ITQs for Bycatches

Lessons for the Tuna-Dolphin Issue

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1. INTRODUCTION

Bycatch is a term used for catches of fish species that are not targeted. Bycatches occur because fish cannot be caught selectively, except perhaps at a cost. In the latter case the problem becomes one of comparing the cost of disposing of bycatch once it occurs and the cost of avoiding it.

There are different kinds of bycatches, or different reasons why a particular kind of fish (or marine mammal) is a bycatch. In fisheries where more than one species of fish are caught indiscriminately (or selectively only at a cost), fishermen naturally go for the type of fish that gives them the highest revenue for their effort. In fisheries where many valuable species are caught simultaneously it can be a tricky question to define what is a bycatch and what is not; rare items of highly valuable fish would not be unwelcome, but once fishermen are up against hold constraint or on-board processing constraints it can make good economic sense to throw away marketable fish to make space for more valuable fish. This is usually referred to as highgrading or discarding and not as bycatch.

In this paper I will use the term bycatch for fish species (and marine mammals) that are not desired and would therefore ordinarily be discarded. There are different reasons why capturing a certain type of fish would be undesirable. First, even marketable fish may not be desired because it requires too much effort to prepare or preserve them for the market. This is often the case for shrimp trawlers which typically catch a variety of fish in addition to shrimp but are only equipped for handling and preserving shrimp. Second, certain groups of fishing boats are authorized to take certain kinds of fish but not others, even if the latter are marketable. Vessels trawling for Alaska pollock get some salmon and halibut in their trawls but are prohibited from marketing them because these fish are reserved for other types of boats. In cases like this bycatch is caused by regulations which would seem to be the problem rather than the fish catches, but it could also be the case that the pollock trawlers are not equipped for handling these catches and so they are unwanted anyway. Third, there are fish (or marine mammals) which have no commercial value and are therefore not desired and hence discarded. When discarding requires some effort, the bycatch is a nuisance which fishermen have some incentive to avoid if they possibly can.

This paper deals with the last type of bycatch. It is inspired by the tuna-dolphin problem, arising from the fact that dolphins often follow shoals of tuna and get caught in purse seines set on such shoals. This case is a bit more complicated, however. Dolphins do not have any market value for tuna fishermen but help in locating tuna shoals. Fishermen therefore have an incentive to set their seines on dolphins, since it is likely that they indicate the presence of tuna. Since dolphins have no market value, fishermen are probably indifferent to the killing of dolphins in this process, except that it may cost them some effort to get rid of entangled dolphins from their nets. The problem arises because killing of dolphins is deemed undesirable and prescribed to be kept under control by the Marine Mammal Protection Act.

Different methods have been used in controlling bycatch in different fisheries. Some fisheries are closed down if the bycatch exceeds a certain share of the total catch volume (e.g., cod juveniles in Norwegian shrimp fisheries), certain areas are closed for fishing at certain times (e.g., New England gillnet fisheries, to avoid catches of harbor porpoises), in some fisheries certain gear designs are prescribed (e.g., turtle exclusion devices), and in the tuna fisheries there are observers on board the vessels and release of captured dolphins is required. Common to all of these is that they seek to keep the bycatches below a certain level, but accept that bycatches cannot be eliminated altoghether.

Given that a certain maximum level of bycatch is deemed acceptable, it would be possible to frame bycatch regulations as a maximum total quota on bycatches, much as the total catch of targeted fish species is regulated by a total quota. Since gains in efficiency can be attained by dividing such quotas into units and making them transferable, a similar arrangement would seem to be desirable also for bycatch quotas. Bycatch quotas are, however, of a nature somewhat different from what has come to be known as individual transferable quotas (ITQs). ITQs promote economic efficiency through incentives to maximize the value of a given catch and minimize the cost of taking it, including investment in fishing boats. Many empirical studies have documented such gains in efficiency (e.g., Fox et al., 2003; Dupont et al., 2004).

Bycatch quotas on the other hand have nothing to do with incentives to maximize the value of the catch or minimize the cost of taking it. Instead, bycatch quotas are more akin to quotas intended to limit the emission of harmful substances such as sulfur dioxide or carbon dioxide. An overall quota limits the overall volume of emissions. Allocating the overall quota to firms responsible for the emissions helps implementation and determines how the losses from reducing the emissions are shared among the firms. Making the quotas transferable minimizes the economic losses resulting from any given cutbacks in emissions. An overall bycatch quota would limit the total bycatch, and allocating it between firms would help implementation and determine how the disturbances suffered by the fishing industry are shared among the firms. Making these quotas transferable would, just as with emission quotas, minimize the losses from limiting the bycatch.

