The Life Cycle of Fisheries

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ABSTRACT

Fisheries are viewed as organisms that have a life cycle. The typical life cycle begins with an initial emphasis on food production, next a growing interest in recreation develops, and finally comes aesthetic uses. As commercial productivity and the number of commercial and recreational users increases, conservation requires more stringent management measures. Food production opportunities decline and recreation uses expand. Substituting cultured stocks for natural ones increases the quantity of fish available, but usually the life cycle process continues. To adjust to life cycle and evolutionary changes, management needs to separate conservation decisions from allocation issues, manage to include as much of the stock's range as possible, control effort growth, and keep expectations reasonable.

Perspective

Since the 1940s, theory in fishery biology has developed concepts for managing fisheries. The models, e.g., surplus production, yield per recruit, stock and recruitment, and stock life history (Tyler and Gallucci 1980), try to estimate the maximum catch, usually called the maximum sustainable yield (MSY), that does not damage the long-term productivity of the fish stock.

Economic analysis of fishery management adds the behavior of users and shows that it is possible to be at the maximum sustainable yield, but still not use effort in the fishery most efficiently. Maximum economic yield (MEY) promotes the most efficient utilization of fishing effort. This, like MSY, tries to hold a fishery at some optimal steady state.

From these two perspectives, the fishery management problem is to control the common property nature of fishing, where individual incentives are detrimental to long-term resource protection and profitability. Management measures typically introduce gear restrictions and reduce fishing time in an attempt to keep catch and effort where they will not do long-term resource damage. Restricting gear and time means that equipment is not used as effectively nor as long as designed. The result is excess fishing capacity and failure to meet the maximum economic yield criterion. As fishing effort increases, setting rules becomes controversial and often the management measures fail to even protect desired fish stocks.

What if the fishery is viewed not statically, but as an organism? Organisms evolve and they have life cycles. Evolution is the general changes in an organism's form as it adapts to new environmental conditions. In studying an organism's life cycle, the objective is to determine the sequence of changes through all the organism's developmental stages. The problem with a fishery may be related to some transition it is making in its life cycle.

Life Cycle Patterns

Fisheries go through a general pattern in terms of human uses. This pattern is a sequence punctuated by significant changes, like the human life cycle, with the events unfolding through time as the fishery matures. The life cycle of a fishery is an ideal, in the sense that the sequence is altered by changes in production methods, management approaches, and the role of fisheries in society.

The major stages in the life cycle of a fishery consist of an initial emphasis on food production, then a growing interest in recreation, with aesthetic uses developing last (Fig. 1). The life cycle of fisheries is a generalized pattern. Under certain conditions, stages in the life cycle of a fishery may not occur.

When initiated, a fishery struggles to find a market niche. Consumers for the fish catch have to be found. Appealing to consumers' preferences for lower prices and/or better quality, the fishery tries to establish its market niche, and the quantity caught grows (Fig. 1). If consumers are attracted, they generate incentives for fishers to catch more. Fishing effort, represented by the number of user units, expands and the catch grows toward the stock's MSY. Being a natural resource, the amount of the stock that can be captured is limited. If catches increase beyond MSY, the result is reduced future productivity of the fish stock. Coupling an absolute limit with the cultural and personal drive of fishers to be more productive, means that once MSY is exceeded, the fishery supports fewer people or less efficient use of fishing capacity.

A simplified example illustrates this stage in the life cycle of a fishery. Assume there is a fishery in which the maximum sustainable yield averages 100,000 MT per year. If 100 fishing units operate at their maximum capacity, their annual catch would average 1,000 MT. Since improving efficiency of production is a desirable goal, assume that this improvement takes place at an average rate of 2% per year. If this rate of increase in productivity took place for 35 years, the average fishing unit would be capable of catching 2,000 MT. But the fishery can only support, on average, a maximum sustainable yield of 100,000 MT. Now, 35 years later, only 50 fishing units are needed, or each of the 100 fishing units still operating can be fished at only half capacity.

