UNU-INRA WORKING PAPER NO. 26

The Potential of Sustainable Fishery Resource in Mitigating Poverty and Unemployment in Africa

Shiferaw Mitiku Tebeka

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By

Shiferaw Mitiku Tebeka

This work was carried out with the aid of a grant from the International Development Research Centre, Ottawa, Canada.

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The UNU-INRA PhD Internship Programme selects PhD candidates on a competitive basis to carry out policy-relevant research at the Institute, to inform natural resources management policies in Africa. This working paper is one of the outputs of UNU-INRA's project on "*Unleashing the Potential of African Rural Economies through Green Growth*", funded by the International Development Research Centre (IDRC).

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ISBN: 9789988633004

Cover Photo: Author
Cover Design & Layout: Praise Nutakor, UNU-INRA
Editorial Team: Samuel Aderemi Igbatayo, Calvin Atewamba, Dorothé Nje Yong, and Praise Nutakor

Published by: UNU-INRA, Accra, Ghana

Acknowledgement

The author is grateful to **Dr. T. E. George** (Director of Acad. and PG Studies), **Prof. A. Sukumaran** (Associate Dean, CCBM-KAU), and **Prof. Ushadevi K.N** (Head, Department of Rural Marketing Management) of the Kerala Agricultural University for approving my request to proceed for the PhD internship programme at the UNU-INRA.

The author is also grateful to Engineer **Mekonnen Abebe** for the financial support extended during data collection stage of the study.

The financial support and privilege from the United Nations University-Institute for Natural Resources in Africa (**UNU-INRA**) under the PhD internship programme are highly appreciated.

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Abstract

The fishery sector plays a pivotal role in global food security, both in terms of consumption and production, as well as trade and employment. Attaining green growth in the fishery sector would help alleviate poverty because of the benefits from trade, employment opportunities and sustainable food security. This study examined the potential of the fishery sector to mitigate poverty and the growing unemployment rate in Africa. Chad, Egypt, Ethiopia, Madagascar, Mauritania, Morocco, Namibia, Niger, São Tomé and Príncipe, and Seychelles were used as the target sample areas from the five African sub-regions, for the study. The findings revealed that the fishing sector's potential in mitigating poverty and unemployment in the context of a green economy was unsustainable due to over-exploitation of the fishery stock, underutilization of the fishery resource, high employment pressure on the sector, and the increased frequency of export border rejection in the export market destinations because of quality deterioration.

Key Words: Africa, fish, poverty, sustainable, employment

1. Introduction

1.1: Background

Mitigation of poverty and growing unemployment in Africa is becoming the agenda of most African countries' fishery management agencies and their partners in donor and multilateral agencies. A better understanding of sustainable fishery resource management in Africa can play significant role to become an engine of economic growth, as well as a means of providing better income for poor fishing-dependent communities. This can also spur efforts to supply poor consumers with elements of high-quality diets, critical to improving food security.

Poverty is clearly a multidimensional issue and no single economic sector can be expected to deal with it alone. It is a problem, which requires a broad policy agenda. However, the wealth that fish resources are capable of generating under appropriate management arrangements means that the fishery sector does have the potential to play a role in poverty reduction (CEC, 2000).

The fishery sector contributes wild-capture fishing and aquaculture supplies to the world markets, with about 150 million tons of fish, worth over US$ 200 billion annually (FAO, 2012). Furthermore, fish products are essential to food security, providing over 1 billion people with their main source of protein.

The sector's contribution to the global food security framework, both in terms of consumption and production, on the one hand; trade and employment, on the other; is significant. Green economic growth in fishery implies that the sector helps to alleviate poverty through the benefits realized from trade, equitable employment and sustainable food security, thus, ensuring the viability and sustainability of the two marine-based economies (fishing and aquaculture) in trade, employment, and production of fish would contribute to alleviate poverty to a large extent.

Making the production and marketing of fish and fish products available in a process that mirrors a green economy; which is in harmony with consumer interests and their environment, would benefit all participants across the fish supply chain. In connection to this, UNEP (2011) has put in place a working definition for Green Economy, as a system of economic activities related to the production, distribution and consumption of goods and services that result in improved human wellbeing over the long term, while not exposing

future generations to significant environmental risks and ecological scarcities. The concept behind green economic growth in the fishery sector implies that the sector can help to alleviate poverty. In order to ensure green economic growth in the fishery sector, the consumption and production aspects of fish should attain sustainable growth and contribute to food security, so they are economically viable and help to alleviate poverty (Mathiesen, 2011). Therefore, the sustainability of fish trade and production depends on how the risks associated with fish and fish products are mitigated for human and animal, as well as conserving the ecology of the fishery stock.

From this point of view, there are a number of factors that come into play to determine which type of fish to eat; one of which is the source, where the fish was raised or caught. This is not a very simple decision when one considers that the nutritional value of fish varies from each source and carries a different potential for contamination, nutrition and environmental impact. Generally, there are two sources of fish: farmed fish (Aqua culture) or wild- caught fish. Each source of getting fish has its own advantage and disadvantage, which every consumer will have to weigh to make the best decision for his or her own health and environmental priorities.

There are different arguments and findings on fishery from a green economy standpoint that might challenge fishermen, consumers and decision makers in the marketing of fish and fish products. The following are some of the arguments and findings to substantiate the importance of the study. Wild fish are usually healthier (higher in Omega-3s) and less contaminated than farmed fish; however, some farmed fish can have higher levels of Omega-3 fatty acids than wild fish. This is because fish farmers can better control the diets of the fish they raise, making sure that their fish eat more feed that is converted into Omega-3s than a fish might normally eat in the wild. However, farmed fish usually contain higher levels of contaminants due to the fact that they are fed processed pellets, often made from processed anchovies, sardines and other small fish, which are usually caught in polluted waters closer to shore and are often contaminated with industrial chemicals. Similarly, fish farms may also use hormones to help their fish grow bigger; pesticides to keep the water clean; artificial dyes to give their fish a brighter color and antibiotic drugs to protect their fish (Davidowitz and John, 2014).

A widely-cited study by Hites R.A. *et al* (2004) on global assessment of organic contaminants in farmed Salmon fish found that the levels of Polychlorinated Biphenyls, a potentially carcinogenic chemical, to be ten times higher in farmed fish than in wild-caught fish. Subsequent studies by

Salmon of the Americas (2004), and Alaska Department of Environmental Conservation found Polychlorinated Biphenyls levels in farmed fish to be similar to those of wild fish. However, the contaminant level of fish with mercury is high in all wild-caught fish, while the farm-raised fish all have low or very low mercury levels. The latest round of Polychlorinated Biphenyls monitoring carried out by Salmon of the Americas show levels of Polychlorinated Biphenyls in farmed salmon at about the same levels as those from wild Alaska Chinook and sockeye salmon. Further, they argued that this should put to rest any fears that arose from the notorious Hites R.A. *et al* (2004) study, which appeared in the journal "Science" in January 2004, proclaiming farmed salmon to have higher levels of Polychlorinated Biphenyls than their wild cousins.

Based on the above findings and arguments, it is clear that farmed fishing (aquaculture) is more in harmony with the environment, provided the fish farmers control the type of input they are using to grow the fish through regulatory mechanisms. Accordingly, source of fish was taken to examine the potential of the fishery sector in mitigating poverty and the rising levels of unemployment in the selected African countries.

Additionally, fish trade is governed by the general national regulations applying to trade in goods. They include customs procedures and health-related legislation, in particular sanitary measures, origin and catch certification requirements. In specific cases, trade in fishery products is also subject to national Illegal, Unregulated and Unreported (IUU) certification schemes, sustainable management requirements, and regional fisheries management organizations catch documentation schemes (UNEP, 2013). Thus, the marketing of fish and fish products has to comply with the above norms to ensure quality in the sector. Accordingly, the sustainability of the fishery sector, from trade perspectives, can be ensured, when the sector adheres to export quality and risk-free fish and fish products to the major fish import target market. However, some exported fish and fish products from African countries were rejected at the export market destinations, due to non-compliance with the different export norms, such as hygienic conditions, existence of heavy metal, mycotoxins, micro biological contamination, adulteration (missing documents), labelling, veterinary drug residues, bacterial contaminations, food and feed additives, packaging, pesticide residues and etc.,. This is mainly due to export boarder rejection notification. This rejections would result in reduction of income that is associated with the fishery sector. Accordingly, attempts were made in the study to show the

trend of how the fish trade in African countries is trending along the path to a green economy.

1.2 Objective of the Study

The objective of the study was to examine the potential of Africa's fishery sector and its potential to mitigate poverty and the challenges associated with rising unemployment.

Specific objectives are to:

- appraise the sustainability of the Africa's fishery sector's potential in terms of fish production, trade and employment potential.
- explore the potential of aquaculture fishing, as a means of generating income to mitigate poverty
- assess the practice of green fish trading across selected African countries.
- examine and predict the fishery sector's maximum sustainable employment and production potential, by maintaining the ecological balance of the fishery stock

1.3 Research questions

- How does Africa's fishery sector secure sustainability, in terms of fish production and trade to mitigate poverty?
- What is the maximum sustainable yield and employment creation potential of the Africa's fishery sector?
- How green fish trading is being practiced across African countries?

2. Materials and Methods

The total production volume of fish from the year 2000-2011 was taken into account to draw a total of ten sample countries from the five African sub-regions. Accordingly, one lowest volume of fish producers and one highest volume of fish producing countries from each African sub-region were selected. Thus, Egypt and Morocco from Northern Africa, Madagascar and Namibia from Southern Africa, Ethiopia and Seychelles from Eastern Africa,

Niger and Mauritania from Western Africa, and São Tomé and Príncipe as well as Chad from Middle African region were selected to represent Africa[1].

Accordingly, the potential of sustainable fishery resources to mitigate poverty and the problem of rising unemployment in the selected African countries was examined. Secondary data, mainly fish production, fish commodity trade, number of employment in the fishery sector and the frequency of export border alert notification[2] and export border rejection notification received[3] from export destinations, which resulted from quality deterioration. By using the aforementioned secondary data, the trend in employment, production and trade from the year 1980-2012 was analysed.

Time series data were collected mainly from FAOSTAT, International Labor Organization (ILO), Europe Direct (The Rapid Alert System for Food and Feed) and National Food Safety Authorities.

Accordingly, analytical econometric time series models such as Generalized Auto Regressive Conditional Hetro Schedasticity (GARCH) and Auto Regressive Conditional Hetro Schedasticity (ARCH), Schaefer's and Fox's maximum sustainable yield model (Surplus production model), Exponential compound annual growth rate (CAGR) and Linear coefficient of variation (CV) models were computed to analyse the data.

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[1] *From the entire African countries only 43 countries were found to be involved in the production of fish. Accordingly, only 43 countries were considered in drawing the sample representative of fish producing African countries. Additionally, countries under the five African regions were identified based on the United Nations country grouping.*

2 An 'alert notification' or 'alert' is notification sent when a food or a feed presenting a serious risk on the market or when rapid action is required. Alerts are triggered by the member of the network that detects the problem and has initiated the relevant measures, such as withdrawal/recall. The notification aims at giving all the members of the network the information to verify whether the concerned product is on their market, so that they can take the necessary measures (RASFF, 2009).

