GLOBAL AQUACULTURE PRODUCTION AND ITS IMPACT TO BIODIVERSITY

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ABSTRACT

This paper examines trends in aquaculture production in selected countries in Asia, Africa, Europe, North America, and South America and infer from these trends where biodiversity loss would be most observed and least observed. This study made use of the descriptive research design utilizing secondary data obtained from Food and Agriculture Organization. The data consists of the annual aquaculture production from 1960 to 2014 from several countries worldwide. Ten (10) countries were randomly chosen to represent each of the continents of Asia, South America, North America, Europe and Africa. The graphical presentations showed where the highest increases in aquaculture production would most likely occur. This information was then utilized as a basis for inferring the state of biodiversity loss in the various continents. Results revealed that aquaculture production increases in Asia are about seven times more than the production in other continents. Likewise, intensified aquaculture production implies magnification of six (6) newly-identified threats to biodiversity. As a result, countries in Asia are seven times more vulnerable to biodiversity loss than in any other continents despite the fact that Asia is home to majority of the earth's floral and faunal species.

Keywords: *aquaculture production, biodiversity loss, factor analysis by principal components*

1.0 Introduction

Meeting the food requirements of an ever-growing global population puts a huge strain on the environment and natural resources worldwide. Malthus (1798) posited that while population grows exponentially, man's capacity to produce more food increases linearly. Consequently, there will be episodes of food shortage that will be experienced by countries whose natural resources are deficient. Meanwhile, in the process of food production the unavoidable consequence of adversely affecting the biological diversity of a developed area takes place.

Inland aquaculture is a strategy adopted by many countries to respond to the demand for freshwater fish, mollusks and others. Diana (2009) estimated that aquaculture increased from 12 million metric tons in 1985 to 45 million metric tons by 2004. Aquaculture includes species at any trophic level that are grown for domestic consumption or export. While aquaculture often boosts natural production and species diversity as well as enhancing employment to replace more destructive resources, there are also negative effects observed. First, species that escape from aquaculture can become invasive in areas where they are non-native. Second, effluents from aquaculture can cause eutrophication. Third, aquaculture species may consume endangered fish species. Fourth, aquaculture species can transmit diseases to wild fish. While it is surmised that aquaculture will continue to grow at significant rates until 2025 and will remain the most rapidly increasing food production system, the adverse impact of aquaculture on biodiversity will also likely become more pronounced over these years.

Statistics show that 72.4 % of all capture harvest and 92.3 % of all culture harvest occurs in developing countries (UN, 1992). Aquaculture or the farming of aquatic organisms is the fastest growing food growing production system globally with an increase in production of animals of 9 % per year since 1985 (Diana, 1993, FAO, 2005). Gulburg and Triplett (1997) expressed concern about the sustainability and influence on the environment of aquaculture. In response, several systems have been developed to ensure sustainability and minimum impact to biodiversity such as the Seafood Watch (Monterey Bay Aquarium, 2006), Guide to Ocean Friendly Seafood (Blue Ocean Institute, 2007). These ratings use color coding to indicate which seafood should be avoided. Farmed seafood is generally a minor component of all rated seafood and the ratings are often ignored.

Aquaculture systems mirror agriculture in that some aquaculture operations convert land into ponds to grow aquatic organisms. Although land conversion would be problematic, far less land has been converted to aquaculture than has been for agriculture. Aquaculture is most commonly assessed by examining its impact on natural ecosystems. (Flaherty et al., 1995). Many evaluations have demonstrated that exotic species, habitat loss, pollution and exploitation explain most of the animal extinctions that have occurred (Wilcove et al. 1998). Homogenization results from biodiversity loss. Diana (2005) showed that land conversion, introduction of exotic species and predator control are the causes that are high in the list for introducing homogenization.

This paper examines trends in aquaculture production in selected countries in Asia, Africa, Europe, North America, and South America and infer from these trends where biodiversity loss would be most observed and least observed.

2.0 Conceptual Framework

The conceptual Framework to which the study is anchored is based on the hypothesis that production in agriculture contains information about the relative impact of aquaculture production process on biodiversity. The theory exposed in this paper shall be called "Production-Biodiversity Synergistic Theory".

