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# The Promise of Transferable Fishing Concessions on EU Fisheries

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The Promise of Transferable Fishing Concessions on EU Fisheries[1]

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Abstract: Two of the primary issues of the next Common Fisheries Policy (CFP) reform are maximum sustainable yield (MSY) and transferable fishing concessions (TFCs). The European Commission agreed on implementing TFCs under some major principles including reserving a part of total quotas for small-scale fishermen in order to prevent the reduction in the fish catching sector employment. Besides, the European Commission set the goal of achieving MSY for all European fisheries by 2015. The interrelation between these two objectives should be well understood. In this study, the impact of fishing on total biomass is analyzed under an age-structured model, and the potential effects of TFCs on the achievement process of MSY harvesting conditions are explained. It is shown that the implementation of TFCs, under the major principles defined by the European Commission, has an impact on both the total biomass growth and the time path to reach the goal of MSY. The paper concludes that initial allocation of quotas does matter since reserving quotas for small-scale fishermen reduces the time needed to achieve MSY.

Keywords: Transferable fishing concessions; Maximum sustainable yield, Small-scale fishermen, Individual transferable quotas, Age-structured model.
JEL codes: D02, D04, D47, D78, Q22

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## 1. Introduction

In the course of time, demand for fish has increased, vessels have become larger and hence fishing has become a complex activity not only for fishermen but also for governments. The idea of private ownership or intervention of government was not on the agenda when stocks were abundant and fishing fleets were small. Private ownership of fisheries was banned in England in the 13th century, and fishing was free in English waters till the 19th century (Scott, 2000). The situation was similar in other European countries where both inshore waters and high seas were regarded as common property. The only limitation agreed upon by European countries was related to the exclusion of foreign fishermen from domestic fishing activities to protect local markets and local fishermen (Scott, 2000). Changes in environmental conditions, uncertainty in fisheries and increasing competition in the fishing industry made researchers and governments highly interested in property rights for management of fisheries. Recently, the European Commission agreed on the implementation of transferable fishing concessions (TFCs) for all European fisheries. TFCs will be distributed by Member States to vessel owners at a fixed percentage of their national quotas for each fish stock.

In this evolutionary period of the fisheries management, quota allocation mechanisms became one of the most significant issues in output control management systems. These mechanisms for distribution of quotas and secondary markets for quotas are very important for the effectiveness of a TFC system in Europe. The EU Commission also puts an emphasis on the sustainability of social welfare and employment in the fishing industry. Thus, the importance of distribution and trade mechanisms for fishing quotas come to the forefront not only for economic reasons but also for protection of social welfare. In the meantime, maximum sustainable yield (MSY) is one of the other main goals stated in the proposals for the Common Fisheries Policy (CFP) reform package. Achieving MSY harvesting conditions for all European fisheries by 2015 is targeted by the European Commission. It is undoubted that there is a mutual interaction between the implementation problems of MSY and TFCs. Moreover, these two policies may have interrelated effects on EU fisheries. The mentioned mutual interaction is going to be shaped by the major principles defined by the European Commission, which are focusing on the protection of social welfare. The main purpose of this study is to investigate the promise of TFCs for EU fisheries and demonstrate its possible impacts on the implementation problem of MSY by clarifying the interactions between these two objectives.

The focus of this paper is on the most well-known version of TFC systems, ITQ system, in order to foresee the potential effects of TFC systems on European fisheries. The rest of the paper is organized as follows. The next section evaluates the advantages and disadvantages of ITQ systems, the most well-known rights based management (RBM) systems. The third section analyzes the possible effects of TFCs on EU fisheries. In the model part, firstly the impact of fishing on total biomass under an age-structured model is explained. Then, the initial quota allocation mechanisms and their impacts on achieving MSY harvesting conditions are discussed in the light of the relevant principles committed by the European Commission. The fourth section concludes.

## 2. Individual Transferable Quota (ITQ) System

History of implementation of ITQ systems to manage fisheries dates back to 1970s. Iceland implemented a completely developed ITQ system in herring fisheries in 1979 and started to implement ITQs in its all important demersal fisheries in 1984 (Arnason, 2007). New Zealand started to implement ITQs in its deep-sea fisheries in 1983 and adopted a uniform ITQ system in its all fisheries in 1986. It was the first such comprehensive ITQ system in the world (Arnason, 2007). Iceland and New Zealand were the leading countries for the implementation of ITQ systems. After these initial implementations, many papers has been written on the advantages and disadvantages of ITQ systems. Arnason (1993), Gauvin et al. (1994), Buck (1995), Geen and Nayar (1988) analyzed ITQ systems in the late 1980s and 1990s. These studies promoted the efficiency of ITQ systems by showing the possibility of reductions in overcapacity and elimination of 'race to fish' under ITQ regimes. Furthermore, Grafton and Mcllgorm (2009) performed cost-benefit analysis of ITQ systems for the Australian fisheries. Higashida and Takarada (2009) and Higashida and Managi (2010) discussed the efficiency of ITQ systems under different market conditions.

Besides the strong scientific arguments in support of ITQ systems, there is also a literature discussing inefficiencies of these systems due to high costs of management and imperfect market conditions such as unstable quota prices or not properly functioning secondary markets for quotas. Anderson (1991) mentioned that the total cost would not be minimized under non-perfectly competitive market conditions under ITQ systems. Newell et al. (2005) stated that ITQs can only be a solution for the long-run since unstable quota prices are observed in the short-run. Vestergaard (2005) pointed out that achieving efficiency for fishing fleets under an ITQ system would be delayed due to sunk costs. See also Chavez and Stranlund (2013) for a model of ITQ management system with management costs and their effects on the secondary quota markets.

The quota allocation mechanisms are always in the core of these discussions about ITQ systems. For real-life applications of these mechanisms in different fishing regions, we refer the reader to Shotton (2001) and Cox (2009). Our results also imply that the design of the initial quota mechanisms is very important to achieve sustainable fisheries. In addition to the existing literature, this paper models the impact of fishing on total biomass and discusses the implementation of TFCs in tandem with the implementation of MSY harvesting conditions under an age-structured model. In order to understand the economic and social impacts of the TFCs in details, firstly the advantages and disadvantages of the ITQs are analyzed in the next subsection.

