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Abiaobo NO
Department of Zoology, Akwa Ibom State University, Mkpat Enin, Nigeria

Etuk MA
Department of Zoology, Akwa Ibom State University, Mkpat Enin, Nigeria

Akpan II
Department of Zoology, Akwa Ibom State University, Mkpat Enin, Nigeria

Udosen IE
Department of Zoology, Akwa Ibom State University, Mkpat Enin, Nigeria

George UU
Department of Fisheries and Aquaculture, Akwa Ibom State University, Mkpat Enin, Nigeria

Asuquo IE
Department of Fisheries and Aquaculture, Akwa Ibom State University, Mkpat Enin, Nigeria

Corresponding Author:
Abiaobo NO
Department of Zoology, Akwa Ibom State University, Mkpat Enin, Nigeria

Trophic ecology, growth pattern and wellbeing of blueback herring (*Alosa aestivalis*) from Iko River estuary, Southeastern Nigeria

Abiaobo NO, Etuk MA, Akpan II, Udosen IE, George UU and Asuquo IE

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Abstract
Background: Studying the trophic ecology, growth pattern and well-being of *Alosa aestivalis* are important aspects of fish biology. It is a crucial knowledge needed for its mass cultivation by fish farmers and also its implication for its management in the wild. The main objective of the study was to investigate the food and feeding habits, growth and well-being of *Alosa aestivalis* from Iko River estuary in Eastern Obolo Local Government Area, Nigeria.
Methods: Samples of Blueback Herring (*Alosa aestivalis*) were collected from December, 2022 to April, 2023 from fisher catches at Iko landing point. The specimens were preserved with formalin immediately after capture in transparent container and transported to the Department of Zoology Laboratory and kept prior to analysis. Specimens were weighed with electronic weighing balance to the nearest 0.01 g and total length, standard length, and fork length of each fish sample were measured to the nearest 0.01 cm using a measuring board. Specimens were dissected and the gut contents examined, individual food items sorted, counting the number of each food item present in the gut of the species and summing up these numbers to obtain the grand number of all food items in the guts. Frequency of occurrence, numerical abundance, point method, Index of Relative Importance (IRI) and Gut Repletion Index were all computed. The length-weight relationship and condition factor of *Alosa aestivalis* were also determined.
Results: *Alosa aestivalis* from Iko River estuary fed mainly on micro-plant and animal, macro-animal and non-living materials such as zooplankton, detritus, crayfish, small fish, phytoplankton and sand. The stomach content analysis revealed that *Alosa aestivalis* from Iko River estuary is an omnivorous species. Based on index of relative importance, Zooplankton formed the major food item with % IRI of 51.81. Detritus, second most important food item composed 35.63% IRI. Crayfish ranked third in the importance with an IRI value of 5.63% while small fishes ranked fourth with an IRI value of 3.45%. However, Phytoplankton and sand constituted a little above 3%. The species was found to be an active feeder based on the Gut Repletion Index of 85.03%. The length-weight relationship ‘b’ values of males, females and combined sexes were 2.253, 2.278 and 2.253 respectively.
Conclusion: Based on the food items isolated from the stomach contents, the species is considered to be an omnivore. The condition factor values obtained for both male and females depict a negative allometric growth. This implies that the fish was in poor condition during the duration of study.

Keywords: Trophic ecology, growth pattern, well-being, blueback herring, Iko river estuary, Nigeria

1. Introduction
Food is one of the important factors that promotes growth and enriches the biochemical composition of the fish, any variation in the food items may affect the well-being of the fish (Abiaobo, *et al*., 2020; Assan, *et al*., 2021) [4, 11]. Food provides the basic body functions; growth, development and reproduction of an organism. The successful culture of any fish species requires proper understanding of the various food habits or ecological niche for the production of different species and different sizes of the same species (George, *et al*., 2009) [20]. A good knowledge of food and feeding habits of fishes at different stages of their life cycle is inevitable in aquaculture (Joyce, *et al*., 2002) [26]. Feeding ecology is an important aspect of the life-history of a species to understand the functional role of the fish within their ecosystems (Abdel-Aziz and Gharib, 2007) [1]. Feeding is the dominant activity of the entire life cycle of fish (Joyce *et al*., 2002) [26].

Therefore, the study of food and feeding habits of a fish is very important as it is essential for any fishery management (Abiaobo *et al*., 2020; George, *et al*., 2013; George, *et al*., 2011) [4, 23, 22]. The diversity in feeding habit of fishes is the result of evolution leading to structural adaptation for getting food from equally great diversity of situations that have evolved in the environment. (George, *et al*., 2011) [22].

Study of dietary habits of fish is based on stomach content analysis which is widely used in fish ecology as an important means of investigating trophic relationship in the aquatic communities. Information from food studies can be used during species selection in fish culture. This is particularly useful in polyculture because proper selection of fishes with different feeding habits will prevent or significantly reduce competition during culture (George and Edidiong, 2015) [21]. It is virtually impossible to gather sufficient information of food and feeding habits of fish in their natural habitat without studying its gut contents (Manon and Hossain, 2011) [31]. Pius and Benedicta (2002) [45] also reported the use of stomach content in reducing intra and inter specific multi species competition for ecological niche.

