a whole from achieving its ultimate production possibilities frontier.

Exponents of the inefficiency argument maintain that because no one owns the fishing grounds, and thus all who wish to do so may fish, too many boats enter, and the "rent" which each ground is capable of producing is "dissipated in excessive effort, higher costs, and depletion of the stocks" (Crutchfield and Zellner, 1962). The solution which all seem to agree upon is to restrict the number of boats allowed in a given fishery, thereby permitting the "rent" to go to the few who are not excluded. A more recent argument is: because each boat reduces the fish population, there should be a specific tax per

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[3] Gordon (1954), Scott (1955), Turvey and Wiseman (1957), Crutchfield (1956, 1962, 1964), Crutchfield and Zellner (1962), Christy and Scott (1965), Turvey (1964), and Smith (1968).

unit of output on each boat in a given fishery (Smith, 1968). Smith also advocates a license fee per boat to reflect the external costs of crowding by vessels. The following will present the essential arguments of several contributors to fishery economics literature.

H. Scott Gordon

As indicated earlier, H. Scott Gordon made the first major effort at constructing an economic model of the fishery. Gordon maintained that common property fisheries had the following traits in common: (1) too much total effort being used in the fishery; (2) a misallocation of effort between grounds of differing quality; (3) poverty among fishermen; (4) depletion or extinction of the basic resources; and (5) immobility of fishermen. Because of the impact which Gordon's work has had on later economists, a rather detailed account of his analysis will be presented.

Level of Total Fishing Effort

In making his point that there is "too much effort" in harvesting a common property resource, Gordon utilizes a model which closely resembles that used in traditional firm theory to determine the proper use level of a single variable input. Figure 1 is a reproduction of Gordon's Figure 1.[4]

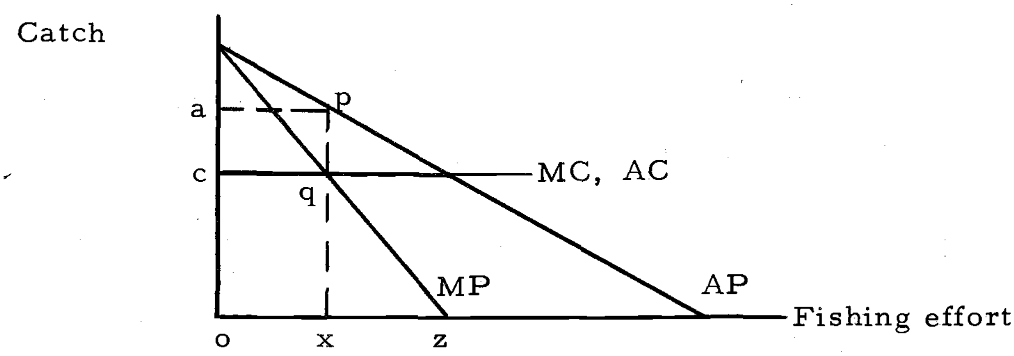

Figure 1. Gordon's model relating total fishing effort to production.

The costs of fishing supplies, and the other factors used in production are assumed to be unaffected by the level of fishing effort and hence marginal cost of effort equals average cost of effort. These costs are assumed to include an opportunity income for the fishermen.

By Gordon's definition, the optimum degree of fishing effort on any fishing ground is that level which maximizes the net economic yield; where the difference between total fleet costs, and total fleet revenues is a maximum (where fleet marginal costs equal fleet marginal revenue). This concept of economic efficiency is the key to the Gordon analysis, as well as that of the other workers.

Through this precept of performance by the fleet, Gordon is able to state that <u>ox</u> units of fishing effort is the optimum on this particular ground, and at that level of exploitation, the ground will

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[4]However, instead of depicting the situation for a single firm, it should be noticed that this represents the aggregate of all boats in a given fishery. It is <u>firm</u> theory applied to the whole fleet.

provide the maximum net economic yield indicated by the area apqc. He further maintains that the maximum sustained yield which biologists are prone to advocate will occur at oz level of effort. "Thus, as one might expect, the optimum economic fishing intensity is less than that which would produce the maximum sustained physical yield" (Gordon, 1954, p. 130). Therein lies Gordon's justification for restricting fishing effort in a given fishery.

As if expecting reaction to the maximization of rent to a specific ground, Gordon comes to his own defense:

> The area apqc in Figure 1 can be regarded as the rent yielded by the fishery resource. Under the given conditions, ox is the best rate of exploitation for the fishing ground in question, and the rent reflects the productivity of that ground, not any artificial market limitation. The rent here corresponds to the extra productivity yielded in agriculture by soils of better quality or location than those on the margin of cultivation, which may produce an opportunity income but no more. In short, Figure 1 shows the determination of the intensive margin of utilization on an intramarginal ground (Gordon, 1954, p. 130).

Allocation of Fishing Effort Among Grounds

Because the fishery is not private property, and the rent it may yield is not capable of appropriation by anyone, Gordon maintains that fishermen compete among themselves until the rent of the intramarginal ground is dissipated. Gordon says this can be easily understood by relating the intensive margin and the extensive margin of resource exploitation in fisheries. The following is taken from Gordon.

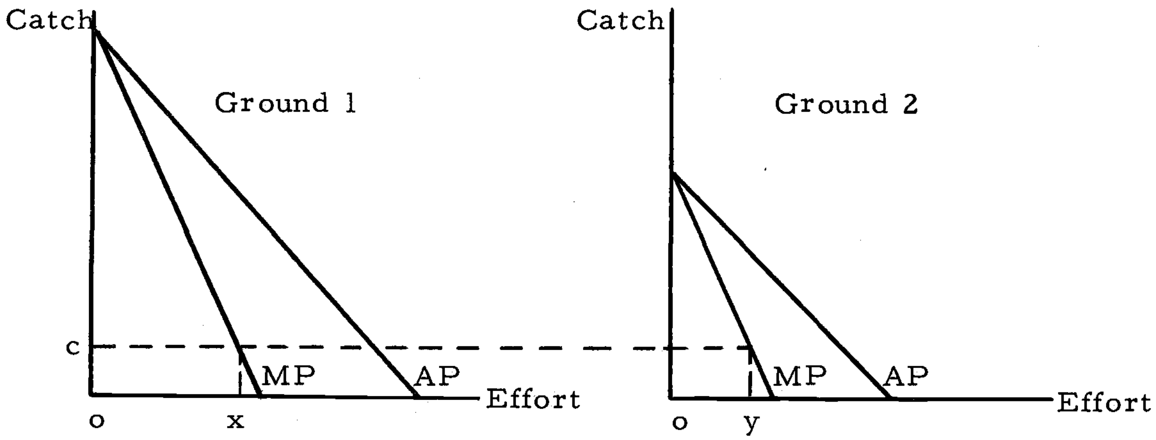

Figure 2. Comparison of effort on two grounds of differing quality.

In Figure 2, ground two is either of lower fertility, or further from market, than is ground one. Hence, any given amount of effort devoted to ground two will yield a smaller total (and thus average) product than if devoted to ground one. The maximization problem is one of correctly allocating total effort between grounds one and two. The optimum allocation is where the marginal productivities of effort are equal on both. With effort costs being oc, ox of effort on ground one, and oy on ground two would maximize net yield if ox plus oy were the total effort used.

Because fishermen are free to fish whichever ground they desire, they will overuse the good ground. The argument goes that upon leaving port, and deciding which ground to fish, the fisherman does not care about marginal productivity, but average productivity, for it is the latter which indicates where the greater total yield may be obtained. Thus, in uncontrolled exploitation, effort will be allocated between the two grounds such that average productivity will be brought to equality, not marginal productivity. Assuming a continuous gradation of fishing ground quality, the extensive margin would be on that ground which yielded nothing more than outlaid costs plus opportunity income, that is, where average productivity and average cost were equal. But, Gordon maintains that since average cost (of inputs) is the same on all grounds, and the average productivity of all grounds is brought to equality by the "free and competitive nature of fishing," the intramarginal grounds also yield no rent. The rent which the intramarginal grounds are capable of yielding is dissipated through misallocation of fishing effort.

This leads directly into the third "result" of common property resource use, which is the poverty of fishermen.

Poverty

Gordon asserts that because the intramarginal ground receives no rent, fishermen are poor. To quote:

> This is why fishermen are not wealthy, despite the fact that the fishery resources of the sea are the richest and most indestructible available to man. By and large, the

> only fisherman who becomes rich is one who makes a lucky catch or one who participates in a fishery that is put under a form of social control that turns the open resource into property rights (Gordon, 1954, p. 132).

The crux of Gordon's assertion of poverty is that fishermen receive no economic rent from the wealth of the fishery resource. Further quotes shed more light on Gordon's reasoning:

> Up to this point, the remuneration of fishermen has been accounted for as an opportunity-cost income comparable to earnings attainable in other industries. In point of fact, fishermen typically earn less than most others, even in much less hazardous occupations or in those requiring less skill. There is no effective reason why the competition among fishermen described above must stop at the point where opportunity incomes are yielded. It may be and is in many cases carried much further (Gordon, 1954, p. 132).

Gordon is now saying that fishermen often earn less than opportunity incomes. He places the blame on immobility and the lust for a "lucky catch." In Gordon's words:

> Two factors prevent an equilibration of fishermen's incomes with those of other members of society. The first is the great immobility of fishermen. Living often in isolated communities, with little knowledge of conditions or opportunities elsewhere; educationally and often romantically tied to the sea; and lacking the savings necessary to provide a 'stake,' the fisherman is one of the least mobile of occupational groups. But, second, there is in the spirit of every fisherman the hope of the 'lucky catch.' As those who know fishermen well have often testified, they are gamblers and incurably optimistic. As a consequence, they will work for less than the going wage (Gordon, 1954, p. 132).

Gordon later cites several opinions of biologists on the success of the Pacific halibut program and then states: "Quite aside from the biological argument on the Pacific halibut case, there is no clear-cut evidence that halibut fishermen were made relatively more prosperous by the control measures" (Gordon, 1954, p. 133) (emphasis his). Gordon states that what has happened is a rise in the average cost of fishing effort allowing no gap between average production and average cost to appear, and thus no rent.[5]

Gordon speculates that the Canadian Atlantic Coast lobster fishery could produce the same catch with half the existing traps. In a few places, he indicates, fishermen have banded together in a local monopoly, preventing entry and controlling their own operations. "By this means, the amount of fishing gear has been greatly reduced and incomes considerably improved" (Gordon, 1954, p. 134) (emphasis added).

Extinction of the Basic Resource

Gordon finds further undesirable consequences of common property and expresses this in the following manner:

> That the plight of fishermen and the inefficiency of fisheries production stems from the common-property nature of the resources of the sea is further corroborated by the fact that one finds similar patterns of exploitation and similar problems in other cases of open resources. Perhaps the most obvious is hunting

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[5]Recall that economic rent (profit) arises when the gap Gordon speaks of does exist. And that in the normal competitive situation, any profit attracts new producers.

> and trapping. Unlike fishes, the biotic potential of land animals is low enough for the species to be destroyed. Uncontrolled hunting means that animals will be killed for any short-range human reason, great or small: for food or simply for fun. Thus the buffalo of the western plains was destroyed to satisfy the most trivial desires of the white man, against which the long term food needs of the aboriginal population counted as nothing. Even in the most civilized communities, conservation authorities have discovered that a bag-limit _per man_ is necessary if complete destruction is to be avoided (Gordon, 1954, p. 134).

While Gordon's point is no doubt true, its emotive nature ignores the fact that current fisheries regulations insure that no species will be eliminated.

Immobility of Fishermen

It was seen that in addition to common property causing poverty among fishermen, it also implicitly led to their immobility. The two issues are related and will be treated in Chapter III.

Anthony Scott

One year after Gordon's article appeared in the _Journal of Political Economy_, Anthony Scott published, in the same journal, an article which both utilized, and criticized the Gordon article. Several of Scott's points are of direct relevance and will be discussed below.

Scott opens his article with the famous line--"everybody's property is nobody's property," and points out as long as property rights are unspecified, no one will take the effort to husband the basic resource. He further maintains that the mere existence of private ownership is not sufficient to insure efficient management of natural resources. What is necessary is ownership on a scale sufficient to insure that one management body has complete control of the asset. His intentions in the paper cited are to show that "private property in fishing boats is not a sufficient condition for efficiency; sole ownership of the fishery is also necessary" (Scott, 1955, p. 116).

Scott disagrees with Gordon on the subject of diminishing returns. One of the fundamental assumptions in Gordon's bionomic model is that there are no diminishing returns in fishing, and hence no incentive to stop operations short of the equality of total costs and total value of landings. As Scott points out, in the short run, with fish population and equipment fixed, each fishing boat will experience increasing costs as it attempts to increase landings. To quote Scott:

> Gordon's analysis, which I have followed in Figure 1, relies upon the depletion of the population to produce a species of 'diminishing returns' effect that will explain, with price given, why the competitive fishery does not expand indefinitely. But this explanation applies only to the long run and cannot hold within a single season, when the fish population is one of the fixed inputs. In the short run, fishermen do not expand their catch indefinitely because they <u>do</u> experience increasing costs in attempting to increase their landings. Gordon depends upon the omnibus variable 'effort' to cover the changeable combinations of men, boats, and other equipment used by individual fishermen. But if we look through this omnibus variable, we see that in fact the short run situation in a fishery

> exploited by competing fishermen will be very [sic] like the standard situation in pure competition. The supply curve of this fishery (with the price given by the world market situation) will be made up by the addition of the relevant portions of the supply curves of the individual fishermen (Scott, 1955, p. 120).

Then Scott indicates that each will produce, or capture fish, until its supply price (marginal cost) is equal to the going price. Any surplus which might be captured is the usual quasi-rent, available to each boat by producing where marginal costs are equal to marginal revenue.

In comparing the present competitive exploitation with the sole ownership case, Scott maintains that if a sole owner were taking over for <u>one season</u> only, he would operate it in exactly the same way as they had, that is, where the marginal cost of fishing equaled the price of the product. Quoting from Scott:

> There is, however, one qualification of this assertion. If it were the case that competing fishermen were so numerous that boats got in each other's way, then the sole owner would rationally lay off some of the boats (and perhaps canneries and collecting boats) for the season. In this way he could reduce the external diseconomies of fishing. But, apart from this qualification (which is really a matter of the long run), the sole owner and competitive fisherman would in the short run operate the fleet identically, so that marginal cost equaled price and so that the marginal product of labor equaled the price of labor (Scott, 1955, pp. 120-121).

A second case under the short run situation is where the sole owner expected to have permanent tenure of the fishery, and here

Scott outlines some of the probable organizational changes. After these changes, Scott maintains he would still tend to operate where short run marginal cost equaled price. Thus, Scott concludes that the mere fact of sole ownership does not bring about a significant change in the exploitation of the fishery in the short run. Both the competitive fisherman and the sole owner will produce where price equals marginal cost. "Only if there is an opportunity for adopting alternative fishing techniques that reduce the investment necessary for a given output is there an argument in favor of sole ownership" (Scott, 1955, p. 121).

Before moving on to the long run case, Scott discusses the costs of variable factors--a point in reference to Gordon's concern for low opportunity cost of fishermen. Scott asserts that the cost of variable factors can be divided into cash costs and opportunity costs of the fishermen. The lower the opportunity costs, perhaps because of immobility, the greater the use of factors, regardless of whether the industry is competitive, or under control by a sole owner.

> The low opportunity costs do not provide a basic explanation of the inefficiency of competitive exploitation of fisheries; it is the inability to control the size of the fish population in the long run which does that. Hence, even in areas where relevant opportunity costs are high, as they are in the West Coast industry, we find more men and more rigs employed than would be employed in a 'monopolized' fishery (Scott, 1955, p. 121).

Scott continues:

> The price system, when it works well, does not depend only upon high opportunity costs to draw factors into the most productive employment. It also relies on employers dispensing with factors that are not needed; and our subject here is really the alleged failure of competitive fisheries to do this. Low opportunity costs are not relevant to the immediate problem. Where Gordon brings in the low opportunity costs of the industry, he drags in a red herring (Scott, 1955, pp. 121-122).

Scott thus rejects part of Gordon's "poverty hypothesis," yet continues to advocate the sole ownership concept so that industry profit can be maximized. Scott says what is needed is a long run concept. He utilizes the following diagram to expedite his discussion.

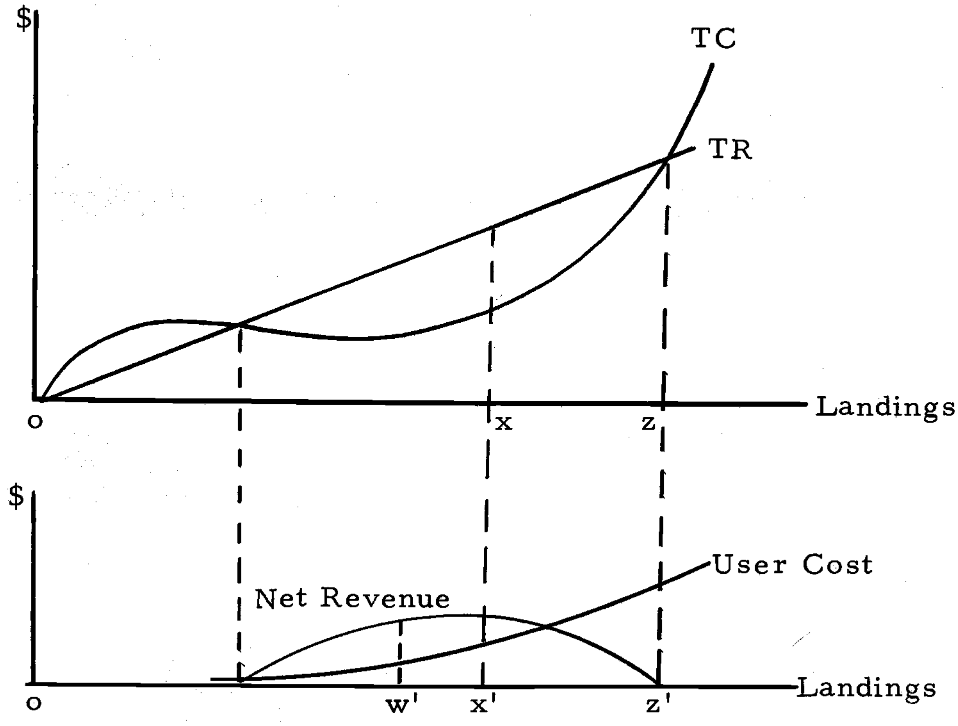

Figure 3. Total revenue and cost, net revenue, and user cost.

Scott maintains that under competitive fishing conditions, or under sole ownership, the tendency is to maximize net returns from the fishery by producing x, where marginal cost equals marginal revenue (price). This holds, however, only in the short run. Since the catch today influences the catch tomorrow, the sole owner will be interested in the optimum series of landings over a period of time. He will want to maximize the expected, present value of his property. This will be done by determining the effect of his marginal current output on this present value and by adjusting current output where marginal current net revenue is equal to marginal user cost. He thus succeeds in keeping the future returns from the fishery as high as possible while still maximizing current income (Scott, 1955, pp. 122-123).

This position is found at w', where the net revenue curve is parallel to the user cost curve. The user cost curve shows the effect of succeeding units of current output on the present value of the enterprise. Higher interest rates imply a lower value on future landings and a correspondingly lower user cost curve. If increased catch tends to diminish the population and hence reduce net revenue in future periods, the user cost curve will slope up more steeply, marginal user cost will equal marginal revenue at a lower level of landings, and the sole owner will cut back on landings. If increased output increased the population, net revenues in future periods would be enhanced, and the user cost curve would slope downward.

In conclusion, Scott asserts that the equilibrium position of the sole owner who maximized the expected present value of the fishery would correspond more closely to the social optimum than would the competitive equilibrium. Assuming that the rest of the economy is meeting the usual first and second order conditions for welfare maximization, Scott holds that the social optimum "in both the long run and the short run would demand that common-property resources be allocated to maximizing owners, associations, co-operatives, or governments" (Scott, 1955, p. 124).

J. Crutchfield and A. Zellner

Another popular argument is that presented by Crutchfield and Zellner which, by their own admission, follows that presented by Gordon (1954), Scott (1955), and Turvey and Wiseman (1957). Figure 4 is taken from Crutchfield and Zellner (1962) and is used to justify the conclusion that "overexploitation" is present in the fishery.

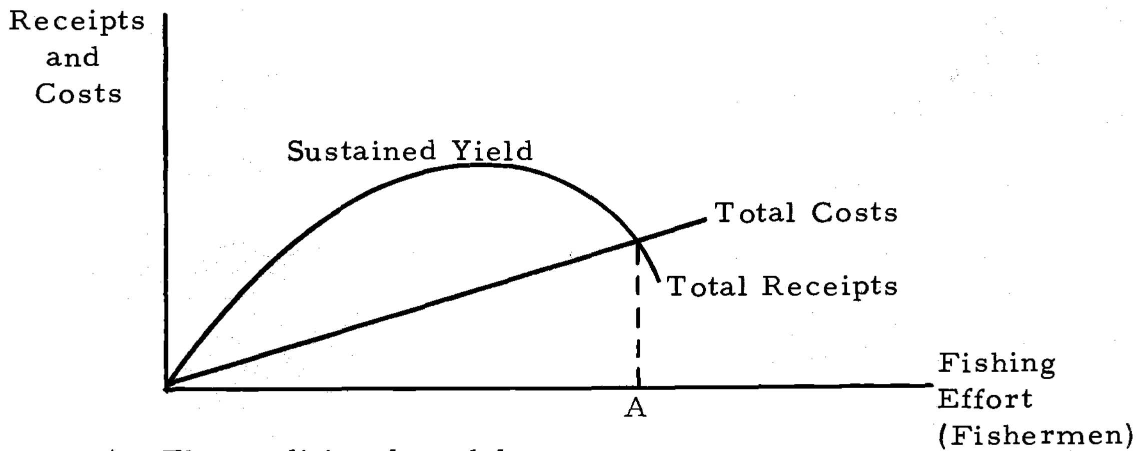

Figure 4. The traditional model.

The curvilinear function is labeled sustained yield and is thus said to represent a long run concept. It is also labeled total receipts. The linear function is labeled total costs. It is maintained by all of the above, that at any level of fishing effort less than A, excess profits (greater than opportunity return) are earned and vessels enter the fishery until A units of effort are being used. It is stated that at the levels of prices and costs assumed in Figure 4, uncontrolled exploitation of a common property fishery would lead to a smaller sustained physical yield than would be possible with less effort (and hence cost). They say this apparent violation of sound business practice is a direct result of the fact that the basic resource is not "owned" by any decision making unit.

> In technical terms, the rent that would normally accrue to the owner of a valuable resource, limited in quantity, is simply divided among all participating fishermen. With no restrictions on new entry, efforts to increase profits by reducing fishing effort, individually or collectively, would simply result in more vessels entering the grounds until all but necessary minimum profits are again wiped out (Crutchfield and Zellner, 1962, p. 15).

To quote Crutchfield and Zellner further:

> Leaving aside for the moment the problem of a precise definition of overfishing, a situation in which more fishing effort results in lower output, higher costs, and higher prices obviously makes no sense from the standpoint of producer, consumer, or the general public. The root of the problem lies in the simple fact that 'everyone's resource is no one's resource.' No single fisherman or group of fishermen has any incentive to restrict effort; to do so would merely

> result in capture of the fish by someone else. If price-cost relations are favorable, the 'unclaimed rent' on a fishery is simply dissipated in excessive effort, higher costs, and depletion of the stock (Crutchfield and Zellner, 1962, pp. 17-18).

It is further argued by Crutchfield and Zellner that the "...essential problem of fishery management is to provide the benefits of private ownership and use of the scarce fishery resources" (Crutchfield and Zellner, 1962, p. 18).

V. L. Smith

In 1964, Ralph Turvey published a paper which mentioned that the fishery exhibited external diseconomies among fishermen. Smith (1968), drawing upon the works of earlier writers, developed an elaborate mathematical model to illustrate how a sole owner would "internalize the externalities" present in a common property fishery. His article will be summarized here for two reasons; its rigor in mathematical terms makes it more specific than much of the other literature, and secondly, because this very rigor is destined to attract a wide following and hence have a significant impact on future policy concerning common property resource use.

The summary of Smith will consist of two parts; his formulation of the situation under a regime of competitive recovery, and the situation under centralized ownership and management of the fishery.

Competitive Recovery

Smith assumes that recovery from a given resource is accomplished by K homogeneous firms or units of capital, each producing an output rate, x. Total industry output is then Kx, where both K and x are variables. The biological restriction is that total catch, Kx, equal the surplus production [f(X)] from the standing parent population, or $Kx = f(X)$. Smith lets p(Kx) be the total revenue from the sale of Kx units of output, and thus revenue per firm is p(Kx)/K. His general cost function of each individual firm is,

$$C = \phi(x, X, K) + \hat{\pi} \tag{2.1}$$

where X is the fish population, and $\hat{\pi}$ is the normal profit or return required on a unit of capital to hold it in the industry. Smith then asserts that the general form of the firm's pure or excess profit function is:

$$\pi = \frac{p(Kx)}{K} - C(x, X, K) \tag{2.2}$$

It is assumed that each firm views this profit to vary only with its own output. Price is thus treated as a given constant, p(Kx)/Kx, and C(x, X, K) is a function only of the private control variable, x.

To maximize profit, each competitive fisherman will equate the constant price to his respective marginal cost:

$$\frac{p(Kx)}{Kx} = \phi_1 (x, X, K) \qquad (2.3)$$

Smith asserts that new firms will be attracted into the industry when $\pi > 0$, while existing firms will be driven out when $\pi < 0$. He says this capital flow is proportional to pure profit, or:

$$\dot{K} = \delta [\frac{p(Kx)}{K} - C (x\ X, K)] \qquad (2.4)$$

where $\delta > 0$ is a behavioral constant for the industry. He then says that the behavioral equation system for the industry is,

$$f(X) = Kx \qquad (2.5)$$

$$\frac{p(Kx)}{Kx} = C_1 (x, X, K) \qquad (2.6)$$

$$\dot{K} = \delta [\frac{p(Kx)}{K} - C (x, X, K)] \qquad (2.7)$$

where $\dot{K}$ is the rate of change of capital in the industry, and equation (2. 5) is the above mentioned equality of total catch, and surplus fish. Equation (2. 6) is the price equals marginal cost condition for the individual firm, and equation (2. 7) relates the change in vessel numbers to the profit level of the typical vessel.

Centralized Fishery Ownership and Management

Smith says:

> In the literature of fishery economics the important papers by H. Gordon and A. Scott have emphasized the advantages of unified management or 'sole ownership' of the fishing grounds as distinct from the unregulated decentralized exploitation of the resource. Sole ownership permits the social costs of production to be borne privately with

> the result that the private producer has the incentive to manage the resource in the interests of society as well as his own (Smith, 1968, p. 425-426).

Ignoring the usual divergence between private and social time preferences with respect to resource use, Smith develops a model of centralized management.

His first assumption is the familiar one made in the works he cites: that there are enough fishing grounds such that centralized ownership does not introduce monopoly elements. He says this assumption is unnecessary but makes the arithmetic simple.[6] Under centralized management $\underline{x}$, X, and K will all be decision variables subject to control by the manager. Now the profit function for a given fishery is given by:

$$\pi = pKx - KC(x, X, K) \qquad (2.8)$$

This is to be maximized with respect to $\underline{x}$, X, and K, subject to the biological constraint that $f(X) - Kx = 0$. The Lagrangean is therefore,

$$W = pKx - KC(x, X, K) + \lambda[f(X) - Kx] \qquad (2.9)$$

To maximize profit, he would form:

$$\frac{\partial W}{\partial x} = pK - KC_1(x, X, K) - \lambda K = 0 \qquad (2.10)$$

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[6] This assumption will be seen to make a difference in the analysis in later chapters. Smith and the other traditional writers also assume that the cost curves of a sole owner are identical to those of the competitive industry. This is a common fallacy made in graphical "proof" that monopolized industries restrict output compared to competitive situations.

$$\frac{\partial W}{\partial X} = -KC_2(x, X, K) + \lambda f'(X) = 0 \qquad (2.11)$$

$$\frac{\partial W}{\partial K} = px - KC_3(x, X, K) - C(x, X, K) - \lambda x = 0 \qquad (2.12)$$

$$\frac{\partial W}{\partial \lambda} = f(X) - Kx = 0 \qquad (2.13)$$

and solve the first three equations for $\underline{x}$, X, K, subject to the constraint that $f(X) = Kx$.