### 2.1 The Advantages and Disadvantages of ITQ Systems

The purpose of implementing the ITQ management system is to increase market functionality by providing flexible conditions and at the same time to create self-control mechanism in the fishing industry for sustainable fisheries. There are two key management decisions in traditional fisheries management. The first one is the target biomass and hence fishing effort and harvest for a given species. The second one is to decision on the instruments to achieve this target (Grafton and Mcllgorm, 2009). Likewise, determining the TACs and quotas, issuing the rules on transfers of quotas and establishing the control systems are the building blocks of an ITQ management system. Thus, under an ITQ system and the policy of achieving MSY harvesting conditions, estimating the MSY level and appropriate TACs, creating an effective design for initial quota allocation and secondary markets for quotas become the most important steps of the implementation process.

There are several reasons why ITQs became one of the most popular management systems in fisheries, and why ITQs are widely accepted worldwide. First of all, ITQ programs are intended to reduce overcapitalization, positively impact the conservation of stocks, improve the market conditions and promote safety in fishing fleets (Buck, 1995). Moreover, ITQs guarantee a catch share and this property of ITQs slows or eliminates the ‘race to fish’ and allows fishermen to be flexible about their timing and fishing rate decisions (Buck, 1995). As one of the key parameters used for measuring the economic efficiency, resource rents can also be used to evaluate the efficiency of the management system. Resource rents are increased returns per unit effort, and they occur when management systems such as ITQs reduce the level of fishing effort, which is resulted in the exit of less efficient operators and increase in catch rates and per unit of effort (Geen and Nayar, 1988). Geen and Nayar also show that according to the simulations resource rents under ITQ systems would be 25% higher than the resource rents under alternative management systems for the same total catch. The resource rents in the European fisheries will also be affected by protective regulations of the European Commission. Total resource rents may decrease as a result of the relevant principles issued by the next CFP reform that put more emphasis on protecting small-scale fishermen who are less efficient operators. On the other hand, increasing equity in the distribution of resource rents is aimed by these new policies.

It is illustrated in the Commission Staff Working Document that ITQ systems significantly reduced the total fleet capacity in the United States surf clam and ocean quahog fisheries, the Australian bluefin tuna fishery and Iceland's purse seine fishing (EC, 2007). On the other hand, Geen and Nayar (1988) state that the average catches per boat in Western Australia and South Australia under the ITQ system to be respectively 67% and 28 % higher than the average catches which might have been under aggregate quota or limited entry system, and also 90% higher in Western Australian system if they have maintained to implement previous aggregate quota system. However, elimination of high cost vessels is not a solution in terms of social welfare since another aspect of transferable quota systems is the reduction in total employment. Under ITQ systems, total employment decreases due to the exits of fishing vessels from the industry. For example, there has been %86 decrease in the number of fishing vessels in Iceland herring fishery after implementation of transferable quota system (Edwards, 2000). Employment in fish catching sector is highly affected from decreasing number of vessels rather than employment in processing and aquaculture sectors.

Employment in sub-sectors of fisheries in 1996-8 and 2005 is given in Figure 1. It shows the changing employment levels in few years in sub-sectors of fisheries. Note that the decline in employment level was experienced intensely in the fish catching sector, whereas the decline in the processing sector employment was around 1%.

**[Figure 1 is about here.]**

In the last decade, traditional fishing techniques has been affected from new technologies used in fish catching. The technological developments may be one of the main reasons for decreasing employment in fish catching sector. Another reason for decreasing employment in the fish catching sector is the elimination of small-scale fishermen under new market conditions. Therefore, the number of employees may decrease in the fish catching sector due to the reduction in the number of vessels unless protective regulations are issued. The EU Commission aims to design an optimal management system for EU fisheries in order to provide the sustainability of fish stocks, increase market efficiency and protect social welfare and employment in the fishing industry. In accordance with these purposes, the European Commission updates the CFP, which has always been a controversial topic because of its broad concepts including sustainability of fisheries, increasing productivity and protecting consumers and producers.

Many studies on ITQs emphasize that ITQs create positive net returns for the fishing industry if these programs are managed effectively. Principally, there are some pre-conditions to be satisfied for successful implementation of ITQ programs. These pre-conditions are defined as adequate monitoring and control, well defined and binding TACs and flexibility in reconciliation of quota (Grafton and Mcllgorm, 2009). According to Kompas and Che (2003), there are two necessary conditions at least to render ITQs efficient in management of fisheries. Firstly, there should be a well-organized market to implement transfer of quota effectively. Secondly, quota holders should participate in the quota market in order to transfer quotas from high to low marginal cost producers, and also there should be an ex post transfer to compensate catches which are different from planned or prior quota holdings (Kompas and Che, 2003).

Despite its effective outcomes such as reducing race to fish and overcapacity, ITQ system may create some negative conditions such as increasing discards and high grading. These negative consequences of ITQs lead to the questions about benefits of ITQ systems. ITQs can create incentives to discard lower valued fish since returns from catches will increase if they catch higher valued fish rather than lower valued ones (Geen and Nayar, 1988). The other much-debated issue about ITQ systems is the increasing management and production costs under ITQs. Fixed costs, information costs and costs of control are due to change under ITQ management systems. Information costs are higher under ITQ management and other TAC-based systems compared to the systems which simply regulate fishing effort (Yandle and

Dewees, 2008). Implementation of ITQs may also increase the fixed costs of production because of the ‘user pays’ principle for government services. This principle prescribes payments by fishermen to cover a portion of management costs in fisheries. Hence, the management levy paid by each fisherman is also high under ITQs (Geen and Nayar, 1988). On the other hand, the situation is not similar for the governments. Total government financial transfers are much higher under input control systems than output control systems. Grafton et al. (2006) state that the total government transfers were on average 20% of the total landings value in OECD countries in 1999 while it reduced to 4% in New Zealand and Iceland under individual transferable quota systems. Hence, besides the increasing costs to fishermen, ITQ systems may reduce the financial burden on governments observed under input control systems.

To sum up, decreasing employment level in fish catching sector and increasing highgrading and discards and higher costs under some implementations are the pronounced problems of ITQ systems. The new CFP reform aims to overcome these problems by putting some restrictions on transfer of quotas, increasing output controls and determining TACs according to MSY approach, which make the next CFP reform a corner stone for European fisheries. In the next section, the impact of fishing on total biomass and the results of TFCs on the goal of achieving MSY level of fishing are analyzed.