Studying the gut content is a key technique to collect adequate information on food and feeding habits in their natural habitat. The length of the gut of a species of fish or any other animal reflects its diet and the percentage composition of food items present in the stomach also show the feeding habits of fish (George, *et al*., 2011) [22]. Analysis of stomach content and features of the alimentary canal provide information on food, feeding habits and selective feeding in fishes (Arthi, *et al.*, 2011) [10]. Analysis of gut content by numerical abundance, point and frequency of occurrence used traditionally in evaluating stomach contents of fish fall short of depicting true relative value (George, *et al*., 2009) [20]. Numerous small organisms overshadow the importance of a few large ones. Differential digestive rates distort point estimation. Frequency of occurrence tabulations is sensitive to sampling error (Abiaobo, *et al*., 2020) [4]. An ideal representative value would probably be one, which integrates each of the analysis's methods. An index of relative importance (IRI) assists in evaluating the relationship of the various food items found in stomachs knowing fully well that it may fall short of some theoretical ideals (George, *et al*., 2009) [20]. The Index of Relative Importance is a composite measure that reduces bias in descriptions of animal dietary data. This index is useful in evaluating the relative importance of various food items (George, *et al*., 2009; Nunoo *et al*., 2013; Abiaobo, *et al*., 2020) [20, 41, 4].

Length-weight relationship (LWR) indicates the average weight of fish at a given length by making use of a mathematical equation to show relationship between the two. Fish can attain either isometric or allometric growth (Sakar, *et al.*, 2013; Abiaobo *et al*., 2021) [46, 4]. Isometric growth (b = 3) indicates that both length and weight of the fish are increasing at the same rate. Allometric growth can be either positive or negative. Positive allometric implies that the b value is > 3 while negative allometric is when the b value is < 3.

Length and weight data are useful standard results of fish sampling program (Morato, *et al.*, 2001) [33]. In fish, size is generally more biologically relevant than age, mainly because several ecological and physiological factors are more size dependent than age dependent. Consequently, variability in size has important implication for diverse aspects of fisheries science and population dynamics (Erzini, 1994) [17]. Length-weight relationship (LWR) is an important tool in fishery management; its importance is pronounced in estimating the average weight at a given length of a fish. Length-weight regression have been used frequently to estimate weight from length because direct weight measurements can be time consuming in the field (Sinovcic, *et al.*, 2004) [48]. One of the most used analyses of fisheries data is length-weight relationship (Mendes, *et al.*, 2004) [32]. LWRs explain mathematically the correlation between fish length and weight and are useful for converting length observation into weight estimate to provide some measure of biomass (Froese, 1998) [18]. In fish studies, the length of a fish is often more rapidly and easily measured than its mass, therefore it is easier to determine mass where only the length is known using length-weight relationship (Harrison, 2001) [24]. The morphometric relationship between fish length and weight can be used to assess the well-being of individuals and to determine possible difference between separate stocks of the same species (King, 1996) [27]. Understanding the length-weight relationship parameters play a major role in fisheries biology and population Dynamics.

Condition factors (K) is an estimation of general wellbeing of fish and is based on hypothesis or assumption that heavier fish are in better condition than the lighter ones (Oribhabor *et al.*, 2011; Ogamba *et al.*, 2014) [44, 42]. Condition factor can be influenced by season, sex, type of food organism consumed by fish, age of fish, amount of fat reserved, and the environmental conditions (Abowei, 2009) [6]. Condition factor is an index reflecting interaction between biotic and abiotic factors in the physiological conditions of fishes. Therefore, the condition factor may vary among fish species in different locations (Blackwell *et al.*, 2000) [15].

Abodi and Ekau (2013) [5] reported that length weight relationship and condition factors are important to fishery industry as they help to predict the best length and weight and time suited to harvest a particular species of fish. Condition index is therefore often used as a rapid measure of ecophysiological state in exploited fisheries (Udoh and Abiaobo, 2014) [50].

The genus *Alosa* (Clupeiformes: Clupeidae) commonly known as Blueback Herring is an anadromous, schooling, coastal, pelagic species (Munroe, 2002) [34]. Blueback Herring is a medium-sized, relatively deep-bodied fish. It is grayish green on its back and is silvery on its belly and sides. Blueback herring are distinguished from other Atlantic herring by differences in body depth, origin of the dorsal fin, coloration patterns, and markings on the underside. They also appear similar to young American shad, although there are differences in jaw shape, body shape, and numbers of gill rakers. Blueback Herring are similar in appearance to alewife. However, they can be distinguished by differences in eye size, body depth, and the color of the peritoneum which is the abdominal cavity membrane. Blueback Herring occupies distinctly different habitat depending upon life stage and time of the year. Juvenile river herring are the dominant life stage found in freshwater and estuarine habitats; Adults enter freshwater only to spawn.