In this paper I shall look at how individual transferable bycatch quotas could promote efficiency. I will assume that such quotas are set at a correct or at least acceptable level of bycatch, but not deal with how this level should be determined. The basis for the argument is that there will be some distribution of individual quotas among the fishing boats that would minimize the economic loss that limitation of the bycatch will cause, but the fisheries managers typically have no way of knowing what that distribution is. Unrestricted buying and selling would on the other hand provide incentives to achieve such a distribution, as those who can attain the greatest catch value with a given bycatch quota are the ones who are able to pay the highest price for it.

There are two settings in which transferability would achieve efficiency gains. First, even if bycatches are a totally random process, in-season transferability could be helpful in realizing efficiency gains. Second, and more obviously, if fishermen are not equally skilled in avoiding bycatches, transferability would direct the quotas to those who are better at doing this than others, and so catches would be maximized for any given total bycatch. Before discussing these cases, I will briefly review the literature on bycatch quotas. Then, in Section 3, the case of random bycatch will be discussed, and in Section 4 the case with different skills at avoiding bycatch. Finally, Section 5 concludes with a discussion of how this might apply to the tuna-dolphin issue.

2. A REVIEW OF THE LITERATURE

There are few studies of individual transferable bycatch quotas in the economic literature. One undoubtedly important reason is that such quotas have nowhere been tried. There are not many examples of bycatch quotas either, the only one I know of are the bycatch quotas for dolphins in the Eastern Pacific tuna fishery. These are not transferable.

The first and, to my knowledge, only theoretical paper on this issue is by John Boyce (1995). In his model, one species is a bycatch in a particular fishery, but could be a targeted catch in another fishery and thus commercially valuable. He shows that ITQs for both species could achieve within-season optimality (his model is not dynamic, but intertemporal optimality can be thought of as being achieved by an adequate total catch quota for each season). He points out that this will not be true if the bycatch species has existence value; i.e., value as such, even if it has no commercial value. This is not necessarily a relevant argument; one can think of existence value being taken into account in the setting of the total bycatch quota. He also points out that the optimality properties are not unique to an ITQ system; the same could be achieved by taxes.

The background for Boyce's paper is the arrangement where a group of vessels is authorized to catch one or more fish species but not other species of commercial value, which are being reserved for other vessel groups. An example is the North Pacific pollock fishery which inadvertently captures other valuable species reserved for other fisheries, such as salmon and halibut. In two related papers, Larson, House and Terry (1996, 1998) showed how the marginal value of bycatch quotas could be calculated and an optimal bycatch quota established, but stopped short of considering a set of fully-transferable quotas à la Boyce.

Guillermo Herrera (2005) discusses various types of bycatch regulations. Bycatch quota is not one of these, but he discusses a catch value quota which includes the value of bycatch. This is consistent with the bycatch being of a kind similar to what occurs in the Alaska pollock fishery and others where it has a commercial value and is marketed but is for some reason not supposed to be taken. It is also possible to interpret his paper as dealing with the case where no particular species is targeted a priori, but some fish are discarded to maximize the value of the catch under given time or capacity constraints.

A recent and empirically oriented paper is by Kathryn Bisack and John Sutinen (2006). In response to the Marine Mammal Protection Act the New England gillnet fishery has been regulated by time and area closures, in order to limit bycatch of harbor porpoises. Bisack and Sutinen compare this to regulation by ITQs for porpoise bycatches. They use an optimization model grounded in microeconomic theory; fishermen are treated as profit-maximizers under the relevant constraint, time/area closures versus bycatch ITQs. Model relationships were estimated from available data and predictions compared with observed landings. The model was run both with area and time closures to satisfy given bycatch constraints, and with porpoise ITQs for the same overall bycatch constraints. The results showed that ITQs generated higher profits, but also lower total catches, which is surprising; one would have expected the benefits of bycatch ITQs to consist in a greater catch for any given bycatch constraint (this is what happens in a simple theoretical model used for illustration below). The ITQ regime also results in fewer closures of areas and time periods.