## 3. Reform of the CFP: Implementation of TFCs

The EU represents about 4.60% of global fisheries and aquaculture production, which makes the EU the 4$^{th}$ largest fish and fish products producer after China (32.80%), India (5.20%) and Peru (5.20%) (EC, 2010a). Furthermore, catches in the EU constitute the 3$^{rd}$ largest catch volume (5.70%) after China (16.30%) and Peru (8%) (EC, 2010a). Nevertheless, as a result of the high demand, European countries import fish and fish products in spite of high levels of fish production in Europe. Besides, the fishing industry is important not only for supplying food to consumers or fish products to different industries but also for creating employment opportunities and generating primary sources of income in some coastal areas, such as Galicia in Spain, Algarve in Portugal and Voreio Aigaio in Greece (EC, 2010b).

The general belief is that the next reform package will increase the efficiency in the fishing sector by implementation of TFCs. Furthermore, the next CFP reform focuses on providing sustainable fisheries by implementing MSY harvesting conditions while preserving social welfare and employment opportunities in the fishing industry under a well-designed TFC system. In the rest of the paper, firstly the major principles issued by the European Commission in CFP reform proposals are explained, and then the age-structured modeling is carried out under these principles in order to explain the role of TFCs on achieving MSY harvesting conditions.

### 3.1 Transferable Fishing Concessions (TFCs) in CFP Reform Proposals

Transferable fishing concessions will be introduced by all Member States (MS). TFCs will be implemented by MS under some major principles determined by the European Commission. These major principles are described by the European Commission as the following (EC, 2013):

- "Determining a maximum percentage of total national quotas that can be given to any vessels,
- Reserving a part of national quotas to small-scale fishermen and allocating the rest of the quotas as TFCs,
- Reserving a minimum quota level for only new entries,
- Putting restrictions on selling, leasing or swapping of TFCs that only the owners of licensed and active vessels can buy TFCs in order to use them for licensed and active vessels,
- Showing respect to the principle of relative stability,
- Withdrawing the TFCs of a vessel owner by the state in case of a serious infringement by the vessel owner."

The principles above are important steps for increasing total economic profitability and employment in fish catching sector. As emphasized before, the other primary concern of the CFP reform is achieving MSY harvesting conditions by 2015 for all European fisheries. The MSY is the optimal catch level while protecting the fish capacity to sustain regeneration for the future. Thus, main aim under MSY approach is stabilizing the total fish biomass at a level which will result in maximum growth of total biomass that will be the maximum level of yield for that period. As a result, MSY level of biomass will be the steady state level of total biomass providing the highest level of growth and hence the highest level of yield. In this study, since we employ an age-structured model, it is not adequate to determine only the biomass level at MSY ($B_{MSY}$) without determining the optimal population levels for each fish stocks. The reason is that different compositions of fish population at the same level of total biomass may result in different levels of biomass growth since each age group has a different fertility rate under the age-structured population. Thus, in order to achieve MSY conditions, it is not only enough to determine the total allowable catch. Furthermore, catch compositions of fishermen, which steer the composition of the remaining fish population, is another parameter that should be investigated to implement MSY. We begin with analyzing the impact of fishing on total biomass and then continue with interpretation of MSY approach under TFCs.

### 3.2 The Impact of Fishing on Total Biomass

One of the main results of the paper is related to the impact of fishing on the total biomass growth under an age structured model. The age-structured fish population dynamics are described by three age classes following Skonhoft et al. (2012) and Kanık and Küçükşenel (2013):

Juveniles, $X_{0,t}$ (age < 1)

Young matures, $X_{1,t}$ (1 ≤ age < 2)

Old matures, $X_{2,t}$ (2 ≤ age)

The juveniles refer to the youngest class in the population. The juveniles are not harvestable, and also they are not members of the spawning stock. The old and young mature classes are both harvestable and members of the spawning stock. Different than young matures, old matures have higher fertility as supposed by Reed (1980). Moreover, weight per fish is higher for old mature fish than young mature fish ($w_0 < w_1 < w_2$). We consider two possible cases at any given year or time t: fish stock dynamics without fishing and fish stock dynamics with fishing. The aim is to reveal the role of management systems or quota allocation mechanisms on the effect of fishing to the total biomass. We first assume that the planner is myopic and/or allocation of fishing rights are not permanent. That is, fishing management plans are designed annually and hence fishing rights are granted on a yearly basis. The total biomass with fishing at time t+1 is denoted by $B_{t+1}$ and the biomass of age class i at time t+1 is denoted by $X_{i,t+1}$. Similarly, $B^*_{t+1}$ and $X^*_{i,t+1}$ refer to the total biomass and the population of age class i at time t+1 without fishing.

In this study, we employ the Beverton-Holt recruitment function, which is increasing and concave for both age classes (Beverton and Holt, 1957). The number of recruits to the fish population at time t is:

$$X_{0,t} = R(X_{1,t}, X_{2,t}) = a(X_{1,t} + \beta X_{2,t})/[b + (X_{1,t} + \beta X_{2,t})] \quad (1)$$

The number of recruits is a function of the size of the old mature and young mature age classes and parameters of $a, b$ and $\beta$. The scaling and shape parameters are denoted by $a$ and $b$, respectively. Moreover, $\beta > 1$ is the fertility parameter indicating that the natural fertility rate of the old mature fish is higher than the natural fertility of young mature fish. The total biomass at time t after spawning is:

$$B_t = w_0 R(X_{1,t}, X_{2,t}) + w_1 X_{1,t} + w_2 X_{2,t}.$$

For the first case in which there is no fishing, the total biomass at time t+1 after spawning is defined as the following:

$$B^*_{t+1} = w_0 R(X^*_{1,t+1}, X^*_{2,t+1}) + w_1 X^*_{1,t+1} + w_2 X^*_{2,t+1}.$$

At time t, there are new recruitments to the population at an amount of $R(X_{1,t}, X_{2,t})$ and these new recruits constitute young mature fish population at time t+1. That is, $X_{0,t} = R(X_{1,t}, X_{2,t})$, $X^*_{1,t+1} = s_0 X_{0,t}$, and $X^*_{2,t+1} = s_1 X_{1,t} + s_2 X_{2,t}$. Given this transition equations, the total biomass (without fishing) at the beginning of time t+1 is:

$$B^*_{t+1} = w_0 R(X^*_{1,t+1}, X^*_{2,t+1}) + w_1 s_0 R(X_{1,t}, X_{2,t}) + w_2( s_1 X_{1,t} + s_2 X_{2,t}) .$$

In order to measure the total biomass change between time t and t+1, the difference between $B^*_{t+1}$ and $B_t$ is taken. Let $\rho^*$ be the total biomass change between time t and t+1, where

$$\rho^* = B^*_{t+1} - B_t$$

$$= w_0\ R\left(X^*_{1,t+1}, X^*_{2,t+1}\right) - w_0\ R\left(X_{1,t}, X_{2,t}\right) + w_1\ s_0\ R\left(X_{1,t}, X_{2,t}\right) + w_2\ s_1\ X_{1,t} + w_2\ s_2\ X_{2,t}\ - w_1\ X_{1,t} - w_2\ X_{2,t}$$

.

