The Australian Journal of
Agricultural and
Resource Economics

Journal of the Australian Agricultural and Resource Economics Society

The Australian Journal of Agricultural and Resource Economics, 53, pp. 37–58

Encumbering harvest rights to protect marine environments: a model of marine conservation easements*

Robert T. Deacon and Dominic P. Parker†

We adapt the concept of a conservation easement to a marine environment and explore its use to achieve conservation goals. Although marine environments generally are not owned, those who use them for commercial fishing often are regulated. These regulations grant harvesters rights to use marine environments in specified ways, and the possibility of encumbering these rights to achieve conservation goals creates a potential role for marine easements. We examine this potential under alternative fishery management regimes and find, generally, that marine easements tend to be most effective when harvest rights are delineated most fully. Our analysis suggests ways that marine easements can have flexibility and transactions cost advantages over other approaches to achieve marine conservation goals. We also propose ways in which the design of laws allowing marine easements should follow, or depart from, the design of laws authorising conservation easements on land.

Key words: conservation easement, resource economics, marine habitat protection.

1. Introduction

The nature conservancy (TNC) recently purchased seven federal trawling permits and four trawling vessels from commercial fishermen based in Morro Bay, a coastal town in central California. This deal, which cost TNC $3.8 million, was unprecedented in that it was the first private purchase of Pacific permits and vessels for conservation purposes. The permits are for commercial groundfish, including sole and sable, and the goals are to reduce the bycatch of depleted seafloor species that are not valued commercially, for example, canary rockfish and cow cod, and to reduce the negative impacts of bottom trawling on their sloping rocky habitat. One way for the Conservancy to pursue these goals is for it to retire the fishing permits and to sell the vessels for use elsewhere. Such a strategy, however, may lead to costly ‘conservation

* For helpful discussions, authors thank Chris Costello of UCSB, Dan Hennen of the Alaska SeaLife Center, and Steve MacLean of TNC. Authors are responsible for any errors in this article. Authors acknowledge valuable comments from Howard Chong and from other participants at the 10th Occasional Workshop on Environmental and Natural Resource Economics at UCSB, 21 March 2008.

† Robert T. Deacon (email: deacon@econ.ucsb.edu) is a Professor of Economics, University of California, Santa Barbara, California, USA and University Fellow, Resources for the Future. Dominic P. Parker is a PhD student, Department of Economics, University of California, Santa Barbara, California, USA.

doi: 10.1111/j.1467-8489.2007.00429.x

overkill', meaning that TNC will also absorb the foregone value of harvesting groundfish in ways less damaging to other seafloor species. Instead, TNC is experimenting with leasing permits back to fishermen, but with lighter gear and restrictions that constrain fishing to areas with sandy or muddy bottoms and away from rock slopes. Depending on the success of this experiment, TNC and other conservation NGOs (non-governmental organisations) will consider similar transactions in other fisheries across the world (see Barringer 2007; TNC 2007).

In this article, we examine 'marine easements' as a way for conservation NGOs to achieve a reduction in environmentally damaging actions without incurring excessive costs. Marine easement is a term we use to describe legally binding agreements between commercial fishermen (grantors) and conservation NGOs (grantees) that amend certain fishing practices in exchange for payment. A marine easement differs from the buy-and-lease arrangement used by TNC in Morro Bay because, under easements, the NGO does not have to enter the business of owning permits. The grantor retains the right to harvest target species as regulated by law, but agrees to amend the methods of fishing for the benefit of non-commercial stocks and habitats. Importantly, the easement encumbers the commercial permit and thus remains binding when the permit is transferred to another fisherman.

Our interest in exploring the uses of easements as a conservation management tool for marine environments is prompted in part by the impressive growth of terrestrial conservation easements in the US. Conservation easements are agreements between private landowners (grantors) and conservation organisations, known as land trusts (grantees).[1] Easements over land conserve open-space amenities, such as scenery and wildlife habitat, typically by prohibiting intense residential and commercial development but sometimes also by restricting certain farming and logging practices. The easement acreage held by state and local land trusts alone increased from 148 000 acres in 1984 to 6.2 million acres in 2005. During the same period, the acres acquired outright by these land trusts increased from 292 000 acres to only 1.7 million acres (Parker 2007). Conservation easements now comprise a significant fraction of land in some US regions, encumbering approximately eight percent of all private acres in Vermont, for example.

Although agreements that would qualify as marine easements currently are rare at best, the concept is analogous in many respects to conservation easements over land. The key difference in the marine context is the absence of property rights to marine habitats; there is no outright owner with whom a conservation NGO can negotiate. However, the regulatory policy in place to manage a fishery typically establishes property rights to use the habitat in various ways, and at specific times and places. An agreement by these rights holders to restrict their actions in specified ways, in exchange for compensation, would constitute a marine easement. The nature and extent of use rights

[1] Conservation easements are also held by various government agencies.

established by existing fishery regulations is therefore a key consideration in the efficacy of the marine easement approach to management.[2] In this article we consider the potential for marine easements under four fishery regulatory regimes: sole ownership, open access, limited entry and individual transferable quotas.

Our analysis suggests that greater delineation of commercial harvest rights will improve the effectiveness of marine easements in achieving conservation goals. The intuition for this is clear if we compare a regime in which such rights are entirely absent, open access, to a hypothetical regime in which such rights are complete, sole ownership.[3] Under open access, a NGO clearly could negotiate a marine easement, paying a fisherman to refrain from taking an environmentally damaging action and thereby raising the firm's harvest costs. Yet there is nothing to prevent another harvester from entering the fishery and out-competing the fisherman under easement. In this case, the easement yields no conservation benefit in aggregate. Under sole ownership a firm or association holds rights to make coordinated decisions on all aspects of a marine habitat's use. So long as the habitat of interest is spatially contained within the area controlled by the sole owner, a NGO could seemingly achieve its goals by negotiating to constrain damaging actions. In fact, it may well be possible to go beyond specifying prohibited actions in this case and instead negotiate easements that delineate performance standards, e.g. directly specifying the desired stock of non-commercial species or the quality of its habitat. Performance easements should be more efficient than prohibitions on actions because they give the sole owner flexibility to adjust actions to minimise the costs of achieving conservation goals.

