Monopsony Processing in an Open-Access Fishery

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Abstract In a recent paper, Clark and Munro (1980) showed that monopsony processing more than offsets the effects of open-access in the harvesting sector of a commercial fishery, and leads to overconservation of the resource. We show here that this conclusion depends critically on the cost of capacity and consequent ease of entry and exit from the harvesting sector. In particular, for low entry and exit speeds the monopsonist has a high degree of monopoly power and by depressing the price overconserves the natural resource relative to the social optimum, while as the adjustment speed approaches infinity a monopsonist employing a discount rate equal to the social rate of discount will be induced to behave optimally from the viewpoint of society. By means of a simulation employing parameters from the Pacific halibut fishery, we also show that a monopsonist subject to relatively sluggish entry or exit may reap profits considerably less than the resource rents accruing if the resource were optimally managed.

1. Introduction

Beginning with H. Scott Gordon's (1954) seminal article, a great deal of effort has been expended in describing the economics of open-access natural resources such as the fisheries, but almost

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without exception the implicit assumption has been of classical perfect competition in both the fishering and processing industry. However, this is at variance with what in many cases is recognized as the often monopsonistic character of fish processing (Crutchfield and Pontecorvo, 1969; Capalbo, 1976; Clark and Munro, 1980; Fraser, 1980). The effects of monopsony processing have been analyzed by Clark and Munro (1980).

As one would expect, monopsony processing to the extent that it depresses the price paid to the fisherman is a conservationist force, and thus tends to offset overfishing caused by the open-access nature of the resource. Clark and Munro in fact showed that monopsony more than offsets the effects of the externality, to such an extent that a monopsony processor employing the social rate of discount is more conservationist than is socially optimal. This conclusion is based on the fact that the perceived cost of harvesting to the monopsonist exceeds the true social cost given an upward sloped harvesting supply curve. However, the slope of the long-run fishing supply curve, and consequently the ability of the monopsonist to depress the price paid to the fishermen depend critically on the ease of entry and exit in the competitive fishery. For example, frictionless entry or exit in response to profit changes in the competitive harvesting sector removes the motive for overconservation, with the result that a processor employing the social discount rate behaves optimally from the viewpoint of society. This results from the fact that the monopsonist in this case is able only to collect the resource rents in the fishery and, in maximizing these rents, maximizes total rent for the society. At the other extreme, in a fishery where exit is blocked, a monopsonist (also employing the social discount rate) will behave in a manner that is more conservationist than is socially optimal. In intermediate cases profits are a combination of resource and monopsony rents. Ironically, if exit is not completely blocked the monopsonist makes less total profits in equilibrium with a low-exit speed than a high one; because the stock cannot be controlled directly the loss of resource rents due to overconservation outweighs the monopsony profits. Some of these cases are illustrated by means of a simulation employing parameters from the Pacific halibut fishery.

The paper is divided into three subsequent parts. The first adds a constant returns to scale monopsony processing sector to a dynamic fishery model modified to include the cost of new capacity and derives the conditions applicable in dynamic equilibrium. The second section shows the relationships between the cost of capacity, speed of entry and exit, equilibrium price and the resource stock, and the final part offers conclusions.[1]

2. A Model of Monopsony Processing

We begin with the model of an open-access fishery developed by Smith (1968, 1969) which assumes free entry and exit into the fishery but nonrational expectations concerning equilibrium profits as the result of the externalities inherent in a common property resource. As usual, the biological growth of the fish stock (x) is summarized by the relationship

$$\dot{x} = F(x, \bar{x}) = xg(x, \bar{x})$$

with

$$F(0, \bar{x}) = g(\bar{x}, \bar{x}) = 0, \text{ and } g(x) > 0 \tag{1}$$

$$g'(x) < 0, F''(x) < 0 \quad \text{for} \quad 0 < x < \bar{x}$$

Here $\bar{x}$ is the equilibrium stock size in the unexploited fishery, the restrictions on $g(x)$ (and $F(x)$) ensuring a stable solution. A specific form of the $g(x)$ function corresponding to the familiar logistic relation popularized by Schaefer (1954) further restricts $g(x)$ to be linear; this is assumed in the simulations in the following section.