In the United nation report (UN, 1992), we deduce that production $\{P_t\}$for any time *t is* attributed to capture fisheries $\{Cap_t\}$and cultured fisheries $\{Cul_t\}$ expressed as:

$$P_t = \frac{.724}{.724+.923} Cop_t + \frac{.923}{.724+.923} Cul_t$$

$$P_t = 0.44\ Cop_t + .56\ Cul_t,\ t=1, 2, 3\ldots \quad (1)$$

that is, total fishery production consists of 44% capture fishery production and 56% cultured aqua cultured fishery production. On the other hand, fishery production $\{P_t\}$is driven by global fishery demand $\{D_t\}$. The aquaculture food production system responds to demand by adjusting either the captured fish production $\{Cap_t\}$ or the cultured fish production $\{Cul_t\}$. Thus, when demand for fishery products increases, production correspondingly increases either by increasing $\{Cap_t\}$or $\{Cul_t\}$.however, the Food and Agriculture Organization (FAO, 2005) reported that production in captured fisheries has become relatively stable over recent years. It follows that increases in food production can now be modified as:

$$P_t = 0.44\ Cop_t + .56\ Cul_t \quad (2)$$

(M=90*m* metric tons, Watson and Pauly, 2001)

when *M* is the stable/constant captured fish production. Variations in fish production can be mostly explained by charges in the magnitudes of cultured fish production.

For this reason, the connection between biodiversity loss and fish production can be confined to the impact of aquaculture or cultured fish production on the environment. Mungkung et al. (2006) have used life-cycle assessment (LCA) including calculations of costs, greenhouse gas emissions and eutrophication potentials in their impact analysis. However, no objective method to quantitatively compare and rank the effects of aquaculture on biodiversity currently exists.

Boyd et al. (2005) evaluated a variety of species groups and environmental impacts, focusing on negative influences that certification programs should try to reduce. Diana (2007) used their results to rank the negative effects in decreasing importance as threats to biodiversity loss. In this paper, we consolidate the results of Boyd et al. (2005) and Diana (2007) using factor analysis. The idea behind this consolidation process is as follows: the negative effects of aquaculture as established are composed of underlying constructs (called "threat factors") plus a common threat factor. The "threat factors" can be fewer than the original number of threats (as few as 2 or 3 factors). The factors are not ranked but are considered to interact together to produce the observed biodiversity loss.

The conceptual framework is illustrated below:

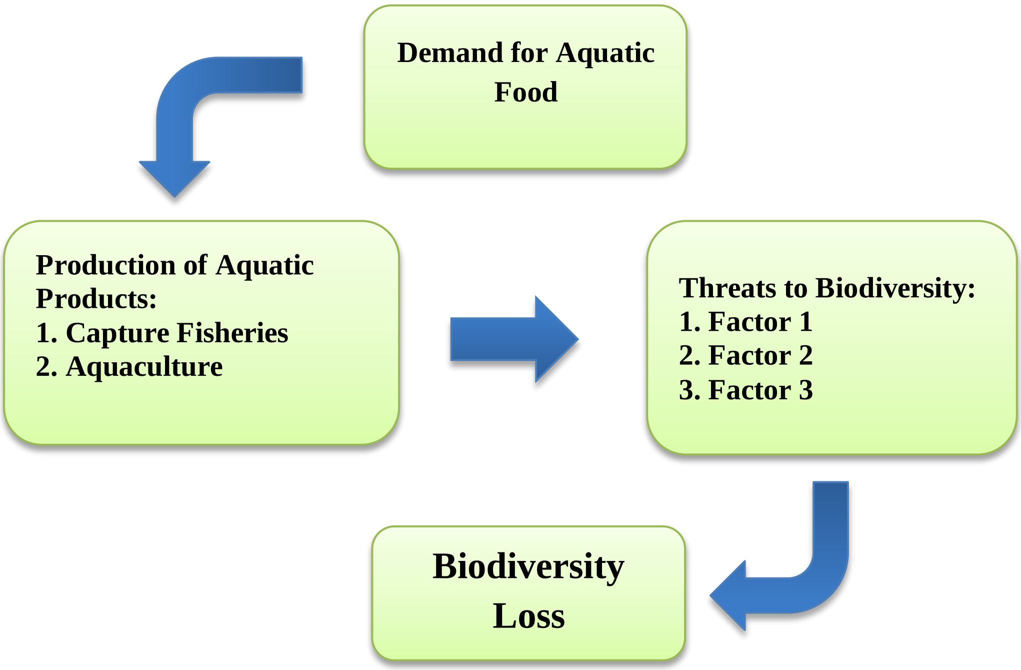

Figure 1. Production – Biodiversity Synergism

3.0 Research Design and Methods

This study made use of the descriptive research design utilizing secondary data obtained from Food and Agriculture Organization (2016). The data consist of the annual aquaculture production from 1960 to 2014 from several countries worldwide. Ten (10) countries were randomly chosen to represent each of the continents of Asia, South America, North America, Europe and Africa. The average culture production in million metric tons across six (6) continents in 1984, 1994 and 2004 were reproduced from Diana J.S. (2009). This was used as benchmark for evaluating the impact of Aquaculture production to Biodiversity loss. The data from 1960 – 2014 were presented in graphical forms such as the average production in million metric tons, aquaculture production trends since 1960 and the actual average increase per year by continents. The graphical presentations showed where the highest increases in aquaculture production would most likely occur. This information was then utilized as basis for inferring the state of biodiversity loss in the various continents.

Of the twelve (12) identified threats to biodiversity by Boyd et al. (2005), a principal components factor analysis was performed to group the threats into factors. Fifteen (15) experts in aquaculture and marine biology were asked to rate the twelve(12) variables that are threats to biodiversity loss. Six (6) factors were identified by factor analysis and relabeled for easier qualitative descriptions. It is likewise assumed in the analysis that the conceptual framework where intensified aquaculture production results to more pronounced impact to biodiversity will operate.

4.0 Results and Discussions

Figure 2 shows the average culture production in million metric tons across six (6) continents in 1984, 1994 and 2004. These figures are to be compared with the current production as shown in Figure 3.

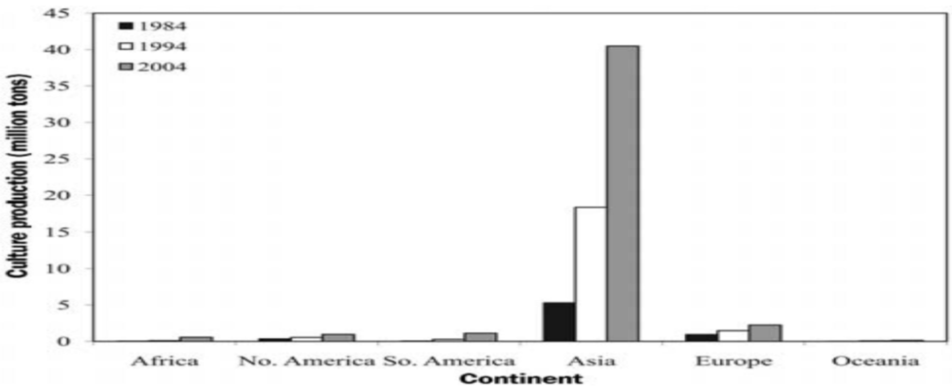

Figure 2. (FAO 2005), referenced by James S. Diana (2009).