Common fishery regulation regimes such as limited entry and ITQs (individual transtervable quotas) lie between these extremes in the extent to which they establish rights to use a marine environment. Under common regulations, contracting for a performance standard on the state of the marine resource is not feasible because no single harvester controls all actions that determine the marine environment's state. Enforceable easements can only prohibit or require observable actions in these cases, and easement grantors can be expected to adjust their unobservable actions in ways that are privately optimal. These unobservable adjustments may substitute or complement observable actions specified in easements and will therefore also affect the non-commercial stocks and habitat that are of interest. The model we develop shortly examines

[2] Access to harvest groundfish off the coast of central California, for example, is limited by a fixed number of commercial permits. TNC recognised that these access rights are legal interests that it could buy and lease. Our claim is that the efficacy of using easements to achieve goals, such as reducing the bycatch of rockfish and cow cod, in this fishery depend generally on how well easements can work in a limited entry fishery.

[3] By open access we mean a circumstance in which any agent with the requisite capital can enter the industry and engage in harvesting fish without restrictions. By sole ownership, we mean a situation in which a single agent has the right to exclude others from taking any actions that alter the state of a specific marine environment and an ability to monitor how that resource is used.

these potentially offsetting effects and identifies other factors that determine the conservation benefits that marine easements can achieve.

The article proceeds as follows. Section 2 briefly reviews the literature on conservation easements, with emphasis on the advantages easements have over other policy approaches and a discussion of enforcement problems and related issues. Section 2 also describes the relevant literature on marine bycatch and the policy approaches that may be used to conserve habitats and non-commercial stocks. Section 3 presents our model of marine easements. After describing the objectives of fishermen and NGOs, the model compares the effectiveness of marine easements under different regulatory regimes. Section 4 summarises the policy implications of our analysis and gives recommendations for further study.

2. Literature on conservation easements and marine habitat protection

2.1 Conservation easements

Legal scholars often describe conservation easements by comparing land to a bundle of sticks. Each stick represents a right to use land or exclude others from using land in a certain manner. A conservation easement is simply a legal agreement in which a landowner cedes some sticks from his or her bundle for a specified duration, usually perpetuity. Rights ceded to land trusts via conservation easements can be categorised as negative or positive. Negative rights prevent landowners from actions such as building commercial structures, subdividing, clear-cutting, farming near streams, altering water courses, and erecting billboards. Positive rights allow trusts access to the property to do such things as construct recreational structures, remove non-native vegetation, and monitor wildlife. Whether negative or positive, the rights conveyed in easements 'run with the land.' Successor landowners and successor land trusts are bound to the terms agreed upon by the original parties (Korngold 1984).[4]

Although the term 'conservation easement' was coined in 1959, the widespread use of easements by land trusts did not begin until the latter half of the twentieth century with the strongest growth occurring over the last 20 years (Brewer 2003). The number of U.S. state and local land trusts increased from 535 in 1984 to 1663 in 2005. The easement acreage held by these trusts increased from 148 000 acres in 1984 to 6.2 million acres in 2005. During the same period, the acres acquired outright by these trusts increased from 292 000 acres to only 1.7 million acres. These figures do not include the nation's largest land trust, TNC, which increased its conservation easement

[4] Conservation easements fall under the broader umbrella of servitude law. Servitude law also governs rights of travel across another's land, rights to use another's land or remove resources from it, and the covenants of housing associations (Dnes and Lueck 2007).

acres in the US from approximately 174 000 acres in 1984 to 1.6 million acres in 2003 (Parker 2007).

Three factors have probably contributed to the recent growth in conservation easements. First, during the 1980s and 1990s many U.S. states passed statutes explicitly allowing conservation easements and specifying that they can be held by land trusts, thereby overriding concerns that negative easements would not be enforceable under common law (Dana and Ramsey 1989; Gustanski and Squires 2000). Second, an increasing number of tax benefits were made available to donors of conservation easements. Federal income tax deductions for easement donors were made permanent in 1981, federal estate tax benefits were granted in 1997, and a number of states began offering state income tax credits to donors in recent years (Small 2000; McLaughlin 2005). The extent of tax benefits depends on the appraised value of easements, which is the difference between the full-market price of land and the price of the encumbered parcel (Boykin 2000). Third, land trusts, attorneys, judges, and landowners have become more familiar with conservation easements in recent years. This familiarity has reduced some of the long-term enforcement uncertainties associated with holding or granting easements (Parker 2004).

The potential benefits of conservation easements are well-recognised by economists and legal scholars. In contrast to land-use regulations, easements are incentive-based policies that can be customised to motivate voluntary conservation by landowners. Even if site-specific land-use regulations were allowed under law, governments would have difficulties imposing them in an efficient manner. As Boyd *et al.* (2000) note, selecting properties where land restrictions offer the highest net benefits would require detailed information about private land-use values. Such information would be difficult to obtain without market negotiations. Conservation easements can also have efficiency advantages over the outright purchase of land. Efficiency gains from easements are most likely when the land has valuable commodities (e.g. soil, timber, or minerals) that are better managed by a specialised landowner, and when the terms of the easement can easily be enforced over future time periods. Conservation easements meeting these criteria will tend only to prohibit activities that compete with open space, but leave production decisions to the more specialised landowner (see Parker 2004).

The main criticisms of conservation easements stem from concerns about their perpetual nature and about their tax deductibility. These concerns are linked because only perpetual easements are eligible for most tax benefits. Perpetuity means that easements cannot easily be extinguished or amended in the future even if changes are desired by the NGO holding the easement. The perpetuity requirement is inconsistent with centuries of common law, which tends to discourage perpetual constraints on land use (Mahoney 2002), and it can reduce the long-term conservation benefits generated by an easement. As economic and ecological conditions change, the benefits and costs of conserving different parcels will change. Yet land trusts cannot respond by selling some of the easements in their portfolio to acquire the cash needed to reinvest in conservation elsewhere (Parker 2007).[5]

2.2 Policies for conserving non-commercial stocks and marine habitats

The goal of reducing actions that damage marine environments, or of improving the stocks of non-commercial marine species, can be achieved using a variety of policies discussed in the literature. Most of these policies are presented in the context of managing bycatch in multispecies fisheries, where bycatch is 'the incidental take of a species that has some value to some other group' (Boyce 1996). The bycatch literature is relevant to our assessment of marine easements because 'incidental take' can be interpreted broadly to encompass any incidental, negative impact on non-commercial stocks and habitats.

In an early analysis, Marasco and Terry (1982) summarised several management options for controlling the incidental catch of commercial species (including halibut, salmon, and crab) by groundfish fishermen. The options they considered include a TAC (total allowable catch) quota for prohibited species, a tax on incidental catch, time and area closures, gear restrictions, and a decrease in the TACs for target groundfish species. The authors favour taxing incidental catch (so long as monitoring and informational problems can be solved), but this option has not gained traction in practice.