The Schaefer model is also followed with respect to the fishery production function. Let q and e be catch and effort respectively per individual fishery boat (which we take to represent a single firm). The Schaefer production function assumes q/e proportional to the fish stock, so $q = hxe$ with h a parameter. Unlike Clark and Munro (1980) who define effort as comprising the long-run services of both capital and labor, this specifies per-boat effort (e) as the services of labor and materials in fishing given a fixed number of boats (capital) in the fishery.[2] The individual cost curve of effort in the short-run thus naturally has the usual convex shape, and for simplicity it is assumed quadratic, i.e.

$$C_f(e) = c_0 + c_1 e^2/2 \tag{2}$$

with

$$C'_f(e) = c_1 e \text{ and } C_f/e = c_0/e + c_1 e/2.$$

Although the fisherman's control variable is individual effort, because we are concerned with processing we shall find it convenient to work primarily in terms of catch and stock levels; in terms of these variables the short-run cost function per boat becomes

$$C_f(q, x) = c_0 + \frac{c_1}{2}(q/hx)^2 = c_0 + c'_1 q^2/2x^2 \tag{3}$$

with

$$c'_1 = c_1/h^2$$

The parameter c_0 denotes fixed cost, while c'_1 determines the slope of the marginal cost curve. With P_f the exvessel price of unprocessed fish, the short-run profits of a vessel in the harvesting sector are

$$\pi_f(e, x) = P_f hxe - C_f(e) \tag{4}$$

In the long run it is necessary to allow for the possibility of entry into the fishery. To model entry we follow the neoclassical theory of investment deriving from the seminal contribution of Eisner and Strotz (1963), extended by Lucas (1967) among others. Unlike McKelvey (1985) who treated investment in the fishery as irreversible, we allow possible disinvestment representing exit from the fishery in response to a monopsony-caused depressed price for unprocessed fish.

The basis for less than instantaneous entry or exit is the cost of providing new capacity (a "cost of adjustment" for investment in real fixed capital) in contrast to relatively cost-free changes in amounts of effort per boat. In our context this means an upward-sloped industry supply curve for new boats, of the sort that Anderson (1982) has recently discussed in the context of total industry effort. For simplicity we represent this cost of new capacity by a quadratic function of the change in boat numbers (each boat being of fixed size). Assuming for simplicity that boat capital does not depreciate and that exit and entry are equally costly, total industry costs of adjusting capacity are simply

$$TC_k = c_k(\dot{n})^2/2 \tag{5}$$

with the parameter c_k denoting the slope of the supply curve for new capacity.

The competitive harvesting sector then acts to maximize the present value of expected future profits net of entry costs or

$$J_c(t) = \int_t^{\infty} e^{-\rho(z-t)}\,(n\pi_f^e - c_k(\dot{n})^2/2)dz \tag{6}$$

where $\dot{n}(z)$ denotes the time derivative in period $z > t$ and ρ is the rate of discount, which we assume equal to the social discount rate throughout the paper.

While the competitive industry members can control the rate of investment and effort per boat, by the nature of the common property externality they can control neither the stock nor the future unprocessed price. Consequently, their expectations being by nature myopic, they assume $\pi_f^e(z) = \pi_f(t)$ for all $z > t$ (Berck and Perloff, 1984). Taking the terms with t outside the integral, the problem for the competitive fishery becomes

$$\max_{\{e,\dot{n}\}} J_c = e^{\rho t}\pi_f(t)\int_t^{\infty} e^{-\rho z} n(z)dz - e^{\rho t}\int_t^{\infty} e^{-\rho z}\, c_k(\dot{n}(z))^2/2\, dz \tag{7}$$

Treating this as a problem in the calculus of variations, the solution follows the relations

$$\frac{\partial J_c}{\partial e} = 0 \rightarrow \partial \pi_f / \partial_e = P_f hx - C'_f(e) = 0 \tag{8}$$

$$\frac{\partial J_c}{\partial n} - \frac{\partial}{\partial z}\left(\frac{\partial J_c}{\partial \dot{n}}\right) = c_k e^{-\rho(z-t)}\left[\frac{\pi_f(t)}{c_k} + \dot{n}(z) - \rho \ddot{n}(z)\right] = 0 \tag{9}$$

Equation (8) simply equates marginal revenue and marginal cost of effort at each period, t, or

$$P_f = C'_{fq}(q, x) = c'_1 q / x^2$$

in terms of the catch rate, q. Inversion of this function then derives the short-run harvesting supply function per vessel:

$$q(P_f, x) = C'^{-1}_{fq}(P_f, x) = P_f x^2 / c'_1 \tag{10}$$

Investment in the fishery can be derived from equation (9). Integrating over z gives investment as a function of expected future profits per boat, i.e.:

$$\dot{n}(t) = e^{\rho t} \int_t^{\infty} e^{-\rho z}\, \pi_f(t)/c_k \, dz \tag{11}$$