3 A 'border rejection notification' concerns a food or a feed that was refused entry into the community for reason of a risk to human or animal health (RASFF, 2009).

2.1 GARCH and ARCH model

The ARCH and GARCH model was fitted to examine the persistence level of variation in the monetary value of aquaculture fish from the year 1981-2012. Engle, R.F. (1982) and David Harper, CFA, FRM, CIPM, AIM (2010) noted that GARCH (p, q) have the following key assumptions: Autoregressive (AR): tomorrow's variance (or volatility) is a regressed function of today's variance, it regresses on itself.

Conditional (C): tomorrow's variance depends on condition of the most recent variance. An unconditional variance would not depend on today's variance.

Heteroskedastic (H): variances are not constant; they flux over time.

GARCH regresses on "lagged" or historical terms. The lagged terms are either variance or squared returns. The generic GARCH (p, q) model regresses on (p) squared returns and (q) variances. Therefore, GARCH (1, 1) "lags" or regresses on last period's squared return (i.e., just 1 return) and last period's variance (i.e., just 1 variance).

GARCH (1, 1) given by the following equation:

$\sigma^2_t=a+br^2_{t-1,t}+c\sigma^2_{t-1}$ ……………………. (Equation 1)

The same GARCH (1, 1) formula can be given with Greek parameters: Hull (1998) wrote the same GARCH equation as:

σ2n=γVL+αu2n-1+βσ2n-1 ……………... (Equation 2)

The first term (γVL) is important because VL is the long-run average variance. Therefore, (γVL) is a product: it is the weighted long-run average variance. The GARCH (1, 1) model solves for the conditional variance as a function of three variables (previous variance, previous return squared and long-run variance):

$h_t = \alpha_0+\alpha_1+r^2_{t-1}+\beta h_{t-1}$……………………. (Equation 3)

Where,

h_t or σ^2_t= Conditional Variance (i.e., we are solving for it)

a or α = weighted long-run (average) variance

h_{t-1} or σ^2_{t-1} = previous variance

r^2_{t-1} or $r^2_{t-2,t}$= previous squared item

Based on the above formula, persistence = (b + c) or (alpha-1+ beta), it is a feature embedded in the GARCH model, which refers to how quickly (or slowly) the variance reverts or “decays” toward its long-run average. High persistence equates to slow decay and slow “regression toward the mean;” low persistence equates to rapid decay and quick “reversion to the mean. A persistence of 1.0 implies no mean reversion. A persistence of less than 1.0 implies “reversion to the mean,” where a lower persistence implies greater reversion to the mean.

The sum of the weights assigned to the lagged variance and lagged squared return is persistence (b+c = persistence). A high persistence is where the sum of the weights assigned to the lagged variance and lagged squared return persistence = (b + c) or (alpha-1+ beta), greater than zero but less than one implies slow reversion to the mean. But if the weights assigned to the lagged variance and lagged squared returns are greater than one (if b+c > 1), the model is non-stationary and, according to Hull, unstable.

2.2 Schaefer’s and Fox’s maximum sustainable yield (Surplus production Models)

Surplus production models (Schaefer-models) was computed to determine the optimum level of effort, that is the effort (employment) that produces the maximum yield that can be sustained without affecting the long-term productivity of the fishery stock, the so-called maximum sustainable yield (see Graham,1935; FAO- Fishery and Aquaculture department, 2014) in the selected ten African countries from 1980-2012.

The maximum sustainable yield (MSY) can be estimated from the following input data:

f(i) = effort (number of employees) in year i, where, i = 1,2,...,n

Y/f = yield (catch in weight) per unit of effort (employees) in year i.

Y/f may be derived from the yield, Y(i), of year i for the entire fishery and the corresponding effort, f(i), by

Y/f = Y(i)/f(i), i = 1,2,...,n..(Equation 1)

The simplest way of expressing yield per unit of effort, Y/f, as a function of the effort, f, is the linear model suggested by Schaefer (1954):

Y(i)/f(i) = a + b*f(i) if f(i) £ -a/b..(Equation 2)

Equation 2 is called the "*Schaefer model*".

The slope, b, must be negative if the catch per unit of effort, Y/f, decreases for increasing effort, f. The intercept, a, is the Y/f value obtained just after the first boat fishes on the stock for the first time. The intercept, therefore, must be positive. Thus, -a/b is positive and Y/f is zero for f = -a/b. Since a negative value of catch per unit of effort Y/f is absurd, the model only applies to f-values are lower than -a/b.

An alternative model was introduced by Fox (1970). It gives a curved line, when Y/f is plotted directly on effort, f, but a straight line, when the logarithms of Y/f are plotted on effort:

ln (Y(i)/f(i)) = c + d*f(i)..(Equation 3)

Eq. 3 is called the "Fox model", which can also be written:

Y(i)/f(i) = exp(c + d*f(i))……………………………………........(Equation 4)

Both models conform to the assumption that Y/f declines as effort increases, but they differ in the sense that the Schaefer model implies one effort level for which Y/f equals zero, namely when f = -a/b; whereas in the Fox model, Y/f is greater than zero for all values of f.

The Catch per unit Effort (CPUE w(t) = q*B(t). Since Y/f is also the catch per unit of effort in weight, we can write:
Y(i)/f(i) = q*B = a + b*f(i) for the Schaefer model and
Y(i)/f(i) = q*B = exp(c + d*f(i)) for the Fox model
Where, B is the biomass and q the catchability coefficient (a constant).

For f close to zero Y/f takes the maximum value and so does the biomass because Y/f = q*B, and q is a constant. The biomass corresponding to f = 0 is called the "*virgin stock biomass*" or the "*unexploited biomass,*" denoted by "Bv". Thus, replacing Y/f by q*Bv in Eqs. 2 and 4 gives:
q*Bv = a or Bv = a/q (Schaefer)
q*Bv = exp(c) or Bv = exp(c)/q (Fox)

In order to obtain an estimate of the maximum sustainable yield (MSY) and determine at which level of effort maximum sustainable yield has been or will be reached, it is necessary to rewrite Eqs.2 and 4, expressing the yield as a function of effort, by multiplying both sides of the equation by f(i):

Schaefer: Y(i) = a*f(i) + b*f(i)^2 if f(i) < -a/b............................ (Equation 5)

or

Y(i) = 0 if f(i) = -a/b

Fox: Y(i) = f(i)*exp[c + d*f(i)].. (Equation 6)

Eq. 5 of the Schaefer model, is a parabola, which has its maximum value of Y(i), the MSY level, at an effort level

f_{MSY} = -0.5*a/b.. (Equation 7)

and the corresponding yield:

MSY = -0.25*a^2/b.. (Equation 8)

Eq. 6, the Fox model, is an asymmetric curve, with a maximum (the MSY level), and a fairly steep slope on the left side, with a much more gradual decline on the right of the maximum. The MSY and f_{MSY} for the Fox model can be calculated by formulas, which are derived from Eq. 6 by differentiating Y with respect to f and solve dY/df = 0 for f,

f_{MSY} = -1/d................………………………………………..…..(Equation 9)

MSY = -(1/d)*exp(c-1)...(Equation 10)

2.3 Exponential Compound Annual Growth Rate (CAGR)

The trend and composition in the volume of the fish production, trade and employment in the fishery sector were estimated, using the exponential compound annual growth rate function, which has wide applications in previous studies (see Elias and Patil, 2013; Kusuma and Basavaraja, 2014; Shiferaw-Mitiku T. and Ushadevi, 2015) and takes the form:

$Y_t = a\beta^t e^{ut}$ ………………………..…..(Equation 1)

Where,

Y_t = Dependent variable in period t (volume of fish production, exports, imports and number of employment)

a = Intercept

β = Regression or trend coefficient = (1+g)

t = years which take the values, 1, 2, 3…, n (1981-2012)

u_t = Disturbance term for the year t

e = the natural Logarithm (=2.71828)

The equation was transformed into log linear form $LnY_t=\beta o+\beta_i t_i+u_i$ to allow for the ordinary least squares (OLS) estimation. The compound growth rate (g) in percentage was then computed, using the relationship g = (10^{b-1})*100 (see Veena, 1996).

Further, descriptive statistics, like means and coefficient of variation, were computed to substantiate the statistical value of the study. Specifically, in order to study the variability in the time series data, the linear coefficient of variation was fitted as an index of instability of the fish sector performance.

Previously, the model was used by a study which was conducted by Bhaskar N. Patil and A. J. Nirban 2013). Economic Views (EVIEWS), Statistical Package for the Social Sciences (SPSS) and Advanced Excel Analysis computer packages were used to analyses the data.

3. Results

3.1. Sustainability of fish production in selected ten African countries

In the study, an attempt was made to examine and predict the maximum sustainable fish harvest potential of the Africa's fishery sector to view the sector's ability to adopt green fishery practice.

3.1.1. Captured-fish production from 1980-2011

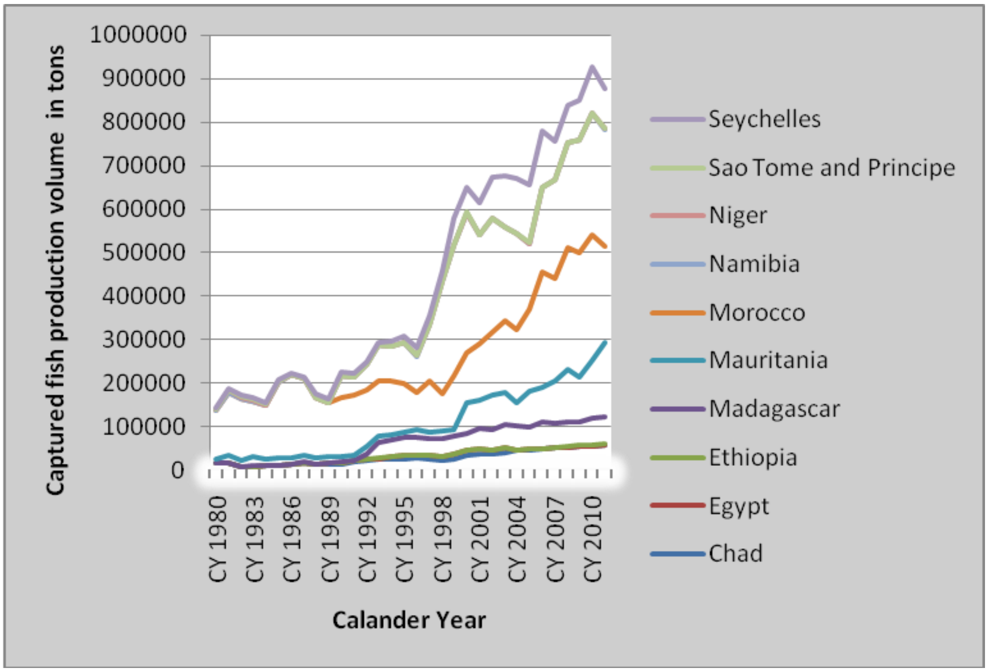

Figure 1. Captured-fish Production volume from selected ten African countries 1980-2011, (Qty ton)

Figure 1 above shows the trend in the total volume of captured-fish production in ten selected African countries from the year 1980-2010. The trend indicates that majority of African countries' captured-fish production

volumes have been experiencing an increasing trend, especially from 1998 onwards.