On the other hand, for the second case with fishing, the total biomass at time t+1 is defined as the following:

$$B_{t+1} = w_0\ R\left(X_{1,t+1}, X_{2,t+1}\right) + w_1\ X_{1,t+1} + w_2\ X_{2,t+1}$$

$$= w_0 R\left(X_{1,t+1}, X_{2,t+1}\right) + w_1\ s_0\ R\left(X_{1,t}, X_{2,t}\right) + w_2 \sum_{i=1}^{2} s_i\ \left(1 - f_{i,t}\right) X_{i,t}\ .$$

In the above equation, the total fishing mortality rate (or exploitation rate) of age group of $i \in \{1,2\}$ at time t is denoted by $f_{i,t}$ where $f_{i,t} \in [0,1]$. Thus, $f_{i,t} = 0$ means that there is no harvesting of age class of i at time t, and $f_{i,t} = 1$ means that all of the fish population in the age class of i is harvested by fishermen at time t. Note that $X_{2,t+1} = s_1\left(1 - f_{1,t}\right) X_{1,t} + s_2\left(1 - f_{2,t}\right) X_{2,t}$. Given this formulation, the change in the total biomass for the second case is equal to $\rho$ where

$$\rho = B_{t+1} - B_t$$

$$= w_0\ R\left(X_{1,t+1}, X_{2,t+1}\right) - w_0\ R\left(X_{1,t}, X_{2,t}\right) + w_1\ s_0\ R\left(X_{1,t}, X_{2,t}\right) +\ w_2\ s_1\ X_{1,t} + w_2\ s_2\ X_{2,t} -\ w_2\ s_1\ f_{1,t}\ X_{1,t} - w_2\ s_2\ \ f_{2,t}\ X_{2,t} - w_1\ X_{1,t} - w_2\ X_{2,t}$$

.

The one year net impact of fishing on total biomass is the difference between the total biomass change from time t to time t+1 for the first case and the total biomass change from time t to time t+1 for the second case, ($\rho^* - \rho = B^*_{t+1} - B_{t+1}$), which is equal to:

$$\rho^* - \rho = w_0\left[R\left(X^*_{1,t+1}, X^*_{2,t+1}\right) - R\left(X_{1,t+1}, X_{2,t+1}\right)\right] + w_2(s_1\ f_{1,t}\ X_{1,t} + s_2\ f_{2,t}\ X_{2,t}) \qquad (2)$$

In the fishing fleet, there are $N = |S \cup L|$ fishermen characterized by their fishing selectivities and harvest capacities. Let $S$ be the set of small-scale fisherman operating inshore, and $L$ be the set of large-scale fisherman operating off-shore. Let $j_i \in [0,1]$ be the fishing selectivity or technology of fisherman $i$. Let $c_i$ be the harvest capacity of fisherman $i$ where $c_i > c_k$ for all $i \in S$ and all $k \in L$. The fishing selectivity determines the catch composition of a fisherman. The total biomass harvest of fisherman i at time t, $h_{i,t}$, consists of $100 j_i$ percent of old mature fish and $100(1 - j_i)$ percent of young mature fish. If $j_i = 1$, the fisherman can perfectly select for the old mature age class. That is, the fisherman can harvest only old mature fish due to perfect selectivity. The fishing selectivity is imperfect for the other possible cases ($j_i \neq 1$). Small-scale fishermen are coastal fleets which target the old mature fish and harvest more old mature fish than young mature fish, compared to large-scale fishermen. Large-scale fishermen have higher ratios of young mature fish harvest compared to coastal fleets. That is, $j_i > j_k$ for all $i \in S$ and all $k \in L$. As pointed in Turris (2000), small-scale fishermen focus on harvesting quality products, old mature fish in our environment, rather than large volumes. Moreover, small-scale fishermen can be interpreted as coastal vessels and large-scale fishermen can be interpreted as trawlers. This type of selectivity is also observed in some fisheries. For example, Armstrong (1999) characterizes Norwegian fisheries with these two types of vessels. Coastal vessels are operating inshore and trawlers are mostly operating off-shore. In this fishing environment described by Armstrong (1999), coastal vessels are tend to catch old mature fish at a higher ratio since mature fish migrate to coastal areas for spawning; on the other hand, trawlers, which operate off-shore, catch more young mature fish than old mature fish.

Fishing rights or quotas defined as privileges to harvest a certain fraction of the total allowable catch (TAC). The TAC is set each year as a function of the biomass of mature fish ($TAC_t(X_{1,t}, X_{2,t})$). We also assume that $\sum_{i \in S} c_i < TAC_t$ which means that total harvest capacity of small-scale fishermen is not very large. That is, they will not be able harvest all of the possible levels of total allowable catch if all quotas are assigned to small-scale fishermen. Let $\alpha_{i,t} \in [0,1]$ be a quota, a percentage of the total allowable catch, that fisherman (or vessel) i owns at time $t$. There is also no waste of quota and fishermen can fulfill their quotas if it is profitable to do so. That is $c_i \geq \alpha_{i,t} TAC_t = h_{i,t}$ for all $i \in N$. Denote $\alpha_t = (\alpha_{1,t}, \dots, \alpha_{N,t})$ as a feasible quota allocation at time $t$ where $\sum_{i \in N} \alpha_{i,t} = 1$ for all t, and $\alpha_0$ as the initial quota allocation. This means that the fishery moves from open access to the rights-based management system at $t = 0$. There are different allocation methods used in major fisheries to determine the initial allocation of quotas: historical catch, auction, equal share and combination of these methods. Historical catch was used in 54% of the fisheries, combination of the methods was used 37% of the fisheries, equal sharing rules were used in 6% of the fisheries, and auctions were used in 3% of the fisheries[2]. If the quotas are permanent and non-transferable, $\alpha_{i,0} = \alpha_{i,t}$ for all $t$ and all $i$. If quotas are transferable then there might be a time $t$ where $\alpha_0 \neq \alpha_t$. There may also be some restrictions on the transferability of quotas in the