Evaluating further given myopic expectations, this becomes the familiar "accelerator principle":

$$\dot{n}(t) = \pi_f(t)/\rho c_k = \alpha \pi_f(t) \tag{12}$$

with entry or exit proportional to current profits. The parameter $\alpha = 1/\rho c_k$ represents the speed of entry or exit, inversely related to the discount rate used by firms and to the slope of the marginal cost of new capacity. $c_k = 0$, for example, denoting an infinitely elastic supply curve of new boats, implies immediate entry or exit and a zero profit equilibrium at each instant. Whatever the value of α, long-run equilibrium where $\pi_f = 0$ drives effort to

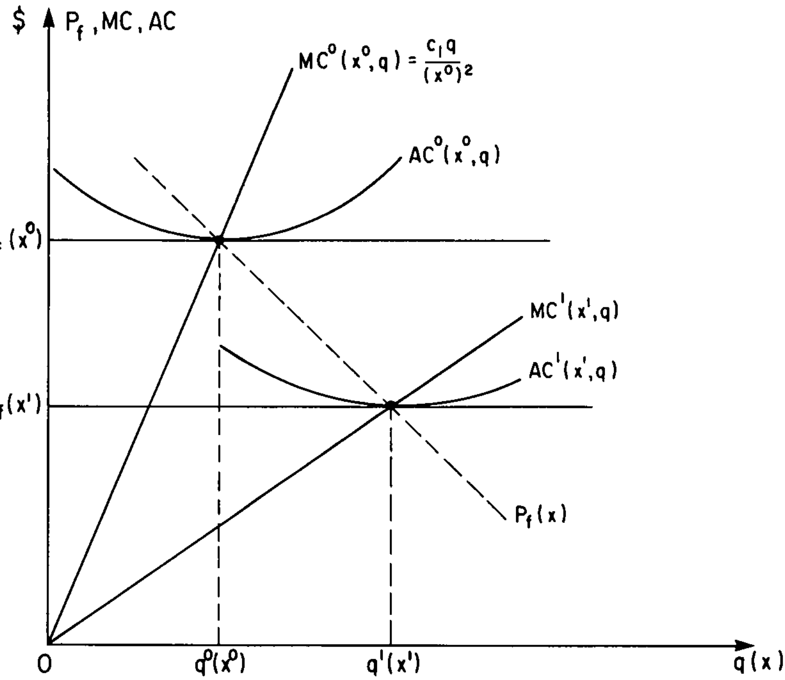

FIGURE 1. Harvesting sector equilibria at different levels of the resource stock.

the minimum point of the average fishing cost curve, where $C_f'(e) = C_f(e)/e$ or $C_{fq}'(q, x) = C_f(q, x)/q$. From (2) or (3) this determines equilibrium effort ($e^* = \sqrt{2c_0/c_1}$) and makes equilibrium catch per boat ($q^* = he^*x = q_0x$) simply proportional to the stock of fish. Substitution of q^* into (3) then implies a long-run marginal fishing cost function that is a rectangular hyperbola, costs being inversely proportional to the stock with $C_f'(q^*(x), x) = c_1'q_0/x$. Two harvesting sector equilibria for different values of x are illustrated in Figure 1.

Following Clark and Munro (1980), the processing sector is described very simply by assuming constant returns to scale in processing and, because we wish to focus on monopsony power, by assuming the processed fish price to be fixed in an international market. With the fixed process price, $\overline{P}_p$, and average processing costs, $A\overline{C}_p$, processor cash flow per vessel is $\pi_p = (P'_p - P_f)q$ with $P'_f = \overline{P}_p - A\overline{C}_p$, the net marginal revenue in processing.

