Reproductive ecology studies for sustainable fisheries management in Iberoamerica.
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Updated insights into the reproductive biology and somatic condition of *Pagellus bellottii* (Teleostei: Sparidae) in tropical waters of the Gulf of Guinea (West Africa)

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Summary: The red pandora (*Pagellus bellottii*) is a coastal demersal species of great social and economic importance in West African fisheries. Increasing fishing pressure and environmental variability threaten the sustainability of its exploitation, highlighting the need for updated biological and reproductive data to inform management strategies. This paper examines weight-related and reproductive parameters of *P. bellottii* in Côte d'Ivoire and Ghana from 2745 individuals sampled monthly between October 2019 and March 2021 (10–32.5 cm total length). The length-weight relationship, condition factor (K), sex ratio (M:F), gonadosomatic index (GSI), reproduction period and length at first maturity of females (L_{50}) were determined. Males predominated in both countries (1:0.6 in Côte d'Ivoire, 1:0.8 in Ghana). The presence of mature females most of the year suggests continuous reproduction. However, monthly variations in GSI and in the proportion of mature females revealed two reproductive peaks: a main one between May and August/September, and a secondary one between December and February, likely associated with coastal upwelling. An inverse pattern between K and GSI was observed, reflecting energy allocation to gonadal development. The estimated female L_{50} in both countries was 17.8 cm. These findings, ideally complemented by longer study periods, provide essential data for science-based fisheries management and stock assessment.

Keywords: *Pagellus bellottii*; length-weight relationship; sexual maturity; condition factor; gonadosomatic index; reproduction; spawning season; length at maturity.

Nuevas evidencias sobre la biología reproductiva y la condición somática de *Pagellus bellottii* (Teleostei: Sparidae) en aguas tropicales del Golfo de Guinea (África Occidental)

Resumen: La breca africana *Pagellus bellottii* es una especie demersal costera de relevancia social y económica en las pesquerías de África Occidental. El incremento de la presión pesquera y la variabilidad ambiental amenazan la sostenibilidad de su explotación, destacando la necesidad de disponer de datos biológicos y reproductivos actualizados que sustenten estrategias de gestión. Este estudio analiza parámetros somáticos y reproductivos de *P. bellottii* en Costa de Marfil y Ghana a partir de 2745 individuos muestreados mensualmente entre octubre de 2019 y marzo de 2021 (10-32.5 cm TL). Se determinaron la relación talla-peso, el factor de condición (K), la proporción sexual (M:H), el índice gonadosomático (GSI), el periodo reproductivo y la talla de primera madurez de hembras (L_{50}). Los machos predominaron en ambos países (1:0.6 en Costa de Marfil; 1:0.8 en Ghana). La presencia de hembras maduras durante casi todo el año sugiere reproducción continua. Sin embargo, las variaciones mensuales de GSI y de la proporción de hembras maduras revelaron dos picos reproductivos: uno principal entre mayo y agosto/septiembre y otro secundario entre diciembre y febrero, probablemente asociados al afloramiento costero. Se observó un patrón inverso entre K y GSI, reflejando la asignación energética al desarrollo gonadal. La L_{50} estimada en ambos países fue de 17.8 cm. Estos resultados, idealmente complementados con periodos más prolongados, proporcionan información esencial para la evaluación de stocks y la gestión pesquera basada en criterios científicos.

Palabras clave: *Pagellus bellottii*; relación talla-peso; madurez sexual; factor de condición; índice gonadosomático; reproducción; época de puesta; talla de madurez.

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INTRODUCTION

The sustainability of fisheries depends on the productivity of exploited stocks. Therefore, a comprehensive understanding of their reproductive biology is essential for modelling their dynamics and evaluating the impact of fishing pressures (Kjesbu 2016, Domínguez-Petit et al. 2017, Saborido-Rey and Macchi 2021). Monitoring of landings, including biological parameters, is crucial for assessing the status of fish stocks.

To determine reproductive periods and other key life-history phases, a combination of biological parameters, including the condition factor (K), the gonadosomatic index (GSI), and the proportion of mature females, is commonly employed (Begg 1999b, 2005). In addition to length-weight relationships, condition indices serve as integrative metrics reflecting key physiological aspects of an organism's life history, including growth dynamics and phenotypic plasticity (Granados-Amores et al. 2019, Blackwell et al. 2000). These indices provide a practical and informative measure of individual health and are widely used in fisheries science to assess population fitness and responses to ecological disturbances (Le Cren 1951, Ferreri 2014).

The red pandora (*Pagellus bellottii* Steindachner, 1882) inhabits the continental shelf from Gibraltar to Angola (Russell and Carpenter 2014). The highest abundance of this species has been recorded at depths of approximately 50 metres, while lower values are observed in very shallow waters (less than 30 metres) and at depths exceeding 200 metres (Caverivière 1993).

This demersal coastal fish holds significant social and economic importance in West Africa (Fernández-Peralta and Ramos 1993, FAO 2019). In the Gulf of Guinea, where red pandora is the most widespread species within the Sparidae family, it is a key component of multi-species demersal fisheries, supporting both artisanal and industrial/semi-industrial bottom trawl fleets (Russell and Carpenter 2014, Kouame et al. 2018). In Ghana and Côte d'Ivoire specifically, red pandora is fished using trawls, bottom-set nets and hooks and lines (Amponsah et al. 2016, FAO 2019). Locally known as *Wiriwawa* in Ghana (Amponsah et al. 2016) and *Pageot* in Côte d'Ivoire (Kouame 2018), this species contributes significantly to fishery landings. It accounted for 2.5% of demersal catches (5438 t) and 4.6% of the commercial value in Côte d'Ivoire and Ghana in 2019 (Derrick 2020, Polido et al. 2020, Quenum et al. 2024). In Côte d'Ivoire, it accounts for approximately 10.3% of the total marine fish catch (FAO 2008, Kouame et al. 2018). The species has experienced a sharp decline in both countries, with joint catches dropping from nearly 11000 t in 1999 to around 5000 t in 2019 (Amponsah et al. 2016, FAO 2022).

