Thesis for the Degree of Master of Fisheries Science

Estimation of productivity growth, technical progress and efficiency changes of fisheries in Egypt

by

Mohamed Gamal El Basiouny

KOICA-PKNU International Graduate Program of Fisheries Science

Graduate School of Global Fisheries

Pukyong National University

February 2018

Estimation of productivity growth, technical progress and efficiency changes of fisheries in Egypt

(이집트 어업의 생산성 향상, 기술 진보 및 효율성 변화 측정)

Advisor: Prof. Kim Dohoon

by

Mohamed Gamal El Basiouny

A thesis submitted in partial fulfilment of the requirements

for the degree of

Master of Fisheries Science

in KOICA-PKNU International Graduate Program of Fisheries Science,

Graduate School of Global Fisheries

Pukyong National University

February 2018

Estimation of productivity growth, technical progress and efficiency changes of fisheries in Egypt

A dissertation

by

Mohamed Gamal El Basiouny

Approved by:

(Chairman) Prof. LEE Sang-Go

(Member) Prof. NAM Jongoh

(Member) Prof. KIM Dohoon

February 23, 2018

Tables of Contents

List of Figures

List of Tables

Estimation of productivity growth, technical progress and efficiency changes of fisheries in Egypt

Mohamed Gamal El Basiouny

KOICA-PKNU International Graduate Program of Fisheries Science
Graduate School of Global Fisheries
Pukyong National University

Abstract

In this study, technical efficiency was estimated for 16 fishing vessels from 2001 to 2014 by using Data Envelopment Analysis (DEA). Output orientated with assuming a constant return to scale (CRS) was used. As a result of this analysis, the technical efficiency TE of trawl (I), purse seine (E), trammel net (C) and longline (G) fishing vessels were equal to 1. It means all of them are efficient, but the other vessels are inefficient because TE < 1.

On the other hand, the changes in total factor productivity of trawl, purse seine, trammel net and longline fisheries that are common to Ezbet EL Borg between the same period

(2001 and 2014) was evaluated by a nonparametric technique which is titled as Malmquist total factor productivity index. The total factor productivity change TFPCH decomposed into technical change TECHCH and efficiency change EFFCH. The total factor productivity change was analyzed through analyzing TECHCH and EFFCH. According to the analysis, the change in mean total factor productivity of the fisheries in Ezbet EL Borg was 1.2% yearly. The changes in both of the mean total technical efficiency and technological change were 0.1% and 1.1% respectively.

The activity of technological progress led to the increase in productivity of Ezbet EL Borg fisheries. Above all, technological progress and technical efficiency played an important role in the changes in total factor productivity of each fishery. To maintain productivity, it's better enact good fisheries management policies by the government and efforts by the fishing industry that help productivity increases.

Keywords: Technical efficiency (TE), Data Envelopment Analysis (DEA), Constant return to scale (CRS), Ezbet EL Borg fisheries, Total factor productivity, Technological progress, Malmquist productivity index.

Introduction

Productivity describes various measures of the efficiency of production. A productivity measure is expressed as the ratio of output to inputs used in a production process, i.e. output per unit of input. Productivity growth also helps businesses to be more profitable (Kurosawa, 1975). The productivity of fisheries must be developed and improved on optimal use and good management of fisheries resources. In general, productivity development occurs through improved technological progress and technical efficiency (Kalirajan et al., 1996).

With increasing worldwide demand, imports will be more difficult to source, and Egypt's future needs will have to be met by domestic production. According to GAFRD (2014), the imports of fish products in 2013 and 2014 were 235,851 and 354,571 tons respectively, which reflects an increase about 50.33 % in 2014 more than 2013. That means the fisheries sector vision should be improved at least to produce needs from fishes and cut imports and increase exports to enhance the national income in Egypt.

The fishery sector contributes immensely to social and economic developments in Egypt where fish consumption is also considered as one of the main sources of animal protein in terms of food security. Restoring the balance between the growth rates of fish production and rates of population growth is the main objective in the development of fish production in order to meet the needs of consumption and contribute to food security (Hassan et al., 2014).

Egypt's fishery sector has been a vital part of the national culture and economy throughout recorded history. With rich water bodies, lakes, rivers, coastal lagoons and the open sea, catches of fish, and increasingly their culture has been a key ingredient in the national food supply and potential export earnings (El-Naggar et al., 2006).

Fish is a traditional and important part of the Egyptian diet. People prefer fish to poultry and red meat, which are more expensive. Fish is the main source of cheap animal protein for a growing population (FAO, 2010).

Egypt is located in the eastern corner of North Africa. The country is surrounded by the Mediterranean Sea, amongst Libya and the Gaza Strip, and the Red Sea north of Sudan. Fisheries play a slight role in Egypt's economy, making up fewer than 0.5% of Egypt's total GDP in 2008 (FAO, 2010). Even so, fishery products are essential locally both as a source of affordable protein and as part of the traditional food. Marine capture fisheries have a long history in Egypt, but their importance has decreased relative to freshwater fisheries and aquaculture, with the latter accounting for 74% of total fish production in Egypt in 2012 (GAFRD, 2013).

Egypt's Mediterranean fisheries are multi-species and the majority of its fleet are made up of wooden hulled boats that fish primarily in inshore waters. Most of the fish catch is sold and consumed locally, where the first choice is for fresh fish over more expensive poultry and red meat (FAO, 2010). The main fishing ports along the Egyptian Mediterranean coast are Matrouh, Alexandria (Anfoshi), Alexandria (Abu Qir), Madaaia, Rashid, Motobas (Burullus), Baltim, Damietta (Ezbet El-Borg), Port Said and Arish (Samy-Kamal, 2015). This study focuses on Damietta Governorate, especially Ezbet El-Borg as it has about 815 fishing vessels (trawling, Purse Seine, Longline and trammel net), which represents 16.9% of the Egyptian fishing fleet (GAFRD, 2014).

Data envelopment analysis (DEA) is a nonparametric method in operations research and economics for the estimation of production frontiers. It is used to empirically measure the productive efficiency of decision-making units (or DMUs). In the circumstance of benchmarking, the efficient DMUs, as defined by DEA, may not necessarily form a "production frontier", but rather lead to a "best-practice frontier" (Cook et al., 2014). In this study, output orientated DEA under assuming constant returns to scale (CRS) has been used to calculate and know which fishing vessels are efficient in each fishery (Fare et al., 1994). The main reason for using output orientated DEA is how much can output quantities be proportionally expanded without altering the input quantities used. The CRS assumption was appropriated when all DMUs were operating at an optimal scale (Coelli, 1996). Finally, Malmquist index approach was used for calculating indices of total factor productivity (TFP) change; technological change; technical efficiency change and scale efficiency change in each fishery (Färe et al., 1994).

According to Kirkley et al., (2001); Kim et al. (2007); Zheng et al. (2005); and Pascoe et al. (2006); technical efficiency was analyzed in short-term to measure fishing capacity. It is necessary to pay attention to conduct a lot of research in this field because this can help us know more about fisheries productivity and choosing the right decisions for development. Until now, it's difficult to find studies with symmetric analyses to estimate total factor productivity and technological progress for long-term productivity changes.

The study aims to calculate technical efficiency by using (Output orientated-DEA model with assuming CRS) for 16 fishing vessels and to estimate the total factor productivity from 2001 until 2014 of common fisheries in Ezbet El Borg by a nonparametric technique named Malmquist productivity index and to analyze the basis of the changes in productivity which segmented into technical efficiency and technological progress (Caves et al., 1982). It is also aimed to offer policy implications for the improvement of future fisheries productivity.

Situation of fisheries in Ezbet EL-Borg

1. Study site

Damietta is a fishing industry town, with one of the largest fleets on the Mediterranean Sea which accounts for fully half of the fishing vessels of Egypt. It is well known for the port (El-Batrawy and Omnya, 2010). Ezbet El Borg is a shoreline city with a huge fishing industry in Damietta Governorate, Egypt. It is 15 km (9 mi) northeast of Damietta and 210 km (130 mi) from Cairo. Its population is approximately 70,000. The city is situated on the north coastline of Egypt at the entrance of the Damietta River, a distributary of the Nile, contrasting Ras El Bar. The fishermen berth their fishing boats along the Damietta branch of Nile, which extends to 3.6 (km) in length and is approximately 260 m wide (Negm et al., 2017).

The metropolis is home to around 10,000 fishermen (1% of Egypt's total), and the base of Egypt's biggest fishing boat fleet, containing boats of the traditional felucca sort. The city is also home to a sardine-canning factory functioned by the Edfina Company (Encyclopædia Britannica, 1993). The fishing sector affords the main source of income for the locals. Many of the fishing boats venture far along the Eastern Mediterranean and the Red Sea. It is also a center for ship and yacht-building in Egypt (Hopkins and Harry, 1969). Ezbt El-Borg is one of the main fishing ports along the Egyptian Mediterranean coast. The highest fishing effort was registered in Ezbet El-Borg port with almost 17 % of the total motorized vessels in Egypt. Damietta area alone accounts for 28% of the total number of vessels and 35% of the total engine power (EastMed, F. A. O., 2014).

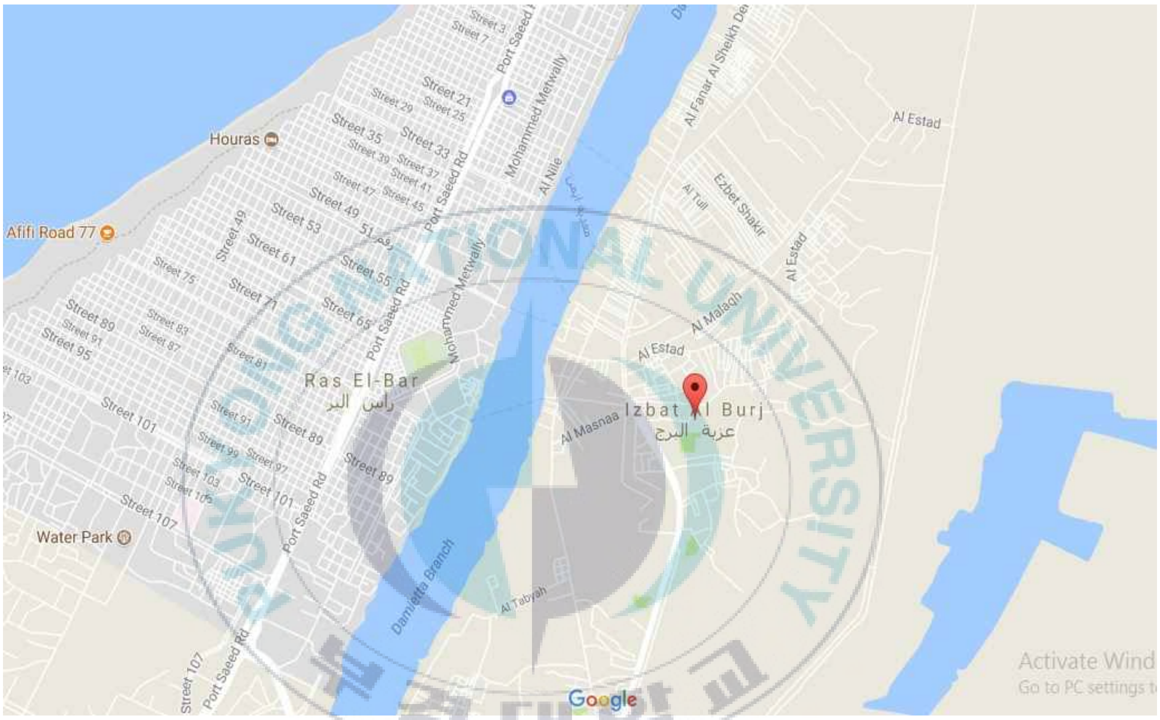

Fig. 1. Map of Ezbet EL-Borg city (Google Map).