Assume this hypothetical fishery operates in a society of 1,000,000 people, and this society grows at the rate of 2% per year. In 35 years the population doubles. Fishers started as one ten-thousandth of the population. If people choose

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fishing at the same rate as in the past, after 35 years, there will be 100 new fishing units. Each fishing unit now has an average capacity of 2,000 MT. With only 100,000 MT available, 200 fishing units could average only 500 MT, one-fourth of the average capacity. To preserve the resource against twice the fishing units who have grown to twice the capacity, requires rules reducing fishing time. This makes fishing more of a part-time occupation. Fishers must enter other fisheries or activities.

Recreational uses of the fishery develop next. They generate additional user units. A user unit is an effort measure that standardizes the effort given to commercial, recreational, and aesthetic uses. Recreational uses involve much larger numbers of people than commercial fishing, but the average time each person spends is less. In the aggregate, recreation effort is greater than commercial (Fig. 1). Aesthetic uses expand the numbers of people interested in the fish stock over recreational.

With more people using the fish stock, a decision has to be made regarding the number who can be supported in each activity. With democratic decision-making, use rights usually go to the most numerous. Anglers who develop an interest in the fishery for its pleasure or subsistence value typically outnumber commercial fishers. This numerical advantage leads to the life cycle pattern of shifting from food production to recreational uses (Fig. 1).

The general evolutionary state of society influences the life cycle process. Technological innovation changes the exploitative power of commercial fishing as illustrated in the example above. Food production that leaves time for leisure pursuits, the recognition that recreation renews people's productive energy, and aesthetic appreciation are all factors in the general state of cultural evolution that call for nonfood uses of fish populations.

Aesthetic interests develop after recreation. For aesthetic uses the quantity is not consumed but reserved for some group's aesthetic appreciation. Marine sanctuaries, public view areas at fish ladders, legislation having protection as the primary purpose, reservation of portions of stocks primarily for viewing, preservation of wild stocks, and catch-and-release fisheries are examples where aesthetics have become a primary consideration.

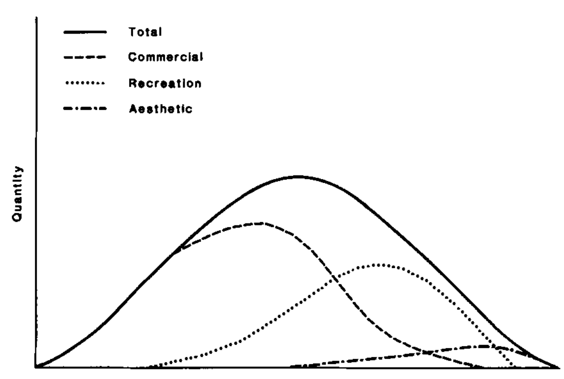

Figure 1. Generalized life cycle process showing total available for a hypothetical fishery, and the relative shares for commercial, recreational, and aesthetic uses as the number of users increases.

Aesthetic consumption is that portion of the stock reserved for nonconsumptive purposes. Many aesthetic uses are compatible with commercial and recreational uses. When the stock declines to a very low level as a result of excessive fishing effort, or more often, due to destruction of habitat, the entire stock is usually reserved for aesthetic purposes. Preservation of whales, porpoises, and restoring New England stocks of Atlantic salmon (*Salmo salar*) are cases in which aesthetic concerns have become primary. Aesthetic interests restored Atlantic salmon in streams where they were once extinct.

Experience with many wildlife populations illustrates the same life cycle for resource use. The food that these wildlife once provided now comes from domesticated stocks. Deer populations may be larger than ever before in North America, but they provide mainly recreation and do not serve as basic subsistence in any substantial way. Deer herds illustrate management to meet both recreational and aesthetic interests. Wildfowl populations, once commercially hunted, provide mainly recreation. Management of migratory bird flyways increasingly provides for aesthetic uses. Market gunning brought extinction to the passenger pigeon, just as 19^{th} century market pressures and subsequent habitat decline put the shortnose sturgeon (*Acipenser brevirostrum*) on the endangered species list (Reiger 1977).