Optimal Processing

The optimal management of both processing and harvesting sectors requires control of both q and n to maximize joint harvesting and processing rents. In this case the raw fish price nets out, and optimum harvesting and processing are represented by the solution of

$$\begin{aligned} \max_{\{q,i\}} J_0 &= \int_0^\infty e^{-\rho t}\{n(\pi_p + \pi_f) - c_k i^2/2\}dt \\ &= \int_0^\infty e^{-\rho t}\{n(P'_p - C_f(q, x) - c_k i^2/2\}dt \end{aligned} \qquad (13)$$

$$s.t.\ \dot{x} = F(x) - nq \quad \dot{n} = i(t) \text{ (investment)} \qquad (14)$$

By assumption the optimal path embodies perfect foresight (rational expectations and no uncertainty) so expected future rents equal their realized values. The Hamiltonian for this optimal control problem is

$$H = e^{-\rho t}\{n(\pi_p + \pi_f) - c_k i^2/2 + \lambda(F(x) - nq) + \gamma i\} \qquad (15)$$

with $\lambda(t)$ and $\gamma(t)$ the costate variables associated with the resource and capital constraints. The routine optimal control solution is provided by (14) along with the relations:

$$\frac{\partial H}{\partial q} = [n\partial(\pi_p + \pi_f)/\partial q]e^{-\rho t} = 0 \rightarrow n(P'_p - C'_{fq} - \lambda) = 0 \qquad (16)$$

$$\frac{\partial H}{\partial i} = \gamma - c_k i = \gamma - c_k \dot{n} = 0 \qquad (17)$$

$$\dot{\lambda} = \rho\lambda - \frac{\partial H}{\partial x} = (\rho - F'(x))\lambda + nC'_{fx} \tag{18}$$

$$\dot{\gamma} = \rho\gamma - \frac{\partial H}{\partial n} = \rho\gamma - (P'_p - C_f/q - \lambda)q \tag{19}$$

$$\lim_{t\to\infty} \lambda(t)e^{-\rho t} \geq 0 \lim_{t\to\infty} \lambda(t)x(t)e^{-\rho t} = 0 \tag{20}$$

$$\lim_{t\to\infty} \gamma(t)e^{-\rho t} \geq 0 \lim_{t\to\infty} \gamma(t)n(t)e^{-\rho t} = 0. \tag{21}$$

Since $i = \dot{n} = \emptyset$ in equilibrium, this implies $\gamma^* = \emptyset$ from (17), and (16) and (19) then determine the optimum catch $q^*(x)$ where $C'_{fq} = C_f/q$ at the minimum point of the average cost curve. Equilibrium capacity is determined from (14) as $n^* = F(x)/q^*(x)$ when $\dot{x} = 0$, given that the transversality conditions (20) require the long-run solution to lie on the stable saddlepoint branch.

When $\dot{\lambda} \to 0$, (18) becomes the "modified golden rule" relation for investment in the resource (Clark and Munro, 1980) which can be rewritten as

$$F'(x) + \left.\frac{\partial(\pi_p + \pi_f)/\partial x}{\partial(\pi_p + \pi_f)/\partial q}\right|_{\dot{x}=0} = \rho. \tag{22}$$

The reward for waiting and allowing growth of the stock, expressed as the biological return from stock growth plus the real increase in fishery rents due to cost decline from increased stock abundance, must be balanced against the opportunity cost of a deferred harvest. Notice that because we assume the no depreciation, optimum equilibrium stock is independent of c_k, the slope of the supply curve for new capacity.

Long-Run Competition in Both Sectors

Competition in harvesting drives π_f to zero in the long-run, so $\dot{n} = 0$ and $q = q^*(x)$ at minimum average harvesting cost. Competition in processing will do the same for π_p, and since average equals marginal processing cost by assumption, this implies $P'_p = \overline{P}_p - A\overline{C}_p = P_f = C'_{fq}(x) = c'_1 q_0/x$, evaluated at $q =$

$q^*(x)$. Stock decline must continue to the point where minimum average harvesting plus processing cost equals the processed price. As is well known, this competitive common property equilibrium represents overexploitation of the resource.

Monopsony Processing

In this case, employing the social rate of discount, ρ, the present value of processing profits alone is

$$J = \int_0^\infty e^{-\rho t}(P_p' - P_f)nq\, dt \tag{23}$$

maximized $s.t.$ $\dot{x} = F(x) - nq$, $\dot{n} = \alpha(P_f q - C_f)$ and $q = q(P_f, x)$. The Hamiltonian for this two-state variable control problem is

$$H = e^{-\rho t}\{(P_p' - P_f)nq + \lambda(xg(x) - nq) + \alpha\gamma(P_f q - C_f(q, x))\} \tag{24}$$

