Conservation Biology

Contributed Paper

Testing the feasibility of a hypothetical whaling-conservation permit market in Norway

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Abstract: *A cap-and-trade system for managing whale harvests represents a potentially useful approach to resolve the current gridlock in international whale management. The establishment of whale permit markets, open to both whalers and conservationists, could reveal the strength of conservation demand, about which little is known. This lack of knowledge makes it difficult to predict the outcome of a hypothetical whale permit market. We developed a bioeconomic model to evaluate the influence of economic uncertainty about demand for whale conservation or harvest. We used simulations over a wide range of parameterizations of whaling and conservation demands to examine the potential ecological consequences of the establishment of a whale permit market in Norwegian waters under bounded (but substantial) economic uncertainty. Uncertainty variables were slope of whaling and conservation demand, participation level of conservationists and their willingness to pay for whale conservation, and functional forms of demand, including linear, quadratic, and log-linear forms. A whale-conservation market had the potential to yield a wide range of conservation and harvest outcomes, the most likely outcomes were those in which conservationists bought all whale permits.*

Keywords: conservation demand, economic uncertainty, free riding, whaling demand

SPrueba de la Viabilidad de un Mercado Hipotético de Permisos de Caza de Ballenas y Conservación en Noruega

Resumen: *Un sistema de compra de derechos de emisión para manejar la caza de ballenas representa una estrategia potencialmente útil para resolver la paralización actual en el manejo internacional de las ballenas. El establecimiento de un mercado de permisos de caza, disponibles tanto para balleneros como para conservacionistas, podría develar la fuerza de la demanda de conservación, de la cual se sabe poco. Esta falta de conocimiento dificulta la predicción del resultado de un mercado hipotético de permisos de caza de ballenas. Desarrollamos un modelo bioeconómico para evaluar la influencia de la incertidumbre económica en la demanda de la conservación o caza de ballenas. Utilizamos simulaciones a lo largo de una gama extensa de parámetros de la demanda de la caza de ballenas y de la conservación para examinar las potenciales consecuencias ecológicas del establecimiento de un mercado de permisos de caza en aguas noruegas bajo una incertidumbre económica restringida (pero sustancial). Las variables de incertidumbre fueron la pendiente de la caza de ballenas y de la demanda de la conservación, el nivel de participación de los conservacionistas y su disposición a pagar por la conservación de las ballenas, y las formas funcionales de la demanda, incluyendo las formas lineales, cuadráticas y log-lineales. Un mercado de caza y conservación de ballenas tuvo el potencial de producir una amplia gama de resultados para la conservación y la caza, y los resultados más probables son aquellos en los que los conservacionistas compraron todos los permisos.*

Palabras Clave: demanda de la caza de ballenas, demanda de la conservación, incertidumbre económica, polizón

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Paper submitted March 11, 2016; revised manuscript accepted February 17, 2017.

Conservation Biology, Volume 31, No. 4, 809–817

DOI: 10.1111/cobi.12916

Introduction

The treatment of whales divides individuals and societies. The arguments for and against whaling are rooted more in cultural and ethical norms than in economic considerations and seemingly offer little scope for negotiated agreement. Attempts to reconcile global whale harvest and conservation are stalemated. Costello et al. (2012) and Gerber et al. (2014) propose that a transferable whale permit program may increase conservation relative to the status quo. We evaluated the likely implications of such a market-based approach, given what is currently known about demand for whaling products and willingness to pay for whale conservation. We examined the economic conditions under which establishment of a cap-and-trade program that allows trade of annual whaling entitlements between whalers and conservation interests would result in full exploitation, complete conservation, or the coexistence of whaling and conservation.

The transferable whale permit program proposed by Costello et al. (2012) and Gerber et al. (2014) envisages the establishment of an international market under the control of the International Whaling Commission (IWC). The IWC would set an allowable annual biological catch limit that ensures a sustainable stock even if the entire catch limit is harvested. It would then allocate the annual catch limit in the form of whale shares (use rights) to whaling and conservation groups. A shareholder would have the right, but not an obligation, to harvest whales. The number of whales actually harvested relative to the allowable catch would be determined by agents' willingness to pay for whaling or conservation as revealed in the marketplace for entitlements. The benefit of a market is that it allows the parties to reveal their willingness to pay for conservation or harvest and reconciles these differences through exchange (Fig. 1).