[2] See Lynham (2013) for more details about the allocation methods used in major fisheries.

secondary markets. For example, the quotas assigned to small-scale fishermen may not be transferable. That is, $\alpha_{i,0} = \alpha_{i,t}$ for all $i \in S$. Since these restrictions affect the final quota allocation ($\alpha_{i,t}$) at a given time $t$, the impact of fishing on total biomass change depends on these restrictions. If fisherman $i$ bought (sold) some quotas at time $t$ in the secondary market, then $\alpha_{i,t} > \alpha_{i,t-1}$ ($\alpha_{i,t} < \alpha_{i,t-1}$). We assume that secondary markets for quotas are perfect. That is, the secondary markets are frictionless, and liquid. The details of the secondary market for quotas are not necessary for the general purpose of this article. See Ledyard (2009) for more details about secondary markets for quotas in fisheries.

Given the above information the profit of fisherman $i$ is

$$\pi_{i,t} = p_{2,t} j_i \alpha_{i,t} TAC_t + p_{1,t}(1 - j_i)\alpha_{i,t} TAC_t - q_t(\alpha_{i,t} - \alpha_{i,t-1}) - C_i(X_{1,t}, X_{2,t}, h_{i,t}, j_i),$$

where $p_{i,t}$ is the market price of age mature age class $i$ at time $t$, $q_t$ is the price per quota at time $t$, and $C_i(.)$ is the cost of fishing which depends on the total number of old and young mature fish, total harvest of fisherman $i$ and his fishing selectivity. Depending on the cost structure of a fisherman he may prefer to sell or buy quotas in secondary markets for quotas. Large-scale fishermen are more efficient than small-scale fishermen. That is, $MC_i > MC_j$ for all $i \in S$ and all $j \in L$. The additional details of the cost function is not necessary for calculating MSY. However, it is important for the calculations of maximum economic yield (MEY) which is outside the scope of this paper.

The equation (2) implies that the impact of fishing on total biomass change depends on fishing mortality rates (or exploitation rates) of old and young mature fish. Since fishermen have different fishing selectivities and hence different catch compositions of old and young mature fish, the impact of fishing and the number of new recruitments to the total biomass depend on fishing selectivity of each fisherman. Given a fishing selectivity of a fisherman, his harvest consists of old mature fish and young mature fish. That is, fishermen catch different biomass weights of old mature and young mature fish depending on their fishing technology. If the fishing selectivity of a fisherman is high (small-scale fisherman) then he catches relatively less young mature fish. Thus, fishing selectivity of fisherman is a determinant for computing the total catch of old mature and young mature fish of a fisherman. Accordingly, levels of $f_{1,t}X_{1,t} = \sum_{i\in N}[(1 - j_i)\alpha_{i,t}TAC_t]$ and $f_{2,t}X_{2,t} = \sum_{i\in N}[(j_i)\alpha_{i,t}TAC_t]$ depend on the fishing selectivity, the final quota levels and hence the catch compositions of fishermen. The main result of this section can now be stated.

**Result 1:** Quota allocation mechanisms and restrictions on the transferability of quotas are determinants to reduce the effects of fishing on the total biomass.

**Proof:** According to the equation (2), the impact of fishing can be minimized by maximizing $X_{2,t+1}$ since $X^*_{1,t+1} = X_{1,t+1}$ and by minimizing $w_2(s_1\, f_{1,t}\, X_{1,t} + s_2\, f_{2,t}\, X_{2,t})$. That is, the difference between $R\left(X^*_{1,t+1}, X^*_{2,t+1}\right)$ and $R\left(X_{1,t+1},\, X_{2,t+1}\right)$ is shaped only by the total population of the old mature age class. The difference between the total population of the old mature fish without fishing and with fishing is equal to $s_1\, f_{1,t}\, X_{1,t} + s_2\, f_{2,t}\, X_{2,t}$. This implies that the function, $w_2(s_1\, f_{1,t}\, X_{1,t} + s_2\, f_{2,t}\, X_{2,t})$, is the objective function of the minimization problem. If the given objective function is minimized, then $X_{2,t+1}$ is maximized and the difference between the recruitment functions is minimized. As a result, the impact of fishing is minimized. Since $w_i$ and $s_i$ values are constant, minimizing the impact of fishing just depends on the rates of total fishing mortalities for different mature age classes. There are three possible cases. If $s_1 X_{1,t} > s_2 X_{2,t}$ at the initial point of the fish population, then the impact of harvesting old mature fish is less than the impact of harvesting young mature fish to the total biomass change of the fish population. On the other hand, if $s_1 X_{1,t} < s_2 X_{2,t}$, the results are reversed. That is, the impact of harvesting old mature fish is higher than harvesting young mature fish. Finally, if $s_1 X_{1,t} = s_2 X_{2,t}$, then either harvesting old mature fish or young mature fish results in the same impact of fishing. Let without loss of generality $s_1 X_{1,t} > s_2 X_{2,t}$, which is a more realistic case since the survival rate of old mature fish tends to be less than the survival rate of the young mature fish and also the number of young mature fish is usually higher than the number of old mature fish. In this case, switching one unit harvest of young mature fish with one unit harvest of old mature fish is always preferable to minimize the impact of fishing on total biomass. Note also that $f_{1,t} X_{1,t} = \sum_{i \in N} [(1 - j_i) \alpha_{i,t} TAC_t]$ and $f_{2,t} X_{2,t} = \sum_{i \in N} [(j_i) \alpha_{i,t} TAC_t]$ and final quota allocations depend on the initial quota allocation. If there are restrictions on the transferability of quotas, this will affect the final allocation of quotas, $\alpha_t$. Thus, restrictions on transfer of quotas affects the impact of fishing on the total biomass. □

### 3.3 Achieving MSY under TFCs

Member States have agreed to manage EU fish stocks at MSY (EC, 2006). Under the MSY approach, the management goal of the EU is to produce both economically and biologically sustainable harvest levels. Currently, most of the fish stocks are overfished with respect to MSY harvesting conditions (Da Rocha et al., 2012). For example, 13 of fish stocks out of 14 different evaluated fish stocks are overfished with respect to MSY in Western Waters Area (EC, 2012).

