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Research Article

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The population size structure and length–weight relationships (LWRs) are fundamental tools in fishery science, providing valuable insights into the health, dynamics, and management of fish populations and contributing to the sustainable use of aquatic resources. The data used in this study were estimates from the main small pelagic fishes exploited in the Gambia. They were collected using surface and bottom gillnets between November 2020 and October 2021 during scientific fishing operations. The main small pelagic fish size composition showed a modal class of 20 cm for *Ethmalosa fimbriata*, 21 cm for *Sardinella aurita*, 22 cm for *Sardinella maderensis*, and 30 cm for *Trachurus trecae*. The parameter *b* value of these fish species ranged from 1.6831 to 2.9461, and the correlation coefficient ranged from 0.81 to 0.95. Statistical LWRs for all species were very significant. Information obtained is essential in reviewing and establishing basic management measures for depleted shared pelagic stocks in the Gambian fisheries and the sub-region. In the context of poor data fisheries, such results also encourage the Gambian government and intergovernmental subregional organizations to support data collection in the long term.

Keywords: Carangidae; Clupeidae; fisheries management; growth; small pelagic; West Africa

1. Introduction

Population dynamics is essential for understanding ecosystem functioning and managing exploited populations [1, 2]. Small pelagic fish are widely known to have rapid and large population fluctuations, making their management particularly difficult [1]. The Gambia's coasts are recognized for their rich fishery resources because of favorable hydrodynamic, climatic, and geomorphological factors. Small pelagics represent significant biomass and are sources of abundance [3]. They are also known to be sensitive to environmental change [3, 4]. As such, it is important to deepen our understanding of their adaptations to environmental changes, to estimate the impacts of these changes on ecosystems, and to develop instruments (reliable and sustainable indicators) and models to predict the evolution of ecosystems in various contexts.

Population size structure, length, and weight can influence responses to other physiological stressors [5–7]. The length–weight relationship (LWR) varies in time and space depending on parental wealth (e.g., weight condition), food availability (abundance and quality), environmental parameters (temperature and salinity), and evolutionary stressors, for example, density and fishing pressure [8–11].

Thus, the information obtained from this relationship can help identify the adaptation strategy versus environmental conditions [5, 12, 13] and the modeling of population dynamics versus anthropogenic factors of many fisheries [14].

The fishery sector contributes to 12% of the GDP in The Gambia [15, 16]; it is the third largest sector after agriculture and tourism. The estimated per capita fish consumption is about 26 kg compared to the 8.2 kg average for Africa. However, fish consumption is much higher in the coastal region than in the country's interior [15–17]. In The Gambia, the small pelagic has been a traditional activity since the 70's, mostly on a small-scale level, men exclusively lead it. The industrial sector became interested in small pelagic in the early 2000s. Several agreements on fisheries have occurred since 1994 [15–18], with Senegal in Africa and at the industrial level with the European Union and Japan, notwithstanding the joint venture, including vessels from China. For exportation, the most important species are octopus, shrimp, and sol. For food security and local employment, this is mostly *Ethmalosa fimbriata*, *Sardinella aurita*, and *Sardinella maderensis* [15–19]. Population size structure and the LWR of the leading small pelagics (*E. fimbriata*, *Trachurus trecae*, *S. maderensis*, and *S. aurita*) in The Gambia are still missing. This study reports the population size structure and LWR of fish species of main interest for food security that have never been published. This kind of basic information is essential for fishery management measures.

2. Materials and Methods

2.1. Study Area. Sampling was conducted at the main small pelagic landing sites of The Gambia (West Africa) between November 2020 and October 2021. The Gambia is a small sub-Saharan country with a Sahelo–Sudanian climate, bordered by Senegal and extending to the Western Coast of Africa between 13° and 14°N. The country is part of the Canary Current Large marine ecosystem characterized by high productivity [20]. The Gambia is a wide estuary from the Gambia River, which drives turbid and low salinity waters [21]. The dry season is cool from November to March, warm from April to June, and the hot rainy season occurs from June to October [22]. No vertical stratification was observed for salinity, but the longitudinal distribution of salinity showed that the brackish water extended from 80 km in length in September to up to 220 km in June.

2.2. Materials. This study sampled only specimens captured with surface and bottom gillnets [23]. It focused on the species most targeted by pelagic artisanal fisheries. The data were collected in the Lower North River (Ballingho and Bamba tenda), Lower River South (Bintang, Mandinary, Tankular, and Tendaba), Upper River South (Bansang and Basse), and Atlantic Ocean (Bakau, Banjul, Barra, Gunjur, Jeswang, Kartong, and Tanji) (Figure 1).