Stock assessment, which in our case of study is conducted within the regional framework provided by the Fishery Committee for the Eastern Central Atlantic (CECAF), faces significant challenges in the region due to data gaps, particularly in the southern area, where the acceptance rate of assessment models remains low. In general, biological sampling of the landings is practically non-existent for the whole region. Thus, the lack of biological sampling and reliable time series of abundance indices (catch per unit effort or survey indices) further complicates the evaluation of demersal stocks in this area (FAO 2025). Given these limitations, the intense exploitation of *P. bellottii* (FAO 2022) and its ecological and economic importance (Amponsah et al. 2016), updated reproductive data from Côte d'Ivoire and Ghana can contribute to improving stock assessments, thus supporting science-based fisheries management in the region. This study aims to analyse the length-weight relationship, condition factor and reproductive characteristics of *P. bellottii* in waters of the Gulf of Guinea, providing updated biological data to support conservation and management strategies for this important fishery resource in West Africa.

MATERIALS AND METHODS

Biological samplings

Samples of *Pagellus bellottii* individuals were collected on a monthly basis from landings at two ports of Côte d'Ivoire (San Pedro in the west and Abidjan in the east, from March 2020 to February 2021) and two ports in Ghana (Takoradi in the west and Tema in the east, from October 2019 to March 2021) (Fig. 1). Sampling followed a stratified design by length class to ensure representative coverage of the size distribution of each area. The planned monthly coverage was not achieved in certain months and ports, mainly for reasons related to the COVID pandemic. The same sampling protocol was used for both countries to ensure standardization of the data collection systems (García-Isarch et al. 2020).

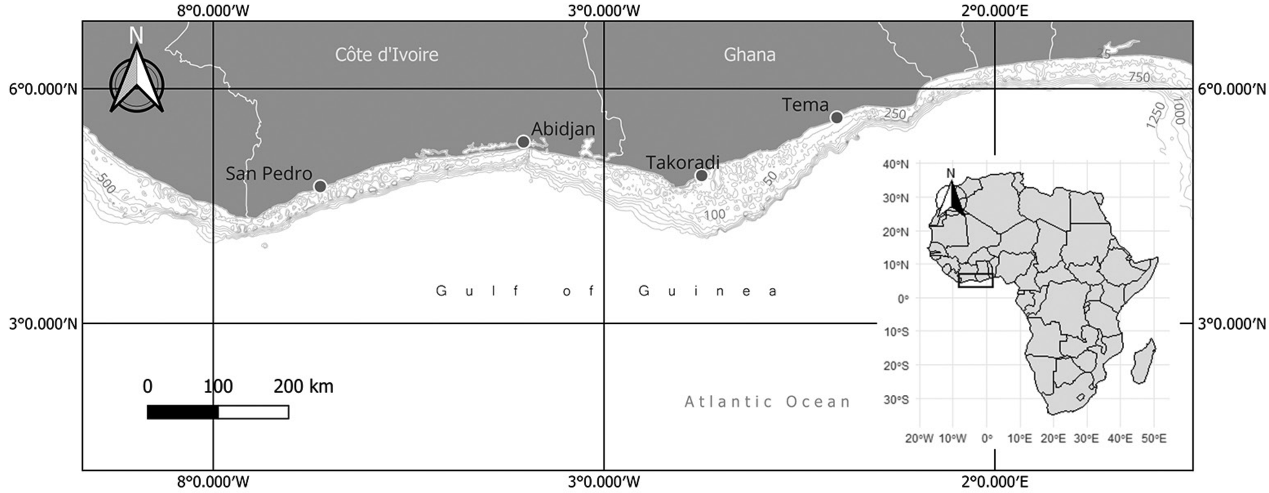

Fig. 1. – Location of the study area in the Gulf of Guinea (West Africa), showing the four sampling ports: San Pedro and Abidjan in Côte d'Ivoire, and Takoradi and Tema in Ghana.

A total of 2745 individuals of *P. bellotti* were measured for total length (TL), total weight (Wt) and gutted weight (Wg) (Fig. 2). Sex and maturity stage of every fish were visually determined. For sex, fish were classified as males, females and indeterminates. Five stages of maturity were established: 1, immature or resting; 2, maturing; 3, nearly ripe; 4, gravid; and 5, spent, adapted from the macroscopic maturity stages described by Kouame (2018) for this species. Finally, the weight of the gonad (Wgo) of each sampled individual was also recorded.