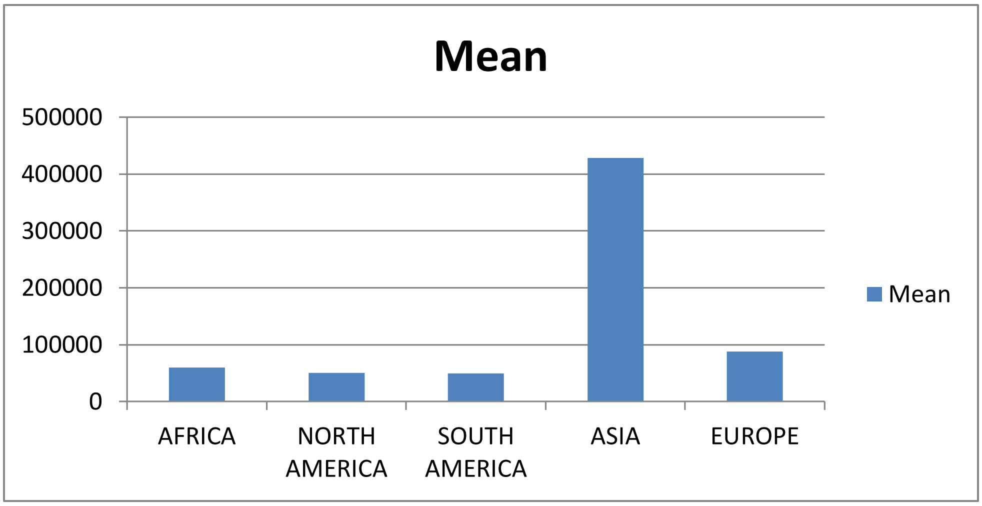

Figure 3: Average production in million metric tons by continents 1960-2014

The general distribution of the aquaculture production has not changed significantly over a ten-year period from the last census of 2004. While capture fisheries have stabilized since 1985, most of the production figures can be attributed to increased cultured fish production. Asia remained the top aquaculture producer followed by Europe and Africa.

Figures 4 to 8 show the aquaculture production trends since 1960 in these continents.

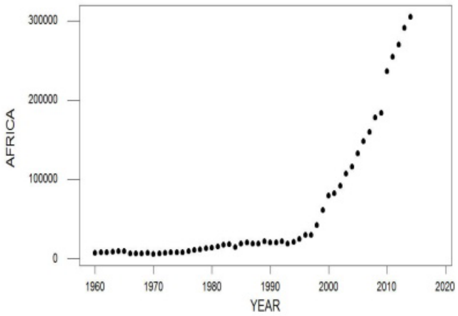

Figure 4: Production trend for Africa

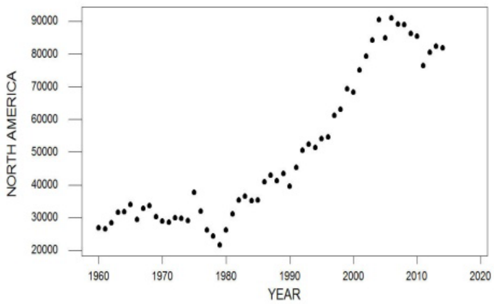

Figure 5: Production trend for North America

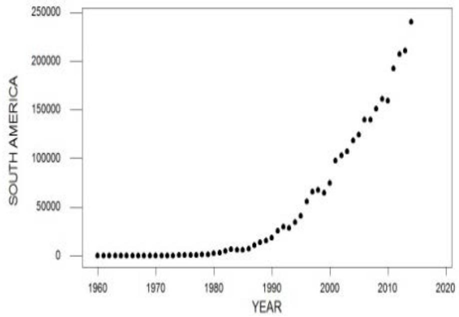

Figure 6: Production trend for South America

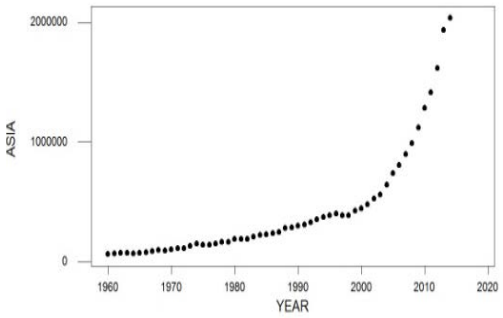

Figure 7: Production trend for Asia

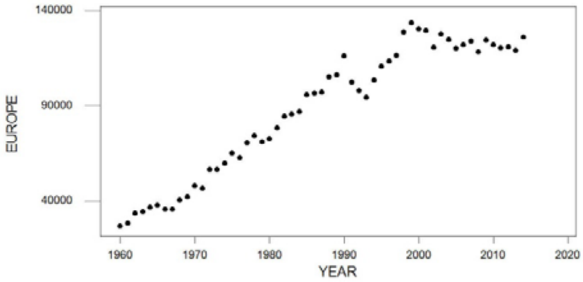

Figure 8: Production trend for Europe

The figures demonstrate that aquaculture production has an increasing trend over all continents.

Figure 9 shows the continents and their average annual aquaculture production in 55 years for the period 1960 to 2014.