Smith rewrites the four equations in the following manner, retaining their order from above:

$$\frac{\partial W}{\partial x}: \quad p - C_1(x, X, K) = \lambda \qquad (2.14)$$

$$\frac{\partial W}{\partial X}: \quad \lambda = \frac{KC_2(x, X, K)}{f'(X)} \qquad (2.15)$$

$$\frac{\partial W}{\partial K}: \quad p - \frac{C(x, X, K)}{x} - \frac{KC_3(x, X, K)}{x} = \lambda \qquad (2.16)$$

$$\frac{\partial W}{\partial \lambda}: \quad f(X) = Kx \qquad (2.17)$$

By way of interpretation, Smith offers approximately the following:

(a) The Lagrangean multiplier, λ, is the marginal profitability of the total fleet catch;

(b) Equation (2.14) requires that the marginal profitability of increasing catch by intensive use of the fleet (increasing $\underline{x}$) be equal to the marginal profitability of total fleet catch;

(c) Equation (2.15) indicates that the marginal profitability of the catch from the total fleet equals the marginal "external or social cost of the fleet catch;"

(d) Equation (2. 16) requires the marginal profitability of the total catch from fleet expansion to equal λ, the marginal profitability of the total fleet catch;

(e) Equation (2. 17) is the same constraint on total catch.

Also, $C_1(x, X, K)$ is the change in costs per boat with respect to a change in individual boat output, $C_2(x, X, K)$ is the change in costs per boat with respect to a change in fish population, X, and $C_3(x, X, K)$ is the change in costs per boat with respect to a change in the number of boats in the fleet, K. Smith asserts that when $C_2(x, X, K)$ is < 0, there are stock externalities, and when $C_3(x, X, K)$ is > 0, there are vessel crowding externalities.

Smith explains equation (2. 15) this way: an increase in catch will tend to lower the fish mass and thus contribute fishing costs external to the individual boats. Under competitive harvesting, $KC_2(x, X, K)/f'(X)$ is a social cost which does not affect firm behavior.[7] Under his idea of centralized ownership, this cost is "privatized" when property rights are vested in a central manager-owner who adjusts his operations according to the system given by

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[7]It is interesting to speculate about Smith's "social cost" when $f'(X) \geq 0$. For protection, and to insure that $f'(X) < 0$, Smith maintains that a sole owner would not permit $f'(X)$ to be anything but < 0. His "proof" does not obviate the fact that under competitive exploitation, $f'(X)$ can be greater than, equal to, or less than zero. Since $C_2(x, X, K) < 0$, this implies that when $f'(X) > 0$, "social costs" are negative (i. e. "social benefits"), and when $f'(X) = 0$, "social costs" are undefined (i. e., infinity). See Chapters IV and VI, and footnote 17, Chapter IV.

equations (2.14) through (2.17). When this system is adhered to, the owner is accounting for social costs.

It is also maintained that the sole owner will adjust boats according to equation (2.16). Multiplying (2.16) through by $\underline{x}$, px is the gross marginal revenue from an additional vessel, $C(x, X, K)$ is the long run direct internal cost, while $KC_3(x, X, K) + \lambda x$ is the long run marginal external social cost of operating an additional vessel. Therefore, an addition to the fleet supposedly produces external crowding cost at the rate $KC_3(x, X, K)$, and external fish scarcity cost at the rate λx.

Finally, Smith maintains that to "correct" the competitive exploitation case, it is only necessary to make the system in equations (2.5) through (2.7), comparable to the system in equations (2.14) through (2.17). It is also necessary to insure that $\dot{K} = 0$ and that $f(X) = Kx$. To Smith, the two systems differ only in that the sole owner perceives a unit catch cost, $\lambda = KC_2(x, X, K)/f'(X)$, and an annual boat cost, $KC_3(x, X, K) + \lambda x$, which is not incurred by the competitive fisherman.

He than states that it is only necessary to impose these unperceived costs on the industry. The partial equilibrium solution, to Smith, is then to levy an extraction fee, $U = KC_2(x, X, K)/f'(X)$ per unit of catch unloaded at the wharf, plus an annual license fee, $L = KC_3(x, X, K)$ on each fishing vessel. Thus, the after-tax profit function of each competitive vessel is :

$$\pi^{*} = px - C(x, X, K) - L - Ux \qquad (2.18)$$

Taking partials with respect to this function, Smith obtains the following system:

$$f(X) = Kx \qquad (2.19)$$

$$\frac{\partial \pi^{*}}{\partial x} : p - C_1(x, X, K) = U \qquad (2.20)$$

$$\frac{\partial \pi^{*}}{\partial K} : p - \frac{C(x, X, K)}{x} - \frac{L}{x} = U \qquad (2.21)$$

Now this system is said to be identical with that presented in equations (2.14) through (2.17), provided the regulating authorities can set the taxes at the optimizing values satisfying equations (2.14) through (2.17).

To sum up the position of the traditional writers in fishery economics, sole ownership of the resource and centralized decision making is the only way to eliminate the "inefficiencies" currently present in a common property fishery. The following chapter presents a discussion of some of the conclusions derived by these writers.

III. RENT, RESOURCE ALLOCATION, AND ECONOMIC EFFICIENCY

The present chapter is devoted to investigating certain aspects of the traditional models and some of the conclusions derived therefrom. This will serve to fulfill objectives (1) through (4), as outlined in Chapter I.

In the first section (Rent Maximization and Net Social Benefits), the conclusion of traditional theorists that maximization of industry profits is a desirable social goal will be discussed. In the second section (Rent Maximization and Resource Allocation), the rudiments of resource allocation theory will be outlined briefly. In addition, an hypothesis of factor returns in the fishery will be developed. This section is aimed at accomplishing objectives (2) and (3). The final section (The Traditional Model) will focus attention on several weaknesses of the model used by traditional theorists. The aim of this section is to meet objective (4). The conclusions of this section, as well as those of the preceeding sections, provide justification for an attempt to develop a more precise model of a common property situation. Chapters IV, V and VI are devoted to the development of this revised model and will fulfill objectives (5) through (8).

Rent Maximization and Net Social Benefits

As has been indicated, the goal of traditional theorists is to maximize the difference between industry[8] costs and industry receipts. This is claimed to represent rent to the fishing ground. In actuality, it represents higher-than-competitive returns to those firms not excluded from the ground; that is, it is economic rent, or pure profit. The models used by traditional theorists place emphasis on the wrong variables; it is not the number of firms in an industry which is relevant from a social point of view, it is the output of that industry which is either socially correct or incorrect. Similarly, it is not industry profit, plotted as a function of the number of firms in the industry ("fishing effort"), which is relevant, but net social benefits.

Consider the following commodity for which D represents the aggregate demand curve.

If Q_o were produced in a given period, total revenue received by the producers would be OQ_oCP_o. If the industry producing this commodity were a perfectly competitive one, then the difference between industry costs and industry receipts is zero. Yet, the net

[8]The term "industry" is here referring to the group of vessels engaged in catching a given species of fish from a common area. "Fleet" would apply equally well.

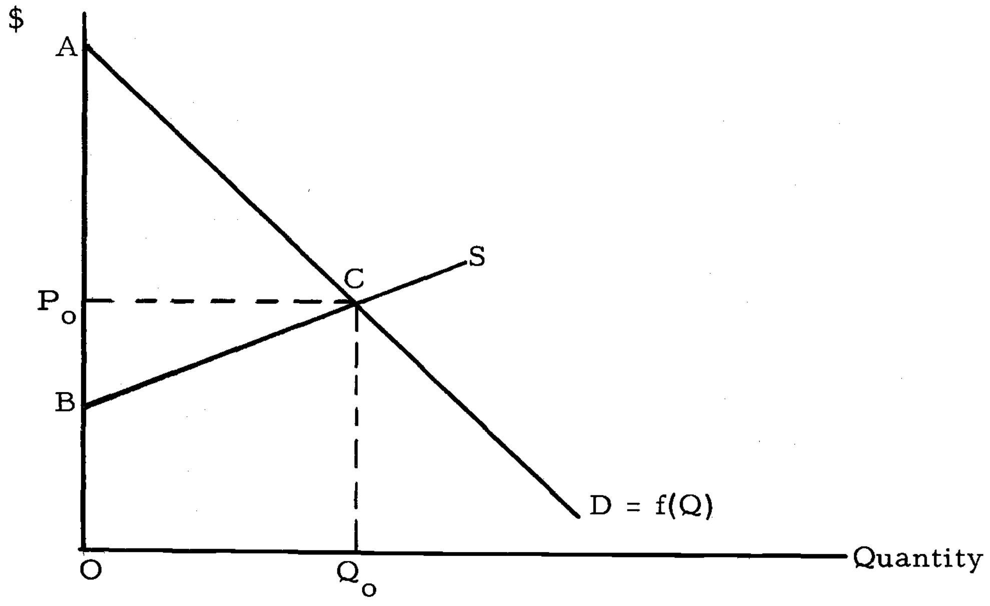

Figure 5. Net social benefits.

social benefit from this commodity could be said to consist of the consumer's surplus ($P_o CA$). The total evaluation of the commodity is OQ_oCA, but consumers had to forego OQ_oCP_o to obtain it.

That is, total willingness to pay is given by:

$$\int_0^{Q_o} f(Q)\,dQ \qquad (3.1)$$

while net social benefits are:

$$\int_0^{Q_o} f(Q)\,dQ - (OQ_oCP_o) \qquad (3.2)$$

Since it was assumed that all firms in the industry were of equal efficiency, the portion of the supply curve from B to C does not exist and the supply curve is actually given by the line segments

OP_o and CS.

It would thus appear that a realistic social goal is not the maximization of industry profits. While under certain limiting assumptions[9] it can be said that society will be better off when net social benefits are maximized, it is not so that society is made better off by restricting entry to an industry so that its profits are maximized. Turvey (1964), has defined the optimum optimorum as being reached when "the excess of the value of the catch to consumers over the value to them of the alternative goods and services sacrificed by devoting resources to fishing" is maximized. That is:

$$G = (TR + S) - (TC - R)$$

where: TR is the total payment to the industry for the product (total industry revenue);

S is the consumer's surplus;

TC is the value of goods and services sacrificed by society to obtain the fish; and

R is the rents going to the intramarginal resources in the fishery.

Hence, TR + S is equal to total willingness to pay as defined in equation (3. 1), and TC is given by the area OQ_oCPo in Figure 3. Turvey's "G" is thus seen analogous to net social benefits. This

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[9]One of the most important assumption is that income distribution be optimal. There is mounting evidence that this is not the case.

would seem to be a more proper maximand than industry profits.

The supposed rationale for maximizing profits on each fishing ground is that each small ground assumes the role of the fixed factor in the usual analysis, and variable factors (in this case boats) are then applied in a fashion such that the net return to the fixed factor is maximized. However, even were it correct, would it be possible and economically efficient to maximize profit on each small fishing ground?

While Gordon is quick to point out that demersal fishes are often morphologically unique from their neighbors, the feasibility of defining, assigning, marking, managing and policing each small ground is very likely in question; the costs of such a program would very likely outweigh the benefits. In addition, the restricting of boats is being advocated now on a general basis; it is no longer being recommended for only demersal fisheries. A model derived for a very specific problem has been generalized to a considerable degree.

The economic efficiency of such a scheme may also be questioned. The ocean is a vast, complex ecosystem and the social desirability of managing large numbers of very small grounds in an atomistic profit maximizing context can be questioned on economic, as well as ecological grounds. Since no ground or species can be managed or controlled in isolation, similarly, socially desirable fisheries management is not accomplished atomistically, but as a part of the larger ecosystem.[10] Overt profit maximization on each small fishing ground could result in altered predator-prey relationships such that one or several presently valuable species could be endangered.

Rent Maximization and Resource Allocation

The model used by traditional writers permits them to derive three rather curious conclusions, and observations of the real world seem to provide the necessary "proof." It is the intent here to investigate these three conclusions and hence question the appropriateness not only of their model, but the validity of their argument.

Anthony Scott (1957) maintains that fishermen are paid according to their average value product, while workmen in all other occupations receive their marginal value product. Scott Gordon (1954) maintains that the common property fishery causes fishermen to be poor, immobile, and receive less than their opportunity wage. Christy and Scott (1965) maintain that the production of goods and services for society as a whole is reduced because of "excess" numbers of fishermen. All conclusions are "supportable" by observation of actual phenomena. It will be instructive to explore these allegations.

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[10]That is, grounds which are ecologically interdependent, are also economically interdependent.

Factor Returns

Scott (1957) used the following diagram to "prove" that excessive labor is hired in the fishery, and that instead of receiving its marginal (value) product, it recieved its average (value) product.

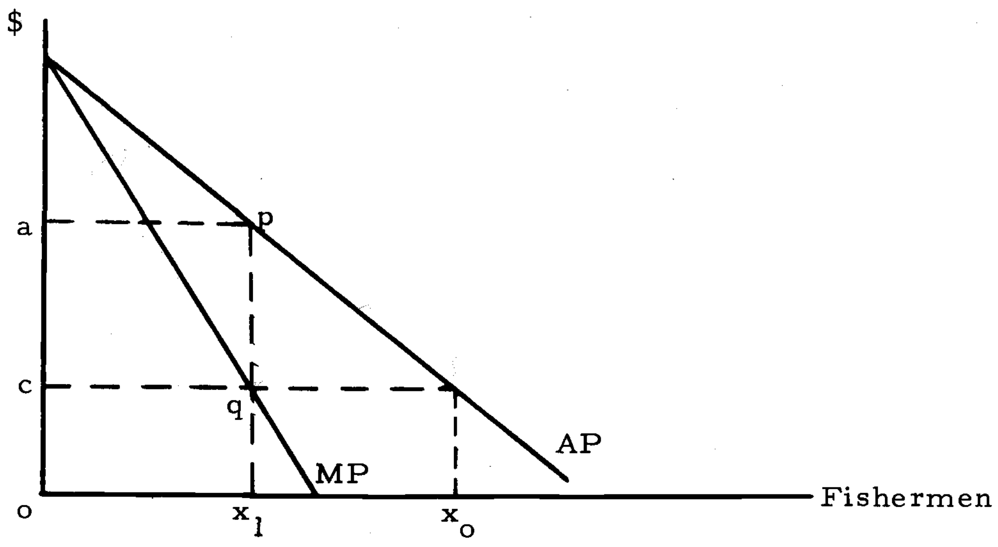

Figure 6. Labor use in a common property fishery.

In Figure 6, the same variables are shown as in Figure 4 but in terms of revenues and costs per fisherman rather than for all fishermen taken together. Scott maintains that labor continues to enter until its average (value) product is equal to its wage, c, which is the marginal (value) product of labor in all other occupations. Notice that if Scott is correct, this would imply added labor actually diminishes total product. While it is difficult to conceive of fishermen entering the fishery with negative productivity at the margin, Scott's diagram illustrates just that situation.

It is difficult to prove that labor in the fishery is not paid according to its average product but it would seem that the following discussion is more helpful in this regard than is a diagram such as Figure 6.

Poverty, Immobility and Social Inefficiency

The charges of Gordon (1954) and Christy and Scott (1965) will be treated simultaneously in this section. First, the rudiments of resource allocation theory will be presented. Following this, a modification of classical resource allocation theory will be developed. With this basis, the related arguments that fishermen are poor, immobile, and cause the production of goods and services (G. N. P.) to be lower than it need be, can be evaluated in a fairly thorough fashion.

Assuming some degree of "full employment," the principle of equimarginal returns implies that the value of the marginal product (VMP) of a productive factor will be everywhere equal. That is, the VMP of an hour's worth of work from a given productive factor is the same in all occupations. This condition can be expressed mathematically as:

$$MPP_{XA} P_{A} = MPP_{XB} P_{B} = MPP_{XC} P_{C} = \cdots = MPP_{Xn} P_{n} \quad (3.3)$$

where MPP_{XA} is the marginal physical product of X in producing commodity A, and P_B is the market price of A. Alternatively, this can be written as:

$$VMP_{XA} = VMP_{XB} = VMP_{XC} = \cdots = VMP_{Xn} \qquad (3.4)$$

If the demand for good B increases, the price of B (P_B) will rise, increasing the VMP of X in producing B. When this happens, factor X will be attracted away from producing goods A, C, D, $\cdots$ n and move into industry B. Eventually, output of B increases enough such that its price falls, causing the VMP of X in producing B to fall, and some units of X move back into their former occupation. The freedom of factors to move to their highest paying opportunity is the very essence of a perfectly competitive economy; and it is from this that efficiency arises. For if a factor is not productive in a given occupation (low MPP), or the product which it is currently producing is in little demand (low price), the factor will leave of its own volition and move to those industries where it is more productive, or whose goods are in greater demand. In this manner, factors move into those occupations which produce goods that are in demand (incentive stems from product price) and into those occupations where they have a comparative advantage (incentive stems from differential MPP among industries).[11]

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[11]The above assumes zero transfer cost. If this cost is non-zero, then the increment in value from shifting a marginal unit of a factor from industry A to B must equal the cost of this shift.

While the above treatment outlines how factors are allocated in theory, the actual allocation occurs in such a fashion that the theory requires some modification. As should be obvious, transfer costs are not zero, and all factors are not perfectly mobile. Some work in the field of agricultural policy is instructive in this regard.

In American agriculture, the demand for food and fiber increases rather proportionately to increases in population, while improvements in technology cause output to increase at a rate faster than population growth. The result, to some at least, is that "too many" farmers are producing "too much" such that the share each gets of total agricultural income is "too small." Likewise in the fishery, with total harvest of a given species somewhat fixed, it is said that there are "too many" sharing the resource and hence each receives "too little." Incomes in both industries could be raised (for those remaining) if restrictions were put on entry into each. Restricting a person's right to be a farmer is not very likely; restricting a person's right to become a commercial fisherman has been recommended[12] and, as seen in Chapter II, is widely advocated.

While there are those who believe that society would be better off if some of the "excess" farmers or fishermen were prevented from entering their respective occupations, there are many

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[12] The "grandfather" clause referred to in Chapter I.

economists who believe that the production of goods and services would not be increased by the out-migration of marginal farmers, and the reason is best explained by the fixed-asset theory.

Agricultural economists have long been puzzled by the way in which the agricultural industry, in aggregate, misbehaves; that is, in periods of falling output price, total output increases and, theoretically, it should not. There have been many suggestions as to why this happens but the most plausible, and the best accepted explanation has been advanced by Glenn L. Johnson.

Johnson started with a dissatisfaction with the way in which neoclassical economic theory defines a fixed asset or a fixed cost--basing it largely upon the length of expected life of the asset. Thus Johnson defined a fixed asset as one for which the marginal value product in its present use neither justifies acquisition of more of it, nor its disposition (G. L. Johnson, 1958, p. 78 ff).

An integral part of asset fixity in agriculture is the concept of an acquisition cost and a salvage value. The acquisition cost is what a farmer (or the industry) has paid (or would have to pay) to acquire a given input (asset). The salvage value is what the farmer (or the industry) could get for the input (asset) if it were disposed of.

As pointed out by Hathaway, where acquisition cost for one or more inputs is greater than salvage value, there are many cases where there would be no incentive to change the quantity of inputs used, and hence, output. These are situations where no gain in social efficiency will be realized by transferring resources out of agriculture--once the asset is fixed in agricultural production. Only where earnings at the margin equal acquisition cost is the value related to efficiency equal to value relating to the concept of equimarginal returns. Thus, only when earnings equal acquisition costs can the situation in agriculture be defined as representing equilibrium. Other situations where earnings are less than acquisition costs, even though they represent points where no changes may occur, are defined as disequilibrium (Hathaway, 1963, p. 117).

For durable inputs in both agriculture and the fishery, this concept has intuitive appeal. A tractor, a combine, or a fishing boat have little usefulness outside of their respective industries.[13] Scott recognized the problem for the fishery when he said that the competitive fishery allegedly does not dispense with "unneeded factors" (Scott, 1955, p. 122). But, given the high probability of a wide divergence between acquisition cost and salvage value with the kinds of equipment listed above, it is no wonder that boats, once in the fishery, tend to remain, just as tractors and combines, once in agriculture, tend to remain; and not to remain idle, but to be used.

Given the importance of labor in both agriculture and the

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[13]The salvage values would be higher in other similar operations than they would be out of fishing or farming completely.

fishery, it is necessary to explain the fixed asset concept for human inputs. According to Hathaway:

> For an individual engaged in farming the acquisition cost is the opportunity cost of the income foregone by not entering another occupation at the time he entered farming. Thus, for a forty-year-old farmer, it is the earnings of forty-year-olds in other occupations requiring comparable abilities. For new entrants into agriculture at a specific point in time, the relevant acquisition cost is the opportunity cost of other potential income which is foregone. Thus, allowing for skills, preferences, etc., it is the wage which would induce an individual to work in agriculture rather than elsewhere, assuming he has other alternatives open to him (Hathaway, 1963, p. 120).
>
> The salvage value of labor from the agricultural industry is essentially the earnings that are available to farm people in other industries. Because the specialized skills in agriculture have little or no value in other industries, farmers who want to leave agriculture can rarely command the wages of experienced nonfarm workers (Hathaway, 1963, p. 120).

Hathaway points out that the divergence between acquisition cost and salvage value for labor is relatively small for the young people in agriculture, but that it increases as a function of time.

The above discussion would seem to provide a framework within which the charges of poverty, immobility, and unnecessarily low G. N. P. can be analyzed.

As seen in Chapter II, Gordon concluded from his model that fishermen often received less than opportunity incomes, even lower than workers in less hazardous and specialized occupations. Yet in advancing such a claim, Gordon is overlooking the fact that the salvage value of fishermen is most likely much below their acquisition cost. The VMP of a fisherman is therefore not the earnings of similar aged men in other occupations requiring comparable skills, his VMP is the earnings of fishermen in other industries. Since fishermen tend to be rather old, and because their training is in a specialized skill, their salvage value in monetary terms is quite low. Fishermen are not the only occupational groups with low salvage value, but to state that because of common property they receive less than "opportunity" income, would appear open to question.

Allied with the above is immobility. In addition to a low salvage value, fishermen are indeed, romantically tied to the sea. Their "gambler's instinct" adds to this immobility. But to say that common property is to blame may be stretching the point somewhat. Restricting fishermen in the name of efficiency is difficult to justify but when equity is considered, one cannot say, a priori, what is the social ideal without making reference to income distribution.

A related point regarding immobility of fishermen would appear appropriate. While Gordon says that fishermen are "one of the least mobile of occupational groups," consider other groups of entrepreneurs. It has been said that farmers "live poor, but die rich," which is another way of saying that while current cash income of many farmers may be low, the appreciation of land holdings provides a sizable inheritance for their survivors. Thus, although current earnings may be low, the opportunity for maintaining the asset in the family is usually a significant incentive for immobility in agriculture. In contrast, the fisherman has no such incentive; he gains nothing in the long run from remaining in the fishery.[14]

The final point, and one closely related to the above, is that society in general would benefit by restricting fishing vessels. To quote Christy and Scott:

> The goal of economic efficiency can be approached by preventing excessive entry into the industry, so that those who fish would be producing the maximum net economic revenue (to be shared by them, or appropriated by the public) and so that those who are prevented from participating will be able to produce other goods and services valued by the community (Christy and Scott, 1965, p. 11).

The earlier analysis should provide a basis upon which to question this conclusion. If society valued "other goods and services" more than fish, the VMP of labor in these activities would increase such that the salvage value of fishermen exceeded their present earnings. When this happened, fishermen would voluntarily leave the fishery. As long as acquisition cost is greater than salvage value, there is no incentive to change occupations, and it is these situations where there is no gain in social efficiency (production of "other goods and services") resulting from transferring resources out of the

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[14] In fact, agriculturalists are one of the few groups to hold an asset which is in an absolute fixed quantity, and hence reap gains from increased demand for land.

fishery.

The Traditional Model

The final section of this chapter is devoted to raising several basic questions with the models used by traditional theorists. The models are founded upon several very restrictive assumptions which significantly alter the correctness of conclusions derived from them; yet they have gained widespread support in the realm of public policy making. In addition to what is assumed, it would appear that more significant variables are excluded from the models than are included. A clarification follows.

The first weakness would seem to be the lack of any specified demand conditions for the product of the fishery. Demand is assumed infinitely elastic, yet as Hutchings (1967) has shown, a slight deviation from this assumption causes the conclusions to be altered. Figure 7 is taken from Hutchings and depicts four total revenue functions, all from the same physical yield function, derived by allowing elasticity of demand to assume four levels. Notice that the notion of a "social optimum" would be less clear if demand were not assumed infinitely elastic.

A second point relates to the nature of the model itself. In any one season, the relationship between total catch of the fleet and effort would resemble that depicted in Figure 8.

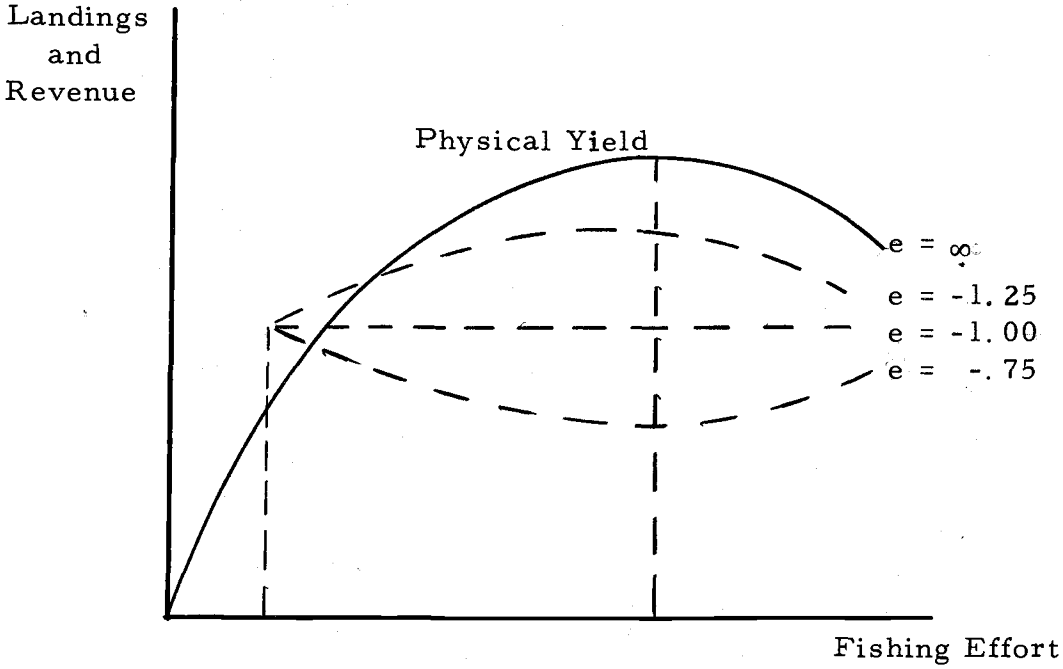

Figure 7. Total revenue under four different assumptions of demand elasticity.

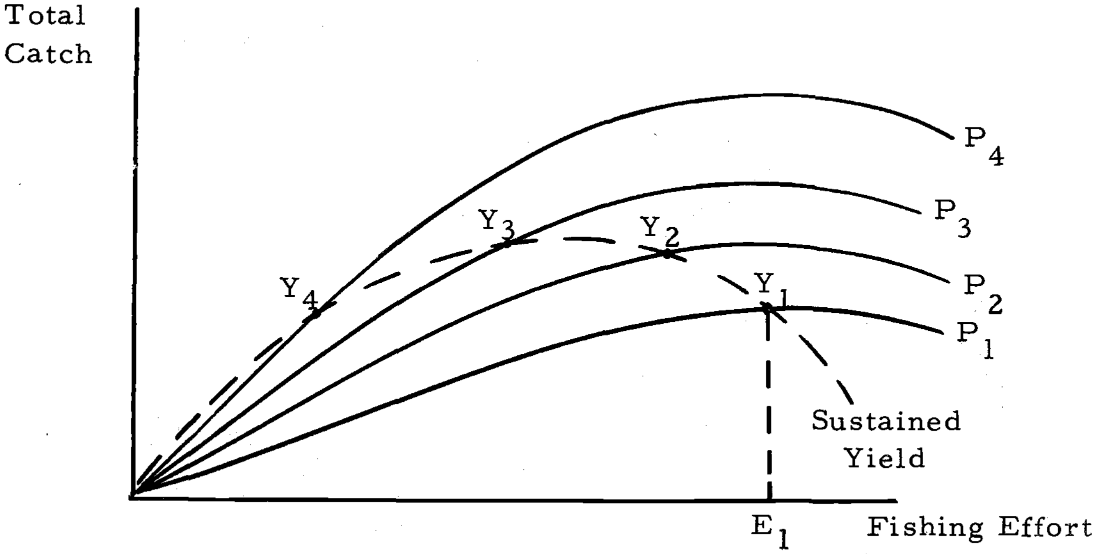

Figure 8. Total fleet catch under four levels of population.