One reason for the life cycle shift from fishing for food to recreation, to aesthetic uses, is the overall value of the species to society. When highly valued stocks become rare, preservation assumes a very high value. Nelson (1982) estimates the social cost to protect pairs of spotted owls at $250,000 in lost timber revenues. Bishop (1980) estimates the total 1974 social costs of protecting California condors at $3,200,000. Aesthetic appreciation of non-game birds was estimated to have a half billion dollar value in 1974 (DeGraff and Payne 1975). Through 1983, duck stamps brought in $285 million to purchase 3.5 million acres for refuges (Madson 1984). The snail darter (*Percina tanasi*) is one of the most controversial fish species protected under the Endangered Species Act.

Breaking the Pattern

The life cycle pattern for fisheries is a generalized set of stages. Departures from the typical pattern help elaborate the features of this process. Certainly fisheries that do not develop a recreational or aesthetic constituency are much more susceptible to at least economic extinction, and eventually total extinction, since the effort to preserve the remaining biomass is not likely to attract broad interest. Consumers switch to other products, fishers take other occupations, and without an aesthetic component, advocates for the fish stock are absent.

At least one species, the Miller Lake lamprey (*Lampetra minima*), was exterminated because it preyed on recreationally important trout in the Klamath River system (Robins et al. 1980). The Miller Lake lamprey never constituted a fishery, never having a population of users who were concerned about its existence.

Nineteenth century commercial fishing in the Great Lakes is an illustration of the life cycle process. The shortnose sturgeon was initially viewed as a nuisance. These fish were piled on the bank and burned (Reiger and Hartman 1973). Later, when the sturgeon's value for caviar, isinglass, and food was demonstrated, they were overfished. Likewise, overfishing and habitat change led to extinction of the blue pike (*Stizostedion vitreum glaucum*). Subsequently, fish culture and management recreated many Great Lakes fisheries. The user population is now mainly recreational.

Some suggest the life cycle pattern only applies to fish stocks high on the food chain. Will northern anchovy (*Engraulis mordax*), mackerel (*Scomber scombrus*), or Alaskan pollack (*Theragra chalcogramma*) ever experience this life cycle? The Pacific Fishery Management Council's (1983) anchovy management plan reserves a portion of the stock as food for "attracting and maintaining stocks of recreationally important marine fish species." Management options also consider the role of anchovies as feed for the brown pelican. The Mid-Atlantic Council's (1985) draft Atlantic mackerel, squid, and butterfish plan allocates a portion of the Atlantic mackerel to the recreational fishery and recognizes the place of Atlantic mackerel in the forage of endangered species of marine mammals and other recreationally important species. Pollack, which populate North Pacific waters well away from population centers, are not likely to become the basis for a recreational fishery. They are still subject to overexploitation due to commercial overfishing, as are many other resources which once were perceived as inexhaustible.

More interesting than the efficacy of the life cycle analogy are the actions humans undertake to change this pattern. Primary among these is intervention in the reproduction process to increase the quantity of fish available. Fishery management tries to hold the life cycle in one place. Restrictions on the number of users, encouraging alternative activities, and changing people's expectations, too, are ways to alter the life cycle pattern.

Evolutionary Processes

Contrasting fishing activities with the general pattern of human evolution shows that most food produced for human consumption comes from cultivation techniques. Fishing is a capture rather than culture method of production, and the life cycle analogy assumes a resource whose productivity is limited by natural factors.

The terrestrial evolutionary pattern of the last 10,000 years has been to change the method of food production by domesticating important plants and animals that serve as basic subsistence foods. The development of agriculture and animal husbandry not only greatly increases plant and animal productivity, but extends control to productive plant and animal populations by enabling clear demarcation and control.

Domestication enables control of resource production and gives producers the benefits of their effort to produce more. H. Scott Gordon (1954) extended this concept to fisheries. Gordon patterned his pioneering bioeconomic theory on the evolutionary process for human food production. In fact, Gordon (1954, p. 134) acknowledges, "The results of anthropological investigation of modes of land tenure among primitive peoples render some further support to this thesis."

