Modelling deemed value catch balancing regime in New Zealand multi-species fishery

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Abstract *Since the lack of control over harvest levels, it is common for fishers to exceed their Annual Catch Entitlements (ACEs). This situation presents a challenge to the design of a right-based management system. Deemed value catch balancing regime was introduced under purpose of managing bycatch. This paper provides a standard bioeconomic model of deemed value system for analysis purposes. It can be concluded that setting deemed values depends on varies of resource such as target species port price, target species ACE price, target/bycatch ratio, operating cost of both target and bycatch units, and the number of active firms in the target fishery.*

Key words: Deemed value, fisheries management, QMS.

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1. Introduction

Institutional change is one of the most powerful instruments that government is able to use to provide the conditions necessary for economic growth. Prior to the early 1980s commercial fishing in New Zealand was characterised by low profitability and unsustainable harvest levels. This bioeconomic state was turned around with the implemental of the quota management system (QMS) in 1986. Today, New Zealand is considered a world leader in rights-based fisheries management.

Bycatch is one of the problems associated with rights-based fishery management. Fish bycatch is, by definition, the incidental caught of non-targeted species. Boyce (1996) indicates that fish bycatch presents several unique problems to fishery managers. The most serious problem in a rights-based fishery is discarding. A number of options have been introduced to manage discarding species by the Ministry of Fisheries such as the quota trade-off system and the deemed value catch balancing regime. Between 1990 and 2001, the quota trade-off system was used in New Zealand. But due to its computational complicity, deemed value catch balancing regime replaced the quota trade-off system as the main instrument for managing fish bycatch in 2001.

The Ministry of Fisheries sets deemed value as a proportion of port price. However, JWG (2005) suggests that the deemed value should also depend on other sources. The purpose of this paper is to develop a standard model of deemed value catch balancing regime. We found that deemed values are not just related to port prices and ACE prices, it is also in terms of bycatch ratio, operating costs and numbers of active firms in target fishery.

The paper is organized as follow. The second section presents bycatch problems in New Zealand fisheries. The third section reviews the deemed value management systems. Basic concepts of fishery economics are presented in section four followed by the bioeconomic model of deemed value balancing regime in section five.

2. The bycatch problems in New Zealand multi-species fisheries

Bycatch in multispecies fisheries has long time been recognized as an issue requiring specific attention; New Zealand is not an exception. When harvesting, fishers are not able to exactly limit their catch within their holdings of rights. Although fisher skills and experience might help to reduce the bycatch problem, in almost every fishery some species which are not targeted will be accidentally caught as bycatch. Table 1 lists target and bycatch species commonly caught in New Zealand. Cases 1 and 4 illustrate single target species and single bycatch species. Due to its simplicity, such one-to-one relationship is used in the bioeconomic model developed in section three. More importantly, studying this simple relationship will benefit more advanced research in multi-species fisheries. Case 2, 3 and 5 illustrate that the same species can be caught as bycatch for different target species such as john dory can be considered as bycatch for both snapper and tarakihi fisheries. Monkfish is a bycatch of tarakihi, red cod and flatfish fisheries. Dark Ghost is almost entirely caught by Hoki, Sliver warehou, Arrow squid and Barraconta fisheries. Cases 1 and 4 show that one fish species can be a bycatch in one fishery and can be a target specie in another. Trevally is bycatch in snapper fishery but for fishers who target trevally, creamfish becomes the bycatch species. This chain of relationships provides a challenge of managing bycatch and therefore the deemed values settings.

Boyce (1996) indicates that bycatch presents several unique problems to fishery managers. The main problem which caught the attention of fishery economists is that it leads to the discard of unwanted fish species. There are two assumptions which are related to discarding problem that we should be aware of here. First, assume there is one-to-one target/bycatch relationship between two fisheries as illustrated in cases 1 and 4 in Table 1. Second, we assume that both species have commercial value. Vessels such as trawlers typically having unselective gear can catch both species. Thus the vessel's limited holding capacity is partly used by the bycatch, which is not what the owner wants. Removing the bycatch can increase the vessel's capacity to target species for profit. Moreover, carrying the bycatch to port is an additional cost for fishers. Therefore, fishers will have an incentive to dump, rather than land bycatch. Discarding unwanted catch is considered as a wasteful practice that may pose a threat to marine ecosystem over time and more importantly, it is seen as an economic waste of the species which are a scarce commercial resource.