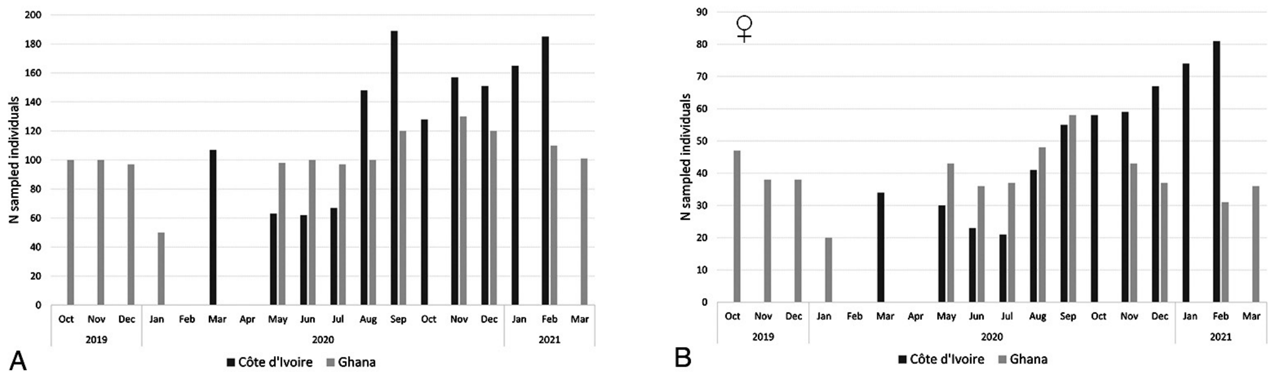

Fig. 2. – Number of sampled individuals of *P. bellottii* by month and country, for all individuals (A) and for females (B). Bars represent counts for Côte d'Ivoire (dark grey) and Ghana (light grey).

Data analysis

Length-weight relationship and condition factor

The length-weight relationship was analysed separately by sex and combined sexes. The calculations were performed with the regression model defined by Le Cren (1951) as

$$Wg = a(TL)\ b$$

where *Wg* is the gutted weight in grams and *TL* is total length (cm), serving as the dependent and independent variables, respectively. The parameters *a* and *b* correspond to the regression coefficients in this model. Based on these coefficients for females, Le Cren's (1951) relative condition factor (K) was calculated for potentially mature *P. bellottii* by country and bimonthly, using the formula

$$K = \frac{Wg}{aTL^b}$$

where Wg is the gutted weight, *TL* is total length, and *a* and *b* are species-specific parameters of the length-weight relationship for females.

This factor was used to assess fish condition, under the assumption that heavier individuals at a given length are in better condition (Froese 2006). The relative condition factor (K) was estimated on a bimonthly basis for mature females, with the classification of maturity based on the theoretical length at first maturity (L_{50}) of 12.4 cm taken from previous estimations in Côte d'Ivoire (Kouame et al. 2018). Restricting the analysis to mature females reduces variability related to sex, size and maturity stage, and isolates changes in somatic reserves associated with vitellogenesis and spawning. This approach provides a clearer indicator of physiological condition and reproductive investment (Lloret and Planes 2003, Reñones et al. 2010, Gubiani et al. 2020) and enables meaningful comparisons of reproductive dynamics among countries, when relevant, while avoiding potential bias arising from mixing life-history stages with differing energetic strategies.

Sex ratio

The sex ratio is defined as the proportion of males to females within a given population, expressed as M:F. This ratio was determined for the overall sample and by country, and also by month within each country.

Gonadosomatic index and proportion of mature females

The GSI was estimated for mature females using the formula

$$GSI = \frac{Wgo}{Wg} \times 100$$

where *Wgo* is gonad weight and *Wg* is gutted weight. The analysis was conducted on females bigger than the theoretical L_{50} of 12.4 cm determined by Kouame et al. (2018). The proportion of mature and immature individuals was analysed monthly, with maturity stages 1–2 grouped as immature and 3–5 grouped as mature.

Spawning period

The spawning season was determined by analysing the seasonal changes in the monthly percentages of mature females (maturity stages 3–5) relative to the total number of females, and the monthly average GSI values of potentially mature females over a one-year period.

Maturity ogives and length at first maturity (L_{50})

The length at first maturity (L_{50}) was estimated using a logistic regression approach based on a generalized linear model (GLM), applying a non-parametric bootstrap method to obtain median L_{50} and 95% confidence intervals (Torrejón-Magallanes 2020). The logistic function used for the maturity ogive was

$$Y = \frac{1}{1 + e^{-(a+bX)}}$$

where *Y* is the probability of an individual being mature, *X* is the allometric variable (TL), and *a* and *b* are estimated regression parameters.

RESULTS

The number of sexed fishes sampled in each area is shown in Table 1. A total of 2745 individuals of *Pagellus bellottii* were analysed, comprising 1422 from Côte d'Ivoire and 1323 from Ghana. Their total length ranged from 10.0 to 32.5 cm TL, with the distributions by sex and country shown in Figure 3.

Table 1. – Total number of *P. bellottii* individuals sampled by country and sex.

Sex	Côte d'Ivoire	Ghana	Total
Females	543	512	1055
Males	876	619	1495
Total	1422	1323	2745

Note: Only a subset within the common length range (13–25.5 cm TL) was used for regression analyses (see Table 2).

