1995

Regulating the blue crab, Callinectes sapidus, fishery in Virginia : biological and economic concerns

James E. Kirkley
Virginia Institute of Marine Science

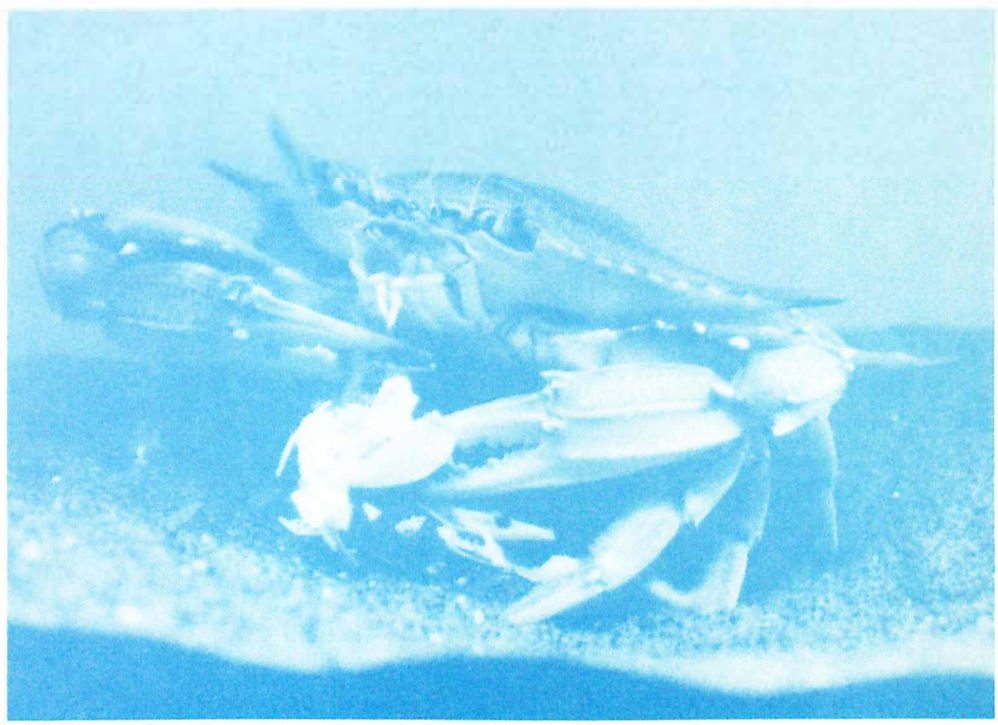
William D. DuPaul
Virginia Institute of Marine Science

Michael J. Oesterling
Virginia Institute of Marine Science

Recommended Citation

Kirkley, J. E., DuPaul, W. D., & Oesterling, M. J. (1995) Regulating the blue crab, Callinectes sapidus, fishery in Virginia : biological and economic concerns. Virginia Sea Grant publication ; no. VSG-95-14.; Marine Resource Advisory ; no. 63.. Virginia Institute of Marine Science, College of William and Mary. https://doi.org/10.21220/V5VC8Z

Regulating the Blue Crab, *Callinectes Sapidus*, Fishery In Virginia: Biological and Economic Concerns



By
James Kirkley
William DuPaul
Michael Oesterling

Virginia Sea Grant
Marine Advisory Program
Virginia Institute of Marine Science
College of William and Mary
Gloucester Point, Virginia
VSG-95-14


This document was published by Virginia Sea Grant's Marine Advisory Program, School of Marine Science, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA 23062.

Authors: James Kirkley, William DuPaul and Michael Oesterling
Editor: Susan C. Waters
Virginia Sea Grant College Program
Virginia Sea Grant Marine Resource Advisory No.63
Virginia Sea Grant Publication No. VSG-95-14

This work is a result of research sponsored by NOAA office of Sea Grant, U.S. Department of Commerce under Federal Grant No. NA90AA-D-SG045 to the Virginia Graduate Marine Science Consortium and the Virginia Sea Grant College Program.

Regulating the Blue Crab, *Callinectes sapidus*, Fishery Of Virginia: Biological and Economic Concerns

J.E. Kirkley, W.D. DuPaul, and M. Oesterling[1]

Introduction

The blue crab, *Callinectes sapidus*, fishery has been one of the most important fisheries of Virginia. The importance of the fishery in terms of commercial activities has substantially increased in recent years in response to declining resource levels of American Oyster, *Crassostrea virginica*, and a growing international and domestic demand for soft crabs, female hard crabs, and crab meat.

The actual economic importance of the fishery, however, is not well known. For example, what are the employment and earning levels generated by the fishery? What portion of a waterman's household income is derived from crabbing? How much does crabbing contribute to state tax revenues? How do regulations affect the economies of coastal communities, and what are the economic impacts on processors, seafood dealers, restaurants, and providers of fishing supplies and services? Answers to these questions are necessary to manage the resource in the best interests of Virginia.

There are many other questions about the blue crab fishery and resource that also must be answered. What are the current and optimum levels of harvests, effort, and fishing mortality? Volstad et al. (1994) suggest that fishing mortality (F) was extremely high in 1993.[2] Rothschild et al. (1993) suggest that resource managers be concerned with the high apparent rate of fishing mortality, particularly given the variability in stock size over time.[3] How valid and stable is the relationship between recruitment and spawning stock biomass? What is the relationship between water quality, abundance, current harvest levels, fishing and natural mortality, and future recruitment?

A major problem which must be considered in evaluating the biological and economic importance and management of the fishery is the biological and economic interactions between the Maryland and Virginia crab fisheries. What are the state relationships and interactions between resource abundance and availability, reproductive activities, harvests, regulation, and recruitment patterns? How would the fishery of one state be affected by various regulations imposed by the other state?

Informed resource management requires answers to the previously posed questions. There appears to be, nevertheless, an urgent need to better manage and regulate the resource and the fishery. In this brief paper, we provide an overview of regulatory options for managing and regulating the blue crab fishery. We initially focus on open-access strategies and subsequently present a discussion of regulations that address the common-property, open-access, fishery. Prior to discussing management options, we discuss goals and objectives of resource management.

---

[1]*Fisheries Management Working Paper, 12/94*
College of William and Mary
School of Marine Science
Virginia Institute of Marine Science
Gloucester Point, VA 23062

[2]Volstad, J. B. Rothschild, and T. Maurer. 1994. Abundance estimation and population dynamics of the blue crab in the Chesapeake Bay. Maryland Department of Natural Resources, Annapolis, Md.

[3]Rothschild, B., J. Ault, E. Patrick, S. Smith, H. Li, T. Maurer, B. Daugherty, G. Davis, C. Zhang, and R. McGarvey. 1992. Assessment of the Chesapeake Bay Blue Crab Stock. Univ. of MD. Chesapeake Bay Biological Lab. DB92-003-036, CEES 07-4-30 307, Solomons, Maryland.