Four small pelagic species were collected in landing sites representing two families: *E. fimbriata*, *S. maderensis*, *S. aurita* for the Clupeidae, and *T. trecae* for the Carangidae. The total *E. fimbriata* sampled was 8699; for *T. trecae*, we get 270 specimens; for *S. maderensis*, 5126; and for *S. aurita*, 770. Length frequency data were collected randomly at about 5 days per week. After fish identification, all specimens were sized (total length in cm, "TL"), and their body individually weighed (in g) following the procedure harmonized at the subregional level [24]. Sampled individuals were grouped into 1 cm interval size classes to calculate size-frequency distributions.

2.3. Statistical Approach. The captured individuals were inventoried, measured, and weighed. The total length was measured for fish with truncated or round caudal fins. Unidentifiable species were transported to the laboratory to classify. The LWR for the total body weight was calculated using the equation from [25]: $W = a \cdot L^b$, where "W" is the total weight (expressed in grams), "L" is the total length (expressed in centimeters), "a" is coefficient related to body form, and "b" is an exponent indicating isometric growth when equal to 3.

$$\log W = \log a + b \log L. \tag{1}$$

The logarithmic form of the LWR, with variables and parameters, are defined above.

The condition factor K was calculated according to the following equation [26]:

$$K = 100 \frac{W}{L^3}. \tag{2}$$

Fulton's condition factor K with W = whole body wet weight in grams and L = length in cm, the factor 100 is used to bring K close to unity.

3. Results

The size distribution of *E. fimbriata*, *S. aurita*, *S. maderensis*, and *T. trecae* in the Gambian waters peaked at 20, 21, 22, and 30 cm, respectively. The maximum length (L_{max}) of *E. fimbriata*, *S. aurita*, *S. maderensis*, and *T. trecae* recorded was 29, 30, 31, and 43 cm, respectively (Figure 2).

The LWRs of the four small pelagic species are presented in Table 1. The species, sample size (n), and range of size range (cm, TL) are given (Table 1). The body weight (W), length–weight parameters, as the coefficient related to body form (a) are maximum for *S. aurita* and minimum for *E. fimbriata*, which is a value close to *T. trecae*. The parameter b varied between 1.6831 (*S. aurita*) and 2.9461 (*E. fimbriata*). The r^2 values (Figure 3) were high, ranging from 0.81 (*S. aurita*) to 0.90 (*T. trecae*). Statistical LWRs for all species were highly significant ($p < 0.001$). Across all species surveyed in the Gambian waters, results (Figure 4) of the condition factor (K) showed that larger specimens have lower health status than smaller specimens, as indicated by the superscript $b < 3$ and shown in Figure 3. The results during the study period showed a K of 1.1, 0.8, 1.1, and 1.1 for *E. fimbriata*, *T. trecae*, *S. aurita*, and *S. maderensis*, respectively.

4. Discussion

Small pelagic fishes are excellent bioindicators of climate-induced changes in marine systems worldwide because of