2. Production and Major fisheries

The total production from Ezbet EL-Borg fisheries represents about 16,947 ton in 2014, corresponding to about 27% of the total catch of the Mediterranean Sea fisheries and about 16% of total marine capture fisheries in Egypt. In contrast, the total production from Ezbet EL-Borg fisheries was the highest in 2008, representing about 26,421 tons, with almost 30% of the total catch of the Mediterranean sea fisheries and about 19% of total marine capture fisheries. This indicates that there was a drop in production by 36% between 2008 and 2014 as shown in Fig. 2.

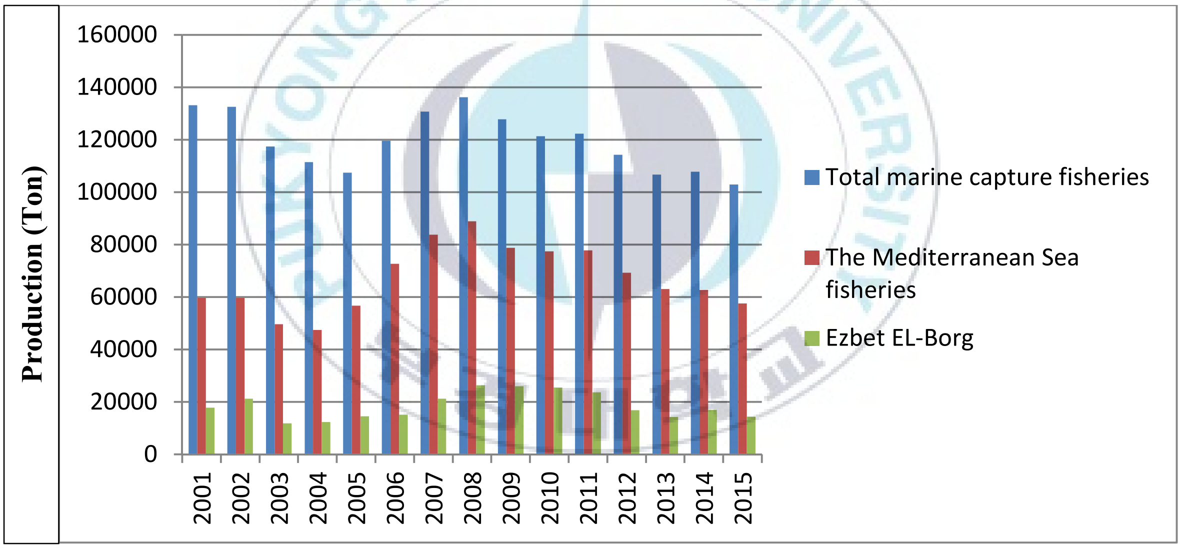

Figure 2. Production of total marine capture fisheries, the Mediterranean sea fisheries and Ezbet EL-Borg fisheries (2001-2015) (GAFRD, 2001-2015).

2.1 Trawl Fishery

Trawl fishery is playing a magnificent role in the commercial fishery. The trawl contains the warp, otter boards, ropes and trawl net. The trawl fishery catch represents more than 46% of the total catch, and more than 79% of total trawl fishery catch are shrimp, blue swimming crab, common cuttlefish, brushtooth lizardfish and grey gurnard (GAFRD, 2014).

2.2 Purse seine fishery

Purse Seine plays an important role in Ezbet EL-Borg fisheries. For most situations, it is the most efficient gear for catching large and small pelagic species that are shoaling (FAO, 2013). The purse seine fishery catch represents more than 25% from the total catch and more than 60% of total purse seine fishery catch are sardinellas nei, anchovy and european barrcudas (GAFRD, 2014).

2.3 Long line fishery

Long line fishery utilizes a long line, called the main line, with baited hooks attached at intervals by means of branch lines called snoods (or gangions). A snood is a short length of line, attached to the main line utilizing a clip or swivel, with the hook at the other end. Longlines are classified mainly by where they are placed in the water column. This can be at the surface or at the bottom. Lines can also be set by means of an anchor, or left to drift. Hundreds or even thousands of baited hooks can hang from a single line. In some unstable fisheries, for example, the Patagonian toothfish, fishermen may be limited to as few as 25 hooks per line (Rice et al., 2006). The longline fishery catch represents more than 12% from the total catch., and the most important species of longline fishery are groupers nei, meagre, European sea bass and narrow-barred Spanish mackerel. (GAFRD, 2014).

2.4 Trammel net fishery in Ezbet EL-Borg

Trammel net is the main fishing gear used by artisanal fishers in Ezbet EL-Borg and is representative of Mediterranean small-scale fisheries using static gear. The use of static gears close to the coast, where seasonal variability and spatial heterogeneity are high, promotes the diversification of fishing practices (Merino et al., 2008). The trammel net fishery catch represents more than 5% from the total catch., and the most important species of trammel net fishery are shrimp, blue swimming crab, grey mullets and marbled spinefoot (GAFRD, 2014).

Methods and Data

3.Data Envelopment Analysis (DEA)

DEA is a linear-programming approach, which uses data on the input and output measures of a group of DMU (or firms etc.) to build a piece-wise linear surface over the data points. DEA can be either input-orientated or output-orientated. In the input-orientated case, the DEA method describes the frontier by looking for the maximum possible proportional reduction in input usage, with output levels held constant for each fishing vessel. While, in the output-orientated case, the DEA method seeks the maximum proportional increase in output production, with input levels held fixed. The two measures provide the same technical efficiency scores when a constant returns to scale (CRS) technology applies, but are unequal when variable returns to scale (VRS) is assumed. This study uses DEAP computer software (version 2.1) developed by Coelli (1996) to measure technical and scale efficiency in the Egyptian fisheries and fishing fleet in Ezbet El Borg.

3.1. Output-Orientated DEA

This study assumes a CRS under output-oriented DEA. Hence the choice of orientation is not a problem in this case. However, this study has chosen an output orientation because it would be fair to assume that, in the case of fishing vessels, each vessel attempts to maximize output from a given set of inputs rather than the converse. If one has data on N fishing vessels in a particular time period, the linear programming (LP) problem that is solved for the i-th vessel in an output-orientated DEA model is as follows:

$\max\phi,\lambda\ \phi,$

st $-\phi yi + Y\lambda \geq 0,$

$xi - X\lambda \geq 0,$

$N1'\lambda=1 \qquad \lambda \geq 0,$ (1)

where

yi is a M×1 vector of output quantities for the i-th vessel;

xi is a K×1 vector of input quantities for the i-th vessel;

Y is a N×M matrix of output quantities for all N vessels;

X is a N×K matrix of input quantities for all N vessels;

λ is a N×1 vector of weights; and ϕ is a scalar.

$1 \leq \phi < \infty$, and ϕ-1 is the proportional increase in output that could achieved by the i-th vessel, with input quantities held constant.

1/ ϕ is a TE score which varies between zero and one (Coelli, 1996). This study used multi-stage DEA, where it conducts a sequence of radial LP's to identify the efficient projected point. The multi-stage DEA is more computationally.

3.2 Productivity change

Productivity growth decomposed into two mutually exclusive and exhaustive components: changes in technical efficiency over time and shifts in technology over time (Färe et al., 1997).

When consider $\left(X^t, Y^t\right)$ is input and $\left(X^{t+1}, Y^{t+1}\right)$ is output at times t and $t+1$, $\left(X^t, Y^t\right) \in F^t$ and $\left(X^{t+1}, Y^{t+1}\right) \in F^{t+1}$. Here, F is production technology that converts the input (X) into the output (Y), and the frontier of F is a production function. The input–output relationship change from $\left(X^t, Y^t\right)$ to $\left(X^{t+1}, Y^{t+1}\right)$ with period of time, and these can be considered as changes in productivity. Production technology is commonly modelled by means of a production function, which in the scalar output case specifies the maximum output obtainable from an input vector. It may be defined using the output set, F, which represents the set of all output vectors, y, which can be produced using the input vector, x. That is,

$F^t = \{(X^t\ ,\ Y^t\ )\ X^t \text{can produce } Y^t\}.$ (2)

3.3 Technical efficiency

Technical efficiency is the degree to which the actual output of a production unit approaches its maximum (Färe et al., 1978). Both of technological progress and technical efficiency will be measured by estimating distance function which can be defined as in Eq.3. Hence, The ratio between the maximum possible output from the input at time t and the actual output called the output distance function at time t . This function is defined as the reciprocal of the "maximum" proportional expansion of the output vector Y^t, given inputs X^t (Farrell, 1957).

$$D^t(X^t,\ Y^t) = \inf\{\theta\colon (X^t,\ Y^t/\theta) \in F^t\} \qquad (3)$$

$D^t(X^t, Y^t)$ is always less than or equal to 1 because $(X^t\ ,\ Y^t) \in F^t$. Using the same technique, the distance function of $(X^t\ ,\ Y^t)$ and $(X^{t+1}\ ,\ Y^{t+1})$ at time t and $t + 1$ can be defined by following Equation

$$D^t(X^{t+1}, Y^{t+1}) = \inf\{\theta\colon (X^{t+1}, Y^{t+1}/\theta) \in F^t\} \qquad (4)$$

Eq.4 is a distance function that estimates $(X^{t+1}\ ,\ Y^{t+1})$ using the production function at time t .