3. The deemed value catch balancing regime in New Zealand

The new deemed value system was implemented on June 21st 2001 with some modifications in September 5th 2003. The primary purpose of deemed value system is to provide an incentive to cover catch with available ACE for fishers. As a result, it is no longer a criminal offence to catch fish which fishers have no rights; instead they pay a deemed value to cover any catch without ACE. Thus deemed values provide an incentive to purchase ACE to cover the bycatch. If deemed values are not paid, then the fisher's permit will be suspended and it is criminal offence fishing without a permit. As Newell (2004) points out that this approach represents a significant change from the prior catch balancing regime, where it was illegal to target QMS species without holding quota for them and the ultimate penalties for catching without quota were criminal in nature.

Deemed values are set as a proportion of the commercial value of landed fish. Port prices are used as the main indicator of market value, which implies that the deemed values are a proportion of port prices. To ensure the port prices are correctly collected, the Ministry of Fisheries has established an annual port-price survey to support this. Table 2 summarizes how the different elements of the deemed value system vary across four categories. Differential deemed values for High Value, Single Species Fisheries and All other apply according to the Table 2. The "High Value, Single Species Fisheries" category is the main analysis focus in this paper. Deemed values change when port prices and overhavest levels change as Table 2 suggests. Since the deemed value is generally expressed as a percentage of port price, an increase (decrease) in port price will lead to increase (decrease) in deemed value for a specific species. Deemed values also depend on levels of overharvest. The more overharvest happens to a species in QMS, the higher the species deemed value should be set.

Peacey (2002), Joint Working Group (2005) and Newell (2004) have reviewed some important aspects of deemed value system and provided theoretical framework for modelling analysis. The primary objective of the modified deemed value system is to provide an incentive for fishers to cover catch with available ACE. Therefore, it is expected that there will be a close relationship between the level of catch relative to the TACC, and the deemed value rate relative to the ACE price. Particularly as the JWG (2005) points out that because the deemed value system can be considered as a substitution for ACE, when setting deemed values the Minister of Fisheries must take into account to provide an incentive for commercial fishers to have sufficient ACE to cover harvest. The margin between deemed value and the price of ACE should be sufficient to more than offset the transaction costs of acquiring ACE. In order to do that, deemed values should be set above the marginal value of ACE such as Figure 1 illustrates. TACC also will have impact on deemed value for a specific species. Figure 1 shows ACE price changes when TACC shifts, which will cause deemed value to be changed. Target/Bycatch ratio and operation cost are another two factors that the fishing authority should take into account. A value maximising deemed value system would set according to these elements based on the biological and economical characteristics of each fishery. The purpose of this paper is to exam deemed values in New Zealand multi-species fisheries by using a bioeconomic model. We expect that the bioeconomic model of deemed values should contain all above sources.

4. Basic concepts of fishery economics

In order to provide structure around the QMS assume there are n identical firms in a single target species fishery (T). Equation (1) states that the sum of all individual entitlements for the species (T), defined as (q_T^i), equals the TACC (Q_T) set for fishers in (T).

$$\sum_{i=1}^{n} q_T^i = Q_T \quad (1)$$

Given the lack of control over harvest levels, it is common for fishers to exceed their ACE. When aggregated over a number of fishers, the excess could be large. Taking into account excess harvest, the harvest could be

$$\sum_{i=1}^{n}\left(q_T^i + y_T^i\right) = Q_T + Y_T \quad (2)$$

where Y_T represents the overharvest in the fishery in equation (2). If the TACC is binding (according to equation (1)) then the possibility of overharvest Y_T (not covered by ACE) exists. This situation presents a challenge to the design of a right-based management system. The problem of over-fishing can be addressed within the governance mechanism at two levels. First, fishers can buy ACE in the market to cover the over-catch. The second option is to pay a deemed value on catch not covered by ACE.