For large populations (P_4), a given level of effort will result in a larger catch than if the population were smaller (say P_1). Associated with each level of population, there is a unique sustained yield.[15] For large populations (P_4) this sustained yield is relatively small (Y_4). At smaller populations (P_3), the sustained yield is larger (Y_3), but as the population approaches a certain level, its ability to produce a harvestable surplus is inhibited. At smaller populations (P_2 and P_1), the sustained yield is reduced (Y_2 and Y_1 respectively).

The locus of sustained yields for each population level is drawn in Figure 8 and it is this function which the traditional theorists multiply times price to call total revenue. That is, consider Figure 9.

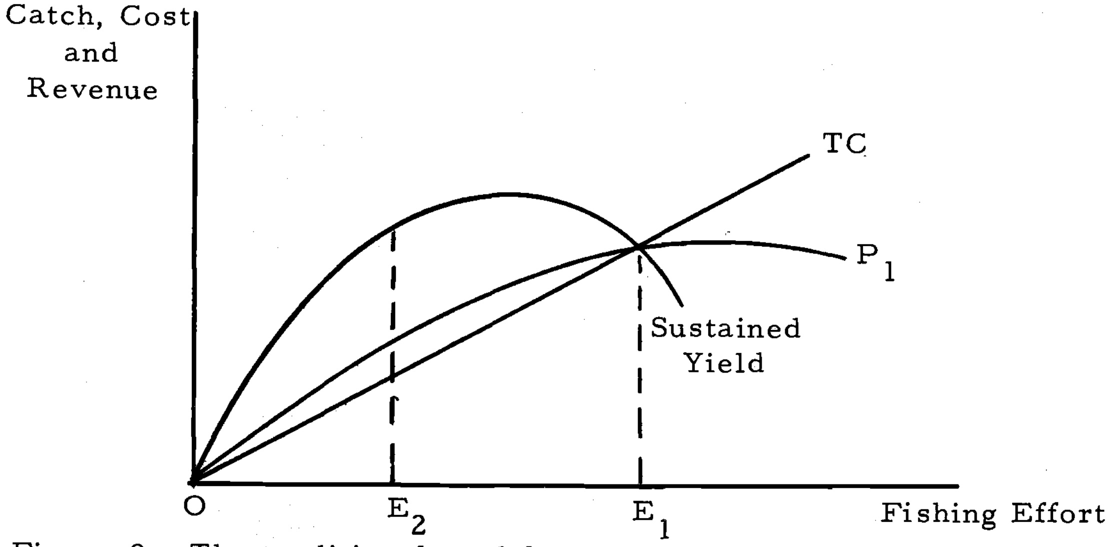

Figure 9. The traditional model.

[15]See Chapter IV.

This is the usual manner in which the model is drawn and the conclusion is therefore made that competitive exploitation of a fishery "inevitably" leads to overfishing, and reduced sustained yield. If "rent" were maximized, only E_2 units of effort would be used and sustained yield would be increased. Yet this simple and straightforward conclusion ignores the fact that there is a whole series of fish populations represented by the sustained yield curve. To make static "maximizing" recommendations based on a long run curve could be open to question.

Assume that E_1 units of effort are currently engaged in the fishery and that the fleet is operating along P_1, in Figure 9. The traditional theorists would conclude that marginal productivity (or revenue) from increased effort is negative, yet along P_1, the added increment from effort is actually positive.

A related point concerns the arbitrary assumption of costs in the fishery. If Figure 10 is followed, "uncontrolled exploitation" results in a larger sustained yield (Y_0) than if effort were restricted to E_2.

While it is recognized that maximizing sustained yield is not a valid economic criterion, maximizing industry profit could harm consumers by restricting output from Y_0 to Y_1. Not only would consumers receive fewer fish, they would have to pay a higher price. While it is not possible to pass precise judgement on the efficiency and

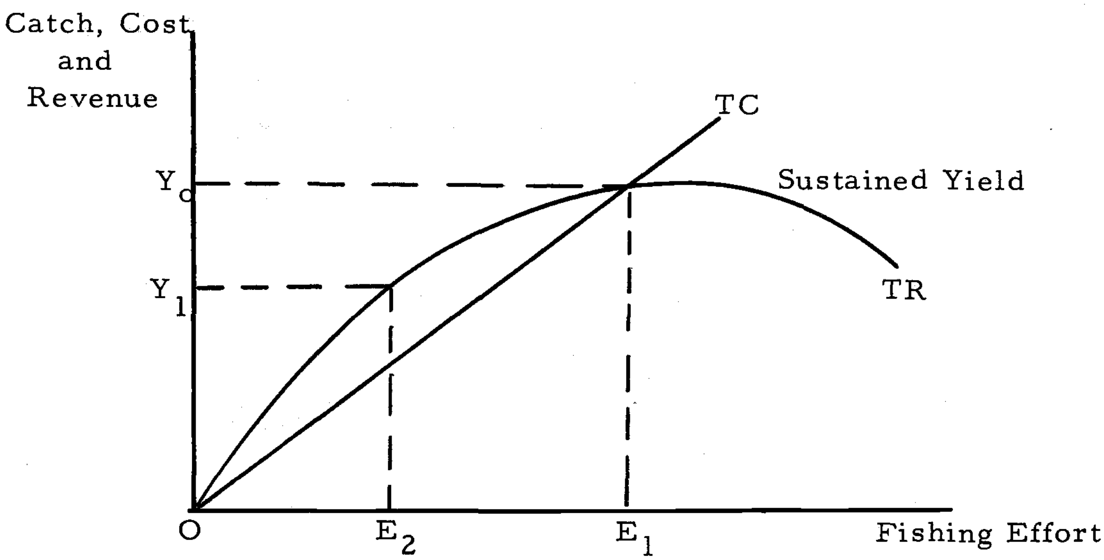

Figure 10. The "traditional model" with a different level of costs assumed.

equity aspects of these changes, the model employed gives no indication of changes in producer's and consumer's surpluses and hence, even first approximations are impossible.

Perhaps the most important aspect of the fishery, yet one which only Turvey (1964) and Smith (1968) mention explicity, is that of productive interdependence. Physical interdependence among firms causes unique economic problems with which the standard models cannot cope. Smith (1968), recognizing interdependence, was seen to use the traditional recommendation of sole ownership to derive his taxes but failed to thoroughly investigate the nature of this interdependence. Chapter VI will make this point clear.

Another weakness, and one mentioned earlier in this chapter, is that, except for Turvey (1964), none of the works speak of social benefits and social costs; the sole maximand is industry profit. Consider the following from Christy and Scott:

> One of the unique characteristics of a common property natural resource, such as the fishery, is that the amount of effort applied is not subject to the restraints that govern the exploitation of a solely owned resource. The individual user of a common property resource is usually in physical competition with all others in his attempt to get a larger share of the product for himself. It is unreasonable to expect an individual producer to willingly and onesidedly restrain his effort; anything that he leaves will be taken by other producers. Furthermore, in the fishery there is no limit on the number that can participate so that as long as there is any profit to be gained, additional producers will enter the industry until all true profit (or rent) is dissipated. With such conditions, with demand increasing, and without controls, it is inevitable that the fishery will not only become depleted but also that the exploitation of the fishery will become economically inefficient in its use of labor and capital (Christy and Scott, 1965, p. 7).

Notice the emphasis on industry profit. Consider the following from Crutchfield and Zellner:

> If the fishery is regarded as a public resource, open to all, the level of fishing effort will tend toward OA in Figure 4 [OE_1 in Figure 9]. At this point, total receipts just cover total costs (including a minimum necessary return to the vessel owner). At any lower level of fishing effort, profits in excess of this would be earned, and vessels would enter the fishery. At higher levels, returns would not cover total costs, and fishing effort would be curtailed. Some vessels would be diverted to other operations, and the usual reduction in number of vessels due to depreciation and losses would not be fully replaced. Obviously, any increase or decrease in prices received by fishermen, whether caused by an increase in retail demand or a reduction in the cost of marketing services, would increase or decrease fishing effort.

> Similarly, increases or decreases in fishing costs would restrict or stimulate fishing activity (Crutchfield and Zellner, 1962, p. 14-15).

Or, from Christy and Scott again:

> The tendency of a common property resource, such as a fishery, to become 'depleted' is therefore a consequence of the absence of any economic restraint on effort. There is also a severe economic consequence. This is that there will tend to be an excessive amount of capital and labor applied to the fishery. The fishermen are operating as individuals, each seeking to maximize the difference between his revenues and his costs. But because there are no restrictions on the number of fishermen that can enter the industry, <u>any</u> true profit will attract additional fishermen. This will mean that the total revenues will be shared by more and more producers until no true profit at all remains to be distributed. For the entire fishery, the fleet's revenues will just equal costs, so that the revenues and costs of the average fisherman will also be equal (Christy and Scott, 1965, p. 9-10).

The striking aspect of the above positions is that the same phenomenon regarding individual profit seeking is a trait common to all open, competitive industries. The equality of total industry costs and total industry receipts is not a sufficient condition for arbitrary restrictions on entry into the fishery. Firms enter any industry (if they can) until total industry costs equal total industry receipts, and there are no industry profits. To restrict entry into an industry so that group receipts are held above group costs is to deny that the competitive equilibrium results in the most efficient use of social resources.

The final shortcoming of the traditional models is their static nature. Although sustained yield is plotted against fishing effort, there is no indication of fish population, the influence of population upon costs, or the level of sustained yield from one period to the next. The models are not even of the comparative statics type since no indication is given as to relations between time periods.

In conclusion, it would seem that enough justification exists to warrant the development of a more explicit and operational bioeconomic model of the fishery. The traditional models were seen to place total emphasis on the relation between the number of firms in the fishery, and group profit; claiming this profit somehow represents net social benefits. The models also permitted their advocates to advance several very questionable conclusions about the effects of common property on resource allocation. In view of the fact that the traditional theorists claim to have all the answers for achieving economic efficiency in a common property context, and these suggestions have received widespread acclaim, it would seem worthwhile to undertake the development of a more explicit model to further subject these "conclusions" to theoretical scrutiny. Following the development of a biological model (Chapter IV), the bioeconomic model will be constructed.

IV. THE BIOLOGICAL ASPECTS

The rudiments of fishery population dynamics are included so that the economic model presented in Chapters V and VI can be given some semblence of reality. Just as the biological model devoid of any economic implications is useless for policy questions, so would be the economic model containing no reference to the ecological variables. The presentation will take the following form. First, the use characteristics of natural resource will be presented. Following this, the characteristics of one particular resource (ocean fishes) will be outlined, and a model of population dynamics developed.

Resource Characteristics

Following Ciriacy-Wantrup (1963), natural resources can be classified as either stock (nonrenewable) or flow (renewable). Stock resources are classified as either "not significantly affected by natural deterioration" (metal ores, coal, stones, clays) or as "significantly affected" (refined metals subject to oxidation, oil and gas seepages, leaching of plant nutrients, evaporation of surface water).

Flow resources can be categorized into "use-independent" (flow not significantly affected by human action) and "use-dependent" (flow significantly affected by human action). Within the latter category (use-dependent), resources are characterized by the presence of a critical zone.[16] A critical zone is defined by Wantrup as:

> .... a more or less defined range of rates below which a decrease in flow cannot be reversed economically under presently foreseeable conditions. Frequently, such irreversibility is not only economic but also technological (Ciriacy-Wantrup, 1963, p. 39).

Figure 11 presents a diagrammatic representation of resource characteristics with some of the more common examples.

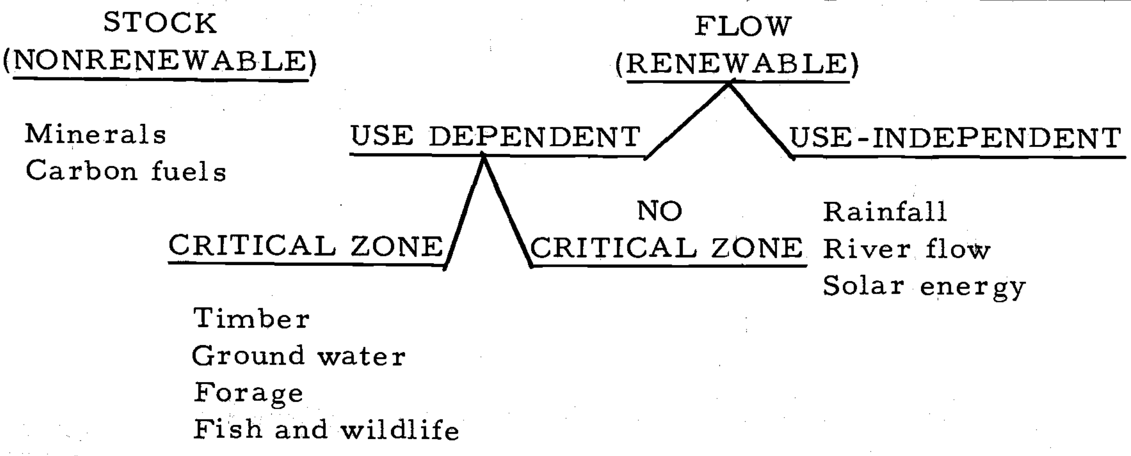

Figure 11. Natural resource characteristics.

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[16]This is in disagreement with Wantrup who says some use-dependent resources are not characterized by a critical zone and cites precipitation as an example. Wantrup maintains that cloud seeding alters the flow, yet these alterations are reversible. I would argue that cloud-seeding does not belong in the category of "flow significantly affected" (use-dependent) but rather in "flow not significantly affected" (use-independent). It is very doubtful whether cloud seeding in one time period "significantly" affects the availability of moisture in the following time period. It is true that given a sufficiently long time period, added moisture could alter vegetation enough to "significantly' alter the flow (permanently) but this is a limiting case. I would submit that if man has a "significant" effect upon resource flows, then a critical zone exists.

As seen from Figure 11, fish populations belong in the flow category and are use-dependent in nature. As Schaefer (1957) has pointed out, if fish populations were use-independent, the following relationship between production and fishing effort would be obtained.

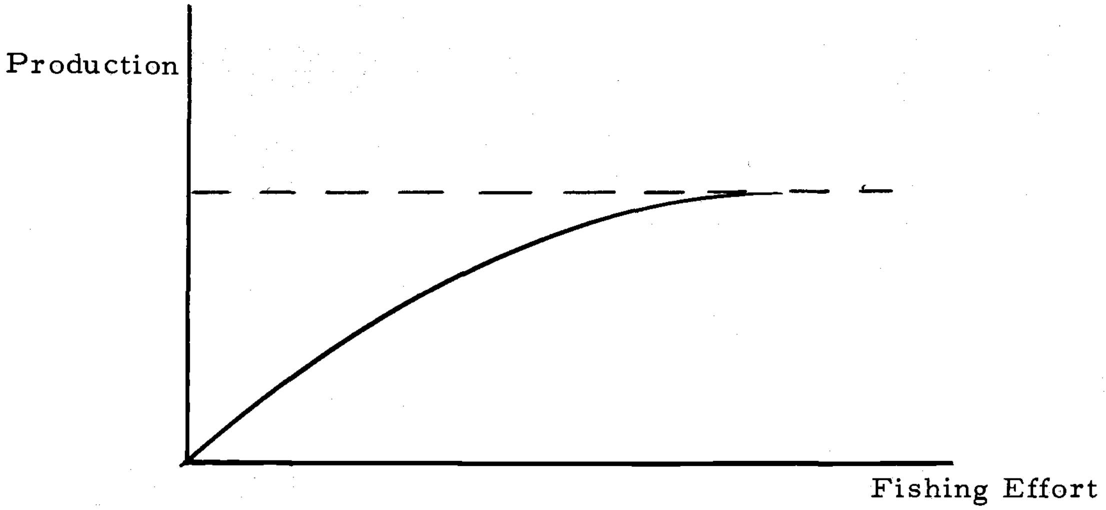

Figure 12. Production as a function of fishing effort assuming use-independence.

The proper functional relationship between yield and effort for a fish population is given by Figure 13.

The derivation of this sort of relationship will be presented in the following section.

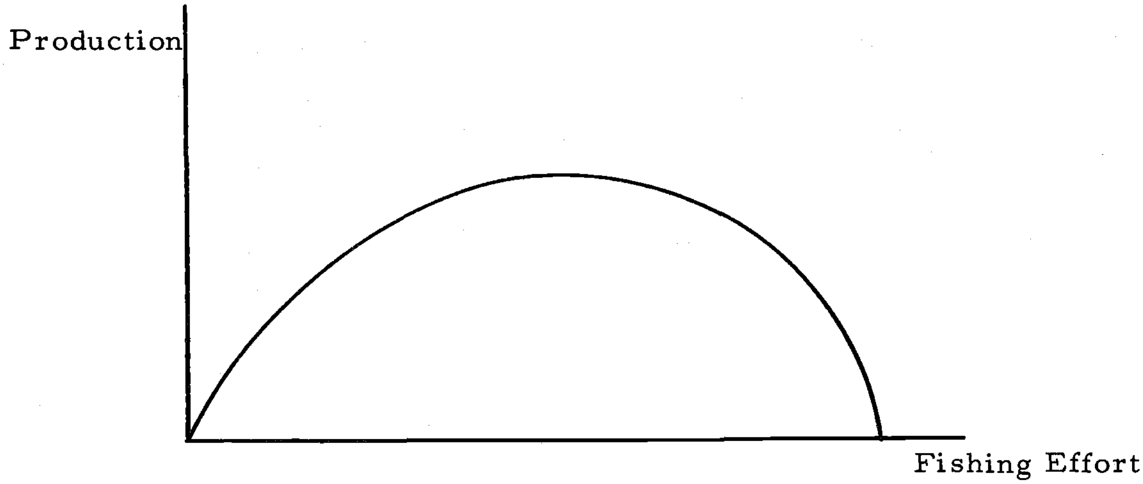

Figure 13. Production as a function of fishing effort assuming use-dependence.

Fishery Population Dynamics

Before discussing the relationships between fishing effort and yield, it is necessary to investigate the dynamics of a fishery in its natural state. Most of this development will follow Ricker (1958).

A common expression of biological production for a fishery in its natural state is given by:

$$\text{Biomass} = f\,(\text{recruitment, growth, natural mortality}) \quad (4.1)$$

As long as fishing does not occur, these three primary influences will govern the size of the population and its weight (biomass). All three variables are in turn a function of the biomass and its relationship to its environment.

For example, recruitment is low at very low population levels because the number of spawners is small. At very large population levels (in relation to environment), recruitment may also be low because the fish are not healthy, and there is severe competition for food. At some intermediate population level, the ability of the spawners to recruit progeny into the standing population is a maximum.

An almost similar condition prevails for individual growth. However, at low population levels, the growth rate of the individual fish is a maximum, decreasing as a function of the standing population. Natural mortality, on the other hand, is low for very low population levels but increases as a function of the standing population.

These three influences combine to provide the following idealized relationship between the number of spawners in one time period, and the mature progeny surviving in the following time period.

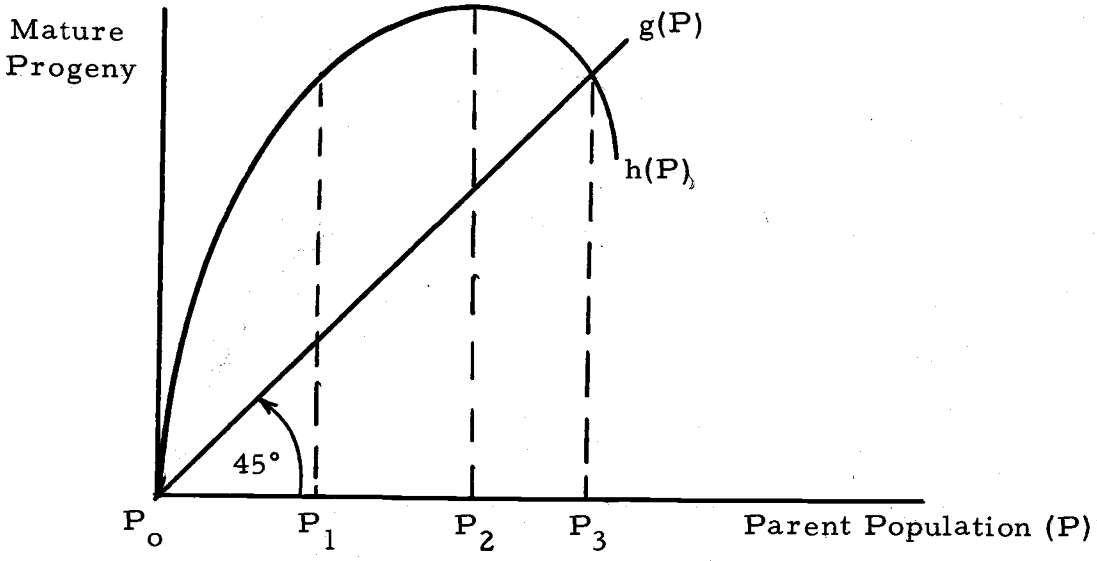

Figure 14. Mature progeny as a function of parent population.

The 45° line [g (P)] is called the replacement line and indicates the level of mature progeny which would just maintain the parent stock at its present levels. At a population of P_1, the production of mature progeny over and above that needed for replacement is a maximum. At a parent population of P_2, the production of mature progeny is a maximum in an absolute sense. At P_3, the production of mature progeny is just adequate to replace the natural attrition of the parent stock.

From Figure 14, it is possible to define equilibrium catch as that level of fishing mortality which will leave the population at its present level. Since at P_3 there is no positive net recruitment, equilibrium catch is zero. As fishing is introduced into the system, this additional source of predation permits the population to increase its production of young. As fishing is increased and the parent population further reduced, the ability to produce young (and the capacity of the young to grow) increases until at P_1, the production of a surplus over that needed for replacement is a maximum. If, in any one year, some catch less than equilibrium catch is taken, the population will move in the direction of P_3. If more than equilibrium catch is taken, the population will be further reduced. If the excess over that needed for replacement is exactly taken each season, it is possible to hold the fish population at P_1. At this level, the sustainable yield will be maximized and the population will be held in a state of artificial equilibrium; artificial in that it is man-caused and man-controlled (Stevens and Bromley, 1967).

It follows from the definition of equilibrium catch that by taking the difference between the $g(P)$ and $h(P)$ functions in Figure 14, it is possible to derive equilibrium catch, $f(P)$, as a function of parent population.[17] Such a relationship is shown in Figure 15.

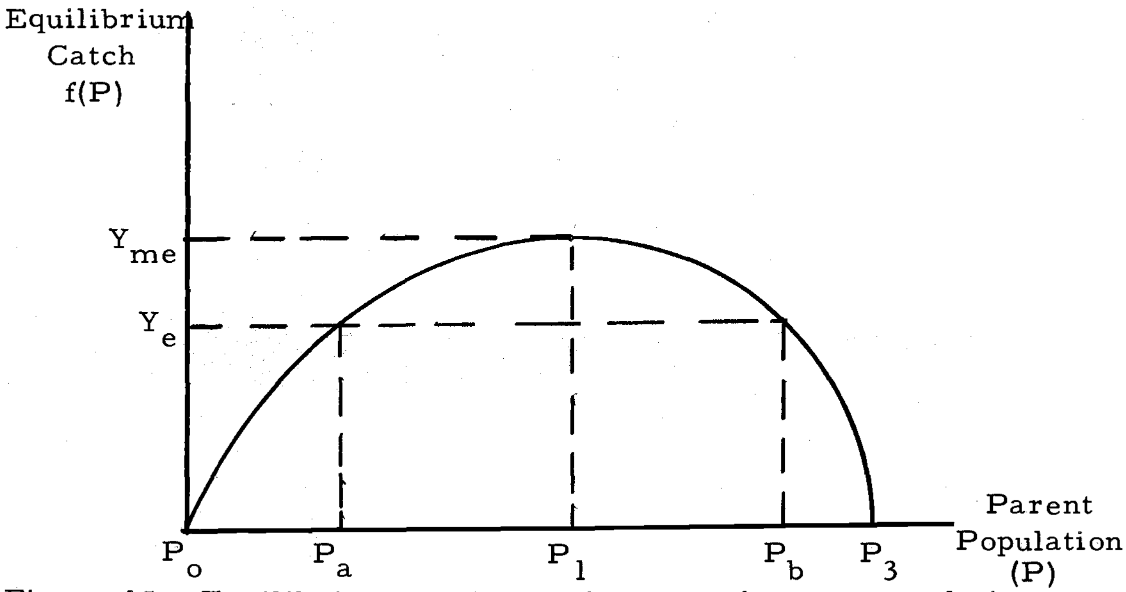

Figure 15. Equilibrium catch as a function of parent population.

At P_o, equilibrium catch is zero; the same at P_3. For intermediate values of P, the yield increases, reaches a maximum at P_1, then declines to zero. It should be noticed that it is possible to

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[17]The $f(P)$ of this Chapter corresponds with the $f(X)$ used by Smith in Chapter II. Notice that Smith's "social cost" defined as $KC_2(x, X, K)/f'(X)$ can be positive, negative (actually a "social benefit"), or infinity, depending upon population, P.

obtain the same equilibrium catch from two different population sizes; for example, P_a and P_b both provide an equilibrium yield of Y_e. Figure 15 will prove instrumental in Chapter VI where the bio-economic model is developed.

It is now possible to investigate the relationship between yield and fishing effort. Aggregate catch depends both upon total fishing effort and the size of the fish population; either can be fixed while the other varies. A given level of effort applied to a large population, for example, will yield a larger catch than if a smaller population existed. Figure 16 illustrates some possible <u>aggregate</u> production functions for a fishery.

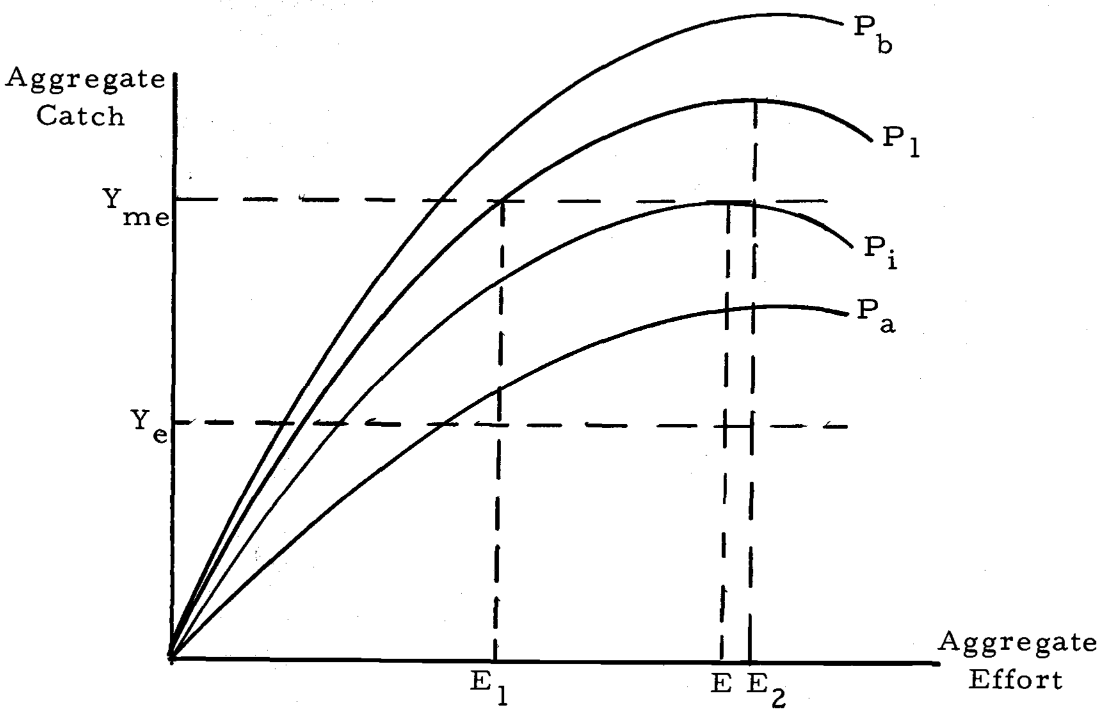

Figure 16. Aggregate catch as a function of aggregate fishing effort.

