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MARINE AQUACULTURE ENFORCEMENT: PASSING THE BUCK

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ABSTRACT All states regulate aquaculture enterprises for several purposes. Similarly all states regulate their wild fisheries as well. In some instances the regulatory authority over aquaculture and wild fisheries overlap. Minimum size regulations for harvested shellfish are one such example. The principal argument supporting maintenance of size restrictions for wild and cultured shellfish in some states is that marine enforcement cannot distinguish between wild and cultured product. Thus, in the interest of protecting public resources, a minimum size restriction is placed on all product regardless of its origin. Harvest restrictions may cause financial losses to aquaculture entrepreneurs in terms of mortalities experienced while waiting for the product to reach a legal size and in terms of increased interest costs. This paper discusses this issue in more detail and presents simulated estimates of financial losses due to harvest size restrictions for a hypothetical oyster (*Crassostrea virginica* Gmelin) aquaculture business. Estimates of the economic cost of enforcing a minimum size regulation on oyster aquaculture producers in Florida are presented.

KEY WORDS: aquaculture, enforcement, regulation, *Crassostrea virginica*

INTRODUCTION

Shellfish resources like other marine fisheries are subject to the "tragedy of the commons." Hardin (1968) described the "tragedy" as one in which the absence of property rights, or equivalently, the inability to control access leads to the ultimate destruction of a resource. However, in point of fact, property rights do typically exist for shellfish resources. All states do claim a territorial right to their coastal waters and access to harvest shellfish resources is restricted in some fashion. Thus, some form of weakly specified property rights are exerted over shellfish resources. Unfortunately, these rights simply grant access to harvest but not to produce shellfish. With no ability to establish property rights to an individual's production activity, no one has the incentive to conserve shellfish resources. Under these conditions, the outcome has been over-harvesting and the typical public policy response has been regulation.

The purpose of marine shellfish regulations—and from here on out we will focus on molluscan shellfish—is to protect public shellfish resources. In most cases this management objective is accomplished by controlling harvest levels, harvesting effort, harvesting technology or, more likely, some combination of all of these. Some common regulatory instruments include, but may not be limited to, daily bag limits, restrictions on areas, seasons or time fished, limits on allowable gear, and minimum size limits.

The conditions that lead to over-harvesting of public shellfish resources encourage the development of private culture on leased bottoms. With a strong demand for seafood and depletion of wild resources, aquaculture of a variety of shellfish species has become an increasingly attractive investment opportunity. In states such as Virginia and Louisiana, with a long history of shellfish aquaculture, private entrepreneurs are exempt from most shellfish harvest regulations that are enforced on public resources. In other states, Florida among them, private aquaculture businesses are subject to some if not all regulations that are designed to protect wild shellfish stocks.

The principle argument made to support regulation of marine aquaculture is that marine enforcement agencies cannot distinguish between wild and cultured product. Therefore, effective management of wild shellfish resources requires that all sources of product be subject to the same rules. Unfortunately, shellfish regulations tend to restrict the ability of private shellfish producers to operate in the most efficient manner possible. Consequently, private aquaculture producers either operate at a higher cost or a lower level of productivity or both. In any case, lower levels of profitability result as the burden of payment for enforcement of regulations designed to protect public shellfish resources is shifted—the buck is passed—to aquaculture businesses.

The objective of this paper is to demonstrate the economic cost of marine shellfish regulations to aquaculture businesses. For demonstration purposes a minimum size limit on oysters (*Crassostrea virginica* Gmelin) in Florida will be used as a case study. Our purpose is to; 1) show how regulations whose purpose is to protect public shellfish resources can indirectly affect aquaculture profitability, hence growth in the shellfish aquaculture industry, and 2) demonstrate the potential gains from designing alternative mechanisms for marine shellfish regulation.

OYSTER AQUACULTURE PRODUCTION SYSTEM

For demonstration purposes a case study of an aquaculture business using a flexible belt production system will be analyzed. The design and production methods for the flexible belt system are documented in Creswell et al. 1989, and in Vaughan et al. 1988. The flexible belt looks much like a ladder with flexible joints at each rung with a nylon mesh bag containing the oysters placed in the space between. The belt is anchored to the bottom with screw anchors that are removed when harvesting or handling. The flexible belt system offers several distinct advantages.