This Eq is a distance function that calculates (X^t, Y^t) using the production function at time $t+1$. According to the definition, $D^t(X^t, Y^t)$ and $D^{t+1}(X^{t+1}, Y^{t+1})$ are less than or equal to 1. Though, with the result of technological progress, $D^t(X^{t+1}, Y^{t+1})$ may take a value larger than 1 if (X^{t+1}, Y^{t+1}) exists outside F^t.

$$D^{t+1}(X^t, Y^t) = \inf\{\theta: (X^t, Y^t/\theta) \in F^{t+1}\} \tag{5}$$

3.4 Malmquist index approach

The Malmquist productivity index, established by (Caves et al., 1982) and extended further by (Färe et al., 1992) relies on distance functions. DEA is an operational method to compute distance functions. Distance functions are very useful in describing the technology in a way that makes it possible to measure efficiency and productivity. The notation of a distance function was introduced independently (Malmquist, 1953) in a special consumption setting and more generally (Shephard, 1953), Distance functions allow one to describe a multi-input, multi-output production technology without the need to specify a behavioural objective. One may specify both input distance functions and output distance functions.

The Malmquist index measures the total factor productivity (TFP) growth. TFP index is well-defined using distance function, where an output distance function is used to consider a maximum relative increase of the output, Y, given the inputs, X. The TFP change (TFPCH) in time t+1 and t can be segmented into (1) technical efficiency change

(EFFCH) or catching up effect, and (2) technical change (TECHCH) or shifts of the frontier or innovation.

That is, this method is based on the concept of frontier (Farrell, 1957). The method can measure productivity and analyze the cause of the change in productivity by segmenting the productivity index into production frontier changes with time and efficiency changes of each unit.

The Malmquist productivity index between two consecutive periods $(\mathrm{t}\,,\mathrm{t}+1)$ can be defined by Eq.6 and Eq.7.

$$M^{t} = \frac{\mathrm{D}^{\mathrm{t}}(\mathrm{X}^{\mathrm{t+1}},\mathrm{Y}^{\mathrm{t+1}})}{\mathrm{D}^{\mathrm{t}}(\mathrm{X}^{\mathrm{t}},\mathrm{Y}^{\mathrm{t}})} \tag{6}$$

$$\mathrm{M}^{\mathrm{t+1}} = \frac{\mathrm{D}^{\mathrm{t+1}}(\mathrm{X}^{\mathrm{t+1}},\mathrm{Y}^{\mathrm{t+1}})}{\mathrm{D}^{\mathrm{t+1}}(\mathrm{X}^{\mathrm{t}},\mathrm{Y}^{\mathrm{t}})} \tag{7}$$

Eq.8 used for calculating Malmquist productivity index by using the ratio of the distance function (Farrell, 1957). When $\mathrm{M} > 1$, it means productivity has increased between two periods. Productivity doesn't change when M=1 and is decreased when $\mathrm{M} < 1$.

$$\mathrm{M}(^{\mathrm{t,t+1}}) = \left[\, \frac{\mathrm{D}^{\mathrm{t}}(\mathrm{X}^{\mathrm{t+1}},\mathrm{Y}^{\mathrm{t+1}})}{\mathrm{D}^{\mathrm{t}}(\mathrm{X}^{\mathrm{t}},\mathrm{Y}^{\mathrm{t}})} \cdot \frac{\mathrm{D}^{\mathrm{t+1}}(\mathrm{X}^{\mathrm{t+1}},\mathrm{Y}^{\mathrm{t+1}})}{\mathrm{D}^{\mathrm{t+1}}(\mathrm{X}^{\mathrm{t}},\mathrm{Y}^{\mathrm{t}})} \,\right]^{\frac{1}{2}} \tag{8}$$

$$\mathrm{M}(^{\mathrm{t,t+1}}) = \frac{\mathrm{D}^{\mathrm{t+1}}(\mathrm{X}^{\mathrm{t+1}},\mathrm{Y}^{\mathrm{t+1}})}{\mathrm{D}^{\mathrm{t}}(\mathrm{X}^{\mathrm{t}},\mathrm{Y}^{\mathrm{t}})} \mathrm{X} \left[\, \frac{\mathrm{D}^{\mathrm{t}}(\mathrm{X}^{\mathrm{t+1}},\mathrm{Y}^{\mathrm{t+1}})}{\mathrm{D}^{\mathrm{t+1}}(\mathrm{X}^{\mathrm{t+1}},\mathrm{Y}^{\mathrm{t+1}})} \cdot \frac{\mathrm{D}^{\mathrm{t}}(\mathrm{X}^{\mathrm{t}},\mathrm{Y}^{\mathrm{t}})}{\mathrm{D}^{\mathrm{t+1}}(\mathrm{X}^{\mathrm{t}},\mathrm{Y}^{\mathrm{t}})} \,\right]^{\frac{1}{2}} \tag{9}$$

The Ratio outside the bracket in Eq.9 is the change of relative efficiency between two years $(t, t+1)$. The geometric mean of the two ratios inside the brackets captures the shift in technology between the two periods evaluated at X^t, X^{t+1}

$$\text{Efficiency Change (EFFCH)} = \frac{D^{t+1}(X^{t+1}, Y^{t+1})}{D^t(X^t, Y^t)} \tag{10}$$

$$\text{Technological Change (TECHCH)} = \left[\frac{D^t(X^{t+1}, Y^{t+1})}{D^{t+1}(X^{t+1}, Y^{t+1})} \cdot \frac{D^t(X^t, Y^t)}{D^{t+1}(X^t, Y^t)}\right]^{\frac{1}{2}} \tag{11}$$

Undoubtedly, The Malmquist productivity index depends on the distance function and can be separated into many factors that cause productivity changes. it has the pros of examination factors which help to rise the productivity by analysis.

3.5 Estimation of Malmquist index by DEA method

This study can measure the Malmquist productivity index for two successive periods by estimating four distance functions:

$[D^t(X^t, Y^t), D^t(X^{t+1}, Y^{t+1}), D^{t+1}(X^t, Y^t), D^{t+1}(X^{t+1}, Y^{t+1})]$

The non-parametric approach introduced as Data Envelopment Analysis (DEA) by (Charnes et al., 1978) is a method of measuring efficiency of Decision Making Units (DMUs)/ firms through linear programming techniques, which ‘envelop’ observed input – output vectors as tightly as possible (Boussofiane et al., 1991). The DEA is a methodology directed to frontiers rather than central tendencies (Seiford and Thrall, 1990). The DEA is also capable of handling multiple inputs and outputs at the same time. In order to calculate the productivity of ith DMU between $t, t+1$.

3.5.1 The remaining LP problems

According to Färe et al. (1994), and given that suitable panel data are available, it can calculate the required distance measures were estimated for the Malmquist TFP index using DEA-like linear programs. For the i-th DMU, Therefore, it must calculate four distance functions is important factor to measure the TFP change between two periods, $t+1$ and t. This requires the solving of four linear programming (LP) problems. Färe et al. (1994) assume a constant returns to scale (CRS) technology in their analysis. The required LPs are:

$$[D^t(X^t,\ Y^t)]^{-1} = \max\phi,\lambda\ \phi,$$

$$\text{st} \quad -\phi yit + Yt\lambda \geq 0,$$

$$xit - Xt\lambda \geq 0,$$

$$\lambda \geq 0, \tag{12}$$

$$[D^{t+1}(X^{t+1},Y^{t+1})]^{-1} = \max\phi,\lambda\ \phi,$$

$$\text{st} \quad -\phi yi,t+1 + Yt+1\lambda \geq 0,$$

$$xi,t+1 - Xt+1\lambda \geq 0,$$

$$\lambda \geq 0, \tag{13}$$

$$[D^{t}(X^{t+1}, Y^{t+1})]^{-1} = \max\phi,\lambda\ \phi,$$

$$\text{st} \quad -\phi yis + Yt\lambda \geq 0,$$

$$xis - Xt\lambda \geq 0,$$

$$\lambda \geq 0, \tag{14}$$

$$[D^{t+1}(X^{t}, Y^{t})]^{-1} = \max\phi,\lambda\ \phi,$$

$$\text{st} \quad -\phi yit + Ys\lambda \geq 0,$$

$$xit - Xs\lambda \geq 0,$$

$$\lambda \geq 0. \tag{15}$$

That in LP's Eq.14 and Eq.15, where production points are compared to technologies from different time periods, the ϕ parameter need not be greater than or equal to one, as it must be when calculating standard output-orientated technical efficiencies. The data point could lie above the production frontier. This will most likely occur in LP Eq.15 where a production point from period t is compared to technology in an earlier period, $t + 1$. If technical progress has occurred, then a value of $\phi<1$ is possible. Note that it could also possibly occur in linear program problem (LP) Eq.14 if technical regress has occurred, but this is less likely.

3.6 Scale efficiency

Scale efficiency in each period is constructed as the ratio of the distance function satisfying constant returns to scale (CRS) to the distance function restricted to satisfy variable returns to scale (VRS). The production frontier that assumes variable returns to scale is more flexibly than the production frontier that assumes constant returns to scale. Thus, the distance function under (CRS) assumption is less than or equal the distance function under (VRS). The scale efficiency can be calculated by Eq.16

$$SE= TE_{CRS} / TE_{VRS} \quad (16)$$

There is scale efficiency when SE=1 and if SE<1, there is scale inefficiency. Thus, it can estimate TE_{CRS} (distance function for CRS) from Eq.17.Where, (TE_{VRS}) is pure efficiency.

$$TE_{CRS} =SE / TE_{VRS} \quad (17)$$

As,

Efficiency Change (EFFCH(t, t + 1) = $TE_{CRS}^{t+1} / TE_{CRS}^{t}$ (18)

Pure Efficiency Change (PECH(t, t + 1) = $TE_{VRS}^{t+1} / TE_{VRS}^{t}$ (19)

Scale Efficiency Change (SECH(t, t + 1) = SE^{t+1} / SE^{t} (20)

So, it can calculate the technical efficiency change between two consecutive periods of time can be evaluated from Eq.21

$$(\mathrm{EFFCH}(t, t+1) = (\mathrm{PECH}(t, t+1)\ \mathrm{X}\ (\mathrm{SECH}(t, t+1) \qquad (21)$$

4. Data

Data for this study were collected from the fishing port, landing site and from interviews, questionnaires with Egyptian fishermen in Ezbet ELBorg. Data were divided into two parts primary and secondary. Primary data were collected from 4 kinds of fishing vessels (Trawl, Purse Seine, Longline and Trammel net). Each kind has 4 fishing vessels which include time-series annual catch and fishing effort. Secondary data were extracted from primary data to estimate productivity growth, technical progress and efficiency change in the Ezbet EL Borg fisheries. Data covers the period from 2001 to 2014. The data available for this study are reliable and valid because they are collected by inspectors of the general authority for fish resources development, the government of Egypt (GAFRD, 2001 and 2014).

In this study, data between 2001 and 2014 for 16 fishing vessels like (Trawl, Purse Seine, Longline and Trammel net) in Ezbet El Borg were used for the analysis. Specially, target trawlers include vessel (A), vessel (F), vessel (I), vessel (L), target purse seiners include vessel (B), vessel (E), vessel (K), vessel (O), target Longliners include vessel (D), vessel (G), vessel (J), vessel (N), target vessels that used trammel nets include vessel (C), vessel (H), vessel (M), vessel (P).