For a small population, P_a, the amount of effort required to harvest the equilibrium catch, Y_e, is greater than that required to harvest the same equilibrium catch from a larger population, P_b. The curves labeled P_a and P_b reflect this difference. There exists population sizes between P_a and P_b, however, where equilibrium catch is greater than Y_e. At P_1, the maximum equilibrium catch is obtained with E_1 level of effort. Notice that the production function itself may not be maximized until E_2 level of effort has been applied. Thus, harvesting the maximum equilibrium (sustained) catch would involve maximizing total catch only in the limiting case where population size (P_i) was such that the production function is maximized at Y_{me} level of catch. This would be, indeed, a very special case.[18]

The relationship between fishing effort and aggregate yield is a crucial one in the fishery and the above should make this point obvious; there is a different production function for each population level. Schaefer (1957) has developed a model to relate fishing effort to catch and this is presented below.

Schaefer shows that for each population size, there is a certain rate of natural increase,

$$\frac{dP}{dt} = f(P) \qquad (4.2)$$

[18]This important distinction is ignored by the traditional theorists who talk only of effort and sustained yield.

The catch (L) during the year is some function of the size of the population (P) and the amount of effort (E):

$$L = \phi(P, E) \tag{4.3}$$

As was seen, in equilibrium, the catch is exactly equal to the rate of natural increase. This is termed "equilibrium catch." This is the long-term annual production of the fishery for given population and effort levels. Thus, population size is some function of fishing effort:

$$P = \psi(E) \tag{4.4}$$

The natural rate of increase, f(P), is plotted in Figure 15 where it is labeled "equilibrium catch." Schaefer indicates that a reasonable approximation of the function is given by,

$$f(P) = k_1 P(M-P) \tag{4.5}$$

where k_1 and M are constants.

It also appears as if landings can be represented by the relation,

$$L = k_2 EP \tag{4.6}$$

where k_2 is a constant.

Thus, under equilibrium conditions,

$$k_2 EP = k_1 P(M-P) \tag{4.7}$$

and hence

$$P = M - \frac{k_2}{k_1} E \tag{4.8}$$

That is, for equilibrium conditions, population size is a linear function of fishing effort; and, from equations (4.6) and (4.8),

$$L = k_2 E (M - \frac{k_2}{k_1} E) \qquad (4.9)$$

Such a function is presented in Figure 17.

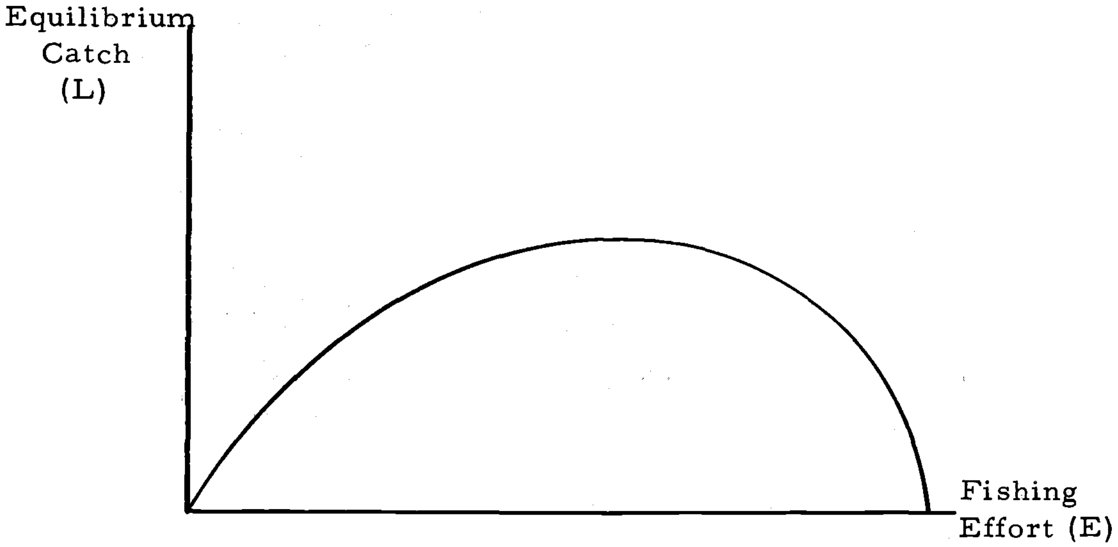

Figure 17. Equilibrium catch as a function of fishing effort.

The relationship depicted in Figure 17 is used by the traditional theorists to make recommendations about output. This was illustrated in Chapter II. Because of the many influences which can alter the relationship between aggregate effort and aggregate catch, and because there is no way to express demand for the product, this type of model will not be employed in this study. Rather, a revised economic model for the fishery will be utilized in Chapter VI. However, prior to that, an economic model of firm behavior in the fishery is needed. For this development, it will be temporarily assumed that there is a given level of equilibrium catch available and the problem is primarily one of determining output per firm in the given period, and the number of firms in the industry. Chapter V presents this model.

V. THE ECONOMIC MODEL

Except for Smith's recent article (1968), the works cited in Chapter II bypassed the treatment of individual firm decision making, and dealt instead with total fishing effort, and total yield. Because the basic decision making unit in the economy is the individual firm, and because it is the interdependence between firms in a common property context which gives rise to both the physical, as well as the economic difficulties of production, the present model will utilize the firm as the basic decision unit. The intent shall be to develop the decision making strategy of a firm under conditions of commonality as it copes with constant changes in its technological infrastructure. Once the individual situation has been depicted, it will be possible to derive the equilibrium position of the industry[19] with respect to number of firms in the industry, catch or output per firm, and thus, total industry catch.

Assumptions

Model building necessarily involves assumptions, and those employed here will be outlined briefly. It is first assumed that the model is deterministic. It is recognized that this is an idealized

[19] As in Chapter III, the term "industry" refers to the group of vessels pursuing a given species on a common ground.

situation yet model building always involves tradeoffs between complexity (reality) and explanatory power with the current interest lying rather strongly with the latter attribute.

The second assumption is that the situation represented here is one of comparative statics. From the biological model presented earlier, it was seen that different levels of parent stock imply different levels of equilibrium catch in each time period. In a given period, this equilibrium catch will be pursued by any number of fishing firms; if it is exactly taken, then, other things assumed equal, the population in the next time period will be the same as in the present period. If more than the equilibrium catch is taken, the next period's population will be something less than in the present period, and if less than the equilibrium catch is taken, the population in the next time period will be greater than in the present period. However, the concern at the present time is the level of fishing by each of the $\underline{n}$ firms in the fishery, and the value of $\underline{n}$. Thus, a given population stock, and hence a given level of surplus, or equilibrium catch, is assumed, and the problem is the equilibrium position of the industry in the present time period.

The third assumption is made with respect to the nature of the firms in the industry. It is assumed that the fishery is being exploited by homogeneous firms. This assumption is consistent with traditional models and while it will be accepted momentarily, a discussion on the relaxation of this and some other assumptions will be presented in Chapter VI.

Another assumption is that of fixed product price in the face of increased industry output. This too, was advanced by the traditional theorists and justified by the fact that the fishing ground was assumed small enough that its produce had no effect on product price. This assumption will be relaxed in Chapter VI.

In addition to constant product price, the prices of the variable factors are assumed constant. The imputation to the fixed factors of the respective firms is assumed to be constant, and everywhere equal. This simplifies the matter considerably without adversely affecting the results. Firms are assumed to enter the fishery as long as there is some excess over fixed and variable cost commitments; that is, as long as there is any economic rent--or "profit."[20]

The matter of uncertainty is one of the most important aspects of competitive use of a fishery and one that will receive more attention at a later stage. For the present, it is assumed that each fisherman is omniscient enough to calculate _ex ante_ relationships between the number of firms already in the fishery, their output levels, and the resulting relationships between input usage, and output in his own firm.

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[20]This coincides with Smith's (1968) formulation of when boats would enter.

A final assumption concerns the nature of the production function for the individual firm. The initial inclination was to use generalized functional notation so as to place emphasis on the salient features of the model; namely, the effects of productive interdependence upon: (1) factor use; (2) firm output, and (3) industry equilibrium (firm numbers and total output). However, the complexity of the model when the number of firms (*n*) becomes a variable precludes this generalized approach. To overcome this problem, a mathematical function was needed which would depict these results, yet remain operational and soluble in its variables. The Cobb-Douglas type of function was thus selected; not because of *a priori* knowledge about the true relationship, but because of its simplicity. It is hoped the reader will recognize that the specific form of the mathematical function does not alter the critical results of this exercise.

The variable factor, *x*, represents labor, and those minor items required in combination with labor, *combined in expansion path proportions*.[21] Thus, each output level is produced at least cost. The fixed factor, a, embodies not only the capital attributes of the boat, but the managerial skill of the captain. As indicated, this is assumed equal over all firms.

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[21]The concept of a "right-to-fish" as a productive factor will be argued later in this chapter.

The Model

With only one firm in the fishery, there can be no inter-dependence, and the production function of firm one is given by:

$$q_1 = f(x_1) = S\alpha_1 x_1^{\delta_1} \tag{5.1}$$

where S represents the level of the stock of fish in the pool,[22]

α_1 is the capital and managerial attributes of the boat,

x_1 is the composite of variable factors used by the firm, and

δ_1 is the variable factor coefficient.

The assumption of decreasing returns to the variable factor is made which implies that $\delta_1 < 1$.

It is assumed that the captain of boat one wishes to maximize profit.[23] Profit is given by:

$$\pi_1 = pq_1 - TC_1 \tag{5.2}$$

or,

$$\pi_1 = p[S\alpha_1 x_1^{\delta_1}] - rx_1 - b \tag{5.3}$$

where b represents the fixed cost commitment of the firm. To

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[22] It is recognized that the firm never has perfect knowledge about "S" but has some subjective evaluation of its level. No firm significantly affects the fish stock, but all firms taken together do. The reader should be warned that this does not necessarily imply an externality (market failure). There is a crucial distinction between productive interdependence, and market failure. This will be established in Chapter VI.

[23] In carrying out his calculations, the captain will use his subjective evaluation to arrive at an expected product price at the date of marketing.

maximize profit, firm one will equate the marginal value product of its variable factor, x_1, to the price of $\underline{x}$. That is, it will hire increasing units of $\underline{x}$ until the marginal value product of $\underline{x}$ is exactly equal to the marginal factor cost of $\underline{x}$, $\underline{r}$.

$$\frac{\partial \pi_1}{\partial x_1} = \delta_1 pSa_1 x_1^{\delta_1 - 1} - r = 0 \tag{5.4}$$

$$\delta_1 pSa_1 x_1^{\delta_1 - 1} = r \tag{5.5}$$

or

$$x_1 = [\frac{\delta_1 pSa_1}{r}]^{\frac{1}{1-\delta_1}} \tag{5.6}$$

That is, the level of input use is a function of the parameters δ_1, S, and a_1, the product price, $\underline{p}$, and the price of $\underline{x}$, $\underline{r}$. The level of output produced by boat one under these conditions is determined by substituting equation (5.6) into equation (5.1). This yields:

$$q_1 = Sa_1 [(\frac{\delta_1 pSa_1}{r})^{\frac{1}{1-\delta_1}}]^{\delta_1} \tag{5.7}$$

or,

$$q_1 = Sa_1 [\frac{\delta_1 pSa_1}{r}]^{\frac{\delta_1}{1-\delta_1}} \tag{5.8}$$

Hence, in the case of one firm operating in a common pool situation, output is determined by the technical attributes of the firm (a_1, δ_1), the fish population (S), the price of the final product ($\underline{p}$), and the price of inputs ($\underline{r}$).

As soon as the second firm decides to enter the fishery, physical interdependence becomes a production determining force on each of the two firms. Given that boat one is already in the fishery, it is possible to express the production function of boat[24] two as:

$$q_2 = f(x_2, q_1) = \frac{S\alpha_2 x_2^{\delta_2}}{1 + \gamma_2 q_1} \quad (5.9)$$

where q_1 is the output of boat one, α_2 and δ_2 are the shape parameters of boat two's production function, S is the fish population, and γ_2 is an interdependence coefficient which expresses the effect of the output of boat one upon the productivity of boat two.

Likewise, with the entry of boat two, the production function of boat one is altered from that given in equation (5. 1), to:

$$q_1 = f(x_1, q_2) = \frac{S\alpha_1 x_1^{\delta_1}}{1 + \gamma_1 q_2} \quad (5.10)$$

Assuming that the operators of boats one and two each wish to maximize profit, the following profit equations hold:

$$\pi_1 = p\left[\frac{S\alpha_1 x_1^{\delta_1}}{1 + \gamma_1 q_2}\right] - rx_1 - b_1 \quad (5.11)$$

$$\pi_2 = p\left[\frac{S\alpha_2 X_2^{\delta_2}}{1 + \gamma_2 q_1}\right] - rx_2 - b_2 \quad (5.12)$$

To maximize profit, each will utilize its respective variable factor up to the point where respective marginal value products are brought into equality with the input price, r. The only distinguishing

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[24]The terms "boat" and "firm" shall be used to imply the same thing--a decision making unit.

characteristic from the ordinary case is the physical relationship between production functions. As a result, the variable factors are now applied to a production function which represents a lower "quality" than was embodied in the original function. That is, the marginal value product function has been shifted downward by some factor, and the profit-maximizing level of input use is reduced.

$$\frac{\partial \pi_1}{\partial x_1} = \frac{\delta_1 p S a_1 x_1^{\delta_1 - 1}}{1 + \gamma_1 q_2} - r = 0 \qquad (5.13)$$

$$x_1 = \left[\frac{\delta_1 p S a_1}{r(1 + \gamma_1 q_2)}\right]^{\frac{1}{1-\delta_1}} \qquad (5.14)$$

And likewise for firm two,

$$\frac{\partial \pi_2}{\partial x_2} = \frac{\delta_2 p S a_2 x_2^{\delta_2 - 1}}{1 + \gamma_2 q_1} - r = 0 \qquad (5.15)$$

$$x_2 = \left[\frac{\delta_2 p S a_2}{r(1 + \gamma_2 q_1)}\right]^{\frac{1}{1-\delta_2}} \qquad (5.16)$$

Equations (5.14) and (5.16) are expressions which tell boat one and boat two how much of their respective factors, x_1 and x_2, to use in the production of q_1 and q_2. Comparing equation (5.14) with the earlier expression of input usage, equation (5.6), will show the former to be less by a factor of $\left[\frac{1}{1 + \gamma_1 q_2}\right]$. Thus, given fixed factor prices, the presence of productive interdependence implies a lower level of factor use than if no such mutual interdependence existed. This occurs because the production function of each firm is shifted downward due to the action of the other firm. Figure 18 illustrates three hypothetical production functions, one with only one firm in the fishery (a), another (b) showing the same function as (a) with a second firm producing some constant level of output, and a third function (c) showing the effects on the function (a) from the second firm producing exactly that amount being produced by firm one.

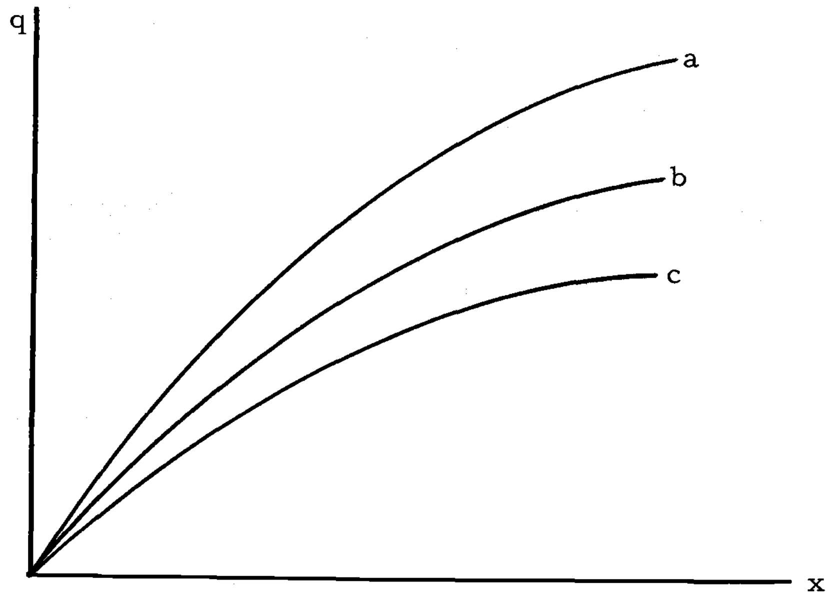

Figure 18. A hypothetical production function under three different assumptions.

Upon entry of the third firm into the fishery, the production function of firm one becomes:

$$q_1 = f(x_1, q_2, q_3) = \frac{S\alpha_1 x_1^{\delta_1}}{1 + \gamma_1(q_2 + q_3)} \quad (5.17)$$

In general, assuming n homogeneous firms in the industry, the production function of the ith firm is given by:

$$q_i = f(x_i, n, q_j) = \frac{S\alpha_i x_i^{\delta_i}}{1 + \gamma_i(n-1)q_j} \quad (5.18)$$

where the α_i, δ_i, γ_i, and S are the same as described previously, n is the size of the industry (number of firms), and q_j is the output of the typical firm in the fleet. Since all firms in the industry are assumed equal, and since the profit-maximizing output level is the same for each firm $(q_i = q_j)$, it is possible to express inputs, x_i, as a function of output by taking the inverse of the production function. Taking the inverse of equation (5.18) yields the following expression for input usage by the ith firm:

$$x_i = \left[\frac{q_i + \gamma_i(n-1)q_i^2}{S\alpha_i}\right]^{\frac{1}{\delta_1}} \quad (5.19)$$

Now, input use is a function of individual output, as well as of the number of firms in the industry.

The total cost of the ith firm will be a function of the number of firms in the industry as well as of its own output.

$$TC_i = rx_i + b_i \quad (5.20)$$

Substituting equations (5.19) into equations (5.20) yields the following total cost function for the ith firm:

$$TC_i = r \left[\frac{q_i + \gamma_i (n-1) q_i^2}{S a_i} \right]^{\frac{1}{\delta_i}} + b_i \qquad (5.21)$$

Equation (5.21) is the total cost function of the typical firm assuming all firms produce the same quantity. In actuality, there are three possible total cost functions, and hence three possible marginal cost functions. Equation (5.21) assumes $q_i = q_j$, but, relaxing that assumption, total cost of the ith firm may be expressed as:

$$TC_i = r \left[\frac{q_i + \gamma_i (n-1) q_i q_j}{S a_i} \right]^{\frac{1}{\delta_i}} + b_i \qquad (5.22)$$

With n and q_j fixed, the firm's total cost changes only with q_i. This would be the case if the number of firms in the industry was fixed, and all other boats continued to produce the same quantity. With n being fixed, but with output of all firms in the industry varying, a different total cost function for the firm results. Finally, with both n and q_j varying, firms are allowed to enter, and each firm expands output as long as per unit price is greater than marginal cost. Assuming all firms in the fishery behave similarly, the latter situation is the relevant one for deriving the marginal cost of the typical firm. That is,

$$MC_i = \frac{r}{S \delta_i a_i} \left[\frac{q_i + \gamma_i (n-1) q_i^2}{S a_i} \right]^{\frac{1}{\delta_i} - 1} \left[1 + 2\gamma_i (n-1) q_i\right] \qquad (5.23)$$

And, as with total cost, the firm's marginal cost is a function of its own output, which it can control, and the number of firms in the industry, which it cannot.

To illustrate the effect upon output level of an individual firm from the entrance of another, set equation (5.23) equal to product price. This is given by equation (5.24).

$$p = \frac{r}{S\,\delta_i a_i} \left[\frac{q_i + \gamma_i\,(n-1)\,q_i^2}{S\,a_i} \right]^{\frac{1}{\delta_i} - 1} \left[1 + 2\,\gamma_i\,(n-1)\,q_i \right] \qquad (5.24)$$

Everything in equation (5.24) is constant except q_i and n. Thus, it describes the locus of all points relating q_i and n. This plotting is depicted in Figure 19.

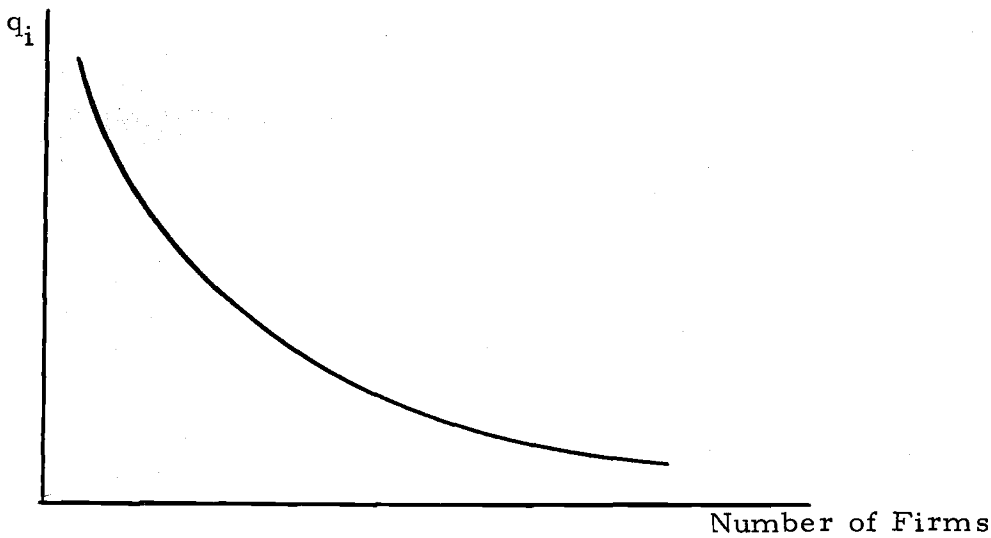

Figure 19. Relation between output per firm and the number of firms in the industry.

As can be seen from Figure 19, the profit maximizing level of output of the firm is a decreasing function of industry size. If the exact magnitude of this change were desired, the partial derivative of

q_i with respect to n could be found from equation (5.24) by implicit differentiation.

The third relevant function is that of average total cost for the firm. It is the level of per unit total cost at the profit maximizing level of output which determines the extent (or presence) of economic rent to the firm, and, because all firms are assumed equal, the presence of this excess would attract other firms into the fishery.

To derive average total cost, divide equation (5.21) by q_i,

$$ATC_i = \frac{r}{q_i} \left[\frac{q_i + \gamma_i (n-1) q_i^2}{S a_i} \right]^{\frac{1}{\delta_i}} + \frac{b_i}{q_i} \qquad (5.25)$$

Again, notice that as n increases, the per unit production cost of the firm will increase.

Input-Mix in the Fishery

Up to this point, the bundle of variable inputs (x_i) of the fishing firms has consisted only of the usual tangible factors such as labor and machinery. However, it would seem that fishing firms utilize a variable productive factor in addition to the usual inputs; this input might be thought of as the "right-to-fish." Coase (1968) argues convincingly that "rights" are also productive factors and reference to his position is warranted.

> A final reason for the failure to develop a theory adequate to handle the problem of harmful effects stems from a faulty concept of a factor of production. This is usually thought of as a physical entity which the businessman

> acquires and uses (an acre of land, a ton of fertilizer) instead of as a right to perform certain (physical) actions. We may speak of a person owning land and using it as a factor of production but what the land-owner in fact possesses is the right to carry out a circumscribed list of actions. The rights of a land-owner are not unlimited (Coase, 1968, p. 456).

Later in the same vein Coase says:

> If factors of production are thought of as rights, it becomes easier to understand that the right to do something which has a harmful effect (such as the creation of smoke, noise, smells, etc.) is also a factor of production (Coase, 1968, p. 456).

If the concept of a right-to-fish is accepted as a realistic factor of production, then it might be illustrative to think of this factor as a "fishing-day," just as a man-day is used to signify a given factor per unit of time. If a fishing day is a meaningful factor of production, then its price would appear to be of some interest. At the present time, firms are not charged for daily use of this right-to-fish. As long as the opportunity cost for a fishing day is zero, then there should be no charge. If, on the other hand, the use of the sea for commercial fishing is competitive with some other endeavor,[25] then the opportunity cost of a fishing day is non-zero.

Whether or not the opportunity costs to society are zero will

[25] The relevant opportunity cost is the value of other goods and services foregone by using the sea to produce fish, not the value of fish foregone by boat one because boats two, three . . . n, got there first. The appropriate criterion is among alternative products, not among firms producing the same product.

not be treated. However, if these costs were non-zero, and if a decision was made to charge the commercial fishing industry for a fishing day, several things would happen.

First, the variable input mix in the fishery would be altered with fewer fishing days taken than previously. If firms desired to hold costs of production at their present level, the firms would use fewer of the other variable factors as well. The result would be reduced output by each firm. On the other hand, if firms desired to hold output constant, they would incur higher production costs.

In either case, a fee per fishing day, λ, would cause the following change in the total cost function of the typical firm:[26]

$$TC'_i = (r + \lambda) \left[\frac{q_i + \gamma_i (n-1) q_i^2}{S \alpha_i} \right]^{\frac{1}{\delta_i}} + b_i \qquad (5.26)$$

The increased variable input price causes the total cost function to rise more steeply as output increases, and hence raises the marginal cost function of the firm. It also causes per unit production costs to rise. Hereafter, it will be assumed that all cost functions reflect the "proper" fee for a fishing day.

[26]To be consistent it is assumed that all other costs are on a comparable basis as regards units of time.

The Industry Supply Curve

As a transition into the following chapter, the concepts outlined above can be given in terms of the more familiar graphics.

As has been illustrated mathematically, productive interdependence influences the efficiency of a firm's fixed and variable inputs. The extent of this interdependence is a function of several things: (1) the output level of the firm in question; (2) the output level of the other firms exploiting the common pool; (3) the number of other firms producing from the pool; and (4) the intrinsic nature of the pool. To generalize is often dangerous, yet the following situation is a general explanation of the effects of technological interdependence upon the individual firm.

In Figure 20, it is assumed that only one firm is participating in the fishery, that it can sell all its output at the constant price P, and that at the present time it is producing q_o, and making a profit of AB per unit of fish sold.[27]

Upon the entry of a second firm into the fishery, it was seen that the cost functions of the first firm shift upward. The curves ATC' and MC' reflect the effects of a second firm in the industry.

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[27] It should be noted that the cost functions depicted here would not arise from the production function assumed earlier. The functions used here correspond to those in common usage and are used for expositional sake.

