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On the Resumption of Commercial Whaling: The Case of the Minke Whale in the Northeast Atlantic

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ABSTRACT. The International Whaling Commission (IWC) met in Reykjavik, Iceland, in May 1991 to determine whether the five-year moratorium on commercial whaling, implemented in 1986, was to expire or be extended. Japan, Iceland and Norway sought to resume commercial whaling on stocks of fin and minke whales, which they regard as capable of supporting commercial harvest without risk of extinction. The IWC voted to extend the moratorium at least one more year. Iceland has subsequently withdrawn from the IWC, and Norway and Japan are also considering withdrawal. A bioeconomic model is constructed that might be used to manage the industry if commercial whaling is resumed. It is applied to the stock of minke whales in the Northeast Atlantic. The optimal stock and level of harvest depends on eight bioeconomic parameters. For a fleet with average productivity, the stock ranged from 81 052 adult whales, supporting a harvest of 137 animals, to 57 770 adult whales, supporting a harvest of 1675. The price/cost ratio will be important in determining the optimal stock and the long-run viability of whaling.

Key words: economics, commercial whaling, minke whale

RÉSUMÉ. La Commission baleinière internationale (CBI) s'est réunie à Reykjavik, en Islande, en mai 1991, pour déterminer si le moratoire de cinq ans sur la chasse commerciale à la baleine devait expirer ou être prolongé. Le Japon, l'Islande et la Norvège demandaient la reprise de la chasse commerciale des stocks de rorqual commun et de petit rorqual, qui, d'après ces pays, sont capables de supporter une prise commerciale sans risque d'extinction. La CBI a voté pour la prolongation du moratoire pendant au moins un an. L'Islande s'est par la suite retirée de la CBI, et le Japon et la Norvège envisagent de faire la même chose. On construit un modèle bio-économique qui pourrait être utilisé afin de gérer l'industrie si la chasse commerciale reprend. On l'applique au stock du petit rorqual de l'Atlantique du Nord-Est. Le stock optimal et le niveau des prises dépendent de huit paramètres bio-économiques. Pour une flotte de productivité moyenne, le stock va de 81 052 baleines adultes supportant une prise de 137 animaux, à 57 770 baleines adultes supportant une prise de 1675 animaux. Le rapport prix/coût sera un facteur important qui déterminera le stock optimal et la viabilité à long terme de la chasse à la baleine.

Mots clés: économie, chasse commerciale à la baleine, petit rorqual

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INTRODUCTION

In 1986 the International Whaling Commission (IWC) declared a five-year moratorium on commercial whaling. The moratorium had been adopted for at least three reasons. First, there was scientific evidence that many of the stocks of baleen whales were dangerously depleted and making only slow recovery from the intensive whaling that had taken place between the two world wars and in the thirty-year period following World War II. In a special section of the *Marine Fisheries Review*, scientists at the U.S. National Marine Mammal Laboratory (1984) listed eight "great" whales as being endangered: the blue, fin, right, bowhead, sei, sperm, humpback and gray whales.

Second, there was a conspicuous lack of information on the status of many stocks. Each of the endangered species had two or more "unit stocks," thought to be sufficiently independent of other stocks that they could be managed independently. Of the 34 unit stocks listed by the U.S. National Marine Mammal Laboratory in 1984, there was insufficient information on 13 stocks to estimate pristine (original) or current population numbers.

Third, and perhaps most important, the whale had become a powerful symbol within the environmental movement. For many the depleted stocks of baleen whales, in particular the blue whale, typified the "tragic" result of man's exploitation of the environment and common property resources (see McVay, 1966; Small, 1971).

During the moratorium several countries, including Iceland, Japan and Norway, continued to harvest a limited number of whales for research purposes. Japan's "scientific whaling" was the most controversial. In 1987 Japan submitted a proposal to kill 900 whales for research purposes. The IWC rejected the proposal and Japan countered with a reduced scientific harvest of 300 whales. This too was rejected by the IWC. The Japanese filed a formal objection and proceeded to harvest over 300 whales in 1987. After determining the sex, length, weight, approximate age and pregnancy status of females, the whales were butchered and the meat was sold for human consumption through fish markets in Japan.

While many questioned the motive, number and even the need to kill whales for research purposes, it was agreed that when the IWC met in 1991 new stock assessments would be presented. Information on pregnancy rates, natural mortality and other "life history parameters" would be needed to construct models of population dynamics that could be used to simulate the effect of alternative harvest rates. If commercial whaling were resumed, it would be from stocks that were abundant and at rates that would pose little or no risk of extinction. Prime candidates for harvest were the minke whale in the Atlantic, Pacific and Southern oceans (around Antarctica), the sperm whale and the fin whale off the coast of Iceland.

Scientists from Japan, Iceland and Norway arrived in Reykjavik in May 1991 with statistical studies and computer simulations to back their claims that commercial whaling could be resumed without risking extinction (Kasamatsu *et al.*, 1991; Institute of Cetacean Research, 1991; Øien, 1991). The IWC was more cautious and voted to extend the moratorium for at least another year. Former whalers in Norway threatened to

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resume coastal whaling immediately, and in December 1991 Iceland announced its intention to withdraw from the IWC.