3. RANDOM BYCATCHES

Assume a fishing season of length T. Let fishing be a discrete event, with one trip per unit of time. Bycatch occurs with a probability p for each trip. There is a bycatch quota of K units per vessel, and if bycatch occurs one unit of quota is exhausted. There are N boats with an equal bycatch quota each, and the boats continue fishing either until the quota has been exhausted or the fishing season has ended. The minimum length of the fishing season (number of trips) is *K*, which would require that the first *K* trips have resulted in a bycatch, so the probability of this is

Prob($S = K$) = p^K,

where *S* is the actual length of the fishing season (number of trips). During the last trip, bycatch must necessarily occur. The probability that the fishing must be halted after *K*+1 periods is

$$\Pr\text{ob}(S = K+1) = p^{K-1}(1-p)\,p + \ldots + (1-p)\,p^{K-1}p = \frac{K!}{(K-1)!\big(K-(K-1)\big)!}(1-p)\,p^K$$

and in general

$$\Pr\text{ob}(S = K+s) = \frac{(S-1)!}{(K-1)!\big(S-1-(K-1)\big)!}\,p^K(1-p)^{S-K}\ ,\ s \geq 0$$

The expected number of fishing trips (E*S*) will be the minimum *K* plus the sequence of the remaining years up to *T*, each term multiplied by the probability that the fishing has not yet been stopped:

$$\text{E}S = K + \sum_{L=K+1}^{T}\left[1 - \sum_{s=0}^{L-K-1}\big(\Pr\text{ob}(K+s)\big)\right]$$

For simplicity, I assume that the value of the catch from each trip is unity. Now consider some period S^* ($K < S^* < T$) in the fishing season. Some boatowner has been unlucky and exhausted his quota while the others have some left of their quota. The expected value from transferring one quota unit to the unlucky boatowner is

$$X_1 = 1 + \sum_{L=2}^{T-S^*}\left[1 - \sum_{s=0}^{L-2}\big(\Pr\text{ob}(1+s)\big)\right]$$

$$X_2 = K^* - 1 + \sum_{L=K^*}^{T-S^*}\left[1 - \sum_{s=0}^{L-K^*}\big(\Pr\text{ob}(K^*-1+s)\big)\right] - K^* - \sum_{L=K^*+1}^{T-S^*}\left[1 - \sum_{s=0}^{L-K^*-1}\big(\Pr\text{ob}(K^*+s)\big)\right]$$

Numerical calculations show that the sum $X_1 + X_2$ is positive but approaches zero as the time horizon is extended. Hence a mutually beneficial trade in quotas is possible, but the scope for mutually beneficial trade lies in the time constraint on the fishing season. There is the risk that somebody will have an unused quota at the end of the season, and so it would have been beneficial to transfer this to someone else who exhausted his quota early in the season. Without any time constraint on the fishing season, a boatowner would always be able to use a quota allocation, and in the absence of discounting there would be no room for mutually beneficial trade. From this follows that a quota transfer will be beneficial to the extent it helps extend the fishing season for all boats, preventing some of them from being barred from fishing because they were unlucky enough to exhaust their quota before the season was over.

These points can be illustrated by a simple simulation model. The model compares two situations, one in which quotas are not transferable between boats and each boat must stop fishing as soon as the bycatch quota has been exhausted, and another where the bycatch quota is common and the fishery is not stopped until the total bycatch quota has been exhausted. The latter solution can be envisaged as resulting from transferability, since it will always be beneficial, in terms of expected values, to transfer a unit of quota from a boat that has some quota left to a boat that has none.