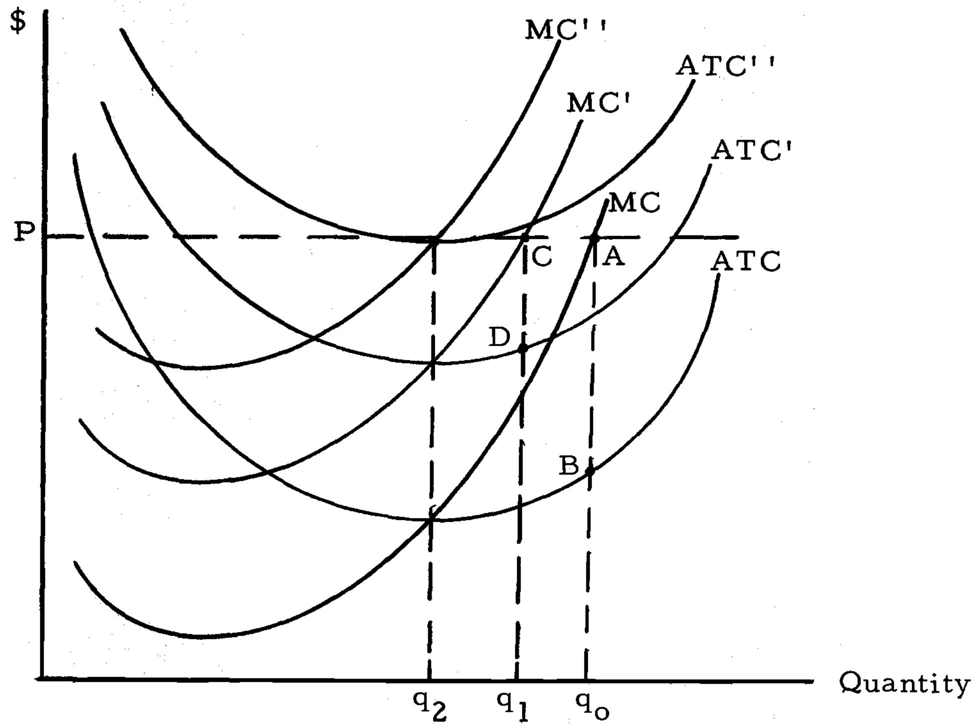

Figure 20. The effects of productive interdependence in a common pool setting.

Now, with both firms trying to produce where MC equals price, they cause the costs of each to be such that firm one now operates along the MC' function, producing only q_1, and enjoying a profit per unit of CD. As more firms enter the industry seeking the profits which firms one and two now enjoy, costs of firm one (and also of all the others) are shifted up until, eventually, firm one is operating along MC'', producing only q_2, and making no excess above per unit production costs.

With the situation depicted by the MC'' and ATC'' curves, and assuming homogeneous firms, the industry would be in equilibrium; no more firms would enter. Should product price (P) increase, each firm would expand output along its MC'' function, but this increased output by all, combined with the entrance of new firms would shift costs up again to some higher level, reducing output per firm, but increasing total industry output.

This relationship between total industry output, and cost per unit of product, is the single most important aspect of technological interdependence and it is upon this basis that followers of A. C. Pigou recommended that output of "increasing-cost industries" be restricted. This will be elaborated upon in Chapter VI. If the fishery were like most other economic endeavors (no interdependence), and if productive factors had constant prices for all levels of use, the situation depicted in Figure 20 would be different. Instead of the firm's cost curves being shifted upward until all profit per unit was eliminated, costs would remain constant and increased industry output would cause product price to fall, eliminating any profit.[28] In such instances, the total costs of the industry can be depicted as a linear function of total output. Curve (a) in Figure 21 depicts this hypothetical relationship.

When there are technological conditions within an industry which cause per unit production cost to decline as industry output

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[28]In the following chapter the assumption of constant product price is relaxed. In that situation, the fishing firm is the victim of a genuine "price-cost squeeze."

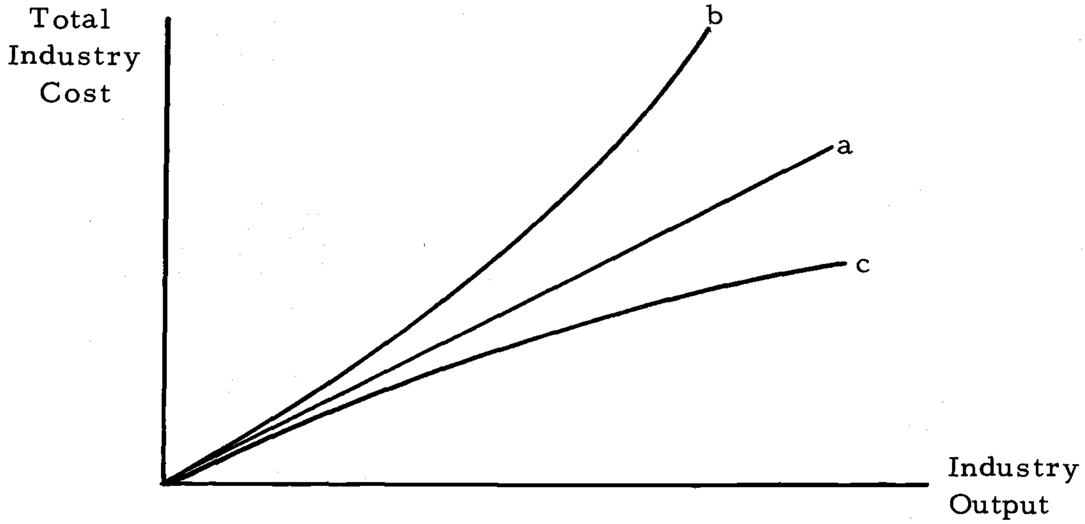

Figure 21. Total industry costs as a function of total output under three different assumptions.

expands, the relation between total industry cost and total output is given by curve (c).

In industries such as the fishery, where interdependence between firms causes per unit production cost to rise as output increases, curve (b) in Figure 21 portrays the relationship between total industry costs and total industry output. This latter function is the one of current interest and from it, can be derived functions tracing out the change in per unit production cost as industry output expands (industry supply curve), and the change in total industry costs as industry output changes (industry marginal cost).

In Figure 22, the S_o function traces out the supply curve of a constant cost industry as output expands. Its height represents the slope of the (a) curve in Figure 21, and it indicates that regardless of the level of industry output, cost per unit of producing that output is constant, and equal to C.

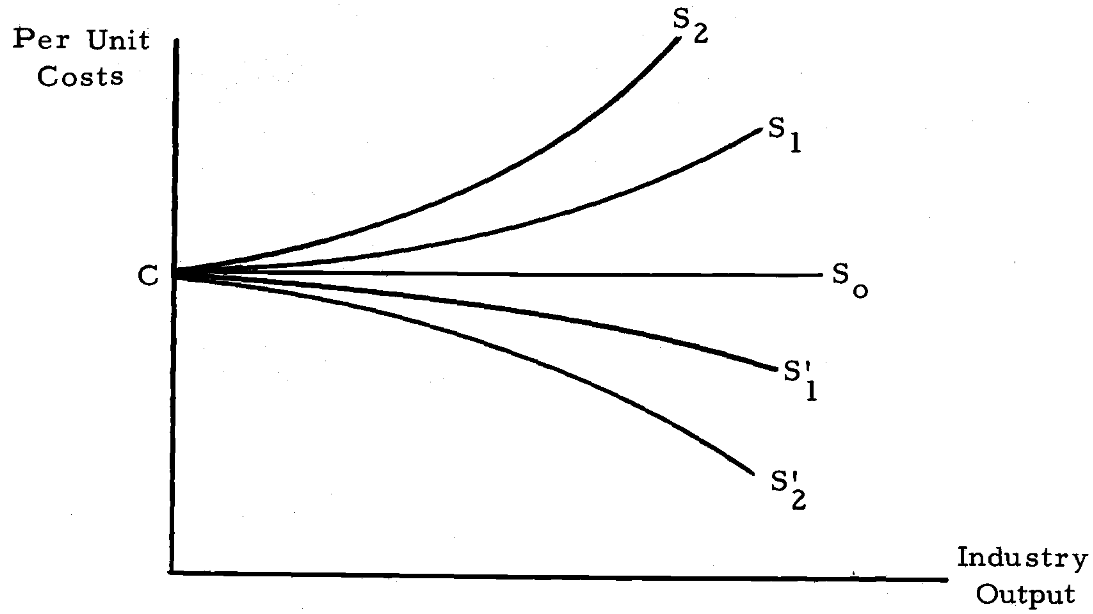

Figure 22. Possibilities for industry supply curves.

The function S_1' is derived from the (c) curve in Figure 21 and shows the relationship between per unit production cost, and total industry output. The S_2' function traces out the slope of the (c) curve at various levels of industry output. These two functions represent the situation of technological interdependence which alters favorably, rather than negatively, the production functions of the firms in the industry.

Finally, the S_1 and S_2 functions are of direct relevance to the fishery for they reflect productive interdependence of the negative type. Notice that as industry output expands, the cost of a unit of output increases (S_1) and that the change in total industry cost as a function of total industry output is increasing at an increasing rate (S_2). Recall that these results could have been deduced from Figure 20.

Before proceeding to the next chapter and the bioeconomic model, it would seem appropriate to discuss what types of influences in the fishery can alter the supply curve as depicted by the S_1 function in Figure 22.

Recall that from equation (5.21), the cost to the firm is a function of the level of fish stocks, S. Large populations imply that a given quantity of fishing gear will contact more fish and hence, per unit cost of production will be reduced. With this being the case, the cost of each firm would be lower, and the supply curve of the industry would be displaced downward. Similarly, a smaller population would mean higher per unit production cost, and thus the supply curve of the industry would be displaced upward.

In a like fashion, if fish population, S, is assumed the same, but technology changes, the supply curve of the industry (S_1) would be displaced vertically; a downward shift representing better technology, and an upward shift representing poorer technology. Figure 23 depicts these possibilities.

Curve S^3 depicts a hypothetical industry supply curve for a given fish stock and state of technology. If technology remains constant, but fish population increases, S^3 is displaced to S^2. Now, if

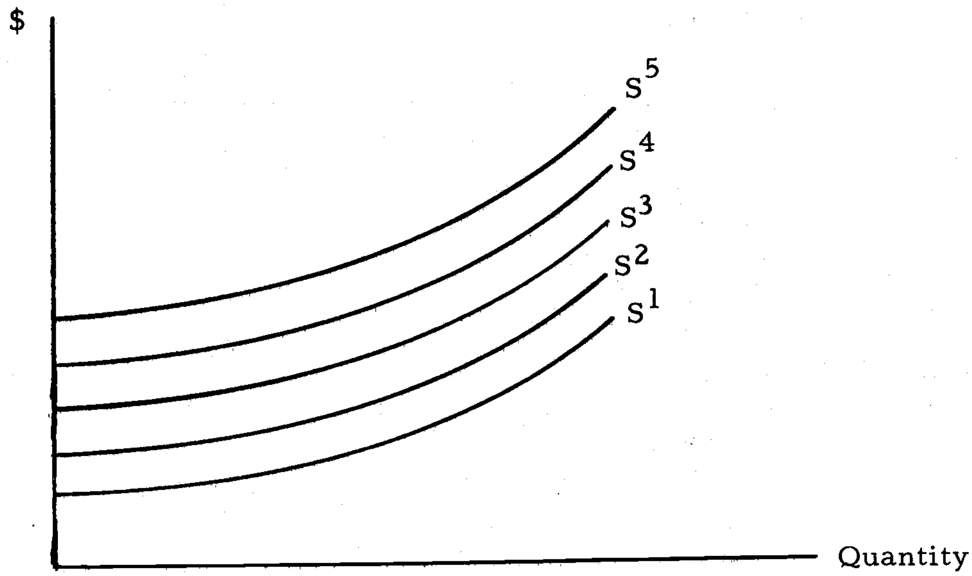

Figure 23. Industry supply curves under various assumptions on fish population and technology.

a technological innovation were introduced into the fishery, S^2 would shift down even further, to S^1.

Similarly, if S^3 is assumed the original situation, a restriction on gear efficiency in an attempt to prevent overfishing would cause S^3 to shift upward to S^4. The higher supply curve would lead the industry to place a smaller quantity on the market, at the same price. If, in the next time period, population were reduced from its present level, while technology remained constant, S^4 would shift upward to S^5.

The final concept to be elaborated upon is that of productive interdependence. Earlier in this chapter, an interdependence coefficient, γ_i, was defined. This coefficient expressed the extent of influence which the production of other boats would have on the production of the ith boat. When γ_i is large, this implies that the degree of interdependence is relatively more severe than if γ_i were small. Recall that $\gamma_i = 0$ implies no productive interdependence.

The magnitude of γ_i will be a function of the particular fishery. If the fish are pelagic or demersal, the spatial distribution and the methods used to catch them may imply that γ_i is relatively small. On the other hand, anadromous fish, captured by traps as they migrate up a river, would seem to imply a larger γ_i. That is, when it is fairly easy to capture the fish, and any one producer can catch a large quantity in a brief period of time, γ_i will be larger than when the fish are scattered over a large area, the production of any one boat requires more time, and no one producer can capture enough to significantly affect the others.

It is therefore possible to hypothesize the following impacts upon the industry supply curve from various values of γ_i: a γ_i of zero would, of course, cause the industry supply curve to be a horizontal line; a small γ_i would cause the industry supply curve to rise slowly as industry output expands; while a large γ_i would cause the supply curve to rise much more rapidly. Figure 24 depicts these three cases.

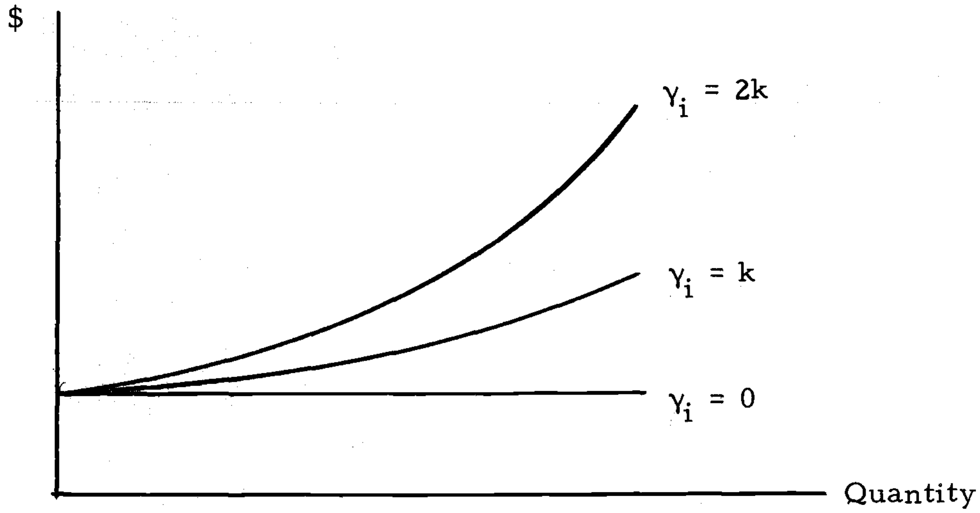

Figure 24. Industry supply curves under three different values of γ_i.

Summary

By way of summarizing this chapter, the following seems relevant. Productive interdependence in a common pool situation causes the downward displacement of firm's production functions. This means upward displacement of cost functions and an accompanying reduction in the profit-maximizing output level of the firm. These influences imply a positively-sloped supply curve for the industry. This supply curve is displaced upward by a low level of fish stock, or a low state of technology, and is displaced downward by a higher fish stock, or improved technology. The degree of interdependence influences the rate at which the industry supply price increases as industry output expands.

The concept of a right-to-fish was introduced and reference was made to the input-mix in the fishery. The pricing of a fishing-day based on its opportunity cost to society would imply that the fishery was using the socially ideal level of fishing days in combination with other variable inputs.

VI. ECONOMIC EFFICIENCY IN A COMMON PROPERTY CONTEXT

In Chapter IV, the basic concepts of fishery population dynamics were presented. In Chapter V, the rudiments of productive interdependence were developed and the effects of this interdependence among firms was made explicit in a hypothetical firm production function. The influence of interdependence on a firm's cost curves was also detailed. Finally, the concept of rising supply prices for a commodity produced under such conditions was introduced.

With this foundation, it is now possible to combine the above concepts into a bioeconomic model of a common property natural resource such as the ocean fishery. Once developed, the model will permit the analysis of charges that the common property fishery is fraught with economic inefficiencies.

The Bioeconomic Model

In Chapter V, the assumption was made that there was a given quantity of fish in the common pool, and the effect of increased numbers of firms pursuing these fish was outlined. Now, the more realistic situation will be approached with the biological and economic aspects being coordinated into one model. The development will draw upon an idea presented by Crutchfield and Zellner (1962), and utilizes the economic model developed in Chapter V.

It will be recalled from Chapter IV that a functional relationship between fish population and equilibrium catch takes the following form:

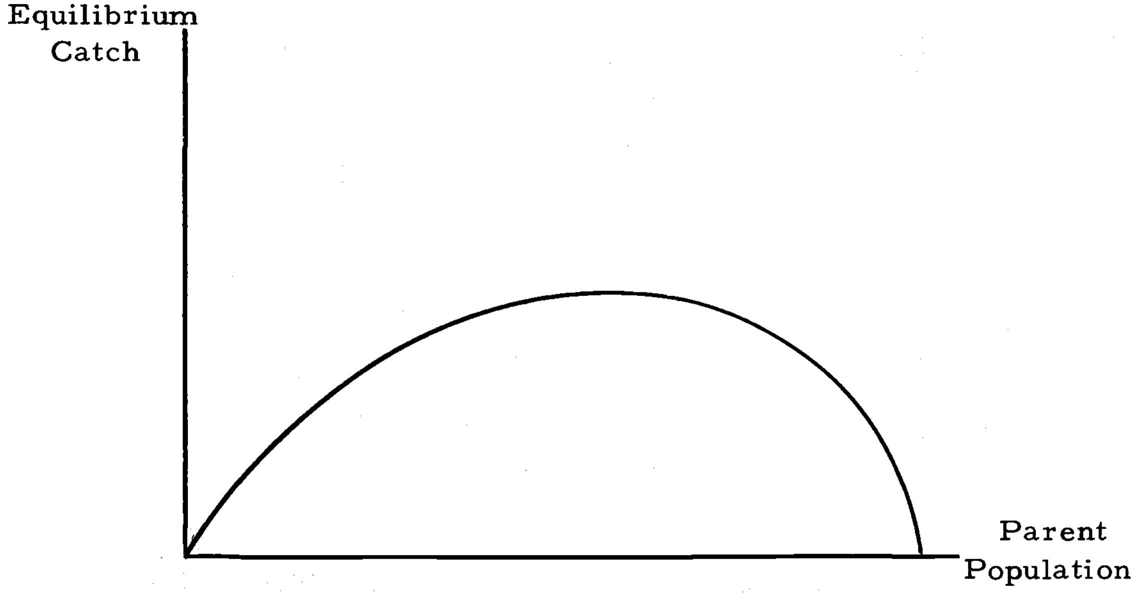

Figure 25. Equilibrium catch as a function of parent population.

By transforming Figure 25, it is possible to create Figure 26. Figure 26 provides a convenient means to relate the biological and economic variables in any given time period, or over several periods. It has an advantage over those models presented in Chapter II in that this ability to indicate not only comparative statics, but also physical interdependence, changes in technology, and as will be seen later, demand for the product, makes it a much more realistic tool for analysis.

Before including the demand relationships, consider Figure 27.

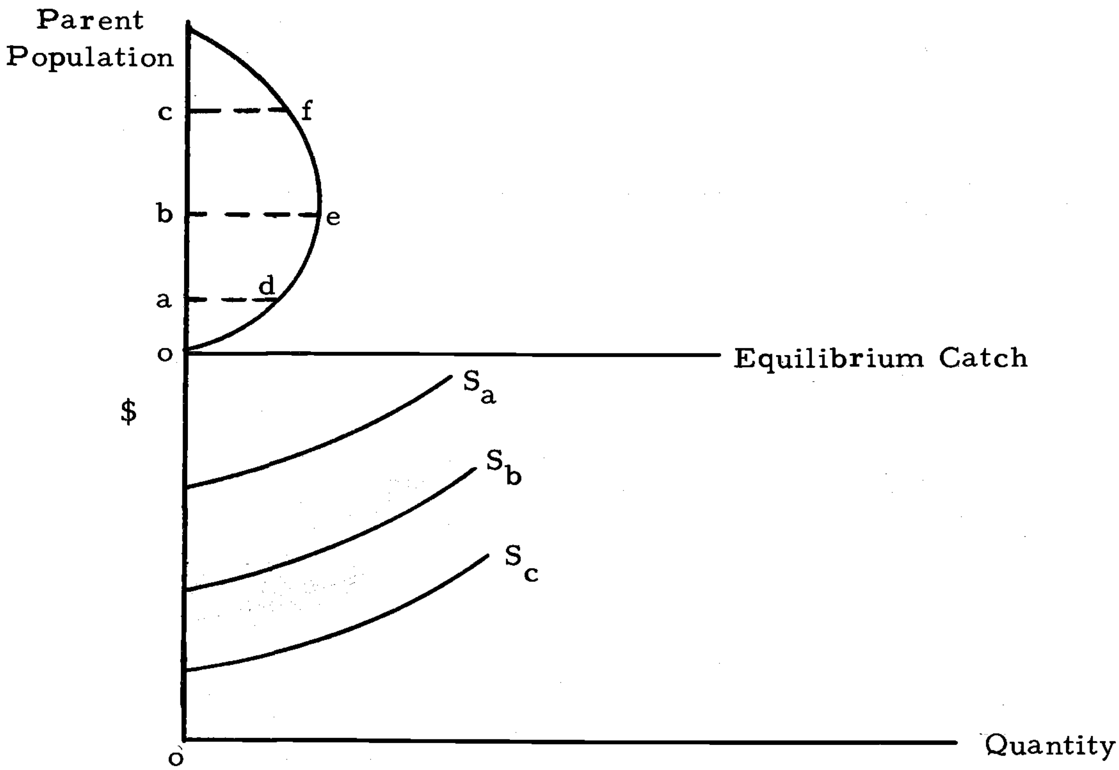

Figure 26. Industry supply curves under three different population levels.

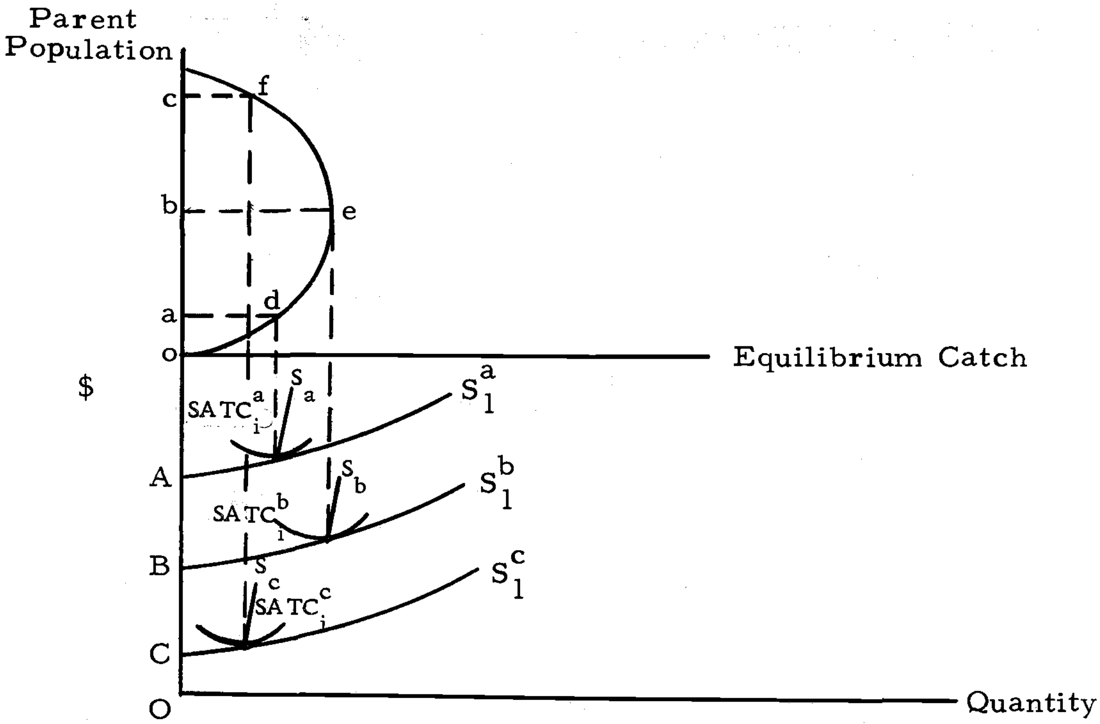

Figure 27. Bioeconomic model assuming three different population levels.

Assume that the parent population is quite large and represented by oc. This population would imply relatively low harvest costs and the curve CS_1^c represents a hypothetical industry supply curve, given that fish population is oc. If firms are assumed homogeneous, and if industry output is restricted to equilibrium catch (cf), then $SATC_i^c$ represents the short-run average total cost curve for the typical firm in the industry. With that number of firms in the industry, S_c is the short-run industry supply curve.[29]

With the number of firms constant, increased output from the industry would occur along S_c. If the number of firms was variable, then as $SATC_i^c$ moved along S_1^c, S_c would shift accordingly; S_c is the sum of individual firm marginal cost functions above the minimum point of their average total cost curve. The point of intersection of $SATC_i^c$ and S_c traces out the locus of increasing supply price of industry output as more firms enter the industry; it is the industry supply curve with increased output coming from more firms.

If fish population were only ob, then the industry must pay more to produce a unit of fish, and BS_1^b becomes relevant. If population were reduced to oa, then costs per unit increase even further and AS_1^a becomes relevant.

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[29] The term "short-run" means that no other boats enter the fishery; any increase in industry output must come from the firms already in the fishery.

The latter portion of Chapter V contained illustrations of various levels of parent stock and technology, and the subsequent effects upon the supply curve of the industry. Now, demand for the product will be included. To illustrate the interrelations among all of the variables in the model, it will be instructive to create several hypothetical situations.

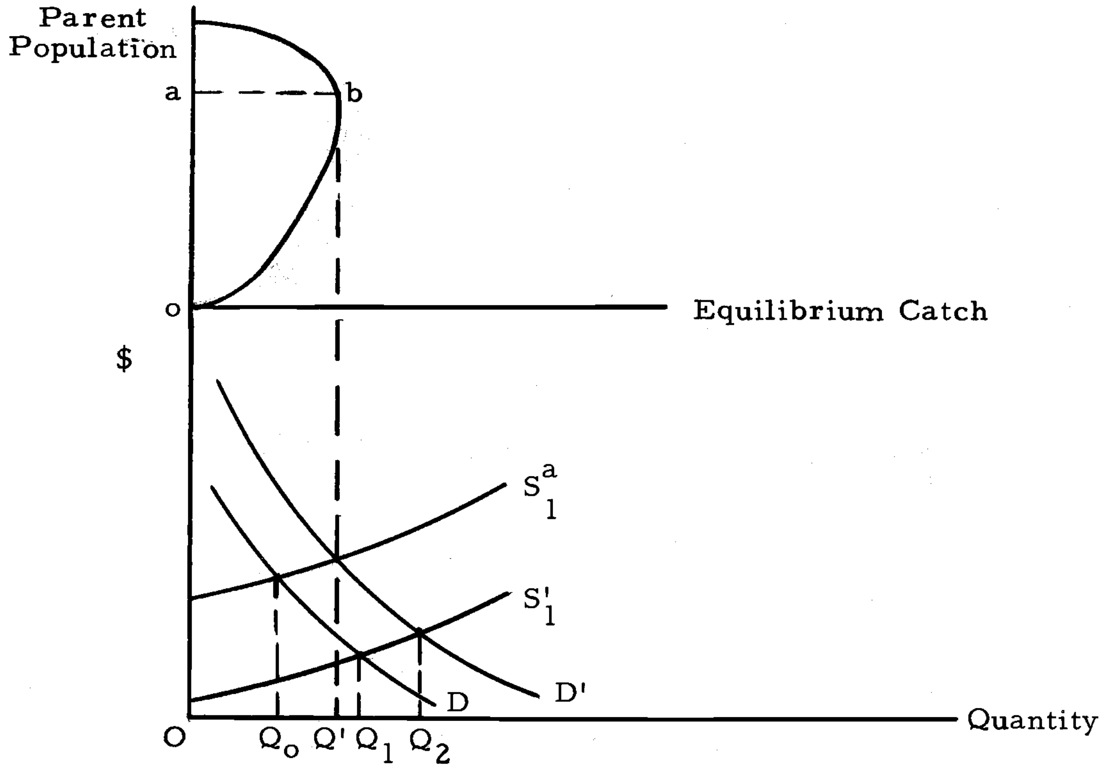

Figure 28. Relation between demand and technology.

Assume that parent population is oa. Consistent with this level is a supply curve, S^a_1. If demand for the product were given by D, then the industry would produce Q_o in the present time period. This production would be less than equilibrium catch and hence, in the following time period the population would increase slightly, and equilibrium catch would fall.