In order to analyze the technical efficiency (TE), this study chooses production quantity per fishery as the output variable with tonnage, horsepower, fishermen and numbers of fishing days as the input variable. The mean values of input and output used in the analysis are summarized in Table 1. On the other hand, secondary data were extracted for each fishery to estimate the total factor productivity for fisheries in Ezbet EL Borg. In addition, CPUEs of each fishery were considered as index of stock biomass because it's so hard to estimate the fish stock biomass in the reality. The catch per unit efforts (CPUEs) was used as the input variable and it was calculated from (Total production / fishing days) to make the analysis more accurate. Target fisheries are Trawl(T), Purse seine(Ps), Longline(L) and Trammel net (Tn) (Table 2).

Table 1. Mean values of output and inputs variables of fishing vessels (period 2001-2014)

	Output (Y)	Input (X)			
Fishing vessels	Production (tons)	Tonnage (tons)	Horsepower (HP)	Fishermen (Persons)	Fishing (days)
A	40	43.93	114	9	171
B	34	19.88	90	18	163
C	22	7.97	30	5	202
D	23	15.85	45	9	192
E	41	18.02	67	17	169
F	38	36.79	74	10	163
G	73	11.6	56	11	230
H	10	5.77	20	4	178
I	119	47.09	147	19	227
J	21	6.94	30	6	141
K	40	17.96	95	18	235
L	23	29.01	108	8	151
M	11	12.1	40	4	148
N	23	5.7	40	10	151
O	20	25.06	80	13	140
P	11	5.3	20	4	152

Table 2. Mean values of output and inputs variables of Ezbet EL Borg fisheries (period 2001-2014).

	Output (Y)	Input (X)				
Fishery	Production (tons)	Tonnage (tons)	Horsepower (HP)	Fishermen (Persons)	Fishing days	CPUE
Trawl (Tr)	55	39	111	12	178	0.308483
Purse seine(Ps)	34	20	83	16	177	0.191863
Longline (L)	35	10	43	9	178	0.196602
Trammel (Tn)	14	8	28	4	170	0.080809

Results

5. Technical Efficiency

Technical efficiency has been calculated for each fishing vessel in different fisheries using DEA method as presented in Tables 3-6 by Eq.1. Output-oriented DEA method has been used. The technical efficiency assumes the most efficient fishing vessel equals 1. When the value is closer to 1, it means that the fishing vessel is working near to the production frontier.

5.1. Technical Efficiency of trawl fishing vessels

The mean technical efficiency was about 0.701.The mean technical efficiency of trawler (L) was the lowest at 0.459 because of its production was the lowest one by 23 tons compared with other fishing vessels. Based on tonnage, horsepower, number of fishermen and number of fishing days were the lowest compared with other fishing vessels that are made; trawler (L) is inefficient. In contrast, trawler (I) was the highest at 1.000 because of its production was the highest one by 119 tons compared with other fishing vessels. Based on tonnage, horsepower, number of fishermen and number of fishing days were the highest that’s why trawler (I) is the most efficient. The mean technical efficiency of trawlers (A) and (F) were about 0.710 and 0.634, respectively. Because of the production of trawlers (A) and (F) were less than trawler (I) by 40 and 38 tons and also based on tonnage, horsepower, number of fishermen and number of fishing days were less too. That made both trawlers (A) and (F) inefficient as shown in Table 3.

Table 3. Mean technical efficiencies of trawl fishing vessels

DMU	Output (Y)	Input (X)				(TE) **θ**
Fishing vessel	Production (tons)	Tonnage (tons)	Horsepower (HP)	Fishermen (Persons)	Fishing days	Technical Efficiency
A	40	43.93	114	9	171	0.710
F	38	36.79	74	10	163	0.634
I	119	47.09	147	19	227	1.000
L	23	29.01	108	8	151	0.459
Mean						0.701

5.2. Technical Efficiency of purse seine fishing vessels

The mean technical efficiency was about 0.701.The mean technical efficiency of purse seiner (O) was the lowest at 0.638 because of its production being the lowest one by 20 tons compared with other fishing vessels. The number of fishermen and number of fishing days for purse seiners (O) were the lowest compared with other fishing vessels making it less efficient while tonnage and horsepower were not the lowest. In contrast, purse seiner (E) was the highest at 1.000 because of its production was the highest one by 41 tons compared with other fishing vessels. In spite of, tonnage, horsepower, number of fishermen and number of fishing days were not the highest that's why purse seiner (E) is the most efficient. The mean technical efficiency of purse seiners (B) and (K) were about 0.860 and 0.979, respectively. Tthe production of purse seiners (B) and (K) were less than purse seiner (E) by 34 and 40 tons, however, both of horsepower and number of fishermen were higher than purse seiner (E). That makes both of purse seiners (B) and (K) operating near the production frontier as shown in Table 4.

Table 4. Mean technical efficiencies of purse seine fishing vessels

DMU	Output (Y)		Input (X)			(TE) **θ**
Fishing vessel	Production (tons)	Tonnage (tons)	Horsepower (HP)	Fishermen (Persons)	Fishing days	Technical Efficiency
B	34	19.88	90	18	163	0.860
E	41	18.02	67	17	169	1.000
K	40	17.96	95	18	235	0.979
O	20	25.06	80	13	140	0.638
Mean						0.606

5.3. Technical Efficiency of trammel net fishing vessels

The mean technical efficiency was about 0.779. The mean technical efficiency of trammel netter (C) was the highest at 1.000 because of its production was the highest one by 22 tons compared with other fishing vessels. Also based on number of fishermen and number of fishing days were the highest that's why trammel netter (C) is the most efficient. The mean technical efficiency of trammel netter (H) and (M) were about 0.682 because of the production of trammel netter (H) and (M) was less than trammel netter (C) by 10 and 11 tons respectively. However, the production of trammel netter (M) is higher than trammel netter (H) because there were differences in tonnage, horsepower and fishing days but the number of fishermen was the same. The mean technical efficiency of trammel netter (P) was about 0.752 because of its production was less than trammel netter (C) by 11 tons as shown in Table 5.

Table 5. Mean technical efficiencies of trammel net fishing vessels

DMU	Output (Y)	Input (X)				(TE) **θ**
Fishing vessel	Production (tons)	Tonnage (tons)	Horsepower (HP)	Fishermen (Persons)	Fishing days	Technical Efficiency
C	22	7.97	30	5	202	1.000
H	10	5.77	20	4	178	0.682
M	11	12.1	40	4	148	0.682
P	11	5.3	20	4	152	0.752
Mean						0.779

5.4. Technical Efficiency of longline fishing vessels

The mean technical efficiency was about 0.643. The mean technical efficiency of longliner (G) was the highest one at 1.000 because of its production was the highest one by 73 tons compared with other fishing vessels. Also based on horsepower, number of fishermen and number of fishing days were the highest that’s why longliner (G) is the most efficient. The mean technical efficiency of longliner (J) was about 0.537 because of its production was the lowest one by 21 tons and also horsepower, number of fishermen and number of fishing days were the lowest too. However, the production of longliner (J) was the lowest, its technical efficiency was greater than longliner (D). The technical efficiency of longliner (D) was about 0.392 because its production was about 23 tons. On the other hand, the mean technical efficiency of longliner (N) was about 0.641 because of its production was about 23 tons. Despite, the production of longliner (D) and (N) were the same but the technical efficiency of longliner (N) was better than longliner (D) as shown in Table 6.

Table 6. Mean technical efficiencies of longline fishing vessels

DMU	Output (Y)	Input (X)				(TE) **θ**
Fishing vessel	Production (tons)	Tonnage (tons)	Horsepower (HP)	Fishermen (Persons)	Fishing days	Technical Efficiency
D	23	15.85	45	9	192	0.392
G	73	11.6	56	11	230	1.000
J	21	6.94	30	6	141	0.537
N	23	5.7	40	10	151	0.641
Mean						0.643

5.2. Distance functions

Distance functions were estimated for each fishery using output oriented Malmquist DEA are shown in Table 7. The VRS/CRS option has no influence on the Malmquist DEA because both are used to calculate the various distances (technical efficiencies). Four distances were calculated for each fishery in each year. These are relative to the previous periods CRS DEA frontier (t-1), the current periods CRS DEA frontier (t), the next periods CRS DEA frontier (t+1) and the current periods VRS frontier(t). The distance function accepts the most productive or efficient fishery measure up to 1 and demonstrates the relative efficiency between fisheries. When the value is nearer to 1, it implies that the fishery is working close the production frontier.

Table 7. Distance functions of fisheries in Ezbet EL Borg

	Trawl (Tr)	Purse seine (Ps)	Trammel net (Tn)	Longline (L)	Average
2001					
CRS(t-1)	0.000	0.000	0.000	0.000	0.000
CRS (t)	1.000	0.958	0.891	1.000	0.962
CRS (t+1)	1.006	1.025	0.895	1.150	1.019
VRS (t)	1.000	1.000	1.000	1.000	1.000
2002					
CRS(t-1)	1.182	0.991	0.948	1.048	1.042
CRS (t)	1.000	0.967	0.923	1.000	0.972
CRS (t+1)	1.158	1.051	1.013	1.174	1.099
VRS (t)	1.000	1.000	1.000	1.000	1.000
2003					
CRS(t-1)	0.991	0.963	0.883	0.945	0.946
CRS (t)	1.000	1.000	0.920	1.000	0.980
CRS (t+1)	1.164	0.961	0.862	0.962	0.987
VRS (t)	1.000	1.000	1.000	1.000	1.000
2004					
CRS(t-1)	1.151	0.940	0.973	1.245	1.077
CRS (t)	1.000	0.896	0.919	1.000	0.954
CRS (t+1)	1.014	0.841	0.894	1.093	0.961
VRS (t)	1.000	1.000	1.000	1.000	1.000
2005					
CRS(t-1)	1.285	1.028	0.866	1.166	1.086
CRS (t)	1.000	1.000	0.794	1.000	0.948
CRS (t+1)	1.187	0.939	0.742	0.931	0.950
VRS (t)	1.000	1.000	1.000	1.000	1.000
2006					
CRS(t-1)	0.973	1.054	1.029	1.392	1.112
CRS (t)	1.000	0.988	0.962	1.000	0.987
CRS (t+1)	1.131	0.957	0.963	1.194	1.061
VRS (t)	1.000	1.000	1.000	1.000	1.000
2007					
CRS(t-1)	1.108	1.039	1.005	1.028	1.045
CRS (t)	1.000	1.000	1.000	1.000	1.000
CRS (t+1)	0.960	0.973	0.959	0.981	0.968
VRS (t)	1.000	1.000	1.000	1.000	1.000