1. The entire belt is constructed of rope, PVC, and nylon bags.

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This makes the belt light, durable, corrosion resistant, and easy to handle.

2. The oysters can be moved or handled simply by bringing the belt to the surface offering operational ease in cleaning, sorting or sampling oysters.
3. Harvesting can be accomplished by raising the belt and removing the oysters from each bag. Harvesting in this manner reduces labor requirements and reduces harvest costs.
4. The oysters are retained at all times in a nylon mesh bag and are protected from benthic and free-swimming predators.
5. The flexible belt system produces a cultchless oyster that is uniform in size and shape. Such an oyster may be regarded as a premium product for restaurants and the raw bar trade.

Table 1 presents a production schedule used for the flexible belt production system. Seed oysters 8 mm in size are placed in 2 mm nylon mesh nursery bags at the beginning of the production cycle at a stocking rate of 10,000 oysters per bag. Management of the flexible belt system requires periodic cleansing of the belt and monitoring of the growing oysters to assure proper stocking densities and optimal growing conditions. While in the first nursery bag the oysters are inspected and the bags are cleaned twice each week. When the oysters reach a 6.25 mm size they are restocked at a rate of 4,000 oysters per bag into a second nursery bag having a 3.25 mm mesh size. Inspection and cleaning of the second nursery bag is also done twice weekly. The production cycle continues as indicated in Table 1 with the oysters being sequentially restocked in three growout bags of 6.25, 12.5, and 18.75 mm size mesh until being harvested.

PROCEDURES

The state of Florida enforces a 75 mm (three inch) minimum size limit on oysters harvested from state waters. To evaluate the economic cost of enforcing a 75 mm minimum harvest size a baseline condition must be established. Therefore, the first step in the analysis is to estimate costs and returns for an oyster aquaculture business subject to a 75 mm minimum harvest rule. Once baseline profitability has been established, the growout period can be varied to estimate the difference in profitability for different harvest sizes. For comparative purposes, growout periods for 75 and 62.5 mm oyster sizes were used. Field trials under Florida growing conditions indicate that, on average, oysters reach a 62.5 mm size in approximately 12 months and take an additional 3 to 6 months to reach the legal 75 mm size. Therefore, there is a 3 to 6 month period over which Florida producers incur mortalities (hence losses in revenue) and higher operating costs than would be the case if oysters were harvested at the 62.5 mm size. To estimate these losses, an economic analysis using a spreadsheet computer program, of a representative Florida oyster aquaculture business using the flexible belt system was developed.

TABLE 1.

Production schedule for flexible belt.

Production Activity
1) Stock 8 mm seed @ 10,000/bag in 2 mm mesh nursery bags Clean/Inspect bags twice weekly
2) Stock 6.25 mm seed @ 4,000/bag in 3.25 mm mesh nursery bags Clean/Inspect bags twice weekly
3) Stock 18.75 mm seed @ 1,500/bag in 6.25 mm mesh growout bags Clean/Inspect bags weekly
4) Stock 25 mm seed @ 500/bag in 12.5 mm mesh growout bags Clean/Inspect bags weekly
5) Stock 37.5 mm seed @ 250/bag in 18.75 mm mesh growout bags Clean/Inspect bags monthly
6) Harvest oysters

Economic Analysis

Figure 1 depicts the structure of the spreadsheet program and how the different elements are linked. The analysis provides an economic framework from which to analyze a representative oyster aquaculture business on a monthly basis from start up and continuing for a five year period. The economic analysis consists of a series of linked budgets beginning with a "process" budget. The process budget provides an itemized monthly record of all production activities (listed in Table 1) and the resources required to conduct those activities. Listed in the box labeled "Process Budget" in Figure 1 are the choice variables that define the technical production conditions used in constructing the process budget. According to field trials, survival rates for a 15 month production period have ranged between 85 and 90 percent. A simplifying assumption of a 99% monthly survival rate is made (a 99% monthly rate results in an 86% survival rate at harvest for a 15-month production period). In practice, monthly survival rates fluc-