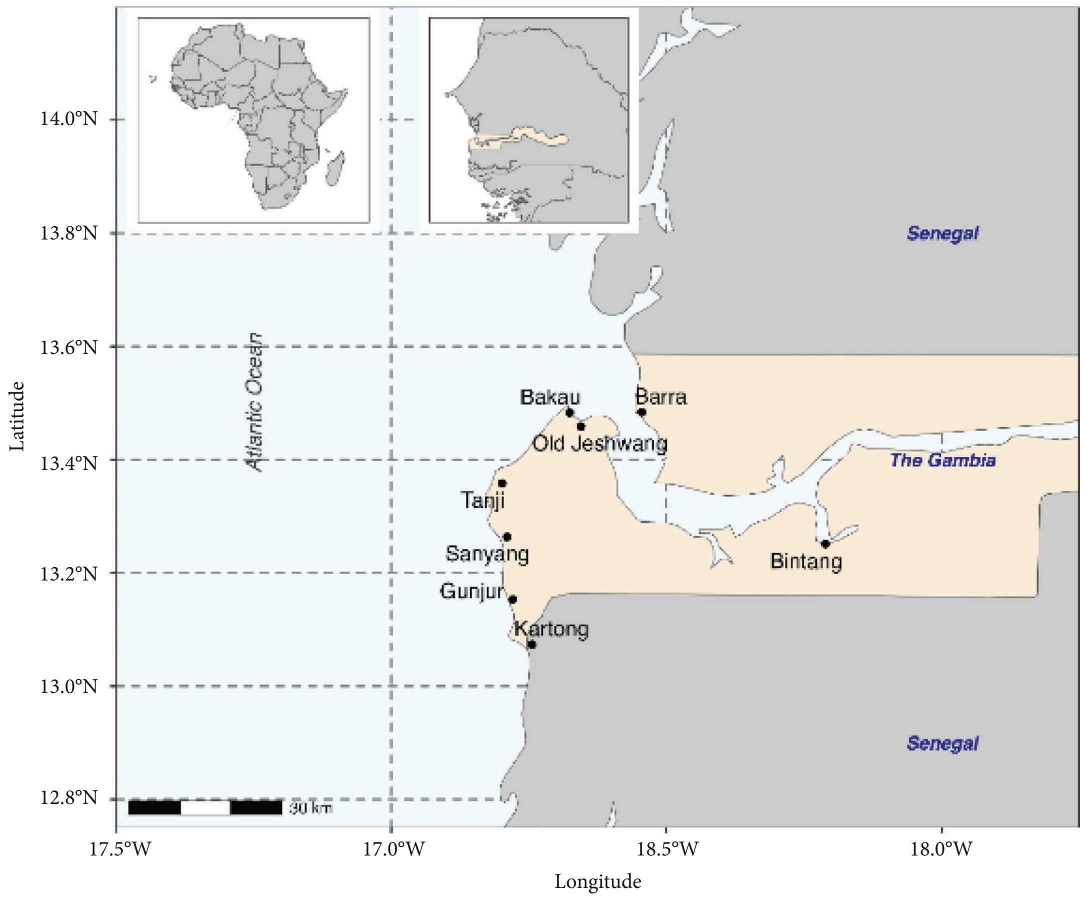

Figure 1: The most important fishing grounds for small pelagic fish in The Gambia (West Africa). Triangles mark the main landing sites (where fish sampling took place).

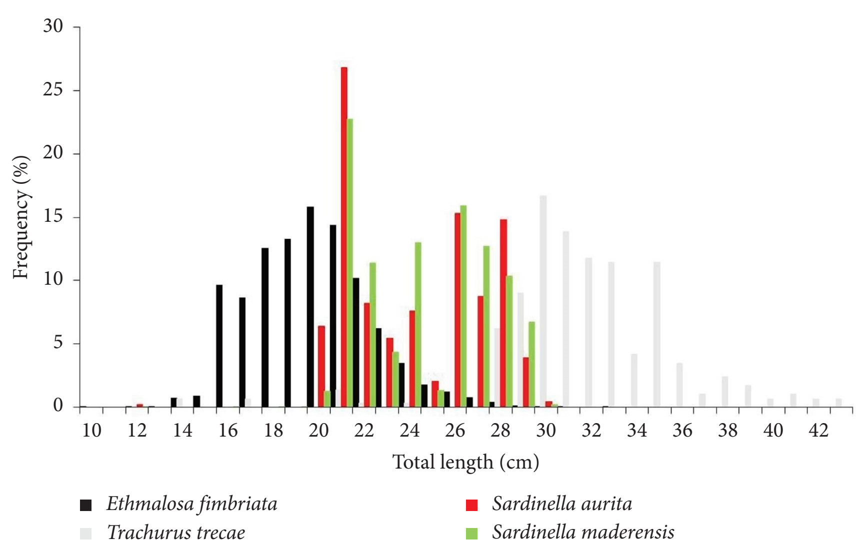

Figure 2: Size frequency distributions for *Ethmalosa fimbriata* ($n = 8699$), *Trachurus trecae* 270), *Sardinella maderensis* ($n = 5126$), and *Sardinella aurita* ($n = 770$) caught in the Gambian waters by small-scale fishers. The total length (in cm) was used for *Ethmalosa fimbriata*, *Trachurus trecae*, *Sardinella maderensis*, and *Sardinella aurita*, and the modes were 20, 30, 21, and 21 cm, respectively.

their population characteristics and trophodynamic role [5]. The results showed a variation in the size structure between species caught in The Gambia. In species with indeterminate growth, age-related size variation is often high. This allows the selection of divergences in growth tactics between species [5]. However, growth rates closer to maximum

Table 1: Length and weight of fishes collected in The Gambia.