Goals and Objectives of Resource Management

Management and regulation of the blue crab fishery has primarily focused on resource conservation and industry maintenance. That is, resource conservation is of primary concern but conservation cannot be so stringent that people become unemployed. Under this strategy, the Virginia Marine Resources Commission (VMRC) has had to constantly balance and assess trade-offs between the current and future well-being of the industry and the resource. Under such a strategy, biological and economic problems will nearly always occur for the fishery in question. Simply, resource abundance, age classes, biomass levels, economic opportunities, and social benefits will be jeopardized if management does not have clearly defined goals and objectives that integrate the underlying population dynamics and economic aspects of the fishery (i.e., a bio-economic optimum).

There are strong arguments being made to change the management and regulatory policies for the blue crab fishery. It is currently the opinion of VMRC and research scientists that the blue crab resource is in serious trouble. Between 1990 and 1992, reported landings of blue crab plummeted by more than 50%. Over the last 50 years, however, blue crab landings have exhibited regular periodicity or cyclic behavior in which landings rapidly decline to very low levels. Scientists are concerned, though, that the resource may not be simply following the normal cycle of ups and downs.

Changing the management and regulatory policies begs the question "What are the goals and objectives of blue crab management?" The goals and objectives of managing any fishery in Virginia are given in General Provision (28.2-203, p. 21) "Laws of Virginia Relating to The Marine Resources of The Commonwealth." It states "Conservation and management measures shall prevent overfishing while achieving the optimum yield from each fishery. The "optimum yield" of a fishery means the amount of fish or shellfish which will provide the greatest overall benefit to the Commonwealth, with particular reference to commercial fishing for food production and to recreational fishing."

Unfortunately, the state's concept of optimum yield (OY) is quite vague. As stated in General Provision 28.2-203, numerous interpretations are possible. The state could manage for maximum economic opportunities in terms of employment and earnings. Alternatively, the
state could attempt to maximize the economic concept of net benefits. Last, the state could simply try to maximize production or landings of blue crabs.

There is, however, an agreement between Maryland and Virginia which specifies the goal of managing blue crabs as "to manage blue crabs in a way which conserves and protects the ecological value of the stock, and at the same time generates the greatest long term economic and social benefits from the resource."[4]

While there is a stated goal, it is vague and does not specify an actual optimum yield (OY) for blue crabs. What exactly does it mean to conserve the baywide stock, protect the ecological value of blue crabs, and optimize the long-term use of the resource? Moreover, if management is to generate the maximum long-term economic and social benefits from the resource, VMRC will have to initiate a substantial economic data collection program. The state currently has mandatory reporting but the program does not collect information on economic performance such as costs and earnings. Without the necessary specification of OY and economic information, the management and regulation of the blue crab fishery will be difficult. Alternatively, an arbitrary OY might be set equal to the long-term average annual harvest. This would closely parallel the objective of maintaining the industry. This OY, however, creates the risk of resource problems. If the empirical-based long-term yield is in error (overestimate of maximum annual harvest) of the actual long-term potential yield, it is possible to easily overharvest the blue crab resource. The long-term yield also completely ignores the social and economic importance of the fishery.

Even though the VMRC and the bi-state fishery management plan (FMP) do not have well specified objectives and a stated OY, it is, nevertheless, possible to provide some general guidance on managing and regulating the blue crab fishery. In particular, we can examine several possible goals and objectives of resource management in relation to various types of fishery regulations.

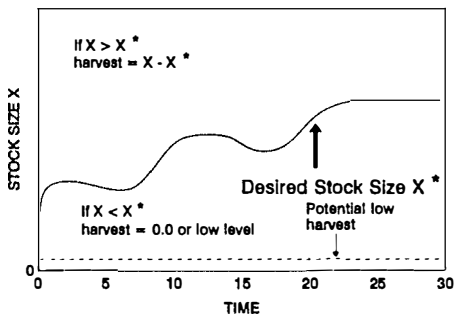
---

[4]Chesapeake Bay Executive Council, 1989. Chesapeake Bay Blue Crab Management Plan. Annapolis, MD: Chesapeake Bay Program.

We first explore the option that the state might want to rebuild or increase the resource as quickly as possible. If this were the case, VMRC would only have to impose an extremely restrictive limit on harvesting activities until the resource obtained its desired level. Extremely restrictive catch limits would, of course, cause severe economic hardships for watermen, seafood dealers, and processors.

Under the scenario of resource conservation first and industry second, management could easily establish regulatory policies (Figure 1): (1) when the resource (X) is below the desired target level (X^*), catch is constrained to zero or nearly zero, and (2) if the resource is above the desired target level, management allows catch to equal the actual resource level minus the target level.

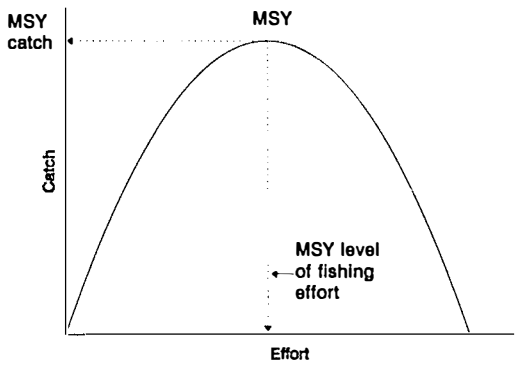
Figure 1. Blue Crab, *Callinectes sapidus*, Resource Recovery Strategy, Minimize Time



The third possibility--when resource abundance equals the desired target level--poses the most difficult problem for VMRC. In theory, when actual stock equals desired stock, the management agency should set the harvest such that benefits to society are maximized. The state and the citizens of the Commonwealth should derive the maximum possible benefits from the resource. Alternatively, the objectives of management, whatever they are, should be realized at minimum cost.

What if the state had the objective of maximizing sustainable yield or harvest levels? This objective would require the state to restrict catch or effort to levels yielding the maximum sustainable yield (MSY) (Figure 2). Alternatively, the state would have to maintain resource conditions at a given level such that maximum sustainable yield could be realized. The same rule would apply to the state attempting to maintain any given level of resource.

Figure 2. Sustainable Yield Curve and MSY



What exactly is maximum sustainable yield? MSY is a long-run equilibrium concept; it is simply the maximum harvest level that can be sustained over time. Alternatively, MSY is the maximum possible average annual harvest such that additions or growth to the resource equals removals from the resource. If the actual harvest exceeds MSY, it is often stated that the resource is being overfished. If the harvest is less than MSY, management may allow harvest levels to increase.

What is wrong with the objective of MSY? Extensive research has shown that MSY is generally very unstable. If MSY is the least bit overestimated, depletion or even extinction of the resource stock is possible. MSY is typically not really sustainable over the long run; environmental conditions and other factors cause substantial fluctuations in the resource stock. In the case of the blue crab fishery or any short-lived marine species, environmental fluctuations are likely to be extremely important factors contributing to resource levels. Last, maximum sustainable yield, safe

yield or harvest, maximum yield per recruit, and similar regulatory targets are primarily biological objectives; they ignore social and economic considerations of renewable resource management.