Table 1. Trend in Captured-fish production from 1980-2012, (Qty: tons)

Country	Mean	Std	CV%	CAGR%	P value
Chad	71993.94	16938.8	23.5281	0.001489	1.49E-05
Egypt	288154.1	95497.04	33.14097	1.662452	8.02E-11
Ethiopia	9643.394	6532.107	67.7366	2.631056	5.27E-13
Madagascar	94414.67	21971.23	23.27099	1.143358	5E-13
Mauritania	110382.2	103959.2	94.18119	3.579579	1.75E-11
Morocco	667769.4	235284	35.23432	25159.09	1.21E-53
Namibia	361052.5	256875.1	71.1462	6.558796	3.36E-08
Niger	17172.88	18096.1	105.3761	0.948703	0.009442
São Tomé and Príncipe	3681.455	941.2634	25.56771	0.97544	1.72E-05
Seychelles	34218.76	36297.93	106.0761	5.816135	9.13E-13
Source: Figures are the author's calculation, based on data collected from FAOSTAT, 2015					

Results from Table 1 above shows the average volume of captured-fish production potential of the ten African countries and its annual growth rate from the 1980-2012. Furthermore, the result indicates the extent to which captured-fish production trend deviated from the mean and the p value indicates the results were statistically significant in all countries.

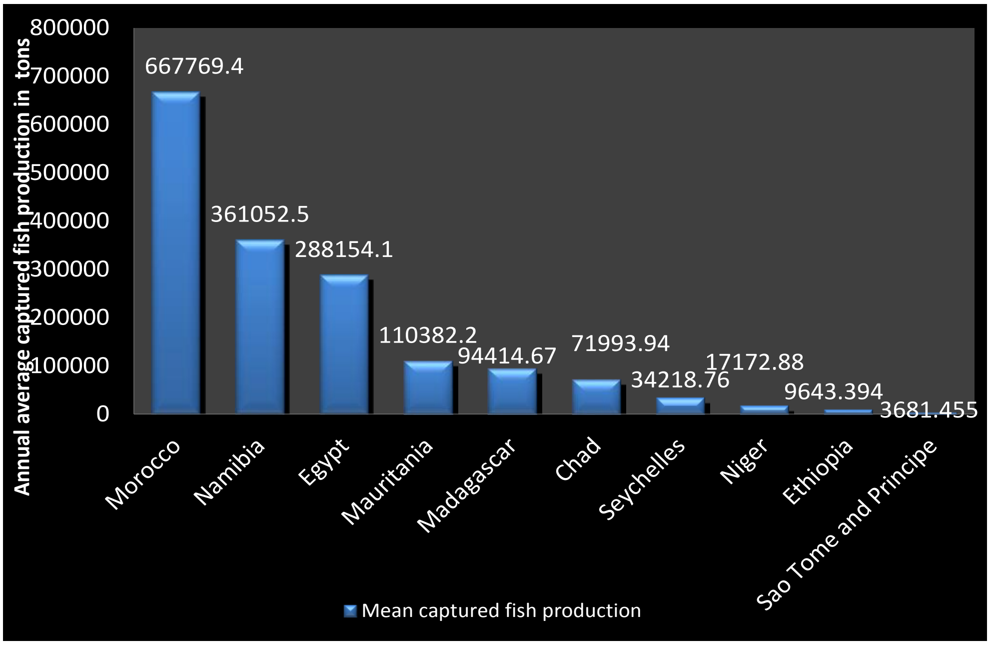

Figure 2. **Average volume of annual captured-fish production from 1980-2010 (Qty: tons)**

The above figure 2 presents the annual average volume of captured-fish production of the ten selected ten African countries from the year 1980-2010.

3.1.1. The volume and monetary value of Aquaculture fish production from selected six African countries, 1980-2012

Table 2. Aquaculture fish production from 1980-2012 (Qty, tons)

Country	Mean	Std	CV%	CAGR%	P value
Egypt	282964.1	313810.7	110.9013	5.922843	4.09E-23
Ethiopia	19.18182	14.47725	75.47384	-0.49514	0.298169
Madagascar	1835.242	1462.812	79.70674	5.615817	6.36E-11
Morocco	959.2961	776.1904	80.91249	7.70943	5.95E-09
Namibia	12.30303	22.34458	181.6185	6.682462	6.13E-10
Niger	27.12121	24.88317	91.74802	3.218242	6.78E-08

NB:

Figures for Aquaculture fish production from Ethiopia were calculated from 1988-2012, figures for Namibia were calculated from 1992-2012, figures for Niger were calculated from 1984-2012. The Researcher failed to find the aquaculture fish production statistical data both in national and international statistical sources for Chad, Mauritania, São Tomé and Príncipe and Seychelles for the study period.
Source: Figures are Author's calculation based on the data collected from FAOSTAT, 2015

Table 2 shows the annual average aquaculture fish production volume from six selected African countries and the compound annual growth rate registered in aquaculture fish production from 1980-2012. With the exception of the growth in aquaculture fish production in Ethiopia, the results were significant for the five countries.

Table 3. Aquaculture production monetary value (1990-2012)

	Egypt	Ethiopia	Madagascar	Morocco	Namibia	Niger
Mean (USD 000)	705825.1	63.1	4660.7	6189.9	40.81	100.2
Std	599584.3	24.57	2977.38	2641.84	70.23	115.53
CV%	84.95	38.94	63.88	42.68	172.09	115.33
CAGR%	6.78	-0.48	4.44	-0.82	7.39	3.69
P value	2.72E-13	0.363646	6.82E-05	0.14951	3.75E-09	0.00079

NB:
-Figures for Namibia were calculated from 1993-2012
-Aquaculture production statistical historical data were not found for Chad, Mauritania, São Tomé and Príncipe and Seychelles.
Source: *Figures are Author's calculation based on the data collected from FAOSTAT*

The Table 3 presents the monetary value derived from aquaculture fishing and its compound annual growth registered in the six African countries, viz., Madagascar, Morocco, Namibia, Niger, Ethiopia and Egypt from 1990-2012. With the exception of the Ethiopia and Morocco fishery sector the monetary value realized from aquaculture fishing in the four countries were found significant.

Table 4. Volatility Shock exhibited in the income derived from Aquaculture fishing

Dependent Variable: Monetary Value of Aquaculture fishing Method: ML - ARCH (Marquardt) - Normal distribution GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*GARCH(-1)					
Country	**Variance equation Coefficient**			**Prob.**	**Sample study period**
	C	RESID (-1)^2	GARCH(-1)		
Egypt	4.34E+11	1.289588	-0.995731	0.0000	1984-2012
Ethiopia	1789.874	0.488011	0.132909	0.9385	1988-2012
Madagascar	462119.2	0.760669	0.483919	0.6103	1984-2012
Morocco	23195019	0.714075	-0.302383	0.6525	1984-2012
Namibia	-111.7726	2.673620	0.097479	0.9677	1994- 2012
Niger	20.67734	1.992151	-0.036403	0.9218	1984- 2012

Table 4 indicates how the income generated from aquaculture fishing experienced income variation throughout the study period across the selected six African countries, though the result is found to be statistically not significant, except for Egypt.

3.1.2. Fish production, Domestic consumption, Export, Import from ten selected African countries from 1980-2012

Table 5. Total export volume of fish from 1980-20126:

Country	Mean (in tons)	Std	CV%	CAGR%	P value
Chad	40.45455	85.15441	210.494	-100	0.238581
Egypt	1912.097	2137.037	111.764	5.070622	5.14E-08
Ethiopia	98.16667	208.1298	212.0167	16.06943	0.001339
Madagascar	8022.968	7238.119	90.21747	11.28423	7.26E-10
Mauritania	37572.71	32548.84	86.62894	3.5908	6.66E-10

Country	Mean (in tons)	Std	CV%	CAGR%	P value
Morocco	139221.1	71129.12	51.09075	1.960227	8.65E-11
Namibia	309486.8	157282.1	50.8203	0.500374	0.05723
Niger	1070.806	2110.648	197.1083	8.222792	0.035512
São Tomé and Príncipe	45.07143	144.732	321.1169	23.45322	0.103856
Seychelles	35207.16	41441.34	117.7071	9.445645	9.41E-18

NB:

- *Re-exported volume of fish from Madagascar for the years 2006, 2007 and 2011, from Niger for the years 1996, 1998, 1999 and 2008 and from Seychelles for the years 1988, 1989, 1996 and 2007 were included in their respective total export figures.*
- *The export figures for Chad, Namibia, São Tomé and Príncipe, Ethiopia and Niger were calculated from the year 2000-2010, 1992-2010, 1983-2010, 1981-2010 and 1980-2010, respectively.*
- *Similarly, CAGR for Chad, Namibia, São Tomé and Príncipe, Ethiopia and Niger were calculated from the year 2007-2010, 1992-2010, 1995-2002, 1995-2010and 1993-2010 respectively only, due to data inconsistency exhibited in the historical statistical figure consideration for the entire study period.*

Source: Figures are Author's calculation, based on the data collected from FAOSTAT

Table 4 indicates the total export volume of fish from the ten selected African countries from the year 1980-2012 and the trend in the growth of the exports.

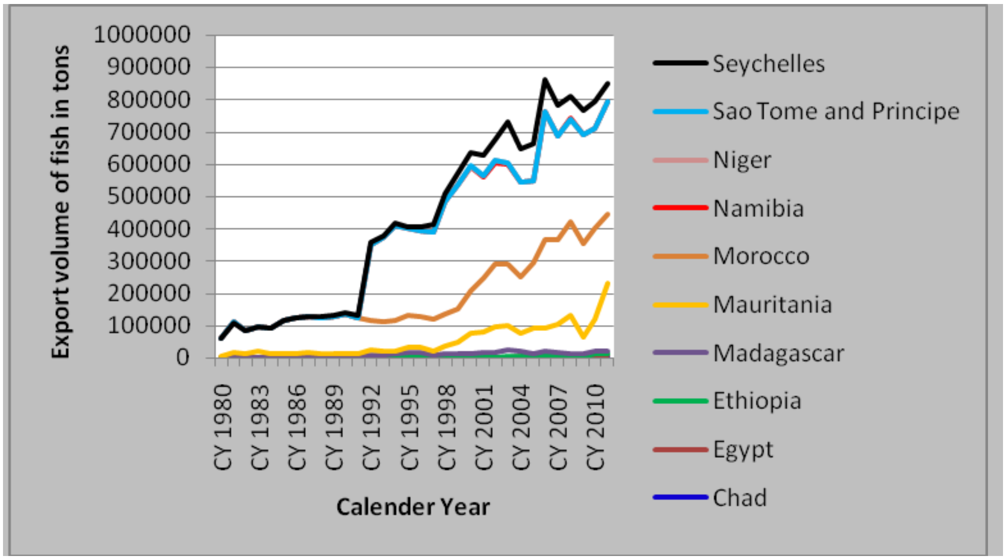

Figure 3. Total export volume of fish from selected ten African countries, 1980-2012, (Qty, tons)

Figure 3 shows the trend in the total export volume of fish from the selected African countries from the year 1980-2012. The trend indicates that majority of the African countries considered in the study witnessed a steady incremental growth from the year 1998 onwards.