The evolution from capture to culture has been going on for 3,000 years for some fish. China, where fish culturing first became popular, produces more than a third of their fish by aquaculture (Ling 1977; National Marine Fisheries Service 1984). In Taiwan, 16% of the fish production in 1974 came from aquaculture (Chen 1976). Japanese fish production peaked in the early 1970s at just over 10 million MT. The ratio of cultured fish increased from less than 4% to over 9% of the total between 1950 and 1979 (Kafuka and Ikenoue 1983). Norwegian Atlantic salmon production in 1984 was equivalent to 1.5 times the average annual catch in the sockeye salmon (*Oncorhynchus nerka*) fishery of Bristol Bay, and Norwegian salmon significantly impact fresh salmon markets. The North American rainbow trout (*Salmo gairdneri*) recreational fishery is built on hatchery innovations of the U.S. Fish and Wildlife Service.

As the maximum sustainable yield is exceeded, and if the fishery is important to society, culturing has the potential for increasing quantities, despite reduction of natural populations due to excessive use or habitat destruction. This process is illustrated in Figure 2. For a threatened fishery to survive as an important food resource, it has to evolve from capturing fish to culturing. This changes the natural patterns of productivity, and the quantity available is greatly increased. Wild stocks lose out in the competition with domesticated ones, sometimes merging into a genetically mixed stock (Reiger 1977). With control of the production, culturing holds the potential for producing enough fish to meet commercial and recreational needs. The life cycle pressure of more and more fishers seeking fewer and fewer fish is eased with the greater productivity possible from fish culture.

Management

When changes are judged to be detrimental, a common response is to manage the fishery. Fishery management tries to hold the life cycle of a fishery at one point. The decision may be to preserve a commercial fishery, or to maintain a mix of commercial, recreational, and aesthetic uses. Usually the goals of management are based on a conception of the fishery as it was at some time in the past. Of 25 stocks managed under the Magnuson Act, Finch (1985) reports eight did not change their status in the 9 years since 1975. The condition of six stocks deteriorated when compared to past conditions. Eleven species groups showed improvement, which meant an improved ability to support historic uses.

Management addresses two primary concerns—*conser-*

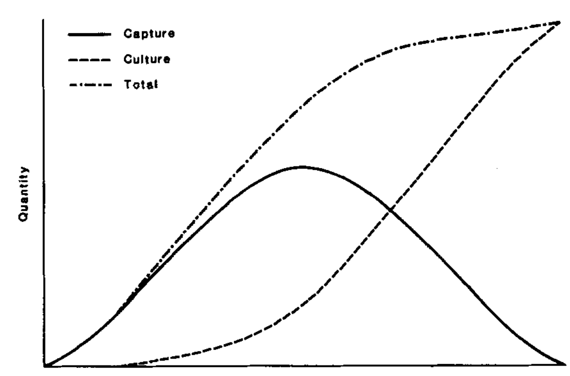

Figure 2. Contribution of fishing natural stocks and growth of fish culture as the number of users increase in a hypothetical fishery.

vation of the resource and *allocation* of the amount available to various users. Public support for conservation is widespread. It is an easily understood objective which people believe to be in their long-term self-interest. Even if they are not directly affected, the public sees the value of conservation. Conservation, then, is a clear and primary objective. It has strong public support.

Allocation of who will catch the fish involves dividing the available catch among fishing groups. The life cycle of a fishery pattern shows how this is difficult to achieve. Since management tends to be dominated by allocations as they were in the past, it is often out of step with the life cycle of the fishery which is changing toward greater recreational and aesthetic use (Finch 1985).

Clarity in management would be enhanced if the Fishery Conservation and Management Act specifically distinguished in the objectives and standards that management is a process of first conservation and then allocation. This could be accomplished in the standards section (16 U.S.C. 1851) by replacing "management" every time it occurs with the word "allocation." "Conservation and management" is acceptable for emphasis in the act's title, but management is the process of both conservation and allocation.