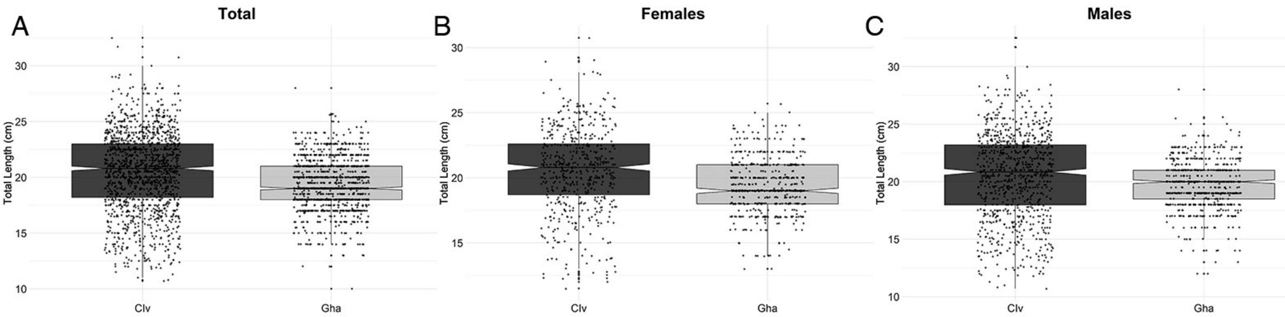

Fig. 3. – Boxplots of total length (cm) of *P. bellottii* by country (CIv=Côte d'Ivoire; Gha=Ghana), shown separately for combined sexes (A), females (B) and males (C). Grey points represent individual observations, and darker points correspond to overlaps of multiple individuals.

Length-weight relationship and condition factor

The TL–Wg relationship of *P. bellotti*, along with the respective coefficients of determination, is presented in Table 2. The table also includes the sample size and length and weight ranges for each country, categorized by sex and combined sexes. A common length range of 13–25 cm was used for this analysis in both countries. The R^2 values, which reflect the precision of the regression, indicate a good fit of the model to the data, though they were higher in Côte d'Ivoire (0.97–0.98) than in Ghana (0.87–0.88). In Côte d'Ivoire, *b* values ranged from 3.01 in females to 3.09 in males, while in Ghana they ranged from 2.82 in females to 2.90 in males. Combined-sex regressions gave *b* values of 3.06 in Côte d'Ivoire and 2.85 in Ghana.

Table 2. – Parameters of gutted length-weight relationships of *P. bellottii* in Côte d'Ivoire and Ghana estimated from the common length range (13–25.5 cm TL).

Country	Sex	N	TL range (cm)	Wg range (g)	Wt range (g)	*a*	*b*	R^2
Côte d'Ivoire	Males	759	13.0-25.0	24-223	25-238	0.010	3.090	0.98
	Females	494	13.0-25.1	27-225	30-237	0.012	3.010	0.97
	Combined	1256	13.0-25.2	24-225	30-237	0.011	3.060	0.98
Ghana	Males	606	13.0-25.3	31-229	32-241	0.018	2.900	0.88
	Females	504	13.0-25.4	33-222	25-238	0.023	2.820	0.87
	Combined	1297	13.0-25.5	31-229	32-241	0.021	2.850	0.88

The trend of the mean K values by country estimated for potentially mature females is shown in Figure 4. The lowest mean K values were observed during the fourth bimester in Côte d'Ivoire and the third bimester in Ghana, while the highest ones were recorded in the last bimester in both countries. Figure 4 also presents GSI values, which show an inverse trend to K, with lower body condition coinciding with periods of higher reproductive activity. A detailed description of GSI patterns is provided in the following section.

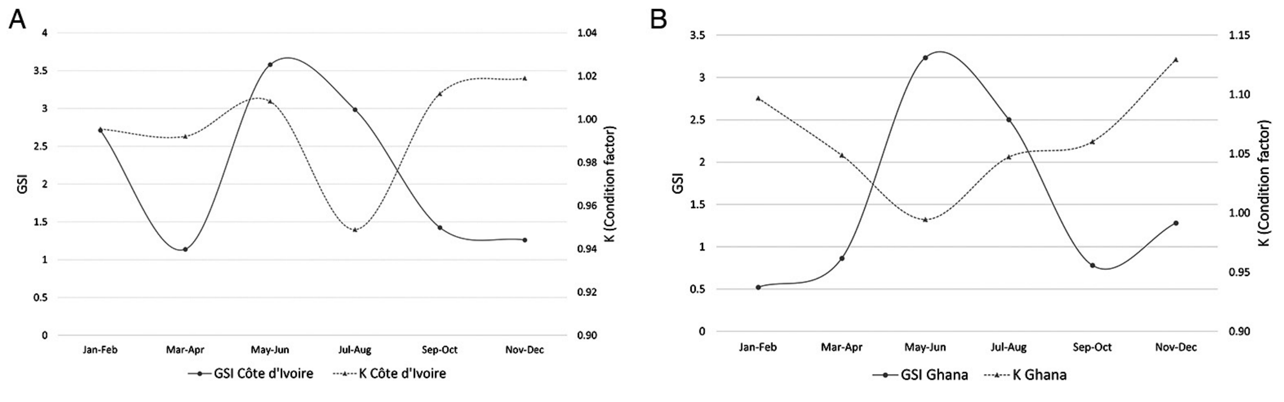

Fig. 4. – Bimonthly variation in Le Cren condition factor (K, dashed line) and gonadosomatic index (GSI, solid line) in female *P. bellottii* from Côte d'Ivoire (A) and Ghana (B).

Sex ratio

In the study area, males predominated in the exploited fraction of the population, with a sex ratio of 1:0.6 in Côte d'Ivoire and 1:0.8 in Ghana. No evidence of a sex-based difference in growth was observed, with mean lengths for females and males, respectively, of 20.6 and 20.5 cm in Côte d'Ivoire and 19.4 and 19.7 cm in Ghana. The sampled individuals were larger in Côte d'Ivoire than in Ghana. The sex ratio was analysed according to length. The length range for females was more limited in Ghana (12–24 cm) than in Côte d'Ivoire (10–28 cm). The proportion of males was generally higher in all length ranges in both countries, with the exception of individuals measuring between 16 and 18 centimetres in Ghana (Fig. 5).