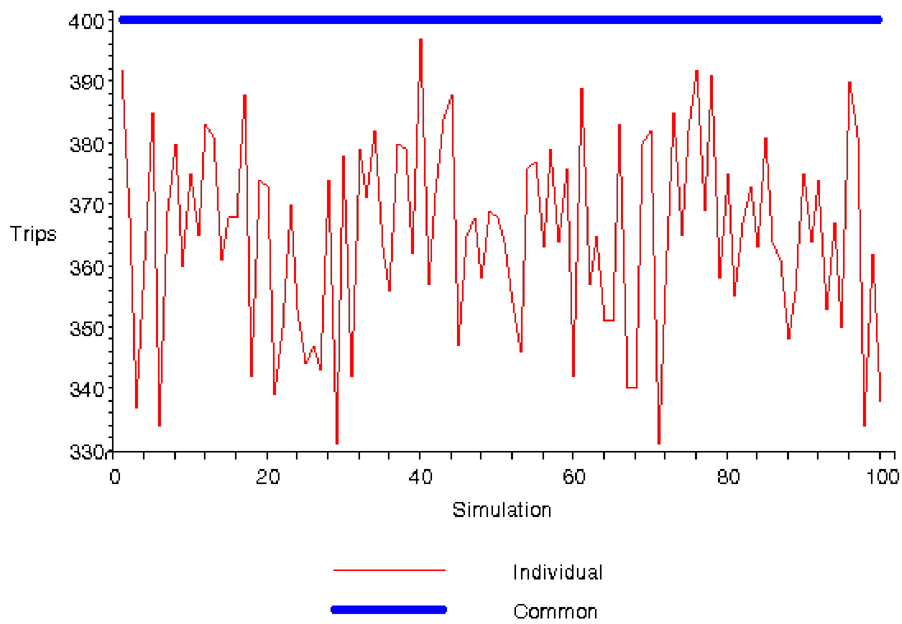

Figure 1: Number of fishing trips with individual, non-transferable bycatch quotas and a common quota. $p = 0.1$, with $N = 20$, $K = 3$ and $T = 20$.

Figure 1 shows a solution where $p = 0.1$, with $N = 20$, $K = 3$ and $T = 20$. A common quota would make it possible for all boats to fish throughout the fishing season, which allows for 400 trips (TxN). There are 100 simulations, represented along the x-axis. In all cases some boats would have to stop fishing before the fishing is over, and in some cases the number of trips is just above 330, just above 80 percent of the maximum.

If we increase the probability of incurring bycatch during a trip to $p = 0.3$ the advantage of a common quota virtually disappears (Figure 2). The number of trips is almost the same with and without a common quota (87.3 and 87.4, respectively, on average). In this case the common quota is not very helpful in allowing the boats to fully utilize the entire fishing season. Similarly, if we extend the fishing season, the advantage of the common quota disappears. This is illustrated in Figure 3 where the number of trips is on average virtually the same in both cases (595 and 594.5). In fact individual non-transferable quotas sometimes result in a larger number of trips, which is due to some boats being more lucky than others. It would be desirable to let the lucky boats continue fishing, but the problem is that we have no way of knowing ahead of time which boats will turn out to be lucky.

The example also illustrates that in this setting of a purely random bycatch, individual quotas would not be necessary; all that is needed is a common quota and monitoring of the fishery so that it will be shut down once the common bycatch quota has been exhausted. But should individual quotas nevertheless for some reason be applied, it would make sense to allow transferability in order to realize a solution similar to that obtained with a common quota.

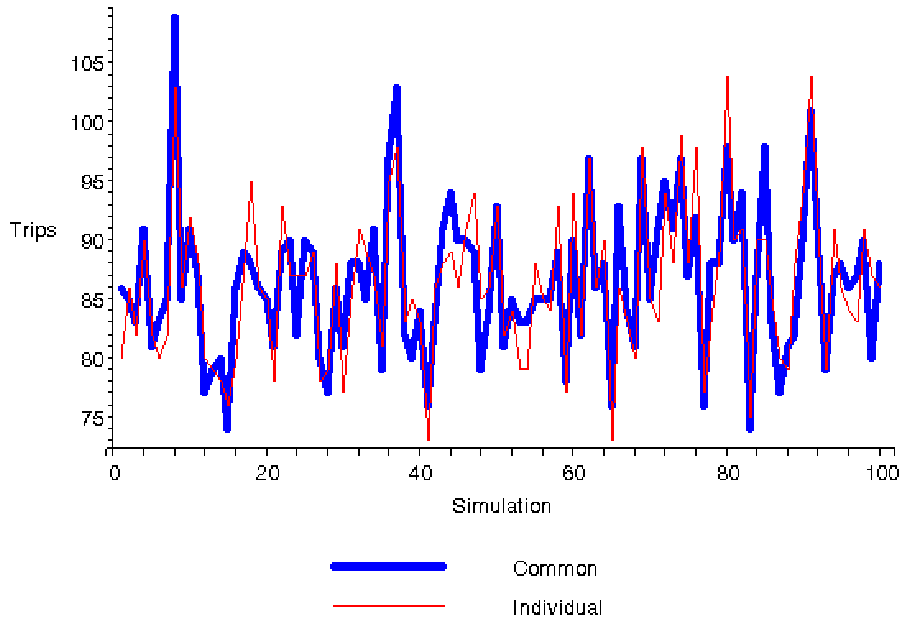

Figure 2: Number of fishing trips with individual, non-transferable bycatch quotas and a common quota. $p = 0.3$, with $N = 20$, $K = 3$ and $T = 20$.