Actual policies have instead favoured gear restrictions, time and area closures for fishing and TAC quotas for entire fisheries (see Larson *et al.* 1996). Some observers point out that these management strategies may only serve to shift stock depletion from one commercial species to another, if the bycatch to be controlled is commercially harvested by another fleet. Ward (1994), for example, models the effects of gear modifications imposed on a multispecies fishery that exclude bycatch of a species that is the target of a single species commercial fishery. In his framework, such gear restrictions might limit harvest in the multispecies fishery, but any gains to the restricted stock could be offset by expansion in fishing effort, and resulting stock reductions, in the single species fishery. Other studies suggest that gear restrictions, time and area closures, and TAC quotas can be effective in increasing bycatch stocks, but note the potentially high cost of these policies to harvesters and fishery regulators.

Prospective rights-based policies for managing bycatch include ITQs for incidental catch and individual habitat quotas (IHQs). In the context of a two-species fishery, Boyce (1996) argues that an ITQ system on both the target and bycatch species creates the correct incentives to maximise efficiency when both species have commercial value. The situation is more complex when the bycatch species has only existence value, for example, dolphins in

[5] Anderson and King (2004) discuss some of the potential implications of funding conservation easements with tax incentives.

the tuna fishery, sea lions in the pollock fishery. Here an ITQ on the bycatch species must be coupled with a tax on the harvest of bycatch. This is because the price of the bycatch quota will only reflect the scarcity of bycatch TAC in the target fishery rather than reflecting the full social cost of taking additional units of bycatch.[6] Holland and Schnier (2006) propose IHQs, a cap-and-trade program on negative habitat impacts. In this system, the marginal damage due to fishing in certain areas or with particular gear types would be estimated by regulators and used to form an index of habitat impact. Total habitat impact would then be capped at an appropriate level and IHQs for imposing impacts would be created and distributed among fishermen. Harvesters engaging in damaging practices would then be charged an appropriate number of IHQs for their actions. IHQs would be similar to ITQs in several respects, including transferability and, presumably, controversy in determining the initial allocation.

3. A model of marine easements under alternative fishery management regimes

We use the phenomenon of bycatch to motivate our model of marine easements and consider a setting where harvesting a commercially valuable stock degrades the stock of a species that has no commercial value but is valued by a conservation NGO for environmental reasons. With different wording and notation our framework would apply more generally to circumstances where actions of commercial harvesters impair the quality of a marine environment. We abstract from all dynamic aspects and assume the amount of the commercial stock that becomes available each year is fixed, independent of harvest in past years. We assume the level of the bycatch stock is determined by the contemporaneous actions of commercial harvesters, subject to environmental conditions. Both assumptions are most appropriate as very long run propositions.

3.1 Modelling a marine conservation easement

A commercial stock of size Y becomes available at the beginning of each year. It is harvested by a commercial fleet consisting of a large number, N, of identical, independent vessels, indexed by i. A commercial harvester's catch depends on its actions a_i and b_i and on a set of factors that determine i's harvest for a given level of fishing effort. Given its own actions, we postulate that the firm's catch depends positively on the size of the commercial stock (Y) and negatively on the number of harvesters (N). The regulatory regime (R) determines the conditions under which the firm can access the stock and thus affects the level of catch from a given choice of actions. The production

[6] Hoagland and Jin (1997) also focus on the bycatch of non-commercial species, referring to this as a 'passive-use stock'.

function for catch is assumed to be strictly concave in the firm's actions and is written

$$h_i = h(a_i, b_i; Y, N, R). \tag{1}$$

Actions a_i and b_i are assumed to be 'normal' in the sense that expansion paths are positively sloped. We explain the difference between actions a and b shortly.[7]

The firm chooses a_i and b_i to maximise profit, taking other determinants of catch as given, subject to relevant regulatory constraints, R. The prices of actions a and b are denoted as u and v, respectively, and the price of catch is p. Firm i's harvest profit is

$$\pi_i = \pi(a_i, b_i; u, v, p, Y, N, R). \tag{2}$$

Because the production function is strictly concave in a and b the profit function has a unique maximum and we assume this is an interior solution. Profits depend negatively on u, v and N, and positively on Y and p. The profit function will generally be non-concave when the firm is assumed to have an exit option; we consider this case later.

A conservation NGO wishes to affect the level of a non-commercial fish stock, called the bycatch stock. Its level, X, is determined by the aggregate actions of N commercial fish harvesters as well as environmental factors, E, as follows:

$$X = X(a_T, b_T; E), \tag{3}$$

where $\sum_{i=1}^{N} a_i = a_T$ and $\sum_{i=1}^{N} b_i = b_T$. We assume the effect of a on X is negative; the effect of b on X could be either positive or negative. Examples of actions that could affect X include the choice of gear used for commercial fishing, the timing and location of commercial fishing, the depth of fishing gear, and the level of care applied in returning bycatch. We assume the bycatch and commercial stocks do not directly interact, although the choices of actions can affect both simultaneously.[8]

To affect the level of bycatch stock, the NGO offers commercial harvesters payments in exchange for easements that restrict the harvesters' actions. The variable over which an easement is defined must satisfy two conditions; the firm must be able to control it and the NGO must be able to observe it to verify compliance. Easements are assumed to confine the firm's choices to a convex set, for example, $a \leq \bar{a}$. Because an easement generally reduces the

[7] Our analysis generalises readily to a context where firms have more than two actions to choose.

[8] In Hoagland and Jin's (1997) model of non-commercial bycatch, the relationship between non-commercial and target stocks can be independent, mutualistic, or predatory. Here we ignore the mutualistic and predatory cases for simplicity.

firm's maximal profit, it will not be accepted without compensation from the NGO.