The aim of this study is to investigate the trophic ecology, growth pattern and wellbeing of *Alosa aestivalis* from Iko River estuary. Findings gotten from this research would provide baseline information on the trophic ecology, growth and wellbeing of *Alosa aestivalis* and will help boost the scientific knowledge of the biology of this species for effective conservation and management in the Niger Delta in particular, Nigeria.

2. Materials and Methods

2.1 Study Area

Eastern Obolo is a Local Government Area in Akwa Ibom State, Nigeria, with headquarters at Okoroette. It is a coastal local government area under great tidal influence from the Bight of Bonny. Eastern Obolo was mapped out of Ikot Abasi Local Government Area by the federal Government of Nigeria on 4th December, 1996 with over 100,361 residents across a total area of approximately 117,000 km^2. Eastern Obolo is an area blessed with many communities with diverse socio-economic activities such as artisanal fishing, timbering and boat transport (NDDC, 2004). The water is fringed with diversity of flora such as *Rhizophora mangle*, *Avicennia africana*, *Lancun gularia*, *Raphia hookeri* and *Nypa fruiticans* and *Sargassum sp* that is normally found during wet season. Oil palm (*Elaeis guineensis*) and coconut palm (*Cocoa nucifera*) are also widely distributed in the villages (NDES, 2000; Abiaobo and Udo, 2017) [39, 2]. The area is also an oil-producing area with several oil exploration wells (NDES, 1999). Palm and red mangrove are the dominant species of flora. The area is characterized by a lot of creeks and with an extensive mudflat at Iko creek and others dotted all over the environment. As part of tropics, this area experiences two seasons, the dry (November to March) and wet (April to October) with an annual rainfall averaging about 2500 mm (AKUTEC Report, 2006).

Coastal water of Eastern Obolo drains into Atlantic Ocean and is connected to Qua Iboe river estuary at the East and Imo River estuary at the west. It is located at 4°33'N - 4°50'N; 7°45'E-7°55'E (Figure 1) and about 650 m above sea level in the tropical mangrove forest belt east of the Niger Delta. The tidal regime here is semidiurnal and has a range of about 0.8 m at neap tides and 2.20 m during spring tides with little fresh water input joined by numerous tributaries (NDES, 2000) [39].

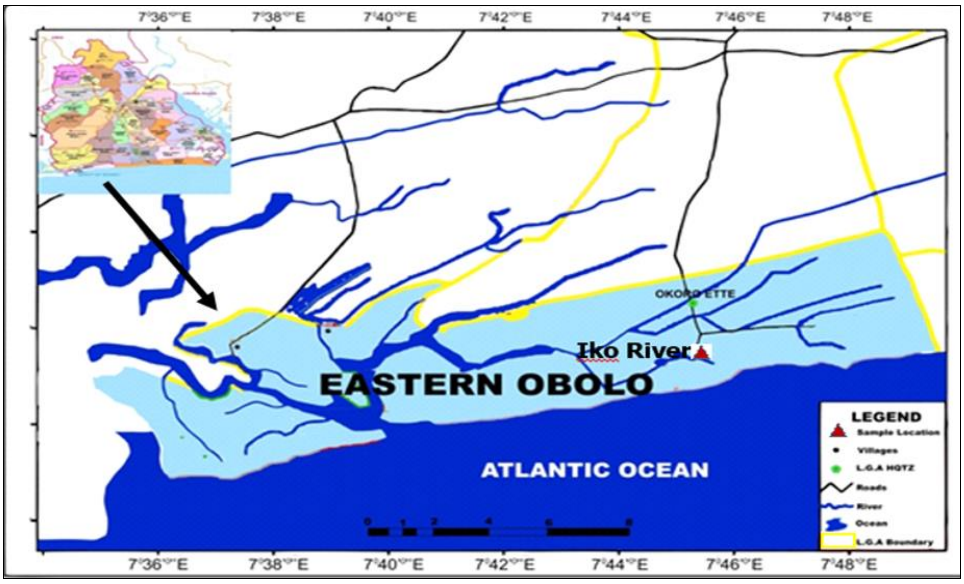

Fig 1: Map of Eastern Obolo L. G. A. Showing Iko River and Its Tributaries

2.2 Samples Collection

Samples of Blueback Herring (*Alosa aestivalis)* (Plate 1) were collected from December, 2022 to April, 2023 from fisher catches at Iko landing point. The specimens were preserved with formalin immediately after capture in transparent container and transported to the Department of Zoology Laboratory and kept prior to analysis.

2.3 Sample preparation

In the laboratory, specimens were removed from the formalin, rinse with clean water and blotted dry using a clean towel. The total length (TL), standard length (SL) was carefully measured using fish measuring board to the nearest 0.01 cm. Fish total weight (TW) was weighed on a top loading electronic metler balance (PS: 165) to the nearest 0.01 g.