Now consider the case of a multi-species fishery. For simplicity assume that there are two species: target species (T) and bycatch species (B). Harvesting target species will catch bycatch simultaneously. Therefore, bycatch harvest is a function of target species production for individual firm

$$y_B^i = f\left(q_T^i\right) \quad (3)$$

where y_B^i is the bycatch harvest level individually and $f\left(q_T^i\right)$ is the production function of target species. Assume there are n identical firms in target fishery, then

$$\sum_{i=1}^{n} y_B^i = Y_B = \sum_{i=1}^{n} f\left(q_T^i\right) = f\left(\sum_{i=1}^{n} q_T^i\right) = f\left(Q_T\right) \quad (4)$$

where Y_B is the aggregate bycatch overharvest level in fishery (T). The two equations show that the harvesting in target fishery (T) can affect the bycatch fishery (B) and cause an overharvesting problem in bycatch fishery if fishers can not obtain quota rights to cover the bycatch(B). Thus, equation (4) suggest that when the fishing authority is setting the TACs for multispecies fisheries, it should take into account of the joint production of species T and B as illustrated in equation (5)

$$Y_B = \varphi Y_T \ (5)$$

Where φ is defined as the target/bycatch ratio. By definition, target/bycatch ratios detail the interdependence between those stocks that are targeted and those stocks that are inevitably caught as a bycatch. Arnason (1990) proved that providing the market price of quotas is positive, firms will not leave any quota unused. If Arnason's results are accepted then it follows that total catch will equal the TACC in both target and bycatch fisheries $Q_T = Y_T$. Substitute back into equation (4) to get

$$Y_B = \varphi Q_T \ (6)$$

Equation (6) states that there will be bycatch harvest associated with target species TACC. Figure 2 illustrates such relationship between target TACC and the bycatch harvest level. In Figure 2, the two heavy lines represent the TACC of target species $TACC_T$ and bycatch $TACC_B$ respectively. Equation (6) suggests that fully exercising rights to $TACC_T$ will yield harvest of bycatch Y_B, which is presented by horizontal dashed line. If fishers in T obtain quota rights sufficient to cover Y_B, the amount of quota available for bycatch fishery is presented as A. If fishers in T can not obtain Y_B quota, then they will face paying a deemed value on Y_B leaving fishers in B to exercise their quota rights $TACC_B$ fully. If $TACC_T$ is adjusted for some reasons, it should take into account these relationships. Figure 3 illustrates how $TACC_B$ will be affected by adjusting $TACC_T$. Assume that the TACCs are initially is the same as in Figure 2. At the beginning of the next fishing year $TACC_T$ is shifted to $TACC'_T$. According to equation (6), the harvest of bycatch Y_B should increase to Y'_B. If fishers in

T obtain quota rights Y_B', then quota rights available in fishers in B reduce to $(TACC_B - Y_B')$ if $TACC_B$ remains constant over time. On the other hand, if fishers in T do not obtain quota rights Y_B' then fishers in T will have to pay deemed value on Y_B' units of harvest. Sometime for individual firms, overharvest is balanced partially by purchasing ACEs and paying deemed value for the rest caught. Defined the partial quantity of quota rights purchased by fishery T as R, thus the range of R is $0 \le R \le Y_B$ in Figure 2 and the range of R is $0 \le R \le Y_B'$ in Figure 3. It is important to point out that R cannot be controlled by the fishery authority; individual firms decide the value of R.

Arnason (1990) provides the basic model for rights based fishing. The general harvesting cost function for firm i is assumed to depend on the harvest level Y and the biomass $x(t)$

$$C = C(Y, x(t); i)$$

Harvesting costs increase when there is an increase in the harvest level, so $\frac{\partial C}{\partial Y} > 0$. The cost function also includes the biomass level, which makes sense since it is easier to catch fish if there is a high level of biomass, so $\frac{\partial C}{\partial x} < 0$.

