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Estimates of maximum sustainable yield of artisanal fisheries resources of Rivers Niger and Benue in Kogi state, Nigeria

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Abstract
The paper investigates estimates of maximum sustainable yield and corresponding efforts of artisanal fisheries resources along Rivers Niger (RN) and Benue (RB) in Kogi State using Schaefer surplus production model at $\alpha_{0.05}$. Three-stage sampling techniques were used to obtain data from RN (n=180) and RB (n=60). Structured questionnaire was used to obtain respondents' fishing effort and monthly catches (kg/month). Empirical evidence from the results indicate that MSY of 47.8kg was achieved at E_{MSY} level of 10.3 hrs/day in River Niger, while MSY of 34.7 kg was achieved at E_{MSY} level of 11.4 hours/day in River Benue. Catch per unit Effort decreased with increasing effort in both Rivers Niger and Benue suggesting negative impact of fishing effort on fish catch. Sustainable fishing can be achieved at level of E_{msy} = 8.2 hrs/day and 7.2 hrs/day, and MSY= 38.2 kg and 27.8 kg, in Rivers Niger and Benue, respectively.

Keywords: Artisanal fisheries, sustainable fisheries, maximum sustainable yield, Rivers Niger and Benue

Introduction
Artisanal fishery sub-sector contributed 68% to domestic production in 2013 and increased by 5.2% to 1,048.58 tonnes in 2014 [1]. The total contribution of Agriculture to Nigeria Gross Domestic Product (GDP) in 2014 was 20.24% and the fisheries sub-sector contributed 0.48% to the Agriculture GDP [2].

The traditional open access nature, which generally reduces fishing harvesting directly or indirectly, coupled with the growing number of people who depend on fisheries exploitation, has put such natural resources under severe strain and, consequently over-exploitation and depletion [3]. Hence, the current fish demand estimate of 2.66 million metric tonnes (MMT) has also created a staggering demand-supply gap of about 1.8MMT [4].

Rivers Niger and Benue course with the confluence at Lokoja covers a distance of 386.4 km. River Niger and Benue is home to wide array of fish species such as *Cynoglossus senegalensis* (sole), *Raiamas senegalensis* (Senegal Trout Barb), *Schilbe mystus* (African Butter Fish), *Synodontis eupterus* (Featherfin Squeaker), *Bagrus bayad* (Bayad), *Synodontis batensoda* (Giant Upside-Down Catfish), *S. membranaceous* (Moustache Catfish) and *Dasyatis garouaensis* (smooth freshwater stingray) [5]. The floodplains are characterized by extensive perennial swamps and lagoons. These provide important fishery resources, which are exploited after the flood has receded [6]. Because of their importance, the exploitation of these species should be well managed. This is to meeting the MDG of sustainable ecosystem and eradicating hunger in most developing countries [7].

In modern fisheries management, Maximum Sustainable Yield (MSY) is often considered as a key tool for management to ensure long- run sustainability of the biomass. MSY for a given fish stock means the highest possible annual catch that can be sustained over time, by keeping the stock at the level producing maximum growth [8].

Rivers Niger and Benue fisheries are the major economic activity of fisher folks due to limited alternative sources of livelihood [9]. The open access nature coupled with relatively high price of fish than other goods motivate fishermen to increase fishing effort for profit maximization.

Considering this, the *in-situ* coupled with lack of enforcement management measures would possibly lead to overfishing. Therefore, this study investigates the key reference points like Maximum Sustainable Yield (MSY) and their corresponding effort levels to know whether the fisheries in Rivers Niger aba Benue, are biologically sustainable.

Materials and Methods

The study was carried out on Rivers Niger and Benue in Kogi State. Kogi State is located in the North-Central geo-political zone of Nigeria. It extends from latitudes 6.33^0 to 8.44^0 N and longitudes 5.40^0 to 7.49^0 E. (Fig. 1). The potential for fish harvesting is very high, with over 900 fishing households and 70 major fishing villages sustained by Rivers Niger and Benue [10]. The species commonly caught are Tilapias *(Tilapia zillii*, *Oreochromis* and *Hemichromis* sp.); catfishes (*Clarias*, *Heterobranchus* and *Synodontis* sp.): silver catfishes (*Chrysichthys* and *Bagrus* sp.); elephant snouts (*Gnathonemus* and *Momyrus* sp.); trunk fish (*Gymnarchus* sp.); and tongue fish (*Heterotis* sp.) [11].