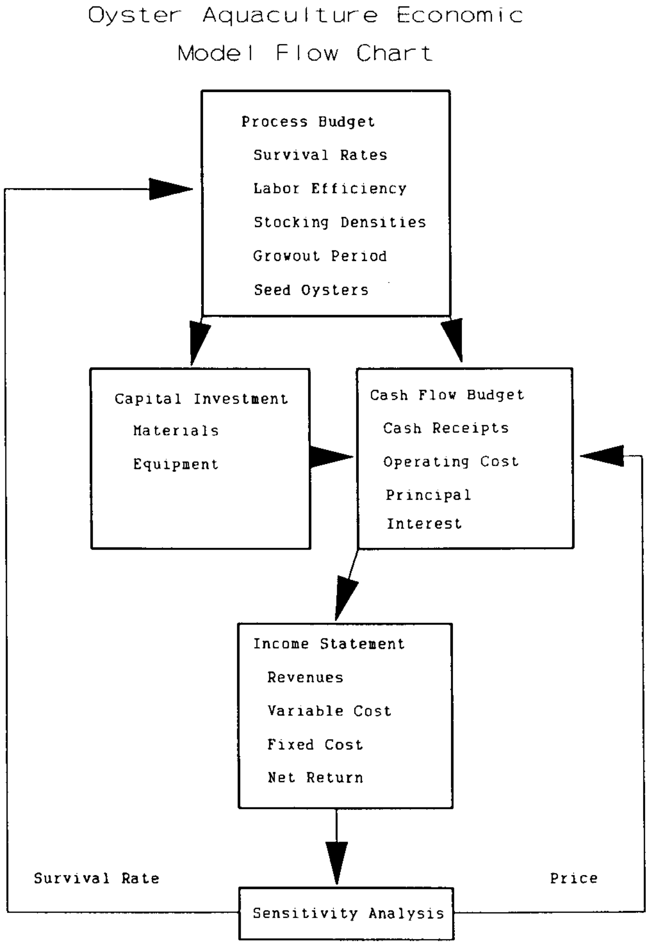

Figure 1. Computer spreadsheet program flow.

TABLE 2.

Five year total financial and resource requirements by growout period (99% MSR and $.20 per oyster).

	Growout Period				
	Twelve Month	Fifteen Month	Eighteen Month	Twelve/Fifteen Month	Fifteen/Eighteen Month
Harvested oysters (each)	4,933,638	3,679,310	2,745,120	4,217,648	3,168,762
Operator labor (hours)	6,445	6,162	6,048	6,177	6,020
Capital investment ($)	35,398	35,386	35,466	35,373	35,430
Cash receipts ($)	1,051,079	735,862	549,024	871,451	63,375
Operating interest ($)	1,865	2,649	3,624	2,036	2,956
Fixed interest ($)	9,292	9,288	9,309	9,285	9,300
Total cost ($)	170,564	146,130	132,383	156,297	138,407
Net return ($)	880,514	589,732	416,641	715,152	495,344
Total seed (each)	7,260,000	5,580,000	4,590,000	6,300,000	5,040,000
Seed per month (each)	121,000	93,000	76,500	105,000	84,000

tuate due to a variety of environmental factors such as weather conditions, predators, and diseases. The principal concern, however, is the net survival at harvest. Alternative survival rates are addressed later in a sensitivity analysis. Labor efficiency is assumed to be 3 bags handled per minute or one complete belt handled in 48 minutes. This labor efficiency applies to all required tasks; cleaning, inspecting, sorting, and harvesting. Stocking densities are the same as that indicated in Table 1. Harvest at the 75 mm size takes place at the end of the 15th month. Seed oysters are planted on a monthly basis to simulate a business that provides product on a sustained year-round basis. The number of seed oysters planted depends upon the size of the operation and the length of the growout period. For any given plant size (one acre or 18 belts in this case) the faster the oysters can be grown and harvested the greater the number of seed oysters that can be planted on a sustained basis. Therefore, once the growout period has been selected and all other factors are held constant, the spreadsheet program selects the maximum amount of seed that can be planted subject to the 18 belt limit.

The process budget provides an itemized list of labor, oysters planted, oysters growing by size class, and the number of bags by size class. The latter information is used to compute the cost of materials for the capital investment schedule. Additional equipment such as a truck, boat, motor etc. are also included in the capital investment schedule. Of the capital investment needs, all equipment except the materials for the flexible belts are invariant with respect to growout period.