This paper examines the economic motivations of the countries that wish to resume commercial whaling and estimates the net revenue for the Norwegian small whale fishery, based on harvests from the stock of minke whales in the Northeast Atlantic. We identify the sustainable levels for stock, harvest and fleet size if one sought to maximize the present value of net revenues. Sensitivity analysis reveals when whaling is optimal and when it is *not* optimal on purely economic grounds.

There is, of course, a more fundamental question. Should commercial whaling be resumed at all? This question has been answered differently by different countries and by the *same* country at different times. It is unlikely that the U.S. will ever resume commercial whaling, even if certain stocks, such as the gray whale, have recovered to near pristine population levels. But it would seem likely that Norway, Iceland or Japan will resume commercial whaling within the year. What will be the response of a nonwhaling country, like the U.S., to a country that resumes whaling? Are trade sanctions likely to be employed and are they appropriate?

MANAGEMENT OF COMMERCIAL WHALING: THE MINKE WHALE

The minke whale (*Balaenoptera acutorostrata*) is the smallest of the rorquals, a group that includes the blue, fin and sei whales. Being the smallest, it was the last to be intensively harvested by whalers working the Southern Ocean in the mid-20th century (Clark and Lamberson, 1982). The population in the Northern Hemisphere is generally thought to be separate from the population in the Southern Hemisphere. The delineation of separate stocks in the North Atlantic is subject to debate, but the IWC recognizes four stocks defined by area as 1) the Canadian east coast stock, 2) the West Greenland stock, 3) the Central North Atlantic stock and 4) the Northeast Atlantic stock (Walløe *et al.*, 1987:7). This latter stock winters in the North Atlantic and then migrates along the coast of Norway into the Barents Sea in the spring and summer.

The minke whale was never listed as an endangered species, and in the Southern Hemisphere the population is thought to be in excess of 600 000 individuals (Woods Hole Oceanographic Institution, 1989). Most of the whales harvested by Japan for scientific purposes were minke whales from the Southern Hemisphere. Norway has harvested minke whales from the Northeast Atlantic stock since the 1930s, and between 1938 and 1986 over 100 000 animals were harvested. To examine the impact of these harvests and to estimate the current population size, we adopt a model used to describe the dynamics of baleen whales and then calibrate it for the stock of minke whales in the Northeast Atlantic.

Estimates of the Minke Whale Stock in the Northeast Atlantic

The dynamics of a single baleen whale population are often modeled using a delay-difference equation (Clark, 1976). It is well known that many species of baleen whale are competitors for the same food sources. Thus, the minke whale might compete with the blue or fin whale for capelin, herring or cod. A complete multispecies model would involve a *system* of simultaneous delay-difference equations, with interaction terms between the various species. Such a model is presently beyond our ability to empirically estimate and, from an economic perspective, to optimize. We therefore restrict ourselves to the dynamics of a single species, modeled by a delay-difference equation taking the general form

$$X_{t+1} = (1 - M)X_t + F(X_{t-\tau}) \quad (1)$$

where X_t is the stock of adult (sexually mature) whales in year t, M is the annual rate of mortality in adults, and $F(X_{t-\tau})$ is a recruitment function defining the recruits to the adult population in year t+1 as a function of the adult population in year $t-\tau$. The recruitment function is assumed to incorporate certain environmental constraints, including the overall availability of food and its effect on the relative rate of population growth.

If the adult population is unchanging over some interval of time, then natural mortality is precisely offset by recruitment and $MX_0 = F(X_0)$. The equilibrium or fixed point, X_0, will be stable if $|F'(X_0)| < M$, where $F'(\bullet)$ is the first derivative of $F(\bullet)$. This equilibrium is sometimes referred to as the pristine population, thought to exist prior to the start of commercial exploitation.

With a commercial harvest of $Y_t < X_t$ adult whales per year, it is useful to define escapement as $Z_t = X_t - Y_t > 0$. Equation (1) is then modified to become

$$X_{t+1} = (1-M)Z_t + F(Z_{t-\tau}) \quad (2)$$

Thus, the adult stock in year t+1 is determined by the unharvested adults that survive from year t, plus recruitment, which is a function of escapement in year $t-\tau$.

The generalized logistic function is often used in modeling whale populations. In this case the recruitment function becomes

$$F(X_{t-\tau}) = rX_{t-\tau}[1-(X_{t-\tau}/K)^{\alpha}] \quad (3)$$

where r is the intrinsic growth rate and K is a positive parameter, which along with r, M and α, defines the pristine population. The value of α will affect the symmetry of $F(X_{t-\tau})$. If $\alpha > 1$, the generalized logistic is skewed to the left and the maximum recruitment level lies above 0.5K. The IWC believes maximum recruitment occurs at about 0.6K, which is the case when $\alpha = 2.39$. For the generalized logistic the pristine population is given by $X_0 = K[(r-M)/r]^{1/\alpha}$.

In addition to α, the parameters M, r, K and τ must be estimated if one wishes to simulate population dynamics using the generalized logistic. Unfortunately, biological estimates for all of these parameters are not available. We will make use of the best estimates for M and τ and then simulate the minke whale population for alternative values of r and K to see which values yield a simulated value for the population in 1990 that is consistent with population estimates from other methods.

Walløe *et al.* (1987) use an annual mortality rate of 0.10 in their study of the minke whale in the Northeast Atlantic. The age at sexual maturity appears to vary by sex, with females reaching maturity at about 7 years and males at about 6 years of age (Christensen, 1981). We set $M = 0.10$ and $\tau = 7$.