Family	Species	*a*	*b*	r^2	*n*	Total length (cm)	Body weight (g)	CL_b 2.5%–97.5%	*p* value
Clupeidae	*Ethmalosa fimbriata* (Bowdish, 1825)	0.0117	2.9461	0.82	8699	15–30	23–251	2.9173–2.9748	< 0.001
Carangidae	*Trachurus trecae* (Cadenat, 1950)	0.0114	2.9062	0.90	270	28–43	175–641	2.7908–3.0215	< 0.001
Clupeidae	*Sardinella aurita* (Valenciennes, 1847)	0.7047	1.6831	0.82	770	20–30	106–259	1.6266–1.7396	< 0.001
Clupeidae	*Sardinella maderensis* (Lowe, 1838)	0.4392	1.8355	0.85	5126	20–30	107–244	1.8144–1.8565	< 0.001

Note: n: sample size of the number of fish; *a*: coefficient related to the body; *b*: slope; r^2: coefficient of determination of the length–weight relationships. Abbreviation: CL, confidence limits.

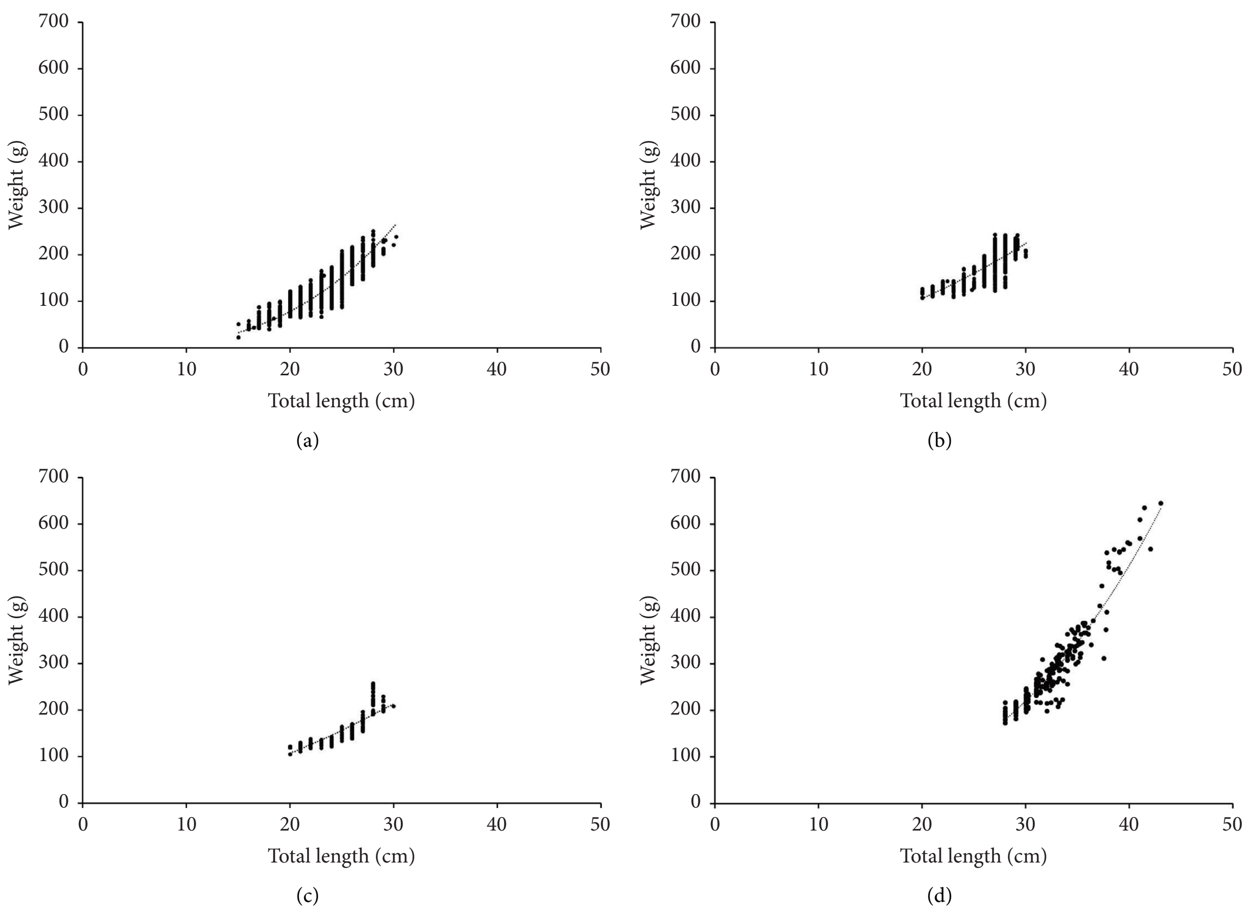

Figure 3: Length–weight relationship of (a) *Ethmalosa fimbriata* (black circle; $n = 8699$), (b) *Sardinella maderensis* ($n = 5126$), (c) *Sardinella aurita* ($n = 770$), and (d) *Trachurus trecae* ($n = 270$) in The Gambia with the exponential regression curve fitted to all measurements of each species. The relationships are detailed in Table 1.