Despite of the recent developments in the EU on achieving MSY, MSY approach is not today's issue. Moreover, the roots of this objective date back to 1982 UN Convention on the Law of the Seas. However, implementation of necessary policies have iterated up to today. Besides, the the way of finding the most accurate estimation of MSY is highly discussed by scientists. Some of the estimations for MSY do not consider the age-structure of fish populations. Those approaches do not take into account the different fertility rates at different ages, but only consider the weight of fish while measuring the effect of harvesting on total biomass. However, considering the age-structure of the fish population results in more accurate estimations for MSY. The most common methods for the estimation of MSY are Scheafer (1954) and Fox (1970) models. Recently, Skonhoft et al. (2012) applied simple Lagrangian method to find fishing mortalities for the young mature and old mature fish at MSY under an age-structured model. They show that if $\frac{w_2}{s_2} > \frac{w_1}{s_1}$, then fishing mortality rates are $f_2^{MSY} = 1$ and $0 < f_1^{MSY} < 1$ at the population equilibrium. Moreover, the total number of fish in each age class is $X_1^{MSY} = s_0 a - \frac{b}{1+\alpha s_1(1-f_1^{MSY})}$ , $X_2^{MSY} = s_1(1 - f_1^{MSY})X_1^{MSY}$, and $X_0^{MSY} = R(X_1^{MSY}, X_2^{MSY})$. Given this the total biomass at MSY is defined as $B_{MSY} = w_0 X_0^{MSY} + w_1 X_1^{MSY} + w_2 X_2^{MSY}$.

In the previous subsection, we investigated the impact of fishing on the total biomass. Since catch compositions of fishermen depend on their fishing selectivities, the impact of fishing on total biomass for every period depends on the quotas held by each type of vessels in that period. The main problem for European fisheries is that total biomass levels at EU fisheries are less than the estimated total biomass at MSY for almost all economically valuable fish stocks. Thus, we deal with the total biomass levels less than the one at MSY ($B_{MSY}$) and investigate the interrelations between TFCs and MSY for a single species fishery which is initially at a biomass level less than $B_{MSY}$. Let's suppose that the initial population is at a biomass level less than $B_{MSY}$ at time t, and at $B_{MSY}$ at time $t^*$. We compare the time needed to achieve $B_{MSY}$, $t^* - t$, under different quota allocations and restricted transferability of quotas. Furthermore, we investigate the impact of initial quota allocation on the time duration to achieve MSY harvesting conditions. To be able to make this comparison, we will look at the convergence rate or population growth rate at each period under different quota allocations and restricted transferability of quotas.

According to the discussion in the previous section, the change in the total biomass from recruitment time $t+n+1$ to $t+n$, where $0 < n \leq t^* - t$, is equal to the following equation:

$$\rho_{t+n} = w_0\left[R\left(X_{1,t+n+1}, X_{2,t+n+1}\right) - R\left(X_{1,t+n}, X_{2,t+n}\right)\right] + w_1 s_0 R\left(X_{1,t+n}, X_{2,t+n}\right) + w_2\left(s_1\left(1 - f_{1,t+n}\right) X_{1,t+n} + s_2\left(1 - f_{2,t+n}\right) X_{2,t+n}\right)$$

Under meaningful TACs where $TAC_t = f_{1,t}X_{1,t} + f_{2,t}X_{2,t} > 0$, maximizing the total biomass growth for every period will minimize the time required to achieve MSY level of total biomass, $B_{MSY}$. Therefore, in order to have higher growth rates and less time for achieving MSY, the equation above should be maximized for every period. Hence, to maximize the total biomass growth for this period, we have to maximize both $R\left(X_{1,t+n+1}, X_{2,t+n+1}\right)$ and $w_2\left(s_1\left(1 - f_{1,t+n}\right) X_{1,t+n} + s_2\left(1 - f_{2,t+n}\right) X_{2,t+n}\right)$ given population parameters, $X_{0,t+n}$, $X_{1,t+n}$, and $X_{2,t+n}$. The second term is maximized by minimizing $f_{1,t+n}$ and maximizing $f_{2,t+n}$ since we assume that $s_1X_{1,t} > s_2X_{2,t}$. Similarly, $R\left(X_{1,t+n+1}, X_{2,t+n+1}\right)$ is maximized by minimizing $f_{1,t+n}$ and maximizing $f_{2,t+n}$ since $X_{1,t+n+1} = s_0X_{0,t+n}$, $X_{2,t+n+1} = s_1\left(1 - f_{1,t+n}\right) X_{1,t+n} + s_2\left(1 - f_{2,t+n}\right) X_{2,t+n}$ and the numbers of recruits are positively correlated with the numbers of old mature fish. As a result, a decrease in the young mature fish population has a greater effect on the new recruitments to the population in the future. To achieve the maximum growth of total biomass at each period, having one more unit of fishing mortality for the old mature fish class is always preferable to having one more unit of fishing mortality for the young mature fish class. Therefore, the fishing mortality of the old mature fish should be maximized and the fishing mortality of the young mature fish should be minimized at each period to converge the total biomass target at a shorter time duration. Note that not only the total population size but also the total biomass proportion and size of each age class is also important to achieve MSY conditions in a dynamic framework.

**[Figure 2 is about here.]**

Figure 2 shows the relationship between growth in fish stocks (in tons) and total fish biomass stock. The MSY under an age-structured model with three cohorts is the point A where the growth in the fish stock is maximized. The growth in the fish stock can also be negative. If the population size is below minimum viable population (the first point where the graph intersects the horizontal axis), the population growth is negative and the extinction of the population is unavoidable. This figure explicitly shows that MSY depends on not only the total biomass level but also the biomass proportion of each age classes. For instance, at $B_1$ level of total biomass, different population structures results in different levels of growth in the total biomass. Furthermore, even at a higher total biomass level, the growth rate of total biomass at $B_2$ may be less than the growth of the total biomass level at $B_1$ depending on the proportions of young and old mature fish in the population. The point A refers to the MSY level at $B_{MSY}$ under an age-structured model. The point of C and D refer to the total biomass growth levels at $B_2$ which are less than the maximum growth level at $B_2$. At a given total biomass level, the higher the ratio ratio of $\frac{X_1}{X_2}$, the higher the total growth of the fish population. Point A refers to the population equilibrium. Even at the same total biomass level, if the ratio of $\frac{X_1}{X_2}$ is less than the level of $\frac{X_1}{X_2}$ at point A, then the total growth of the fish population will be less than the growth at the equilibrium point A. Thus, we can deduce that it is not only important to reach the total biomass level but it is also important to reach the equilibrium population levels for both age group of fish. The constraints below steer the solution (at the population equilibrium) for $X_1$ and $X_2$ at MSY as in Skonhoft et al. (2012):