2.3.1 Stomach Content Analysis

In the Laboratory, the fish specimens in formalin were removed, rinse with clean water and blotted dry with clean towel and were treated individually to determine their biometric data. After blotting dry with clean towel, specimens were dissected and the guts were carefully removed with the aid of a forcep (Plate 2). The Stomach of dissected specimens were slit open and the contents poured into a Petri dish (Plate 3) and smeared with a small drop of distilled water and the food items were examined macroscopically, then under a stereo light microscope (magnification up to 100×) to identify the food items. Information on Total Length, Standard Length, Weight and identified food items were recorded into a data sheet for data analysis. Analysis was carried out using frequency of occurrence, point method and numerical method respectively.

Plate 1: Samples of *Alosa aestivalis*

Plate 2: Sample of Gut with food

Plate 3: Gut Content poured into a petri dish

2.3.2 Point Method

In the point method (Hyslop,1980) [25], each stomach was sorted out visually, categorized as empty, one quarter, half, three quarter and full, and scored 0, 5, 10, 15, and 20 respectively with intermediate score where necessary. These points were shared among the various items, taking into account of their relative proportion by volume. Points scored by each food item was calculated and expressed as a percentage of grand total points scored by all stomach contents giving the percentage point (% P).

$$\%P = \frac{\text{Point by a particular food item}}{\text{Total points by all food items}} \times 100$$

2.3.3 Frequency of Occurrence

The percentage frequency of occurrence (% FO) was based on the number of stomachs in which a food item was found, expressed as a percentage of the total number of non-empty stomachs. Usually expressed as:

$$\%\,FO = \frac{\text{Number of stomach with a particular food}}{\text{Total number of non-empty}} \times 100$$

2.3.4 Numerical Method

This involved counting the number of each food item present in the stomach of the species and summing up these numbers to obtain the grand number of all food items in its guts. The number of each food item was expressed as a percentage of the grand total number of food items. Usually expressed as:

$$\text{Percentage number of food} = \frac{\textit{Total number of a particular food item}}{\textit{Total number of all food items}} \times 100$$

This method expresses the numerical importance of different food items and gives relative importance of each food item.

2.3.5 Index of relative important (IRI)

An index of relative importance (IRI) was also used to determine the most important food items. The principal food items were then identified using the IRI which is a modified version of Bachok, *et al*. (2004) [12] embracing the three methods as follows:

IRI = (% Na + % P) x % Fo

Where IRI = index of relative importance;
% Na = percentage numerical abundance;
% P = percentage point and
% Fo = percentage frequency of occurrence.
The IRI was further expressed as percentage thus:

$$\%\ IRI = \frac{IRI}{\Sigma IRI} \times 100$$

Where ΣIRI refers to the sum of all IRI.
The incorporation of the three methods of stomach analysis and computing the % IRI is more representative (Hyslop, 1980) [25] and reduce to the barest minimum the bias associated with the independent interpretation of result from each analytical method and consequently gives a more accurate picture of dietary importance (Hyslop, 1980) [25].

2.3.6 Feeding Intensity

Feeding intensity was determined using Gut Repletion Index (GRI) and was calculated by dividing the number of non-empty guts by the total number of guts examined multiplied by 100 (Hyslop, 1980) [25]. Gut repletion index (GRI) is given as:

$$GRI = \frac{\text{Number of non-empty guts}}{\text{Total No. of Gut Examined}} \times 100$$

2.4 Determination of Length-Weight Relationship

The raw data of the total length (TL) and total weight (TW) of the fish collected were used to compute the length-weight relationship with the formula:

$W = aL^b$ (LeCren, 1951; Ricker, 1973) (1)

Where
W= Body weight
L= Total length
A = Intercept on the length axis,
b = Slope or regression coefficient which ranges from 2 to 4 with an average of 3.
Equation (1) is log transformed to give a linear relationship;

Log W = log a + b log L. (Koutrakis and Tsikiliras, 2003) [28] (2)

When log W is plotted against log L, the regression coefficient or growth exponent, b, and intercept are obtained.
For each species, the growth exponent (b) was compared to 3 using student's t-test to ascertain whether species grow isometrically or not (Sokal and Rohlf, 1987) [49]. This was achieve using this formula
t_s= student's t-test.
b = slope.
s_b= standard error of the slope.
The b value of 3 was chosen as a standard to compare because

it indicates that the fish grows isometrically.

2.5 Condition Factor (K)

The condition factor which is a measure of the relative well-being of the fish was estimated using the Fulton's coefficient formula (Fulton, 1902) [19]:

$$K = \frac{TW}{TL^3} x100$$

Where:
K = Condition factor
TL = Total length in centimeter
TW = Total weight in grams.