growth are generally observed when a species has experienced limited growth. Small pelagic growth could also change seasonally and throughout ontogeny due to the differential energy allocation to somatic growth, maturation, reproduction, and migration [5, 27]. The morphometric relationship between length and weight of fish is an appropriate index for understanding growth, survival, maturity, and reproduction [25]. In The Gambia, *b* values of *S. aurita* and *S. maderensis* were less than 2.5 and greater than 2.5 for *E. fimbriata* and *T. trecae*. Such values would not correspond to the fixed normality, from 2.5 to 3.5 [14]. Carlander [28] demonstrated that $b < 2.5$ or > 3.5 are often obtained from samples with narrow size ranges. Many factors, for example, morphology, fat ratio, sex, sexual stage, egg density, and digestive tract status, can cause weight fluctuations in a fish [29, 30]. This difference may also be due to the tendency of some larger species to be heavier as they grow. In other words, most of the extreme values of the mean *b* come from species with only a few LWRs, and the average is likely to fall in the expected range if more LWRs become available for these species. However, even if the specimens are rare, lower numbers will also be acceptable [14]. Indeed,

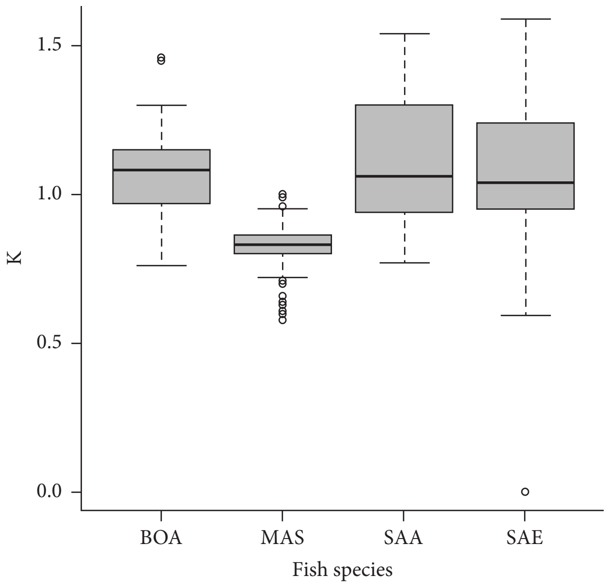

FIGURE 4: Condition factor (K) of *Ethmalosa fimbriata* (BOA), *Sardinella aurita* (SAA), *Sardinella maderensis* (SAE), and *Trachurus trecae* (SAE) in the Gambian waters.

many factors (e.g., morphology, proportion of fatty acids, sex, sexual stage, egg density, and condition of the digestive tract) can cause fluctuations in the weight of an individual fish [14, 31]. The weight is determined by the condition factor (K). The variations in K suggest that the species studied adopt an energy supply strategy. Environmental characteristics and the level of fishing pressure exerted on a small pelagic fish species had a balanced impact on their growth parameters and asymptotic length and should therefore be considered as phenotypic parameters. Adaptive phenotypic plasticity is often the only way for populations to respond rapidly to environmental changes and thus ensure their survival [32]. A change in biological parameters (e.g., length–weight and condition factor) for a small pelagic population is probably one of the best indicators of its response to changes and/or stress in its environment. Panfili et al. [32] showed that growth rates were reduced in the hypersaline environment of Saloum (Senegal). For example, studies by Baldé et al. [5, 33] in Senegal show that the weight of *S. aurita* and *E. fimbriata* seems closely linked to the intensity of upwelling. Other factors such as the nature of the data can influence the condition factor. Indeed, the data made available to us for this work have significant drawbacks to consider. Nominal catches are sometimes inaccurate [2]. They often include an inaccurate transcription of the weights and sizes of individuals, partial fishing effort data, and unreliable and outdated statistical data [2]. For example, during data processing, size or weight values were found that seem abnormal. These values could be related to data entry or measurement errors and are considered outliers. We defined an outlier as a value (e.g., size or weight) that deviates significantly from all other members of a sample of which it is a member [34]. Rohlf [35] and Afifi and Azen [36] indicate that outliers can be defined as values isolated from the main data cloud. However, in the condition of data poor fisheries, the information obtained will be useful in fishery science and will help improve fishery management and inform data collection on other parameters.