3.2. Total number of export border rejection notification and alert received from 1980-2014

Table 7. The total frequency of fish export border rejection notification and alert from the year 1980-2014

Year	Egypt	Morocco	Madagascar	Namibia	Ethiopia	Seychelles	Niger	Mauritania	São Tomé and Príncipe	Chad
1980-1985	0	1	0	0	0	0	0	0	0	0
1986-1990	0	1	0	0	0	0	0	0	0	0
1991-1995	0	0	0	0	0	0	0	0	0	0

Year	Egypt	Morocco	Madagascar	Namibia	Ethiopia	Seychelles	Niger	Mauritania	São Tomé and Príncipe	Chad
1996-2000	0	4	0	0	0	0	0	1	0	0
2001-2005	0	7	0	2	0	1	0	0	0	0
2006-2010	1	120	2	23	0	0	0	24	0	0
2011-2014	3	90	3	13	0	9	0	17	0	0
Total number of border rejection and alert received from the year 1980-2014	**4**	**223**	**5**	**38**	**0**	**10**	**0**	**42**	**0**	**0**

Source: The Rapid Alert System for Food and Feed (RAFF)
NB: Figures are the frequency of both export boarder rejection notification and export boarder alert notification received from EU Border from 1980-2014

The result from Table 6 indicates the frequency of both export border rejection notification and export border alert notification received from EU Border from 1980-2014. The result shows that countries, namely Chad, Ethiopia, São Tomé and Príncipe as well as Niger have received neither border rejection notification nor alert from EU border in the exports of fish from the year 1980-2014.

Table 8. Total imports of fish from 1980-2012 (Qty: tons)

Country	Mean	Std	CV%	CAGR %	P value
Chad	425.2222	403.8772	94.98	4.44	0.347359
Egypt	157331.4	61931.27	39.36	1.85	3.31E-13
Ethiopia	172.5938	208.4653	120.78	6.22	6.27E-07
Madagascar	9952.625	8737.859	87.79	10.99	5.83E-11
Mauritania	478.062	530.024	110.86	3.21	2.42E-

Country	Mean	Std	CV%	CAGR %	P value
	5				05
Morocco	9063.25	11265.29	124.29	12.76	1.5E-09
Namibia	9655.5	17613.19	182.42	7.31	0.015019
Niger	1020.219	947.7033	92.89	2.81	4.86E-06
São Tomé and Príncipe	76.65625	94.42102	123.17	-5.41	0.000297
Seychelles	26971.63	33105.85	122.74	14.66	2.8E-09

NB:
Import figures for Chad, Namibia, São Tomé and Príncipe, Mauritania *and Morocco were calculated from the year 1993-2011, 1995-2011, 1985-2011, 1982-2011and 1981-2011, respectively.*
Source: Figures are Author's calculation based on the data collected from FAOSTAT, 2015

Table 7 indicates the average volume of fish imports and its annual growth rate in selected ten African countries from the year 1980-2012. Furthermore, with the exception of CAGR in Chad, the growth rate was found significant in all countries.

Table 9. Trade and domestic supply of fish from 1980-2011 (Qty: tons)

Countries	Total Production	Total Domestic consumption	Total Exports	Total Imports	Net-Export
Chad	2275800	2282957	497	7654	-7157
Egypt	17500154	22465628	69131	5034605	-4965474
Ethiopia	289875	291627	3771	5523	-1752
Madagascar	3075535	3133081	260938	318484	-57546
Mauritania	3241035	1882560	1373773	15298	1358475
Morocco	20964676	16725773	4528927	290024	4238903
Namibia	11446644	5527082	6228538	308976	5919562
Niger	521000	519637	34010	32647	1363

São Tomé and Príncipe	116131	117322	1262	2453	-1191
Seychelles	1135973	850487	1148578	863092	285486

NB:
Figures are the total volume of fish production, domestic consumption, exports, imports and net exports from the year 1980-2010 in tons

Source: FAOSTAT, 2015

Table 8 shows, the total volume of production, domestic consumption, trade and net export volume of fish from the year 1980-2010 for the selected ten African countries. The result indicates that Mauritania, Morocco, Namibia, Seychelles, and Niger were found as net exporters of fish, while Chad, Egypt, Ethiopia, Madagascar, Mauritania, and São Tomé and Príncipe were found as net importers of fish for the study period.

3.3. The sustainability of the fishery sector in terms of employment, production and catch per unit effort

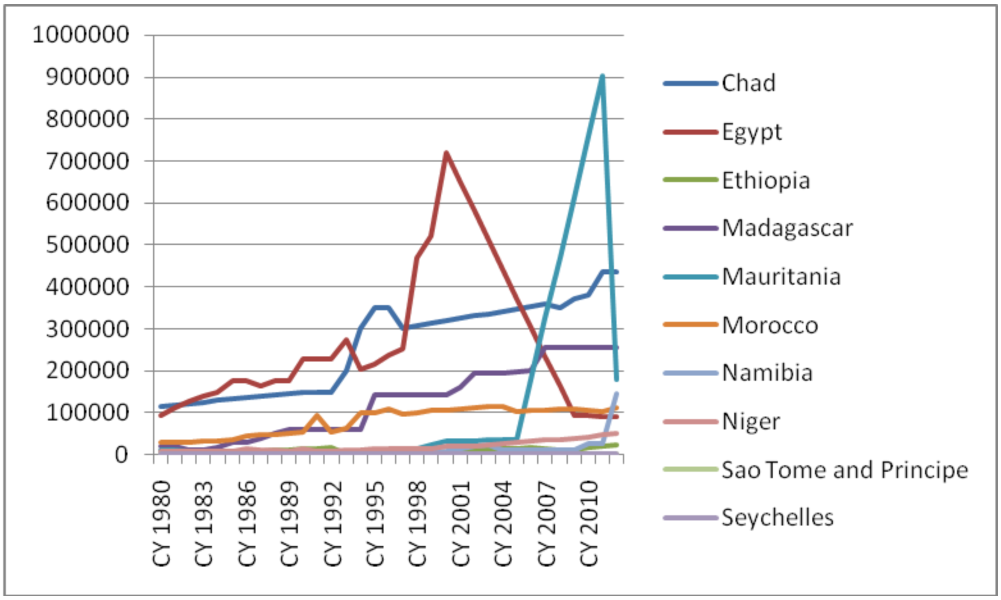

Figure 4. Employment in the fishery sector for calendar years 1980-2012

Figure 4 presents the trend of the fishery sector's potential in creating employment opportunity from the year 1980-2012 in ten selected African

countries. It was noted that the number of employment registered in Chad and Madagascar witnessed an increasing trend throughout the study period.

Table 10. Employment in fishery sector 1980-2010

Country	Mean	Std	CV%	CAGR%	P value
Chad	259321	108899.3	41.99	2.01	1.63E-15
Egypt	264427	172271.6	65.15	0.56	0.249544
Ethiopia	9905	6198.197	62.57	2.30	1.27E-05
Madagascar	125358	87031.59	69.43	4.23	1.42E-17
Mauritania	115951	232002.6	200.08	6.13	3.32E-09
Morocco	81992	32834.6	40.05	2.01	2.52E-12
Namibia	12740	25086.49	196.91	4.05	2.63E-13
Niger	18506	12665.4	68.44	2.70	2.81E-17
São Tomé and Príncipe	2055	539.3677	26.24	0.90	4.79E-06
Seychelles	1656	530.9314	32.05	1.18	3.92E-08

NB:

1. Ethiopia and Ethiopia FDRE time series data from the year 1980-1991 were merged together

2. Data interpolation method was computed to fit the missing time series for the number of employment in fishery sector in Chad from the year 1981-89 and 1998-2006, Egypt for the year 1981 and from 2001-2008, Ethiopia for the years 1981-1985, 1987 and 1991, Madagascar for the years 1984, 1987 and 1988, Mauritania for the years 1981-1989,1991-93, 2002-04, and 2007-2011, Morocco for the years 1987 and 1988, Namibia for the years 1981-89, 1991-95, 1999 and 2001-02, Niger for the years 1983-84, 1987-88, 1993-94, 1996-1999, 2001-02, 2004 and 2006-2007

1) *Data extrapolation method was computed to fit the missing time series data on the number of employment in the fishery sector in Egypt for the year 2011-2012*

Source: Figures are Author's calculation based on the data collected from ILO

Table 9 shows the mean annual number of employment in the fishery sector and growth of employment creation potential of the sector in the selected ten African countries from the year 1980-2010.With the exception of Egypt, the growth registered in employment creation in the fishery sector were found significant in the nine African countries.

Table 11. The maximum sustainable yield and efforts of selected African countries fishery sector (1980-2011)

Country	**Actual**		**Predicted**		**Intercept**	**Slope**	**Fishery stock status**
	Yield (000 kg)	Number of employment	Maximum sustainable yield (kg)	Maximum sustainable number of employment			
Egypt	1332444	93123	1089382463	294249	7404.48	-0.012	Over-exploited
Chad	95000	435000	83209813	307253	541.63	-0.000	Over-exploited
Ethiopia	1332444	93123	12334618	12517	1970.89	-0.078	Over-exploited
Madagascar	62434	254150	171354205	126896	2700.69	-0.011	Under-utilized
Namibia	413564	25716	1064811100	42223	50437.16	-0.597	Under-utilized
Morocco	888137	902520	8532952570	329074	51860.46	-0.078	Under-utilized
Niger	74371	2268	213174314.1	5710.1	8.539453	0.0003	Under-utilized
Mauritania	349744	902520	840938195	361755	4649.21	-0.006	Under-utilized
Seychelles	74371	2268	222954241	11009	16048.61	0.3817	Under-utilized
São Tomé and Príncipe	5057	1601	4079939	2826	2887.39	-0.510	Over-exploited

NB: The result was analyzed using Schaefer's maximum sustainable yield model using fishery historical data collected from FAOSTAT and employment data collected from ILO while, the Fox's model was fitted to calculate the maximum sustainable yield and effort of the Seychellois's and Niger's fishery sector.

Table 10 above shows the actual volume of fish being harvested per year and the number of employees available in the ten African countries fishery sector from the year 1980-2011 and the predicted maximum sustainable yield and efforts required in the selected ten African countries' fishery sector.

The result indicates that the fishery sector in Egypt, Namibia, Niger, Seychelles, as well as São Tomé and Príncipe were found with a potential to absorb additional employees, while the fishery sectors in Chad, Ethiopia, Madagascar, Morocco and Mauritania absorbed employees beyond the sector's potential.