3. Result

3.1 Food Composition of *Alosa aestivalis* from Iko River estuary: The overall food composition based on stomach content analysis of *A. aestivalis* from Iko River estuary is shown in table 1. The highest food item consumed was zooplankton 34.4%, followed by detritus 31.1%, crayfish 11.4%, small fish 8.5%, sand 7.4% and phytoplankton 7.0% as the least. Monthly diet composition of *A. aestivalis* is shown in table 2. The highest number of food items were recorded in December, 2022 and the least was observed in April, 2023.

Table 1: Overall food composition of *Alosa aestivalis* from Iko River estuary (December, 2022 to April, 2023)

S. No.	Food Items	Number of Food Items	Number of Food Items %
1.	Zooplankton	93	34.44
2.	Detritus	84	31.11
3.	Crayfish	31	11.48
4.	Small fish	23	8.51
5.	Sand	20	7.40
6.	Phytoplankton	19	7.03
	Total	270	

Table 2: Monthly variation in diet composition of *Alosa aestivalis* from Iko River estuary (December, 2022 to April, 2023)

	Zooplankton (%)	Detritus (%)	Crayfish (%)	Small fish (%)	Sand (%)	Phytoplankton (%)
December	20.14	50.50	16.18	5.75	5.18	2.23
January	25.98	61.07	6.15	2.35	3.92	0.50
February	56.80	32.38	6.83	0.78	0.99	2.19
March	72.59	21.43	1.45	2.22	0	2.28
April	85.64	5.56	1.34	4.93	0	2.51

The overall percentage of numerical abundance, frequency of occurrence and point method of food consumed by *A. aestivalis* from Iko estuary is shown in table 3. Based on numerical abundance and frequency of occurrence methods, zooplankton was the most consumed food item while phytoplankton was the least consumed food item. However, in the point method, zooplankton was the most dominant food item consumed while sand was the least consumed item. The species was found to be an active feeder based on the Gut Repletion Index of 85.03% (Table 4).

Table 3: Overall Numerical Abundance (%), Frequency of Occurrence (%) and Point Method (%) of diet composition c

Food Items	Number of Stomach in Which Food Item Occurred	% Frequency of Occurrence	% Numerical Abundance	% Point Method
Zooplankton	93	65.4	34.44	40.02
Detritus	84	59.1	31.11	25.56
Crayfish	31	21.8	11.48	12.82
Small fish	23	16.1	8.51	11.68
Sand	20	14.0	7.40	2.18
Phytoplankton	19	13.3	7.03	7.34
Number of specimens with food examined	142			
Total number of specimens examined	167			
Total number of food item	270			

Table 4: Gut Repletion Index of *Alosa aestivalis* from Iko river estuary (December, 2022 to April, 2023).

Species	No. of non- empty Gut	Total no. of Gut examined	% GRI
Alosa aestivalis	142	167	85.03%

The index of relative importance (IRI) of Blueback Herring, *Alosa aestivalis* from Iko river estuary is shown in table 5. Zooplankton formed the major food item with percentage index of relative importance (% IRI) of 51.81. Detritus, second most important food item formed 35.63% IRI. Crayfish ranked third in the importance at % IRI of 5.63%. Small fish ranked fourth in the importance at % IRI of 3.45%. Phytoplankton and sand constituted a little above 3%.

Table 5: Index of Relative Importance of *Alosa aestivalis* from Iko River estuary (December, 2022 to April, 2023).

Food Item	% Na	% Po	% Fo	(% Na + % Po) % Fo	% IRI
Zooplankton	34.44	40.02	65.4	4869.68	51.81
Detritus	31.11	25.56	59.1	3349.19	35.63

Crayfish	11.48	12.82	21.8	529.74	5.63
Small fish	8.51	11.68	16.1	325.05	3.45
Sand	7.40	2.18	14.0	134.12	1.42
Phytoplankton	7.03	7.34	13.3	191.12	2.03
Total				9, 398.9	

3.2 Length-Weight Relationship of *Alosa aestivalis* from Iko River estuary

In the size distribution, the total length (TL cm) of males ranged from 13.50 to 24.50 cm with a mean of 18.09±2.96, in females the TL cm ranged between 14.30 and 24.00 cm (mean = 18.81±2.67) while the combined sexes recorded a TL cm that varied between 13.50 and 24.50 cm. The total weight (TW g) of males ranged from 28.00 to 131.00 g (mean = 59.05) while the combined sexes recorded a TW g that varied between 26.00 and 131.00 g. The plot of total weight (TW g) against total length (TL cm) of males, females and combined sexes of *A. aestivalis* during the period of study is depicted in Figures 2, 3 and 4 respectively.

There was a positive correlation between TW and TL in males, females and combined sexes with an exponential relationship of the form:

Males = $TW = 0.06963\ TL^{2.253}$

Females = $TW = 0.07755\ TL^{2.278}$

Combined sexes = $TW = 0.05093\ TL^{2.253}$

The values of the length exponent (2.253; 2.278 and 2.253) for males, females and combined sexes were significantly less than the cube value (3) ($p< 0.05$) which signified that the increase in size was negative allometric growth. This implies that the fish grew faster in length than in weight. There was a good linear relationship between the length and weight of the males, females and combined sexes as indicated by the high coefficient of determination (r^2) of 0.82319; 0.76441 and 0.79903 for males, females and combined sexes as depicted in table 6.