The cash flow budget includes cash receipts from the sale of oysters, operational cash costs, and principal and interest payments on operating and capital investment loans. The cash flow budget is linked to the process budget in that the number of harvested oysters and required monthly hired labor come from the process budget. Similarly, the cash flow budget is linked to the capital investment schedule in that the level of principal and interest payments on capital loans are ultimately determined by the capital investment schedule.

The income statement is linked to the cash flow budget and provides an annual statement of all costs and earnings and net returns to operator labor, management and risk. The sensitivity analysis determines the effect on net returns under different oyster price and survival rate conditions.

The economic cost of enforcing a minimum size on aquaculture businesses is the difference between net returns under a minimum size restriction and that of no restriction. The current Florida minimum size limit for oysters is 75 mm. Anecdotal evidence from oyster aquaculture industry representatives indicates that a 62.5 mm oyster could be marketed. For the baseline scenario it is assumed that each size is marketed at the same price. The possibility that a smaller oyster will only be marketed at a discounted price will be examined through a sensitivity analysis. Field trials under Florida growing conditions indicate that oysters reach a 62.5 mm size in 12 to 15 months and a 75 mm size in 15 to 18 months. Therefore, net returns for an oyster aquaculture business are estimated for five different growout periods. First, 12 month, 15 month, and 18 month growing periods are analyzed. Given the fact that not all oysters will mature at the same rate two additional scenarios are examined. In the first, 50% of all oysters mature in 12 months and 50% of all oysters mature in 15 months while in the second, 50% of all oysters mature in 15 months and 50% of all oysters mature in 18 months. Many other combinations of maturation rates and growing periods could be examined. The differences in net returns for any two scenarios is a measure of the economic loss associated with a prolonged growing period due to a minimum harvest size restriction.

For each scenario the assumed initial conditions are; 1) a one acre production unit, 2) five year business horizon, 3) 99% monthly survival rate, and 4) $.20 per oyster price. A sensitivity analysis on net returns is performed for each growout period using oyster prices of $.10, $.15, $.20, and $.25 per oyster and monthly survival rates of .85, .87, .89, .90, .95, .97, and .99.[1]

The sensitivity analysis described above produces 24 estimates of net returns for each of the five different growout periods depending upon oyster prices and monthly survival rates. Computing the differences indicated previously, results in 72 estimates of the economic cost of enforcing a 75 mm minimum size limit. Using

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[1] Total number of market sized oysters harvested as a percentage of seed planted is calculated as follows:

% Oysters Harvested = MRS^a
where: MSR = monthly survival rate
n = months to harvest

For example, a 97% MSR results in 69.4% ($.97^{12}$) of all seed oysters harvested at the end of a 12 month period.

TABLE 3.

Resource and financial losses (minimum size versus no minimum size regulations).

	Twelve–Fifteen Month	Fifteen–Eighteen Month	Twelve/Fifteen–Fifteen/Eighteen Month
Harvested oysters (each)	1,254,328	934,190	1,048,886
Operator labor (hours)	283	114	157
Investment capital ($)	12	−80	−57
Cash receipts ($)	315,217	186,838	237,699
Operating interest ($)	−784	−975	−920
Fixed interest ($)	4	−21	−15
Total cost ($)	24,434	13,747	17,890
Net return ($)	290,782	173,091	219,808
Total seed (each)	1,680,000	990,000	1,260,000
Seed per month (each)	28,000	16,500	21,000

these estimates as a data base, descriptive statistics such as ranges, means, and standard deviations can be used to describe the economic cost to a private oyster aquaculture business of complying with a minimum harvest regulation.

RESULTS AND DISCUSSION

Table 2 shows the five year totals for key financial variables for each of the five different growout periods. The number of harvested oysters and, therefore, value of cash receipts increases as growout period decreases, showing the effect on net returns of longer growing periods. The twelve month growout period requires the greatest amount of operator labor because of the greater volume of product being tended and harvested. Capital investment and interest payments on the initial investment loan under all scenarios are virtually constant. Interest payments on operating loans are lowest for the twelve month growout period due to the fact that operating loans are paid off sooner as compared to longer growout periods. Total cost increases as the production period decreases due to the fact that for shorter growout periods more product can be handled and, therefore, larger amounts of seed oysters are purchased. However, even though costs are higher the shorter the growout period, the increase in numbers of oysters sold more than offsets the cost of purchasing larger quantities of seed oysters. Net returns, therefore, are highest for the twelve month growout period.