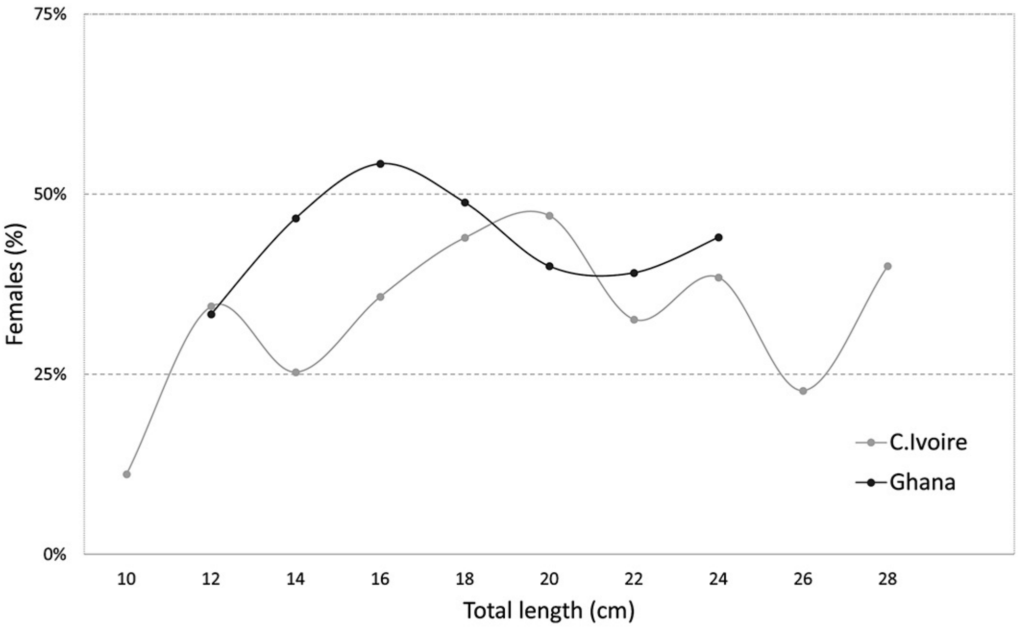

Fig. 5. – Percentage of females of *P. bellottii* by total length class (TL, cm) in Côte d'Ivoire (light grey) and Ghana (dark grey).

The monthly sex ratio of *P. bellottii* by country is shown in Figure 6. In Côte d'Ivoire, males predominated throughout the year, with the proportion of females ranging from 27.7% (August) to 47.6% (May). In Ghana, females accounted fro between 35.6% (February) and 61.8% (October). The proportion of females tended to increase slightly during the second half of the year in Ghana, while in Côte d'Ivoire no clear seasonal pattern was observed.

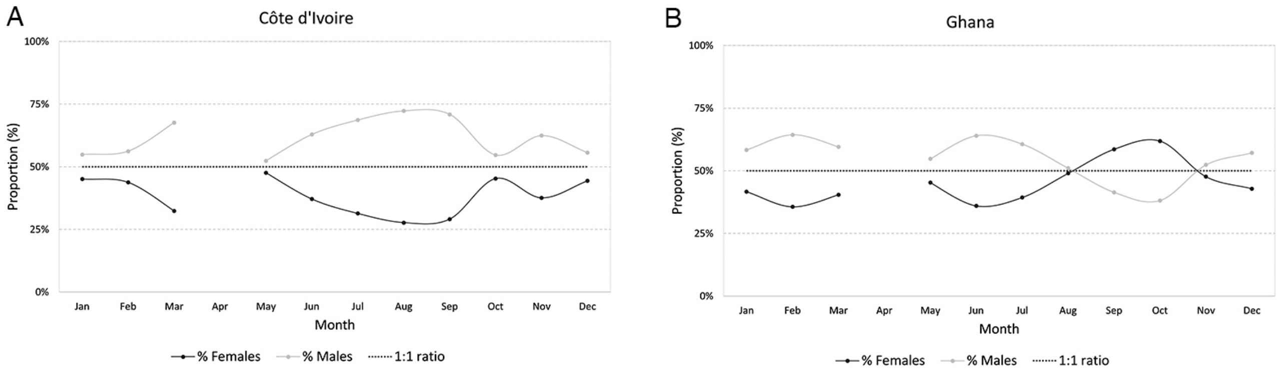

Fig. 6. – Monthly sex ratio (%) of *P. bellottii* in Côte d'Ivoire (A) and Ghana (B). The proportion of females (dark line) and males (light line) is shown for each month. The dashed line indicates the 1:1 sex ratio (50% females).

GSI and proportion of mature females

The monthly GSI values of potentially mature females, together with the percentage of mature and immature females of *P. bellottii*, are shown in Figure 7. In Côte d'Ivoire, GSI values peaked from May to September, declined in October and November, and rose again in December to February. Mature females were present throughout the year, with the highest proportions between May and September and a smaller increase in December. In Ghana, GSI exhibited a clear main peak from May to August, finishing one month earlier than in Côte d'Ivoire. This main peak was followed by a gradual decline in September and October and a secondary increase towards the end of the year. The proportion of mature females followed a similar trend, reaching its highest point from May to August and displaying another peak in November and December.