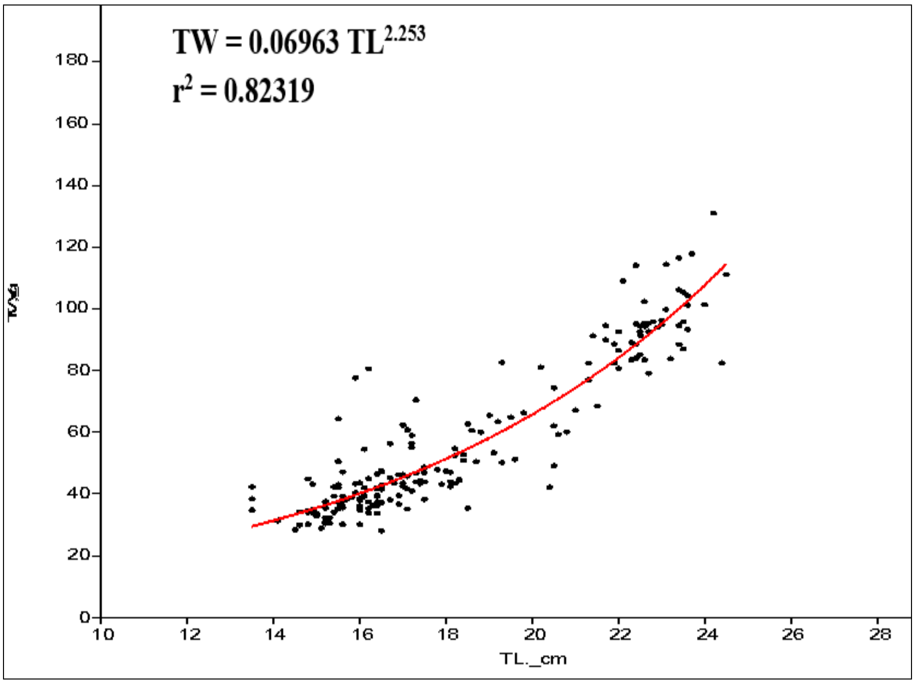

Fig 2: Length-weight relationship of male *Alosa aestivalis* from Iko River estuary (December, 2022 to April, 2023)

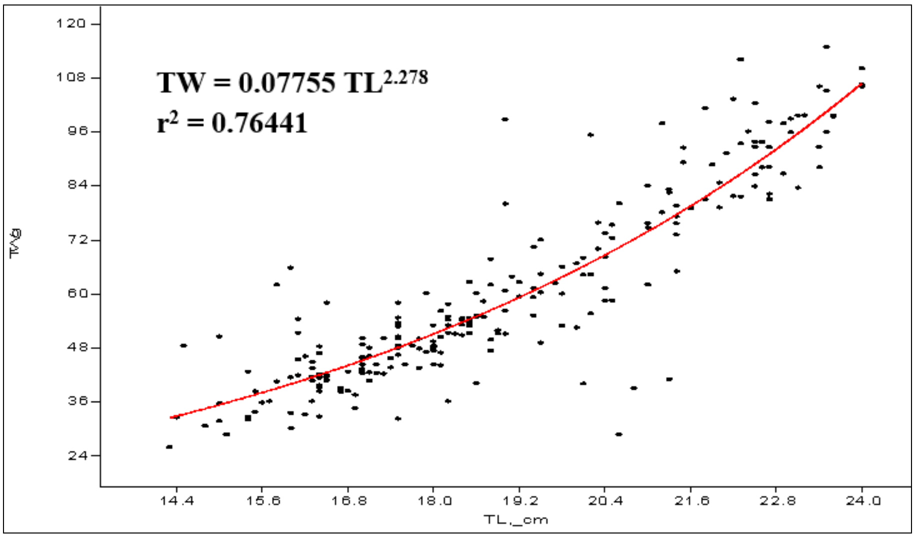

Fig 3: Length-weight relationship of female *Alosa aestivalis* from Iko River estuary (December, 2022 to April, 2023).