Three-stage sampling procedures were used in selection of respondents for this study. The first stage involved the purposive selection of six and two fish landing sites of each Local Government Areas (LGAs) along River Niger (Koton karfe: Jamata; Ajaokuta: Geregu; Ufo: Itobe; Lokoja: Kabawa; Ibaji: Onyedega and Idah: Idah) and River Benue (Omala: Abejukolo and Bassa: Gbedikere) in Kogi State. It was observed that each landing site was patronized by fisherfolks from more than one village. Therefore, in the second stage, three fishing villages operating around each landing sites were randomly selected from each LGAs. Finally, ten fishing households were randomly selected from each fishing villages (Table 1).

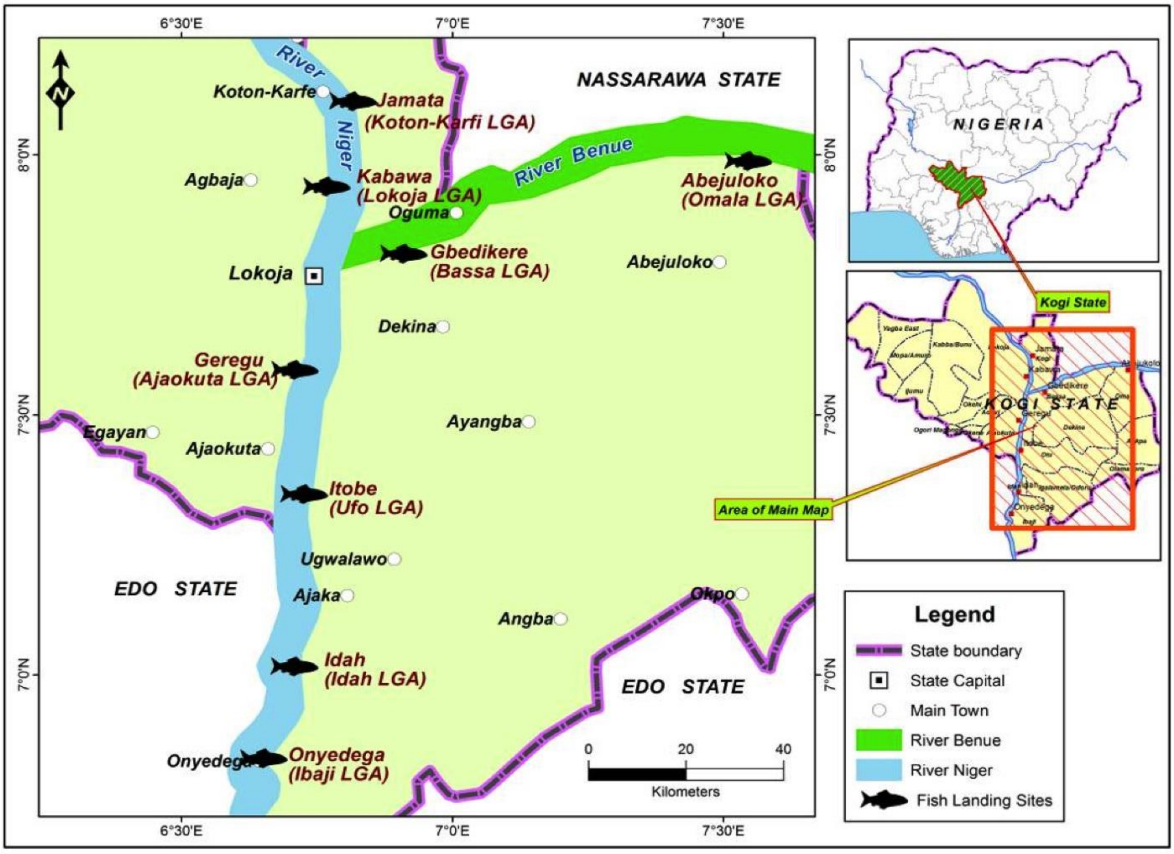

Fig 1: Fish Landing Sites along Rivers Niger and Benue in Kogi State

A total of two hundred and forty (240) fishing households were interviewed of which one hundred and seventy-six (176) were along River Niger and fifty nine (59) were along River Benue. Information on-board catch and effort appraisal was extracted on a per-boat basis through actual fishing operations and interview, using a structured questionnaire. Each fishing household was sampled with the aid of local fishermen once a month for a period of eighteen (18) months, between July 2009 and December 2010.

Data on catch and effort (number of fishing boats) for artisanal fishery of Rivers Niger and Benue fishes between 2009 and 2010 were obtained from the compilation of fishery statistics. These data were used to analyse the CPUE. Then CPUE and effort were inserted in Schaefer surplus model as explained by Sparre and Venema [8] to estimate MSY according to following equation [1]:

$$c/f = a + bf$$

where,

c/f was the CPUE; f was the fishing effort; a was the intercept; b was the slope.

The slope showed negative value indicating the decrease of CPUE with the increase of fishing effort.