We assume there is only one NGO offering to purchase easements and many independent harvesters, and assume the NGO is indifferent as to which harvesters it obtains easements from. Given its monopoly position, the NGO can make all-or-none offers to all harvesters simultaneously. Each harvester is offered an easement $a \leq \bar{a}$ in exchange for a compensation payment that slightly exceeds the loss in harvest profit the harvester would experience in moving from the original equilibrium, or status quo, to a new situation in which all harvesters are bound by the same easement. The same offer is made to all harvesters simultaneously, with the proviso that compensation will be provided only if all agree to accept the easement; if any harvester refuses, the status quo remains in effect.[9] Because posteasement profit, including the compensation payment, exceeds the status quo profit for each harvester, each harvester's best response is to accept the easement. The NGO's compensation payment can, in the limit, be lowered to equal the profit differential between status quo and posteasement harvest profits. In the limit, the NGO can reduce its compensation to a level that exactly offsets the firm's profit loss and as a consequence all costs associated with granting easements are borne by the NGO.[10]

We assume that the NGO can observe the firm's choice of action a and the total level of the bycatch stock, X. The firm's choice of action b is hidden, so easements cannot be defined for this action. Action b might indicate the depth of fishing effort or the level of care taken to avoid bycatch or to minimise damage when handling it when a given type of observable gear is used. If a firm grants an easement restricting its use of action a, it will choose the level of b to maximise its profit subject to the easement and any applicable regulations. Individual firms can control levels of their own actions, but not the actions of others.

The NGO's objective is to achieve a target for the bycatch stock, $X(a_T, b_T; E) \geq \bar{X}$, at minimum cost.[11] Because the NGO compensates harvesters for any profit reduction resulting from easements, its optimal policy will maximise harvester profits (2) subject to the bycatch stock constraint (3) and subject to the firms' profit maximising choices of actions. We examine the cost and feasibility of marine easements under each of four regulatory regimes: sole ownership ($R = S$), a benchmark regime in which a single agent controls all actions that affect the commercial and bycatch stocks, open access ($R = O$),

[9] We are indebted to Howard Chong for suggesting this formulation of the NGO's strategy choice.

[10] As discussed in Section 2, the level of compensation for conservation easements over land is determined in the same way.

[11] If it fears the influence of unpredictable factors on the bycatch stock, the NGO may choose to buys easements that will achieve a greater degree of protection under average conditions, to have a degree of assurance that its goal will be met even under adverse circumstances. We do not model this explicitly, however.

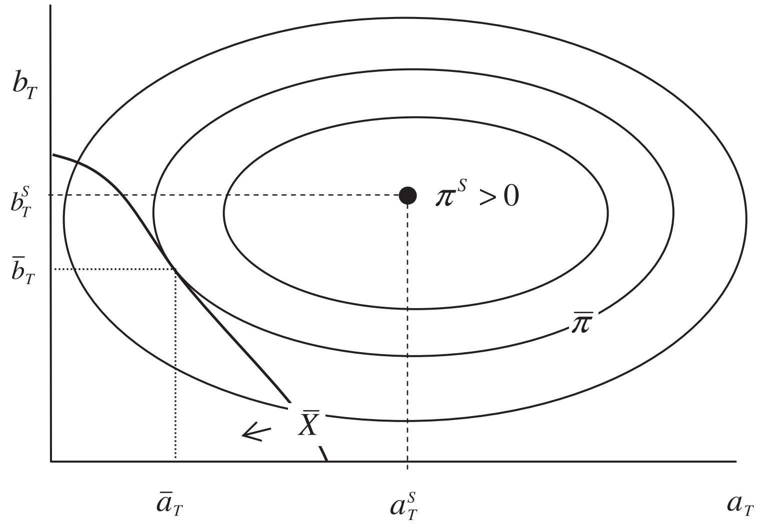

Figure 1 Firm's actions and NGO's constraint with sole ownership.

which places no restrictions on the actions of firms or their numbers, limited entry ($R = L$) which limits the number of firms but not their actions and an ITQ ($R = Q$) which limits the catch of individual harvesters. We also comment on the efficacy of marine easements under an ideal TURF system.

3.2 Marine easements with sole ownership

We first consider an idealised case of sole ownership in which the commercial and bycatch stocks share the same habitat. This habitat is governed by a profit maximising firm and no stock is affected by actions taken outside this habitat. The firm can choose fishery-wide levels for actions a and b and can therefore determine the level of the bycatch stock in the subhabitat it manages, subject to environmental factors, E.[12] Figure 1 illustrates this case. It shows the firm's profit contours as a function of its actions.[13] Absent an easement, the owner would choose actions a_T^S, b_T^S, achieving a maximum profit of π^s. The downward sloping dark line is the NGO's target for the bycatch stock and its downward slope implies both actions are detrimental. The case where b helps conserve the stock is considered later. Action combinations on or below this line achieve the NGO's goal. Assuming the NGO can observe the bycatch stock directly, it can define a 'performance' easement in terms of a bycatch stock outcome, $X(a_T, b_T; E) \geq \bar{X}$. The hidden nature of

[12] The firm also presumably chooses an optimal number of harvesting entities, e.g. vessels, which corresponds to N in the other regulatory regimes. We do not discuss this explicitly as it is of no concern for the main points we make regarding sole ownership.

[13] Concavity of the production function ensures that the iso-profit contours enclose convex sets.

action b is of no consequence because the easement is defined in terms of the outcome. The sole owner will maximise posteasement profit by choosing actions $\bar{a}_T$ and $\bar{b}_T$. The NGO pays $\pi^S - \bar{\pi}$ for the easement in this case.[14] Assuming the profit function is positive and strictly concave for all a, $b > 0$, the performance standard will meet the NGO's goal at minimum cost.[15] A real world institution that may approximate sole ownership is a TURF; if the relevant habitat is encompassed within the territory of a single TURF operator, then the preceding analysis and results will apply. Alternatively, a harvester cooperative that controls the entire harvest over a defined territory might effectively function as a sole owner.

3.3 Marine easements with open access harvesting

At the opposite end of the spectrum is open access, where firms are unconstrained in their choices of actions and free entry and exit guarantees that profit is zero in equilibrium.[16] The equilibrium number of firms under open access is denoted N^0. The only type of easement available in this case is a limit on the firm's use of action a, e.g. $a \leq \bar{a}$; action b is unobserved and no individual firm has the ability to control the overall level of the bycatch stock. A restriction on a necessarily lowers the firm's profit. The firm's pre-easement profit is zero, however, and the firm can always earn zero profit by exiting the fishery. Any firm granting an easement under open access will therefore choose to exit the fishery and will be replaced by a new entrant to restore the zero profit equilibrium. Consequently the NGO cannot accomplish any increase in X by using easements in the case of open access.[17]

Figure 2 shows the firm's profit as a function of its choices of actions. In cases where there are many harvesters, it is diagrammatically convenient to express the NGO's target, $\bar{X} \leq X(a_T, b_T; E)$, as a function of the action levels of an individual firm, as follows:

$$\begin{aligned} \bar{X} &\leq X(a_T, b_T; E) \\ &= x(a_T/N, b_T/N; N, E) \\ &\equiv x(a, b; N, E) \end{aligned} \tag{4}$$

[14] Considering the potential for bilateral monopoly, which arises because there is a single owner, would distract us from our central concerns, so we continue to assume the harvester captures no surplus from the easement transaction.