Previous and current blue crab regulations suggest that the state is quite concerned with the underlying economics and not only with resource conservation. If Virginia only wanted to pursue conservation, the state could adopt policies consistent with those suggested in Figure 1 or 2.

Unfortunately, the state does not have clearly specified operational objectives. It is not possible, therefore, to adequately determine the best management and regulatory strategy for blue crabs unless certain assumptions about the objectives of regulating the blue crab fishery are made. In the following discussion, we assume the VMRC desires to restore the resource but is concerned about the economic ramifications of various regulatory options.

The Blue Crab Fishery: Simple or Complex?

The blue crab fishery is a single species fishery. Resource issues under the purview of VMRC involve the Chesapeake Bay, its tributaries, and the territorial sea (ocean waters out to 3 miles). That is, the resource management area is relatively small and localized in comparison to the large offshore fisheries. The two primary sources of landings and fishing mortality are commercial watermen and recreational crabbers.

Unfortunately, little information is available on the recreational crab fishery. Unlike recreational finfishing in Virginia, recreational crabbers are not required to have a license unless they intend to use more than one pot per crabber. It is, therefore, difficult to determine the number of recreational crabbers in Virginia. Based on a 1988 survey, the National Marine Fisheries Service estimated that there were approximately 200,000 recreational crabbers over the age of 15 harvesting blue crabs in Virginia. It is quite likely that there are many more recreational crabbers than reported by the National Marine Fisheries Service. Moreover, there appears to be a growing number of individuals that exploit blue crabs for pleasure and subsistence.

The recreational harvest of blue crabs is not known. It also is not known what portion of the recreational harvest is commercially sold. Commercial and recreational crabbers, however, have recently complained about each other. Commercial crabbers have indicated a concern that recreational crabbers are catching too many crabs and/or possibly selling crabs. Recreational crabbers have complained that the commercial crabbers are harvesting too much of the resource. In addition, recreational boaters have complained that crab pots are interfering with recreational boating. In the future, the state may have to address the potential problems of user conflict among recreational and commercial crabbers and recreational boaters.

In contrast to the recreational fishery, there is extensive information available on the commercial fishery. Seven types of gear are used to exploit the resource, but crab pots account for the majority of reported catch (Table 1).

Table 1. Virginia Blue Crab Landings, Gear Type

	Landings			
Year	Trap[a]	Pot	Dredge	Total
	----------1000 lbs----------			
1973	12.27	27717.6	8880.7	36747.2
1974	0.00	32713.1	8083.0	40849.4
1975	1.28	30225.6	4461.6	34819.0
1976	0.47	19669.7	6090.8	25760.9
1977	33.60	31003.9	6123.8	37177.2
1978	5.46	29437.1	6606.5	36055.1
1979	0.22	32681.5	7106.0	39834.3
1980	3.04	28166.7	9443.2	37691.4
1981	0.00	31708.2	10294.5	42044.1
1982	64.19	36193.4	7678.1	44027.4
1983	1.08	39798.0	6292.5	46104.1
1984	0.04	38789.9	10663.7	49463.7
1985	2.91	33987.0	6569.6	40732.8
1986	0.49	301.8	8200.1	37527.0
1987	0.14	28792.6	4770.5	33591.6

[a]Peeler pound trap.

Source of Data:Virginia Marine Resource Commission.

Although the fishery is a single species fishery, there are several products landed. Hard crabs are marketed by size and sex. Peelers and soft crabs are two other product forms of *Callinectes sapidus*. Taking the market chain one step up, there is the problem that what is landed partly determines the processed product form. For example, large crabs may be processed as jumbo lump while smaller crabs may be converted to lump, special meat, mixed meat, and cocktail claws; all of which have different values in the market.

The fishery is, thus, a complex multiproduct fishery with many different products. Multiproduct fisheries are extremely difficult to manage for either conservation or economic purposes. In the blue crab fishery, regulations affecting size and sex of crabs landed will affect not only the harvesting sector but will also substantially affect the economic returns of processors and dealers.

The blue crab fishery is a year-round fishery. The hard and soft crab fisheries, however, have known seasonality in landings. Landings of hard crabs are highest between June and September and during the month of December when seasonal holiday demand is high and the dredge fishery begins. Landings or production of soft crabs are highest between May and August which coincides with the availability of peeler crabs.

Hard crab landings appear to be the dominant source of fishing mortality (Table 2). Detailed data on the production and economic returns of soft-shell crab shedding operations are not available. There is an issue of the accuracy of blue crab landings; industry comments and results of a survey by Rhodes and Shabman (1994) suggest that reported landings may equal slightly more than one-third of the actual landings.[5] That is, reported landings are thought to be in error (underestimated) either because of misreporting or non-reporting of the apparent increasing basket trade in which crabs are sold to buyers who typically do not report landings.

Available data on Virginia landings suggest that the first priority of management should be directed towards hard crabs. The hard crab fishery is the apparent dominant source of fishing mortality. If we examine landings of hard crabs over recent years, it becomes relatively clear that the blue crab resource and fishery are in trouble (Figure 3).

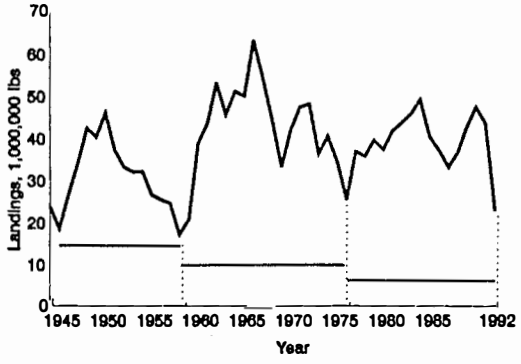
Table 2. Landings of Blue Crabs, 1986-1992

Year	Landings		Value	
	Hard	Soft	Hard	Soft[a]
	--1000 lbs--		---$1000---	
1986	35527	949	9090	1095
1987	33592	562	10055	823
1988	37096	1131	11947	1670
1989	43150	1252	12288	2664
1990	47840	931	15411	1745
1991	44056	1337	10322	1717
1992	23348	519	9073	1394

[a]Soft and peeler crab landings and value.

Source: Virginia Marine Resources Commision.

Figure 3. Hard Blue Crab Landings, Virginia, 1944-1992



[5]Rhodes, and L. Shabman. 1994. Blue Crab Pot Fishery: The Issues and Concerns. Virginia Sea Grant Report No. 94-09.

Landings declined by more than 50% between 1990 and 1992 (47.8 vs. 23.3 million pounds). The landings data may also reflect a shift in marketing strategy by watermen. It is believed that watermen increased their direct marketing or sales of basket crabs and possibly decreased their sales of crabs to picking houses. If this is the case, it is quite possible that the reported decline in crab landings is not at all indicative of the actual trend in blue crab landings.