Cap-and-trade programs have been applied to the U.S. SO_2 and EU CO_2 pollution markets (Carlson et al. 2000; Ellerman & Bucher 2007). The same approach has been applied to fisheries within the Exclusive Economic Zones (EEZs) of the United States, New Zealand, Australia, and Iceland among others. These programs have reversed overcapitalization and enhanced the profitability of the fishery (Grafton et al. 2006; Reimer et al. 2014), increased compliance with catch quotas, reduced variability in stock status (Essington 2010; Melnychuk et al. 2012), and helped prevent fishery collapse (Costello et al. 2008). Nongovernmental organizations (NGOs) such as The Nature Conservancy and Environmental Defense Fund have adopted a market-based approach in acquiring trawl permits in 2003 to protect essential fish habitat (Gleason et al. 2013).

Costello et al. (2012) and Gerber et al.'s (2014) proposal raises 2 issues. First, in the absence of a functioning whale-conservation market, there is considerable uncertainty about the relative demand for whaling permits by whalers and conservationists. Prior research on whale management focuses on biological uncertainty (Taylor et al. 2000; Punt & Donovan 2007), and although there have been a number of studies of willingness to pay for whale conservation (e.g., Loomis & Larson 1994; Wilson & Tisdell 2003), there have been few studies of the economic conditions in which whale conservation might be competitive with whale harvesting. Bulte et al. (1998) investigated the policy implication for whale management but did not consider the effect of economic uncertainty. Gerber et al. (2014) investigated the potential for whale conservation permit markets and found that a market system may ensure the persistence of whale populations and improve social welfare of whalers and conservationists. However, free riding, incentives for illegal harvest and trade, monitoring and enforcement challenges, and increasing costs associated with creating and managing a global whale permit market could reduce social welfare to suboptimal levels and potentially reduce whale populations below current levels (Smith et al. 2014).

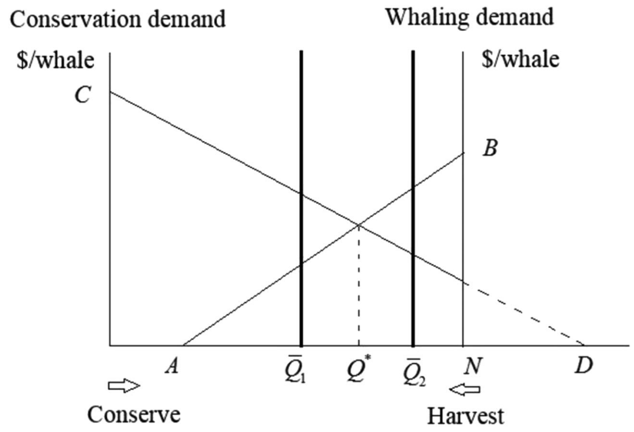

Figure 1. A permit-market system for whales based on the assumption that the demand for whaling and whale conservation is linear. Conservation demand is read from left to right, and whaling demand is read from right to left (N, initial population level; $\bar{Q}$, an absolute constraint on the supply of whales to whalers). A relatively loose harvest limit ($\bar{Q}_1$) suggests an interior solution (i.e., some quotas are retired and whaling and conservation coexist), with whalers harvesting (Q^*) and ($\bar{Q}_1 - Q^*$) whales conserved. A relatively conservative harvest limit ($\bar{Q}_2$) suggests the maximal harvest level ($\bar{Q}_2$). See Kuronuma and Tisdell (1994), Bulte et al. (1998), and Gerber et al. (2014) for a proposal to manage whales under a market system.

Second, the IWC, as an international organization regulating activity in the high seas and across EEZs of multiple countries, has limited power to assign property rights or penalize violators. Costello et al. (2012) implicitly assume all concerned parties would submit to the authority of the IWC for the global management of the whale permit system. Concern over the capacity of the IWC is not new (e.g., Andresen 1993; Bodansky 1999; Miles et al. 2002). The feasibility of establishing tradable quota in high-seas fisheries has been widely canvassed. Although many see the establishment of a system of property rights, full accountability by nation states for the actions of their nationals, and penalties for noncompliance as preconditions of such measures (Berkes et al. 2005; Crothers & Nelson 2006), these are not yet in place. Lesser measures, including capacity-transfer systems, have been suggested as feasible interim solutions (Serdy 2010). However, enforcement remains a challenge. Because the International Convention for the Regulation of Whaling (ICWR) contains no enforcement provisions, the establishment of whale quotas will create severe challenges (Smith et al. 2014).