[15] If there are separate habitats governed by separate sole owners, the NGO's cost minimising strategy may involve paying a subset of these firms to shut down, with the result that their action levels are set to zero and their habitats become no-take zones. This could be efficient if the profit function is non-concave over a range of positive values for a and b, which might result when profit is negative over a range of actions and firms have an exit option.

[16] If profit were positive for some N, entry would reduce the individual firm's catch and profits until the profit is eliminated. A symmetric process would ensue if profit were negative.

[17] The equilibrium price of an easement is zero under open access because the firm earns zero profit both before the easement is granted and after it is granted and the firm has exited.

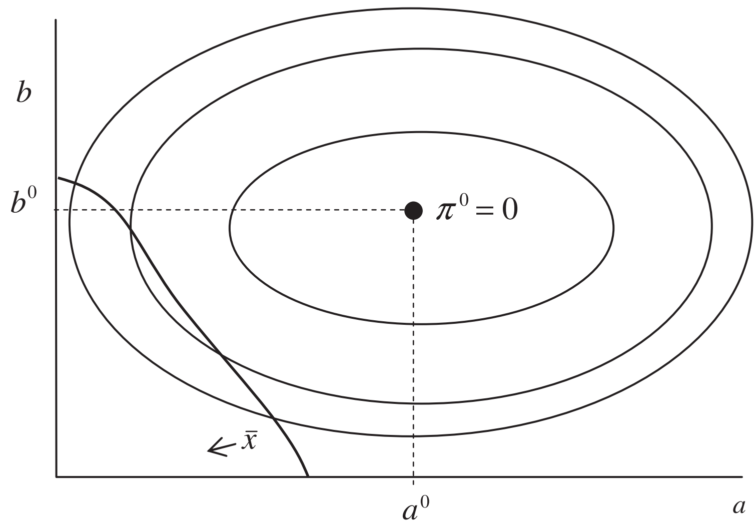

Figure 2 Firm's actions and NGO's constraint with open access.

where a and b without subscripts refer to the common action levels taken by identical individual firms. In equilibrium the firm chooses actions a^0 and b^0 and its maximal profit is $\pi^0 = 0$; all other profit contours reflect losses. The dark downward sloping line is now the NGO's target given that N^0 firms are operating. If the NGO tried to hit its target by buying easements restricting action a, the firm would incur a loss and be replaced by an entrant choosing exactly the same actions, so there would be no improvement in the bycatch stock.

3.4 Marine easements with limited entry

We next examine a simple form of limited entry that requires each firm to hold a license and fixes the number of licenses at a level $N^L < N^0$. The licensing requirement must fix some input used by the firm, e.g. one vessel per license, otherwise firms would be able to replicate all inputs and effectively circumvent the limitation. The specific input rendered scarce by the licensing requirement determines the firm's profit opportunities and input choices, and any profit earned is actually a rent attributable to the licensed input. In what follows we speak of capital per firm as the input constrained by the license requirement and assume the limit on licenses is sufficiently constraining that firms earn positive net revenue in equilibrium.[18] Because harvesters allocate effort independently under limited entry, the NGO cannot use a performance standard for the bycatch stock and must rely on easements on input a.

[18] An alternative form of limited entry fixes the number of licenses and imposes a TAC constraint and season closure when the constraint is met. In this case a race to fish will ensue and profit need not be positive in equilibrium. This type of limited entry regime is not considered here.

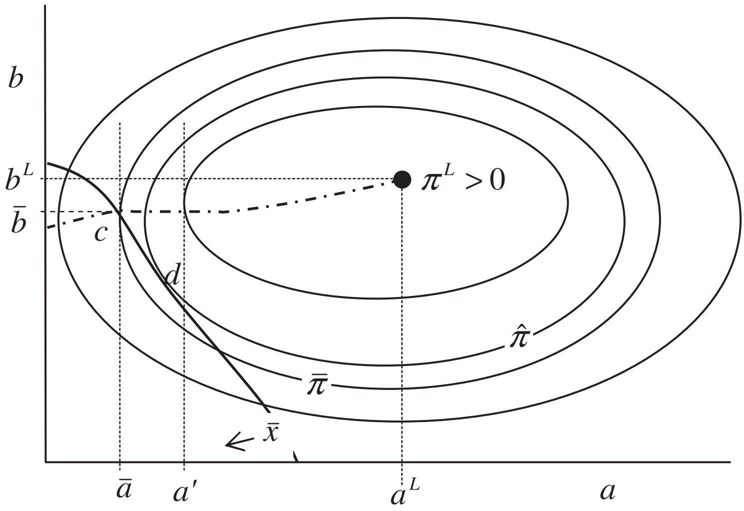

Figure 3 NGO's conservation options with limited entry.

We initially consider a case where all firms' profit functions are identical and strictly concave. In this case the NGO can do no better than to offer identical easements $a \leq \bar{a}$, to all licensed harvesters.[19] In the absence of easements the individual firm's choice of actions, denoted a^L, b^L, maximises (2) given $N = N^L$. If the NGO negotiates an easement specifying $a \leq \bar{a}$, the firm will respond by choosing action b to maximise (2) subject to this constraint. Each possible easement for a thus maps into a unique profit maximising choice for action b, which we denote $b = b^L(a, N^L)$. The level of b required to meet the NGO's target for a given level of a and $N = N^L$ can be found by inverting (4); we denote this function $b = \hat{b}(a, \bar{X}, N^L)$. If $b^L(a, N^L) = \hat{b}(a, \bar{X}, N^L)$ has a solution in a for $a < a^L$, then there is an easement that will meet the NGO's target under limited entry. If there is more than one solution, the NGO's cost minimising policy is the solution yielding the highest harvest profit. It is entirely possible, however, that no feasible easement exists. If the firm's response to an easement that reduces a is to increase b, this works against the NGO's desire to increase the bycatch stock. If the firm's adjustment to b is sufficiently strong, there may be no easement that enhances X enough to meet the NGO's goal.