	Trawl (Tr)	Purse seine (Ps)	Trammel net (Tn)	Longline (L)	Average
2008					
CRS(t-1)	1.256	0.900	1.439	1.492	1.272
CRS (t)	1.000	0.869	1.000	1.000	0.967
CRS (t+1)	1.060	0.861	1.253	1.238	1.103
VRS (t)	1.000	1.000	1.000	1.000	1.000
2009					
CRS(t-1)	1.000	0.955	1.038	1.095	1.022
CRS (t)	1.000	0.933	1.000	1.000	0.983
CRS (t+1)	1.146	0.956	0.985	1.122	1.052
VRS (t)	1.000	1.000	1.000	1.000	1.000
2010					
CRS(t-1)	1.052	1.071	0.986	1.183	1.073
CRS (t)	1.000	1.000	0.970	1.000	0.993
CRS (t+1)	0.987	0.972	0.900	1.175	1.009
VRS (t)	1.000	1.000	1.000	1.000	1.000
2011					
CRS(t-1)	1.139	0.947	0.942	1.106	1.033
CRS (t)	1.000	0.910	0.861	1.000	0.943
CRS (t+1)	1.097	0.938	0.901	1.205	1.035
VRS (t)	1.000	1.000	1.000	1.000	1.000
2012					
CRS(t-1)	1.024	0.796	0.851	0.984	0.914
CRS (t)	1.000	0.809	0.879	1.000	0.922
CRS (t+1)	1.096	0.817	0.938	1.135	0.996
VRS (t)	1.000	1.000	1.000	1.000	1.000
2013					
CRS(t-1)	1.003	1.005	0.890	0.964	0.966
CRS (t)	1.000	1.000	0.907	1.000	0.977
CRS (t+1)	1.253	1.017	0.909	1.000	1.045
VRS (t)	1.000	1.000	1.000	1.000	1.000
2014					
CRS(t-1)	1.063	0.992	0.922	1.123	1.025
CRS (t)	1.000	1.000	0.897	1.000	0.974
CRS (t+1)	0.000	0.000	0.000	0.000	0.000
VRS (t)	1.000	1.000	1.000	1.000	1.000

	Trawl (Tr)	Purse seine (Ps)	Trammel net (Tn)	Longline (L)	Average
Average					
CRS(t-1)	1.016	0.905	0.912	1.055	0.972
CRS (t)	1.000	0.952	0.923	1.000	0.968
CRS (t+1)	1.018	0.879	0.872	1.025	0.948
VRS (t)	1.000	1.000	1.000	1.000	1.000

During the sample period, (2001-2014) for Ezbet El Borg fisheries, the mean technical efficiency in the current period CRS (t) was about 0.968, and the mean technical efficiency of trawl (Tr) fishery was about 1.000 because of its production was the highest by 55 tons and based on tonnage, horsepower, fishing days and CPUE were the highest compared with other fisheries. The mean technical efficiency of longline (L) fishery was about 1.000 because the production was 35 tons and also the same fishing days of trawl (Tr) fishery. Both of trawl (Tr) and longline (L) fisheries were efficient. In contrast, the mean technical efficiency of purse seine (Ps) fishery was 0.952 because of its production was about 34 tons and also the number of fishing days was less than trawl (Tr) and longline (L) fisheries. The mean technical efficiency of trammel net (Tn) fishery was the lowest at 0.923 because of production, tonnage, horsepower, number of fishermen, number of fishing days and CPUE were the lowest compared with other fisheries as shown in Table 2.

5.3. Malmquist index approach

Following calculation of distance functions, the Malmquist indices were presented. All indices are relative to previous year. Hence the output begins with year 2. Five indices are presented for each fishery in each year. These are technical efficiency change (EFFCH) under CRS technology, technological change (TECHCH), pure technical efficiency change (PECH) relative to a VRS technology, scale efficiency change (SECH) and total factor productivity change (TFPCH).

Results from estimation Eq.8 are presented in Table 8. TFPCH represents the change in Malmquist productivity index between two successive periods. The productivity will be improved, if the value of TFPCH is greater than 1, in contrast, if the value of TFPCH is less than 1, that denotes regress in performance. In addition to mean values by fishery and period were calculated as geometric means. The total factor productivity change can be estimated by subtracting 1 from the value appeared in Table 8.

5.3.1. Total factor productivity change (TFPCH)

The total factor productivity of Ezbet EL Borg fisheries was estimated to increase per year on average by 1.2%. However, the annual mean productivity rates for the trawl fishery (Tr) has decreased slightly by - 0.2% and on the other side, the total factor productivity for the purse seine fishery (Ps) has increased annually by 1.7%, The total productivity rates for the long line fishery has increased by 1.2%. The annual mean total factor productivity for the trammel net fishery (Tn) was the highest increase by 2.2%.

5.3.2. Technological change (TECHCH)

It's known that the total factor productivity (TFPCH) consists of two parts; technological progress (TECHCH) and technical efficiency (EFFCH). The results were estimated by Eq.11. The mean value of technological change of Ezbet EL Borg fisheries was increased slightly by 1.1%. In terms of the fishery, the technological rate of the trawl fishery (Tr) has reduced by - 0.2%. On the other hand, The other fisheries like purse seine (Ps), trammel net fishery (Tn) and longline (L) have increased by 1.3%, 2.1%, and 1.2% respectively.

Table 8. Malmquist productivity index by fisheries in Ezbet EL Borg (TFPCH)

	Trawl (Tr)	Purse seine (Ps)	Trammel net (Tn)	Longline (L)	Average
2001/2002					
TFPCH	1.084	0.987	1.047	0.954	1.017
EFFCH	1.000	1.009	1.036	1.000	1.011
TECHCH	1.084	0.979	1.011	0.954	1.006
PECH	1.000	1.000	1.000	1.000	1.000
SECH	1.000	1.009	1.036	1.000	1.011
2002/2003					
TFPCH	0.925	0.974	0.932	0.897	0.932
EFFCH	1.000	1.034	0.997	1.000	1.008
TECHCH	0.925	0.941	0.935	0.897	0.925
PECH	1.000	1.000	1.000	1.000	1.000
SECH	1.000	1.034	0.997	1.000	1.008
2003/2004					
TFPCH	0.994	0.936	1.062	1.138	1.030
EFFCH	1.000	0.896	0.998	1.000	0.973
TECHCH	0.994	1.045	1.063	1.138	1.059
PECH	1.000	1.000	1.000	1.000	1.000
SECH	1.000	0.896	0.998	1.000	0.973
2004/2005					
TFPCH	1.126	1.168	0.914	1.033	1.056
EFFCH	1.000	1.116	0.864	1.000	0.991
TECHCH	1.126	1.047	1.058	1.033	1.065
PECH	1.000	1.000	1.000	1.000	1.000
SECH	1.000	1.116	0.864	1.000	0.991
2005/2006					
TFPCH	0.905	1.053	1.296	1.223	1.109
EFFCH	1.000	0.988	1.212	1.000	1.046
TECHCH	0.905	1.066	1.070	1.223	1.060
PECH	1.000	1.000	1.000	1.000	1.000
SECH	1.000	0.988	1.212	1.000	1.046
2006/2007					
TFPCH	0.990	1.048	1.041	0.928	1.001
EFFCH	1.000	1.012	1.040	1.000	1.013
TECHCH	0.990	1.036	1.002	0.928	0.988
PECH	1.000	1.000	1.000	1.000	1.000
SECH	1.000	1.01	1.040	1.000	1.013

	Trawl (Tr)	Purse seine (Ps)	Trammel net (Tn)	Longline (L)	Average
2007/2008					
TFPCH	1.144	0.897	1.225	1.233	1.116
EFFCH	1.000	0.869	1.000	1.000	0.966
TECHCH	1.144	1.032	1.225	1.233	1.156
PECH	1.000	1.000	1.000	1.000	1.000
SECH	1.000	0.869	1.000	1.000	0.966
2008/2009					
TFPCH	0.971	1.092	0.910	0.941	0.976
EFFCH	1.000	1.073	1.000	1.000	1.018
TECHCH	0.971	1.017	0.910	0.941	0.959
PECH	1.000	1.000	1.000	1.000	1.000
SECH	1.000	1.073	1.000	1.000	1.018
2009/2010					
TFPCH	0.958	1.096	0.986	1.027	1.015
EFFCH	1.000	1.072	0.970	1.000	1.010
TECHCH	0.958	1.022	1.016	1.027	1.006
PECH	1.000	1.000	1.000	1.000	1.000
SECH	1.000	1.072	0.970	1.000	1.010
2010/2011					
TFPCH	1.074	0.941	0.964	0.970	0.986
EFFCH	1.000	0.910	0.887	1.000	0.948
TECHCH	1.074	1.035	1.086	0.970	1.040
PECH	1.000	1.000	1.000	1.000	1.000
SECH	1.000	0.910	0.887	1.000	0.948
2011/2012					
TFPCH	0.966	0.869	0.982	0.904	0.929
EFFCH	1.000	0.889	1.021	1.000	0.976
TECHCH	0.966	0.977	0.962	0.904	0.952
PECH	1.000	1.000	1.000	1.000	1.000
SECH	1.000	0.889	1.021	1.000	0.976
2012/2013					
TFPCH	0.957	1.233	0.990	0.922	1.019
EFFCH	1.000	1.236	1.032	1.000	1.063
TECHCH	0.957	0.998	0.959	0.922	0.958
PECH	1.000	1.000	1.000	1.000	1.000
SECH	1.000	1.236	1.032	1.000	1.063
2013/2014					
TFPCH	0.921	0.988	1.002	1.060	0.991
EFFCH	1.000	1.000	0.989	1.000	0.997
TECHCH	0.921	0.988	1.013	1.060	0.994
PECH	1.000	1.000	1.000	1.000	1.000
SECH	1.000	1.000	0.989	1.000	0.997

	Trawl (Tr)	Purse seine (Ps)	Trammel net (Tn)	Longline (L)	Average
Average					
TFPCH	0.998	1.017	1.022	1.012	1.012
EFFCH	1.000	1.003	1.001	1.000	1.001
TECHCH	0.998	1.013	1.021	1.012	1.011
PECH	1.000	1.000	1.000	1.000	1.000
SECH	1.000	1.003	1.001	1.000	1.001

5.3.3. Technical efficiency change (EFFCH)

The results were estimated by Eq.10. The technical efficiency change of Ezbet EL Borg fisheries was calculated to increase by 0.1% slightly. For fisheries, the annual mean technical efficiency of the trawl fishery (Tr) and longline fishery (L) was constant or equal to 1, hence it means both of them are efficient. In contrast, purse seine fishery (Ps) and trammel net fishery (Tn) have slightly increased annually by 0.3% and 0.1% respectively.

5.3.4. Pure efficiency change (PECH)

Efficiency change can be segmented into pure efficiency (PECH) and scale efficiency (SECH). The pure efficiency can be estimated by Eq.21. The mean pure efficiency change of Ezbet EL Borg fisheries during the sample period showed as stable by 0%.