The Norwegian government has recorded data on the number of minke whales harvested from 1938 to 1989. These data are shown in Figure 1 and come from Øien *et al.* (1987) and Statistisk Sentralbyrå (1989). (The actual numerical data are available from the first author upon request.) With $\alpha = 2.39$, $M = 0.10$, and $\tau = 7$, we ran numerous simulations for various combinations of r and K. In each simulation it was assumed

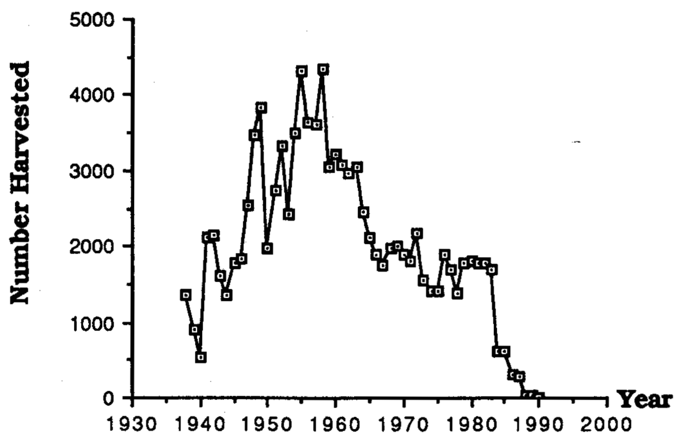

FIG. 1. Harvest of minke whales from the Northeast Atlantic stock.

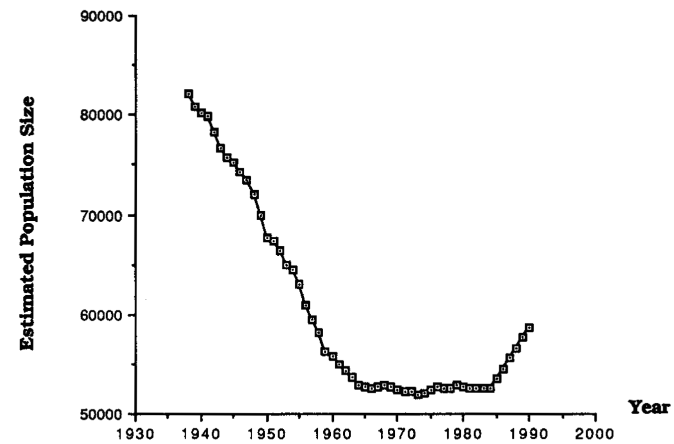

FIG. 2. Estimated population of minke whales in the Northeast Atlantic stock.

that the stock was in pristine equilibrium at X_0 for the years before and including 1938. The number of whales harvested was deducted from each successive value of X_t in order to calculate the level for escapement as needed in equation (2) to obtain X_{t+1}.

The results when $r = 0.15$ and $K = 130\ 000$ are plotted in Figure 2. The parameter values imply a pristine population level of $X_0 = 82\ 093$ adult whales and a 1990 population of 58 742 mature animals. The simulated population of minke whales declines from the pristine population to a low of slightly less than 52 000 whales in 1973, after which it slowly climbs to 58 742 adults in 1990.

Øien (1991), using the "line transect" methodology, estimates a total population of 34 600 minke whales in the Northeast Atlantic in 1989. His analysis presumes that all whales along a line are in fact sighted. It is well known that visibility, rough seas and submerged whales result in a downward bias to the number of whales actually observed along a transect line. Schweder *et al.* (1991) provide a 95% confidence estimate of 0.36-0.49 for the fraction of whales actually observed. When this interval is applied to Øien's estimate, one obtains an interval estimate of 70 612 to 96 111 animals in the Northeast Atlantic population. Our 1990 estimate of 58 742 adult minke whales thus seems conservative when Øien's estimate is adjusted for observation bias.

A Bioeconomic Model of the Minke Whale in the Northeast Atlantic

To examine the value to Norway of a resumption of its small whale fishery based on the minke whale, we next develop a "bioeconomic" model with the objective being the maximization of discounted net revenue. This model assumes that either the IWC or the Norwegian government will regulate total harvest through limited entry and a system of individual transferable quotas (ITQs). The maximization of the present value of net revenue will imply values for the stock of minke whales, annual harvest and vessel numbers that maximize the net economic value of the resource. This objective might be criticized as being overly narrow. It does not consider the "existence value" of whales or the value of employment in the whaling industry. While these values are likely to be important, they are also very difficult to quantify. By solving the present value problem first, we can examine the solution and see if it needs to be adjusted to account for existence or employment values.

The model to be constructed is similar to those described by Clark (1990). It assumes that the price per harvested whale is constant, denoted by p, and that the cost of harvesting Y_t whales from a population of size X_t is given by the cost function $C(Y_t,X_t)$. Net revenue in year t may be written as

$$\pi(Y_t,X_t) = pY_t - C(Y_t,X_t) \tag{4}$$

Maximization of the present value of net revenue subject to the dynamics of the whale population may be stated as

$$\text{Maximize} \sum_{t=0}^{\infty} \varrho^t \pi(Y_t,X_t)$$

$$\text{Subject to}\quad X_{t+1} = (1 - M)Z_t + F(Z_{t-\tau})$$
$$Z_t = X_t - Y_t$$

where $\varrho = 1/(1 + \delta)$ is a discount factor and δ is the rate of discount.