The limited entry outcome is illustrated in Figure 3 for the case where action b is detrimental. If the NGO acquires an easement fixing the observable action at a', the firm will respond by setting b to maximise profit. This occurs at the vertical segment on the profit contour above a'. The dot-dashed line in

[19] This is an instance of the equal marginal cost principle for minimising the sum of costs across firms, where each individual firm's cost function is strictly convex. Assuming profits are strictly concave implies that either profits are positive throughout the range of actions considered or that firms cannot avoid negative profits by shutting down.

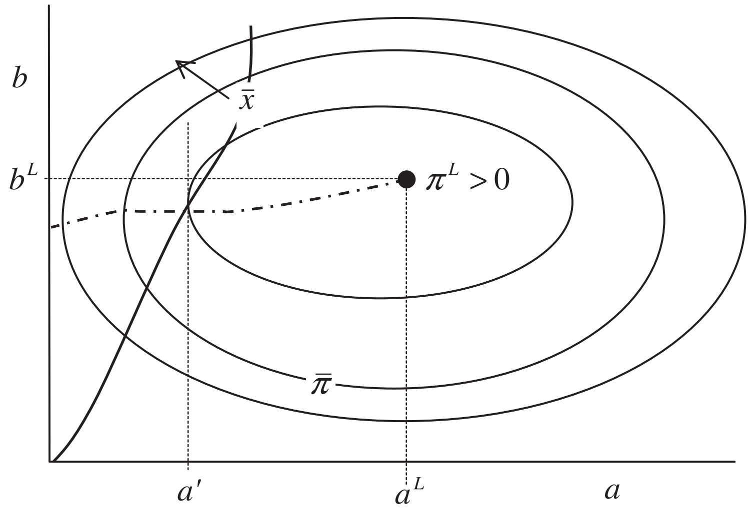

Figure 4 The limited entry case when action b is beneficial.

Figure 3 is an 'offer curve' that traces out the firm's profit maximising choice of b for each level of a. In Figure 3 the easement $a \leq \bar{a}$ achieves NGO's target at minimum cost, given that it cannot observe b, and the easement's price is $\pi^L - \bar{\pi}$. Here we see that if the NGO could observe b, it could instead contract for an outcome at point d and this would reduce the price of the easement by the amount $\hat{\pi} - \bar{\pi}$. If the NGO's constraint were more stringent, however, it might be impossible to reach it under limited entry by purchasing easements on action a. In Figure 3 this would be a case where the NGO's constraint lies below the offer curve. For completeness, Figure 4 illustrates a case where action b is beneficial to the bycatch stock. Combinations of actions above the $\bar{x}$ line meet the NGO's target. The NGO's minimum cost strategy is to negotiate an easement restricting a to a'.

In limited entry cases where the conservation goal can be achieved with an easement, the easement must be linked to the fishing permit rather than the specific firm holding it when the easement is granted. If the firm granting an easement left the industry for some reason, a new firm using the vacated permit must be bound by the same constraint.

3.5 Options under limited entry: identical easements vs. selective shut-downs

If some combinations of a and b yield negative profits and a firm can avoid these by shutting down, the NGO's marginal cost for achieving additional reductions in a and b from the firm in question goes to zero at the firm's zero profit point. In this case it may be less costly to shut some firms down by purchasing their licenses and retiring them than to obtain identical easements from all harvesters. We refer to this option as a policy of 'selective shut-downs'.

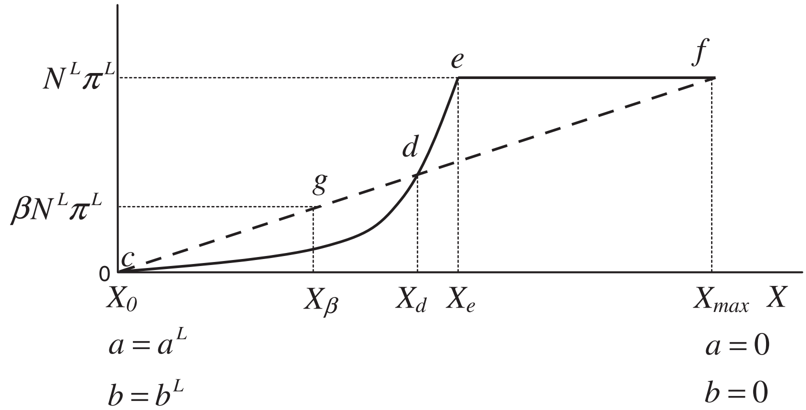

Figure 5 Identical easements vs. selective shut-downs with limited entry.

To see the principles involved consider successive increases in X, the NGO's target for the bycatch stock, and the outcome under limited entry. Figure 3 indicates that more stringent targets require more stringent restrictions on action a, leading to successively lower harvest profits and higher costs (foregone harvest profits) for the NGO. In Figure 5, the curve *cdef* shows the cost of achieving various targets, X, by obtaining identical easements from all N^L firms. For reference, point c is the 'no easement' outcome where profit equals the equilibrium level under limited entry. At point e harvesting has been eliminated and, from here, the bycatch stock can be increased without cost to its maximal level corresponding to point f.

When the number of harvesting firms is large, the cost of achieving various conservation goals by a policy of selective shut-downs can be approximated by *some* curve between points c and f. Notice that points c and f depict the same NGO actions under identical easements or selective shut-downs; all firms are shut down at point f and all are operating without easements at point c. The shape of this curve depends on the shape of the profit function (2) and the shape of the function that determines the bycatch stock, (3). We defer a detailed examination of this function to future research, and here consider its properties only in a special case. The case we examine is one where the bycatch stock function, (3), is linearly homogeneous in the actions, actions a and b are both detrimental, and the firms' choices of actions and their resulting profits are independent of the number of firms operating. While these assumptions, particularly on actions and profits, are clearly implausible, they establish a benchmark outcome that is useful in discussing what is possible in more general settings.

With these assumptions, suppose the NGO purchases and retires the fraction β of the existing licenses, so $(1 - \beta)N^L$ firms continue to operate. The choice of which licenses to retire is a matter of indifference to the NGO since all operators are identical, so the NGO arbitrarily designates a set of individual operators it wishes to shut down. It makes each of them an all-or-none offer, where the compensation offered is slightly greater than the firm's status quo profit from harvesting. As before, the NGO's offer is subject to the proviso that if the offer is rejected by any of the firms targeted, the offer will be withdrawn from all and the outcome will remain the status quo. Taking the offer is then the best response for each of the target firms. The NGO's offer can again, in the limit, be reduced to the point where it equals the target firms' harvest profit in the status quo situation. The assumption that firms continuing to operate do not alter their actions and that their profits are unchanged when the number of harvesters falls imply that the lost profit is simply $\beta N^L \pi^L$. The additional assumption of linear homogeneity implies that the bycatch stock will be found at the fraction β of the distance between X_0 and X_{max}, indicated by X_β on Figure 5. Point *g* therefore lies on the cost function for increasing X by selective shutdowns, under the maintained assumptions. Similar reasoning indicates that the entire curve, *cgdf*, is a straight line in this case.