We recommend growth assessment of small pelagic fish in The Gambia, underling the fact that LWRs help evaluate the growth of fish populations over time. Changes in length and weight can provide information about the age structure, recruitment rates, and overall population health. Knowledge of LWRs in The Gambia's small pelagic fishery is essential for effectively reviewing the recommended sizes in the Fisheries Regulation 2008 for minimum sizes of small pelagic fishes. It aids in implementing conservation measures to ensure the long-term viability of fish stocks. The length of the first capture by the Gambian regulation is 15 cm for *E. fimbriata*, 12 cm for both *Sardinellas* species, and 19 cm for *T. trecae*. This management gap needs to be reviewed to use the length at first maturity as the reference point. These species' appropriate size limits can enhance the sustainability of fishing practices and ensure that fish have the opportunity to reproduce before being harvested.

Changes in LWRs can indicate shifts in environmental conditions, such as changes in water temperature, food availability, or habitat quality. Monitoring these relationships can provide early warnings of potential environmental impacts on fish populations. Fish are integral to aquatic ecosystems, and their size and weight dynamics can reflect the broader ecological balance within these systems. In this work, we demonstrate the capability of the Gambian fishery department to lead this kind of monitoring and analysis, which requires state long-term investment in data collection and national fishery research capacity.

Data Availability Statement

The data used to support the findings of this study are available from Momodou Sidibeh (mbailo85@hotmail.com) upon request.

Ethics Statement

No specific authorization was required for any activities undertaken during the search at any sites visited. The study was conducted in the waters of The Gambia State. The activities were carried out in collaboration with the fishermen on the site. Threatened or protected species have not been involved in any part of the field studies. Fish samples were collected randomly from commercial catches of professional fishermen. No approval was required from the Institutional Animal Care and Use Committee, and no field license was required during any part of the experiment.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

Conceptualization: B.S.B., M.S., P.B., and M.S.J.; data curation: B.S.B., M.S., and M.S.J.; formal analysis: B.S.B. and M.S.J.; methodology: B.S.B. and M.S.J.; project administration: P.B.; resources: P.B. and M.S.; software: B.S.B; validation: P.B.; supervision: P.B.; visualization: B.S.B.; writing—original draft: M.S., B.S.B., and M.S.J.; writing—review and editing: B.S.B., M.S.J., and P.B. The manuscript was written through contributions of all authors.

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References

[1] A. Bakun, T. J. Pitcher, P. J. B. Hart, et al., *Ocean Triads and Radical Interdecadal Variation: Bane and Boon to Scientific Fisheries Management* (London, UK: Chapman & Hall, 1998).

[2] B. S. Baldé, "Dynamics of Small Pelagic Fish (*Sardinella aurita* and *Ethmalosa fimbriata*) in Senegal in a context of climate change: Bioecological Diagnosis and Synthesis" (https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers19-08/010076741.pdfThése de Doctorat, Dakar, Senegal: Université Cheikh Anta Diop, 2019).

[3] C. Roy, "Réponse des Stocks de Poissons Pélagiques à la Dynamique des Upwelling en Afrique de l'Ouest: Analyse et modélisation. Response of Pelagic Fish Stocks to Upwelling Dynamics in West Africa: Analysis and Modeling" (https://www.documentation.ird.fr/hor/fdi:34170Thése de doctorat, Brest, France: Université de Bretagne Occidentale, 1992).

[4] N. Diogoul, P. Brehmer, H. Demarcq, et al., "On the Robustness of an Eastern Boundary Upwelling Ecosystem Exposed to Multiple Stressors," *Scientific Reports* 11 (2021): 1908–1912, https://doi.org/10.1038/s41598-021-81549-1.

[5] B. S. Baldé, J. Döring, W. Ekau, M. Diouf, and P. Brehmer, "Bonga Shad (*Ethmalosa fimbriata*) Spawning Tactics in an Upwelling Environment," *Fisheries Oceanography* 28, no. 6 (2019): 686–697, https://doi.org/10.1111/fog.12451.