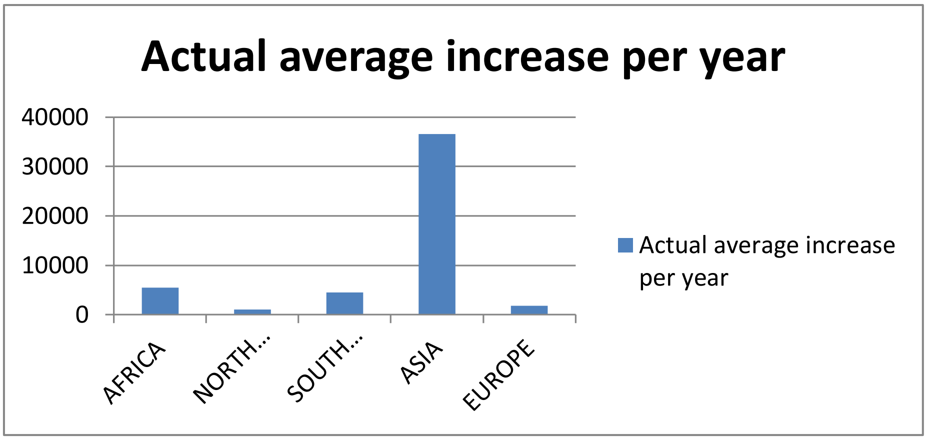

Figure 9: Actual Average Increase Per Year by Continent

The figure shows that the annual increase in aquaculture production in Asia is almost seven (7) times the increases in all other continents. Consequently, we would expect that the Asian biodiversity would be most affected by the intensified aquaculture production in the same period.

Table 1: Actual average increase per year by continent

CONTINENT	Actual average increase per year
AFRICA	5520
NORTH AMERICA	1019
SOUTH AMERICA	4459
ASIA	36627
EUROPE	1839

With increased aquaculture production, threats to biodiversity would also become more pronounced. These threats are listed down by Boyd et al. (2005) and are reproduced in Table 2 below:

Table 2: Threats to biodiversity of species or species group

	Species or species group										
Issue	**Tuna**	**Shrimp**	**Salmon**	**Trout**	**Catfish**	**Tilapia**	**Abalone**	**Scallops**	**Oysters**	**Clams**	**Mussels**
Antibiotic use	M	H	H	H	M	M	M	–	–	–	–
Benthic biodiversity	H	M	M	M	–	M	–	M	M	M	M
Chemical use	M	H	M	H	H	–	M	–	M	M	–
Disease transfer	H	H	H	–	–	–	M	–	H	–	–
Escapees/invasive	H	M	H	–	–	H	M	–	H	–	–
Genetic alteration	–	–	H	H	H	H	–	M	H	–	M
Land and water use	–	H	–	H	H	H	M	M	M	M	M
Removal of dead fish	–	–	M	M	H	H	–	–	–	–	–
Fish meal/oil use	H	H	H	H	M	M	M	–	–	–	–
Water pollution	H	H	M	H	M	H	–	–	–	–	–
Predator control	–	M	M	H	H	H	H	H	H	H	H
User conflicts	M	H	M	–	–	M	–	M	M	M	M

H, high level of concern; M, medium level of concern.
Note: The level of concern was derived from focus group and published evaluations (from Boyd et al. 2005).

Table 3 translates the results of Table 2 into quantities that can be ranked. The translation process consisted of replacing H by 2, M by 1 and (___) by 0. The mean values obtained represent the cumulative threats to all species mentioned in Table 2.

Table 3: Quantified data for ranking of threats

Variable	**Mean**	**Rank**
Antibiotic use	0.909	5.5
Benthic biodiversity	0.909	5.5
Chemical use	1.000	8.5
Disease transfer	0.818	2.5
Escapees/invasive	0.909	5.5
Genetic alteration	1.091	10.0
Land and water use	1.182	11
Removal of dead fish	0.545	1.0
Fishmeal/oil use	1.00	8.5
Water pollution	.909	5.5
Predator control	1.636	12.0
User conflicts	0.818	2.5
Note: the level of concern was derived from focus group and published evaluations (from Boyd et al. 2005)		

With increased aquaculture production, the top 3 major threats to biodiversity are, from Table 3, predator control, land conversion and water use, and genetic alteration. These three major threats would be most pronounced in Asia consistent with their intensified aquaculture production.