Table 3 shows the computed differences for the resource and financial variables shown in Table 2 for different growout periods. For example, 1,254,328 more oysters are harvested over a five year period when harvested at the end of 12 months (at a 62.5 mm size) as compared to harvest in fifteen months at a 75 mm size. Under different assumed growout periods the difference in the number of oysters harvested under a 75 mm harvest regulation as compared to a 62.5 mm harvest size ranges between 934,190 and 1,254,328 fewer oysters. This difference results in a reduction in cash receipts of between $315,217 and $186,838 over a five year period.

TABLE 4.

Sensitivity analysis of year five net returns for price, survival rate and growing period.

	Growing Periods				
Price/Survival	Twelve Month	Fifteen Month	Eighteen Month	Twelve/Fifteen Month	Fifteen/Eighteen Month
$.15/85%	19,847	−50,729	−95,235	−15,434	−73,621
$.20/85%	62,457	−15,823	−73,696	31,131	−44,829
$.25/85%	101,715	19,084	−52,158	63,833	−16,038
$.15/87%	48,403	−9,498	−52,857	24,600	−30,898
$.20/87%	91,275	30,261	−27,013	60,994	1,749
$.25/87%	131,460	58,976	−1,169	96,077	34,321
$.10/89%	24,800	−17,376	−45,070	3,711	−31,222
$.15/89%	71,481	26,293	−14,982	48,810	5,753
$.20/89%	118,162	57,184	15,105	87,342	39,264
$.25/89%	164,844	87,482	42,701	125,873	65,091
$.10/90%	33,431	−3,275	−30,204	17,700	−16,923
$.15/90%	81,726	37,717	2,145	59,455	22,819
$.20/90%	130,021	69,837	33,776	99,742	5,2347
$.25/90%	178,316	101,956	57,017	140,028	80,114
$.10/95%	70,103	42,668	26,667	55,651	34,201
$.15/95%	126,842	82,974	57,650	103,826	69,568
$.20/95%	183,579	123,280	88,633	152,002	104,934
$.25/95%	240,317	163,587	119,615	200,177	140,300
$.10/97%	82,726	54,835	39,402	68,170	47,091
$.15/97%	143,090	98,529	74,079	119,927	86,334
$.20/97%	203,455	142,224	108,756	171,683	125,577
$.25/97%	263,819	185,918	143,433	223,440	164,820
$.10/99%	94,963	67,285	50,856	92,304	58,316
$.15/99%	159,315	115,276	89,160	155,700	101,019
$.20/99%	223,667	163,267	127,464	219,096	143,722
$.25/99%	288,019	211,258	165,768	282,492	186,425

net returns are higher when a 62.5 mm oyster is marketed even though they are marketed at lower price.

CONCLUSIONS

The economic analysis showed that economic losses to an oyster aquaculture business due to a minimum harvest size restriction averages between $49,052 and $6,892 per year taking into account differences in assumed survival rates and growing periods and whether a price discount is applied to 62.5 mm oysters. Assuming a continuously operating business for a ten year period and a 10% discount rate the present value of such an economic loss is between $331,522 and $46,580 for a single aquaculture business. According to the most recent estimates there are 24 active oyster producers in Florida (Florida Agricultural Statistics Service, 1990). The present value of the economic loss of enforcing a minimum harvest size on private aquaculture businesses ranges between $7,956,528 and $111,792 on an industry-wide basis.

The analysis presented herein was for demonstration purposes and a hypothetical oyster aquaculture business was used as the unit of analysis. Nevertheless, the point that enforcement of shellfish harvest regulations designed to protect public resource stocks effectively may shift a part of the burden of payment for such policies to the private sector was demonstrated.

The state of Florida and many other coastal states have begun to explore and promote the potential of shellfish aquaculture as a way of reviving or diversifying depressed coastal economies. The need to protect and conserve public shellfish resources for those who wish to continue to harvest them is a real and legitimate justification for regulation. However, the need to examine the effects of public shellfish resource management policy on private and public initiatives to promote shellfish aquaculture industry development was demonstrated in this paper.

The principal reason for uniform regulatory treatment of public and private shellfish producers in the state of Florida remains the inability to tell the difference between wild and cultured product once the oysters leave the water. The findings of this study indicate that returns to innovative policies such as tagging or monitoring programs may be in the best long term interest for both private and public concerns.

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