Conrad (1989) derives the first-order necessary conditions for this problem. When they are evaluated in steady state, optimal escapement will be defined by the equation

$$\left[\frac{\pi_X + \pi_Y}{\pi_Y}\right][1 - M + \varrho^\tau F'(Z)] = 1 + \delta \tag{5}$$

where π_X and π_Y are the partial derivatives of $\pi(Y,X)$ and $F'(Z)$ is the first derivative of the recruitment function.

Suppose the production function relating harvest to stock size and effort takes the exponential form $Y = X(1 - e^{-qE})$, where E is the level of effort and the parameter $q>0$ might be referred to as the "catchability coefficient." If the unit cost of effort is constant, denoted by c, then the cost equation is $C = cE$. Solving the production function for E as a function of Y and X and substituting into the cost equation yields the cost function, $C = (c/q)\ln[X/(X - Y)]$, where $\ln[\bullet]$ denotes the natural log operator. Substituting the cost function into the expression for net revenue results in the partial derivatives $\pi_x = cY/[qX(X - Y)]$ and $\pi_y = [pq(X - Y) - c]/[q(X - Y)]$. When these partial derivatives are substituted into equation (5), and noting $Z = X - Y$, it is possible to derive an expression defining X as a function of Z. (A detailed derivation is available from the first author.) This takes the form

$$X = \frac{Z[1-M+p^{\tau}r(1-(\alpha+1)(Z/K)^{\alpha})]}{(p/c)qZ[\varrho^{\tau}r(1-(\alpha+1)(Z/K)^{\alpha}) - (\delta+M)]+(1+\delta)} \quad (6)$$

Evaluating the delay-difference equation in steady state, it is possible to obtain an expression defining Y as a function of Z. This is less tedious algebraically and takes the form

$$Y = [r - M - r(Z/K)^{\alpha}]Z \quad (7)$$

By substituting the last two expressions into the definition of escapement, we can obtain a single expression in Z. Unfortunately, it is not possible to obtain an explicit expression for optimal escapement, but we can write the implicit form as

$$G(Z) = \theta(Z)\{(p/c)qZ[\phi(Z) - (\delta + M)] + (1+\delta)\} - [1 - M + \phi(Z)] \quad (8)$$

where $\phi(Z)=\varrho^{\tau}r(1-(\alpha+1)(Z/K)^{\alpha})$ and $\theta(Z)=1+r-M-r(Z/K)^{\alpha}$. Optimal escapement is a root or zero of G(Z). If a root exists, the optimal values of X and Y can be obtained from equations (6) and (7).

The optimal level of escapement depends on the five biological parameters α, M, r, K and τ and on three economic parameters, q, (p/c) and δ. With our simulated values for the minke whale stock, we are in a position to directly estimate a production function. While this stock was harvested commercially until 1988, the fleet of Norwegian vessels came under quota restrictions as early as 1973 (Walløe *et al.*, 1987). We opted for a sample period of 1952–72 and estimated the exponential production function $Y = X(1 - e^{-qE})$ by regressing ln[(X – Y)/X] on effort, E, measured as the number of vessels. This time series is plotted in Figure 3. The data on vessel numbers comes from Statistisk Sentralbyrå (1978, 1989). One would anticipate a negative coefficient on effort and an insignificant constant.

The results are shown in Table 1, which reports the ordinary least squares (OLS) regressions with and without correction for first-order autocorrelation. The estimate for q is 2.7045E–4 without correction and 2.4465E–4 with correction, and both are significant at the 1% level. The constant is not significant at the 5% level in either regression and is dropped from the equation. In the numerical analysis that follows the catchability coefficient will be set at 2.0E–4, 2.5E–4 and 3.0E–4 in order to examine the sensitivity of stock, harvest and vessel numbers to changes in q.

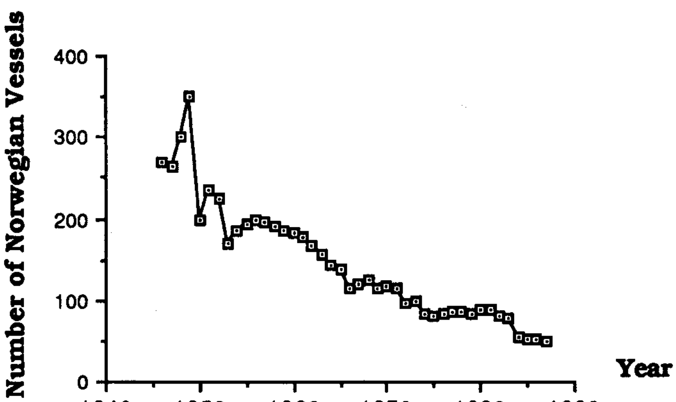

FIG. 3. The number of Norwegian vessels harvesting minke whales.