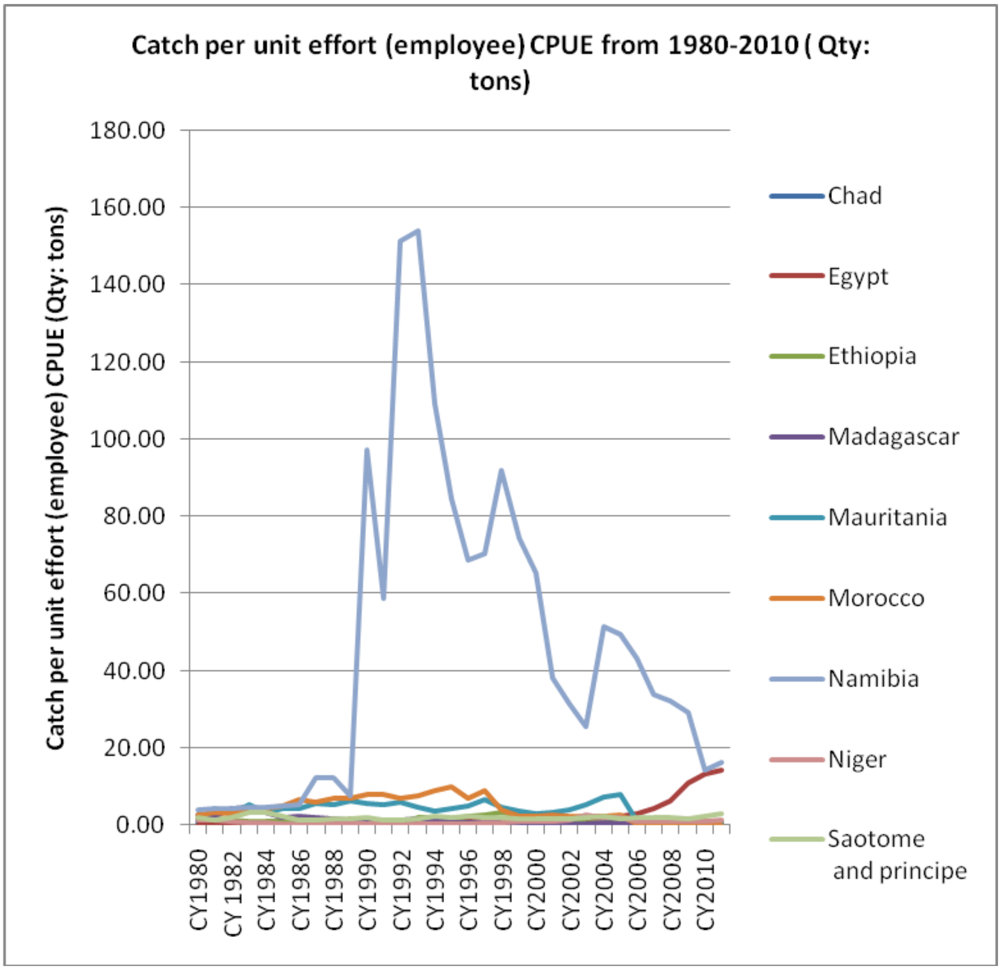

Figure 5. Catch per unit effort (employee), CPUE from 1980-2010 (Qty: tons)

Figure 5 presents the trend in the volume of fish realized by individual fisher men per year (catch per unit employees per year) from the ten African countries from the year 1980-2010.

Table 12. Catch per unit employee (CPUE) in selected African countries from 1980-2010 (Qty: tons)

Country	Mean CPUE (Qty in tons, from 1980-2011)	Std	CV%	CAGR%	P value
Chad	0.32	0.11	0.35	-1.18	0.00
Egypt	3.4	3.9	1.15	3.96	0.00
Ethiopia	1.22	0.76	0.62	0.39	0.49
Madagascar	1.41	1.1	0.78	-3.04	0.00
Mauritania	3.92	2.08	0.53	-2.46	0.00
Morocco	4.29	2.95	0.69	-4.35	0.00
Namibia	45.33	41.26	0.91	2.85	0.00
Niger	0.77	0.56	0.73	1.7	0.00
São Tomé and Príncipe	1.86	0.55	0.29	0.14	0.53
Seychelles	17.59	16.68	0.95	4.56	0.00

NB:
-For detail of employment see Table 9 and for production figures see Table 8
-Figures for Chad were calculated from the year 1989-2011
Source: Figures are author's calculation based on employment data collected from ILO and fish production data collected from FAOSTAT

The growth in catch per unit employee (productivity of fishermen) registered in Chad, Madagascar, Mauritania and Morocco witnessed a significant negative incremental growth, while the reverse was the case in Egypt, Namibia, Niger and Seychelles, with positive incremental growth. Although, there were positive incremental growth of catch per unit effort in Ethiopia, as well as São Tomé and Príncipe fishery sectors, the growth was not statistically significant.

4. Discussions

4.1 Trend in Captured-fish production (1980-2011)

From the year 1998 onwards, the trend in volume of captured-fish production in the selected ten African countries witnessed a steady upward trend (see Figure 2). A steady growth in captured-fish production was noted after the year 1998, mainly in Seychelles, São Tomé and Príncipe, Morocco and Mauritania. (See Table 1).

Based on the mean volume of captured-fish production from the year 1980-2012; Morocco secured 667769.4 tons of fish and ranked first, followed by Namibia (361052.5 tons), Egypt (288154.1 tons), Mauritania (110382.2 tons) and Madagascar (99414.67 tons). However, the coefficient of variation exhibited in the volume of captured-fish production in Namibia found higher (71.15%) than that of Egypt (33.14%) throughout the study period. São Tomé and Príncipe accounted for the lowest volume of captured-fish production in the selected ten African countries; with mean annual production volume of 3681.45 tons, followed by Ethiopia (9643.4 tons), Seychelles (34218.8 tons) and Chad (719934.9 tons). The high coefficient of variation in the trend of fish production indicates the extent of sustainability of the catch environment (see Table 1).

The model further detected that, with the exception of the annual growth rate registered in Chad (0.001%), all other fish producing countries' captured-fish production levels grew by almost 100 percent and above for the study period. However, the variation exhibited in the growth of captured-fish production was found higher in Seychelles (106.1%), followed by Niger (105.4%), Mauritania (94.2%), Namibia (71.1%) and Ethiopia (67.7%); while the variationnoted in the growth of captured-fish production in Morocco, Egypt, São Tomé and Príncipe, Chad and Madagascar was 35 percent and below. Figure 3 indicates that, with the exception of Morocco, Namibia, Egypt and Mauritania, the remaining selected African countries considered in the present study witnessed average captured-fish production volume below 100,000 tons per year.

4.2 Sustainability of aquaculture fish production

In addition to wild-catch fishing, aquaculture fishing was found in practice in Egypt, Ethiopia, Madagascar, Morocco, Namibia and Niger, among the

sample selected ten African countries for the study. However, fish production in countries like Chad, Mauritania, São Tomé and Príncipe, and Seychelles relied only on captured-fishing method. It was further noted that there existed a big difference in the mean volume of fish production among and between countries involved in aquaculture fish production in Africa. Egypt, followed by Madagascar and Morocco were the top three countries with high mean annual volume of fish production of 282964.1 tons, 1835.24 tons and 959 tons, respectively, among the selected ten African countries. Despite the high volume of aquaculture fish production recorded in Egypt, the variation exhibited in the volume fish production for the study period were higher than the variation recorded in Ethiopia, Madagascar, Morocco and Niger.

On the other hand, Namibia, Ethiopia and Niger were the three countries witnessing insignificant mean volume of fish production from aquaculture fishing for the study period (1980-2012). In this respect, Niger accounted for a mean annual production volume of only 27.12 tons, while Ethiopia accounted for 19.2 tons, and Namibia accounted for 12.3 tons of fish at compound annual growth rate of 3.21 percent, -.0.49 percent and 6.68 percent, respectively (see Table 2).

Namibia witnessed the highest annual growth rate (6.68%) in fish production, next to Morocco (7.7%), in a development that is largely attributed to the Government of Namibia's effort in placing aquaculture as a top priority to play major role in the enhancement of food security, poverty alleviation, and improvement of livelihood in rural communities, as defined in the Namibian Vision 2030 document (National Planning Commission, 2004).

Furthermore, with the exception of Ethiopia, the volume in aquaculture fish production in Morocco, Namibia, Egypt, Madagascar, and Niger witnessed a steady positive growth rate for the study period. This indicates the sustainability of the aquaculture fish production in Ethiopia and its economic benefits to reduce poverty, unemployment, as well as contribution to the food security of the nation from the fish sector become questionable.

In this regard, despite the current huge volume of captured-fish production in the global fish production figure, the volume is lower for aquaculture fishing. FAO has projected to make capture production and aquaculture fishing to be closer to equality by the year 2030, in order to foster sustainable

production and food security (FAO, 2002). Therefore, special attention should be paid to the Ethiopian aquaculture fishery sector in examining the major challenges exhibited in the sector, which led to the downward trend in the volume of aquaculture fish production.

The study also found that aquaculture fishing in African Countries such as Chad, Mauritania, São Tomé and Príncipe and Seychelles played no role in mitigating poverty and unemployment (see Table 2). Accordingly, government and private organizations have to work on aquaculture fishing, given its potential contributions to the economy of the nation, particularly in mitigating poverty, unemployment and food insecurity.

4.3 Sustainability of the income realized from aquaculture fishing

It can be inferred from the result (see Table 3) that, the contribution of aquaculture fishing to mitigate poverty in Chad, Mauritania, São Tomé and Príncipe and Seychelles was non-existent, as they were not involved in aquaculture fishing. The result indicates that the income derived from aquaculture fishing for the past two decades was higher in Egypt, with a mean annual monetary value of USD 7058251000, followed by Morocco (USD 61899720) and Madagascar (USD 46607390), Niger (USD 1001757), Ethiopia (USD 631130) and Namibia (USD 408095).

Thus, the contribution of aquaculture fishing towards poverty reduction through the income derived from it was higher in Egypt, followed by Morocco, Madagascar and Mauritius, at compound annual growth rate of 6.78 percent, -0.84 percent, 4.44 percent, and 8.84 percent, respectively. Aquaculture fishing as a means of income generating activity for fishermen to ultimately mitigate poverty was found at a negative incremental growth at the rate of -0.82 percent and -0.48 percent in Morocco and Ethiopia, respectively (see Table 3).

Result from Table 4 indicates that, the ARCH and GARCH coefficients ($\alpha+\beta <1$) is less than one, for countries viz., in Egypt, Ethiopia and Morocco. The result implies that income derived from aquaculture fishing from the aforementioned three countries for the study period witnessed no significant long run persistence of volatility. While the ARCH and GARCH coefficients ($\alpha+\beta >1$) is greater than one, for countries like Namibia from the year 1994-2012 and Niger from 1984-2012. The result implies that persistent shock was noted in the income derived from aquaculture fishing in Namibia and Niger

for the study period; however, the shock was not significant to reflect the effect on long run persistence of volatility (Variation).