As Smith (1968) pointed out that for the purpose of production analysis, one of the most important technological features of a commercial resource like fish species is its law of growth. The population growth of a species depends on biological characteristics of the species and the marine environment. The growth of fish stock is illustrated by the differential equation

$$\dot{x} = \frac{\partial x(t)}{\partial t} = G(x) - Y, x \geq 0$$

where $G(x)$ is the natural growth function and is assumed to be twice continuously differentiable and Y is the output level. The next section combines all basic fishery concepts together to form a bioeconomic model for the deemed value bycatch regime.

5. Bioeconomic model of the deemed value catch balancing regime

Under rights-based governance, the fishing authority and individual firms have different maximizing problems. The fishing authority has the problem, defined as the managers' problem, decides the TACCs for target species (T) and bycatch species (B) and deemed values for (B) so as to maximize economic benefits from the fishery. For individual firm, given an endowment of ACE, the firm trades ACE so as to maximize its profit and faces deemed values set by the fishery authority. Each of them is discussed below.

5.1 The managers' problem

According to the production process discussed previously, the bycatch harvest Y_B in target fishery (T) is proportional to target species harvest $(Y_B = \varphi Q_T)$. Provided the price of target species is P_T and the price of bycatch is P_B, the total revenue of fishery (T) is

$$TR = P_T Q_T + P_B Y_B$$

The new catch balancing regime is designed to encourage fishers to obtain ACE rather than paying the deemed value of bycatch that is harvested without the necessary ACE. The aim is to set deemed values so that fishers prefer to obtain ACE on the market rather than paying deemed value. Now, consider a situation where fishers in fishery (T) obtain bycatch ACE defined as R from the quota market in order to cover the bycatch harvesting, where R satisfies the condition

$$0 \le R \le Y_B$$

It is important to point out that here R is not a control variable for the manager. The bycatch quota available in the market depends on ACE owners in fishery (B). Assume the bycatch ACE price is S_B, then the total cost of obtaining ACE is $(S_B R)$. If condition $0 \le R \le Y_B$ holds, then fishers in fishery (T) pay deemed value on $(Y_B - R)$. Furthermore if the deemed value for bycatch is P_{DV}^{B}, then the deemed value cost is $\left[P_{DV}^{B}(Y_B - R)\right]$. Thus, the aggregate profit function for fishery (T) is

$$\pi_T = P_T Q_T + P_B Y_B - C_T(Q_T + Y_B, x_T, x_B) - S_B R - P_{DV}^{B}(Y_B - R)$$

In the above profit function, the total revenue is $(P_T Q_T + P_B Y_B)$, $C_T(\bullet)$ is the cost of harvesting and $\left[S_B R + P_{DV}^{B}(Y_B - R)\right]$ is the cost of covering bycatch. Notice that the part $(S_B R)$ goes to fishery (B) as revenue and the other part $\left[P_{DV}^{B}(Y_B - R)\right]$ goes to the manager as a penalty of over harvesting for fishery (T). In fishery (B) the TACC is Q_B, the total available quota rights to be exercised are $(Q_B - R)$ assuming there is no overharvesting. The revenue function is made up by two parts; revenue that is generated by exercising ACE $(Q_B - R)$ and revenue that is generated by selling R units of ACEs to fishery (T), thus

$$TR = P_B(Q_B - R) + S_B R$$

So, the profit function for fishery (B) is

$$\pi_B = P_B(Q_B - R) + S_B R - C_B(Q_B - R, x_B)$$

where $C_B(\bullet)$ is the operation cost of harvesting $(Q_B - R)$ quota rights.

The growth function of fishery (T) is described by

$$\dot{x}_T = G_T(x_T) - Q_T$$

where $G_T(x_T)$ is the nature growth rate of target species. The biomass growth function of fishery (B) is

$$\dot{x}_B = G_B(x_B) - (Q_B + Y_B - R)$$

where $G_B(x_B)$ is the nature growth rate of bycatch. Note in above equations that the total output of bycatch in both fisheries is $(Q_B + Y_B - R)$. Fishery (T) has total overharvest $(Y_B - R)$ and fishery (B) has total output Q_B.