5.3.5. Scale efficiency change (SECH)

The annually mean scale efficiency change of Ezbet EL Borg fisheries during the sample of the period implied an increase slightly by 0.1%. In fisheries term, the mean scale efficiency change for trammel net fishery (Tn) and purse seine fishery (Ps) slightly increased annually by 0.3% and 0.1 %, respectively. In contrast, trawl (Tr) fishery and longline fishery (L) were the same without any change.

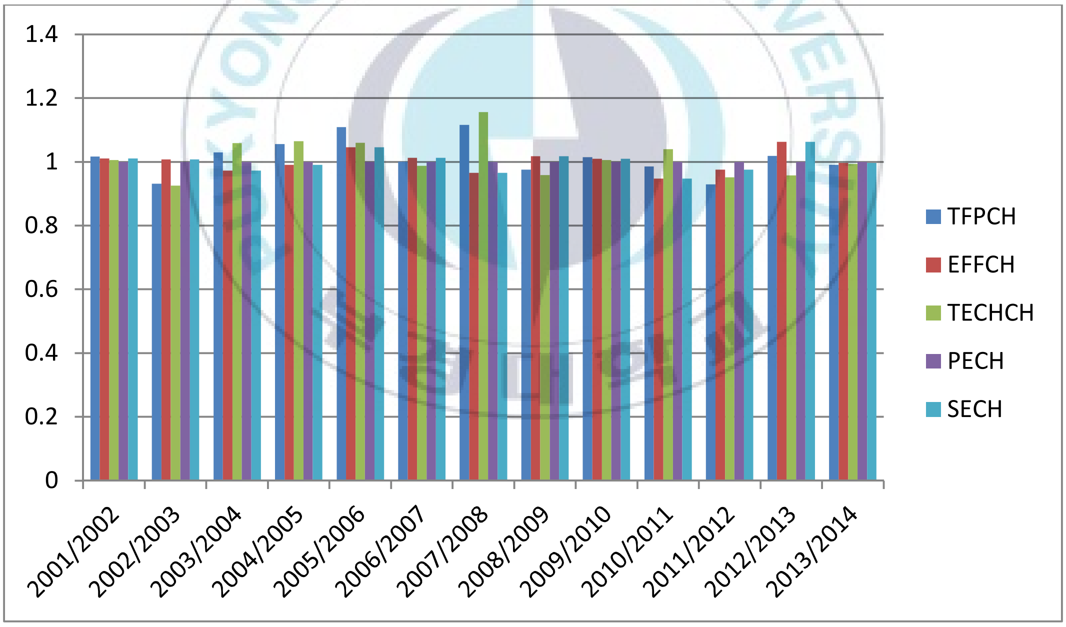

Figure 3.Malmquist index showing TFPCH,EFFCH,TECHCH,PECH and SECH

For analyzing the total factor productivity change (TFPCH) of Ezbet El Borg fisheries which segmented into technical change (EFFCH) and technological progress (TECHCH), they contributed 0.1%, 1.1% respectively. The mean annual value of total factor productivity was increased by 1.2% during the sample period. Activity or stagnancy of technical progress can be the main reason of increasing or decreasing of the total factor productivity. In the case of the total factor productivity of trawl fishery (Tr) was recorded decreasing by – 0.2% and lower than the other fisheries in Ezbet EL Borg. Moreover, decreases in technological progresses can cause decreases in total factor productivity of trawl fishery (Tr). In contrast, this is totally different in the other fisheries. When technological progress increased, hence the total factor productivity led to an increase as well.

Conclusion and Implications

This study is limited because the data was collected from one region (Ezbet El Borg) and did not have data for fishing vessels and other fisheries. Therefore, the data from Ezbet El Borg were assumed to be relevant to the analysis of the total factor productivity of the regions fisheries, as well as the relationship to technological progress and technical efficiency. According to (GAFRD, 2015), the production of Ezbet EL Borg's fisheries decreased in 2015 compared to 2014 by 14.6% . Fisheries legislation in Egypt is based on a 1983 Decree which provides the administrative basis of fisheries management. However, the legislation is generally inadequate in providing a basis for effective management for fisheries in Egypt. In addition, enforcement of these laws is generally weak and, as a result, fisheries are essentially unregulated. This has led to large increases in fishing capacity as well as to concerns regarding overexploitation of a number of species. Effective management is also hampered by the general lack of adequate assessments of major commercial fish stocks and by the complexities inherent in the shared nature of many of these stocks. Furthermore, in addition to the lack of specific policy objectives within the Fisheries Act, there is no stated policy framework for marine fisheries by the GAFRD or the Ministry of Agriculture and, therefore, marine fisheries policy needs to be inferred from actions taken (or not taken) by the GAFRD. Although the power exists within the national legislation to address fisheries management issues, these powers have not been used to any great extent. As a result, the marine fisheries of Egypt are essentially unregulated. There are no policy objectives established for the management of marine fisheries in Egypt and the Act is primarily an administrative tool (De Young, 2006). Also, there is no system for monitoring fishing vessels which could help fishermen to use a different fishing gear that leads to a reduction in the productivity of the fisheries. Another problem is that many fishermen are use fish nets with small slots that catch immature fish which leads to a reduction in fish catch.

Productivity is an important factor for economic development, in particular, for fisheries where increased productivity leads to self-sufficiency in fish production. All proper conditions must be provided to improve productivity. Fisheries are different than the manufacturing industries. Natural environmental factors can have an impact on production. Hence, it’s important to protect fishery resources and do steady management for productivity improvement from target fisheries. On the other side, stable management is needed if the fishery is exploited. In addition, an instruction system or program for monitoring fishing vessels is very important to maintain the fish stock. For the viability of sustainable fisheries development, much research should be conducted. According to Karagiannakos (1996), The total allowable catch (TAC) and individual transferable quotas (ITQs) are considered as the corner stone of resource management and conservation policy of the Common Fisheries Policy (CFP). Hence both of (TAC) and (ITQs) should be applied.

Strategies designed to encourage fishery development require an appreciation of the roles of two kinds of externalities: 1) those that exist within the fishery sector; and 2) those that operate between the fishery and other sectors of the economy. The former dominates most discussions of how to manage a fishery. Because of this, fishery management is an important component of fishery development. Collective action involving fishing groups may perform a management function, whether done alone, with foreign partners, or in cooperation with governments. Addressing the second set of externalities requires an understanding of how decisions in the fishery sector affect outcomes elsewhere and vice versa. These effects may be both "real", in which output levels in one sector are influenced by decisions in another, or "financial", in which the primary effects are on the prices of outputs or inputs in the affected sector. A development policy that looks at the potential contribution of the fishery to the entire economy and considers development from that perspective, minimizes frustration and increases the chances of achieving development goals (Johnston, 1992).

Acknowledgement

"In the name of Allah the Merciful"

Foremost, I would like to express my deep gratitude and my heartfelt thanks to Almighty God. I write these words for my parents, particularly my mother. Also my kind greeting to my brother and my sister. I would like to thank KOICA for giving me this opportunity. Exceptional thanks goes to Professor Dohoon KIM for his guidance, advice and support during my study. Countless thanks to my TAC members Prof.LEE Sang-Go and Prof.NAM Jongoh, thank you very much for your unlimited help. I also wish to thank the course program coordinator Professor Kang and her assistant Ms. Seulki for all their support during the course of the program. Lastly, I would like to mention Ms. Hala EL Sakaary (The general manager of the guidance and development management) and all my friends in GAFRD, Egypt.

References

Boussofiane, A.; R. Dyson and E. Thanassoulis (1991); “Applied Data Envelopment Analysis”, European Journal of Operational Research, Vol. 52, pp. 1-15.

Britannica, E. (1993). Encyclopædia britannica. Chicago: University of Chicago.

Caves K, Christensen L, Diewert W (1982) The economics theory of index numbers and the measurement of input, output, and productivity. Econometrica 51:1393–1414.

Charnes, A.; Cooper, W. W. and Rhodes, E. (1978): “Measuring the Efficiency of Decision Making Units”, European Journal of Operational Research, Vol. 2, pp.429-444.

Coelli, T. (1996). A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program. CEPA Working Papers, No. 8/96.

Cook, W. D., Tone, K., & Zhu, J. (2014). Data envelopment analysis: Prior to choosing a model. Omega, 44, 1-4.

De Young, C. (Ed.). (2006). Review of the state of world marine capture fisheries management: Indian Ocean (No. 488). Food & Agriculture Org..

EastMed, F. A. O. (2014). Socio-economic analysis of Egyptian fisheries: options for improvement. GCP/INT/041/EC–GRE–ITA/TD-19.

El-Batrawy, O. A. (2010). Relationships between Personal, Indoor, and Outdoor PM10 in the Residential Environment in Damietta, Egypt. Journal of American Science, 12, 6.

El-Naggar, G. A. M. A. L., Nasr-Alla, A. H. M. E. D., & Kareem, R. O. (2006). Economic analysis of fish farming in Behera Governorate of Egypt. Department of Agricultural Economics, Obafemi Awolowo University, He Ife, Nigeria.

FAO (2010) Fishery and aquaculture country profile: The Arabic Republic of Egypt. Food and Agriculture Organization of the United Nations (FAO), Rome.

FAO (2013) Fishing Gear types. Purse seines. Technology Fact Sheets. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 13 September 2001. [Cited 18 August 2017]. http://www.fao.org/fishery/geartype/249/en

Färe, R., & Lovell, C. K. (1978). Measuring the technical efficiency of production. Journal of Economic theory, 19(1), 150-162.

Fare, R., Grosskopf, S., & Lovell, C. K. (1994). Production frontiers. Cambridge University Press.

Färe, R., Grosskopf, S., & Norris, M. (1997). Productivity growth, technical progress, and efficiency change in industrialized countries: reply. The American Economic Review, 87(5), 1040-1044.

Färe, R., Grosskopf, S., Lindgren, B., Roos, P. 1992. Productivity changes in Swedish pharmacies 1980-1989: A non-parametric approach. Journal of Productivity Analysis, 3(1-2):85-101.

Färe, R., S. Grosskopf, M. Norris and Z. Zhang (1994), "Productivity growth, technical progress, and efficiency change in industrialised countries", American Economic Review, 64:66-83.

Farrell, M. J. (1957). The measurement of productive efficiency. Journal of the Royal Statistical Society. Series A (General), 120(3), 253-290.

GAFRD (2013) Annual fishery statistics reports. General Authority for Fish Resources Development, Ministry of Agriculture and Land Reclamation, Cairo.

GAFRD (2014) Annual fishery statistics reports. General Authority for Fish Resources Development, Ministry of Agriculture and Land Reclamation, Cairo.