But assume that D' is the relevant demand function. In this case, the industry would supply Q', and since Q' exactly coincides with equilibrium catch, ab, the biological and economic aspects would be in harmony. Now assume a significant technological change in catching methods such that each unit of fish can be produced for much less than its former cost. S'_1 now reflects the industry supply curve for population level oa.

If it is assumed that D is the relevant demand curve for the product, then the industry would place Q_1 on the market. This quantity exceeds equilibrium catch (ab) and would lead the industry to "overfish" the ground. If demand curve D' is assumed relevant, the extent of "overfishing" would be even greater. It is this direct relationship among technology, demand, and fishery population dynamics which makes the fishery such a complex economic problem.

To analyze the charges of economic inefficiency and resource misallocation in the fishery, it will be convenient to first treat the unrestricted entry aspect, and then, the externality aspect.

Unrestricted Entry and Economic "Inefficiency"

As seen in Chapter II, the prevalent attitude among those writing about the fishery is that lack of ownership of the basic resource, and open access to any who wish to participate, leads inevitably to "overfishing," lower sustained yield, higher costs, and zero economic yield from the resource. These things are said to occur because of excessive entry into the fishery in the absence of a profit-maximizing sole owner. Also identified are poverty, immobility, and a misallocation of effort over grounds of differing quality. The causal relation between common property, and poverty and immobility was investigated in Chapter III. The question of misallocation of fishing effort among grounds will be treated in the next section. The charge of excessive effort and its supposed ramifications will be discussed here.

The models used by traditional theorists led them to the conclusion that all of the above inefficiencies could be eliminated if a sole owner were given control over the fishery. The following discussion is therefore an effort to illustrate that the general conclusions derived by the traditional writers depend upon a very vague and simplified economic model.

The following sections will cover several topics. The first one is the relationship between net social benefits, and the equilibrium position of a competitive fishery. Secondly, three closely related issues will be treated jointly: overfishing, lower sustained yield, and higher costs. The conclusion reached by the traditional writers is that open entry to the fishery <u>necessarily</u> leads to these three consequences. That conclusion will be proven false. Finally, it will be demonstrated that the recommendation to equate industry marginal cost with industry marginal revenue can easily lead to the same position as would occur under open entry and that therefore the universal recommendation for sole ownership to "solve" the problems of the fishery is not well founded, nor supportable in a rigorous fashion.

Open Access and Net Economic Yield

As was indicated in Chapter III, the net economic yield from the fishery is not given by the profits of the fishing industry, but by the surplus in consumer evaluation over the necessary costs of harvest. To charge that because industry costs equal industry receipts, the economic yield of the resource is zero is to confuse industry profits with net social worth.

If it is assumed that the demand for the product of the given fishing ground under question is infinitely elastic, then the following diagram would correspond to that situation hypothesized by the traditional theorists. The biological aspects are momentarily disregarded.

If the demand price for the product from this particular fishery is given by P_o, boats would enter the industry until per unit production costs for the typical firm[30] are given by $SATC_i^o$. At this point, output from the fishery is Q_o and total costs to the industry equal

[30] It is still assumed that all firms are homogeneous.

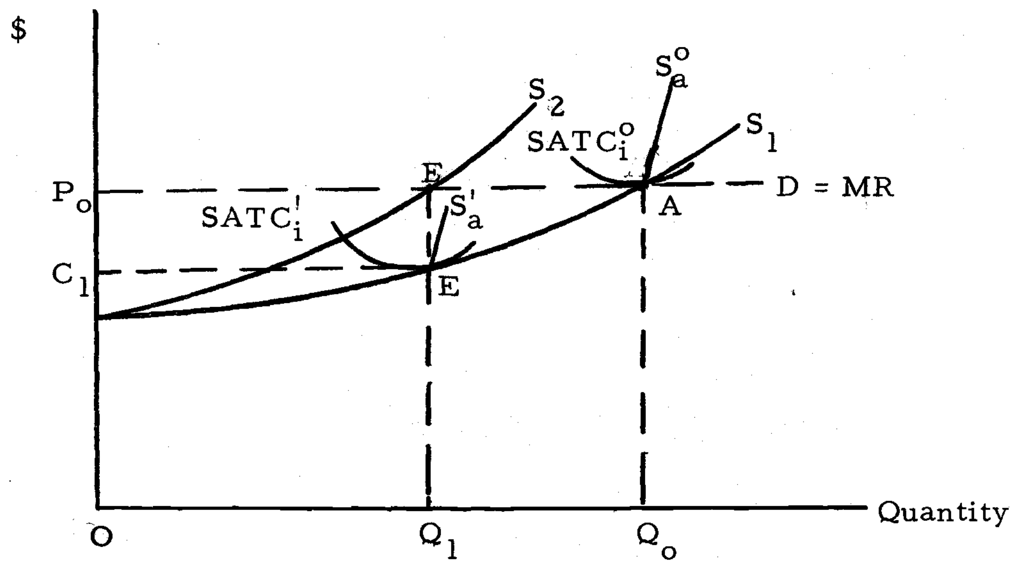

Figure 29. Restricting output from the fishery.

total receipts (OQ_oAP_o).

According to traditional theorists, a superior situation would be to restrict boats and output to the point where industry marginal revenue (P_o) is equal to industry marginal cost (S_2). At that point consumers still pay P_o, but receive only Q_1 of the commodity. Consumers pay a total of OQ_1FP_o for this quantity, while production costs are only OQ_1EC_1. Can it be said with certainty that "society" is better off? The factors formerly used to produce $Q_o - Q_1$ have been released to find employment elsewhere. Yet the analysis of Chapter III would indicate that returns to these factors are most likely higher in the fishery or they would not be there.

It might be argued that with boats restricted to where Q_1 were the industry output, the price to consumers could be reduced to C_1.

However true this may be, it does not remove the fact that if the original demand price for fish were only C_1, the industry would voluntarily produce Q_1 with no arbitrary controls. The output of the industry will expand and contract in a direct relation to consumer demand, just as the production of any commodity adjusts to consumer demand.

As pointed out in Chapter III, it is probably unrealistic to assume that any fishing ground of manageable size can be assumed so small that its output would not influence the price receivable from it. Therefore consider the following diagram.

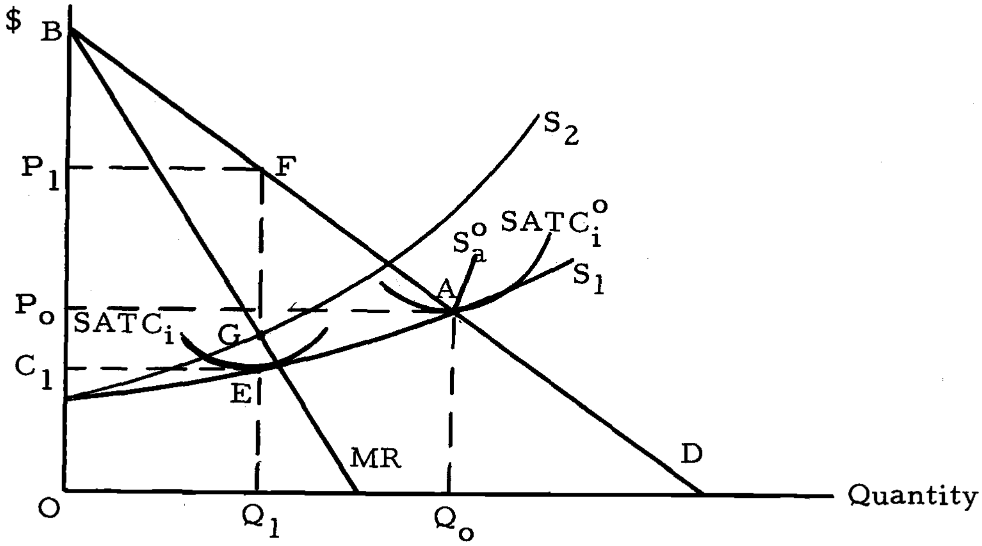

Figure 30. Actual and "ideal" output assuming less than infinitely elastic demand.

Now, with unrestricted entry, industry output expands to Q_o, and sells at a per unit price of P_o. Industry receipts equal industry costs and both are given by the area OQ_oAP_o. But while industry profits may be zero, consumer's surplus is given by the area P_oAB; net social benefits are not zero. Restricting output to where industry marginal revenue (MR) equals industry marginal cost (S_2) reduces consumer's surplus from P_oAB to P_1FB, and creates monopoly profit of C_1EFP_1.

Open Access and Sustainable Yield

In spite of the vague nature of the model used by Gordon (1954), Christy and Scott (1965), and others, its supporters are quick to add that restricted entry is desirable in all situations. The following illustration will show this conclusion to be false.

The most significant relationship in a fishery is that between available technology and demand for the product. Assume that demand and technology are such that the situation in Figure 31 would prevail.

Assume initial population level is oa. With demand for the output of this fishery represented by D, the competitive fishery would place Q_o on the market in the present time period. Because equilibrium catch from a population of this size is only ab, the stock will be "overfished" in the present time period by the amount E.

In the following period, parent population would be reduced to oc, which implies an industry supply curve of S_1^c. Assuming demand remains unchanged, Q_1 would be placed on the market in this

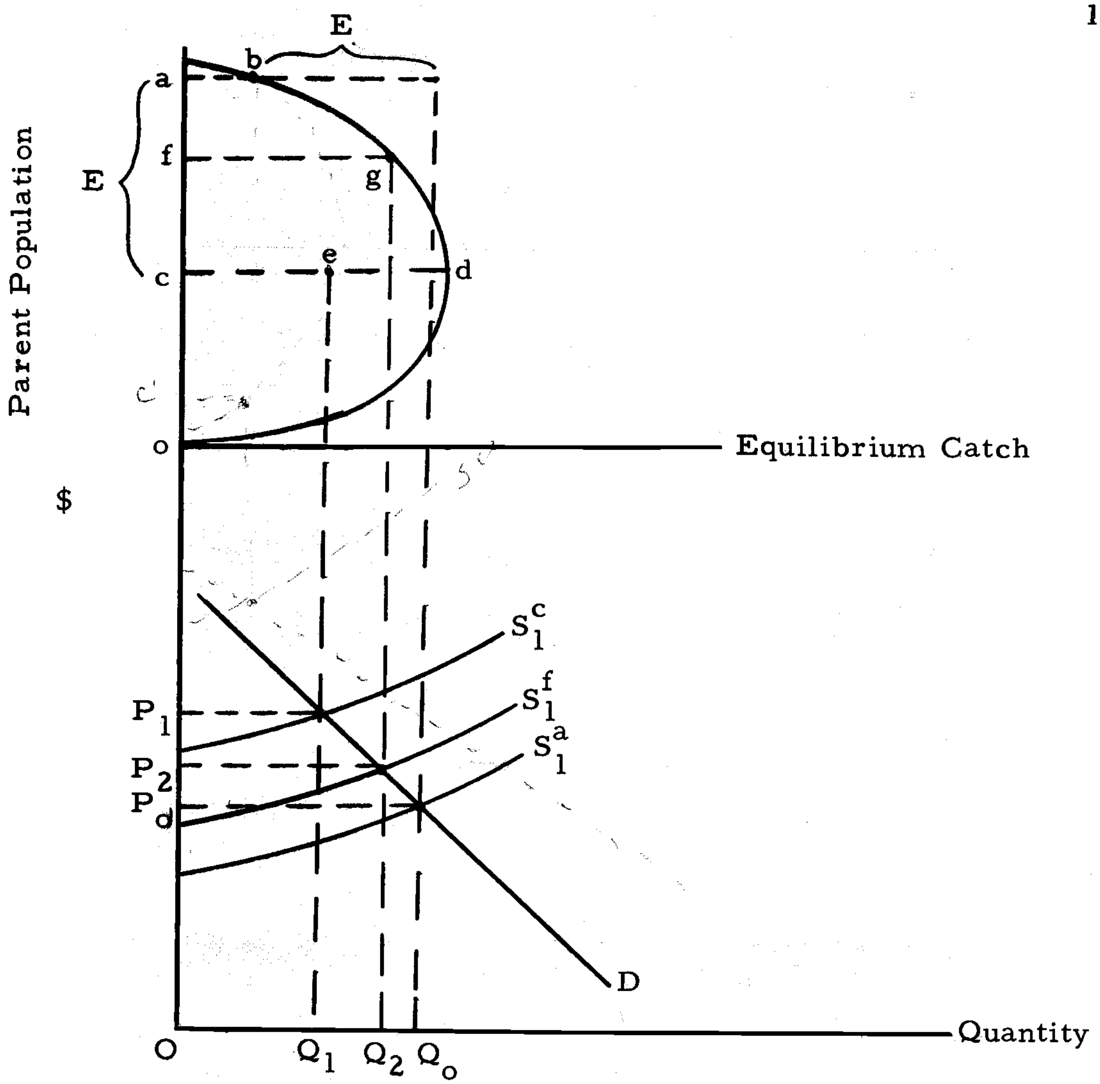

Figure 31. Achieving bioeconomic equilibrium.

time period and the prevailing price would be P_1. But this quantity is less than equilibrium catch (<u>cd</u>) by the quantity <u>ed</u>. In this period, the stock is "underfished."

As a result of "underfishing" in this time period, the parent population will be larger by the magnitude of surplus population not taken. Thus, in the following period, parent population is increased to <u>of</u>. This population implies an industry supply curve of S_1^f. If it just happened that S_1^f intersected D at the level of equilibrium catch (fg) associated with population of, the biological and economic systems would be in harmony. If this equating did not occur immediately, the move towards an equilibrium would take several more periods. But the point is, unrestricted entry need not necessarily lead to "overfishing," lower sustained yield, and higher costs.

In this case, "overfishing" occurred in one period, "underfishing" occurred in the following period, production costs have increased from S_1^a to S_1^f, but so has sustained yield increased. Now, a sustained yield of Q_2 is available from the fishery and it can bring P_2 in the market place. If demand, technology and input prices remain constant, it will be possible for the bioeconomic equilibrium to prevail indefinitely; and open access has not reduced, but has increased sustained yield.

Thus such statements as: "The analysis just given--which follows that of Gordon (1954), Scott (1955), and Turvey and Wiseman (1957)--makes it clear that a sea fishery open to all comers tends inevitably toward overexploitation" (Crutchfield and Zellner, 1962, p. 17) must be viewed with suspicion.

This is not to say that a fishery open to all cannot become "overexploited," but it is poor scholarship to use this type of inductive process to say that observation of correlation guarantees causality. It is not open access which "causes" this sweeping conclusion, but rather the models employed by the traditional theorists.

Now consider the case where entry is restricted to the point where industry marginal cost (S_2) is equated with industry marginal revenue.

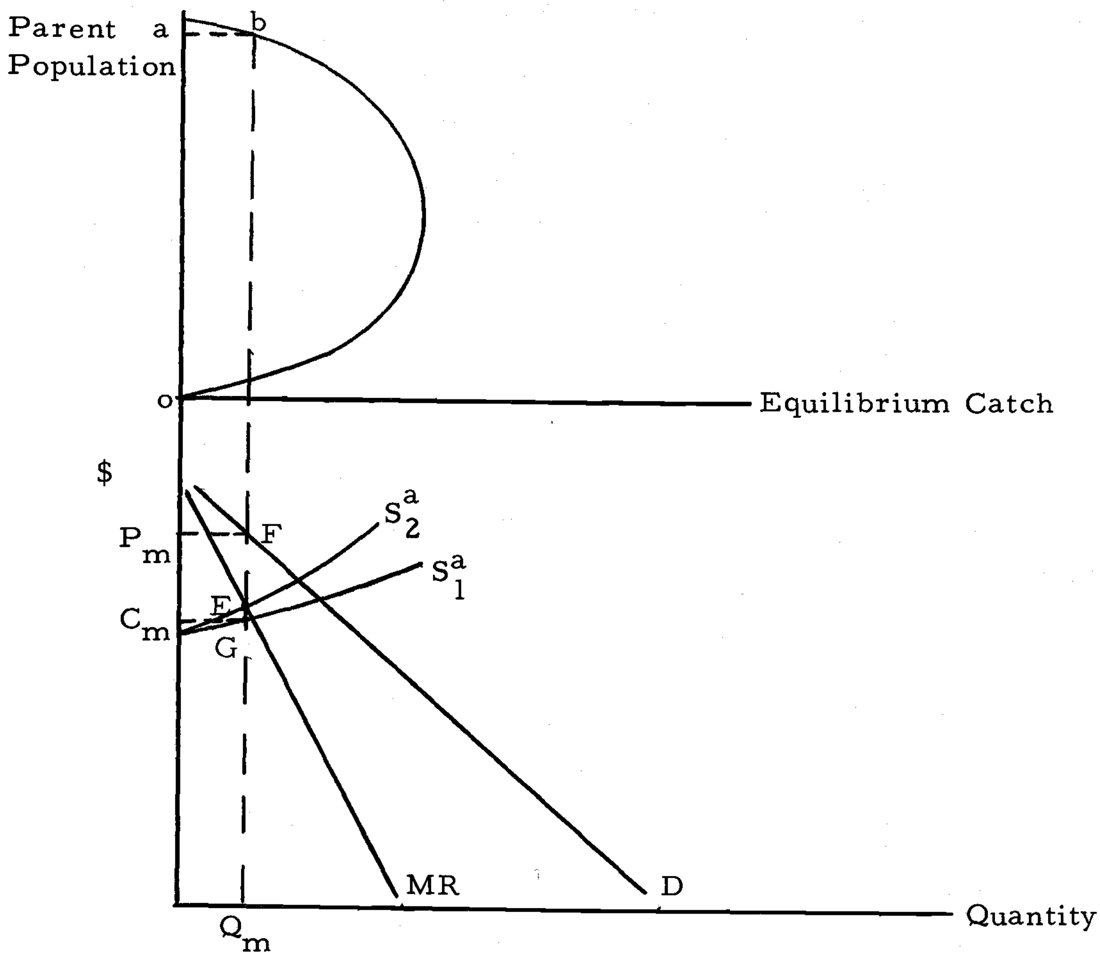

Figure 32. The creation of monopoly profit in a fishery.

Figure 32 represents similar physical and economic relationships as Figure 31. Except now, the usual recommendation to restrict entry is followed. In this case, point E would determine output of the fishery, Q_m. At this restricted output level, the price received would be P_m, while the per unit production costs would be only C_m. Thus, a monopoly profit of $C_m GFP_m$ is created to be shared by those fortunate enough to remain in the fishery.

Also notice that since Q_m happens to exactly coincide with equilibrium catch ab, the industry would be taking precisely equilibrium catch. Making the same assumptions regarding factor prices, technology and demand, the fishery could continue to produce Q_m, generating a profit for producers, and be placing a smaller quantity on the market, which brings a higher price, than would be the situation under open access to the resource.

Restricted Entry and Sustainable Yield

Consider Figure 33. Here, the demand for the product is so substantial that the equating of industry marginal cost with industry marginal revenue results in a production of Q_o. This level exceeds the equilibrium catch associated with the fish population oa by E. Therefore, in the following time period, population would be reduced to od, which would imply a supply function of S_I^d.

In this period then, Q_1 would be placed on the market and since this coincides exactly with equilibrium catch de, the biological and economic systems would be in balance. The usual suggestion to equate industry marginal cost with industry marginal revenue has led to the kind of situation (lower sustained yield) which, supposedly, can

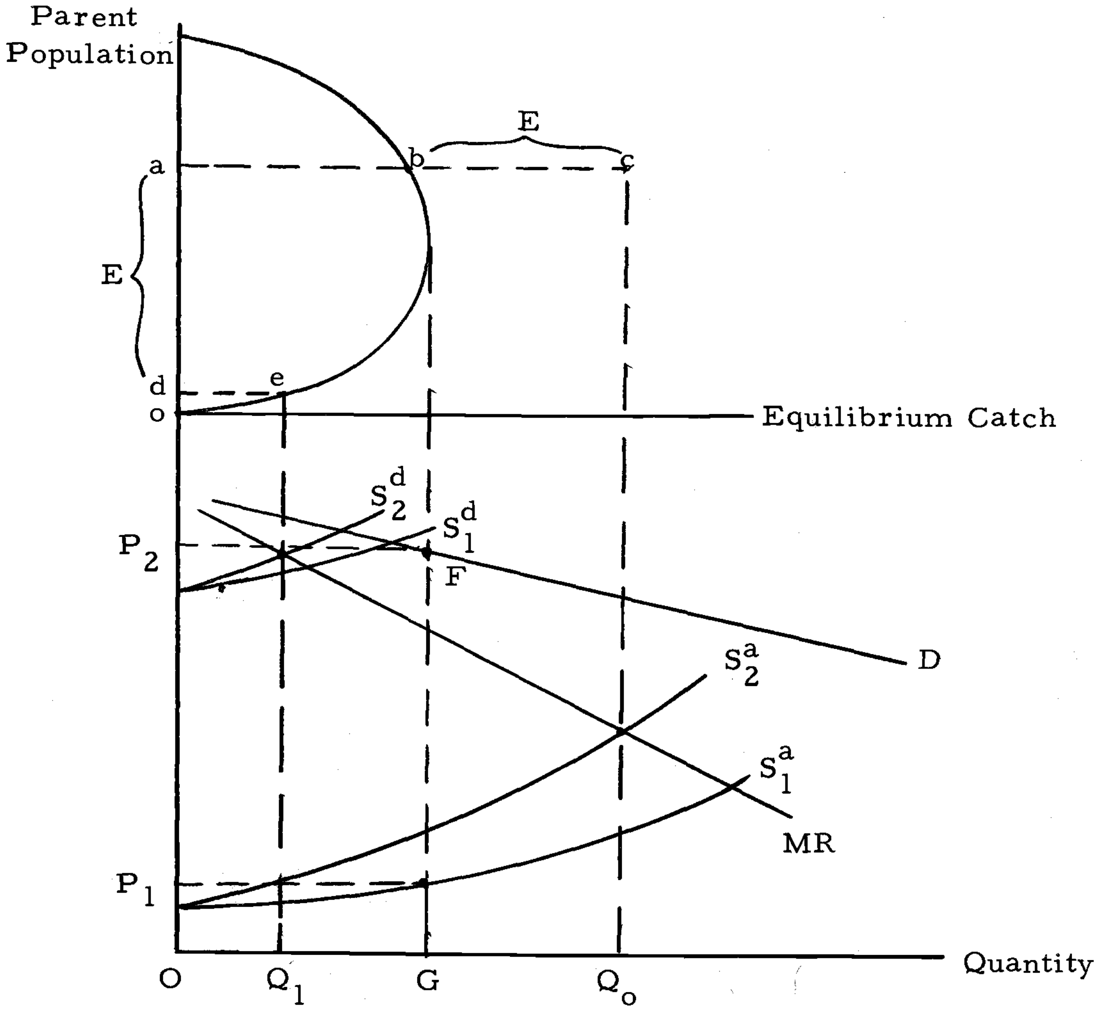

Figure 33. Excessive demand in a fishery.

only occur under competitive exploitation.

Two final points can be made using Figure 33. Crutchfield and Zellner (1962) use a diagram similar to Figure 33 to "point out the nature of the economic inefficiency that may be involved if no restriction on entry exists."

> Here OG is the maximum sustained yield. Consumers are willing to buy OG at a price P_2. Producers will be willing on grounds of profit maximization to supply OG at the price of P_1. The difference between P_2 and P_1 would produce higher than competitive returns in the

fishery--provided additonal fishermen could be kept out. With no restriction on entry, more and more fishermen will enter, driving up costs, until returns in the fishery are just equal to the going competitive rate of return. Gains that could have been reaped by restricting entry have been dissipated by rising costs of production associated with excessive entry[31] (Crutchfield and Zellner, 1962, p. 17) (emphasis added).

Thus, as has been seen earlier, the recommendation of the traditional theorists to restrict entry admittedly results in the earning of "higher-than-competitive" returns. These "gains," which Crutchfield and Zellner speak of, are, in actuality, excessive profits shared by those fishermen not excluded from the fishery.

The concluding point of this section concerns the true cause of economic disequilibrium in the fishery. It is not the presence of common property which causes problems; it is the fact that demand for the product, and the technology of the industry, are, except in the rarest of circumstances, such that a competitive or centralized fishery would not be led to produce exactly the sustained yield of the fishery. There are conflicting social goals: preserve the fishery resource, and achieve economic efficiency. With the situation depicted in

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[31]The actual driving up of costs would occur in the following period. In the present period, with total output restricted, those boats producing G receive higher than competitive returns. In the next season, other fishermen are attracted, interdependence becomes more severe, γ_i increases and causes S_1^a to rise more steeply, until intersecting D at F. Another possibility would be that fear of overfishing the stock led to restrictions on fishing efficiency such that S_1^a was shifted upward to intersect D at F.

Figure 33, an improvement in technology which arose from a smaller, but more modern fishing fleet, would only compound the disparity between the quantity called for in the market, and the quantity which can safely be removed from the ecosystem.[32] To advocate blocked entry so that more modern fishing techniques can be adopted may only worsen the situation.

The nature of the choice can perhaps best be illustrated in Figure 34.

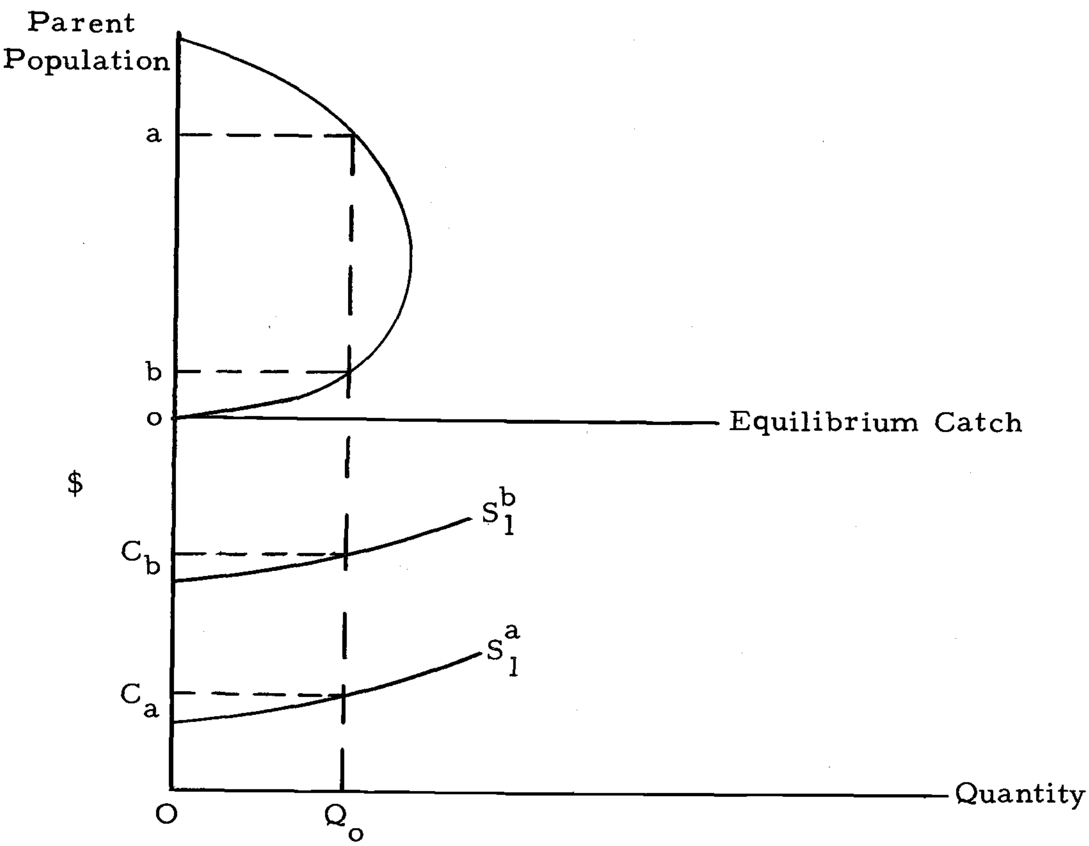

Figure 34. Social choices in a fishery.

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[32]This would occur because S_1^a would be shifted downward, reflecting the lower per unit production costs of the more modern fleet.