Fishery managers do not generally conceive of themselves as allocating fish among users. They would rather be the conservators of the resource for the public, although there is a long history of fishing groups lobbying and legislating allocations to themselves. Allocation of salmon is explicitly included in the Pacific Fishery Management Council's salmon management plan. The plan follows the life cycle pattern. When numbers of coho salmon (*O. kusutch*) are large, 86% go to commercial fishers. When the numbers of coho are small, the percentage reverses and anglers are allocated most of the available fish (Pacific Fishery Management Council 1984, p. 32421).

Stock Conservation

One of the factors reducing the effectiveness of management decisions is lack of control over the full range of the fish stock. When management does not control all potential users, additional people enter the fishery. People beyond the control of management add to the number of users and continue the life cycle process.

Where political boundaries crosscut the fish stock's range, those on one side of the boundary can operate with the best of conservation intentions, but unless the other side does also, conservation regulations will not be respected. The boundaries for conservation decisions will be most effective if they encompass the territory of the fish stock.

Another reason for making the management boundaries synonymous with the fish stock is the inherent variability in fish productivity. Different temperatures, oceanographic conditions, and other factors affect reproduction and growth. Uncertainty in environmental conditions makes predicting stock sizes more difficult. Where the decision-making institution is able to follow fish stock variability from year to year and to monitor stock conditions, the condition of the stock will be better known. Historical records help show that increased numbers of users are adversely affecting the stock.

Ideally, management institutions need to control habitat changes critical to the fish stock. In most cases, forestry, navigation, agriculture, waste disposal, and dam construction have priority over fisheries. These economic activities alter fish habitats and lower productivity. This is most often the case when the fish stock is at the aesthetic end of its life cycle.

The Analogy of the Firm

Economic theory applied to fishery management is an important allocation tool, particularly where the objective is to maintain a viable commercial fishery. The analogy is the firm, where the sole owner behaves to maximize profits.

In a common property setting each fisher acts independently of what is good for the whole, and the sum of individual behaviors results in resource decline from overfishing. The solution, following Gordon (1954), is to establish a property right. This puts those fishing in the position of owner, having the economic incentive to make decisions that maximize the long-term value of returns from the fishery. Property rights for fisheries follow the examples of the English enclosure movement during the Industrial Revolution and barbed wire fencing of Great Plains farms. Both stimulated greater production by protecting the fenced lands from external forces and enabling landowners to benefit from their innovativeness.

Establishing property rights in a fishery is not as simple as fencing. To receive the economic benefit of long-term good management, ownership must be exerted over the whole stock. Keen (1983, p. 211) states that limited entry "formalizes rights to harvest . . . These rights fail to correct problems associated with the commons and create serious impediments to efforts made to restore and enhance productivity of fishery resources." The problem with fisheries is that the unit is not as easily divided as is the fencing of farms.

The private property solution requires some more encompassing, usually government, agency to set the number of users that can most profitably operate in the fishery and not overfish the resource. Auctioning quotas lets the market make the allocation decision, but unless the management agency has control over all the effort in the fishery or the entire fishery is auctioned to one sole owner, those operating in the fishery have no incentive to conserve the stock. Even if some market mechanism is designed to provide the incentive for fishermen to conserve the stock, the destruction of fish habitat from societal growth overwhelms the conservation effort.

The costs of managing a complex multi-user fishery are quite high (Wilson 1982). Considerable expense is incurred in obtaining information, facilitating public participation, and defending legal challenges to conservation and allocation decisions. Support is usually inadequate for effective management and the life cycle process continues according to pattern. When the fishery consists of multiple species, the problems and costs are compounded.

Transition to Other Employment

Due to unwillingness to allocate catch, inability to control the full range of the stock, and difficulty controlling the number of users, the life cycle process continues and reduces opportunities for commercial fishers to participate full-time.

(*Continued*)

Successful fishery management coordinates with programs that promote other alternatives for fishers and fishing communities.