GAFRD (2015) Annual fishery statistics reports. General Authority for Fish Resources Development, Ministry of Agriculture and Land Reclamation, Cairo.

Hassan, H. B. A., Zaghloul, E. A., El-Gebaly, M. R., & Hussein, Y. M. M. (2014). An Economic Study of Fish Production in Egypt. Middle East J, 3(1), 71-80.

Hopkins, Harry (1969). Egypt, the Crucible: The Unfinished Revolution in the Arab World. Boston: Houghton Mifflin Company. ISBN 9780436201516.

Johnston, R. S. (1992). Fisheries development, fisheries management, and externalities. The World Bank.

Kalirajan, K. P., Obwona, M. B., & Zhao, S. (1996). A decomposition of total factor productivity growth: the case of Chinese agricultural growth before and after reforms. American Journal of Agricultural Economics, 78(2), 331-338.

Karagiannakos, A. (1996). Total Allowable Catch (TAC) and quota management system in the European Union. Marine Policy, 20(3), 235-248.

Kim D, An H, Lee K, Hwang J (2007) Fishing capacity assessmentof the octopus coastal trap fishery using data envelopment analysis. J Korean Soc Fish Tech 43:339–346 (in Korean with English abstract).

Kirkley, J. E., Färe, R., Grosskopf, S., McConnell, K., Squires, D. E., & Strand, I. (2001). Assessing capacity and capacity utilization in fisheries when data are limited. North American Journal of Fisheries Management, 21(3), 482-497.

Kurosawa, K. (1975). An aggregate index for the analysis of productivity and profitability. Omega, 3(2), 157-168.

Malmquist,S (1953),Index Numbers and Indifference Surfaces,Trabajos de Estatistica,4,209-42.

Merino, G., Morales-Nin, B., Maynou, F., & Grau, A. M. (2008). Assessment and bioeconomic analysis of the Majorca (NW Mediterranean) trammel net fishery. Aquatic Living Resources, 21(2), 99-107.

Negm, A. M., Sharaan, M., & Iskander, M. (2017). Assessment of Egyptian Fishing Ports Along the Coasts of the Nile Delta. The Nile Delta, 471-494.

Pascoe S, Tingley D (2006) Economic capacity estimation in fisheries:a non-parametric ray approach. Res Energy Econ 28:124–138.

Rice J, Cooper J, Medley P and Hough A 2006. South Georgia Patagonian Toothfish Longline Fishery. Moody Marine, May 2006.

Samy-Kamal, M. (2015). Status of fisheries in Egypt: reflections on past trends and management challenges. Reviews in fish biology and fisheries, 25(4), 631-649.

Seiford, L. M., & Thrall, R. M. (1990). Recent developments in DEA: the mathematical programming approach to frontier analysis. Journal of econometrics, 46(1-2), 7-38.

Shephard ,R.W.1953. Cost and Production Functions,Princeton University Press,Princeton.

Zheng Y, Zhou Y (2005) Measures of the fishing capacity of chinese marine fleets and discussion of the methods. J Oceanogr 61:623–630.

Appendices

Appendix 1. Initial data of fishing vessel Trawler (A).

Year	Production	Tonnage	Horsepower	Fishers	Fishing days	CPUE
2001	40	43.93	114	11	149	0.268456
2002	48	43.93	114	8	184	0.26087
2003	50	43.93	114	12	157	0.318471
2004	30	43.93	114	10	136	0.220588
2005	42	43.93	114	7	166	0.253012
2006	25	43.93	114	9	179	0.139665
2007	29	43.93	114	8	190	0.152632
2008	55	43.93	114	10	189	0.291005
2009	33	43.93	114	11	154	0.214286
2010	35	43.93	114	7	125	0.28
2011	42	43.93	114	9	185	0.227027
2012	57	43.93	114	8	200	0.285
2013	41	43.93	114	9	187	0.219251
2014	26	43.93	114	10	197	0.13198
Mean	**40**	**43.93**	**114**	**9**	**171**	**0.233017**

Appendix 2. Initial data of fishing vessel Trawler (F).

Year	**Production**	**Tonnage**	**HorsePower**	**Fishers**	**Fishing days**	**CPUE**
2001	32	36.79	74	11	121	0.264463
2002	23	36.79	74	8	158	0.14557
2003	29	36.79	74	10	166	0.174699
2004	42	36.79	74	9	137	0.306569
2005	56	36.79	74	12	144	0.388889
2006	33	36.79	74	8	170	0.194118
2007	20	36.79	74	11	188	0.106383
2008	45	36.79	74	12	200	0.225
2009	47	36.79	74	10	190	0.247368
2010	25	36.79	74	7	150	0.166667
2011	50	36.79	74	9	133	0.37594
2012	39	36.79	74	11	174	0.224138
2013	45	36.79	74	8	209	0.215311
2014	44	36.79	74	10	147	0.29932
Mean	**38**	**36.79**	**74**	**10**	**163**	**0.238174**

Appendix 3. Initial data of fishing vessel Trawler (I).

Year	**Production**	**Tonnage**	**HorsePower**	**Fishers**	**Fishing days**	**CPUE**
2001	115	47.09	147	23	232	0.49569
2002	124	47.09	147	19	190	0.652632
2003	95	47.09	147	17	173	0.549133
2004	99	47.09	147	13	258	0.383721
2005	112	47.09	147	15	240	0.466667
2006	120	47.09	147	16	166	0.722892
2007	128	47.09	147	20	206	0.621359
2008	132	47.09	147	22	223	0.591928
2009	140	47.09	147	23	231	0.606061
2010	125	47.09	147	18	187	0.668449
2011	133	47.09	147	21	249	0.534137
2012	119	47.09	147	19	280	0.425
2013	110	47.09	147	17	260	0.423077
2014	117	47.09	147	25	276	0.423913
Mean	**119**	**47.09**	**147**	**19**	**227**	**0.540333**

Appendix 4. Initial data of fishing vessel Trawler (L).

Year	Production	Tonnage	Horsepower	Fishers	Fishing days	CPUE
2001	21	29.01	108	8	140	0.15
2002	13	29.01	108	7	115	0.113043
2003	20	29.01	108	9	120	0.166667
2004	18	29.01	108	7	157	0.11465
2005	25	29.01	108	8	122	0.204918
2006	17	29.01	108	7	138	0.123188
2007	29	29.01	108	9	160	0.18125
2008	35	29.01	108	10	168	0.208333
2009	32	29.01	108	7	200	0.16
2010	19	29.01	108	6	179	0.106145
2011	22	29.01	108	9	199	0.110553
2012	16	29.01	108	7	133	0.120301
2013	20	29.01	108	8	146	0.136986
2014	30	29.01	108	11	135	0.222222
Mean	**23**	**29.01**	**108**	**8**	**151**	**0.151304**

Appendix 5. Initial data of fishing vessel Purse seiner (B).

Year	**Production**	**Tonnage**	**HorsePower**	**Fishers**	**Fishing days**	**CPUE**
2001	38	19.88	90	20	117	0.324786
2002	30	19.88	90	18	129	0.232558
2003	24	19.88	90	19	136	0.176471
2004	20	19.88	90	15	120	0.166667
2005	29	19.88	90	17	150	0.193333
2006	44	19.88	90	18	173	0.254335
2007	50	19.88	90	20	166	0.301205
2008	29	19.88	90	22	189	0.153439
2009	40	19.88	90	16	175	0.228571
2010	35	19.88	90	21	183	0.191257
2011	42	19.88	90	14	191	0.219895
2012	22	19.88	90	19	200	0.11
2013	41	19.88	90	17	184	0.222826
2014	28	19.88	90	13	169	0.16568
Mean	**34**	**19.88**	**90**	**18**	**163**	**0.210073**

Appendix 6. Initial data of fishing vessel Purse seiner (E).

Year	**Production**	**Tonnage**	**Horsepower**	**Fishers**	**Fishing days**	**CPUE**
2001	44	18.02	67	18	120	0.366667
2002	51	18.02	67	20	143	0.356643
2003	30	18.02	67	16	156	0.192308
2004	27	18.02	67	19	113	0.238938
2005	20	18.02	67	17	145	0.137931
2006	35	18.02	67	18	160	0.21875
2007	49	18.02	67	21	184	0.266304
2008	25	18.02	67	19	177	0.141243
2009	60	18.02	67	15	194	0.309278
2010	55	18.02	67	17	200	0.275
2011	63	18.02	67	14	206	0.305825
2012	23	18.02	67	19	167	0.137725
2013	50	18.02	67	16	189	0.26455
2014	47	18.02	67	15	215	0.218605
Mean	**41**	**18.02**	**67**	**17**	**169**	**0.244983**

Appendix 7. Initial data of fishing vessel Purse seiner (K).

Year	**Production**	**Tonnage**	**HorsePower**	**Fishers**	**Fishing days**	**CPUE**
2001	44	17.96	95	21	246	0.178862
2002	28	17.96	95	22	230	0.121739
2003	36	17.96	95	19	222	0.162162
2004	51	17.96	95	20	216	0.236111
2005	43	17.96	95	18	240	0.179167
2006	25	17.96	95	15	234	0.106838
2007	38	17.96	95	21	210	0.180952
2008	58	17.96	95	19	195	0.297436
2009	40	17.96	95	20	202	0.19802
2010	55	17.96	95	17	213	0.258216
2011	32	17.96	95	16	255	0.12549
2012	29	17.96	95	14	251	0.115538
2013	33	17.96	95	13	273	0.120879
2014	45	17.96	95	14	300	0.15
Mean	**40**	**17.96**	**95**	**18**	**235**	**0.173672**

Appendix 8. Initial data of fishing vessel Purse seiner (O).

Year	**Production**	**Tonnage**	**Horsepower**	**Fishers**	**Fishing days**	**CPUE**
2001	15	25.06	80	10	110	0.136364
2002	23	25.06	80	13	125	0.184
2003	16	25.06	80	11	100	0.16
2004	15	25.06	80	10	123	0.121951
2005	19	25.06	80	9	135	0.140741
2006	25	25.06	80	12	150	0.166667
2007	17	25.06	80	15	170	0.1
2008	20	25.06	80	13	106	0.188679
2009	19	25.06	80	14	145	0.131034
2010	30	25.06	80	15	230	0.130435
2011	18	25.06	80	14	115	0.156522
2012	15	25.06	80	16	90	0.166667
2013	26	25.06	80	11	200	0.13
2014	28	25.06	80	12	166	0.168675
Mean	**20**	**25.06**	**80**	**13**	**140**	**0.148695**

Appendix 9. Initial data of fishing vessel Trammel netter (C).