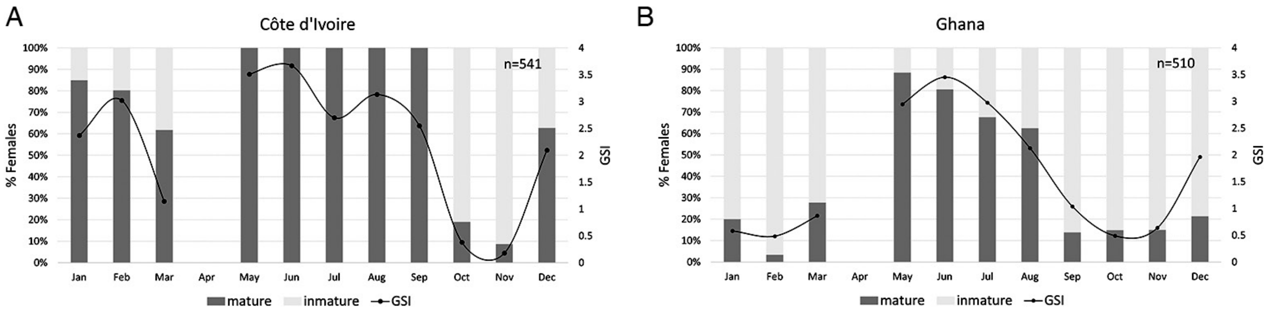

Fig. 7. – Monthly proportion of mature (dark grey) and immature (light grey) females and monthly variation in gonadosomatic index (GSI, black line) of *P. bellottii* from Côte d'Ivoire (A) and Ghana (B). Sample sizes are indicated in each panel.

Spawning period

From these patterns in GSI and maturity proportions, two reproductive peaks were identified in both countries. In Côte d'Ivoire, the main spawning peak extended from May to September, coinciding with the period of maximum GSI values and the highest proportion of mature females. A secondary, less intense peak was observed between December and February. In Ghana, a shorter main peak was identified between May and August, followed by a weaker secondary peak in November to December. As April could not be sampled in either Côte d'Ivoire or Ghana, it remains uncertain whether the main spawning peak may start earlier during that month. These findings suggest a longer and more extended spawning season in Côte d'Ivoire, whereas in Ghana the reproductive cycle appears more seasonal and clearly defined.

Maturity ogives and length at first maturity (L_{50})

The maturity ogives of females by country are shown in Figure 8. L_{50} was estimated using data from all sampled months, since mature individuals were recorded during the identified reproductive peaks. Estimates of the length at 50% maturity (L_{50}) of *P. bellottii* females were 17.8 cm TL in Côte d'Ivoire (confidence intervals: 17.2–18.3 cm) and 17.8 cm TL in Ghana (confidence intervals: 16.8–18.3 cm). Summary statistics of TL of females used for the estimation of L_{50} are shown in Table 3.

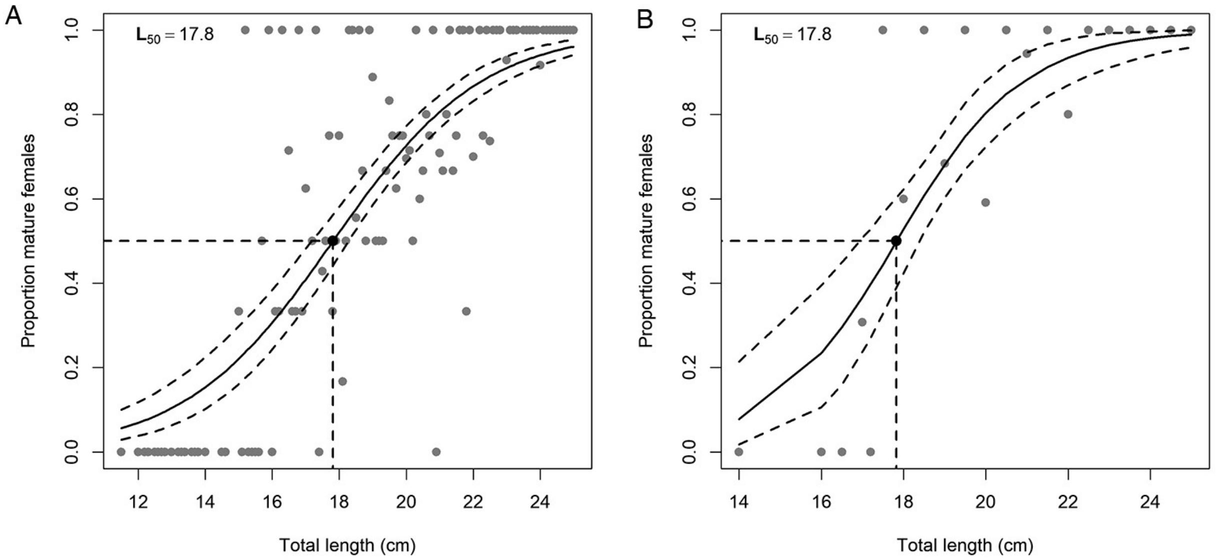

Fig. 8. – Maturation ogives for female *P. bellottii* in Côte d'Ivoire (A) and Ghana (B), fitted using a logistic regression model (GLM). Solid lines represent the estimated probability of maturity, dashed lines indicate 95% confidence intervals. The length at 50% maturity (L_{50}) is shown in each panel.

Table 3. – Summary statistics (minimum, maximum, mean, and median) of total length (TL) of *P. bellottii* females used to estimate length at first maturity.