4.4 Sustainability of fishery commodity trade in the African Countries

4.4.1 Sustainability of export of fishery commodity

Among the ten selected African countries, results show the five leading fish exporters from 1980-2012 were Namibia, ranked first with a mean annual export volume of 309486.8 tons of fish; followed by Morocco (139221.1 tons); Mauritania (37572.7tons); Seychelles (35207.16 tons) and Madagascar (8022.96 tons). Despite the highest annual growth rate of fish production registered in São Tomé and Príncipe (23.45%), Ethiopia (16.06%) and Niger (8.22%), the mean annual export volume of fish was very low, with coefficient of variation of 321.11 percent, 212.01 percent, 197.10 percent, respectively. Furthermore, the model detected that, with the exception of Chad, the growth rate of fish export from the nine countries as projected by the model were found significant (see Table 5).

Chad witnessed the lowest mean volume (40.45 tons) of fish export at negative (-100%) incremental growth rate from the year 1980-2012. This is attributable to fish production in the country, which was not supported by aquaculture, as well as the increasing pressure of domestic demand for fish (See Table 8). As a result, Chad was found as net importer of fish, with a mean annual import of 425.2 tons of fish (see table 8). This indicates that international trade has played significant role in maintaining the food security of the nation in striking the balance between the domestic demand and supply, given the limited volume of domestic fish supply in the country.

The sustainability of the fishery sector to carry out fishery trade by adhering quality standard, which is risk-free to human or animal and generate income, has witnessed a decreasing trend in majority of African countries selected for the study (See Fig 4). It revealed a growing trend in failing to comply with the quality standard of exportable fish from the selected ten African countries from the year 2006 onwards (see Table 6). This was true mainly for fish exported from Morocco, Mauritania, Namibia and Seychelles by receiving a total of 223, 42, 38 and 10 respective frequency of export border rejection notification and export border alert notification from EU borders from 1980-2014 (see Table 6). Similarly, Madagascar and Egypt also received export border rejection notification and export border alert

notification from EU borders for five and six times, respectively. This indicates, despite the high volume of fish exported from Namibia, Morocco, Mauritania, Egypt and Madagascar their fishery sector's is failing to export fish and fish products, which is risk-free to human and animal, particularly, in the EU market (see Table 6). Among the reasons for the export border rejection notification and export border alert notification received by the aforementioned countries, were poor hygienic conditions, existence of heavy metal, mycotoxins, micro biological contamination, adulteration (missing documents), labeling, veterinary drug residues, bacterial contaminations, food and feed additives, packaging, pesticide residues and related factors.

Hence, receiving export border rejection notification and export border alert notification can adversely impact the marketing efforts of African countries in the product and market positioning of fish and fish products in the international consumer market. Thus, the productivity, marketability, profitability, and acceptability of the fishery sector would be undermined.

Most importantly, Ethiopia, Niger, São Tomé and Príncipe, as well as Chad were found as countries, which were running fish commodity trading in sustainable conditions by supplying fish and fish products, in harmony with the consumer and their environment and without receiving a single border rejection notification and export border alert notification from EU border from 1980-2014 (see Table 6).

A study conducted by Lahsen Ababouch (2005) found that thousands of tons of seafood products at the post-harvest stage were being detained, rejected or destroyed each year at the national borders of importing countries.

The economic losses incurred because of fish spoilage, product rejections, detention and recalls, and the subsequent adverse publicity for an industry and even for a country are substantial, and so are the human health-related costs. Billions of dollars in medical expenses stem from fish-borne illnesses and the loss of productivity of those infected causes large indirect costs to communities (Ababouch, 2005). Accordingly, to realize the sustainability of fish trade to benefit traders and all actors across the supply chain, the sector has to adhere to the quality standards at local and international levels.

4.4.2. Sustainability of fish imports in selected African countries

The domestic demand of fish in most African countries has been backed by import. This shows international trade is playing a prominent role in many African countries to ensure food security of their nation and to fight poverty.

The contribution of fish imports to augment the domestic demand of fish in Egypt was the highest among the selected sample African countries, with mean annual import capacity of 1573731.4 tons of fish, followed by Seychelles (26971.63 tons), Madagascar (9952.63 tons), Namibia (9655.5 tons), and Morocco (9063.25 tons), at a compound annual growth rate of 4.4 percent, 14.6 percent, 10.99 percent, 7.3 percent, and 12.7 percent, respectively. However, the contribution of fish import to the domestic supply of fish in São Tomé and Príncipe was very low, with mean annual import capacity of only 76.65 tons, at negative incremental growth, followed by Ethiopia (172.59), Chad (425.22 tons), Mauritania (478.06 tons) and Niger (1020 tons), with a compound annual growth rate of -5.4 percent, 6.22 percent, 4.4 percent, 3.21 percent and 2.8 percent, respectively; and the results were found statically significant, except for Chad (see Table 7).

4.4.3. Trade and domestic supply of fish from 1980-2011

Results from Table 7 show that, with the exception of Egypt, the remaining nine African countries were able to meet above 98 percent of their domestic demand of fish from their domestic production. However, 22.1 percent of Egypt's domestic demand for fish was found to be augmented by international trade (import) while, countries such as Namibia, Mauritania, Seychelles and Morocco were found to be net exporters of fish by supplying 107%, 72%, 33.6% and 25%, respectively, above their domestic demand (see Table 7).

Despite the high volume of fish production witnessed in Namibia, the domestic consumption accounted only 48.2 percent of total supply of fish for the study period. This is attributable to the long distance between the ocean, the harbors and the major cities and towns, leading to challenges associated with easy accessibility to fish products. This indicates unavailability of well-organized eco-friendly cold storage devises in the local market, particularly in countries with far distance where major water bodies can be a hindrance for fish accessibility and food security of their nations. Therefore, public and private efforts are necessary to invest in green market infrastructure, such as cold storage vehicles and refrigeration plants, with a range of capacities

suitable for storing a large variety of fish products to be quickly and permanently frozen from the time of being caught to the time it is purchased by the consumer at the different local market. Thus, it would help fish and fish products to be easily accessible by the local market in order to help the sector play significant role in poverty reduction and food security, by ensuring fishery resource equity to the local community. In addition, fish in local market are so expensive because of the high prices offered by international markets (FAO. 2007).

4.5. Sustainability of employment creation in selected African countries fishery sector

The potential of the fishery sector to mitigate the growing unemployment in African countries indicates that (see Table 8), Egypt's fishery sector was found with a mean annual capacity to absorb huge number (264427) of employment, followed by Chad (259321), Madagascar (125358), Mauritania (115951), and Morocco (81992) at annual growth rate of 0.55 percent, 2.01 percent, 4.22 percent, 6.12 percent and 2.01 percent, respectively. However, this result can only be taken positively if the existing number of employees in the sector is less than or equal with their respective predicted maximum sustainable number of employee (see Table 9).

It was further inferred from the result that (see Figure 5), the variation exhibited in the growth of the sector's potential to create employment opportunity was high in Mauritania among the aforementioned five African countries. Likewise, the potential of the fishery sector to create employment opportunity was found low in Seychelles (1656), followed by São Tomé and Príncipe (2055), Ethiopia (9905), Namibia (12740) and Niger (18506), at a compound annual growth rate of 1.18 percent, 0.9[illegible] 23 ent, 2.30 percent, 4.04 percent and 2.70 percent, respectively.

The sustainability of the fishery sector's potential in mitigating unemployment in Africa varies from country to country (see Table 8). However, countries such as Egypt, Chad, Madagascar and Mauritania witnessed higher employment creation capacity rate than the other African countries (countries which were considered in this study) for the past three decades (1980-2010).

4.6. The maximum sustainable yield and effort of selected African countries fishery sector

Schaefer's maximum sustainable yield model was used to predict the maximum sustainable yield and effort (employee) of Egypt, Chad, Ethiopia, Madagascar, Namibia, Morocco and Mauritania, São Tomé and Príncipe's fishery sectors; while, Fox model was used to predict the maximum sustainable yield and effort of the Seychelles' and Niger's fishery sectors. Accordingly, the results are discussed country wise as follow:

Egypt

It was found that the maximum sustainable effort of Egypt's fishery sector should not exceed 294242 employees to get sustainable harvest of 1089382463 kilograms of fish per year. Even though, the sector did not absorb the maximum sustainable number (294249) of employees, the actual yield was found above the maximum sustainable yield; thus, the fishery stock is being over-exploited. This might be due to the existence of illegal, unreported and unregulated fishing or deployment of fish harvest technologies (see Table 10). In this respect, a study, which was conducted by Wisdom Akpalu and Ametefee K. (2013) indicated that capture-fish stocks are facing an increasing threat of extinction, partly due to the use of illegal fishing methods. According to Organization for Economic Cooperation and Development (2006) estimates, illegal fishing has contributed greatly to the world fisheries crisis. As means of mitigating the risk, the binding 2009 FAO Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (PSMA) was made but has not yet come into force, but it has the potential to be a cost-effective and efficient means of combating IUU fishing (FAO, 2014).

Chad

It was found that the maximum sustainable yield of the Chad's fishery sector is 83209813 kilograms of fish per year, with a maximum sustainable potential to absorb 307253 employees. However, the sector was found with high employment pressure beyond the sustainable effort, which resulted in over-exploitation of the fishery stock. The potential of the Chad's fishery sector in creating sustainable employment, as well as maintaining the ecological balance of the fishery stock was found not to be efficient.

Therefore, it will be advisable for Chad's fishery sector to deploy aquaculture fishing to diversify the existing employment pressure in the sector; and this will ultimately maximize return from the investment to mitigate poverty and unemployment (see Table 10). Stocks fished at biologically unsustainable levels have abundance lower rates than the level that the fishery sector can produce at the maximum sustainable yield (MSY) and are therefore overfished. They require strict management plans to rebuild the stock levels to full and biologically sustainable productivity (FAO, 2014).

Ethiopia

The maximum sustainable yield of the Ethiopia's fishery sector was found at 12334618 kilograms of fish per year, with maximum sustainable effort of 12517 employees. However, the sector absorbed a total of 93123 employees; which is beyond the potential of the sector to attain sustainable harvest, which resulted in reduction in catch per unit effort (employment). Accordingly, the sector has failed to realize the maximum sustainable yield throughout the years. Hence, Ethiopia's fishery sector was found to be below the sustainable level of employment creation potential, due to the existing high employment pressure and over-exploitation of the fishery stock. Thus, it is advisable to diversify the existing employment pressure in the sector to aquaculture fishing in order to maintain the fishery ecology and improve the yield and the income being realized per individual fishermen (see Table 10). A related study conducted by Assefa (2014) on production, consumption and management of fishery resource in Ethiopia found that due to inappropriate fishing practice, the fishery stock is being over-exploited. Hence, the potential of the fishery sector was underdeveloped and the fishery resource management rule and regulation at federal and regional levels, that is to control the devastation of the fishery stock was poor.