If it is assumed that through a series of technological changes, and periods of excessive demand, the industry is eventually found to be producing Q_o along the industry supply curve S_1^b, it is indeed true that economic "inefficiency" might be considered present since, if population could somehow be restored to oa, this same level of catch could be produced on a sustained basis for only C_a per unit. To state unequivocally that the situation warrants correction however, would require proof that the present value of all production foregone in the process of restoring the population to oa, is less than the present value of all future goods and services produced by the realized savings in the fishery $[(C_b - C_a)Q_o]$, minus the required compensation to those fishing firms denied income during the required period of reduced production. The construction of this proof would not be easy.

The above illustrations are not intended as proofs that centralized decision making is, or is not, superior to the current situation of open access. The major intent is to demonstrate that it is the models used by the traditional theorists which permit them to: (1) erroneously define industry profit as a net social benefit; (2) "prove" that the equating of industry marginal cost with industry marginal revenue will always prevent "overfishing" and lower sustained yield; and (3) "prove" that it is "inevitable" that when "everyone's resource is no one's resource," overexploitation necessarily results.

Productive Interdependence, Externalities, and Economic Efficiency

Probably fewer areas of economics are as unclear as that of externalities. Most all economists, though perhaps unclear about what externalities really are, seem rather unanimously convinced of how they can be "corrected." The issue of externalities is of vital concern in the analysis of economic efficiency in common property natural resource use, for recent welfare economists, as well as others, identify the ocean fishery as an example of an economic activity where technological externalities can be found (Buchanan, 1956; Mishan, 1964; Turvey, 1964; and Smith, 1968).

The currently popular way to express an externality is to show the production function of one firm containing the output of the firm creating the "externality." This is consistent with the model developed in Chapter V and would be illustrated in the following manner:

$$X_1 = f\,(v_1,\ v_2,\ \ldots\ v_n,\ X_2) \qquad (6.1)$$

Expression (6.1) indicates that the output of firm one is not only a function of its n inputs, but also the output of firm two. If this represented technological diseconomies, X_2 would have a detrimental effect on firm one. If it represented technological economies, X_2 would have a favorable effect on X_1. The fact that X_2 is physically instrumental in the production process of X_1, and this effect is not accounted for in the market place, supposedly implies that a technological externality is present. The presence of externalities is said to lead to a divergence between private and social net products (or costs).

This interdependence between producing units, as was seen in Chapter V, causes the per unit production costs in the fishery to rise, as industry output expands. And, these industries supposedly produce excessive outputs. A. C. Pigou was concerned about socially correct levels of output for industries in general. His conclusion was that those industries which are known as "increasing cost industries" produce too much, while those known as "decreasing cost industries" produce too little. The results of Pigou's work have had far reaching impact in the field of social control, for the usual justification for government intervention is a divergence between private and social costs.

Pigou presented the following diagram as "proof" that competitive industries produce excessively when total industry costs increase proportionately greater than industry output.

Function SS_1 is called a supply curve of the ordinary type, and SS_2 is called "a curve of marginal supply prices." The function SS_1 shows, at each point, the cost or price at which the corresponding output could be maintained in the long run, and SS_2 shows, at each point, "the difference made to aggregate expenses" by producing

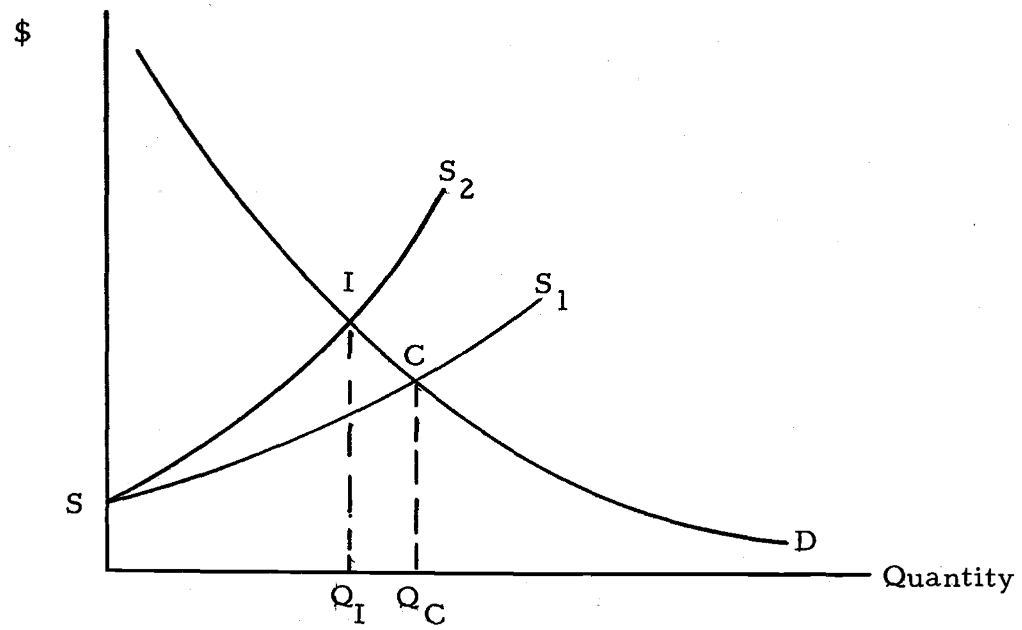

Figure 35. Pigou's increasing cost model.

one more unit. To quote Ellis and Fellner:

> With austere brevity, Pigou concludes directly from the description of the two functions that the intersection of S_1 with the demand schedule at C corresponds to output and price under competition, whereas the intersection of S_2 with the demand schedule at I represents the correct output under an ideal allocation of social resources (Ellis and Fellner, 1943, p. 495).

In Allyn Young's review of Pigou's book, he hailed the S_2 curve as a "new and powerful instrument of economic analysis," particularly in monopoly theory, but denied that it verified a divergence of competitive from ideal output.

Young said:

> Is equality of marginal aggregate expenses the equality which we have in mind when we say that the maximum product will be achieved when marginal net products are equal? Does Professor Pigou mean by the term "resources" the services of labor and capital which are

> used up in production or does he refer to the money expenses of entrepreneurs? (Young, 1913, p. 682).

What Pigou discovered, are now known as pecuniary diseconomies, and Young's reluctance to accept S_2 as a social cost function is now well accepted. As expressed by Ellis and Fellner:

> If the expansion of an industry gives a factor a higher per unit remuneration, whether or not that higher price induces a greater aggregate (social) supply of the factor, the units already being supplied earn producers' rents (or increase the previous rent); and rent is not a cost in social resources. Consequently if the output of a commodity expands, the rise in transfer costs (i.e., in the value) of the intramarginal units of the transferred resource is not part of the marginal social cost of producing the commodity under consideration. The marginal social (opportunity) cost of transferring resources yielding n units is merely the cost of transferring the resources required for the production of the nth unit. This cost is expressed by (S_1) not by (S_2). The (S_2) function is not a social cost curve because it includes increments to rent (Ellis and Fellner, 1943, p. 497-498).

Pigou accepted the criticism as it relates to transfer costs but maintained that it was relevant to diminishing returns. Quoting Ellis and Fellner, who are in turn quoting Pigou:

> The reason why diminishing returns in terms of money [read: "increasing costs," Ellis and Fellner] appear when they do is, in general, not that the money price of factors employed is increased, but that the proportionate combination of different factors, which it is most economical to employ when $(x+\Delta x)$ units of commodities are being produced is a less efficient proportionate combination than that which it is most economical to employ when x units are being produced; and the extra cost involved in this fact is real, not merely nominal (Ellis and Fellner, 1943, p. 498).

This approach has been followed by the traditional workers in fishery economics to justify their recommendation for sole ownership. They view this rising cost of output as a sufficient condition for government intervention. That it costs firms more to produce a unit of output when industry output is Q_C than it does when industry output is Q_I cannot be denied. But this is not the central issue. What is important is that a misallocation of resources has not occurred.

The present section will thus make clear that productive interdependence among firms within the same industry[33] does not necessarily imply that externalities also are present. For the term "externality" is used to signify market failure and market failure occurs when resources are not allocated in a socially ideal fashion. Market failure does not necessarily occur when productive interdependence exists. This being the case, the derivation of various taxes for firms in a common property fishery to "internalize the externality" is subject to serious question.

The hypothesis that physical interdependence within an industry is insufficient grounds (though perhaps necessary) for outside control must digress to the time-worn example of the "road-case" to illustrate a situation where adjustment may be necessary. In this fashion the problems in the fishery become much easier to analyze.

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[33]Actually, the important distinction is the commodity; when firms producing the same commodity are physically related, this does not necessarily imply that there is market failure (externalities).

The Road Case

Assume that there are two roads of equal length joining points A and B. One road, C, is paved, very smooth, but narrow. As a result of its width, congestion occurs. The other road, D, is of gravel surface, replete with chuckholes, but of infinite width. As a result of D's width there can be no congestion. Further, assume that to transport a unit of commodity X between A and B on route D costs $10, regardless of the number of vehicles on the route. Also assume that this trucking activity is the only one carried on between points A and B.

Road C is a different case. For small volumes of traffic, the cost of hauling good X between A and B is quite low, but this cost increases as a linear function of the number of units hauled (one unit per truck).

Since highways are constructed not to benefit truckers but to aid society in transporting its commodities, a reasonable objective for social action would be to minimize the cost of hauling various quantities between points A and B. Therefore, assume the following situation.

It costs $5 to haul one unit of X from A to B on road C, but this cost increases by $1 for each additional unit hauled (truck) per unit of time. Recall that the per unit cost on road D is $10, and remains constant. Assume that society wishes for only one unit of X to be transported between A and B in the present time period. A trucker agrees to take the job at cost and wisely uses road C. If two units were desired moved,[34] then another truck would use the road. In so doing, society must pay $6 per unit now because of the mutual interdependence (congestion) of the two trucks. If demand for road services were sufficient, it would cost $7 per unit to move three units; $8 per unit for four; $9 per unit for five, and $10 per unit for six. If the demand were for five units in the current time period, each truck would, quite rationally, use route C. Each truck would be foolish to use route D since the per unit production costs on that route are $10. Assuming all trucks of equal efficiency, and each charging society only costs, consumers would pay a total transportation bill of $45 (five units at $9).

But it is possible to demonstrate that the total shipping bill to society can be reduced by a reallocation of truck traffic.[35] Consider the following table.

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[34]There is only sufficient time in each period for one trip per truck.

[35]This assumes that any savings realized by a trucker is passed on to the consumers in lower transportation costs and not as economic rent (profit).

Table 1. Costs of transporting various quantities of X between A and B.

Units (trucks)	Per Unit Cost	Total Industry Cost	Marginal Industry Cost
1	5	5	
2	6	12	7
3	7	21	9
4	8	32	11
5	9	45	13
6	10	60	15
7	10	70	10
8	10	80	10
9	10	90	10
10	10	100	10

The per unit and marginal industry costs are plotted against industry output in Figure 36. The per unit cost function is labeled S_1 and corresponds to the S_1 function developed previously, and the marginal industry cost function corresponds to S_2. The horizontal curve, AC=MC, shows the average and marginal cost of using road D. It is the industry "opportunity marginal cost curve."

The claim that users of common property natural resources equate price with average cost can now be given some clarity. Firms still produce where their price is equal to their respective marginal cost, but would continue to use road C until the average (or per unit) cost became equal to the average and marginal cost on road D. It should be obvious that truck six is indifferent as between road C or D, but that all subsequent trucks would prefer road D.

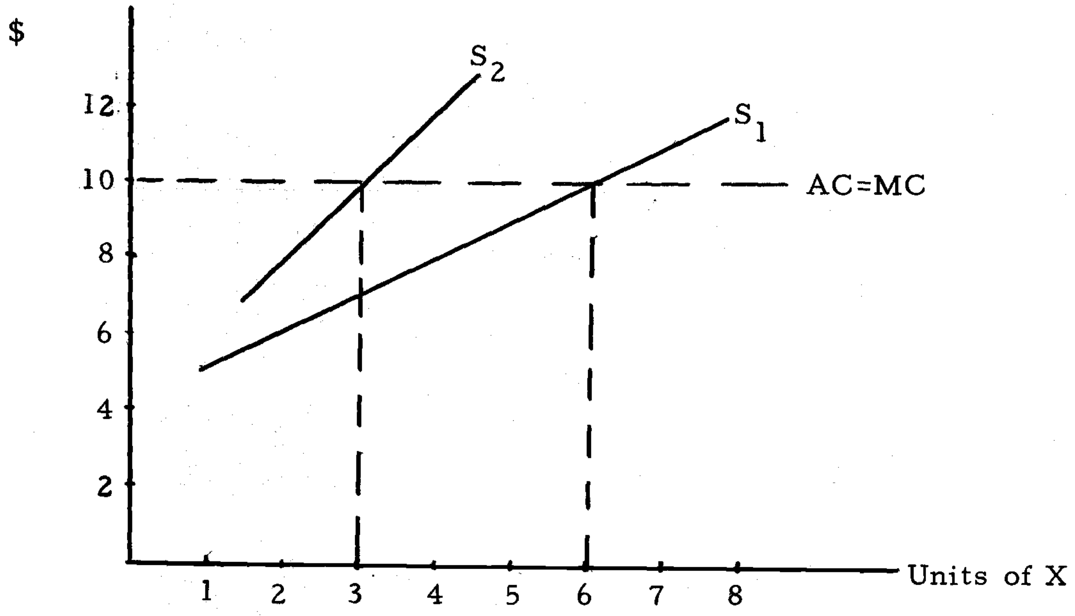

Figure 36. Cost curves for trucking industry.

Now, to illustrate the nature of the misallocation when five units are transported, recall that if left to their own devices, truckers would cause society to pay a shipping bill of $45. Assume that it could somehow be arranged for all trucks after three to use road D. Would there be a social gain? The reason for selecting the third truck is that upon its entry onto road C, the marginal industry cost becomes equal to that on road D, the opportunity marginal cost.

If trucks four and five (more specifically units four and five) were made to use route D, the total shipping bill for society would be only $41. This combination is less expensive than any other way of allocating the five units between the two roads. For if only two trucks could use road C, total costs would be $42 (two at $6 plus three at $10), which is the cost if four trucks used road C, and one used D (four at \$8 plus one at \$10). Thus, if it is assumed that the truckers would pass this savings on to society, social welfare could be enhanced by reallocating truck traffic.

The same results hold for the moving of eight units between A and B. If left to allocate themselves, six trucks would use road C (causing each to incur costs of \$10) and the remaining two would use road D (and also incur costs of \$10). If this prevailed, society would pay a total shipping bill of \$80, whereas this could be reduced to \$71 (three at \$7 plus five at \$10) if only three trucks were permitted on road C. Again, reallocation has resulted in a net social gain.

Notice from Figure 36 that if it is desirable to have the fourth truck use road D, a toll of \$2 will make that vehicle indifferent as between C and D and a toll of \$2.01 to use C will be sufficient to effect reallocation. Likewise, truck five requires a toll of only \$1.01 to shift it to road D. Thus the taxable quantity is between AC=MC and S_1, not between S_2 and S_1.

The above example is one of technological interdependence which results in a misallocation of resources between two opportunities. Since an allocation problem can only arise when there is a choice to be made, and since the market was not present to guide this choice, an externality exists. In Bator's (1968) terminology, there is "market failure." In this situation, the S_2 function contains relevance for social allocative choice; it is relevant because when S_2

becomes equal with another industry marginal cost function (in this case AC=MC), society will benefit (assuming prices equal costs) if further output of the industry is conducted along this latter function. The function AC=MC represents an opportunity marginal cost function and when output (trucks) reaches three units, reallocation is justified.

The Ocean Fishery

Now consider the fishery. Whereas the trucking firms had an available alternative for hauling their freight, and the misallocation resulted because they individually made the wrong choice, the fishery is different. There is not the range of choice in the fishery. If it is assumed there is one, homogeneous fishing ground, there is, in actuality, no alternative for the fisherman.

Assume that there is only large homogeneous area where a certain species can be harvested. The problem is one of ideal levels of total fishing services (fish). Define a unit of fish to be some given mass of the product. Assume that with one boat plying the ground, it costs society \$5 to obtain this one unit of fish per period of time. Two boats could fish, but in so doing, it costs each \$6 to produce a unit of fish. When the third boat enters, the unit costs \$7, with the fourth boat its costs rise to \$8, and so on in a fashion similar to the road case. Except that here, there is no other place for the industry to provide the service. Thus, costs continue to increase as in Table 2.

Table 2. Costs of providing various quantities of fish.

Units	Per Unit Cost (S_1)	Total Industry Cost	Marginal Industry Cost (S_2)
1	5	5	
2	6	12	7
3	7	21	9
4	8	32	11
5	9	45	13
6	10	60	15
7	11	77	17
8	12	96	19
9	13	117	21
10	14	140	23

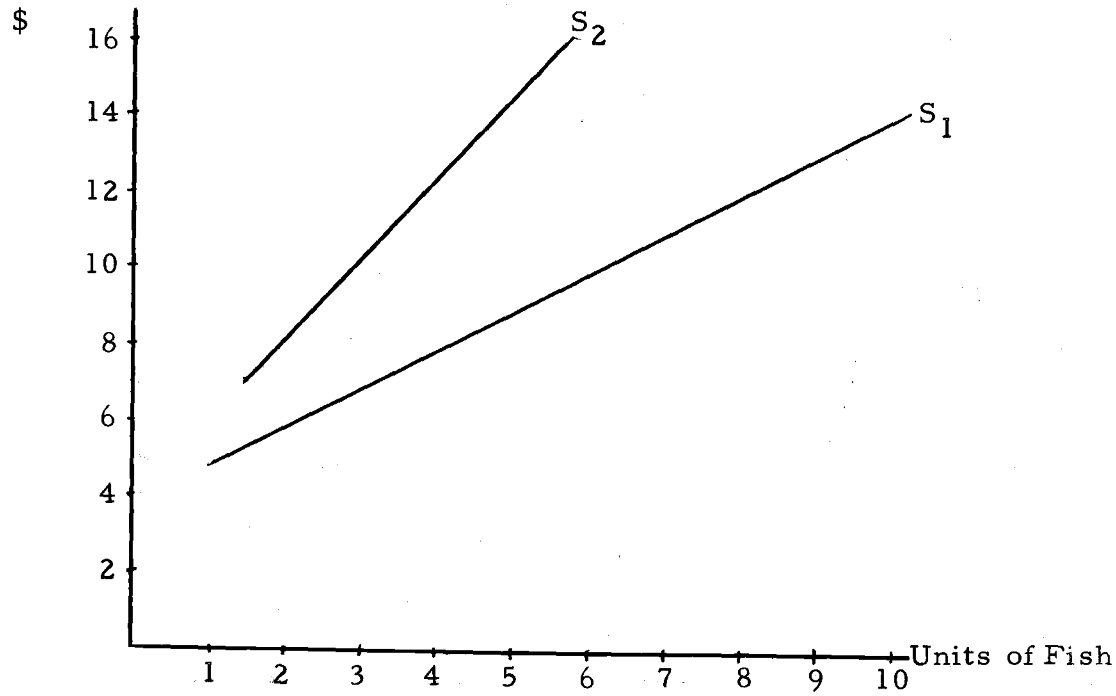

Figure 37. Cost curves for various levels of industry output.

Now, this situation is analogous to the road case, except that there is no alternative method of providing the desired commodity. S_1 and S_2 correspond to those curves developed in Chapter V.

Society's demand price for fish will be equated with the long run supply curve for fish (S_1) and there is no basis to state that society could save money if output were provided in a different fashion. There is only one way to provide the fish, and an "opportunity marginal cost" curve of the road case does not exist.

The fact that S_2 lies above S_1 has no allocative significance. In the road case, the S_2 curve indicated that after the third truck was on road C, another truck would add more to costs of providing the service than if that fourth truck were reallocated to the wide, bad road, <u>and</u> if trucks one, two and three passed the savings in transportation along to consumers.

The road case would be exactly analogous to the fishery if it were assumed there were no alternatives to moving the good from A to B. There can only be economic problems of resource misallocation if there are choices involved. Thus, the problems of increasing costs of supply in the fishery, although providing an example of technological (physical) interdependence, do not constitute an externality. There is no market failure because there is no wrong choice. Output in such circumstances cannot therefore be termed excessive. Nor can a call to equate marginal industry revenue with marginal industry cost claim any validity since marginal industry cost has no relevance to socially ideal output.

It will be recalled that earlier in this chapter, Figure 29 depicted the following situation.

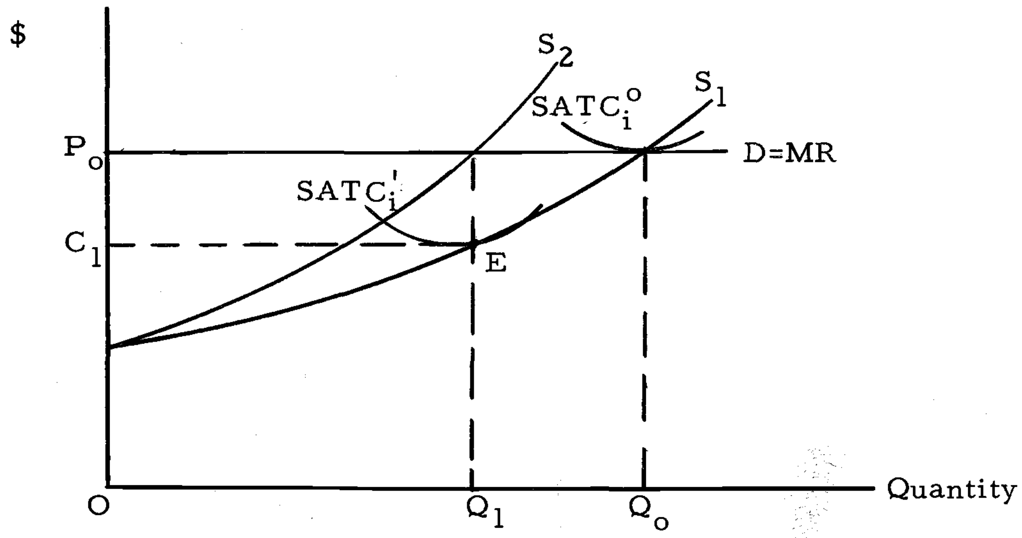

Figure 38. Restricted output of a common property fishery.

The traditional theorists were seen to advocate restricting boats to the point where industry marginal costs (S_2) equal industry marginal revenue. In light of the preceding analysis it would appear that unless society can obtain the foregone quantity $Q_o - Q_1$ elsewhere, then no increase in social benefit would result from restricting output.[36]

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[36]This assumes that the resources formerly producing $Q_o - Q_1$ could not be put to use elsewhere producing a substitute consumption item. The difficulty over what is a "commodity," and what is an "industry" precludes any sweeping conclusions about substitutes for food from the sea. If one is talking of mere protein production, then land-based agriculture does provide a socially relevant production opportunity. However, the unique character of Dungeness Crab, or salmon, make it much more difficult to talk of alternative possibilities.

It can also be said that the specific taxes derived by Smith (1968) to cover vessel crowding "externalities" and resource stock "externalities" are incorrect since no misallocation of social resources exists; taxes merely reduce the total output of fish.

The final issue to be resolved concerns the conclusion that fishing effort is misallocated over grounds of differing quality. Assume ground A of this particular fishery is well stocked with fish and that the first boat on this ground can produce a unit of fish for $5. As more boats use the ground their respective production costs per unit increase in $1 increments as in the previous cases. Also assume that ground B, of equal distance from port, contains this particular species but in much smaller quantities. Thus, the first boat on ground B can produce a unit of fish for $10, and subsequent boats increase this cost in $1 increments. This situation is depicted in Table 3.

As boats leave port and decide which of the grounds to fish, they consider only average costs, as Gordon has rightly stated. And, left to their own devices, six boats would use ground A, before becoming indifferent as between the two grounds. Boat six would be indifferent, and his actions dictate what boat seven decides to do; if boat six chooses ground A, then boat seven will use ground B because it is cheaper by $1. Now with this situation, all boats in the fishery (both grounds) are producing fish at a per unit cost of $10, six

Table 3. Costs of fish production assuming two fishing grounds of different quality.

Units	Per Unit Cost on Ground A	Per Unit Cost on Ground B	Total Industry Cost Ground A	Total Industry Cost Ground B	Marginal Industry Cost Ground A	Marginal Industry Cost Ground B
1	5	10	5	10		
2	6	11	12	22	7	12
3	7	12	21	36	9	14
4	8	13	32	52	11	16
5	9	14	45	70	13	18
6	10	15	60	90	15	20
7	11	16	77	112	17	22
8	12	17	96	136	19	24
9	13	18	117	162	21	26
10	14	19	140	190	23	28
11	15	20	165	220	25	30
12	16	21	192	252	27	32

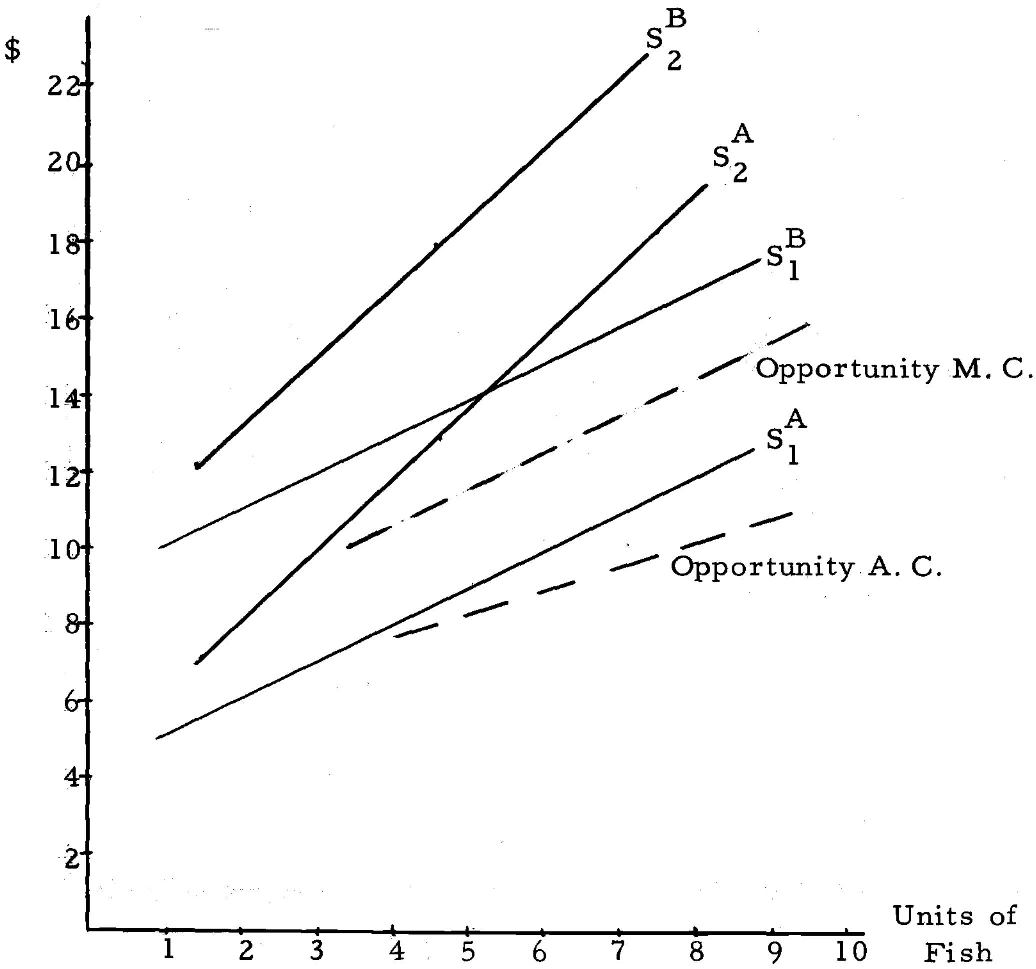

Figure 39. Cost curves for two grounds of different quality.

of them on A, and one on B.

As before, boat eight is now indifferent between A and B, as each will cost $11 per unit produced. Assume boat eight chooses ground B, now both boats seven and eight are paying $11 per unit of production, while the six boats on A are paying only $10. Each boat on A is making a profit of $1 if the product is selling for $11. If this is the case, boats seven and eight are the marginal firms in the industry.