The manager adjusts TACCs and the bycatch deemed value in order to maximize economic profit for both fishery (T) and fishery (B). The Hamiltonian function corresponding to the problem can be written as

$$H = \pi_T + \pi_B + \sigma_T[G_T(x_T) - Q_T] + \sigma_B[G_B(x_B) - (Q_B + Y_B - R)]$$

where $\pi_T = P_T Q_T + P_B Y_B - C_B(Q_T + Y_B, x_T, x_B) - S_B R - P_{DV}^B(Y_B - R)$ and $\pi_B = P_B(Q_B - R) + +S_B R - C_B(Q_B - R, x_B)$, σ_T and σ_B are shadow prices of target species and bycatch attach to constraints. The control variables in this Hamiltonian are target species TACC (Q_T), bycatch TACC (Q_B), deemed value P_{DV}^B, target species biomass x_T and bycatch biomass x_B. Along with the joint production function $Y_B = \varphi Q_T$, the necessary conditions include

$$\frac{\partial H}{\partial Q_T} = P_T + \varphi P_B - (1+\varphi)C_{T\,Q_T} - \varphi P_{DV}^B - \sigma_T - \varphi\sigma_B = 0 \quad (7)$$

$$\frac{\partial H}{\partial Q_B} = P_B - C_{B\,Q_B} - \sigma_B = 0 \quad (8)$$

$$\frac{\partial H}{\partial P_{DV}^{B}} = Y_B - R = 0 \; (9)$$

Equation (7) can be rewritten as

$$P_T + \varphi P_B - (1+\varphi) C_{T\,Q_T} - \varphi P_{DV}^{B} = \sigma_T + \varphi \sigma_B \; (10)$$

In the above equation, $(P_T + \varphi P_B)$ is the revenue associated with harvesting one unit of the target species. Since the bycatch problem exists, harvesting one unit of the target species will also yield φ units of bycatch, thus the total revenue has two parts. The term $\left[(1+\varphi) C_{T\,Q_T} + \varphi P_{DV}^{B}\right]$ is the cost of harvesting one unit of the target species, which includes the cost of harvesting the target species and bycatch, and φP_{DV}^{B} represents paying deemed value for φ units that are not covered by ACE. $(\sigma_T + \varphi \sigma_B)$ is the total shadow value attached with growth constraints. Rearranging equation (8) results in

$$P_B = \sigma_B + C_{B\,Q_B} \; (11)$$

Equation (11) states that the ACE price of bycatch can be represented as the shadow value of increasing one unit of bycatch and the marginal cost of harvesting bycatch in fishery (B). Equation (9) points out that the profit is maximized in both fishery (T) and (B) if the bycatch harvesting in fishery (T) can be fully covered by purchasing ACE from fishery (B). But in reality, it is difficult to achieve because Y_B and R are not directly controlled by the manager. Both of them are decided by individual firms.

5.2 The individual firm's problem

Unlike the manager, the individual firm can not control TACCs or the bycatch deemed value, but firms can trade ACE freely in the quota market, which is defined as R in the manager's problem. Assume there are N identical firms in fishery (T) and

M identical firms in fishery (B). Individual firm harvests q_T^i in fishery (T) and associated bycatch y_B^i, where $\sum_{i=1}^{N} q_T^i = Q_T$ and $\sum_{i=1}^{N} y_B^i = Y_B$, the revenue for individual firm should be $\pi_T^i = P_T q_T^i + P_B y_B^i$.

The cost for individual firm i can be considered as $C_T\left(q_T^i + y_B^i, x_T\right)$. Furthermore, if a firm in fishery (T) obtains r^i bycatch ACE quota from fishery (B), then the firm has to pay deemed value to cover the rest $\left(y_B^i - r^i\right)$ bycatch caught and the total amount of ACEs that in fishery (T) obtain is $\sum_{i=1}^{N} r^i$. Since $\sum_{i=1}^{N} r^i$ depends on how many units of ACEs that fishery (B) decides to trade, then

$$\sum_{i=1}^{N} r^i = \sum_{j=1}^{M} r^j = R$$

where r^j is the bycatch ACEs that firm j in fishery (B) willing to sell. Defined z_B^T as the firm's i instantaneous bycatch quota purchase from fishery (B), thus the cost of covering overharvest is now expressed as $\left[S_B\left(r^i + z_B^T\right) + P_{DV}^B\left(y_B^i - r^i - z_B^T\right)\right]$ and