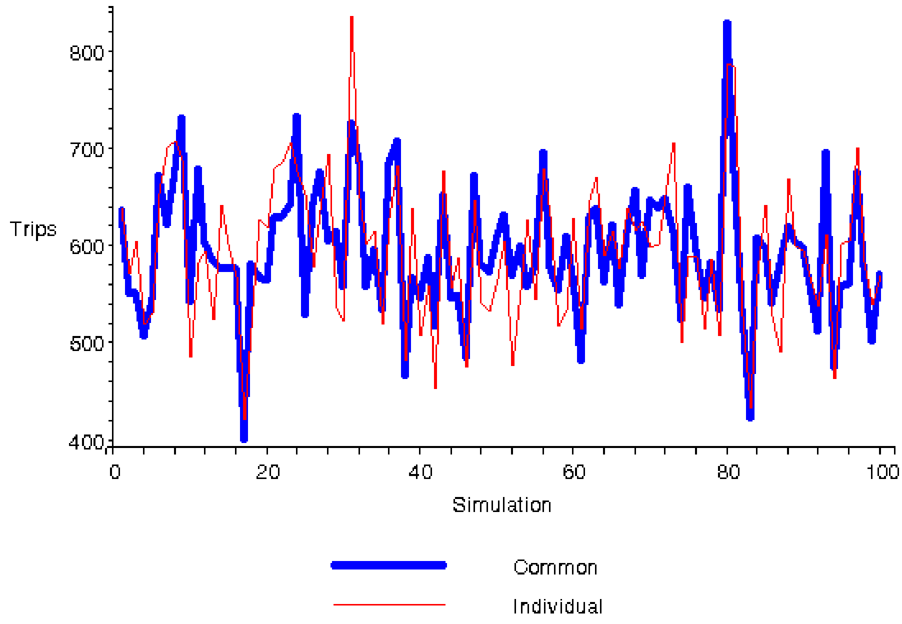

Figure 3: Number of fishing trips with individual, non-transferable bycatch quotas and a common quota. $p = 0.1$, with $N = 20$, $K = 3$ and $T = 100$.

4. DIFFERENCES IN SKILLS TO AVOID BYCATCH

The case for transferable quotas if there are efficiency differences between the boats is a variant of a more general case which has been made an innumerable number of times; transferability will allow more efficient producers to buy pollution permits (here, bycatch permits) from less efficient producers and so a greater (or more valuable) production will be accomplished for a given amount of pollution. The total amount of pollution is assumed to be set at an optimal or at some acceptable level. Given that level, it makes obvious sense to minimize the cost, i.e., production value foregone. This section purports to no more than illustrate this general point once again.

Suppose catches of targeted fish (*y*) necessarily result in some bycatch (*q*). The boat captains and crew differ, however, in that some are better able than others to avoid the bycatch. For boat *i* we have

$$q_i = a_i y_i \,,\ 0 < a_1 < a_2 < ... < a_N$$

Suppose the length of the fishing season constrains the amount of fish that can be caught and that this is the same for all ($\bar{y}$). This determines the volume of bycatch:

$$\sum_i q_i = \bar{y} \sum_i a_i$$

Now suppose that the bycatch is reduced to $\bar{Q} < \sum_i q_i$ and that this is accomplished by allocating to each boat a bycatch quota $\bar{q} = \frac{\bar{Q}}{N}$. This will constrain the catch to

$$\sum_i \frac{\bar{q}}{a_i} < N\bar{y}$$

with those who had the largest bycatches suffering most of the reduction in catch. An even allocation of the bycatch quota may thus be regarded as unjust and a proportional reduction in all bycatches as more acceptable, as all would share the cost in equal proportion in the latter case.