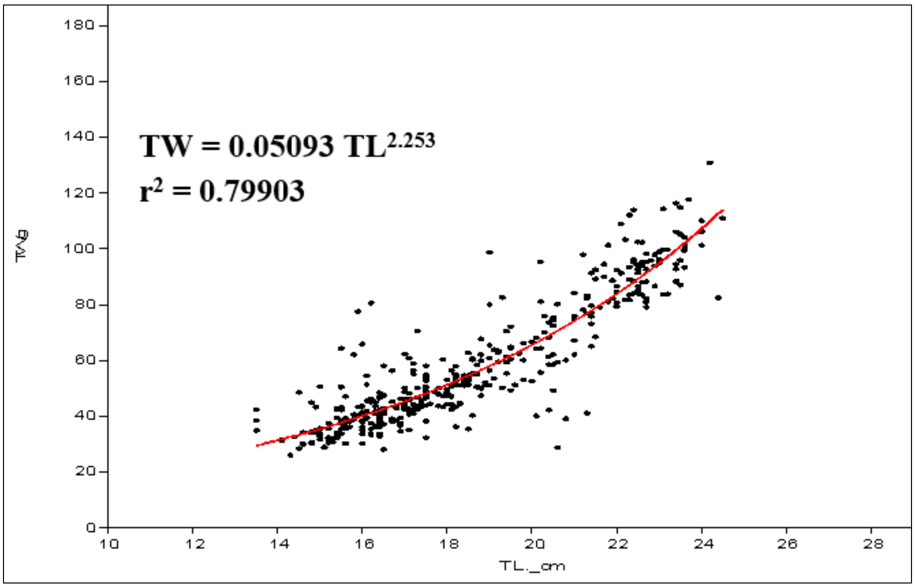

Fig 4: Length-weight relationship of combined sexes of *Alosa aestivalis* from Iko River estuary (December, 2022 to April, 2023).

Table 6: Length-weight relationship parameters of males, females and combined sexes of *Alosa aestivalis* from Iko River estuary (December, 2022 to April, 2023).

Overall	Sex	n	A	b	r	r^2	t	Growth pattern
	M	227	0.06963	2.253	0.90731	0.82319	32.366, p, 0.001	-A
	F	268	0.07755	2.278	0.87439	0.76441	29.376, p, 0.001	-A
	C	495	0.05093	2.253	0.89389	0.79903	44.273, $p<0.05$	-A

Where, M = Male; F = Female, C = Combined Sexes

3.3 Condition Factor of *Alosa aestivalis* from Iko River estuary: Table 7 depicts the monthly mean $\pm$ standard deviation of condition factor of *A. aestivalis* from Iko River estuary. In December condition factor (K) values ranged between 0.09 and 2.32 with a mean value of 0.83$\pm$0.28. In January it ranged from 0.01 to 1.93 (mean 0.88$\pm$0.24). In February it ranged from 0.43 to 1.61 (mean 0.95$\pm$0.19). In March it ranged from 0.32 to 1.72 (mean = 0.90$\pm$0.19). In April it ranged from 0.14 to 1.56 (mean 0.79$\pm$0.33). In overall for the combined sexes, K ranged between 0.01 and 2.32 with a mean value of 0.87 $\pm$ 0.25.

Table 7: Monthly variation in Condition Factor of *Alosa aestivalis* from Iko River estuary (December, 2022 to April, 2023).

Parameter	Months	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
K	December	120	0.8251	0.27994	0.02556	0.09	2.32
	January	97	0.8827	0.23661	0.02402	0.01	1.93
	February	105	0.9547	0.19271	0.01881	0.43	1.61
	March	100	0.8966	0.19027	0.01903	0.32	1.72
	April	73	0.7859	0.32941	0.03855	0.14	1.56
	Overall	495	0.8725	0.25274	0.01136	0.01	2.32

4. Discussion

4.1 Food items and feeding habit of *Alosa aestivalis*

Examination of the gut contents of *Alosa aestivalis* revealed that the species feeds mostly on diets of animal origin including zooplankton and small fish some plant matter (phytoplankton), detritus and sand were also encountered. Five (5) different diet components were encountered in the gut of the species during the investigation. The overall Gut Repletion Index of 85.03% is an indication of high feeding intensity showing that the species is an active feeder. The most dominant food material encountered during the duration of study was zooplankton. This result is in agreement with the findings of Simonin, *et al.* (2007) [47] when working in Hudson and Mohawk Rivers, New York. The authors observed that *Alosa aestivalis* fed mainly on zooplankton and fish eggs. Similarly, Billy (2002) [14] when working on the food and feeding habits of *A. aestivalis* in Lake chatuge observed the species to be a planktivore (feeding mainly on zooplankton and phytoplankton). It also aligns with Ekinadose *et al.* (2021) [16] who worked at East coast of North America from Cape Breton, St John's River in Florida and reported that plankton, small fishes, shrimp were the main food items of *A. aestivalis*. Zooplankton play an important role in nutrient cycling in aquatic ecosystems and support healthy fish population (Lampart and Sommer, 2007) [30].

The presence of sand particles and detritus in the gut content is an indication that the species is a bottom feeder. The assumption being that these items are abundant in the benthos and that the species may be a benthic feeder (George *et al.* 2011) [22]. This however, is merely a reasonable guess as these materials might have been incidental diet components which were obtained alongside the main diet components of the species in the habitat (George *et al.*, 2011) [22].