Madagascar

It was found that the maximum sustainable effort (employment potential) of the Madagascar's fishery sector should not exceed a maximum of 126896 employees to witness a sustainable harvest of 171354205 kilograms of fish per year. However, the actual volume of fish harvest in the country accounted for 62434000 Kilograms, which is below the maximum sustainable yield. The result shows the sector absorbed a total of 254150 employees, which is above the predicted maximum sustainable number of

employees. Despite the existing high employment pressure in the sector, the actual yield has deviated from the maximum sustainable harvest by 108920.2 tons of fish per year. This indicates the sector is not efficient to utilize the fishery resource of the country to its maximum sustainable extent; which might be due to the deployment of primitive fishery technologies, as well as traditional methods of fishing (see Table 10).

Morocco

The result from Table 10, reveals that the Morocco's fishery sector production performance was below its maximum sustainable yield potential of 8532952.57 tons of fish per year, against the actual harvest of only 888137 tons of fish per year. This affirms that the sector performed below capacity, deviating from the sustainable harvest volume by 7644815 tons of fish per year. However, the sector absorbed a total of 573446 employees; which is above the sector's predicted maximum sustainable effort of 329074 employees. This shows, the sector witnessed high employment pressure beyond its potential. Despite the existing high employment pressure exhibited in the Morocco's fishery sector, which resulted in reduction of catch per unit effort; the sector's potential was found to be underutilized (see Table 10).

Morocco's fishery sector has to diversify into aquaculture fishing to reduce the existing employment pressure in the sector, on the one hand; and devising appropriate fish harvest technologies to increase productivity, on the other.

Niger

The Niger's fishery sector actual fish harvest potential was 74371 tons of fish per year, against the predicted maximum sustainable yield of 213174 tons of fish per year. Similarly, the actual number of employment in the sector was only 2268 employees, against the required maximum sustainable effort of 5710 employees. Furthermore, it was noted that the sector has a capacity to absorb additional 3442 employees. Thus, the sustainability of the Niger's fishery sector in creating employment opportunity, through maintaining the fishery ecology was found unsustainable due to underutilization of the fishery resource. This might be due to the low productivity (32.79 tons per year) or catch per unit effort (employee), by deviating with 4.54 tons of fish from the predicted catch per unit effort (employee) of 37.33 tons of fish per year (see Table 10).

São Tomé and Príncipe

It was found that the predicted maximum sustainable yield for the São Tomé and Príncipe's fishery sector was 4079939 kilograms of fish per year, with a maximum sustainable effort of 2826 employees. However, the sector has deviated from the predicted maximum sustainable effort by 1225 employees. Similarly, over-exploitation of the fishery stock was noted since the actual fishing volume exceeded the predicted maximum sustainable yield by 977061 kilograms of fish per year. This might be due illegal, unprotected and unreported fishing in the sector or deployments of harvest technologies (see Table 10).

Seychelles

The Seychelles' fishery sector has a potential for sustainable harvest of 222954241 kilograms of fish per year, with a maximum sustainable effort of 11009 employees. However, the sector didn't absorb the predicted number of employees, thus deviating from the expected sustainable harvest and sustainable effort by 148583241 kilograms of fish and 8741 employees, respectively. Therefore, the Seychelles' fishery sector potential to mitigate poverty and unemployment was found underutilized (see Table 10).

Mauritania

It was found that the Mauritania's fishery sector has sustainable potential to harvest 840938195 kilograms of fish per year, with a maximum sustainable effort of 361755 employees. However, the actual yield deviated by 491194195 kilograms of fish from the predicted sustainable harvest volume of fish. Thus, the Mauritania's fishery sector's harvest potential was found underutilized and it was noted with high employment pressure beyond the predicted sustainable effort (see Table 10), which resulted in the reduction of the volume of the catch per unit effort.

Namibia

The Namibia's fishery sector's predicted maximum sustainable yield potential was found at 1064811 tons of fish per year, which is above the actual harvest of 413564 tons of fish. This affirms that the sector deviated from the predicted sustainable yield by 651247 tons of fish per year. Similarly, the sector absorbed a total of 25716 employees, which is below its predicted maximum sustainable number of 42223 employees. Thus, the study affirms that the Namibia fishery sector's harvest potential was found underutilized and the sector has the potential to absorb additional of 16507 employees (see Table 10).

4.6 Fishermen’s productivity in selected African countries

The result shows that the trend in catch per unit employee of the fishery sector in Chad, Madagascar, Mauritania and Morocco were found at negative incremental growth, while Seychelles, Egypt, Namibia, Niger, Ethiopia and São Tomé and Príncipe witnessed a positive incremental growth for the study period (see Figure 6).

With the exception of Seychelles, Namibia, Ethiopia and São Tomé and Príncipe; the growth rate noted in six African countries, in the study, was found significant at 0.00 percent. Furthermore, the fish productivity trend line of the ten African countries indicates the existence of extreme differences in the productivity of fishermen across countries, ranging from the lowest volume catch per unit employee of 0.32 tons of fish in Chad; followed by 0.77 tons of fish in Niger; 1.22 tons of fish in Ethiopia; 1.41 tons of fish in Madagascar and 1.86 tons of fish in São Tomé and Príncipe. Also, the highest productivity (catch per unit employee) of 45.33 tons of fish was recorded in Namibia; followed by 17.59 tons of fish in Seychelles; 4.29 tons of fish in Morocco and 3.40 tons of fish in Egypt (See Table 11).

5.0 Conclusion

The marked increase in fishing effort during the past thirty years (1980-2010), accompanied by the rapidly increasing local and international demand for fish products has subjected many of the African countries’ wild catch fishing and aquaculture fishing to intense fishing pressure and has resulted in over-exploitation of the fishery resource stock, particularly in Egypt, Chad, Ethiopia and São Tomé and Príncipe. Thus, the fishery sectors in several African countries are already under stress and their potential was found environmentally unsustainable (over-exploited), which is creating imbalanced fishery ecosystem. If this trend continues, countries such as Egypt, Chad, Ethiopia and São Tomé and Príncipe will have to undertake heavy tasks and burdens to restore the destroyed fishery resources base. On the other hand, the fishery resources of Madagascar, Mauritania, Morocco and Niger were found underutilized. Furthermore, the increasing frequency of export border rejection notification and alert for fish exported from Morocco, Mauritania, Namibia, Seychelles, Madagascar and Egypt resulted in reduction of income from the fishery sector. Thus, quality control should be firmed across the export market supply chain.

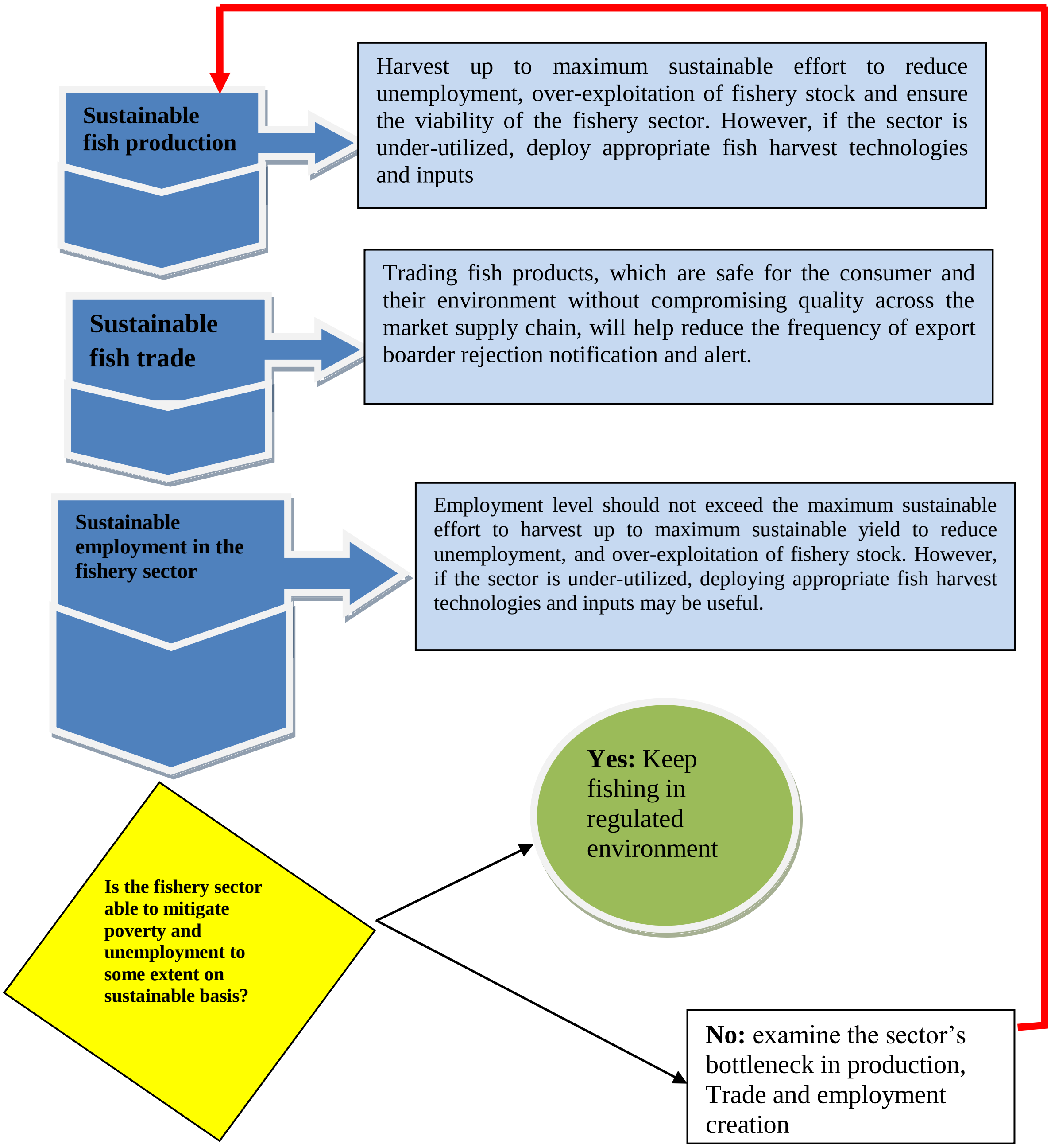

Figure 6. Sustainable fishery resource management model

Definitely, the sector's potential in mitigating poverty and unemployment in line with a green economy was found unsustainable, due to over-exploitation of the fishery stock, underutilization of the fishery resource, high employment pressure and increasing frequency of export border rejection.

5.1 Recommendations

- Given the role of the fishery sector in the economy, fishery policies should recognize the trade-offs between increasing contribution to mitigation of poverty and unemployment; and the need to conserve the fishery resource stock;
- Targeted investments could be made in areas, where the main beneficiaries are known to be the poor, particularly in aquaculture fishing and fish value added business;
- Strengthening quality control system to adhere to quality standard across the fish supply chain would help provide hazard-free fish and fish products to the export market, and thus increase the benefits derived from fish trade;
- Placing aquaculture as a top priority in the fishery sector, particularly in countries with negative incremental growth in Aquaculture fishing (Ethiopia), high employment pressure (Chad, Ethiopia, Madagascar, Morocco, and Mauritania) and over-exploitation of the fishery stock (Egypt, Chad, Ethiopia and São Tomé and Príncipe), would help reduce the existing pressure on fishery ecosystem, and create alternative employment opportunity and;
- Deploying modern fish harvest technologies in countries with underutilized fishery resources, particularly in Madagascar, Mauritania, Morocco, Niger, Namibia and Seychelles, would help improve income derived from the sector by increasing the catch per unit effort (productivity).