Our thought experiment accordingly involves a more tractable problem: a permit market implemented by a single nation state. The ICRW provision that allows Norway to whale legally as an IWC member appears to grant individual countries substantial capacity to act over the objections of IWC members (Maffei 1997). This suggests that something closer to an individual transferable quota (ITQ) for fisheries within the EEZ of Norway, a single nation, might be more feasible via related Norwegian proxies or subsidiaries who could directly and actively participate in the transaction process. However, the right of conservationists to hold legal rights to whale may be limited. A cap-and-trade whale conservation program might also require the development of new institutions or adjustments to current legal frameworks. We assumed it is possible for conservation interests outside Norway to participate in the market either directly or through Norwegian proxies. Our purpose was to test the feasibility of Costello and colleagues' proposal in an ITQ-like system operated within the Norwegian EEZ while maintaining the whaling moratorium elsewhere. In this way, we also tested the value of the market-based approach to whale conservation that avoids the challenges associated with global whale management. Within this structure, we explored uncertainty about the strength of demand for different whale uses (Costello et al. 2012; Gerber et al. 2014), albeit through simulation with limited data. In particular, we explored uncertainty about whaling demand (WD) and conservation demand (CD).

We considered 4 distinct sources of uncertainty: uncertainty about the functional form of whaling- and conservation-demand curves (whether they are linear or nonlinear); uncertainty about the marginal willingness to pay (WTP) for an additional whale, either hunted (whalers) or saved (conservationists) and the elasticity of marginal WTP to changes in whale stocks (i.e., slope, the responsiveness of marginal WTP to additional conservation or harvest); uncertainty about the choke price (i.e., maximum marginal WTP of whalers as the number of whales available for harvest approaches zero) for WD; and uncertainty about the degree of free riding among conservation interests. The choke price is the maximum marginal WTP of whalers as the number of whales available for harvest approaches zero. A choke price for the CD curve becomes irrelevant when the enforcement of conservative catch limits is in place. Free riding exists because whale conservation is an impure public good (Kuronuma & Tisdell 1994). It refers to a situation where individuals benefit from a resource without paying their share of the cost of its provision; thus, they are free riding on the contributions made by others (Samuelson 1954). Uncertainty as to the extent of free riding directly influences the degree to which latent demand for whale conservation actually materializes, which in turn creates uncertainty as to the outcome of a whale permit market.

We asked, under what circumstances would market outcomes in which either conservation or whaling interests dominate and how sensitive are such outcomes to the different sources of uncertainty? To address these questions, we built a model of whale-permit demand and tested the sensitivity of demand for harvest and conservation to uncertainty relative to a range of parameters affecting whale population dynamics, harvest policies, and preferences for consumptive and nonconsumptive uses of whales.

Methods

Minke Whale Case Study

To test the feasibility of a permit market for conservation, we considered the Norwegian minke whale (*Balaenoptera bonaerensis*) fishery. In addition to large-scale whaling during the nineteenth and twentieth centuries, Norway has always maintained a small coastal whaling industry; whaling vessels are owned by family members and close relatives are the crew. Norway formally objects to the IWC commercial whaling moratorium and is thus not bound by it. Management of the fishery is ecosystem based and aims to conserve marine mammal stocks and promote involvement of local communities (Norwegian Ministry of Trade, Industry and Fisheries 2015).

The minke whale fishery is a plausible candidate for market-based conservation for several reasons. First, minke whales in the Northeast Atlantic are abundant and listed as least concern by the International Union for Conservation of Nature (Norwegian Ministry of Trade, Industry and Fisheries 2015). Second, minke whales in the Northeast Atlantic are straddling stocks, migrating along the Norwegian coast into the Barents Sea (Schweder et al. 1993; Bjørndal & Conrad 1998). Minkes in the Northeast Atlantic are taken almost exclusively in Norwegian waters (Amundsen et al. 1995) under a regulatory authority with the capacity to secure the property rights of market participants and to penalize noncompliance—both preconditions for a market to exist. Quotas are set based on the procedures developed by the IWC (Norwegian Ministry of Trade, Industry and Fisheries 2015), which requires Norway to submit whaling quotas and associated scientific data. In addition, all whaling vessels in Norway have monitoring systems and are assigned inspectors during the hunting season to ensure compliance (Norwegian Ministry of Trade, Industry and Fisheries 2015). Illegal hunting of whales is punished with a fine up to NOK 1 million (US$135,000), and violators can be imprisoned for 1 year (Raymakers 2001).