Year	**Production**	**Tonnage**	**HorsePower**	**Fishers**	**Fishing days**	**CPUE**
2001	23	7.97	30	6	165	0.139394
2002	18	7.97	30	5	200	0.09
2003	10	7.97	30	4	170	0.058824
2004	16	7.97	30	5	199	0.080402
2005	19	7.97	30	4	176	0.107955
2006	22	7.97	30	3	210	0.104762
2007	30	7.97	30	6	202	0.148515
2008	35	7.97	30	4	185	0.189189
2009	28	7.97	30	5	200	0.14
2010	25	7.97	30	4	197	0.126904
2011	23	7.97	30	5	215	0.106977
2012	20	7.97	30	7	222	0.09009
2013	15	7.97	30	6	237	0.063291
2014	21	7.97	30	6	250	0.084
Mean	**22**	**7.97**	**30**	**5**	**202**	**0.109307**

Appendix 10. Initial data of fishing vessel Trammel netter (H).

Year	**Production**	**Tonnage**	**HorsePower**	**Fishers**	**Fishing days**	**CPUE**
2001	10	5.77	20	3	150	0.066667
2002	12	5.77	20	2	160	0.075
2003	7	5.77	20	4	144	0.048611
2004	9	5.77	20	4	165	0.054545
2005	10	5.77	20	5	130	0.076923
2006	11	5.77	20	3	180	0.061111
2007	8	5.77	20	6	175	0.045714
2008	8	5.77	20	3	155	0.051613
2009	13	5.77	20	2	193	0.067358
2010	15	5.77	20	4	200	0.075
2011	14	5.77	20	5	210	0.066667
2012	10	5.77	20	5	220	0.045455
2013	9	5.77	20	6	205	0.043902
2014	8	5.77	20	4	200	0.04
Mean	**10**	**5.77**	**20**	**4**	**178**	**0.058469**

Appendix 11. Initial data of fishing vessel Trammel netter (M).

Year	**Production**	**Tonnage**	**HorsePower**	**Fishers**	**Fishing days**	**CPUE**
2001	12	12.1	40	4	90	0.133333
2002	12	12.1	40	5	112	0.107143
2003	10	12.1	40	3	100	0.1
2004	8	12.1	40	2	120	0.066667
2005	9	12.1	40	2	97	0.092784
2006	11	12.1	40	6	138	0.07971
2007	15	12.1	40	5	166	0.090361
2008	14	12.1	40	3	180	0.077778
2009	9	12.1	40	6	210	0.042857
2010	10	12.1	40	4	235	0.042553
2011	13	12.1	40	3	145	0.089655
2012	12	12.1	40	2	170	0.070588
2013	11	12.1	40	3	190	0.057895
2014	13	12.1	40	4	125	0.104
Mean	**11**	**12.1**	**40**	**4**	**148**	**0.082523**

Appendix 12. Initial data of fishing vessel Trammel netter (P).

Year	**Production**	**Tonnage**	**HorsePower**	**Fishers**	**Fishing days**	**CPUE**
2001	8	5.3	20	3	111	0.072072
2002	10	5.3	20	4	127	0.07874
2003	9	5.3	20	3	160	0.05625
2004	8	5.3	20	2	135	0.059259
2005	9	5.3	20	5	120	0.075
2006	15	5.3	20	4	153	0.098039
2007	10	5.3	20	6	169	0.059172
2008	14	5.3	20	2	145	0.096552
2009	9	5.3	20	5	188	0.047872
2010	11	5.3	20	7	173	0.063584
2011	11	5.3	20	4	200	0.055
2012	15	5.3	20	3	150	0.1
2013	12	5.3	20	5	122	0.098361
2014	14	5.3	20	5	178	0.078652
Mean	**11**	**5.3**	**20**	**4**	**152**	**0.074182**

Appendix 13. Initial data of fishing vessel Longliner (D).

Year	**Production**	**Tonnage**	**Horsepower**	**Fishers**	**Fishing days**	**CPUE**
2001	23	15.85	45	10	195	0.117949
2002	14	15.85	45	8	188	0.074468
2003	10	15.85	45	9	161	0.062112
2004	30	15.85	45	7	173	0.17341
2005	25	15.85	45	11	190	0.131579
2006	20	15.85	45	8	200	0.1
2007	16	15.85	45	10	198	0.080808
2008	22	15.85	45	9	210	0.104762
2009	31	15.85	45	7	201	0.154229
2010	27	15.85	45	8	188	0.143617
2011	19	15.85	45	11	217	0.087558
2012	29	15.85	45	11	225	0.128889
2013	35	15.85	45	9	160	0.21875
2014	26	15.85	45	7	177	0.146893
Mean	**23**	**15.85**	**45**	**9**	**192**	**0.123216**

Appendix 14. Initial data of fishing vessel Longliner (G).

Year	**Production**	**Tonnage**	**HorsePower**	**Fishers**	**Fishing days**	**CPUE**
2001	70	11.6	56	11	212	0.330189
2002	64	11.6	56	12	200	0.32
2003	55	11.6	56	10	196	0.280612
2004	53	11.6	56	9	187	0.283422
2005	65	11.6	56	12	206	0.315534
2006	80	11.6	56	10	246	0.325203
2007	88	11.6	56	11	215	0.409302
2008	93	11.6	56	10	222	0.418919
2009	85	11.6	56	12	255	0.333333
2010	79	11.6	56	10	231	0.341991
2011	82	11.6	56	11	244	0.336066
2012	73	11.6	56	13	279	0.261649
2013	63	11.6	56	12	260	0.242308
2014	68	11.6	56	12	270	0.251852
Mean	**73**	**11.6**	**56**	**11**	**230**	**0.317884**

Appendix 15. Initial data of fishing vessel Longliner (J).

Year	**Production**	**Tonnage**	**HorsePower**	**Fishers**	**Fishing days**	**CPUE**
2001	15	6.94	30	6	110	0.136364
2002	11	6.94	30	6	130	0.084615
2003	10	6.94	30	5	90	0.111111
2004	12	6.94	30	3	102	0.117647
2005	17	6.94	30	4	175	0.097143
2006	20	6.94	30	5	120	0.166667
2007	18	6.94	30	6	140	0.128571
2008	29	6.94	30	4	96	0.302083
2009	35	6.94	30	8	105	0.333333
2010	25	6.94	30	7	190	0.131579
2011	44	6.94	30	8	200	0.22
2012	21	6.94	30	6	177	0.118644
2013	19	6.94	30	4	163	0.116564
2014	23	6.94	30	5	180	0.127778
Mean	**21**	**6.94**	**30**	**6**	**141**	**0.156579**

Appendix 16. Initial data of fishing vessel Longliner (N).

Year	**Production**	**Tonnage**	**HorsePower**	**Fishers**	**Fishing days**	**CPUE**
2001	10	5.7	40	7	90	0.111111
2002	17	5.7	40	9	120	0.141667
2003	15	5.7	40	6	100	0.15
2004	9	5.7	40	10	112	0.080357
2005	11	5.7	40	11	88	0.125
2006	22	5.7	40	9	144	0.152778
2007	26	5.7	40	12	135	0.192593
2008	35	5.7	40	10	160	0.21875
2009	29	5.7	40	12	202	0.143564
2010	40	5.7	40	6	180	0.222222
2011	33	5.7	40	8	209	0.157895
2012	30	5.7	40	11	190	0.157895
2013	24	5.7	40	13	180	0.133333
2014	27	5.7	40	12	200	0.135
Mean	**23**	**5.7**	**40**	**10**	**151**	**0.151583**

Appendix 17. Extracted data for trawl fishery (Tr) in Ezbet EL Borg.

Year	**Production**	**Tonnage**	**Horsepower**	**Fishers**	**Fishing days**	**CPUE**
2001	52	39	111	13	161	0.323988
2002	52	39	111	11	162	0.321484
2003	49	39	111	12	154	0.314935
2004	47	39	111	10	172	0.274709
2005	59	39	111	11	168	0.349702
2006	49	39	111	10	163	0.298622
2007	52	39	111	12	186	0.276882
2008	67	39	111	14	195	0.342308
2009	63	39	111	13	194	0.325161
2010	51	39	111	10	160	0.318253
2011	62	39	111	12	192	0.322454
2012	58	39	111	11	197	0.29352
2013	54	39	111	11	201	0.269327
2014	54	39	111	14	189	0.287417
Mean	**55**	**39**	**111**	**12**	**178**	**0.308483**

Appendix 18. Extracted data for purse seine fishery (Ps) in Ezbet EL Borg.

Year	**Production**	**Tonnage**	**Horsepower**	**Fishers**	**Fishing days**	**CPUE**
2001	35	20	83	17	148	0.237774
2002	33	20	83	18	157	0.210526
2003	27	20	83	16	154	0.172638
2004	28	20	83	16	143	0.197552
2005	28	20	83	15	168	0.165672
2006	32	20	83	16	179	0.179916
2007	39	20	83	19	183	0.210959
2008	33	20	83	18	167	0.197901
2009	40	20	83	16	179	0.222067
2010	44	20	83	18	207	0.211864
2011	39	20	83	15	192	0.202086
2012	22	20	83	17	177	0.125706
2013	38	20	83	14	212	0.177305
2014	37	20	83	14	213	0.174118
Mean	**34**	**20**	**83**	**16**	**177**	**0.191863**

Appendix 19. Extracted data for trammel net fishery (Tn) in Ezbet EL Borg.

Year	Production	Tonnage	Horsepower	Fishers	Fishing days	CPUE
2001	13	8	28	4	129	0.102713
2002	13	8	28	4	150	0.086811
2003	9	8	28	4	144	0.062718
2004	10	8	28	3	155	0.066236
2005	12	8	28	4	131	0.089866
2006	15	8	28	4	170	0.086637
2007	16	8	28	6	178	0.088483
2008	18	8	28	3	166	0.106767
2009	15	8	28	5	198	0.074589
2010	15	8	28	5	201	0.075776
2011	15	8	28	4	193	0.079221
2012	14	8	28	4	191	0.074803
2013	12	8	28	5	189	0.062334
2014	14	8	28	5	188	0.074369
Mean	**14**	**8**	**28**	**4**	**170**	**0.080809**

Appendix 20. Extracted data for longline fishery (L) in Ezbet EL Borg.

Year	**Production**	**Tonnage**	**Horsepower**	**Fishers**	**Fishing days**	**CPUE**
2001	30	10	43	9	152	0.194399
2002	27	10	43	9	160	0.166144
2003	23	10	43	8	137	0.164534
2004	26	10	43	7	144	0.181185
2005	30	10	43	10	165	0.179059
2006	36	10	43	8	178	0.2
2007	37	10	43	10	172	0.215116
2008	45	10	43	8	172	0.260174
2009	45	10	43	10	191	0.235911
2010	43	10	43	8	197	0.21673
2011	45	10	43	10	218	0.204598
2012	38	10	43	10	218	0.17566
2013	35	10	43	10	191	0.184797
2014	36	10	43	9	207	0.174123
Mean	**35**	**10**	**43**	**9**	**178**	**0.196602**