There also appears to be a possible predictable cycle in landings. Landings of hard blue crabs appear to dramatically decline every 16-18 years (Figure 3). In the past, recovery of landings has usually been quite rapid. In the current situation, the resource does not appear to be rapidly recovering. It is not known whether or not resource declines experienced in 1992, 1993, and1994 are indicative of long-run patterns or related to overfishing and environmental degradation. The VMRC, however, has few control points for improving resource levels (e.g., they cannot regulate environmental and climatic conditions). The VMRC must focus on regulating the fishery to manage the resource.

Even in the absence of a resource problem, there is a perceived economic problem. There is likely to be too much effort or individuals in the fishery which causes profits per operating unit and economic efficiency to decline to unnecessarily low levels. Alternatively, less effort would allow higher returns per operating unit and increased benefits to the Commonwealth.

Reliable effort data, such as number of boats, manpower, days at sea, boat characteristics, and trap or pot days, are not available. Fishery scientists have suggested, however, that fishing effort is too high and needs to be reduced to enhance resource recovery and provide the maximum benefits to the state of Virginia.

The crab pot fishery, the major source of fishing mortality, is an open-access, common property fishery. There is also, however, a delayed entry restriction that delays new entrants from entering the fishery for two years. Under a conventional open-access regime, anyone that wants to enter the fishery may do so. Thus, as long as a profit can be realized, entry will occur. Under the common property condition, no one entity owns the resource and its use is relatively free. Since the cost of using the resource is free, exploiters will tend to overharvest the resource (this is like an employer not having to pay its employees).

It is because of the open-access nature and common property problem of fisheries that economists and fishery researchers have suggested controlled-access and privatization schemes. Controlled-access is usually advocated because it offers a potential cap on overall fishing effort and greatly facilitates state-required monitoring of the resource, harvest levels, and industry. Privatization or resolving the common-property problem is typically advocated to promote economic efficiency and net social benefits to society.

Prior to considering controlled-access schemes and more elaborate regulatory regimes, such as property rights and privatization, in the blue crab fishery, we first explore open-access regulations. This is necessary to demonstrate that resource conservation goals could be obtained without addressing the common-property and open-access nature of the blue crab fishery.

Open-access Solutions

The state currently has an open-access fishery for the pot fishery and a limited entry fishery for the dredge fishery. There is, however, a delayed entry restriction which requires potential entrants to wait two years before they may enter the pot fishery. Regulation of the fishery includes gear restrictions, time and day and week limits, delayed entry, and size and sex restrictions. None of these regulations address the root problem of over-capitalization--too much effort directed at harvesting blue crabs or excessive production costs. Alternatively, open-access solutions do not address the problem of wasteful exploitation of a resource.

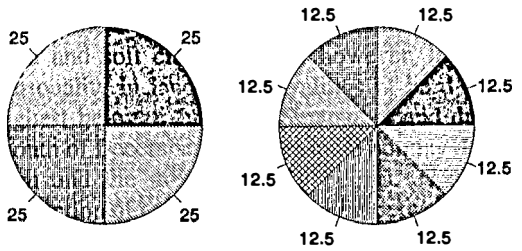
It has long been advocated that in any fishery in which entry is open to all, overfishing and serious economic problems will eventually occur. The major economic problem is dissipation or reduction of profit. Technically, the problem is that revenues less costs less a normal return to the operator become zero because harvesting costs increase relative to revenues. This situation is more commonly referred to as rent dissipation.

In an open-access fishery, production and revenues per individual decline while costs per unit of production increase. Eventually, overall profit is zero and the economic incentives to enter the fishery are diminished. Alternatively, it is costing more to produce a given level of fish than it should. Under the open-access position, production is technically and economically inefficient, and society is not receiving the maximum

possible benefit from the resource. Moreover, some of the resources being used to harvest fish could be better employed elsewhere in the economy.

If we think of a pie chart where the area of the pie represents total profit or rent given a fixed number of fishermen, we can easily see the effects of allowing unrestricted entry (Figure 4). As the number of fishermen in the fishery increase, the slice of the profit available to each fishermen becomes smaller. Eventually, the number of entrants increases to such a level that overall profit for the fishery becomes zero. All possible profit or rent is dissipated.

Figure 4. Open-access and Dissipation of Profit



The blue crab regulations for the pot fishery are examples of typical open-access, common property regulations. They can, if properly implemented, address biological concerns; they can never, however, resolve the economic problems. Other open-access regulations include quotas, trip limits, number of days allowed to fish per week, number of gear (pots) allowed to fish, gear size or configuration (e.g., cull rings), crew size limits, seasonal closures, sanctuaries, and area restrictions. In the absence of regulations that control access and grant property rights, the common-property, open-access fishery will not provide maximum benefits to society. Open-access regulations can, however, be used to resolve resource problems.

A quota is the most frequently used open-access regulation to control fishing mortality and rebuild fish stocks. Quotas typically restrict total annual landings to some level consistent with biological objectives such as maximize the yield or weight per recruit or set harvest levels equal to maximum sustainable yield.

Quotas can also be modified for a variety of factors. For example, quotas can be spread out over time such as monthly or quarterly; a quarterly quota might allow 2,500,000 pounds of hard crabs per quarter. They can be imposed on sex and size. In the blue crab fishery, for example, a quota of 10,000,000 pounds of hard crabs larger than 6.0 inches could be imposed.

To effectively achieve biological or resource conservation goals, quotas must be closely monitored and enforced. Managers must take care not to get into the borrowing mode (allow some of next year's harvest to be taken this year because the fishery has reached its stated quota). The borrowing mode is quite typical of quota-based management and is one major reason why quotas fail to achieve biological and economic goals and objectives of management. Also, quotas, when borrowing is allowed, typically fail to improve resource conditions.

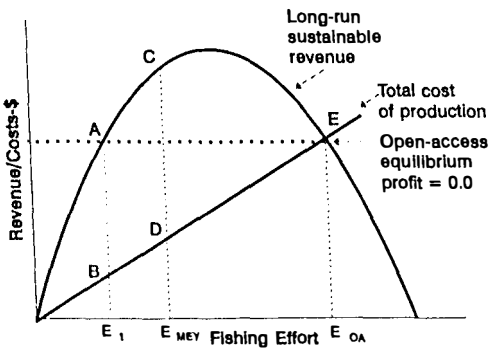
Most important, however, is that quotas and open-access regulations fail to address the dissipation or loss of rent and do not maximize benefits to society. Quotas, in fact, typically worsen economic conditions by increasing the cost of fishing per unit of time. Quotas may also force too much product on the market at one time which can depress prices received by watermen. Quotas, unless substantially modified, offer no opportunity for society to capture rents from the fishery. In the case of the blue crab fishery, quotas would likely force rent to zero and Virginia would be unable to collect any rent from the fishery. In addition, quotas tend to reduce the tax base since taxes are imposed on earnings after expenses or profits.

Under quotas and open-access management, adverse economic repercussions are usually not recognized until it is too late to do something about the problems. Simply, fishermen or boats enter a fishery as long as profits can be earned. Fishermen continue harvesting the resource until total cost equals total revenue. When revenues equal cost, profit is zero, and there is no economic incentive for new entrants. Unfortunately, over-fishing also usually occurs, even before profit becomes zero.