[6] D. Checkley, J. Alheit, Y. Oozeki, and C. Roy, *Climate Change and Small Pelagic Fish* (Cambridge: Cambridge University Press, 2009), https://www.researchgate.net/profile/Juergen_Alheit2/publication/266567677_Climate_Change_and_Small_Pelagic_Fish/links/54b5057c0cf26833efd05664.pdf.

[7] K. A. Sloman, G. R. Scott, S. Wood, et al., "The Effect of Size on the Physiological and Behavioural Responses of Oscar to Hypoxia," *Comparative Biochemistry and Physiology A-Molecular & Integrative Physiology* (New York: Elsevier Science, 2005), S176–S177.

[8] K. Ba, M. Thiaw, N. Lazar, et al., "Resilience of Key Biological Parameters of the Senegalese Flat Sardinella to Overfishing and Climate Change," *PLoS One* 11, no. 6 (2016): e0156143, https://doi.org/10.1371/journal.pone.0156143.

[9] B. S. Baldé, P. Brehmer, S. Faye, and P. Diop, "Population Structure, Age and Growth of Sardine (*Sardina pilchardus*, Walbaum, 1792) in an Upwelling Environment," *Fishes* 7, no. 4 (2022): 178, https://doi.org/10.3390/fishes7040178.

[10] B. S. Baldé, P. Brehmer, F. N. Sow, et al., "Population Dynamics and Stock Assessment of *Ethmalosa fimbriata* in Senegal Call for Fishing Regulation Measures," *Regional Studies in Marine Science* 24 (2018): 165–173, https://doi.org/10.1016/j.rsma.2018.08.003.

[11] F. W. Tesch and W. E. Ricker, "Age and Growth," *Methods for Assessment of Fish Production in Fresh Waters* (Oxford, UK: Blackwell Scientific Publications, 1971).

[12] M. A. Peck, P. Reglero, M. Takahashi, and I. A. Catalán, "Life Cycle Ecophysiology of Small Pelagic Fish and Climate-Driven Changes in Populations," *Progress in Oceanography* 116 (2013): 220–245, https://doi.org/10.1016/j.pocean.2013.05.012.

[13] J. Y. Xie, Y. H. Yang, and S. Q. Lin, "Length–Weight and Length–Length Relationships of Four Fish Species From Rivers in the Tibetan Plateau, China," *Journal of Applied Ichthyology* 34, no. 6 (2018): 1345–1347, https://doi.org/10.1111/jai.13787.

[14] R. Froese, "Cube Law, Condition Factor and Weight–Length Relationships: History, Meta-Analysis and Recommendations," *Journal of Applied Ichthyology* 22, no. 4 (2006): 241–253, https://doi.org/10.1111/j.1439-0426.2006.00805.x.

[15] E. h B. Deme, M. Deme, M. Sidibeh, and P. Failler, "The Exploitation of Small Pelagics Fish in Gambia: What Valorization Policies," *International Journal of Fisheries and Aquatic Studies* 9, no. 4 (2021): 297–305, https://doi.org/10.22271/fish.2021.v9.i4d.2547.

[16] J. Amuzu, "The Socio-Economic Impact of Climate Change on Marine and Freshwater Fisheries Resources in the Coastal Zone of the Gambia," *Natural Resources and Conservation* 6 (2018): 1–12, https://doi.org/10.13189/nrc.2018.060101.

[17] M. Sidibeh, A. Jallow, and A. Sanneh, "Preliminary CMSY Stock Assessment of Bonga Shad (*Ethmalosa fimbriata*) in the Gambia," *Fisheries Centre Research Reports* 28 (2020): 18.

[18] G. Ragusa, "Overview of the Fisheries Sector in the Gambia," *Fisheries and Aquaculture Journal* 05, no. 03 (2014): 1000107, https://doi.org/10.4172/2150-3508.1000107.

[19] M. S. Jallow, B. S. Baldé, M. Sidibeh, and P. Brehmer, "Assessment of Growth and Stock Status of Data-Limited *Ethmalosa fimbriata* Fishery in the Gambia," *Regional Studies in Marine Science* 78 (2024): 103786, https://doi.org/10.1016/j.rsma.2024.103786.

[20] P.-A. Auger, T. Gorgues, E. Machu, O. Aumont, and P. Brehmer, "What Drives the Spatial Variability of Primary Productivity and Matter Fluxes in the North-West African Upwelling System? A Modelling Approach and Box Analysis," *Biogeosciences* 13, no. 23 (2016): 6419–6440, https://doi.org/10.5194/bg-13-6419-2016.