$$X_1 = s_0\ R(X_1, X_2),$$

$$X_2 = s_1\,(1 - f_1)\,X_1 + s_2\,(1 - f_2)X_2.$$

In the light of the discussions above, the rest of the paper focuses on the catch compositions of fishermen. The effect of per weight harvest of small-scale fishermen on the population growth will be lower than the effect of per weight harvest of large-scale fishermen since small-scale fishermen are operating in coastal areas and harvesting old mature fish at a higher rate. This is to say that small-scale fishermen have a higher fishing selectivity than that of larger-scale fishermen. Under different catch compositions of different types of vessels, the question that 'Does initial quota allocation matters?' arises if we consider the major principles for TFC system stated by the European Commission. The reason is that under restrictions such as setting minimum quota levels for small-scale fishermen, there will not be a free trade or perfect transferability for all quotas which means that fishermen may not converge to the pre-determined (target) level of quotas after quota trade occurs at the population equilibrium. On the other hand, Ledyard (2009) shows that whatever the initial quota allocation is, fishermen converge to their target quota shares under free trade mechanism. This result is not valid if there is a minimum level of quotas set for small-scale vessels which are not tradable. The European Commission agreed on such a restriction for protecting small-scale fishermen and providing sustainability of employment in the fishing sector. Thus, it is highly expected to be the case that the level of minimum quotas will be set at a higher level of what would it be under free trade environment. Hence, the final quota shares which are expected to be under perfect transferability of quotas will not be observed after the limitations issued on the quota holdings and transferability of quotas. As a result, it can be deduced that final quota levels of large-scale fishermen may not converge to and most probably be less than the target quota levels of them if the restrictions such as minimum quota reservation for small-scale fishermen are issued. This implies that quotas will not be transferred from high marginal cost small-scale fishermen to low marginal cost large-scale fishermen.

Let's say that the minimum quota ratio reserved for small-scale fishermen is $a > 0$. The final total quota level (at some period depending on the cost structure of the fishery) for small-scale fishermen under transferable quotas is zero since quotas will be transferred from high marginal cost small-scale fishermen to low marginal cost large-scale fishermen given that secondary markets are perfect. Then, the impact of fishing is less than the impact of fishing which would be observed under free trade or transferable quota environment. In order to exemplify that on Figure 2, suppose that the reserved nontransferable quota ratio for small-scale fishermen is a positive amount. As a result, the ratio of old mature fish harvest to total catch will be higher since small-scale fishermen will hold higher levels of final quotas. Thus, the ratio of the young mature fish population to old mature fish population $(\frac{X_1}{X_2})$ will be higher under restricted transfers than which would be under free trade conditions. In figure 2, point D refers to the population structure under free trade conditions and point C refers to the fish population structure under the TFC system having trade restrictions. As a result, under the same levels of TACs, the increase in total biomass will be higher from point C and the convergence to $B_{MSY}$ will ocur in a shorter time. However, as we formerly emphasized, being at $B_{MSY}$ does not guarantee to satisfy MSY harvesting conditions. In order to achieve MSY in a shorter time, fishing mortality of old mature fish should be maximized $(f_{2,t}X_{2,t} = \sum_{i \in N}[(j_i)\alpha_{i,t}TAC_t])$ and fishing mortality of young mature fish

($f_{1,t}X_{1,t} = \sum_{i\in N}[(1-j_i)\alpha_{i,t}TAC_t]$) should be minimized in each period. That is, the population growth rate or converge rate to the population equilibrium has to be maximized. Since small scale fishermen harvest relatively less young mature fish and relatively more old mature fish due to their high selectivity of fishing ($j_i > j_k$ for all $i \in S$ and all $k \in L$), reserving some proportions of the total allowable catch to small scale fishermen and making their quotas nontransferable will be an effective tool both for protecting social welfare and high level of employment and achieving MSY in a shorter time duration. Therefore, protective actions for small-scale fishermen may result in higher levels of total biomass growth and less time required for achieving MSY harvesting conditions.

**[Figure 3 is about here.]**

The situation described above is exemplified in Figure 3. Suppose that the initial total biomass level at time t is $B_1$. The highest sustainable yield level for the total biomass level of $B_1$ is equal to $HSY_1$. In order to have a positive growth rate at $B_1$, TAC should be established at a level below the total biomass growth level at $B_1$, which is between 0 and $HSY_1$ depending on the composition of a fish population. Let's say that the total allowable catch level is determined at $TAC_1$ at time t, which is less than the total biomass growth level without fishing ($G_1$). As a result, the total biomass growth from time t to time t+1 will be equal to $G_1 - TAC_1$. The total biomass level at the beginning of t+1 will be equal to $[B_1 + (G_1 - TAC_1)]$. There are two different conditions to be satisfied for achieving MSY harvesting conditions. The first goal is achieving the MSY level of total biomass and the second goal is achieving the MSY level of population parameters. Suppose that after harvesting at time t, the total biomass level increases to $B_2$ that is $B_2 = [B_1 + (G_1 - TAC_1)]$. The total biomass growth at time t+1 will not only depend on the TAC level at time t+1, but it will also depend on the population parameters, which refers to the composition of the fish population. The composition of the fish population at the beginning of time t+1 is determined by the final quota shares of fishermen having different fishing selectivities at time t. Under the protective actions for small-scale fishermen, if the minimum quota level reserved for small-scale fishermen was higher at time t, then the fishing mortality of old mature fish would be higher at time t and the impact of fishing would be less than the former case. As a result, the total biomass growth will be higher than $G_1$ even if the TAC level remains the same. In the latter case, if the total biomass growth without fishing is $G_2$, then the total biomass level increases to $B_3$ that is $B_3 = [B_1 + (G_2 - TAC_1)]$. In this growth path, the quota allocation mechanisms and the trading rules plays the key role as in the previous section.

**Result 2:** Reserving nontransferable quotas for small-scale fishermen reduces the time needed to achieve MSY and hence sustainable fisheries.