Assume consumers are not getting the desired quantity of fish and the price increases to $12. Other boats will enter the fishery in an effort to capture some of the potential excess earnings. The ninth boat would fish ground A where production costs per unit would then be $11 for all boats on A, while remaining $11 on B. Boat ten could choose either, but whichever one it does choose, boat eleven will certainly chose the other ground. After the eleventh boat had entered, per unit production costs would be the same for all boats on both grounds--$12, and none would make any profit. There would be eight boats on ground A, and three on B. With boats allocated in this fashion, costs would be $96 on ground A (eight at $12) and $36 on ground B (three at $12) for total costs of $132 for providing eleven units of the product. Notice that this is cheaper than producing eleven units from ground A alone ($165) or from ground B alone ($220). Society has received more for its money by the boats allocating themselves between the two grounds.

But, further savings could be realized, assuming the savings do not accrue as rent to the boats, if a different allocation scheme had been followed. Notice in Table 3 that the total costs of providing three units from A is $21. If four units are to be produced, it would cost $32 from ground A, which is where the fourth boat would want to fish (because per unit production costs are only $8 versus $10 on B). But if the fourth boat could somehow be induced to fish on ground B, he loses, but the gain to the other three boats overshadows four's loss. By the fourth boat fishing on B, the total costs of providing four units of fish are $31 (three on A for $21, and one on B for $10). A savings of $1 has been realized by reallocating the fourth boat, and assuming that boats one, two and three charge only $7 per unit, society has saved this $1. If, however, as would most likely happen, all boats received the same price ($10), society would not gain, neither would boat four; only boats one, two and three would gain. Hence for reallocation schemes to be socially relevant, it is mandatory that the savings be passed on to the consumers.

With four boats in the fishery, it was seen that total costs would be $31. Now consider the fifth boat. If it fished on ground B, total costs would be $43 (three on A for $21, two on B for $22). But if it fished A, total costs would be $42 (four on A for $32, one on B for $10). Clearly, society would save $1 by having boat four fish ground A. This line of reasoning would prevail for any number of desired units from the fishery, with alternate units coming from each ground.

This process should make it clear that there are opportunity cost functions for the fishery, but because both grounds experience increasing costs, these cost functions are not of the "wide road" type, but also increase. Table 4 presents numbers from the preceding example.

Table 4. "Ideal" allocation of production from two grounds of different quality.

	Allocation Sequence	Opportunity Per Unit Production Cost	Opportunity Total Industry Cost	Opportunity Marginal Industry Cost
1	A	5	5	
2	A	6	12	7
3	A	7	21	9
4	B	7-3/4	31	10
5	A	8-2/5	42	11
6	B	9	54	12
7	A	9-4/7	67	13
8	B	10-1/8	81	14
9	A	10-2/3	96	15
10	B	11-1/5	112	16

The opportunity average and marginal industry cost curves are plotted in Figure 39. Notice that the per unit costs on ground A (S_1^A) are greater than the opportunity average cost curve for the fourth unit of output, and it is this unit which it would be better to produce from B, than from A.

Thus, assuming that fishing grounds are of distinct quality, it would appear correct that a misallocation of effort (production) is a possibility. The reallocation however, may be practically impossible to achieve in a fashion which would insure social efficiency. The main reason is that instead of there being two grounds of easily identifiable quality, there is most likely a continuous gradation of fishing grounds and achieving the ideal allocation would appear formidable.

Secondly, "quality" is not a permanent attribute as in the road case, but one that changes over time. The migratory nature of fish, and the exogenous influences on stationary populations, cause quality to be variable between periods.

A third factor, and one that has empirical backing, is that it is unrealistic to assume all firms are homogeneous (Comitini and Huang, 1967). With this being the case, the reallocation would more likely result in rent transfers taking place among firms in the fishery, with no real social gain being realized.

A fourth consideration is that in addition to the inherent quality of the fishing ground being variable, the distance from the ground to port also influences "quality."

A final point, yet perhaps the most important, assuming all of the above difficulties could be overcome, and assuming that an "optimum optimorum" (also costless) scheme for allocating fishing boats was devised, unless each boat were to charge only actual harvest costs (including opportunity income, etc.) the reallocation would merely result in differential rents being captured by those firms on the better quality ground. Under these circumstances, no gain in social efficiency would result.

Summary

By way of summarizing the present chapter, the following points seem relevant:

(1) A bioeconomic model was constructed which permits the simultaneous depiction of productive interdependence, demand for the product, fishery population dynamics, and total output of the fishery. Changes in fish population and the technology of the industry can be illustrated and the ramifications of these changes on industry output, and sustainable yield of the fishery can be detailed.

(2) The model facilitates the illustration that net social benefits of the fishery are not given by the profit of the fishing industry, as is traditionally maintained.

(3) The charge that a common property fishery "leads inevitably toward overexploitation" was evaluated and shown to be false. Depending upon demand for the product, and the technology of the industry, a common property fishery is capable of producing a sustained yield from a fishing ground which is not representative of an "overexploited" fishery. In this regard, it was shown that equating industry marginal cost with industry marginal revenue was not sufficient proof that sustained yield could not be reduced.

(4) It was seen that a sole owner would be led to exploit the slope in the demand curve and hence create monopoly

profits for himself.

(5) It was seen that the "gains" which the traditional theorists say are possible, are, by their own admission, returns which are higher than competitive returns and are created by preventing boats from entering the fishery when demand exceeds the available supply.

(6) It was seen that the presence of productive interdependence is not a sufficient condition for concluding that the fishery is fraught with inefficiencies. Hence, the work of Smith (1968), advocating specific taxes to "internalize" vessel crowding "externalities" and resource stock "externalities," is of doubtful validity.

(7) It was seen that if a fishery is being exploited at a level where the parent population is smaller than that which produces maximum sustained yield, per unit costs of producing the same quantity are higher than if the population were larger. It is possible, through restricting current output, to restore the population to a higher level and obtain the same annual production at a lower unit cost. However, such abstinence is only justified if the value of foregone current production is less than the gain to society to be realized by the cost savings in the fishery, minus the compensation to fishermen who had to reduce output,

or leave the fishery entirely, during the period of reduced output.

(8) It was seen that a misallocation of fishing effort over grounds of differing quality may exist but that reallocation of boats was more likely to create profits for those boats on the better grounds than it was to generate a real social savings. The fact that some boats are inherently more efficient than others would greatly complicate the ideal allocation.

(9) Finally, the general conclusion is reached that it is not really common property which gives rise to unique problems in the fishery; it is the fact that available technology to the industry, and the demand for the product, imply that the quantity of current production called for on economic grounds very rarely (if ever) exactly coincides with that quantity of equilibrium catch. As long as society is committed to the maintenance of the fish stock, the workings of the market place will, in most cases, call for a current production which does not coincide with available supply (equilibrium catch) regardless of the form of ownership of the vessels, level of taxes on fish, the "ideal" allocation of boats over grounds of differing quality, or the restricting of entry to the point where

fleet marginal costs equal fleet marginal revenue.

VII. CONCLUSIONS AND IMPLICATIONS

Conclusions

In the course of reviewing the main findings of the present study, it seems appropriate to place them in the general context of a discussion concerning the effects of common property on the socially ideal allocation of resources. In this respect then, what follows is less conclusion than epilogue; less summary than addendum. To facilitate the discussion, the treatment will be divided into three sections: (1) Common Property and Resource Allocation; (2) Common Property and Conservation; and (3) Common Property and Economies of Large-Scale Production.

Common Property and Resource Allocation

Economic theorists have long maintained that whenever the actions of any firm physically interfere with the production process of another, technological externalities are present which require correction. Taxes on the firm doing the harm are the usual "corrective" prescription.

The existence of this type of externality is held to stem from ill defined property rights. That is, if property rights were more explicit, all interaction would be priced in the market, and no externalities would be present. Thus, instead of taxes, it is often suggested that such decentralized decision making that gives rise to these effects be replaced with centralized decision making. Then, supposedly, the externality is "internalized." Demsetz, in an article entitled "Towards a Theory of Property Rights," states:

> What converts a harmful or beneficial effect into an externality is that the cost of bringing the effects to bear on the decisions of one or more of the interacting parties is too high to make it worthwhile. . . Internalizing such effects refers to a process, usually a change in property rights, that enables these effects to bear (in greater degree) on all interacting persons (Demsetz, 1967, p. 348).

Francis Bator adds:

> In its modern version, the notion of external economies--external economies proper that is: Viner's technological variety--belongs to a more general doctrine of 'direct interaction.' Such interaction, whether it involves producer-producer, consumer-consumer, producer-consumer, or employer-employee relations, consists in interdependences that are external to the price system, hence unaccounted for by market valuations. Analytically, it implies the nonindependence of various preference and production functions. Its effect is to cause divergence between private and social cost-benefit calculation (Bator, 1968, p. 462).

For the fishery, both Turvey (1964) and Smith (1968) were seen to emphasize the interdependence between boats (congestion) and the fact that once a fish is removed, higher costs are imposed on remaining fishermen.

But, as was seen in Chapter VI, the presence of productive interdependence is not sufficient evidence that there is market failure, or a misallocation of resources. There can only be a misallocation when there is a wrong choice made as to how resources should be allocated. Yet to say that boat one harms boat two by removing a fish from the pool, or fishing "too close," places undue emphasis on the order in which the boats entered the fishery. Each harms the other, but the presence of harm does not necessarily imply an externality exists.[37]

Coase says it best when he states:

> The traditional approach has tended to obscure the nature of the choice that has to be made. The question is commonly thought of as one in which A inflicts harm on B and what has to be decided is: how should we restrain A? But this is wrong. We are dealing with a problem of a reciprocal nature. To avoid the harm to B would inflict harm on A. The real question that has to be decided is: should A be allowed to harm B or should B be allowed to harm A? The problem is to avoid the more serious harm (Coase, 1968, p. 424).

Coase adds that it is important to evaluate the alternatives both at the margin and in total; the most logical course of action would seem to be the comparison of total product yielded by alternative social arrangements.

When the analysis is in terms of divergencies between private and social products, the concentration is on deficiencies in the

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[37]To carry the usual argument to the extreme would mean that all customers to a "first come-first serve" concert who arrived early and took the better seats should compensate those whom they preempted.

system and tends to foster the belief that any measure which will remove the deficiency is desirable (Coase, 1968). As Coase points out, it makes the analysis easier, and correct, if an opportunity cost approach is utilized.

When the opportunity cost concept is used, the proper analysis follows immediately: intervention into the market allocation of resources is socially justified when it can be shown that the end product of intervention, in terms of the production of goods and services, is better than that which now exists.[38] Unless this can be demonstrated, all the concern with harm and interaction is irrelevant for resource allocation decisions; when a firm embarks upon an economic endeavor, or a home is built near a smoky factory, society cannot, and should not have to guarantee that no "harm" will result.

> A tax system which was confined to a tax on the producer for damage caused would tend to lead to unduly high costs being incurred for the prevention of damage. Of course this could be avoided if it were possible to base the tax, not on the damage caused, but on the fall in the value of production (in the widest sense) resulting from the emission of smoke (Coase, 1968, p. 454).

The point being alluded to is that productive (or consumptive) interdependence is not a sufficient condition for intervention in the allocation process. If the existing allocation can be shown to be a superior position regarding social output, then the economist has no

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[38] As trivial as this sounds, the message has been curiously ignored.

basis to prescribe interference.[39]

The position of Coase is consistent with the conclusion reached in Chapter VI regarding physical interdependence. In the fishery, the interdependence is entirely within the industry. This means that the costs which society must incur to have the fish produced, include all of the sacrifice in social resources required to produce the product; and thus price equals marginal cost determines the ideal level of production for the firm, and hence the industry.

The usual example of externalities involves two different industries and here the problem in allocation of resources arises because the firms in industry A (producing commodity A) are not paying the full sacrifice necessary to create the product when they use (say) a stream to dispose of their waste. The market mechanism is unable to express the fall in production elsewhere brought about by this action and hence the signals received by the firms in A are not the socially correct signals.

The proper signals are received only if the firms in A are made cognizant of the opportunity cost of the free factor of production; that cost is the value of other goods (B, C, . . . , Z) foregone by the use and pollution of the commonly used factor by A's firms. As Coase

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[39]This is consistent with the point made in Chapter III that it is not the number of firms in an industry which is socially relevant, it is the output of that industry, and the manner in which that output is produced.

(1968) has shown, it makes no difference to resource allocation which party (A, or B through Z) has the legal rights, as long as the firms in A are aware of the fall in production[40] from their activity.

Given that the fishery is an example of Mishan's (1964) external effects internal to the industry (yet external to the firm), and that prices for products are society's way of indicating how much of each commodity it would like produced, the recommendations of those advocating a tax on every fish caught, and a tax to reflect vessel crowding "externalities," are seen to be incorrect. For society is only concerned with obtaining a given quantity of fish at the least possible cost, and that quantity of fish desired is in relation to what must be sacrificed. The substitutes for fish have their price and when the costs of catching fish rise, consumers will switch to the less expensive alternative.

To advocate taxes on fish and boats to "internalize the externalities" places the emphasis in the wrong place. The relevant opportunity cost reflects the value of other goods foregone through the use of the sea by commercial fishermen, not the value of fish which could be produced by boat A foregone because boats B through Z

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[40]It should be emphasized that "damage," and "fall in the value of production" are not synonyms since it may be possible for industries B, C, . . . ,Z to produce elsewhere; the fall in value is only the differential to production (rent) afforded by the downstream (from A) site.

got there first. The only correct criterion is among alternative products, not among firms producing the same product. All that is affected in the fishery is income distribution among the firms.

It would appear that economists, eager to make their case for "correcting" externalities, have overlooked a distinction made by Pigou which is of more than parenthetical importance. Pigou said:

> I now turn to the second class of divergence between social and private net product which was distinguished in § 3. Here the essence of the matter is that one person A, in the course of rendering some service, for which payment is made, to a second person B, incidentally also renders services or disservices to other persons (<u>not producers of like services</u>), of such a sort that payment cannot be exacted from the benefited parties or compensation enforced on behalf of the injured parties (Pigou, 1962, p. 183) (emphasis added).

Had those so eager to advocate government intervention into competitive situations believed the underlined phrase with the same fervor as they have the rest of Pigou (which Coase and others have shown to be largely incorrect and misleading), the state of the arts in welfare theory would be an improvement over the present situation.

While it is believed that the above discussion focuses on the most improtant, and far reaching conclusion of the investigation, other conclusions related to the position of traditional writers were also derived. Not all of the conclusions however, can be stated with the same degree of confidence as could those immediately above. Some are definitional in nature and hinge on interpretation of economic theory. Others consist of providing evidence which would tend to cast doubt on the traditional conclusions; not empirical evidence, but theoretical evidence. For this reason, some of these conclusions have no more, nor no less, basis than those of the traditional writers: they are conjectural hypotheses requiring empirical verification.

It was seen in Chapter III that by aggregating fishing effort and total yield, the traditional theorists were able to define the "ideal" level of effort as that which maximized the difference between total industry costs of effort, and total industry receipts. This model treats the fishing ground as the fixed factor, and boats and men as variable factors, and subsequently leads to a questionable conclusion of the socially ideal level of fishing effort. Whatever the reasons given for wanting to restrict entry into the fishery, the most questionable is to raise the incomes of fishermen. And this model provides the basis for restricting entry, supposedly to create "rent" to the resource. This "rent" is really profit to those fishermen not restricted.

The lack of regard for those excluded from the fishery, while raising incomes (creating profit) for those remaining, is not only poor economics, but is based upon a weak, and questionable goal. The related issues of poverty in the fishery, and the "unnecessarily" low production of goods and services elsewhere, were also cited by the traditional theorists as sufficient evidence that exclusion is justified.

Yet, in Chapter III, it was seen that the relevant opportunity cost for fishermen is not merely the earnings of other comparably-aged men in other occupations, but is the earnings available to fishermen in other industries. Because the skills of fishermen are in scant demand outside of the fishery, their "salvage value" is much less. When Gordon (1954) mentions hazardousness of occupation, and skill required, he is talking irrelevancies; the only meaningful criterion is the ability of the fishermen to do tasks besides fish.

In this regard, to charge, as Christy and Scott (1965) do, that the production of goods and services elsewhere in society could be enhanced were fishermen excluded, must be held suspect. For if the salvage value of fishermen is currently below their earnings (both monetary and utilitarian) in the fishery (and if it were not, they would most likely leave the industry), this implies that their value in the next best alternative is less than their present value. In these situations, there is no incentive, and hence no reason from a social point of view, for fishermen to leave the fishery; there is no misallocation of resources.

Allied with this, it was here hypothesized that fishermen are more mobile than those who stand to gain from long term asset appreciation. The traditional conclusion that fishermen are "one of the least mobile of occupational groups" would appear open to empirical verification.

As pointed out by Gordon (1954), there is a distinct possibility that fishing boats are misallocated over grounds of varying quality. However, the result of this is not that the "rent" of each ground is driven to zero, but that the profits of those boats fishing the good grounds are driven to zero. If the rather heroic assumption is made that boats could somehow be allocated in an "ideal" fashion at zero cost, then those permitted on the good grounds receive pure profit, while those on the marginal grounds receive nothing above opportunity costs. Rather than a savings to society, income is redistributed within the fishery.

Another conclusion is in regard to the concept of inputs in the fishery. It is maintained that the proper way to view the economic behavior of the fishery is no different than any other economic problem. The firm, not the fishing ground, is the relevant economic unit. The firm combines various productive factors, including the "right-to-fish," to produce a unit of output. As long as the sea (more specifically, a fishing-day) has no alternative use,[41] the price which the commercial fishing industry should pay for it is zero. When commercial fishing activity is competitive with some other economic endeavor, be it sport fishing, water skiing, or waste disposal, the

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[41]To produce an alternative product, not the same product by an alternative boat. See footnote 25, Chapter V.

opportunity cost of a fishing day is no longer zero and some price for its use is justified.

The final conclusion of this section concerns the bioeconomic model developed in Chapters IV, V, and VI. It is maintained that the traditional models excluded too many important considerations (population, productive interdependence, demand for the product, comparative statics), and concentrated on the wrong variables (effort, and industry profit), to be of much use in rigorously analyzing the fishery. To make policy recommendations based on such a model would therefore seem to be extremely dangerous. The bioeconomic model of Chapter VI, while also not without shortcomings, would appear to permit the economist to at least ask the correct questions when embarking upon empirical studies.

Common Property and Conservation

Perhaps the most often stated objection to the common property exploitation of natural resources is the excessive production which results from the prevalence of the "first come-first served" concept. The resource, which is fugitive, belongs to no one until reduced to capture. With both stock and flow resources, disregard for other producers in the present period, and producers and consumers in future time periods, is said to lead those engaged in exploitation to produce as much as possible; if they acted otherwise, someone else would benefit.

Those concerned with the fishery imply two types of uncertainties resulting from its competitive nature: (1) uncertainty regarding the future flows of the resource over time; and (2) uncertainty as to the nature of the industry over time. Both types of uncertainties are said to inhibit investment in modern equipment by the industry; and the recruitment of young, progressive fishermen is said to suffer.

Yet it would seem that with present fishery regulations, uncertainty regarding future flows of the resource has been removed. Still remaining is the uncertainty as to future fleet size and hence market share, but it seems that this is no different than the uncertainty facing the producer in any competitive industry. In most all instances, society does not guarantee future markets for any producer and the fishery would appear to be no different.

In Chapter VI it was seen that depending on the relation between demand and technology, and in the absence of fishery regulations on total catch, it was possible to overfish (exceed equilibrium catch) the stock in any given time period. If demand is strong enough, it is possible to reduce the fish population past that level which produces the maximum sustainable yield. When this is the case, the industry could produce the same quantity of fish on a sustained basis, with lower costs, if the population were allowed to build back up to its former level. As straightforward as this appears in theory, the actual process involved is extremely complex.

In the first place, it is often difficult to determine whether the parent stock is above or below that which produces the maximum sustained yield. Even if it can be established that population is below that which produces maximum sustained yield, this is not sufficient grounds for reducing catch below that currently taken. To justify such action, it would be necessary that the present value of catch (and fishermen's incomes) foregone in the process of restoring the population be less than the present value of all expected savings in social resources realized from the larger population. There would seem to be little a priori evidence that one situation is superior to the other.

Thus, the allegation by traditional theorists that common property leads to overexploitation is an inductive statement with little theoretical support; it is possible for a common property fishery to be overfished, underfished, or properly fished, and the aim of current fisheries programs is to reduce the probabilities of overfishing. This author is puzzled by the assumption of many that the establishment of property rights automatically insures the socially desirable rates of use over time. The difference between private and social rates of time preference would seem to indicate that private ownership in a natural resource is not a sufficient condition for insuring its socially desired use rate.[42]

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[42]See Marglin (1963a, 1963b, 1967) and Ciriacy-Wantrup (1963).

The intent of most institutional barriers in the field of natural resources is to prevent depletion of the basic resource. Whether these particular resources should or should not be conserved is not an issue here. The social choice has been made and the current interest is in evaluating the charges of economic inefficiency in one of the areas. Given that only a certain total quantity of the resource can be harvested, there is nothing in economic efficiency models which implies that some producers should have preference over others. Those decisions involve income distribution questions and are not of interest at the moment. As long as the workings of the market place call for production levels different than that quantity which can safely be removed from the fishery, changes in ownership of the resource will not eliminate the resulting disequilibrium.

Common Property and Economies of Large-Scale Production

The final issue to be dealt with is the question of the relation between common property and the number of fishing vessels. This is related to most of the previous issues but centers mainly on the inability of a common property fishery to realize the potential savings from large-scale production.

There is substantial intuitive appeal for the notion advanced by many that one large, centrally managed fishing fleet could, through the use of a modern fleet of "mother" and "feeder" vessels, produce fish at a lower per unit cost than is now possible with many small fishing vessels. The effects of this on industry costs has been demonstrated in Chapters V and VI.

Crutchfield and Zellner (1962) and others, make much of the fact that present open entry results in many small vessels fishing for a short period of time to produce the available catch, whereas fewer, more efficient ships would be able to fish longer periods. This latter situation would supposedly be superior to that presently existing because savings in storage costs would be realized, and fishermen would not be off fishing in other fisheries, or have idle time on their hands. Certainly the granting of exclusive franchises to a trucking firm, a power company, or a telephone company is based on this concept of large scale economies.

But, to be weighed against these alleged savings in social resources, are the obvious drawbacks of such a scheme.

Foremost among these is the fact that monopoly control over the resource would be created. As seen earlier in this investigation, it would be impracticable to manage each fishing ground separately and, to realize the gains from such a centralized scheme, the fleet would need access to many production areas. With this sort of control, it would seem to follow that restrictive output and monopoly pricing would result. Those who argue that this could be corrected via "taxes, etc." must bear the burden of proof that what emerged would be superior. It is easy to say that it would, but quite difficult to prove rigorously.

The second ramification is the impact upon regional employment and income distribution. It is not sufficient to state that the transition could take place over a period of years, or that retraining could be part of the program. Given the prevalence of irrigation (and recreation) projects in the West, it would seem reasonable that society is genuinely concerned with regional employment, growth, stability, and income redistribution. It would therefore seem that even assuming economic efficiency could be improved with a monopolized fishing industry, the impacts upon other social goals may overshadow whatever gains were made in the fishery.

The final point concerns the general tenor of traditional workers in the fishery that almost anything would be better than that which exists. It is no doubt true that many industries, particularly agriculture, could produce its output cheaper if all of the small (and hence "inefficient") firms were replaced by large (and hence "efficient") ones. In this way, equipment such as tractors could be used more days per year, decisions could be centralized and many other "inefficient" activities could be streamlined. But, there is more to the issue than mere reduction in per unit production costs, and it would appear that many of the secondary ramifications have been overlooked in the course of prescribing how to attain "efficiency" in the fishery. To close this section, Coase again has some pertinent thoughts:

> Actually very little analysis is required to show that an ideal world is better than a state of laissez faire, unless the definitions of a state of laissez faire and an ideal world happen to be the same. But the whole discussion is largely irrelevant for questions of economic policy since whatever we may have in mind as our ideal world; it is clear that we have not yet discovered how to get to it from where we are. A better approach would seem to be to start our analysis with a situation approximating that which actually exists, to examine the effects of a proposed policy change and to attempt to decide whether the new situation would be, in total, better or worse than the original one. In this way, conclusions for policy would have some relevance to the actual situation (Coase, 1968, p. 455-456).

Implications

It is tautological to state that the function of research is to draw a yet sharper distinction between that which is certain and the remainder; indeed, it is the very existence of this residual which provides justification for yet more research. An investigation which asks as many questions as it answers, can very often be more valuable than one which claims to have all the answers. In the process of subjecting the conclusions of traditional writers to theoretical scrutiny, and by developing a bioeconomic model which would seem to more accurately depict the situation in a fishery, many questions were raised which this study could not begin to answer. It is believed that before broad and general conclusions can be drawn regarding economic efficiency (or the lack thereof) in the common property fishery, further investigation must provide answers to some, or all, of the following issues.

One important area of little empirical knowledge is the salvage value of a commerical fisherman. Work in this realm would permit one to speak with more certainty regarding a misallocation of labor in the fishery.

A question of socioeconomic interest would appear to be the true "mobility coefficient" of fishermen in a common property situation. Contrary to the position of Gordon, it was hypothesized here that fishermen are more mobile than those who stand to gain from long term asset appreciation. It would seem possible, through the joint efforts of economists and sociologists, to test these conflicting hypotheses.

Although the above investigation was critical of the state-of-the-arts of economic theory of the fishery, the traditional theorists have made a significant contribution to knowledge. One of the most appealing aspects is that of Anthony Scott's (1954) concept of "user costs." This would seem to hold considerable value for analyzing long run decisions concerning fish population and social action. An effort to incorporate this concept into the bioeconomic model developed here would seem to be a necessity for socially ideal fishery management over time.

The work of Comitini and Huang (1967), indicating that the assumption of homogeneous fishing firms is unrealistic, implies that the true situation in the fishery is much more complex than depicted in the bioeconomic model developed here. For, with differing per unit production costs, there is a whole array of profit positions in the fishery (just as in all industries) and policy changes will not affect all firms in a like manner. The creation (or enlargement) of differential profits carries with it considerable impact on equity and these ramifications would appear to bear investigation.[43]

Imperfect biological knowledge implies that the exact relationship between parent population and equilibrium catch is, at best, pure conjecture in many fisheries. While this is not an economic problem *per se*, its influence on the bioeconomic model should, by now, require no elaboration. For this reason, any gain in biological knowledge would be of primary interest to the fishery economist.

The bioeconomic model developed herein would appear to provide an operational framework within which certain policies could be analyzed. The impacts on present, and future production from changes in annual license fees, taxes on output, vessel restrictions,

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[43] Friedman (1962) illustrates how the supply curve of an industry would appear when there are differences in technology within an industry, and the presence of producer's surplus must be reckoned with. See Chapter V of Friedman.

improvements in fish stock, technological innovation, and disequilibrium between sustained yield (allowable catch) and the quantity called for in the market, should be predictable; at least within limits.

Given the high degree of concentration among fish processors on the West Coast (Crutchfield, 1956), it would appear that the competitive fisherman may be at the mercy of those buying his product. It would therefore seem fruitful to investigate in some detail, not only the supply side of the common property fishery, but the demand side as well.

In Chapter V, the concept of a fishing day as a factor of production was introduced. At that time, the socially correct price for a fishing day was declared of little current interest. However, this would seem to be one of the more interesting aspects of the fishery. Besides commercial fishing, the ocean holds social value as a recreation site, as a means of transportation, as a source of seemingly unlimited mineral and petroleum reserves, as a sport fishing resource, and even as a waste disposal system. As population increases, these uses are likely to come more into conflict. For society to make the correct decisions regarding how the ocean is to be used, it is necessary that each endeavor pay the appropriate cost for use of the sea; this cost being the value of other goods and services foregone because of the activity in question. The determination of these values would seem to pose a fascinating economic problem for natural resource economists.

In concluding this investigation, one impression cannot, in any way, be emphasized too strongly: rather than possessing all of the answers pertaining to economic efficiency in a common property context, as the works of traditional theorists would have one believe, there are enough unanswered questions of vital importance, that what has been done here is a small part of that necessary in order to prescribe, as has been done so often for the fishery, those courses of action to be followed to achieve economic efficiency. If this research makes that single point obvious, it would need to accomplish little else.

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