[21] M. Simier, L. Blanc, C. Aliaume, P. S. Diouf, and J.-J. Albaret, "Spatial and Temporal Structure of Fish Assemblages in an "Inverse Estuary", the Sine Saloum System (Senegal)," *Estuarine, Coastal and Shelf Science* 59, no. 1 (2004): 69–86, https://doi.org/10.1016/j.ecss.2003.08.002.

[22] J.-J. Albaret, M. Simier, F. S. Darboe, J.-M. Ecoutin, J. Raffray, and L. Tito de Morais, "Fish Diversity and Distribution in the Gambia Estuary, West Africa, in Relation to Environmental Variables," *Aquatic Living Resources* 17, no. 1 (2004): 35–46, https://doi.org/10.1051/alr:2004001.

[23] O. Diankha, H. Demarcq, M. Fall, et al., "Studying the Contribution of Different Fishing Gears to the Sardinella Small-Scale Fishery in Senegalese Waters," *Aquatic Living Resources* 30 (2017): 27, https://doi.org/10.1051/alr/2017027.

[24] P. Brehmer, B. S. Balde, and A. Mouget, *Projet AGD-pélagique (CSRP-IRD): Appui à la Gestion Durable des Pélagiques: Rapport Technique IRD 2020* (IRD, 2020).

[25] E. D. L. Cren, "The Length-Weight Relationship and Seasonal Cycle in Gonad Weight and Condition in the Perch (*Perca fluviatilis*)," *Journal of Animal Ecology* 20, no. 2 (1951): 201–219, https://doi.org/10.2307/1540.

[26] T. W. Fulton, "The Rate of Growth of Fishes," in *22nd Annual Reportof the Fishery Board of Scotland*, 3 (1904), 141–241.

[27] A. Sarré, J.-O. Krakstad, P. Brehmer, and E. M. Mbye, "Spatial Distribution of Main Clupeid Species in Relation to Acoustic Assessment Surveys in the Continental Shelves of Senegal and the Gambia," *Aquatic Living Resources* 31 (2018): 9, https://doi.org/10.1051/alr/2017049.

[28] K. D. Carlander, *Handbook of Freshwater Fishery Biology: Volume 3* (Ames, IA: Iowa State University Press, 1977).

[29] A. James, J. W. Pitchford, and J. Brindley, "The Relationship betwEen Plankton Blooms, the Hatching of Fish Larvae, and Recruitment," *Ecological Modelling* 160, no. 1-2 (2003): 77–90, https://doi.org/10.1016/s0304-3800(02)00311-3.

[30] S. K. Lowerre-Barbieri, K. Ganias, F. Saborido-Rey, H. Murua, and J. R. Hunter, "Reproductive Timing in Marine Fishes: Variability, Temporal Scales, and Methods," *Marine and Coastal Fisheries* 3, no. 1 (2011): 71–91, https://doi.org/10.1080/19425120.2011.556932.

[31] R. J. Wootton, *Ecology of Teleost Fishes*, 2nd edition (Dordrecht: Kuwer Academic Publishers, 1998).

[32] J. Panfili, J.-D. Durand, A. Mbow, et al., "Influence of Salinity on Life History Traits of the Bonga Shad *Ethmalosa fimbriata* (Pisces, Clupeidae): Comparison Between the Gambia and Saloum Estuaries," *Marine Ecology Progress Series* 270 (2004): 241–257, https://doi.org/10.3354/meps270241.

[33] B. S. Baldé, F. N. Sow, K. Ba, et al., "Variability of Key Biological Parameters of Round Sardinella *Sardinella Aurita* and the Effects of Environmental Changes," *Journal of Fish Biology* 94, no. 3 (2019): 391–401, https://doi.org/10.1111/jfb.13903.

[34] V. Planchon, "Traitement des Valeurs Aberrantes: Concepts Actuels et Tendances Générales," *Biotechnologie, Agronomie, Société et Environnement* 9 (2005): 19–34.

[35] F. J. Rohlf, "Generalization of the Gap Test for the Detection of Multivariate Outliers," *Biometrics* 31, no. 1 (1975): 93–101, https://doi.org/10.2307/2529711.

[36] A. A. Afifi and S. P. Azen, *Statistical Analysis: A Computer Oriented Approach* (New York: Academic Press, 1979), https://books.google.fr/books?hl=fr&lr=&id=3wfjBQAAQBAJ&oi=fnd&pg=PP1&dq=Statistical+analysis:+A+computer+oriented+approach&ots=2QtF3cxomI&sig=quruadd-ifIpPHtrZdK7I_laG-c.