## 4. Conclusion

Two major topics of the proposals for the CFP reform are transferable fishing concessions and MSY. In the light of the previous discussions on ITQs, the success of implementation of TFCs depends on various conditions. For instance, EU aims to protect small-scale fleets while increasing the economic performance of fisheries. In this sense, relevant policies will be set such as limiting the maximum amount of quotas that can be held or reserving some non-tradable quotas for the small-scale fishermen. As a result, Member States will be able to protect their coastal communities from the undesired results of the TFC system. These types of restrictions will be effective for stabilizing the employment level in the fishing industry that could be affected by the concentration problem. In principle, transferable fishing concessions may prevent ‘racing to fish’ since assigning property rights or usage rights is used to solve the common resource problem under TFCs. Furthermore, promoting small-scale fishermen can be very important for the sustainability of the social welfare and employment in the fish catching sector.

Besides the benefits of new regulations for protection of social welfare, these regulations may also have a positive impact on achieving MSY conditions. In this study, we show that the mechanism for quota allocation and quota transferring are important to achieve the maximum level of population growth. Furthermore, we indicate that since different catch compositions of fishermen result in different levels of population growth, reserving some part of the total quotas for only small-scale fishermen will result in a higher level of total biomass growth and hence less time for achieving MSY harvesting conditions. As a result, the promise of TFCs depends on the design of the quota allocation process and market structure for quotas, which can be transferable, nontransferable for all fishermen or nontransferable only for small scale fishermen. We show that TFCs can be much more effective to achieve sustainable fisheries if a part of quotas is assigned to small-scale fishermen.

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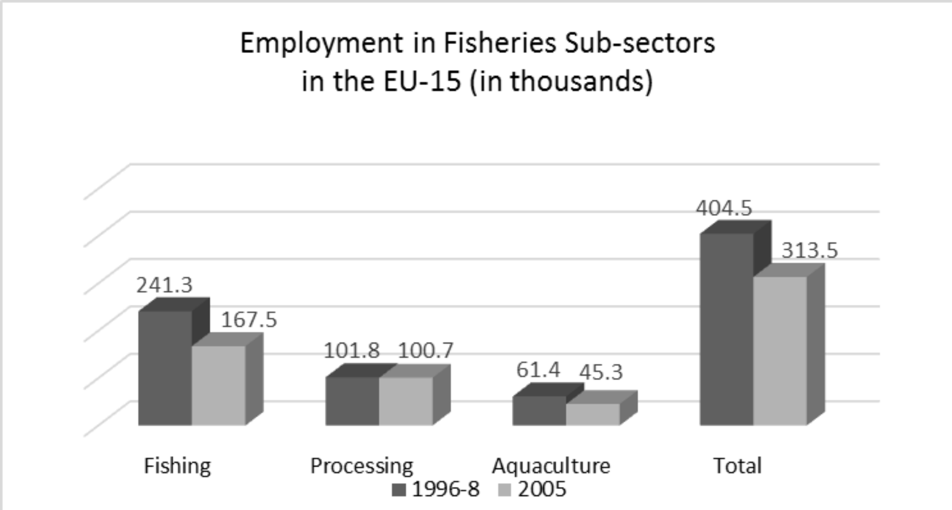
**Figure 1**. Employment in fisheries sub-sectors in the EU




Source: The Economic Performance of Fisheries and Aquaculture in the EU.
http://www.cfp-reformwatch.eu/pdf/002.pdf

**Figure 2**. MSY for an age-structured fish population

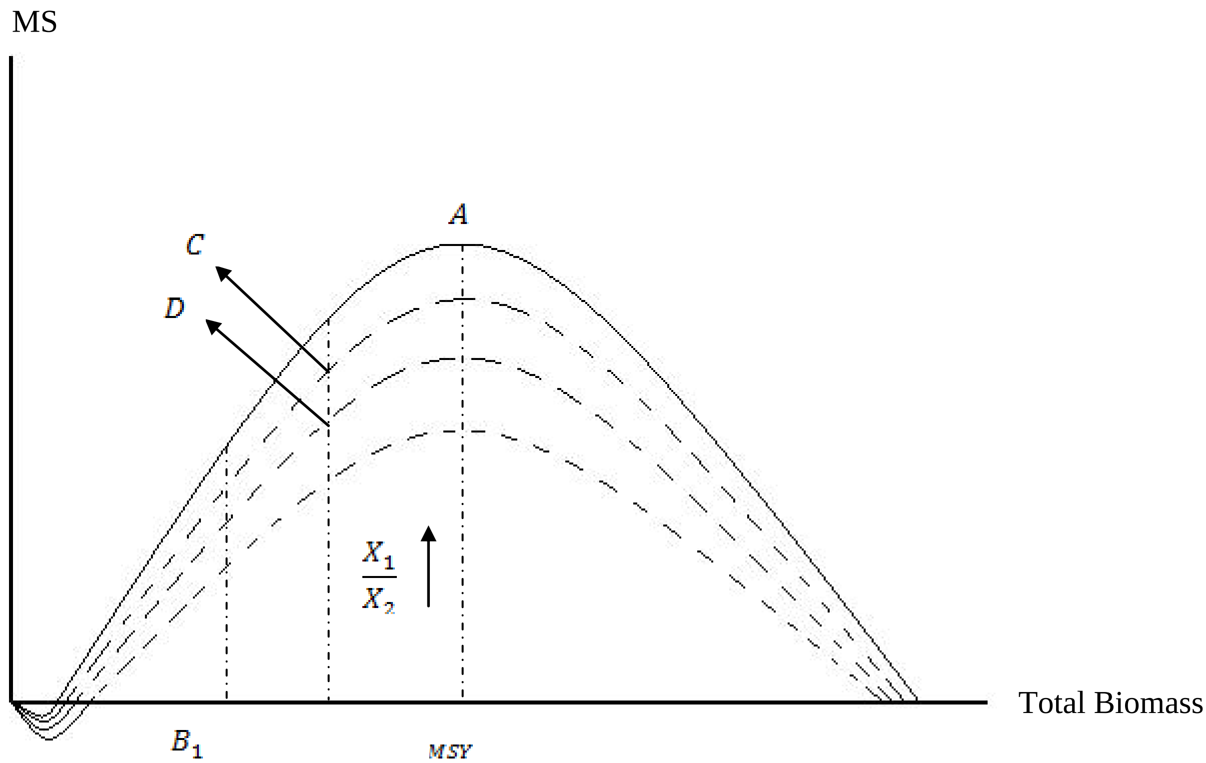


**Figure 3**. MSY and total biomass growth for different weights of age-classes in total biomass