TABLE 1. Estimation of the catchability coefficient for the exponential production function $Y = X(1 - e^{-qE})$ for the period 1952-72, where Y is harvest, X is the estimated stock and E is the number of vessels

A. No correction for autocorrelation			
Variable	Coefficient	Standard error	t-ratio
E	−2.7045E−4	0.49360E−4	−5.4790
constant	−7.6683E−3	7.99220E−3	−0.9595
R-square = 0.6124	R-square adjusted = 0.5920		F = 30.02
Durbin-Watson = 1.1562			

B. Correction for first-order autocorrelation			
Variable	Coefficient	Standard error	t-ratio
E	−2.4465E−4	0.61141E−4	−4.0014
constant	−1.1557E−2	9.96360E−3	−1.1599
rho	0.33145	0.20588	1.6099
R-square = 0.6559	R-square adjusted = 0.6378		
Durbin-Watson = 1.6454			

The relative price-cost ratio (p/c) was calculated for the years 1980-87. Table 2 contains data on the total number of whales taken by vessels in the small-whale fleet and the total revenue (in nominal Norwegian kroner) obtained from meat and blubber. Dividing total revenue by the number of whales, we obtain a price per whale. Table 2 also contains estimates of the operating cost of a small-whale vessel for an entire season of approximately 36 weeks. During each season vessels would typically participate in other fisheries. It was estimated that during this period approximately 35-41% of operating time was spent whaling. The p/c ratios in the right-most column of Table 2 are calculated by dividing price per whale by cost per vessel. If it were appropriate to prorate costs to different fisheries by their percentage of time during a full season, then the (p/c) ratios might increase by a factor of 1/(0.38) = 2.63. We set (p/c) at 0.05, 0.07 and 0.09, which, as it turns out, covers a critical range of operating behavior and resource management.

The final economic parameter needed to calculate optimal escapement is δ, the discount rate. In our sensitivity analysis, we set δ at 0.02, 0.04 and 0.06. A simple interactive algorithm was developed to find the zero of G(Z) in equation (8), which proved to be unique and stable. The results are displayed in Table 3.

There are three blocks to Table 3 corresponding to the base-case q = 2.5E–4, then a less productive fleet (q = 2.0E–4) and a more productive fleet (q = 3.0E–4). Within each block the price-cost ratio is varied vertically and the discount rate horizontally. For the base-case q and the median values of (p/c) and δ, the optimal stock is 68 142 adult whales supporting a harvest of 1297 adults taken by 77 catcher boats. Within the base-case q block, the optimal stock ranges from a high level of 81 052 whales (at [p/c] = 0.05 and δ = 0.02) to a low of 57 770 whales (at [p/c] = 0.09 and δ = 0.06). The high stock was associated with a harvest of 137 whales taken by 7 catcher boats, while the low stock was associated with a harvest 1675 whales taken by 118 vessels.

When the catchability coefficient is reduced to q = 2.0E–4, we observe that whaling becomes unprofitable at the low price-cost ratio. In the long run the stock returns to X_0 = 82 093 whales. In general, the reduction in q causes an increase in the optimal stock and a decrease in harvest and fleet size, *ceteris paribus*.

The case where whaling becomes unprofitable due to a low price-cost ratio may be of relevance if commercial whaling is

TABLE 2. The price-cost ratio (p/c) for the period 1980-87

Year	Number of whales[1]	Value of all products[2]	Price per whale (p)[3]	Cost per vessel (c)[4]	p/c
1980	2 054	39 660 000	19 308	756 805	0.0255
1981	1 890	35 719 000	18 899	945 557	0.0200
1982	1 963	39 837 000	20 293	952 142	0.0213
1983	1 869	45 617 000	24 407	940 714	0.0259
1984	804	32 681 000	40 648	802 423	0.0510
1985	771	34 626 000	44 910	1 007 118	0.0450
1986	383	20 489 000	53 496	846 068	0.0632
1987	375	21 294 000	56 784	944 670	0.0601

[1] The number of whales listed in this table includes the harvest of minke whales from the Northeast and Central Atlantic stock. Source: Statistisk Sentralbyrå, 1989.
[2] The primary products from the minke whale are meat and blubber, which are consumed by Norwegians or exported to Japan for human consumption. Less than 1% by weight is processed into animal feed. This value is given in nominal Norwegian kroner. Source: Statistisk Sentralbyrå, 1989.
[3] The price per whale, p, is calculated by dividing the value of whale products by the number of whales harvested.
[4] During the period 1980-87 vessels in the Norwegian coastal fleet operated approximately 36 weeks per year. The cost estimates listed here are operating costs for the entire 36-week season. During such a season a vessel would typically spend 35-41% of its time whaling. The rest of the time was spent harvesting cod, haddock, herring and other species. The distribution of costs among these fishing activities is problematic. If it were appropriate to calculate whaling cost as season cost times the proportion of time spent whaling, it would more than double the p/c ratios listed in the right-most column. Source: Budsjettnemda for Fiskenæringen, 1981-88.

resumed. In 1981, when a total of 1890 whales were harvested from Northeast and Central stocks (see Table 2), the adjusted price-cost ratio would have been (2.63)·(0.02) = 0.0526. At this ratio whaling would have been unprofitable for vessels with q = 2.0E-4.

It is not possible to estimate q for later years, since the catchers were constrained by quota. It is believed that as newer catchers replaced older vessels, q increased. The five-year moratorium, however, may have had the effect of reducing the efficiency of both catchers that have been idle or regeared for other fisheries and their crews.