Making the quotas tradable would allow gains in efficiency, irrespective of how the bycatch quotas are allocated, as long as the boats with largest bycatches in the absence of quotas get some. In case the quotas are allocated evenly to all, this would compensate the latter, whose production would be most severely reduced by the quota. The value of an additional bycatch quota is $1/a_i$ and thus highest for the boats whose crew and captain are most skilled at avoiding bycatches. They would therefore be able to buy quotas from others at a price the latter find acceptable, and we would end up with a situation where only those who are most able to avoid bycatches fish and the others sell their quotas. Since those who are best able to avoid bycatches catch more fish for each unit of bycatch quota than others, the production of fish would increase.

These points are illustrated by the following simple example. Suppose there are 11 boats, each producing one unit of fish. The a_i coefficients are as follows:

$$a_i = \frac{1}{1+0.1(i-1)}, \text{ i = 1, ..., 11}$$

In the initial situation, Y = 11 (each boat produces one unit of fish), which results in a bycatch of 16.5 units. It is now decided that this should be reduced by one half, to 8.25. Allocating each boat the same share of this would reduce the total catch by almost one half, or to 5.8. The reduction would be greatest for the least efficient boats, as shown in Figure 4.

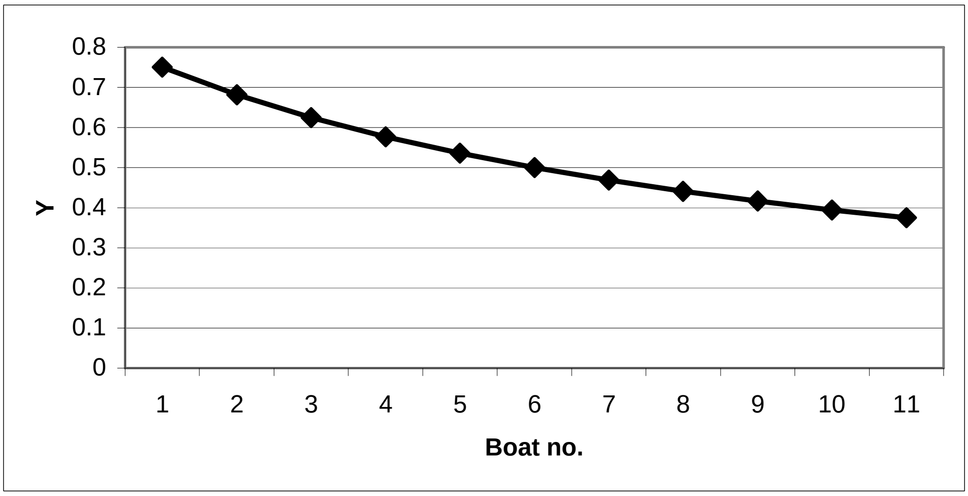

Figure 4: Catch of each boat with equal bycatch quotas.

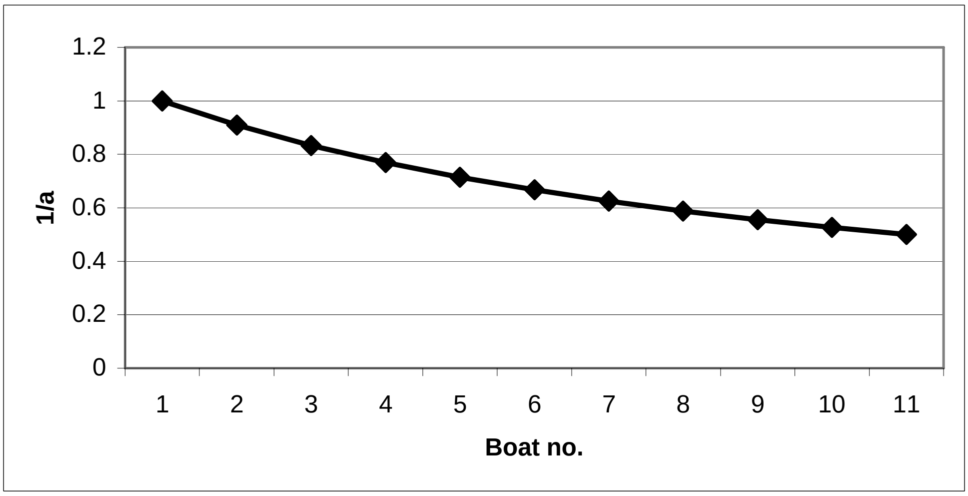

Figure 5: Marginal value (1/*a*) of a bycatch quota.