$$\dot{y}_B^i = \frac{\partial y_B^i}{\partial t} = z_B^T$$

The firm i's instantaneous quota purchase within fishery (T) can be defined as z_T and

$$\dot{q}_T^i = \frac{\partial q_T^i}{\partial t} = z_T$$

Thus for the firm i, the extra cost of purchasing target ACEs is $S_T z_T$. The profit function of the individual firm in fishery (T) can be described as

$$\pi_T^i = P_T q_T^i + P_B y_B^i - C_T\left(q_T^i + y_B^i, x_T, x_B\right) - S_B\left(r^i + z_B^T\right) - P_{DV}^B\left(y_B^i - r^i\right) - S_T z_T$$

Now for fishery (B), defined z_B^B as the instantaneous bycatch quota purchase by fishers in fishery (B), the changing of cost is $S_B z_B^B$ and

$$\left(q_B^j \overset{\bullet}{-} r^j\right) = z_B^B$$

As a result, the profit function for individual is

$$\pi_B^j = P_B\left(q_B^j - r^j\right) + S_B\left(r^j + z_B^T\right) - C_B\left(q_B^j - r^j, x_B\right) - S_B z_B^B$$

Summarizing all above, the problem of individual firm is

$$Maximize\left(\sum_{i=1}^{N}\pi_T^i + \sum_{j=1}^{M}\pi_B^j\right)$$

Subject to

$$(1)\overset{\bullet}{q_T^i} = z_T$$

$$(2)\overset{\bullet}{y_B^i} = z_B^T$$

$$(3)\left(q_B^j \overset{\bullet}{-} r^j\right) = z_B^B$$

where $\sum_{i=1}^{N}\pi_T^i = \sum_{i=1}^{N}[P_T q_T^i + P_B y_B^i - C_T\left(q_T^i + y_B^i, x_T, x_B\right) - S_B\left(r^i + z_B^T\right) - P_{DV}^B\left(y_B^i - r^i\right)$
$-S_T z_T]$

and

$$\sum_{j=1}^{M}\pi_B^j = [P_B\left(q_B^j - a^j\right) + S_B\left(r^j + z_B^T\right) - C_B\left(q_B^j - a^j, x_B\right) - S_B z_B^B]$$

Thus, the Hamiltonian function corresponding to the problem can be written as

$$H = \sum_{i=1}^{N}\pi_T^i + \sum_{j=1}^{M}\pi_B^j + \mu_1 z_T + \mu_2 z_B^T + \mu_3 z_B^B$$

where μ_1, μ_2 and μ_3 are the shadow values. Here the control variables are q_T^i, y_B^i, z_T, z_B^T, $\left(q_B^j - a^j\right)$ and z_B^B. The necessary conditions include

$$\frac{\partial H}{\partial z_T} = -S_T + \mu_1 = 0 \Rightarrow S_T = \mu_1$$

$$\frac{\partial H}{\partial z_B^B} = -S_B + \mu_3 = 0 \Rightarrow S_B = \mu_3$$

Under Arnason's (1990) assumption that when firms are active and $\sigma_T = N_1\mu_1$, where N_1 is the number of active firms in fishery (T), the first necessary condition indicates that the shadow prices of bycatch equal to the ACE prices of bycatch. Such a finding is consistent with JWG (2005) that in a mixed fishery where catch of a primary target stock is being constrained by availability of ACE for an incidentally caught stock, if deemed values are at the appropriate level, the ACE price of the incidentally caught stock will reflect the cost of reducing incidental catch of that species with the target species, which is referred to as the shadow value of the bycatch. Thus, it can be concluded that

$$N_1 S_T = \sigma_T \text{ (12)}$$

Equation (12) implies that the shadow price of the fisheries is the sum of all shadow prices of active firms.