Long-term harvest function whose parameters can be estimated from the catch and effort data through linear regression, and it can be expressed by:

$$H(E) = aE\text{-}bE^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eqn.2)}$$

Data on catch and effort in the fishery allows the estimation of parameters a and b by linear regression of the catch per unit of effort on effort.

Effort at maximum sustainable yield can be obtained from equation (Eqn. 2) by taking partial derivative of H with respect to E and setting it equal to zero as:

$$E_{MSY} = \frac{a}{2b} \quad \text{(Eqn. 3)}$$

And the output at MSY is:

$$MSY = \frac{a^2}{4b} \quad \text{(Eqn. 4)}$$

Results and Discussion

This study revealed that fishing effort (E) of 6.9hrs/day resulted in 43.77 kg of fish catch and the estimated catch per unit effort (CPUE) was 5.92 kg/hour in River Niger (Fig 2) compared with 6.8hrs/day of fishing effort that resulted in 28.40 kg of fish catch with a resultant CPUE of 4.33 kg/hrs along River Benue (Fig 3). Generally, as fishing effort increased, catch per unit effort reduced in Rivers Niger (Fig 2) and Benue (Fig 3). The proportion of fishing effort (t) predictable from catch per unit effort (R^2) was similar in River Niger (0.017) and Benue (0.077).

Table 1: Estimation of Maximum Sustainable Yield Using Schaefer Model

Model	River (s)	Average Catch	Effort	CPUE	Intercept	Slope	MSY	E_{MSY}	Effort
		(kg)	(t)	(kg/hr)	a	b	$a^2/(4b)$	a/(2b)	$(t)/E_{MSY}$
Schaefer	Benue	28.4	6.78	4.27	6.07	0.27	34.7	11.44	0.593
	Niger	43.77	6.92	5.92	5.92	0.45	47.8	10.28	0.673

As shown in Table 1, Maximum Sustainable Yield (MSY) of 47.8kg was achieved at effort (E_{MSY}) level of 10.3 hrs/day in River Niger (Fig 4), while Maximum Sustainable Yield (MSY) of 34.7 kg was achieved at effort (E_{MSY}) level of 11.4 hours/day in River Benue (Fig 5). The ratio of fishing effort (t) and effort at Maximum Sustainable Yield (E_{MSY}) in both locations were < 1 suggesting that fish harvesting was below sustainable level with the values of 0.67 in River Niger higher than 0.59 in River Benue. In many fisheries evaluation, indicators of fish exploitation such as Catch Per Unit Effort (CPUE), yields as well as biological such as Maximum Sustainable Yield (MSY) and Effort at Maximum Sustainable Yield (E_{MSY}), were used to recommend Total Allowable Catch (TAC) [12].

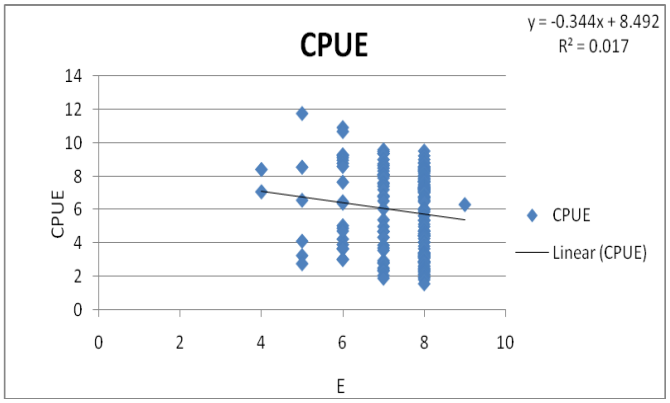

Fig 2: Change of CPUE of fish species with the increase of efforts in artisanal fishery in River Niger

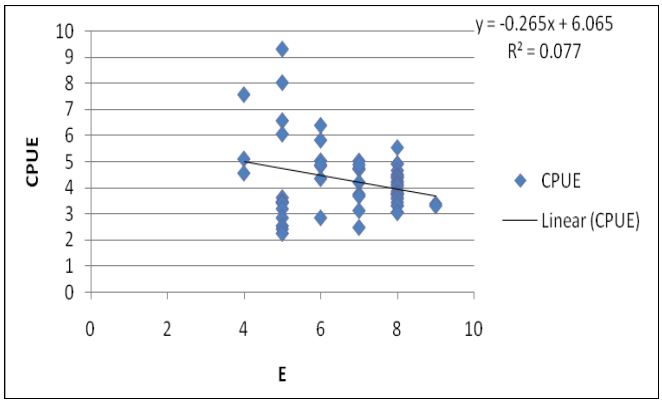

Fig 3: Change of CPUE of fish species with the increase of efforts in artisanal fishery in River Benue