As in fishery management regimes where property rights are granted to fishers (Arnason 2012), we assumed the total number of annual whale permits are de facto allocated to Norway and then allocated by the Norwegian fishing authority to whaling vessel owners with an active history in the fishery– perhaps in proportion to their historical harvest rates. For simplicity, we supposed a single whale permit is equivalent to a right to harvest one whale over a fixed period (e.g., 1 year). A whale permit market would differ from the current system because it would introduce tradability and allow conservationists to acquire and retire permits. Currently, whaling quotas in Norway are not tradable among licensed vessels. Politically, economic efficiency through tradability is not a high priority in Norway; instead, policy is aimed at maintaining whaling tradition. The transferability of quotas has been denied by the government, mainly because it is perceived as privatization of resource rights (Hannesson 2013). As in the case of other tradable use rights, a whale-conservation market could help reduce the cost of managing the resource (Coase 1960; Williamson 1981).

Model of Whale Dynamics

We modeled a Norwegian whale permit market system that included regulatory, economic, and biological components. An initial whaling quota ($H_t^{\max}$) was set based on stock abundance of whales and distributed to whaling companies. The minimum protection level ($N_t - H_t^{\max}$) reflected sustainable stock conservation goals. Beyond the initial allocation, conservation groups were able to reduce harvest pressure in any given year by buying and retiring seasonal whale permits. Whalers had the option of selling or purchasing permits. The initial allocation was for one or more years, depending on how long whalers were grandfathered into the system. The number of permits held was determined by the preferences and the endowments of whaling or conservation interests.

We used a population dynamics model similar to that of Bulte et al. (1998), Conrad (1989), and Gerber et al. (2014), who analyzed potential whale permit markets for Bering-Chukchi-Beaufort bowhead whales (*Balaena mysticetus*), Central North Atlantic minke whales, and Eastern North Pacific gray whales (*Eschrictius robustus*). Population dynamics were assumed to take the simple discrete logistic form $N_{t+1} = N_t + rN_t\,(1 - N_t\,/K) - Q_t$, where N_t is the population stock level at time t, r is the intrinsic growth rate, K is the carrying capacity, and Q_t is the quantity of whales actually harvested. We used the demographic parameters for Northeast Atlantic minke whales from Gerber et al. (2014) ($N_0 = K = 72{,}130$) and assumed r was 0.04.

We assumed the fishery authority set a maximum allowable harvest based on a stock-dependent harvest rule and updated it each year. For illustrative purposes, the maximum allowable harvest was determined based on the potential biological removal (PBR) and was modeled as $H_t^{\max} = 0.5rN_tF_r$ (Taylor et al. 2000). The PBR is transparent and conservative in that it ensures the direct anthropogenic mortality of the species is less than the population necessary to maintain at least half of its carrying capacity (Taylor et al. 2000). Here, F_r is a recovery factor that adjusts upward – increasing the fraction of the stock of whales $0.5rF_r$ that can be harvested—as the stock of whales increases toward carrying capacity and was assumed to be $F_r = 0.1 + 0.4N_t/K$ (Gerber et al. 2014). The resulting quadratic harvest-control rule, $H_t^{\max} = 0.05rN_t + 0.2rN_t^2/K$, reflected a conservative maximum harvest (ensuring a steady state of at least 79% of K given model parameters). We assumed annual whale permits based on stock abundance were initially allocated to whaling vessel owners (as user rights) with an active history in the fishery.

Estimating Conservation and Whaling Demand

Although data exist for whale products and for willingness to pay for whale protection in general, there are no data on the relative demand for whale harvest and conservation. To characterize the implications of this uncertainty, we used Monte Carlo simulations and the limited data on Norwegian minke whale catches and ex-vessel Norwegian minke whale prices from the Directorate of Fisheries (www.fiskeridir.no) to derive CD and WDs. We focused on a number of uncertainty parameters (Table 1). Given the lack of available data, we assumed uniform distributions for these parameters. Our uncertainty parameters included the slope of the WD function, choke price of WD, elasticity of CD, participation rate of conservationists, annual WTP for gray whale conservation, and minke:gray whale conversion ratio. The participation rate of conservationists, for example, ranged from 0 to 1 (0, no participation; 1, full participation). So, a value of 0.4 indicated that 60% of conservationists would free ride on the conservation effort of the remaining 40%, shifting the aggregate conservation demand curve down vertically. In terms of the functional form of demand, we considered and calibrated linear and quadratic WD

Table 1. Uncertainty-variable distribution used to estimate conservation and whaling demands.