When total cost and total revenue are equal, there are more watermen, vessels, and gear than are necessary to harvest a given level of fish. Harvest levels are in excess of socially-desired levels. Production or harvesting becomes inefficient since fishing effort is redundant or unnecessarily high. Profit is zero and society does not receive the maximum possible benefits. The total cost of producing a given quantity

of fish is higher than necessary. The point at which revenue equals cost is known as the open-access equilibrium (Figure 5).

Figure 5. Open-access Equilibrium



In general, open-access regulations can be classified by whether or not they control outputs or inputs. A quota is an output control and a limit on the number of fishing days is an input control. In the absence of controlled-access, output and input controls will seldom accomplish economic goals and objectives of resource management. Fishermen will tend to substitute unregulated inputs for regulated factors of production. For example, a restriction on the number of pots allowed per fishermen might cause fishermen to increase the number of days they fish with pots or to install more powerful winches so they can pull the pots faster. In the case of output controls, particularly annual or seasonal quotas on the industry, fishermen will "race" to harvest the quota before the fishery is closed. In so doing, profit is typically driven to zero or very low levels.

Limited Entry Solutions

Commencing in 1911 with Jens Warming's work "On rent on fishing grounds," economists and fishery administrators have argued that fishery management must include limited entry or controlled access. That is, the number of vessels, gear, and manpower must be restricted in an open-access fishery to prevent overharvesting and inefficient production.

Referring to Figure 5, the open-access equilibrium level of effort is E_{OA}; profit or rent for the open-access fishery is zero (total revenue minus total cost = E - E = 0). The same levels of catch and revenue can be obtained, however, with E_1 ($E_1 < E_{OA}$) units of effort. More important, profit or rent equal to A - B is obtainable with E_1 units of fishing effort. More profit, though, can be obtained by finding the level of effort and catch associated with maximum profit. The maximum profit level of effort is E_{MEY}, and profit equals C - D. The maximum profit equilibrium corresponds to maximum social benefits and is called the maximum economic yield (MEY).

As such, limited entry and controlled access schemes are economic forms of management. Controlled-access regulatory strategies seek to redistribute income and promote economic efficiency. As previously stated, limited entry and controlled-access are not necessary to realize biological goals of resource management.

Unfortunately, there are numerous problems with limited entry. First, what is the necessary level of participants in the fishery? Second, what should be the configuration of the industry (e.g., boat size, gear type, hull construction, engine type, horsepower, many small boats with small crew, or few large boats with large crew)? Third, who stays and who leaves and what are the criteria for remaining? What other regulations will also be necessary to achieve biological, social, economic, and legal goals of management?

Most fisheries, and which appears to be the case for the blue crab fishery, are already severely over capitalized. What additional regulations will be necessary to reduce effective effort in the Virginia blue crab fishery? Moreover, what information is available to establish rational regulations for the fishery?

One major problem with limited entry that has been recognized by researchers is that fishermen will engage in "capital-stuffing." In the case of the blue crab fishery, a limited entry scheme would likely result in watermen increasing the number of pots, purchasing larger boats or engines, or adding additional equipment that allowed pots to be more efficiently fished. The total costs of production or harvesting blue crabs would eventually increase; as a consequence, profits would decline.

In nearly every fishery throughout the world in which limited entry has been implemented, capital stuffing has occurred and effective effort has not been adequately controlled.

Another problem that often accompanies limited entry is a rush of applicants to enter the fishery. This typically occurs before limited entry is actually implemented or during the planning stages of a limited entry program. When this occurs, the fishery typically ends up with more boats and fishing power than prior to the limited entry program. The bottom line is that profit is driven towards zero and society does not realize maximum benefits from the fishery if limited entry is the only regulation used to regulate a fishery.

Taxing output is another form of limited entry. Taxes are to be set at such a level that the least efficient operators are driven out of the fishery. Unfortunately, a tax program requires considerable monitoring of resource and economic conditions. Taxes must frequently be changed in order to maximize benefits. Taxes do, however, offer Virginia an opportunity to collect needed revenue. Unfortunately, it appears that taxing outputs actually forces fishermen to increase their fishing effort and subsequent harvest, at least in the short to intermediate run. Boat owners typically have large fixed costs which they must cover. Taxes lower their revenue and leave them no choice but to try to increase output and revenue.

It is important to realize that limited entry may not solve the resource problem. The use of limited entry to solve the resource problem depends upon how limited entry is implemented and other regulations imposed on the fishery. If Virginia adopts the conventional procedures used to limit entry in which nearly all boats currently in the fishery are allowed to remain, and imposes no other regulations, total nominal effort will remain constant or increase, and total effective effort will likely increase as producers engage in capital stuffing.

There are many other, actually better, ways to restore the resource. For example, a very restrictive limit (small quota) on harvesting for 1-3 years should, at least, theoretically increase resource levels. A low quota would be a draconian measure in that there would be severe economic hardships imposed on watermen who make a living harvesting crabs. In addition, processors, dealers, wholesalers, financial institutions, and restaurants would be affected by an extremely restrictive harvest quota. A restrictive quota or moratorium would, however, minimize the time it takes to restore the resource.

We iterate that it is important to understand that limited entry is primarily an economic regulatory tool. Referring back to the pie chart in Figure 4 and assuming we have a crab fishery with only 4 watermen, we can assess how profit declines as the number of watermen increases. As the number of participants increases, assuming all participants are homogeneous and operating at maximum capacity, the slice per watermen diminishes. As long as profits can be realized, people will enter the fishery. Eventually, the number of entrants drives profit to zero or very low levels for the inefficient operators. At this point, entry stops. More important, society does not realize maximum benefits from the resource. There are more fishermen and vessels than are actually necessary to harvest a given level of crabs.

An alternative to just limited entry is to combine limited entry with other regulations. In the crab fishery, for example, a limited entry scheme might be combined with a restriction on the number of pots an individual may be allowed to fish. There may also be restrictions on areas and times of year when fishermen are allowed to fish, or on gear. It has been shown, however, that under limited entry schemes, it is often necessary to eventually regulate every aspect of fishing power or factor responsible for catching fish to avoid capital stuffing. Failure to do so usually does not prevent the dissipation of profit and loss of potential benefits to society.

Implementing a limited entry program for the blue crab fishery will likely be very difficult. The optimum fleet size and configuration is unknown. A target level of fishing mortality or total harvest has not been set. It is unknown how watermen might change their fishing power in response to a limited entry program. It is likely that a limited entry scheme for blue crabs will have to eventually regulate all components of fishing power. A limited entry program also does not ensure that the citizens of Virginia will receive the maximum benefits from the resource. Last, limited entry schemes are usually ineffective at controlling mortality and generating benefits for species, such as the blue crab, that are short-lived and subject to large changes in abundance caused by environmental factors.