with λ and γ the costate variables associated with the resource and capital constraints. Maximizing H with respect to the control variable P_f gives the condition:

$$P_p' - 2P_f + \alpha\gamma P_f/n - \lambda = 0 \tag{25}$$

This represents the optimum for a static monopsony, that $MR_Q = P_p' = MC_Q = 2P_f$, adjusted for the resource and entry constraints.[3] The time paths of the capital and resource stock shadow prices now follow the relations:

$$\frac{\partial H}{\partial n} = -\frac{\partial}{\partial t}(\gamma e^{-\rho t}) \rightarrow \dot{\gamma} = \rho\gamma - q(P_p' - P_f - \lambda) \tag{26}$$

$$\frac{\partial H}{\partial x} = -\frac{\partial}{\partial t}(\lambda e^{-\rho t}) \rightarrow \dot{\lambda} = (\rho - F'(x))\lambda + \alpha\gamma C_{fx}' - n(P_p' - P_f - \lambda)dq/dx \tag{27}$$

The transversality conditions applicable with an infinite horizon, that $lim_{t\to\infty}\lambda xe^{-\rho t} = lim_{t\to\infty}\gamma ne^{-\rho t} = 0$, again ensure that the profit-maximizing solution with nonzero stocks is on the stable saddlepoint branch. When $\dot{\gamma} = 0$, γ^* is again the discounted value of a fishing vessel to the processor, although in this case $\gamma^* > 0$. When $\dot{\lambda} = 0$, the value of an extra unit of the resource stock is the value of the extra per-vessel catch it allows and, indirectly, the effect of reduced harvesting costs on total catch through entry into the fishery. Combining (25), (26), and (27) in equilibrium ($\dot{\lambda} = \dot{\gamma} = 0$) reduces the resource stock relation (27) to the following function of x:

$$\psi(x) = F'(x) + \frac{n(x)(2\rho n(x)/x - \alpha C'_{fx})}{\alpha(P'_p - C'_{fq}) + \rho n(x)(P'_p - 2C'_{fq})/qC'_{fq}} - \rho = 0 \tag{28}$$

For comparison, the stock relation for the optimal fishery written in equivalent form is (29) below, while (30) results from an industry that is competitive in both sectors.

$$F'(x) - \frac{n(x)C'_{fx}}{P'_p - C'_{fq}} - \rho = 0 \tag{29}$$

$$P'_p - C'_{fq} = 0 \tag{30}$$

In the following section, we compare the equilibrium resource stock under monopsony with that resulting from competitive and optimal processing.

3. Monopsony and Resource Conservation

It is instructive to focus on the role of entry represented by the slope of the supply curve for new capacity, c_k indirectly determining the degree of exploitation possible on the part of the monopsony. This degree of exploitation determines the equilibrium landed price and, indirectly, the level of the stock in comparison with the competitive and optimum levels.

Case I: $c_k \rightarrow 0$ and $\alpha \rightarrow \infty$ (horizontal supply curve of new capacity)
Taking the limit of $\psi(x)$ as $\alpha \rightarrow \infty$ reduces it to $lim_{\alpha\rightarrow\infty}\,\psi = F'(x) - nC'_{fx}/(P'_p - C'_{fq}) - \rho = 0$, which can be seen to be identical to (29), implying that a monopsonist employing the social discount rate will behave optimally. Because of the disappearance of the ability to exploit the fishery when the exit of capacity is costless, the monopsonist in effect behaves as if to maximize resource rent for both fishery and processing sector. Of course, if the monopsonist discount rate exceeds the social rate of discount, then even if exit is rapid monopsony will be no guarantee of conservation.

Case II: $\alpha \rightarrow 0$ (vertical supply curve of new capacity)
At the opposite extreme when exit from the fishery is blocked (as the result of industry-specific capital equipment, for example) the landed price can be driven below the optimal level. Although profits for the competitive sector are always zero in equilibrium, the extent to which the purchase price can be driven down depends on the long-run elasticity of supply, in turn depending on the speed of entry and exit from the fishery. As $\alpha \rightarrow 0$ $\psi(x)$ reduces to

$$lim_{\alpha\rightarrow 0}\psi(x) = F'(x) - \frac{2\bar{n}C'_{fx}(q, x)}{P'_p - 2C'_{fq}(q, x)} - \rho = 0 \qquad (31)$$
$$q(x, P_f)\bar{n} = F(x)$$

which is neither the function representing the competitive (30) nor the optimal solution (29). The equilibrium solution of course now depends on the number of firms (because entry no longer reduces per-boat catch (q) to a simple function of x) but we show by simulation (below) that for $n = n^*$ (the optimum number of firms) a monopsony with fixed n will overconserve the resource.[4]

Intermediate Cases

Because the extent of monopsony overconservation depends on the exit speed, we employ a simple simulation to illustrate the sensitivity of the equilibrium stock to changes in positive and finite values of c_k (or α). The parameters employed are derived from a recent study of the Pacific halibut fishery to Cook (1983), the halibut fishery being both a relatively simple one and one with fairly reliable sources of data.