Variable	*Definition*	*Distribution*
B	slope of whaling demand ($/catch)	uniform (−5, −0.5)
A	choke price of whaling demand ($)	uniform (5,000, 50,000)
e	elasticity of conservation demand	uniform (−5, −0.2)
PLC	participation level of conservationists	uniform (0, 1)
$\mathrm{WTP}_{\mathrm{GW}}$	individual's annual willingness to pay for gray whale conservation ($)	uniform (25, 75)
$\mathrm{TR}_{\mathrm{MG}}$	minke:gray whale transfer ratio	integer uniform (1, 5)

curves and linear and log-linear CD curves. The associated coefficients of these demands are calculated using simulated whaling data and our uncertainty parameters.

Due to the nonlinear form of demand functions, population models, and the time scale involved, we simulated the outcomes of a whale permit market numerically. We considered the following combinations: linear WD and linear CD, linear WD and log-linear CD, quadratic WD and linear CD, and quadratic WD and log-linear CD. For each combination of whaling and conservation demands, we randomly generated 1000 parameter sets from the distributions in Table 1, which we used to produce 1000 pairs of whaling- and conservation-demand curves. The coupled economic-ecological model was then simulated for 300 generations for each of the 1000 calibrations of whaling and conservation demand to ensure that it achieved the steady-state harvest and population levels for each replicate. In the end we had 1000 outcomes for each whaling- and conservation-demand combination.

We focused on the steady-state whale harvest level, H^*, under different demand conditions. To examine the sensitivity of H^* to different parameters, we estimated linear regressions of H^* on the choke price and the slope of the WD function, the slope of the CD function, the participation level of conservationists, and the WTP for minke whale conservation under different whaling and conservation demand combinations. Because the independent variables had different units and domains of support, we standardized each variable so that each had a mean of 0 and a variance of 1 before running the regression analysis. The resulting standardized coefficient (β, for instance) of independent variable x was interpreted to mean that increasing x by 1 SD would increase the dependent variable by β SDs.

Results

All else being equal, increases in the participation level of conservationists, each participant's WTP for minke whale conservation, and the slope of CD decreased the level of whale harvest H^* (Table 2). In contrast, increases in the choke price and the slope of WD increased H^*. We found H^* was the most sensitive to participation level of conservationists and was more sensitive to parameters associated with the CD curve than to those associated with the WD curve.

Table 2. Coefficient estimates derived from standardized regression of steady-state harvest of whales on uncertainty variables under different whaling- and conservation-demand scenarios.[a]

Variable	*L-L*	*L-N*	*Q-L*	*Q-N*
Choke price of whaling demand	0.09	0.08	0.1	0.18
Slope of whaling demand	NA	NA	0.01	0.09
Slope of conservation demand	−0.41	−0.37	−0.4	−0.36
The participation level of conservationists	−0.55	−0.69	−0.57	−0.69
WTP for minke whale conservation	−0.5	−0.53	−0.56	−0.58

[a] *Because perfect multicollinearity exists between the choke price (i.e., maximum marginal WTP of whalers as the number of whales available for harvest approaches zero) and the slope of whaling demand in cases involving linear whaling demand, we dropped the slope of linear whaling demand in the standardized regression. Abbreviations: NA, not applicable; L, linear whaling and conservation demand; N, nonlinear conservation demand; Q, quadratic whaling demand; first letter in a pair, functional form of whaling demand; second letter in a pair, functional form of conservation demand.*

The conservation outcomes associated with the various parameters of the WD and CD fell into 1 of 3 categories: complete conservation ($H^* = 0$; CD curve was above WD curve and all quotas were retired); interior solutions ($H^* < H^{\max}$; some quotas were retired and whaling and conservation coexisted); and zero conservation ($H^* > H^{\max}$). As the whaling choke price and levels of free riding increased (i.e., lower conservationist participation), H^* transitioned from complete conservation, to interior solution (Fig. 2a and 2b), to zero conservation (Fig. 2c and 2d). Combinations involving linear CD generated only interior and zero-conservation solutions. Combinations involving log-linear CD generated all 3 outcomes.