Variations in the diet's components consumed by *A. aestivalis* was also observed in each of the months. The presence of a particular food item in one month and the absence in another month might have been caused by an increase in the quantity of a particular food item in one month and a reduction in one or another food item consumed by the species in the month during the study. This assertion is in consonance with earlier reports made by George, *et al*., (2013) [23] during their studies on the Diet Composition and Condition Factor of *Ethmalosa fimbriata* in the Cross River Estuary and George, *et al*., (2011) [22] when working on the Food and feeding habits of *Ophiocephalus obscura* (African snakehead) in the Cross River estuary.

4.2 Length-Weight Relationship of *Alosa aestivalis*

The length-weight relationship (LWR) provides information on age, growth patterns and growth of animals including fish (Andem, *et al*., 2013) [8]. During their development, fish are known to pass through stages in their life history which are defined by different length-weight relationships (Nkanta, *et al*., 2023) [40]. In this study, growth of *A. aestivalis* from Iko River estuary showed negative allometry. It was observed that if fish must maintain its shape as it grows, their b-values must be equal to 3. Allometric growth is negative (b<3) if the fish gets relatively thinner as it increases in length and positive (b>3) if it gets plumper as it increases in length. The observe variation in b value could be attributed to several factors which include; seasons, environmental parameters, the presence of food, feeding ratio, habitat, sex and physiological conditions of fish.

Fish undergoing negative allometric growth signifies that the rate of weight gained is less than the increase in length making the fish thinner or slimmer showing poor growth probably owing to non-availability and abundant of food items (Abiaobo, *et al.*, 2021) [4]. Negative allometric growth of fishes in a way is an indication of the state of the environment and its suitability in fish growth and reproduction (Ndiaye, *et al.*, 2015) [35]. According to Abiaobo, *et al.* (2021) [4] a negative allometric growth can be caused by environmental factors such as temperature, dissolved oxygen, pH, pollution, overfishing, food competition and trophic potentials of the rivers. This means that the fish became slimmer and thinner as its length increased and would not command a good yield, landing size and high market price for the fishers (Ogunola, *et al*., 2018) [43].

LWR is important in fisheries management for comparative growth studies (Mendes, *et al.*, 2004) [32]; it provides valuable information on the aquatic habitat and in aquatic ecosystem modelling (Kulbicki, *et al.*, 2006) [29].

4.3 Condition Factor of *Alosa aestivalis*

Condition factor is a morphometric index used to evaluate physiological status of fish based on the principle that those individuals of a given length which have a higher mass are in better 'condition'. The condition factor could be influenced by differences in size or age (Anwa-udondiah and Pepple, 2011) [9]. Abiaobo *et al.* (2021) [4] reported that condition factor indicates the degree of wellbeing of the fish in their ecological niche. Higher value of condition factor shows that the fish is healthy and is growing positively. (Ndiaye *et al.*, 2015) [35] stated that when condition factor value is higher, it means that the fish has attained a better condition in the environment. The relationship of length-weight can be used in the estimation of condition factor (K) of fish species. The mean value of condition factor (K) obtained in this study was 0.8725±0.25274 which was less than one and showed poor condition of this species in the environment. This agreed with Simonin *et al.* (2007) who reported a mean condition factor of 0.81±0.05 in the mid spring, 0.61±0.05 in the late spring when working on the same species in Hudson and Mohawk Rivers, New York. However, Bagenal and Tesch, (1978) [13] opined that a fish living in a favorable environment in term of amount of food available and good environmental conditions grow faster with condition factor of one or more. Certain factors are known to affect the wellbeing of fish. Generally, variations in the K values of this fish species could be a reflection of the state of sexual maturity, degree of nourishment, age of the fish and in some species sex of the fish (Ndome and Muabe, 2009) [36].

4.4 Summary and Conclusion

In summary, *A. aestivalis*-Blueback Herring from Iko River estuary fed mainly on zooplankton. The stomach content analysis revealed that the Blueback Herring from Iko River estuary is an omnivore. Based on index of relative importance, Zooplankton formed the major food item with % IRI of 51.81. Detritus, second most important composed 35.63% IRI. Crayfish ranked third in the importance at IRI 5.63%. Small fish ranked fourth in the importance at IRI 3.45%. Phytoplankton and sand constituted a little above 3%. The species was found to be an active feeder based on the Gut Repletion Index of 85.03%. The species showed a negative allometric growth during the study which is an indication of a poor relative well-being of the fish in the environment. The coefficient value shows a high degree of correlation between the weight and total length of *A. aestivalis.* The overall mean condition factor obtained for *A. aestivalis* was 0.8251±0.25274. This result is an indication of a poor growth which might have been due to environmental stressors. In conclusion, *A. aestivalis* is considered to be a voracious omnivore based on the food items isolated from the gut contents during the duration of study.

4.5 Recommendation

However, intensified study is recommended on the biology of *Alosa aestivalis* so as to broaden the understanding of the species and its implication as an aquaculture candidate.

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