Country	Mean TL (cm)	Median TL (cm)	Min TL (cm)	Max TL (cm)	N
Côte d'Ivoire	20.2	20.5	11.5	25	505
Ghana	19.5	19	14	25	183

DISCUSSION

This study provides important insights into the life-history traits of *Pagellus bellottii* in the Gulf of Guinea, with a focus on two major fishing countries: Côte d'Ivoire and Ghana. The parameters analysed, including the length-weight relationship, condition factor (K), sex ratio, GSI, spawning period and length at first maturity (L_{50}), are fundamental for understanding stock dynamics and for supporting fisheries management in data-limited regions.

The updated length-weight relationship of the species revealed *b* values consistent with earlier reports for the region (Amponsah et al. 2016, Kouame et al. 2020). In Côte d'Ivoire, values were close to 3, indicating near-isometric growth, while slightly lower values in Ghana suggested mild negative allometry. Isometric or near-isometric growth has also been reported in Ghana (Amponsah 2024) and Mauritania (Gandega et al. 2022). By contrast, negative allometry was described in Senegal (Ndiaye et al. 2022) and Sierra Leone (Mansaray and Konoyima 2020). Given methodological differences between studies, including the use of total versus fork length and gutted versus total weight, comparisons should focus on growth type (isometric or allometric) rather than strict numerical equivalence of *b* values.

The condition factor (K) also varied between the two countries and across seasons, reflecting energy allocation trade-offs between somatic maintenance and reproduction. In both countries, K decreased during spawning peaks, when GSI was highest, and increased during resting periods. This inverse relationship is typical for teleost fishes and supports the idea that individuals reallocate somatic energy to gonadal development during reproductive phases (Weatherley and Gill 1987, Froese 2006). Although median values of K close to 1 suggest a generally good physiological condition in both areas, consistent with previous findings in the region (Mansaray and Konoyima 2020, Ndiaye et al. 2022), slightly higher values were observed in Ghana than in Côte d'Ivoire, suggesting ecological differences between countries as K is shaped by food availability, environmental conditions and physiological processes such as gonadal development (Bolger and Connolly 1989).

Sex ratio analyses demonstrated a predominance of males in the samples of both study areas, with females comprising 38% and 45% of the samples in Côte d'Ivoire and Ghana, respectively. This pattern in the sex ratios is in line with previous studies across West Africa, suggesting male-biased populations may be a characteristic feature of *P. bellottii* demography in the region (Mansaray and Konoyima 2020, Gandega et al. 2022, Ndiaye et al. 2022). The monthly analysis of sex ratio revealed fluctuations. In Ghana, the proportion of females increased from September to October, which is similar to the seasonal reversals occasionally noted in Senegal (Ndiaye et al. 2022). This increase coincided with the end of the main reproductive peak and the onset of the secondary spawning season. By contrast, in Côte d'Ivoire, female proportions remained consistently low during the spawning months (June-August), which suggests possible sex-specific differences in reproductive investment, migration or catchability. These seasonal variations highlight the importance of considering temporal and spatial factors when analysing sex ratios, rather than relying solely on aggregated data for the entire study period.

Although *P. bellottii* has been described as a protogynous hermaphrodite in other West African regions, notably in Senegal where hermaphrodite individuals between 16 and 22 cm TL have been observed (Ndiaye 2014), no signs of hermaphroditism were detected in our samples from Côte d'Ivoire and Ghana. This absence is consistent with previous findings in these countries (Kouame et al. 2018, Asabere-Ameyaw 2000, Amponsah 2024).

The presence of mature females throughout all sampled months in both fishing grounds suggests that *P. bellottii* maintains continuous reproductive activity in the Gulf of Guinea, consistent with previous observations in Ghana (Rijavec 1973). The GSI is extensively used to assess reproductive investment and identify spawning peaks (De Vlaming et al. 1982, Murua and Saborido-Rey 2003). However, since GSI alone does not confirm actual spawning activity, it is best interpreted in combination with the proportion of mature females, typically assessed macroscopically or histologically (Brown-Peterson et al. 2011). This combined approach enabled the identification of two distinct reproductive peaks of *P. bellottii* in both Côte d'Ivoire and Ghana. The first and main peak occurred between May and August/September and was more extended in Côte d'Ivoire. The possibility of an earlier onset of this main peak in April remains unconfirmed, as sampling could not be conducted during that month due to restrictions imposed by the COVID-19 pandemic. A secondary peak was identified from December to February, although it was shorter in Ghana, where it occurred between November and December.

The reproductive pattern of *P. bellottii* observed in this study aligns with previous findings. In Ghana, Amponsah (2024) reported a main reproductive period from March to September and a secondary one from November to

January. Asabere-Ameyaw (2000) also described a major peak from June to September and a minor one in January to February. In Côte d'Ivoire, Kouame et al. (2018) identified a comparable pattern, with peaks in April–September and December–February. A comparable reproductive seasonality has also been reported in Senegal, with some variation between studies (Ndiaye 2014, Ndiaye et al. 2022). In Mauritania, the spawning period extends from July to December for females and from August to November for males (Gandega et al. 2022).