Whether CD was linear or nonlinear had a significant effect on conservation outcomes. In the linear model, the rate of change in the slope of the linear CD curve (curvature) at low levels of harvest and high levels of conservation was the same. In other words, marginal WTP fell regardless of stock status. In the nonlinear model, however, marginal WTP declined rapidly at low stock levels and slowly at high stock levels. The higher the choke price for WD, the higher the participation level of conservationists corresponding to a given harvest level. The transition from complete conservation to zero conservation was sharpest for the log-linear CD curve (compare Fig. 2c and 2d with Fig. 2a and 2b) and depended

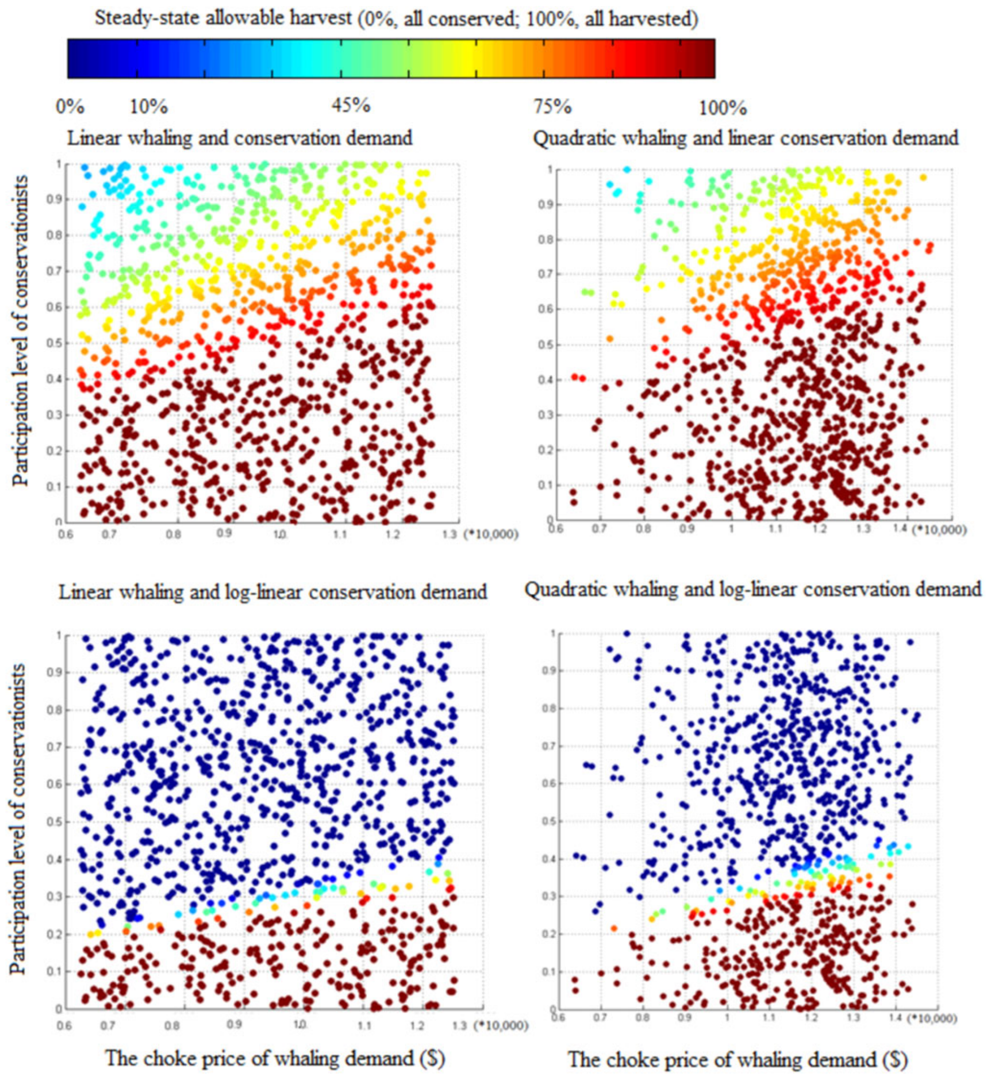

Figure 2. Whale conservation under different combinations of conservationist participation (0, no participation; 1.0, full participation) and choke price (i.e., maximum marginal WTP of whalers as the number of whales available for harvest approaches zero) of whaling demand. Total conservationist number is 20,000,000, average annual conservationist willingness to pay for minke whale conservation is $25, slope for whaling demand is −2.5, and elasticity for conservation demand is −2.

on the distribution of the choke price of WD and the participation level of conservationists.