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Appendices

Appendix 1. Frequency of border rejection notification and export border alert notification received from EU Border from 1980-2014

Country	Egypt	Morocco	Madagascar	Namibia	Ethiopia	Seychelles	Niger	Mauritania	São Tomé and Príncipe	Chad
1980	0	0	0	0	0	0	0	0	0	0
1981	0	1	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0
1989	0	1	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0
1997	0	1	0	0	0	0	0	1	0	0
1998	0	3	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0	0	0
2001	0	3	0	0	0	1	0	0	0	0
2002	0	2	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0
2004	0	2	0	1	0	0	0	0	0	0
2005	0	0	0	1	0	0	0	0	0	0
2006	0	2	0	0	0	0	0	0	0	0
2007	1	31	0	0	0	0	0	0	0	0

2008	0	22	0	8	0	0	0	0	0	0
2009	0	39	1	9	0	0	0	6	0	0
2010	0	26	1	6	0	0	0	18	0	0
2011	0	44	2	2	0	1	0	10	0	0
2012	0	26	1	5	0	1	0	5	0	0
2013	0	10	0	2	0	5	0	0	0	0
2014	3	10	0	4	0	2	0	2	0	0
Source: The Rapid Alert System for Food and Feed(RAFF)										

Appendix 2. Number of employment in the fishery sector

Country	Chad	Egypt	Ethiopia	Madagascar	Mauritania	Morocco	Namibia	Niger	São Tomé and Príncipe	Seychelles
1980	115000	95000	2050	20000	11685	30787	2300	7090	985	1100
1981	118500	112352	2592	21000	11116	30000	2340	7250	1073	1055
1982	122000	129705	3133	12240	10548	30000	2380	7983	1152	1010
1983	125500	139265	3675	12240	9979	32500	2420	7983	1189	965
1984	129000	149142	4217	18551	9411	34570	2460	7983	1277	1082
1985	132500	176114	4758	31174	8842	35000	2500	7983	1837	1082
1986	136000	177667	5300	31330	8274	45100	2540	11800	2132	1100
1987	139500	164327	7367	41085	7705	47400	2580	10321	2136	1108
1988	143000	175960	11500	50839	7137	49700	2620	8843	2141	1078
1989	146500	178622	12198	60594	656	52000	2660	7364	2145	1031
1990	150000	230000	14000	61700	6000	56000	2700	11900	2150	1229
1991	150000	230000	15025	62150	6335	95652	3504	7983	2094	2520
1992	150000	229293	16050	62150	6669	55000	4309	7983	2039	1758
1993	200000	273892	2137	62150	7004	65000	5113	9655	1983	1981
1994	300000	203983	2734	62150	7339	99726	5917	11327	1928	2097
1995	350000	217000	3972	143339	7541	99885	6722	13000	2135	1988
1996	350000	237496	4000	142684	7742	109062	7526	13109	2090	1960
1997	300000	254254	4000	142700	7944	96708	7269	13218	1988	1330
1998	306000	468814	4200	142605	16144	100950	6583	13327	2041	1330
1999	312000	521924	6343	142605	24344	105853	7792	13436	2093	1330
2000	318000	720346	6272	142605	32544	106096	9000	19000	2146	1330
2001	324000	650978	15000	160005	34512	111825	14370	19840	2253	1302
2002	330000	581611	15000	193370	34884	114553	19741	20680	2524	1688
2003	336000	512243	14534	193370	35256	116058	25112	21520	1989	1718
2004	342000	442875	14562	196005	35628	116657	11030	24760	1782	2268
2005	348000	373508	14319	198605	36000	105701	11199	28000	2862	2268

2006	354000	304140	16470	201205	180420	107393	11807	30671	2435	2268
2007	360000	234773	13268	255510	324840	108535	12096	33342	2428	2302
2008	350000	165405	11869	255305	469260	110879	11572	36013	2581	2293
2009	370000	96037	12519	255105	613680	110922	12965	39013	2845	2285
2010	380000	94580	18658	254150	758100	107296	26755	41015	2134	2276.2
2011	435000	93123	21544	254150	902520	104618	25716	47296	1601	2267
2012	435083	91666	23603	254150	180420	114298	146817	50020	3640	2259

Source: ILO

NB: a) Figures for Chad from year 1981-89 and 1998-2006, Figures for Egypt for the year 1981, 2001-2008 and 2011-2012, figures for Ethiopia for the years 1981-1985, 1987 and 1991, figures for Madagascar for the years 1984, 1987 and 1988, figures for Mauritania for the years 1981-1989,1991-93, 2002-04, and 2007-20011, figures for Morocco for the years 1987 and 1988, figures for Namibia for the years 1981-89, 1991-95, 1999, 2001-02, figures for Niger for the years 1983-84, 1987-88, 1993-94, 1996-1999, 2001-02, 2004 and 2006-07 are the Researcher's estimation through data interpolation and extrapolation method.

b) Figures for Ethiopia and Ethiopia FDRE were merged for the years 1980-1991

Appendix 3. Aquaculture fish production monetary value from 1984-20112 in (USD 000)

	Egypt	Ethiopia	Madagascar	Mauritius	Morocco	Namibia	Niger
1984	14400	0	498.34	24.17	113.886	0	16.53
1985	24357.6	0	407.03	23.101	99.459	0	13.36
1986	26500	0	313.11	19.021	70.898	0	19.67
1987	45780	0	264.53	20.821	57.454	0	39.64
1988	68660	2.5	243.46	23.263	86.542	0	63.94
1989	96400	82	224.64	25.275	95	0	41.75
1990	124602	89.5	312	24.822	2760.67	0	112.7
1991	107173.66	89.5	218.8	37.423	5034.43	0	74.72
1992	107273.15	54.5	2548.7	50.688	5406.38	0	25.75
1993	93526.25	69.5	2398.4	149.454	8992.87	7.2	32
1994	103431.9	82	4474.9	195.776	10640.8	7.2	54.4
1995	115194.16	131.5	2986.4	378.16	11707.3	9	70.18
1996	167902.224	94.6	3272.8	358.96	11612.3	9	23.66
1997	183878.478	59	7216.1	264.6	8007.85	9.25	25.65

1998	327263.454	34	2960.2	152.88	7507.36	9.25	23.39
1999	447146.467	35	3743.3	127.068	8020.07	9.25	21.06
2000	815045.993	35	3720	120.669	4714.35	18.5	22.5
2001	756926.3	35	3572	75.183	3039.68	18.5	33.6
2002	654811.091	35	3600	60.084	3920	28.5	79.2
2003	615010.985	35	4904.8	49.501	4745.03	28.5	94.6
2004	613007.724	60	5116.5	1940.99	5905.93	28.5	83.6
2005	756159.081	60	4605.8	2052.16	8083.95	28.5	83.6
2006	947620.901	60	4947.2	2421.87	2938.43	28.5	83.6
2007	1191680.04	60	5300.9	931.545	5045.55	40	85.69
2008	1250084.18	60	5815.8	1366.87	4656.59	40	85.11
2009	1354663.47	60	5251.6	2240.05	4872.51	44	151.1
2010	1540288.16	60	5078.2	3164.78	4910.54	60	149
2011	1958340.51	60	12009	3218.04	4685.69	267.83	413.6
2012	2002947.12	92.5	13144	2861.83	5161.14	247.14	475.3

Source: FAOSTAT

Appendix 4. Total fish production from 1980-2011(Qty: tons)

Year	**Chad**	**Egypt**	**Ethiopia**	**Madagascar**	**Mauritania**	**Morocco**	**Namibia**	**Niger**	**Sao Tome and Principe**	**Seychelles**
1980	60000	136490	3462	51703	16094	316257	8750	8892	1834	4572
1981	55000	138589	3828	52186	46329	363093	9350	8208	1259	5117
1982	30000	152272	3750	53684	32702	326396	10150	6840	2036	3941
1983	40000	153162	3900	57368	52225	406464	10600	3251	3942	3835
1984	50000	161543	4300	60109	31917	418694	11400	3000	4363	3634
1985	55000	212949	4000	61791	37351	434977	12200	2000	3921	4061
1986	60000	225952	4100	76031	34791	548101	13423	2345	2807	4431
1987	70000	226598	4000	82243	43531	454159	30874	2283	2773	3832
1988	58000	279941	4067	91733	38521	493559	31398	2499	3365	4251
1989	64400	287242	4269	88725	40472	454859	20276	4741	3547	4359
1990	70000	307077	4981	92139	33130	488913	261916	3354	3834	5391

1991	60000	336580	4262	85163	34007	497324	205766	3145	2556	8091
1992	80000	339860	4607	93360	39894	462852	652157	2464	2387	6623
1993	87300	347626	4203	103528	31502	527042	786927	2172	2822	5097
1994	80000	357127	5318	99399	27206	663650	645449	2533	4072	4419
1995	90000	384902	6380	101121	31497	751297	567590	3651	4265	3977
1996	100000	421412	8808	99015	39314	540660	515847	4167	4595	4657
1997	85000	444860	10394	104101	53437	713438	511433	6341	3521	12890
1998	51300	532672	14014	100699	72251	627385	605160	7025	3568	23734
1999	59600	627770	15873	105742	85395	617772	577630	11014	3613	34127
2000	83200	703394	15696	106587	93902	741188	586656	16265	3663	32724
2001	75000	751133	15405	109951	118222	976969	544462	20821	3655	53446
2002	70000	778596	12315	115131	138379	875162	619100	23600	3781	63155
2003	71000	854167	9228	115077	182319	870276	634313	55900	3965	85770
2004	74000	844227	10030	122531	253480	880881	566825	51506	4100	100378
2005	77000	864508	9475	121959	285207	948537	550823	50058	4155	108248
2006	79000	946841	9915	122711	149381	805743	506607	29875	4285	92235
2007	82000	981970	13279	129889	206927	818260	407913	29768	4410	64948
2008	85000	1034345	16795	112281	185505	910306	370467	30000	4535	68714
2009	88000	1059341	17072	121156	200515	1067899	376788	29954	4660	80257
2010	91000	1274564	18083	120023	255888	1074426	380830	40070	4785	86317
2011	95000	1332444	24066	118399	349744	888137	413564	53258	5057	74371

Source: FAOSTAT

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MATE MASIE

"What I hear, I keep"- Symbol of wisdom, knowledge and understanding.

NEA ONNIMNO SUA A, OHU

"He who does not know can know from learning, -Symbol of life-long education and continued quest for knowledge.

NYANSAPO

"Wisdom knot" – Symbol of wisdom, ingenuity, intelligence and patience.

ISBN: 978-9988-633-00-4