Figure 5 shows the value of an additional quota for the boats. Since this is constant in this particular case, the most efficient boats would buy quotas up to the limit set by the maximum catch they can take in the season (y = 1). The first boat would buy a_1 - 8.25/11 = 0.25, the second a_2 - 8.25/11 = 0.35, etc. The least efficient boats would sell all their quota, 8.25/11 = 0.75 each. From this we find that the six most efficient boats would buy in total 3 quota units, which is exactly what boats 8 to 11 would sell. The equilibrium price would be the marginal quota value for the 7th boat, which is 0.625, making the boatowner indifferent as to whether he would buy or sell. The total production would be 7, with the 7 most efficient boats producing at full capacity and the others not at all. Hence, for a given bycatch quota, total fish production would increase.

5. CONCLUSION

What conclusions can we draw for the tuna-dolphin issue? It is highly likely that transferable quotas of dolphin bycatch would be helpful to minimize the losses caused by the limitation of dolphin mortality. Presumably this limit is set on the basis of what is an acceptable mortality, and with that as a given it makes sense to minimize the loss to the industry imposed by this limit. Individual transferable quotas are particularly relevant when there are skill differences among boat captains and crew in avoiding killing dolphins. Such differences do exist and appear to be of considerable magnitude (Hall, 1998; Hall et al., forthcoming). It is likely that captains better skilled at avoiding dolphin mortalities would be willing to buy dolphin quotas from less skilled captains at a price the latter would find acceptable. This would result in a greater catch of tunas for the given level of dolphin mortality.

If the killing of dolphins is a purely random process (which however appears not be the case) there is little or no need for individual quotas. In Section 2 it was shown that a common quota would probably be superior to individual non-transferable quotas. Transferability is, however, likely to result in the same solution as the common quota, but is not necessary unless the total quota is allocated to the individual boats.

Returning to the case of differences among boats, how would a dolphin quota system work over time? Dolphin quotas will most likely have to be changed over time, in response to the development of the dolphin stocks affected. An increased dolphin stock could sustain a higher mortality, but there are ethical reasons why it may be desired to keep this mortality as low as possible. Over time, dolphin quotas would provide incentives for development in technology and skills to avoid killing dolphins. Transferability is not required for this; the loss from having to cease fishing because the dolphin quota has been exhausted seems powerful enough. In fact, a very impressive development in technology and skills to avoid killing dolphins seems to have taken place purely because of the pressure generated by denying market access to dolphin-unsafe products (Hall, 1998; Hall et al., forthcoming). It may be noted that, with dolphin quotas, the incentives for improvements in skill and technology to avoid killing dolphins would disappear when everyone has reached a level where the mortality of dolphins caused by fishing at full capacity matches the dolphin quotas of the boats. Then no one would need to buy quotas to extend the fishing, and no one would benefit from improving performance in order to have some unused quota to sell, as there would be no market for quotas. To ensure continued development in skills and technology the dolphin mortality quotas would have to be successively tightened.

Two additional issues about a dolphin ITQ program need to be recognized. First, how long should the dolphin quotas be valid? If selling a dolphin quota for one season implies forfeiture for all future seasons, such sales would not take place unless the boat in question were to be withdrawn permanently from the fishery anyway. Hence, dolphin quotas (or shares in an overall quota) would have to be valid for a long time, although not necessarily in perpetuity. If however the quota allocation of a certain boat has been sold repeatedly for many years and the boat withdrawn from the fishery, questions about the legitimacy of that boat’s entitlement will inevitably be raised.

The second issue arises because of the international character of this fishery. A dolphin quota regime for the entire fishery must be voluntary, since there is no international authority which can force such a regime on all participating states without their consent. This does not preclude dolphin quotas from being used by a single state unilaterally, in order to reduce the dolphin mortalities of its own fleet and to minimize the losses thereof for its own industry, but a country contemplating such a move would inevitably take into account what the other nations are doing and how they would react. One-sided reduction in dolphin mortalities by one particular state is of little significance if it is offset by an increase in mortalities by another state.

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