Discussion

In our thought experiment, we considered the feasibility of market-based whale conservation in a single EEZ, assuming international conservation groups are able to participate in the market either directly or through national proxies. It is impossible to disentangle current expenditure by conservation NGOs on the protection of minke relative to other whales, but a very conservative estimate of the total annual expenditures by such NGOs on all antiwhaling activities is approximately $25 million (L. Peavey, personal communication). In our test of the feasibility of a hypothetical whaling-conservation permit market in Norway, we used this measure to determine global demand for local whale conservation. The average equilibrium quota price for the interior cases in all whaling and conservation combinations from the simulations was $7,300 to 8,900. With whaling quotas at a steady state of 475 whales, this suggests the implied annual expenditure from conservationists to whalers, if conservationists bought all permits, would be $3.47 to $4.23 million. This is 14–17% of current annual expenditure by NGOs on all antiwhaling efforts. The implication is that if the Norwegian market were seen as a test of the strength of conservation demand, harvest could potentially be driven to zero.

A market-based approach to whale conservation is complicated by uncertainties that must be taken into account to anticipate undesirable outcomes and better design institutions to achieve policy objectives. We used limited data on minke whales to explore a hypothetical whale permit market given uncertainty about the demand for whale conservation. The greater influence of the CD curve relative to the WD curve, reflects available data and our calibration procedures. The relatively weak demand for whale harvest seems consistent with the nature of whale meat products in whaling countries; substantial whale-meat stockpiling exists and sales revenues are falling (Simmonds & Fisher 2012). By contrast, the calibrated CD curves—despite uncertainty in many of the essential parameters—had both higher intercepts and lower slopes. These 2 calibrated WD and CD curves produced an equilibrium harvest that was relatively low. This explains the greater sensitivity of harvest level to parameter changes on the CD side relative to the WD side. This argument applies only to this particular and limited set of data, and the sensitivity of the steady-state harvest level highlights the importance of data collection related to whaling and conservation.

Free riding is a serious concern for the voluntary provision of public goods (Cornes & Sandler 1986). Not surprisingly, the outcome of the whale permit market depended strongly on the extent to which free riding prevailed. When conservationists have to compensate whalers to forgo some harvesting, there is an incentive for some conservationists to free ride on other conservationists' contributions, resulting in an underprovision of whale conservation. The potential ecological harm and economic loss from free riding was curbed by the management scenario we envisioned because we assumed harvest was constrained by the allowable catch limit. Furthermore, the possibility that large conservation or animal-rights NGOs may participate in a whale permit market may mitigate the severity of free riding due to their ability to organize funding campaigns and consolidate the contributions of their donors. Although incentives to free ride between NGOs will persist, these incentives are likely far less severe than in the case of a large number of individual donors. Furthermore, the transaction costs of overcoming these free riding incentives may be relatively low given the small number of large NGOs and their existing cooperation in other domains.

As in cap-and-trade systems elsewhere, the main benefit of a permit market would be to allocate both harvest and conservation resources efficiently within the total allowable catch (TAC). Currently, Norway harvests minke whales legally within its EEZ. The Norwegian fisheries authority sets its own TAC but has to provide quotas and relevant information to the IWC. Assuming the TAC under the IWC and the Law of the Sea Convention is adhered to, the effectiveness of a whale permit market as a conservation measure then depends on the way the TAC responds to changes in stocks. If an increase in whale numbers prompted an increase in permits, as dictated by the PBR rule, we assumed, conservationists might expect to face an increasing total outlay for whale conservation over time. This could give conservationists an incentive to oppose the market in favor of lobbying and other measures designed to achieve the same goals at lower cost. If the PBR rule were replaced with one in which whaling quotas were bounded by a ceiling (perhaps tied to recent harvest levels), market-based conservation would be more attractive but would still require annual outlays by conservation organizations. It would certainly be possible to use an optimal control framework to construct an efficient harvest rule as has been applied to economic management of natural resources (Conrad & Clark 2002), including whale conservation (e.g., Conrad & Bjørndal 1993; Horan & Shortle 1999). Changes in the relative scarcity of whales in this case would be expected to alter the shadow value of stocks and hence the optimal TAC.