Individual Transferable Fishing Effort (ITEs)

An interesting alternative to limited entry is individual transferable effort (ITE). An ITE program can be designed that limits the number of participants while allowing flexibility to watermen to harvest blue crabs. If necessary, an ITE program can also incorporate other regulations (e.g., cull rings, area closures, and seasonal restrictions). An ITE program can also be coupled with a limited entry scheme.

Under an ITE program, watermen could be initially allocated a fixed number of fishing days, pot days, or number of pots per year which were consistent with some specified optimum yield. After the initial allocation, holders of ITEs could barter, trade, rent, or sell their ITEs to other watermen. Thus, an ITE regime allows the total effort to be limited while allowing opportunities to improve economic efficiency and returns to watermen.

Implementing an ITE program for blue crabs may be quite difficult. First, data on fishing effort are limited. Second, there does not appear to be an apparent relationship between fishing mortality and fishing effort. Effort and catch per unit effort (CPUE) appear to be uncorrelated; moreover, there are no estimates of fishing mortality. Third, fishing operations are quite heterogeneous, and thus, it would be extremely difficult to determine the level of effective fishing effort necessary to achieve a stated OY. Alternatively, it would be difficult to standardize fishing effort to reflect the heterogeneity of fishing operations (e.g., how many small boat days would be equivalent in fishing power to one large boat day). Fourth, the number of pots or gear restrictions would still be necessary under an ITE program. Last, the compliance, monitoring, and enforcement costs of an ITE program would likely be quite high. For example, watermen might have to install transponders or a vessel tracking system (VTS) to allow VMRC to monitor fishing activities, and VMRC might have to adopt an expensive monitoring and enforcement program.

Individual Transferable Quotas (ITQs)

Another type of controlled-access is the stock certificate program or what has become known as the individual transferable quota (ITQ). In actuality, an ITQ is not really the same as limited entry. It can, however, be implemented with a restriction on the number of participants. Under an ITQ program, quotas or shares, after some initial allocation, are owned by individuals. Holders of ITQs can loan, sell, barter, rent, or give their ITQs to whomever they want. The ITQ program, while usually limiting the number of participants, conveys some notion of ownership of the resource (i.e., conveys imperfect property rights). An ITQ only guarantees access or the opportunity to harvest a given output level, or in the case of the blue crab fishery, a set number of crabs or baskets of crabs.

Under an ITQ program, the problem of profit or rent dissipation typically disappears. Producers now have to pay for the use of the fish stock which was previously free. Nearly every nation of the world with commercial fisheries is currently implementing or exploring ITQ-based management.

In the United States, the surf clam and ocean quahog fisheries are managed by ITQs. The South-Atlantic wreckfish fishery is also managed by ITQs. A great lakes fishery of Wisconsin and the herring roe fishery of California have a long-history of ITQ management. ITQs are being considered for the west coast sablefish and halibut fisheries. The southern bluefin tuna fishery of Australia is managed by ITQs. ITQs are used to manage 23 Canadian fisheries. South Africa manages its highly valuable abalone fishery by ITQs. The National Marine Fisheries Service issued studies on using ITQs to manage and regulate the northwest Atlantic sea scallop fishery, the Atlantic and king mackerel fisheries, the Gulf shrimp fishery, and the Pacific northwest groundfish fishery.

To date, there has been only a limited analysis of the benefits of ITQs. In the southern bluefin tuna fishery of Australia, ITQs were responsible for reducing fleet size by more than 80%. Profits or net returns, however, increased by more than $11.0 million (Australian dollars). Fewer, but larger, fish were being harvested. The downward trend in parental biomass reversed its long-run trend. Boat crews earned substantially more income. Rents or monies received from the fishermen under the ITQ regulation paid for 44% of management, research, and related stock assessment work; prior to ITQs, the fishermen paid nothing towards resource management.

The obvious appeal of ITQs is their seemingly simplicity. Once the procedures for the initial allocation and denomination of tradeable units are determined, ITQs are relatively easy to implement. There are, unfortunately, some downsides or problems of ITQs.

First, ITQ-based management is, in practice, a biomass approach. That is, ITQs seek to reduce total landings of a given resource. They can be modified to reflect size and sex of fish but this adds to the complexity of management. ITQs also tend at least to offer the potential for market power. This latter problem would probably not happen in the blue crab fishery given the large number of small operators. Alternatively, an ITQ scheme could be designed that prohibits any individual from gaining market concentration power.

ITQs usually are inadequate, alone, for addressing the multiproduct or multi-species nature of most fisheries. That is, it is extremely difficult to deal with the multiple product interactions. In the blue crab fishery, an ITQ program would have to address size, sex, product form (hard vs. soft crabs vs peelers), geographic location, time of year, and gear type. ITQs, however, may be easier to use to control multiproduct interactions and fisheries exploited by different types of gear than other types of regulatory strategies.

Differences in size, sex, and product form typically cause a problem known as "high-grading" in ITQ management. Fishermen discard the lower valued products to retain more of the higher valued products; if discard mortality is zero, "high-grading" is not a problem. If discard mortality is nonzero, however, "high-grading" can pose major problems for the resource; the large and more fecund female animals usually command the highest prices in the market. Discard mortality for the blue crab pot fishery is likely to be near zero or extremely low since unwanted crabs are readily culled and returned, generally unharmed, to the environment. Discard mortality in the dredge fishery, however, may be high. Overall, high-grading would not be expected to cause a serious problem for the blue crab fishery.

Potential Regulatory Strategy for Blue Crabs

Although the state does not have well defined or specified objectives for managing *Callinectes sapidus*, it is reasonable to consider two possibly competing objectives of resource management. First, the state may want to maximize economic opportunities. Second, the state may desire to maximize net economic benefits to the citizens of the Commonwealth. Although a cumbersome concept, maximization of net benefits to the Commonwealth would ensure that all and non users of the crab resource would receive maximum benefit from resource management. Alternatively, the dollar value of the resource assessed by society after deducting all costs would be as large as possible.

The first objective, maximize economic opportunities, is a typical objective of less developed countries (LDCs) and coastal communities. The concern in LDCs is to create employment opportunities, provide food and income or subsistence, expand the tax base, and generate foreign currency. The concerns of Virginia coastal communities are similar except for subsistence and generating foreign currency. Under the objective of maximization of economic opportunities, fisheries management focuses on short-run economic growth.

Most growth-based policies focus on subsistence and capital availability policies. Policies that focus on subsistence or capital available typically involve training individuals to harvest fishery resources and making low-cost loans available. Except for underutilized species, growth-based fisheries are short-lived. Over-capitalization, excess fishing effort, and overharvesting usually occur. Society does not receive maximum benefits and profits are quickly dissipated.

Another interesting aspect of the growth-based fishery is that they usually do not generate the greatest tax-base. This is particularly true for U.S. fisheries. As the number of participants increase, profit declines. As profit declines, the tax-base or net income subject to taxation declines.