It is also not known what the price elasticity for whale meat will be in the primary fish markets of Japan. If Japan resumes whaling from the stock of minke whales that migrates through their coastal waters or from the vast stock in the Southern Hemisphere, and if markets are slow to expand and demand is inelastic, the resumption of commercial whaling may be short lived for purely economic reasons.

The final block in Table 3 corresponds to the high-productivity case. Here the optimal stock may fall as low as 51 538 whales, slightly below the minimum of our simulation in Figure 2. This stock would be optimal under a high price-cost ratio and a high discount rate. In this case 1736 whales are harvested by 114 vessels. At the other extreme, a (p/c) = 0.05 and δ = 0.02, the optimal stock is 74 353, supporting a harvest of 853 whales by 38 vessels.

These results seem plausible in light of the historical landings shown in Figure 1. Annual harvests that exceeded 2000 whales during the 1950s and 1960s caused the stock to decline to about 52 000 whales by the mid-1960s. Harvests around 1500 during the 1970s appear, in our simulation, to have been sustainable.

It would also appear that the range of solutions to the present value maximization problem might also satisfy the objectives of stock maintenance and employment, discussed earlier. Under none of the parameter combinations in Table 3 does the adult stock decline below 50 000 adults. Fleets of 70-80 vessels would

TABLE 3. The optimal stock, X, harvest, Y, and effort, E, in the Norwegian minke whale fishery for the bioeconomic model with $\alpha = 2.39$, r = 0.15, K = 130 000, M = 0.10, $\tau = 7$ and alternative values of q, δ and p/c

	With q = 2.5E-4		
	δ = 0.02	δ = 0.04	δ = 0.06
p/c = 0.05	X = 81 052 Y = 137 E = 7	X = 80 995 Y = 145 E = 7	X = 80 941 Y = 151 E = 8
p/c = 0.07	X = 69 472 Y = 1 217 E = 71	X = 68 142 Y = 1 297 E = 77	X = 67 041 Y = 1 356 E = 82
p/c = 0.09	X = 62 735 Y = 1 543 E = 100	X = 59 977 Y = 1 627 E = 110	X = 57 770 Y = 1 675 E = 118
	With q = 2.0E-4		
	δ = 0.02	δ = 0.04	δ = 0.06
p/c = 0.05	X = 82 093 Y = 0 E = 0	X = 82 093 Y = 0 E = 0	X = 82 093 Y = 0 E = 0
p/c = 0.07	X = 76 760 Y = 627 E = 41	X = 76 376 Y = 666 E = 44	X = 76 043 Y = 698 E = 46
p/c = 0.09	X = 68 648 Y = 1 268 E = 93	X = 67 175 Y = 1 350 E = 101	X = 65 960 Y = 1 410 E = 108
	With q = 3.0E-4		
	δ = 0.02	δ = 0.04	δ = 0.06
p/c = 0.05	X = 74 353 Y = 853 E = 38	X = 73 713 Y = 908 E = 41	X = 73 172 Y = 952 E = 44
p/c = 0.07	X = 64 453 Y = 1 478 E = 77	X = 62 120 Y = 1 565 E = 85	X = 60 236 Y = 1 621 E = 91
p/c = 0.09	X = 58 614 Y = 1 659 E = 96	X = 54 637 Y = 1 719 E = 107	X = 51 538 Y = 1 736 E = 114

be consistent with stocks of 67 000 to 70 000 adult animals and a per vessel harvest of 16-17 whales.

The price-cost ratio has a significant effect on the value of the Norwegian small-whale fishery. With a price of 50 000 NK per whale and a seasonal operating cost of 714 286 NK, the value of the price-cost ratio is 0.07. With q = 2.5E-4 and δ = 0.04, the optimal stock is X = 68 142 whales with a harvest of Y = 1297. (This solution is in the second row, second column, of the first block of Table 3.) The annual net revenue is $\pi = pY - (c/q)\ln[X/(X - Y)]$ = 9 943 530 NK. The present value (or asset value) of the fishery would be $\pi(1 + \delta)/\delta$ = 258 531 788. At an exchange rate of 6.5 NK = 1 USD, these values translate to an annual net revenue of $1 529 751 and a present value of $39 774 121.

If the market value of an average whale falls to p = 35 714 NK, and if seasonal operating cost is unchanged, then p/c = 0.05. If the other parameters are unchanged, the optimal adult stock and harvest are 80 995 and 145 respectively. (This corresponds to the optimal solution shown in the first row, second column, of the first block of Table 3.) The annual net revenue drops to 58 989 NK, or a present value of 1 533 735 NK. This translates to an annual net revenue of only $9075, or a present value of $235 959.

At the other extreme, if the price per whale increases to 64 285 NK, and seasonal cost remains at 714 286 NK, then the price-cost ratio equals 0.09. For unchanged values of q and δ the optimal adult stock is 59 977, with a harvest of 1627 whales (first block, third row, second column of Table 3). The annual net revenue increases to 26 015 101 NK for a present value of 676 392 643 NK. These translate to $4 002 323 and $104 060 406 respectively.

From the above analysis it would appear, even under the narrow objective of present value maximization, that the stock of minke whales in the Northeast Atlantic will not be threatened with extinction. At the highest values for q, p/c, and δ the optimal stock is 51 538 adults, which is 62.7% of the pristine adult population of 82 093. The value of the fishery will critically depend on the price-cost ratio. For a p/c of 0.05 or less there may be little or no profit in whaling, and with zero harvest the stock will equilibrate at the pristine population level.