Comparing the two cost curves provides insight as to which policy will be preferred in a given situation. Identical easements will be preferred if the NGO's conservation target falls between X_0 and X_d. For goals in the X_d to X_{max} range, it is cheaper to use selective shut-downs. The range of per firm conservation targets that would result in negative profits if firms continued to operate is X_e to X_{max}. When this range is large relative to the overall range of conservation targets (X_0 to X_{max}), selective shut-downs are likely to be the preferred choice.

The more plausible outcome is that the actions and profits of firms continuing to operate increase following a shut down of some harvesters. We examine the likely effects of these adjustments in two steps. First, the 'spillover' increase in per-firm profit lowers the social cost of achieving any bycatch target.[20] If this profit is realised, but firms do not adjust their activity levels upward, the effect is to pull the cost curve *cgdf* downward. (Logically, the curve must still pass through points *c* and *f*, however.) This reduces the cost of achieving any target and expands the range over which selective shut-downs are the preferred choice. In highly over-capitalised fisheries, reducing the number of operators might even *increase* overall harvest profits, which represents a negative cost for achieving a conservation goal via selective shut-downs. (The curve *cgdf* would lie below the horizontal axis for a range of targets in this case.) Second, if firms adjust actions upward in response to a decline in the number of active harvesters, the bycatch stock resulting from a given number of shut-downs is reduced. This factor drags the cost curve left, partly undoing the gain resulting from increased profits. The conservation NGO could attempt to negotiate easements with the remaining firms, to avoid this response, but this will be frustrated by the inability to observe *b*. A

[20] This raises a possibility for the NGO to lower its costs of achieving any goal by facilitating lump-sum payments from the 'spillover' profits, earned by the firms that keep fishing, to those that are shut down.

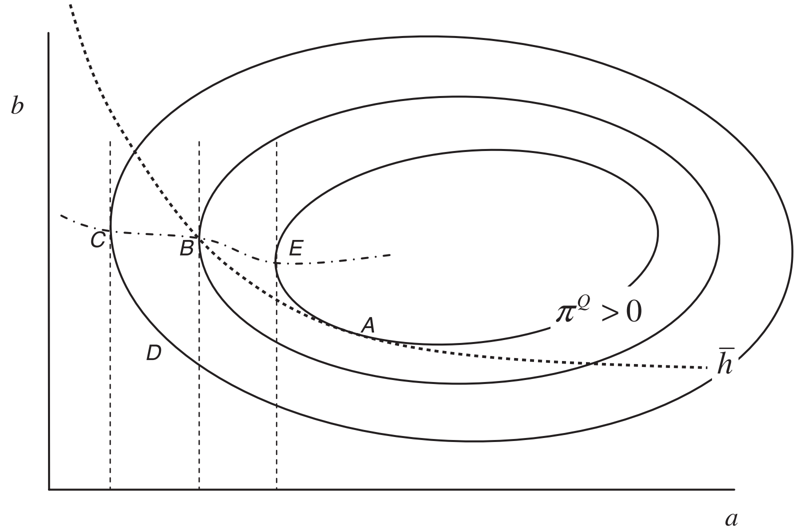

Figure 6 Firm's actions and NGO's constraint with ITQ regulation.

practical solution might be to purchase or lease the remaining vessels and operate them in a way that avoids this second kind of slippage.

3.6 Marine easements with ITQ regulation

When considering ITQ regulation we simplify by assuming all firms are identical and each receives an identical allocation of harvest rights $\bar{h}$. In this case there will be no trade of harvest rights in equilibrium and each firm will use its endowment. We also assume that any easement policy implemented by the NGO involves treating all active participants in the fishery identically. The ITQ policy requires $h(a_i, b_i; Y, N, R) \leq \bar{h}$, which constrains the firm's choices of actions to lie on or below the $\bar{h}$ isoquant depicted in Figure 6.[21] This catch level is assumed to maximise overall profit in the industry and $\pi^Q > 0$ is the resulting profit level for all firms. The profit contours drawn in Figure 6 show perceived profit opportunities for the firm, taking as given the catch levels of all other harvesters. While each firm perceives a profit opportunity from departing from the ITQ constraint and choosing actions interior to the π^Q contour, these outcomes cannot be attained by all firms acting identically. The firm's profit maximising choice of actions occurs at point A. Assuming the catch level was optimally set by the regulator, the result is a first-best optimum with respect to harvest of the target species.

Because an individual firm cannot determine the bycatch stock level under ITQ regulation, the NGO's only option is to negotiate for reductions in observable action a. To see the outcome, consider what would happen if the NGO offered to buy easements specifying various levels of a and ignored the

[21] For simplicity we assume profit is positive at all points on the isoquant.

ITQ constraint. The firm's responses would follow an offer curve of the kind sketched in Figures 3 and 4, shown as the dot-dashed line *EBC*. Outcomes in the segment *EB* are not feasible because they violate the ITQ constraint; outcomes in the *BC* segment are feasible. Starting at point *A*, suppose the NGO offers to purchase an easement that would marginally reduce action *a*. So long as the firm's marginal profit from hidden action *b* is positive, it will respond by reducing *a* and increasing *b*. This is represented by a movement along isoquant $\bar{h}$ from *A* toward point *B*. At point *B*, however, the marginal profit from hidden action *b* is zero and further movements to the north-west along the $\bar{h}$ isoquant would reduce profit. The firm's optimal response to easements restricting *a* below what is indicated by point *B* are given by points on the offer curve. Overall, the firm's response to various easement offers is shown by line *ABC*.

The NGO's target has not been shown to avoid cluttering the figure, but it is clear that that several outcomes are possible. First, the $\bar{x}$ constraint may intersect the firm's offer curve in segment *AB*, in which case an easement on observable action *a* can achieve the NGO's goal and the firm's resulting catch will exhaust its ITQ allocation. A second possibility is that the NGO's constraint intersects the firm's offer curve in a segment such as *BC*, where the ITQ constraint is not binding. In this case, the NGO's easement on action *a* causes the firm to reduce its catch below its ITQ allocation, so the ITQ constraint is no longer binding and the posteasement ITQ price becomes zero. The third possibility is that the firm's offer curve does not intersect the NGO's $\bar{x}$ constraint at all. In this case the NGO cannot reach its target if easements on *a* are its only policy instrument.