Consider the tax base for the hard blue crab fishery. Total revenue in 1992 was $9.1 million. The tax base would be equal to total profit or total revenue less total cost. Given a constant revenue of $9.1 million, total profit and earnings subject to taxation would be smaller for a large number of watermen than it would be for a few highly-efficient watermen. With a lot of fishing firms and a finite resource, cost per unit of output and per operating unit would be higher than with fewer fishing firms. These conclusions, however, assume that the fishery was overcapitalized in 1992.

The economic growth strategy, by and large, no longer characterizes resource management in the United States. Fisheries management often has, however, focused on economic maintenance. This appears to be the case for management of blue crabs as well as many other U.S. fisheries.

In this case, the management agency attempts to maintain the status quo in terms of number of participants and economic opportunities. The management agency may alternatively desire to maximize the number of allowable harvesters. Unfortunately, the status quo for most fisheries, and possibly the blue crab fishery, is incompatible with

resource levels. Thus, we find that even for the status quo strategy, the resource may be overharvested and potential profits are not maximized. At a minimum, it is likely that there are too many watermen and fishing boats exploiting the blue crab resource, and as a consequence, the cost per unit of production is likely to be unnecessarily high.

Managing the fishery to sustain the maximum allowable number of harvesters, as is under consideration by Maryland, is also a regulatory strategy that is not likely to enhance resource and economic conditions. This type of objective is void of any type of economic optimum other than ensuring employment opportunities. It requires determining the configuration of the fishing fleet and gear. To satisfy this objective, management must design regulations that impose extreme inefficiency. An example of an inefficient operation would be a 14 foot boat powered by sail in which the operator could fish only one pot per day. This operation would allow a large number of harvesters but their earnings would likely be very low.

Alternatively, sustaining the maximum number of harvesters could be based on economic criteria. This would require, however, the management authority to determine income levels for fishermen and the optimum fleet size and configuration. For example, regulations would allow fishermen, on average and year after year, to earn a fixed amount of income. This type of regulation would likely be rejected by watermen and would do little to enhance the economic benefits of the crab resource.

If the state should elect to manage the blue crab fishery for the purpose of economic opportunity or status quo, the state will not receive the maximum economic benefit, and quite likely, not the maximum tax revenue from blue crab harvesting. In essence, if the state desires to maximize short-run employment or limited economic opportunities, continuing previous forms of open-access will likely suffice. It will be necessary, however, to better define the optimum yield to ensure some long or intermediate-run stability in the resource.

On the other hand, if the state desires to maximize net benefits from the fishery, individual transferable quotas (ITQs) offer the most promise. Under this regime, the state could auction off the first-round allocation and receive income. Alternatively, the state could allocate the initial total allowable catch (TAC) based on historical participation but implement a transactions fee equal to the cost of managing the blue crab resource. For example, if it cost Virginia $100,000 to manage the fishery and the TAC was 40,000,000 pounds, the state could implement a transactions fee of $0.25 per 100 pounds of ITQ.

The ITQ scheme could also be modified to allow the state to buy and sell quota every year or every season to control the rate of resource removal. If the TAC was higher than the initial allocation, the state could sell ITQs; when the TAC was lower than the initial allocation, the state could buy quota. Monies realized from the transactions fee and subsequent sales of quota could be used by the state to purchase quota and manage the resource.

Historically, the initial allocation of ITQs has been based on historical participation in the fishery. Transactions fees are usually zero. The Mid-Atlantic Fisheries Management Council, however, is considering imposing a user fee for surf clams, ocean quahogs, and other species. Under an initial allocation framework, the management agency simply assigns shares to the vessel owners and allows market transactions to deal with the buying and selling or trading of quota in the future. ITQ schemes in New Zealand and Australia appear to be the only ones that impose a transactions fee or require holders of quota to pay a fee to the nation.

Of all the possible regulatory schemes for blue crabs, the individual transferable quota is likely the most promising if the state desires to generate revenues, promote resource conservation, and convey maximum benefits to the Commonwealth. Implementing an ITQ program, however, is likely to be quite difficult.

If the state decides to initiate an ITQ program to manage the blue crab fishery, a variety of issues will have to be addressed. First, will the ITQs be issued relative to product form or just simply with respect to total blue crabs (e.g., an ITQ for hard blue crabs, an ITQ for peelers, and an ITQ for soft-shelled crabs).

The preferred approach is to issue an ITQ for total production but only after setting the ITQ relative to long-run biological and economic goals and objectives. In this manner, watermen can decide how to allocate their effort and maximize their net returns. Alternatively, watermen have maximum flexibility in deciding on a fishing strategy. A total ITQ strategy also creates the opportunity for the state to maximize tax collections and revenues from the fishery.

ITQs by gear and resource area also could be implemented if managers are concerned about equity and temporal problems. Again, however, it is

preferable that the harvester be allowed to adopt the most efficient gear and exploit the areas yielding maximum economic returns; this could likely occur with an ITQ regime structured to deal with differences in resource area and gear.

What Are Some Likely Problems of ITQs?

There are three primary problems the state must address in an ITQ program for blue crabs: (1) transactions fee, user fee, or tax, (2) the setting of an annual total allowable catch (TAC), and (3) whether or not to establish a centralized market, or at least, electronic access to daily market prices for quota. The three problems are not trivial and all involve increased costs for the state. The costs, however, should be easily recoverable via revenue collection activities (e.g., user fee).

Another potential problem with ITQs is market concentration or market power. Although illegal, ITQs create the opportunity for buyers to collude and purchase large quantities of quota and subsequently control the market. It is unknown whether or not there is an opportunity for buyers and sellers to control the market. It is unlikely that a group of watermen could dominate the market since there are many watermen. Processors or owners of picking houses, however, may have sufficient buying power to collude, and thereby, control the exploitation of the resource. This possibility needs to be thoroughly examined when considering ITQ management.

A potentially serious problem with ITQs in the crab fishery is the need to establish a floor level of TAC and harvest rights to the individual harvester. If there is any possibility that TAC might be set to zero in a given year, watermen will have extreme difficulty in borrowing funds to operate their businesses. Financial institutions simply will not make loans to a business entity in which production might be constrained to zero.

ITQs also require increased monitoring and enforcement. Thus, the state could find that managing the blue crab fishery under an ITQ program could increase their management and regulatory costs. This is currently the situation in the surf clam/ocean quahog fishery. The recent stock assessment suggests that the TAC or annual fleet quota must be reduced. Industry has countered, however, that the assessment is flawed. The National Marine Fisheries Service must now redo its assessment for surf clams and ocean quahogs.

Another problem with ITQs is establishing the denominations of ITQs. Just like money, ITQs have to be available in easily tradeable denominations. Should ITQs be issued in percentage of total allowable catch (TAC) or actual harvest units such as pounds and baskets? Harvest units appear to be the most common denomination for ITQs.

In general, ITQs work best in small fisheries in which the species is long-lived, slow growing, and not subject to large random fluctuations in abundance. The blue crab is short-lived, fast growing, and probably subject to large random fluctuations in abundance. An annual total allowable catch (TAC) may, thus, be difficult to set at the beginning of each harvesting season. This problem can be partly mitigated, however, by imposing a minimum TAC regardless of the current conditions of the resource; the TAC can be adjusted, only upwards, during the season as new information becomes available.