Combining equation (10), (11) and (12) to get

$$P_T + \varphi C_{B\,Q_B} - (1+\varphi)C_{T\,Q_T} - N_1 S_T = \varphi P_{DV}^B$$

Thus, we have

$$S_T = \frac{1}{N_1}\left(-\varphi P_{DV}^B + P_T - (1+\varphi)C_{T\,Q_T} + \varphi C_{B\,Q_B}\right) \text{(13)}$$

Equation (13) suggests that the deemed value in single bycatch species fishery can be expressed as the port price of target species, the bycatch ratio, marginal cost of harvesting both target species and bycatch species, the number of active firms in fishery (T) and the target ACE price, which is consistent with the recommendation that JWG (2005) suggests that ACE prices and cost recovery levies are important informational inputs into the decision making process for setting deemed values.

The interesting finding here is when differentiating deemed value respect to target ACE price

$$\frac{\partial S_T}{\partial P_{DV}^B} < 0$$

which means there is a negative relationship between the target species' ACE price and bycatch deemed value. This can be explained as decreasing the target ACE price leads to increasing the target harvest output, which potentially could be a problem in fishery two because the bycatch output also increases and thus the bycatch deemed value increases. The other interesting finding is there is a negative relationship between the number of active firms and the deemed value setting

$$\frac{\partial N_1}{\partial P_{DV}^B} < -\frac{1}{\varphi}$$

The less firms of fishery (T) in the ACE market, the easier to control the output levels of fishery (T) and thus, it is easier to manage the bycatch problem. Thus, number of active firms in fishery (T) also is a factor that needed to be aware of.

6. Conclusion

Since the lack of control over harvest levels, it is common for fishers to exceed their ACE. When aggregated over a number of fishers, the excess becomes a serious problem for fishing authority. This situation presents a challenge to the design of a right-based management system. Deemed value catch balancing regime was introduced under purpose of managing bycatch. This paper provides a standard bioeconomic model of deemed value system for analysis purpose.

The fundamental idea of maximizing profit between the fishing authority and individual firms is different. The social problem is to pick up quotas and allocate individual quotas to firms so as to maximize economic benefits while for individual firm is to maximize its own profit. In other words, in social problem, the constraint should include the biomass factor of a specific species while for individual problem, the constraint takes account the adjusting factor of purchasing and selling ACEs between firms. By developing a bioeconomic model for deemed value which satisfying different constraints , it can be concluded that setting deemed values should take consideration of target port prices, target ACE prices, marginal costs of target and bycatch species and the number of active firms in fishery(T). Such finding is consistent with JWG's (2005) suggestion that information relevant to setting deemed values should include ACE prices, catch in excess of TACC, and target/bycatch ratios.

Of course, in reality the situation is much more complicated. As Table 1 illustrates there maybe a target species has more than one bycatch or sometimes several target species have the same bycatch and particularly the chain type of target and bycatch relationship. A more advanced model can be developed to illustrate these problems based on this bioeconomic model of deemed value management, which is a future potential research project.

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Table 1

Target and Bycatch Commonly Caught in New Zealand

Cases	Target species	Bycatch species
1	Snapper	Trevally
2	Snapper/Tarakihi	John Dory
3	Tarakihi/Red Cod/Flatfish	Monkfish
4	Trevally	Creamfish
5	Hoki/Sliver warehou/Arrow squid/Barraconta	Dark ghost shark

Table 2

Application of Balancing Regime Elements in Each Category

Category	The base deemed value rate	Increase in response to overcatch	Change with port price
High value, Single Species	200% of highest port price	20% increase if total catch exceeds ACE by >2% in 1 year or >1% in 2 consec. Years	Yes
Low Knowledge	10% of port price	No	No
Low/medium value	75% of port price	No	No
All other	75% of port price	20% increase if total catch exceeds ACE by >2% in 1 year or >1% in 2 consec. Years	Yes

Source: Newell (2004)