Although Pacific halibut is an international fishery, we employ parameters from Area 2, for the most part representing the Canadian sector. According to the regulatory body,[5] the average yield from 1968–1980 in Area 2 was $137*10^5$ lb. (Q). Using data for the size of the stock Cook (1983, p. 7) has estimated parameters for the Verhulst or logistic growth equation for this fishery. This widely used growth function sets $g(x) = \beta(\bar{x} - x)$, estimating the growth rate of the stock to be a linear function of the stock size. $\bar{x}$ represents the maximum equilibrium stock without fishing and was estimated at $\bar{x} = 1096.4*10^5$ lb. The β estimate over the 1968–1980 period was $\beta = 5.29*10^{-9}$.

Price and cost information was obtained by Cook from a Canadian Department of Fisheries analysis of the Canadian Pacific halibut fishery in 1978 (MacKay and McIlroy, 1979). Using these data Cook (1983) estimated average cost per pound of yield to be .33 1961 dollars in 1978, which was assumed to represent an open-access equilibrium as limited entry licensing was established in 1979. The real halibut price varied from a low of \$.14 per pound in 1938 to \$.98 in 1979 with an average of \$.39, reasonably close to the average cost estimate. We have therefore assumed the competitive equilibrium to occur at $\bar{P}_p - \bar{AC}_p = Pf^c = AC_f = MC_f =$ \$.40 1961 dollars for the simulations we report.[6]

The other model parameters were calibrated as follows: with the growth function above a yield of $Q = 137.0*10^5$ lb. implied an open-access equilibrium stock of $x^* = 344.4*10^5$ lb..[7] $C'_{fq}(q^*(x), x) = C'_1 q_0/x = P_f =$ \$.40 then determined $c'_1 q_0 =$ \$137.75. According to the Catch Summary Report of the Canadian Department of Fisheries and Oceans there were 127 boats in the regular halibut fleet in 1980, which in the absence of evidence for monopsony processing in halibut was taken to represent the competitive processing equilibrium. $Q^* = nq^*(x) = nq_0x$ then determined $q_0 = .0031325$ and $c'_1 =$ \$43,974.5. The

Table 1

Simulation of Monopsony Processing with Parameters from the Pacific Halibut Fishery

Industry Structure and Parameter		c_k α	x^*10^5 (lb)	P_f ($)	q^*10^5 (lb)	n	Q^*10^5 (lb)	$n\pi_p{}^*10^5$ ($)	$\pi_p{}^*10^5$ ($)
Competitive Processing			344.4	.400	1.08	127.0	137.0	0	0
Optimum	$\rho = .05$		696.5	.198	2.18	67.5	147.3	29.80	.441
Solution	$\rho = .10$		674.2	.204	2.11	71.3	150.6	29.46	.413
Monopsony Processing									
		10^{-7} 2^*10^8	696.5	.198	2.18	67.5	147.3	29.80	.441
		10^{-2} 2^*10^3	697.2	.198	2.18	67.4	147.2	29.80	.442
		10^0 2^*10^1	744.7	.185	2.33	59.4	138.6	29.79	.502
		10^1 2^*10^0	831.1	.165	2.60	44.8	116.6	27.32	.610
		10^2 2^*10^{-1}	874.2	.158	2.74	37.5	102.07	24.91	.664
		10^9 2^*10^{-8}	882.2	.156	2.76	36.2	100.0	24.38	.673
$\rho = .05$		$n = 67.5$ 0	793.2	.174	1.88	67.5	127.2	28.80	.426