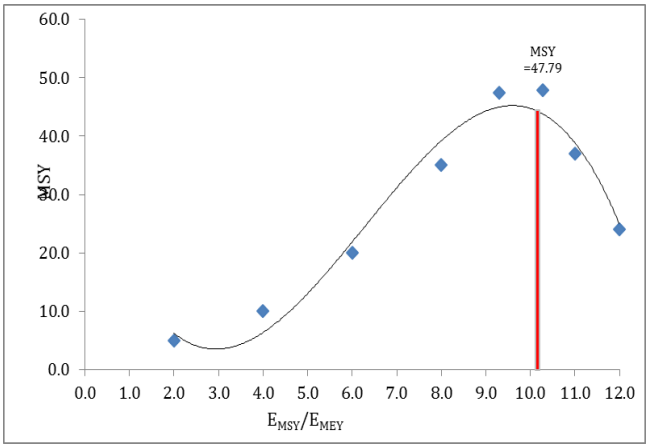

Fig 4: Maximum Sustainable Yield against Effort at Maximum Sustainable Yield in River Niger

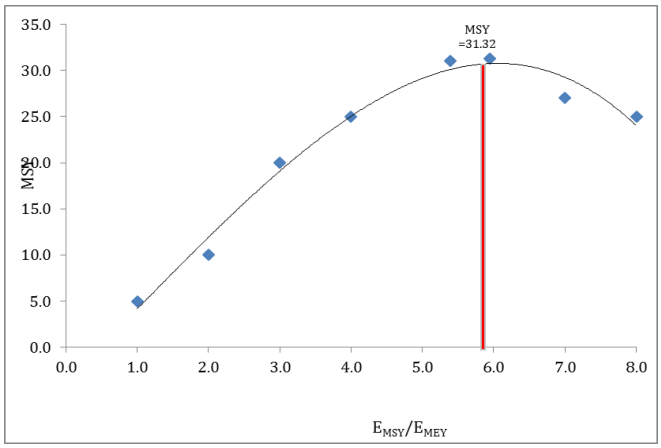

Fig 5: Maximum Sustainable Yield against Effort at Maximum Sustainable Yield in River Benue

The increase of fishing hours (fishing efforts) in Rivers Niger and Benue caused a decrease in catch per unit effort (CPUE) suggesting that fishing effort has negative impact on catch. This is also an indication of potential over capacity in Rivers Niger and Benue. In other words, there are excess fishing activities and diminishing yields in overfished open-access conditions that negatively affect fishers' livelihood [3]. Similar to this study, Marchal *et al.* [13] observed that fishing effort had substantial impact on catch rate in their study of the impact of technological creep on fishing effort and mortality, for a selection of European fleets.

Average catch was less than observed biological reference point of MSY suggesting that there are increasing trends in population size because estimated outputs was lower than surplus production of the stock in both Rivers Niger and Benue. However, Sparre *et al.* [14] recommended a safe level of exploitation (i.e., optimum fishing effort and Total Allowable Catch (TAC)) of 20% less than the fishing effort that gives the maximum sustainable yield (E_{MSY}). Taking 80% of MSY and E_{MSY} obtained in this study (47.79 kg at 10.28 fishing hrs/day and 34.70 kg at 11.44 fishing hrs/day), this gives 38.2 kg/8.2 hrs/day and 27.8 kg/9.1 hrs/day. Hence, the optimum level of fishing to be expanded on Rivers Niger and Benue should not exceed 38.2 kg /8.2 hrs /day and 27.8 k g/7.2hrs/day, respectively. Therefore, sustainability of Rivers Niger and Benue would only be possible if fisher folks' fish catches in the fishery are at a level below MSY.

Abiodun *et al.* [15] reported a CPUE of 6.0 kg/8 hrs in Gerio Lake, Yola Adamawa State, North-eastern Nigeria and recommended a safe level of exploitation of 4.6 kg/8hrs per day for Gerio lake fishery for enhanced management and improved fish production through catch limits. However, the difference between average catch and MSY along River Niger was lower than average catch and MSY along River Benue indicating that over fishing occurred more in River Niger than in River Benue.

Conclusion

CPUE decreased with increasing fishing effort and effort has already reached and surpassed the maximum sustainable level, that is, there is overfishing problem that require the reallocation of resources from existing open access to a controlled system designed to maximize social welfare of the fisherfolks. Hence, the optimum level of fishing to be expanded on Rivers Niger and Benue should not exceed 38.2kg/8.2 hours/day and 27.8 kg/7.2hours/day, respectively. This can be achieved through catch limits (mesh regulation, close season, close area and restrictive licensing).

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