Figure 1. ACE Demand, Deemed Values and Catch

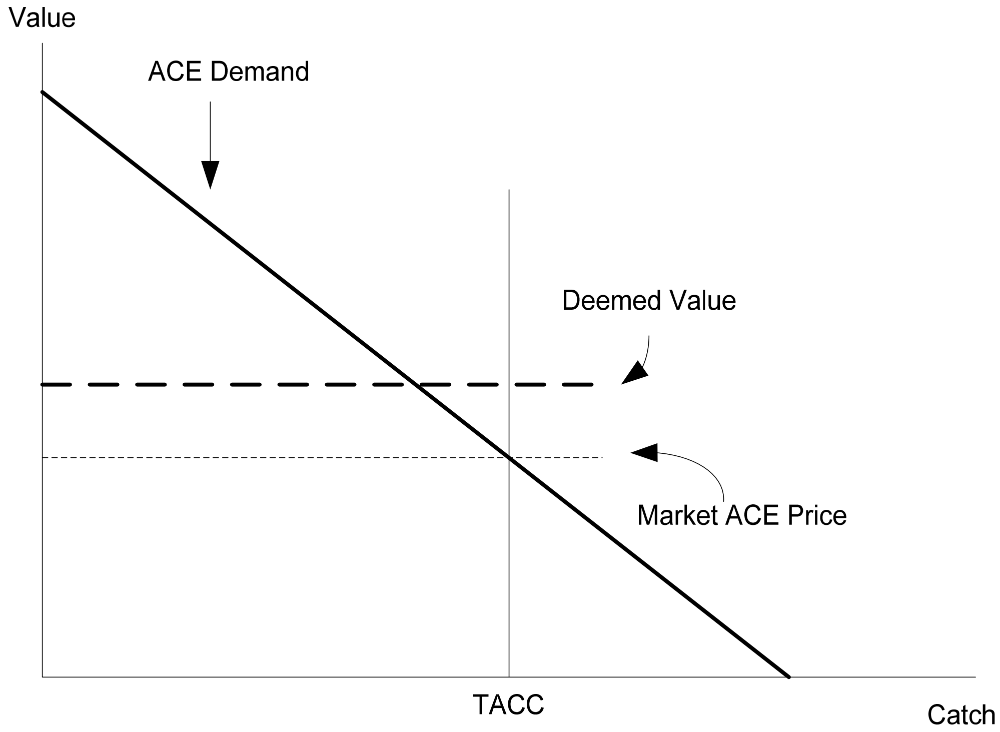

Figure 2. The Relationship between Target TAC and Bycatch TAC

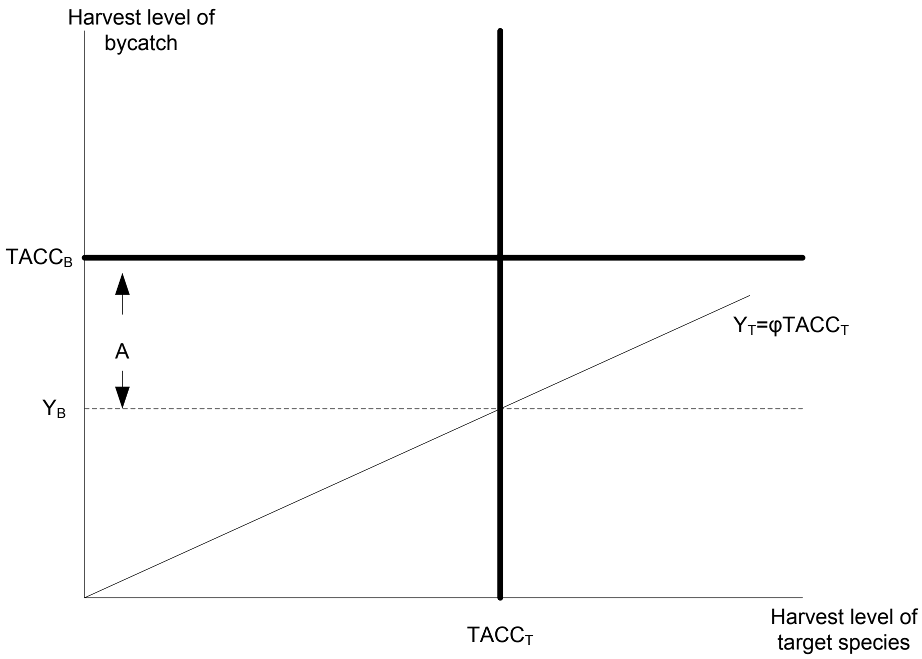

Figure 3. The Changes of Bycatch TACC