	$\underline{c}_k$	α							
	10^{-7}	10^{8}	674.2	.204	2.11	71.3	150.6	29.46	.413
	10^{-2}	10^{3}	677.5	.203	2.12	70.8	150.2	29.43	.416
	10^{0}	10^{1}	784.8	.176	2.46	52.6	129.3	29.04	.552
	10^{1}	10^{0}	854.2	.161	2.68	40.9	109.4	26.13	.639
	10^{2}	10^{-1}	870.5	.158	2.73	38.2	104.0	25.15	.658
	10^{9}	10^{-8}	872.7	.158	2.73	37.8	103.3	25.01	.662
ρ = .10	n = 71.3	0	777.3	.177	1.84	71.3	131.2	29.23	.410

Note: $n\pi_p = (\overline{P}_p - \overline{AC}_p - P_f)nq$ represents total processor cash flow consisting of resource rent in the optimal solution (when $P'_p = P_f = \lambda$) and a combination of resource rent and monopsony profit with monopsony processing.

benchmark competitive and simulated optimum solutions are shown as the first and second lines in Table 1.[8] As expected, a competitive processing industry results in excessive boat numbers at depressed per-boat yields relative to the optimum as well as dissipation of the nearly $3 million resource rent within the fishery. The net landed price is bid above the social optimum by processors who are constrained by competition from being able to extract the rent from the fishery (see note 3). The result is an equilibrium competitive industry resource stock that is less than one-third of the unexploited stock ($\bar{x} = 1096.4*10^5$), and less than half the optimum equilibrium stock size.

Monopsony processor equilibria for different values of the speed of adjustment parameter are shown in the latter part of the table. For very low c_k and large α the monopsony equilibrium stock, landed price, and catch size approach the optimum solution, a finding that confirms our theoretical result. As the exit speed from the industry declines, however, there are conflicting forces operating on the processor cash flow. The processor is able to lower the landed price below the competitive equilibrium, extracting a combination of resource rent and monopsony profit as evidenced by rising profit per boat (π_p). This is possible in equilibrium because conservation of the stock lowers average harvesting cost. However, as the monopsony operates in an open access fishery and can control the stock and vessel numbers only indirectly through its fishermen agents, the resource rent is for the most part still dissipated; the degree of its collection by the monopsony depending on the α parameter. Higher α represents greater control over the level of n and, indirectly, over the resource stock, allowing the monopsony to collect more of the rents. Lower α means greater monopsony power through less mobility in and out of the fishery (higher c_k), increasing monopsony profits but lowering resource rents by overconserving the stock.[9] It is this case that Clark and Munro (1980) analyzed, showing that it results from the monopsony perceiving its marginal harvesting cost above social marginal cost.

Analysis of the equilibrium when $c_k \to \infty$ and $\alpha = 0$ depends on the chosen value of n. Values of n equal to the optimal n^* for $\rho = .05$ and $.1$ have been chosen for comparison. With n

Table 2
Entry and Capital Value in the Canadian Pacific Halibut Regular Fishing Fleet

Year	Boats	Average per Boat			
		Capital[b] ($1000 1971)	Length (ft)	Tonnage	Capital/Ton ($1000/1971)
1975	96	619.6	43.9	18.6	33.31
1976	128	434.0	39.5	13.0	33.38
1977	118	455.7	39.9	13.8	33.02
1978	135	531.4	43.1	17.4	30.54
1979	97	671.4	46.7	17.6	38.15
1980	127	788.9	43.6	15.1	52.25

Source: Catch Summary Report, Halibut, Department of Fisheries and Oceans, Vancouver. Data Obtained under Science Subvention Programme Grant to Dr. Parzival Copes, Institute of Fisheries Analysis, Simon Fraser University. Used with permission.

[a] Include only licensed boats whose catch in each year was 80 percent or more halibut.

[b] Average capital value for each year deflated by B. C. Non-Residential Construction Price Index 1971 = 100 from SC 11-003.

fixed at these optimal values it is clear that the landed price can be depressed below both competitive and optimal levels, again resulting in too little effort expended by fishermen and underutilization of the resource.[10]

Some idea concerning the relevant value of c_k and α in the halibut fishery can be obtained by looking at entry and exit for that fishery in recent years. Statistics for the regular halibut fleet in the Canadian sector (area 2b by the International Pacific Halibut Commission designation) are shown in Table 2. Inspection of the table reveals no clear relationship between the rate of entry into the regular halibut fleet and the cost of vessel capacity despite higher capital costs in recent periods.[11] The market for new fishing vessels is certainly thin in Canada (there are under a dozen fishing boats built each year in the whole country, according to estimates from Statistics Canada, *Shipbuilding and Repair*) but this does not represent a significant entry constraint for a particular fishery. First, in the halibut fishery at least there has recently been significant excess capacity, as evidenced by 82 licensed vessels that did not fish in 1979, for example.[12] Secondly, although longline gear is used by the regular halibut fleet, there are in addition numerous multispecies trollers operating on a part-time basis; in fact 243 part-time craft took some halibut in 1980. This suggests relatively costless entry and exit for this fishery in the absence of government regulation, and indicates, even if there were a degree of monopsony processing, that the stock would not be underutilized.