If the NGO can negotiate easements on *a* and simultaneously purchase and retire ITQ shares, however, then it can achieve any desired goal and do so at minimum cost. For example, suppose the NGO's goal is most efficiently met by going to point *D*. The NGO could achieve this outcome by proceeding in two steps. First, purchase and retire sufficient harvest quotas to reduce catch to the isoquant that intersects point *D*. Given this catch constraint, the firm's optimal choice of actions will be at a point where the relevant isoquant is tangent to a profit contour. In all likelihood this tangency will not occur at point *D*, so the firm would choose a different mix of actions. If so, the NGO can take a second step and purchase an easement restricting the firm's use of *a* to achieve the outcome at *D*.[22]

Some additional comments on these conclusions are in order. First, the NGO's constraint may intersect the firm's offer curve more than once, in which case the NGO's optimal policy is the one that meets the constraint with the minimum sacrifice in harvest profits. Second, if the intersection

[22] With only a single hidden action and a catch function (2) that links observed actions (*a*), catch (*h*), and the hidden action (*b*), fixing both *h* (by purchasing catch quotas) and *a* (by purchasing easements) suffices to determine *b*. If more than one action is hidden, achieving the minimum cost outcome in this fashion is not possible.

occurs in segment *BC*, so the firm's entire ITQ allocation is not used, the firm might seek to sell the unused portion of its ITQ allocation to an outside firm. This raises an important point: when the NGO uses easements on *a* to achieve its goal, the easements must encumber the *ITQ allocations*, rather than the firms holding them when the easement is negotiated. This ensures that if the firm granting the easement were to shut down or sell part of its catch allocation while continuing to operate, the acquiring firm would be encumbered by the same constraint the original firm negotiated.[23] Simply stated, the easement must apply to the ITQ allocation regardless of which firm holds it.

4. Discussion and conclusions

Our analysis of marine easements as a tool for meeting marine conservation goals is motivated by the impressive growth of conservation easements in the US and by TNC's recent purchase of commercial trawling vessels and permits in central California. The model we develop suggests easements will be a cost-effective alternative to the purchase-and-retiring of permits, provided conservation goals can be met in conjunction with commercial harvest and that a legal framework is in place to make easements enforceable. Whether easements will be more cost-effective than a policy of buying permits and leasing them on a temporal basis to fishermen with restrictions depends on tradeoffs that should be the subject of future research. On one hand, easements better exploit the specialisation advantages that commercial fishermen may have in owning and exercising permits. On the other hand, temporal leases let NGOs experiment with different restrictions and adapt lease terms to new information. We expect the relative advantages of each approach to vary across fisheries depending on the importance of specialisation and adaptation.

Although further research on the feasibility and design of marine easements is merited, three strong conclusions emerge from the present analysis. First, effective marine easements must apply to the permit or right in the same way that terrestrial easements 'run with land'. This is true for each of the regulatory regimes we consider (limited entry, ITQ, and sole ownership), and it is a key distinction separating easements from more typical contractual agreements. If easements do not burden the permit, the costs to NGOs of meeting conservation targets will be increased and attempts at conservation will be frustrated by turnover in the fishery.

Second, marine easements are most valuable if the NGO has flexibility to amend and sell easements back to the fishermen who own the encumbered harvest rights. This flexibility is lacking with conservation easements, which perpetually separate land ownership, but it can be especially important in fisheries where institutional rules are rapidly changing. As some fisheries

[23] This analogous to the legal requirement that conservation easements 'run with the land'.

move from limited entry to ITQs, for example, an NGO may find it advantageous to shift their financial resources away from limited entry fisheries and into ITQ fisheries. Also, such a regulatory shift would shift the easement that is optimal for meeting the conservation goal. Flexibility is important even in the absence of institutional change because factors such as biological knowledge, harvest technologies, and prices for harvested species are likely to change over time. NGOs will want to adapt to this new information, possibly by selling easements back to encumbered fishermen and reinvesting the proceeds in other conservation stocks. Because laws concerning marine easements have yet to be written, it is important to study these and related advantages of flexibility now.

Third, our analysis shows that greater delineation of harvest rights implies greater scope for marine easements to accomplish conservation goals efficiently. This is intuitively clear when we compare the performance of easements under theoretical open access and sole ownership regimes. Easements under the former will accomplish nothing, while easements under the latter will achieve conservation goals at minimum cost. Applying this logic to real-world institutions suggests greater prospects for effective marine easements as we move along the completeness-of-rights continuum from limited entry, to ITQs, and possibly to TURFs. However, we note that overcapitalisation within some limited entry fisheries may create opportunities for NGOs to achieve conservation goals within these fisheries while at the same time increasing profits per fisherman. This counterintuitive outcome may be feasible if the NGO uses a policy of selectively shutting down some permits in the overcapitalised fishery.

Our analysis also raises a number of questions that could be the subject of future research. It is a practical necessity to ask which legal constraints exist that might limit the use of marine easements in different fisheries. Are there limitations on who can 'participate' in a fishery and is an NGO 'participating' by owning easements? Could legal rules prohibit easements from encumbering a permit or ITQ when the identity of the permit or ITQ owner changes? Considering the possibility of institutional or regulatory change, can marine easements be framed so that they will respond to such change and remain effective? For example, how could the terms of an easement on a limited entry permit be modified to appropriately encumber an ITQ? In terms of technical extensions, would the implications of our model substantively change if one incorporates bio-economics concerning the growth of stocks, the possible interactions between stocks, and the possibility of stochasticity in conservation outcomes?

A research extension that is of particular interest to us is one that analyses the benefits that could be achieved by negotiating easements with harvester associations or cooperatives, as opposed to individual harvesters. For the NGO, there appears to be a tradeoff. On one hand, a cooperative will have greater market power that it can use to command higher easement prices. On the other hand, a cooperative could internalise some decisions that would otherwise remain external in negotiations with individual vessel-owners. For example, an NGO might negotiate a performance standard easement with a cooperative, especially if the cooperative could act as if it were a sole owner over the relevant habitat. Even if performance easements were not feasible, the costs to the NGO of monitoring restrictive easement compliance could be much lower if the easement was granted by a cooperative rather than by individual fishermen.

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