A Remaining Option--The Buy Back

There is growing interest by resource managers in reducing fleet size--number of vessels--via a buy back scheme. Under this scheme, vessels are purchased by the state or federal government. In New Zealand, the ITQ program was coupled with a buy back program. Unfortunately, the buy back program funds became depleted, and the management agency was unable to purchase the number of vessels necessary to achieve maximum net social benefits.

The United States agency, National Marine Fisheries Service, is currently investigating a buy back program for New England fisheries. The desire is to reduce the fleet size by approximately 60-70%. It remains unknown whether or not an ITQ scheme will be coupled with the potential buy back program.

There are several problems with a buy back program. First, there is the problem of which boats should be targeted to be purchased. Second, how is the purchase price to be determined? Third, the buy back program must be coupled with some other regulatory strategies preferably an ITQ scheme, to promote maximum economic benefits. Fourth, how is the buy back program to be financed? Last, there may be so many boats in the blue crab fishery, it simply may not be economically feasible to consider a buy back program.

Conclusions

The blue crab fishery of Virginia is thought to be important to several coastal economies; its actual importance is not known, though, because of inadequate information. The Virginia Institute of

Marine Science, however, is currently conducting a study to determine the economic importance of Virginia's commercial fisheries. The blue crab fishery has become increasingly important over the past few years as other marine resources have declined in abundance and experienced downward shifts in demand while the worldwide demand for crab meat and related products has substantially increased. For example, watermen previously dependent on oysters for a plurality of income now increasingly depend on crabs.

It is believed by research scientists and resource managers that effort has increased to the point that the short-run and possibly long-run viability of the resource is in jeopardy. As a consequence, fishery researchers and some administrators have suggested that VMRC explore alternative regulations, and in particular, limited entry and effort control schemes.

It is important to recognize that while limited entry programs can reduce the overall level of effort and aid in resource restoration, limited entry does not offer the best approach for quickly restoring the resource. One possible approach for restoring the resource in the minimum amount of time is to drastically restrict the taking and harvesting of blue crabs. While this strategy would minimize the time it takes the resource to rebuild, it would also cause severe economic hardships for watermen, coastal communities, and businesses dependent upon the blue crab fishery. In addition, there is no guarantee that restrictive harvest policies will rebuild the resource.

There are simply too many unknowns in the rebuilding equation. These unknowns include environmental factors, food availability, predation, and water quality. All, except water quality, are generally uncontrollable.

Before controlled-access, private property regimes, or open-access regulations can be successfully evaluated, the state of Virginia and the VMRC must determine the objectives of managing the resource. Does VMRC want to focus primarily on resource conservation or on the benefits to the Commonwealth? Alternatively, does VMRC want to maximize the long-run benefits of the resource which requires joint consideration of resource conservation and economic benefits?

In comparison, federal fisheries management, under the Magnusom Fisheries Conservation and Management Act (MFCMA), is currently focusing on managing fisheries to maximize benefits to society. To do so, however, requires a bio-economic management framework in which the population dynamics and economic benefits are interrelated and jointly considered. Overharvesting or maximum exploitation has occurred in nearly every fishery managed under MFCMA in which the objective was economic growth or maintenance of the fishery or industry.

Allowing a common-property, open-access strategy to continue will not allow the citizens of the Commonwealth to receive maximum benefits from the blue crab resource. A common-property, open-access strategy, however, will offer maximum employment opportunities in the short-run when resource conditions are relatively high. In the long-run, the open-access fishery will cause some type of biological overfishing, loss of profit, and zero or near-zero growth opportunities. A case in point is the New England groundfish fishery. Since 1977, the number of vessels and crew substantially increased. The fishery has historically been an open-access fishery. Today, the New England Fishery Management Council is having to deal with a moratorium on fishing for cod, haddock, yellowtail founder, pollack, and redfish (ocean perch). If the blue crab resource is really declining as suggested by the scientific community, VMRC may have to consider the option of drastically limiting the harvesting of blue crabs in the near future.

Limited entry is not a cure-all for the blue crab fishery. Other restrictions, such as cull rings and the number of pots per individual, will be necessary. Alternatively, limited entry will not necessarily limit total effective fishing effort and prevent the biological and economic waste that potentially occurs with overharvesting adult crabs and the harvesting of small or lean crabs. It will be necessary to consider regulations that also control the age-at-entry and total effective effort.

Of the many potential regulatory strategies to solve the resource and economic problems, ITQs likely offer the most promise for the blue crab fishery. Admittedly, the fishery is not an ideal candidate for ITQs, but neither have been many of the fisheries of the world that have been successfully managed by ITQs. Moreover, many of the potential problems with ITQs for the blue crab fishery could be resolved by imposing a minimum annual TAC. Supplementary regulations, however, might also be required with ITQ management of the fishery (e.g., cull ring size or restrictions on dredges to ensure a reduction in dredge-related mortality). ITQs also may have to be designed explicitly recognizing the multiproduct nature of the fishery; the multiproduct nature, however, should be of concern regardless of the form of management. Also, ITQs likely offer the best management strategy for dealing with multiple products because they allow

watermen flexibility in deciding how and what to produce.

Primary problems of ITQs for the state will be deciding the initial allocation and denomination of ITQs and whether or not to implement user-fees. Another problem for the state will be determining total allowable catches (TACs) each year; VMRC will have to determine if it has the capability to set TAC to levels consistent with resource conditions. Last, VMRC will have to decide whether or not there should be a minimum annual TAC to allow watermen and crab-related businesses to obtain loans from financial institutions.

An ITQ program will require additional investment by the state for data collection and fishery monitoring activities; additional expenditures would be required, however, for any regulatory strategy concerned with maximizing benefits to the Commonwealth. If an ITQ program is to be successful, accurate assessments of resource conditions are essential. Accurate assessments of blue crab abundance, however, may be difficult since there is likely to be a high degree of variability in resource abundance and the relationship between spawning stock and recruitment. Moreover, monitoring of landings and harvesting activities are required for any successful ITQ program just as they are for any successful regulatory regime.

Inevitably, there will be some type of market for ITQs. Whether or not the market will be comprised of many buyers and sellers having little information about ITQ prices or a centralized market in which all buyers and sellers have access to ITQ price information will depend upon decisions made by the state. That is, the state will have to decide whether or not to invest in creating a centralized market. Thus far, none of the U.S. fisheries managed under ITQs have a centralized market or electronic bulletin board for disseminating information about ITQ prices. It has been shown in other ITQ programs and in the case of marketable emission or pollution permits for electric power plants, however, that if an ITQ program is to be successful, there must be some sort of centralized market or electronic bulletin board that summarizes ITQ prices. In the absence of a centralized exchange or electronic posting system, it is unlikely that market equilibrium prices for ITQs will form, and as a consequence, maximum economic efficiency and social and economic benefits may not be realized.