4. Conclusion and Policy Relevance

Clark and Munro (1980) showed that the presence of monopsony in the processing sector of a fishery more than offsets the effects of the common property externality in harvesting, causing the monopsony to overconserve the resource. We have qualified their result to show that the extent of overconservation depends critically on the speed of entry or exit in the harvesting sector, a rapid speed of adjustment inducing the monopsonist to behave in a less conservationist manner. The presence of monopsony processing alone, therefore, cannot be taken as an indication that regulatory attention is unnecessary from the standpoint of conservation. While it has been shown that rapid entry or exit in the fishery sector will induce a monopsonist employing the social rate of discount to behave optimally, the combination of rapid entry and a high discount rate will lead to underconservation of the resource. This point is illustrated by the history of the Pacific halibut fishery. In that fishery, limited entry licensing was imposed in 1979 largely as the result of an exogenous increase in the entry speed of the fishery. Prior to that time the fishery had been for the most part a traditional one with boats handed down through families within a well-defined ethnic and cultural group of Norwegian fishermen. This was upset in the 1970s by entry of fishermen who had been unemployed by limited entry licensing designed to preserve threatened salmon stocks. The resulting disruption of both traditional relationships with fish processors and of the self-imposed conservation measures (voluntary lay-up periods) in the halibut fishery increased harvesting to such an extent that authorities began to regulate entry in this fishery as well.

Notes

1. I am indebted to three anonymous referees for comments which much improved the paper.

2. The analysis of individual boat effort employed in this paper is similar to that found in Anderson (1976).

3. In an optimally managed processing industry, $P_f = P'_p - \lambda^*$, while of course in competition $P_f = P'_p$.

4. When n is fixed the monopsony is prevented from setting $P_f = 0$ by the reduction in per-boat effort that results from lower P_f. The short run supply curve is $Q = nP_f x^2/c'_1$.

5. The regulatory body for the fishery is the International Pacific Halibut Commission, which has conducted management jointly by Canada and the United States since 1923.

6. Values from \$.25 to \$1.00 were employed in sensitivity analysis without qualitatively affecting the results.

7. The quadratic equation $\beta x(\overline{x} - x) = Q = 137.4 * 10^5$ (with $\beta = 5.29 * 10^{-9}$) has the dual roots $x_1 = 344.4 * 10^5$ and $x_2 = 752.0 * 10^5$. The lower root must be the solution given open access to the fishery.

8. Simulations were performed in Fortran employing an International Mathematics and Statistics Software Library program to find the positive roots of the nonlinear equations (29) and (30). Where multiple roots occurred the root that maximized $n\pi_p$ was picked.

9. Unlike a conventional stock adjustment model, α is not a proportion but depends on the units for n and q etc., as it represents the effect of fishery profits on boat numbers. $\alpha = 1$, for example, implies one boat enters or exists the industry for every $\pm$ \$100,000 profit in fishing and thus implies fairly slow adjustment. Put another way, since $c_k = 1/\rho\alpha$, $\alpha = 1$ with $\rho = .10$ indicates each additional boat entering the fishery raises the marginal cost of vessel capacity by \$10,000 as $Mc_k = 10\dot{n}$ measured in \$1000.

10. It would of course profit the monopsonist to be able to control boat numbers as well as the price of fish, for in that case the landed price could be depressed even further and the monopsonist could collect all resource rent. It can be shown that the profit-maximizing price in this case derives from $P'_p - \lambda - 2Pf = 0$ (when $\gamma = 0$) with n set as large as possible. Something approximating this may occur through the mechanism of boat leasing, where fishermen do not own their boats.

11. The inflation of capital values may have resulted from the imposition of limited-entry licensing in 1979.

12. These and subsequent data were obtained from the *Catch Summary Report*, Fisheries and Oceans, Vancouver.

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