Economic growth, tax, loan, and other incentives stimulate growth in the number of fishers. When a fishery reaches its maximum sustainable yield, these incentives are still in place. The incentives continue to attract more effort when none is needed. Rather than incentives to enter fishing, mechanisms are required to promote transition into other economic activities where there is opportunity.

The capture-to-culture evolutionary process creates opportunities, but not for commercial fishing. With more users, the typical pattern is for resource use to shift from food production to recreation. The ratio of total catch taken by angling increases. With still more users, aesthetic, nonconsumptive activities take precedence. This does not help the fishers and communities where commercial fishing is the foundation of their economic enterprise. Where other economic opportunities are limited, fishers will pursue commercial fishing, even if this is not in the long-term best interest of the fish stock. Without competitive employment opportunities, the only choice is continued erosion of the current fishery.

Keeping Expectations Reasonable

Social science research shows that fishing is an attractive occupation (Pollnac and Littlefield 1984). Fishing provides freedom, allows people to be their own boss, gives the opportunity to be involved with nature, and provides a "total experience." These personal advantages generate expectations about fishing. Positive expectations produce incentives that motivate people to take up fishing.

Where the culture associated with commercial fishing adds to the appeal associated with this occupation, this, too, promotes more fishing effort. Literary tradition glorifies fishing experiences and opportunities. The symbols are emphasized in Winslow Homer's art, Herman Melville's writing, and John Masefield's poetry. The desire to challenge nature as a fisher and to live in a picturesque fishing community creates images that make overfishing difficult to control. These expectations are unreasonable given the life cycle pattern of fisheries.

Expectations can be controlled by reminding fishers about the resource's status. Regular reporting to fishery participants of change in fishing effort, catch per unit of effort, the ratio of catch from commercial fishing and angling, and the ratio of capture to culture harvest helps remind people of where the fishery is in its life cycle.

Summary

The life cycle of a fishery is a progression of uses starting with commercial, then adding recreational, and finally aesthetic. Near the end of the life cycle, the fish stock is relatively small and the use primarily aesthetic. This flow of events is driven by growth in the number of people using the fish stock and economic activities external to the fishery that reduce the stock's habitat.

The life cycle process is difficult to redirect. Fish culturing, fishery management, and the role of the fishery in the social system alter the process. Human history with land plants and animals over the last 10,000 years is the basis for predicting a similar evolution in the pattern of capture fishing to culturing techniques. This evolution may ease the transition, but also brings a shift in the users. Fish culturing is more like farming.

Fishery management tries to slow or stop the life cycle process. Management is a two-part process of conservation and allocation. There is broad public support for conservation. Allocation is a complex decision where the situations of people are evaluated against societal goals.

Conservation decisions are best where the management system and the fish stock boundaries are synonymous. This enables a conservation decision which can encompass the greatest number of factors affecting the resource. Allocation decisions are based on economic, social, and political considerations.

One recommendation is to create private property rights for individual fishers. The supposition is that property rights make users more sensitive to the conservation needs of the fish stock. Each person having a private property right, however, is not analogous to the small firm where the sole owner makes decisions to maximize profits for a productive system. For private property to stimulate conservation, some management organization or fishing enterprise needs to be the sole owner. Management systems are very costly, in some cases their cost exceeds the economic benefit that management is designed to produce.

Providing alternative opportunities and keeping expectations reasonable ease the life cycle process. Both ease user pressure.

A fishery is a dynamic, changing organism. It must cope with the processes of growth in society and pressures for increased numbers of users. With a limited resource and more users, the alternatives are to either allow each user to take less or to reduce the number of users. Evolution of fish culturing can produce more fish, but changes the character of the fishery. Management tries to maintain past user patterns. Emphasizing conservation, covering the stock's full range, promoting other opportunities, and keeping expectations reasonable all ease pressures on the life cycle process. Not achieving these management objectives, in a growing society, means the life cycle process will continue to be driven by increased numbers of users.

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