We attempted to define a new scheme for grouping the issues or threats to biodiversity through factor analysis. A group of fifteen (15) aquaculture and biology experts were asked to rate the various issues or threats to biodiversity in terms of their potential impact to biodiversity loss. Factor analysis was performed using the principal components method. The results are shown in Table 4.

Table 4: Eigen-analysis of the covariance matrix

Eigenanalysis of the Covariance Matrix

Eigenvalue	1.3507	0.8248	0.6741	0.5220	0.3177	0.2660
Proportion	0.307	0.188	0.153	0.119	0.072	0.061
Cumulative	0.307	0.495	0.648	0.767	0.839	0.900
Eigenvalue	0.1653	0.1502	0.0754	0.0352	0.0116	0.0030
Proportion	0.038	0.034	0.017	0.008	0.003	0.001
Cumulative	0.937	0.972	0.989	0.997	0.999	1.000

The first factor accounted for 30.70% of the total system variance while the six (6) factors together accounted for 90% of the variance. The factor loadings of the twelve (12) original variables are shown in Table 5. For instance, the variables fish meal, water pollution and antibiotics loaded high on the first factor and so on.

Table 5: Six (6) Principal Components of the covariance matrix

Variable	PC1	PC2	PC3	PC4	PC5	PC6
Antibiot	0.292	0.417	-0.179	0.115	-0.104	-0.472
Benthic	-0.161	0.088	0.581	0.213	0.320	0.179
Chemical	0.087	-0.114	-0.229	-0.132	0.348	0.069
Disease	-0.328	0.598	0.280	-0.245	0.254	-0.149
Escapees	-0.563	0.191	-0.274	-0.338	-0.357	-0.032
Genetic	0.046	0.387	-0.527	0.189	0.090	0.433
Land and	-0.326	0.114	-0.240	0.461	0.440	0.052
Removal	-0.150	0.204	0.191	0.295	-0.473	0.016
fishmeal	0.399	0.333	0.160	0.328	-0.214	0.094
water po	0.291	0.174	-0.088	-0.194	0.241	-0.198
predator	-0.229	-0.196	-0.103	0.420	-0.168	0.019
user con	0.169	0.165	0.098	-0.303	-0.126	0.692

For easier qualitative interpretation of the factors, Table 6 shows the suggested the "threat

factors" labels with the corresponding variables loading high on them.

Table 6: The Threat Factors Based on the Dominant Principal Components

Factor	**Variables**	**Cumulative Variance Explained**
Feed Management	Fish meal, water polution	30.70%
Fish and Mobility Control	Antibiotic use, Disease, Escapees	49.50%
Organismic dislocation	Benthic Biodiversity, Removal of death fish	64.80%
Site Management and Habitat Control	Land and water use, Predator control	76.70%
Chemical and Eutrophication	Chemical Use	83.90%
Genetic alteration	Genetic alteration, User Conflicts	90%

In view of the observation that the highest aquaculture production increases are noted in Asia, it is surmised that the highest biodiversity loss would be in Asia as well. It is perhaps ironic that Asia is the continent that has the highest biodiversity and yet would be also most affected by the intensification of aquaculture production. Recent statistics reveal that Asia is home to over 75% of the floral and faunal species on earth. Likewise, of the six(6) principal threats to biodiversity, Asia is most vulnerable to: (a.) site management and habitat control due to weak land use policy implementation, (b.) feed management due to the absence of more scientific aquaculture practices and (c.) chemical use and euhtrophication. All the six (6) threat factors are magnified seven times in Asia than in any other continents on Earth if the aquaculture production increases were to be made the basis.

5.0 Conclusion

Aquaculture production would be most intensified in Asia than in any other continents in the world in the next decade based on available data. Aquaculture production increases in Asia is about seven times more than the production in other continents. Likewise, intensified aquaculture production implies magnification of six (6) newly-identified threats to biodiversity. As a result, countries in Asia are seven times more vulnerable to biodiversity loss than in any other continents despite the fact that Asia is home to majority of the earth's floral and faunal species.

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