WHALING AND ENVIRONMENTAL DIPLOMACY

If the sperm whale and certain stocks of baleen whale have recovered to near pristine levels, and if the IWC or a nation state is capable of managing a whale population so as to avoid open access dynamics and the risk of extinction, then many biologists would conclude there is no scientific basis to prevent the resumption of commercial whaling. A permanent moratorium on commercial whaling must be based on animal welfare or animal rights arguments. There is an important philosophical difference between a human concerned with animal welfare and a human advocating animal rights. From an economic point of view, the utility *of the human* concerned with animal welfare is influenced by the condition and treatment of other animal species. This philosophical perspective might be akin to an "interspecific altruism or paternalism." Depending on the degree or form of altruism, there may be circumstances where a human concerned with animal welfare might condone the killing and use of another animal species.

This would not be permissible to a human advocating animal rights. To such a human, all animals are entitled to the same rights as exercised by the species *homo sapiens*. There need not be any altruism or species paternalism on the part of humans, because all animals are entitled to exercise their "natural" behavior without the threat of "unnatural" death from man.

If a sufficient number of humans are concerned with animal welfare or advocate animal rights, then a society might collectively choose to ban the killing of some or all animals. The extent to which a concern for animal welfare or a belief in animal rights exists within a society will vary from culture to culture at a point in time and may change within a culture through time. The U.S. passed the Marine Mammals Protection Act (MMPA) in 1972. Only 80 years earlier U.S. whalers working out of San Francisco were trying to harvest the remaining members of the stock of bowhead whales in the western Arctic to provide baleen for the manufacture of corsets (see Bockstoce, 1986). It was clear that the stock of bowheads had been depleted, but there was no outcry for conservation or animal welfare.

A majority of citizens in the U.S. no longer see the need to commercially harvest whales or other marine mammals and have made commercial harvest within U.S. territorial waters illegal. The majority of citizens in Norway, Iceland and Japan apparently do not perceive commercial whaling as undesirable or immoral. They view it as a way of earning income, obtaining a valuable source of protein or, in the case of Japan, constituting an important part of the cultural and religious fabric of those few communities where coastal whaling is still practiced (see Glass and Englund, 1989).

How will citizens of a nonwhaling country, such as the U.S., view the decision of Japan, Iceland or Norway to resume commercial whaling? What has been the response of the U.S. government in the past, and what actions are likely if commercial whaling is resumed?

There are two U.S. federal statutes that have been employed as an economic threat to whaling countries (McDorman, 1991). The first is the 1971 Pelly Amendment, which was initially proposed out of a concern over the diminished stocks of Atlantic salmon. In 1969 the International Commission for the Northwest Atlantic Fisheries (ICNAF) placed a ban on salmon fishing on the high seas, which were generally beyond a 12 nautical mile limit that then defined territorial waters. Denmark, Norway and West Germany objected to the proposed ban. Under ICNAF procedures, objecting countries were not legally bound by the ban. Congressman Thomas M. Pelly felt that the U.S. needed to add teeth to ICNAF's conservation efforts and proposed amendments to the 1967 Fisherman's Protection Act that would prohibit the import of fish from countries in alleged violation of ICNAF quotas. The scope of the Pelly Amendment was expanded during Congressional debate to include all species of fish and by later amendments to include endangered and threatened species under management by an international commission.

Under the Pelly Amendment, if the secretary of commerce determines that nationals of a foreign country are conducting fishing operations that threaten an internationally managed and endangered species, the secretary is to "certify such fact to the President." Upon receiving a letter of certification, the president has the discretion of directing the secretary of the treasury to prohibit the import of fish or wildlife from the offending country. Within 60 days of receiving certification the president must report to Congress on the action taken or the reasons for inaction.

The second U.S. statute is 1979 Packwood–Magnuson Amendment to the 1976 Fisheries Conservation and Management Act (FCMA). Under this amendment the secretary of commerce is to determine when nationals of a foreign country are directly or indirectly conducting operations that diminish the effectiveness of the IWC. In addition to certification of the president, the Packwood–Magnuson Amendment requires the secretary of state to reduce, by not less than 50%, any foreign fishing allocation that the certified country might hold in U.S. territorial waters, which were extended outward to 200 nautical miles under the FCMA. If the conditions giving rise to certification exist one year later, then any remaining foreign fishing allocation is to be rescinded, with no future allocation allowed until "decertification."

In 1973 the IWC set a quota on the harvest of minke whales in the Southern Hemisphere. Japan and the Soviet Union formally objected to the quota. Under provisions of the convention creating the IWC, member countries lodging a formal objection to an IWC regulation are not legally bound by such regulations. Japan and the Soviet Union allegedly harvested more than the total quota, and even though they were not technically in violation of IWC rules, the secretary of commerce certified both countries under the Pelly Amendment. Then-President Gerald Ford declined to take action, reporting to Congress that Japan and the Soviet Union had agreed to abide by future IWC quotas.