These issues and issues of income distribution and resource allocation would need to be addressed before the establishment of a whale-conservation market. One possible remedy to the escalating cost problem would be to strengthen the property rights of whalers by moving from an annually denominated use right to a more durable right to a share of the variable PBR, which could be combined with a policy to ensure that the quota will not become higher due to conservation effort, and by allowing whalers to trade this long-run asset in addition to the annual lease rights (as is the case in most catch-share fisheries). Granting these durable rights to whalers could be politically unpopular. However, the creation of a long-term asset market would allow conservationists to work with whalers to buy out their rights in perpetuity, so avoiding escalating costs of conservation.

The correct shape of the CD curve is essential to determine the robustness of conservation success to free riding (Fig. 2). Despite being calibrated to the same data set, the log-linear CD curve showed a complete-conservation, or buyout, outcome even with high levels of free riding (i.e., only 20–30% market participation) over the range of simulated whaling choke prices, whereas the linear CD curve never yielded a buyout outcome, even at the full participation. A linear CD curve required that marginal WTP decrease at the same rate regardless of the population level. By comparison, the corresponding log-linear CD function flattened as it reached high stock levels. If the concerns of buyers in the market are primarily driven by concerns for the health of the overall population of the whale species, one might expect a rapid falloff in marginal WTP, as in the linear case, where there is little demand for additional conservation of large stocks. However, if CD is instead driven more by concerns for preventing the suffering of individual whales than by stock status, CD may be unresponsive to changes in population levels across a wide range of population levels—causing a fairly inelastic CD curve. We believe the rhetoric of many antiwhaling interests and the nature of public discourse about whaling often tends toward this latter perspective, supporting the case for an inelastic CD. If this is the case, there is a substantial chance that the establishment of a whaling market could lead to a buyout—even with fairly substantial levels of free riding. Nevertheless, this remains nothing more than an informed conjecture in the absence of more information on the shape of the demand curves.

Given the profound uncertainty springing from our data-poor setting, we relied on simulations over a wide range of parameterizations of WD and CD. We also used a simple biological model and parameters from literature. Although uncertainty about population size or population dynamics could influence the market outcome, our purpose was to illustrate the conservation potential of this market approach and to outline key areas of uncertainty that could be resolved through targeted empirical research. This highlights the need for substantial investments in economic and biological data collection to improve whale management.

The challenges of resolving disputes between whaling and nonwhaling nations under the IWC moratorium are formidable. We tested the feasibility of a hypothetical market-based approach to minke whale conservation in the Northeast Atlantic. Our proposal, while politically challenging, takes advantage of the institutional capacity of Norway to monitor and enforce whaling activities in its own EEZ. The proposal therefore appears consistent with current property rights. Conservationists implicitly have rights to whales not hunted in compliant countries while whalers have rights to those whales that they have historically been able to hunt and are allowed to hunt by the IWC for scientific, commercial, and subsistence purposes. Nevertheless, the market mechanism provides a means for conservation interests to mobilize the global demand for whale conservation to alter this allocation in a compensated manner—transforming a zero-sum game into a scenario of mutual gain—and could even result in an effective buyout of the whaling industry if free riding can be overcome. Furthermore, testing a whale-permit market would provide information on how to implement the approach more widely.

Extending the proposed Norwegian system to cases where fleets target whales beyond their EEZs (i.e., Japan) presents considerable governance, monitoring, and enforcement challenges (Smith et al. 2014). Property rights to whales in the high seas are demonstrably poorly defined and enforced—depending as they do on the voluntary assent of whaling nations. There are close parallels in this regard with the governance of high-seas fisheries. Control over access to straddling or migratory fish stocks notionally rests with Regional Fishery Management Organizations, but it turns out to be very close to open access (Bjørndal et al. 2000; Grafton et al. 2010; Squires et al. 2013). It is therefore no accident that the majority of successful cases of fishery management occurs for stocks contained within the coastal waters of nation states, which have sovereign rights for the purpose of harvesting and conserving marine resources within their EEZs. Effective management for whale stocks that cross EEZs or spend substantial time in the high seas may ultimately require multilateral conservation approaches (Smith et al. 2014).

Supporting Information

Detailed methods for calibration of derived WD and CD and a brief discussion on market structure (Appendix S1), simulation methods (Appendix S2), and a graphical analysis of the impact of variations in uncertainty parameters in market equilibrium (Appendix S3) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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