In 1978 the Pelly Amendment was employed in response to the whaling practices of Chile, Peru and the Republic of Korea. At the time, none of these countries was a member of the IWC and was therefore not in violation of IWC quota or other international laws. Then-President Jimmy Carter received certification claiming that the harvest of whales by these three countries was diminishing the effectiveness of the IWC. President Carter declined to impose sanctions on the grounds that all three countries were in the process of joining the IWC. Many in Congress felt that the inaction by Presidents Ford and Carter after certification under the Pelly Amendment was an indication that too much discretion had been given to the president. The Packwood–Magnuson Amendment was an attempt to reduce this discretion through the automatic reduction, if applicable, in foreign fishing allocations.

In 1986 the U.S. Supreme Court agreed to review lower court decisions in the case *Japan Whaling Association v. American Cetacean Society*. At issue was the discretion of the secretary of commerce to certify a country harvesting in excess of an IWC quota. The American Cetacean Society maintained that the secretary was *required* under Packwood–Magnuson to certify any country in violation of an IWC quota. The case arose when in 1982 the IWC established a zero quota for sperm whales for the 1983-84 season and a complete moratorium on commercial whaling in 1986. Japan, consistent with its right under the IWC, filed objections to these measures. The U.S. negotiated an agreement with Japan whereby they would restrict their harvest of sperm whales and abide by the IWC moratorium by 1988. Despite this agreement the American Cetacean Society sought a *writ of mandamus* to compel the secretary of commerce to certify Japan. Both the Federal District Court of Columbia and the U.S. Court of Appeals granted the writ. The U.S. Supreme Court overturned these decisions, concluding that neither the language nor the legislative history of the Packwood–Magnuson Amendment obliged the secretary of commerce to certify a foreign country in violation of an IWC quota.

In 1985 the Soviet Union was certified for harvesting minke whales, even though it had formally objected to the IWC moratorium. They lost 50% of their fishery allocations in U.S. waters. The Soviets continued their harvest of minke whales and lost the remainder of their fishery allocation in the following year. In late 1987 the Soviet Union announced an end to all commercial whaling and it was decertified in early 1988.

Norway had also objected to the IWC moratorium and continued whaling without being in contravention of the IWC. Norway was certified in mid-1987 under the Pelly Amendment. Then-President Reagan declined to impose any trade sanctions, since Norway had also announced its intent to cease commercial whaling.

In the late 1980s several countries were harvesting whales for "research" purposes. A scientific committee within the IWC had the authority to approve or disapprove research programs involving the harvest of whales. Research programs proposed by the Republic of Korea, Iceland, Japan and Norway all came under scrutiny by U.S. officials and environmental groups as well. After consultation with the U.S., the Republic of Korea decided to terminate its research program. In 1988 Norway proposed a harvest of 35 minke whales from the stock in the Northeast Atlantic. The IWC rejected the proposal, but Norway went ahead with its scientific harvest. In subsequent meetings, Norway was able to convince U.S. officials that their research program was *bona fide* and they were able to avoid certification.

Iceland was also threatened with certification and subsequently modified its scientific program to placate U.S. interests. The controversial program of scientific whaling by Japan is discussed in the first section of this paper. In the case of Japan, no action was taken under the Pelly Amendment. Japan was no longer fishing in U.S. waters and U.S. trade sanctions were not imposed because Japan imports more fish from the U.S. than it exports to the U.S. Japan thus had a credible threat of trade retaliation.

The use of the Pelly and Packwood–Magnuson amendments has given IWC regulations an economic clout, particularly for Iceland and Norway. While neither country is fishing in the U.S. Economic Zone, both countries have historically exported fish to the U.S. Iceland has exported fresh and frozen cod, while Norway had, until a recent embargo, exported pen-raised salmon. Norway and Iceland are relatively small countries in economic comparison to Japan, which, because of its trade position, is in a stronger position to object to and ignore IWC policies.

If the IWC were to allow the resumption of commercial whaling, particularly coastal whaling within the territorial waters of Japan, Iceland and Norway, it would give it a legitimacy that might reduce the environmental backlash in nonwhaling countries. If the IWC extends the moratorium and Norway and Japan formally object or, like Iceland, withdraw from the IWC and unilaterally resume whaling, there will be stronger pressure from environmental groups and the U.S. Congress to impose sanctions via the Pelly and Packwood–Magnuson amendments.

The whaling industry and many government officials in these three countries are angered by the IWC, which they view as having been captured by "preservationists," and by the U.S., which they view as arrogant in its attempted use of economic power to impose its environmental ethic on other cultures (see the press release by the Ministry of Fisheries, Reykjavik, Iceland, 27 December 1991). Japan in particular feels that the U.S. is being hypocritical in its consumption of meat from domestic livestock and the hunting of big game while labelling the consumption of whale meat by the Japanese as immoral (see the Seattle Times/Post-Intelligencer, 30 June 1991:A12).

CONCLUSIONS

There is now considerable scientific evidence to suggest that several species of baleen whale and possibly the sperm whale have recovered to levels that would support commercial harvest. The stock of fin whales off the coast of Iceland (Palsson, 1991), the minke whale in the Northeast Atlantic (Øien, 1991) and the minke whale in the Southern Ocean (Institute of Cetacean Research, 1991) are prime candidates for commercial harvest. Japan, Iceland and Norway have an economic interest in the resumption of commercial whaling, which they believe can be done without risking stock extinction or incurring the economic inefficiencies of open access.

Management of the stock of minke whales in the Northeast Atlantic is analyzed through a bioeconomic model. A delay-