The reproductive dynamics of *P. bellottii* appears closely linked to environmental conditions, particularly to seasonal upwelling events. Previous studies on the West African coast indicate that spawning occurs mainly during periods of hydrographic transition, with two peaks observed annually (Franqueville 1980, Kouame et al. 2018). The spawning peaks observed in our study coincide with periods of enhanced planktonic productivity induced by coastal upwelling and riverine input, which provide optimal conditions for spawning and larval development (Quenum et al. 2024). During the upwelling periods, cooler and nutrient-rich sub-thermocline waters rise to the surface, enhancing productivity in the nutrient-depleted but well-lit surface layers (Hardman-Mountford 2000). This increased nutrient input fuels high biological activity, including significant rises in phytoplankton and zooplankton production, creating favourable conditions for fish reproduction (Houghton and Mensah 1978, Koranteng 1998). In the Gulf of Guinea Large Marine Ecosystem (GGLME), the main upwelling occurs from July to September and a secondary upwelling from January to February (Koranteng 1998, Owiredu 2014). Thus, the first spawning peak observed in our study corresponds to the major upwelling season, while the secondary peak is likely associated with the minor upwelling event. Interestingly, in Ghana, fishery catches also tend to peak during this minor upwelling season (December-January), reinforcing the link between environmental productivity, spawning success, and fishery yields (Amponsah et al. 2016, Asabere-Ameyaw 2000). The main physical mechanisms driving the Central West African Upwelling Subsystem (CWAU), which underpin these hydrographic conditions, are illustrated in Figure 9 (adapted from Thiam et al. 2024). These processes influence the timing of the spawning peaks described above. Differences in the duration and intensity of these peaks between Côte d'Ivoire and Ghana may be attributed to local variability in upwelling dynamics and freshwater input (Quenum et al. 2024). Although the upwelling is more intense in Ghana, overall ecosystem productivity has been reported to be higher in Côte d'Ivoire (Djagoua et al. 2011), which may help explain the more extended spawning season observed there.

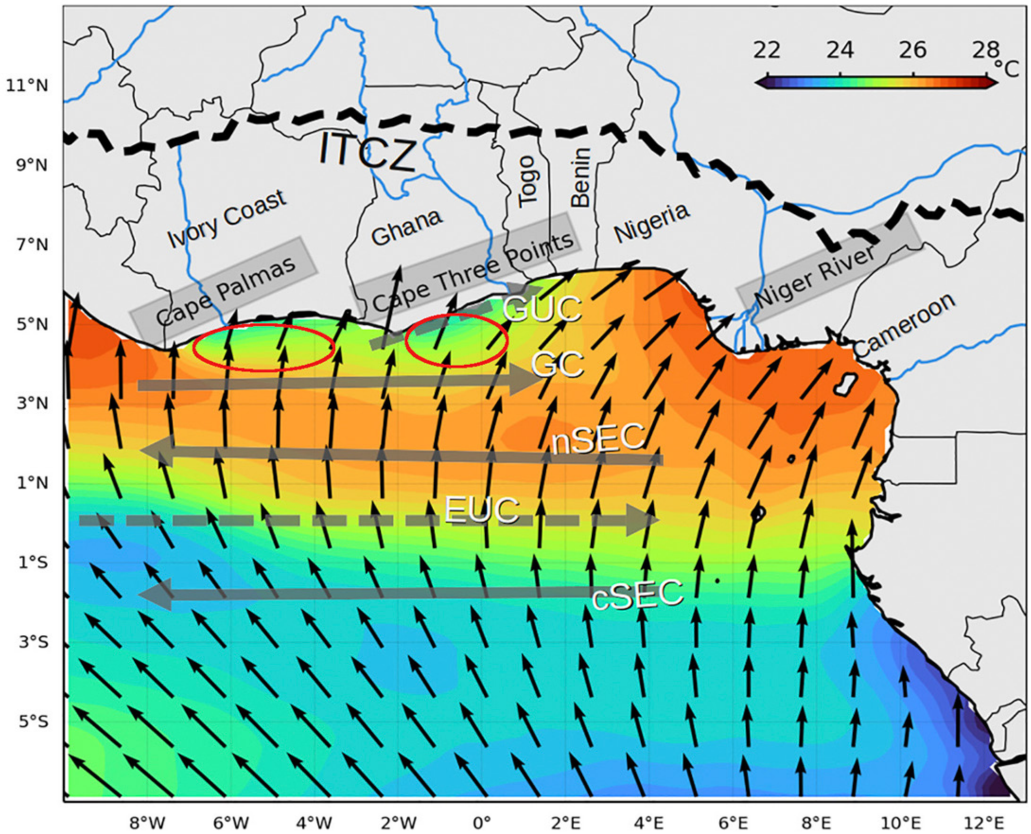

Fig. 9. – Location and main oceanographic features of the northern Gulf of Guinea, including sea surface temperature (°C), major currents (Guinea Current, GC; Guinea Under Current, GUC; Equatorial Under Current, EUC; northern and central branches of the South Equatorial Current, nSEC and cSEC), and the Intertropical Convergence Zone (ITCZ). Black arrows indicate surface winds associated with the West African Monsoon, and grey arrows represent oceanic currents. Coastal upwelling zones off Côte d'Ivoire and Ghana are indicated in red. Adapted from Thiam et al. (2024).

The L_{50} for females of *P. bellottii* estimated in this study (17.8 cm TL) is consistent with values reported in Senegal (17.8–17.9 cm; Ndiaye et al. 2022), but higher than those reported in earlier studies in Côte d'Ivoire and Ghana. For example, Kouame et al. (2018) estimated L_{50} at 12.41 cm (fork length) in Côte d'Ivoire, while Rijavec (1973) and Amponsah et al. (2016) reported 12–13 cm in Ghana. Conversely, more recent studies have reported larger values, such as 20.0–20.8 cm in Ghana (Amponsah 2024), 19.6–20.0 cm in Mauritania (Gandega et al. 2022) and 22.4 cm in Sierra Leone (Konoyima and Seisay 2021). This wide variation in L_{50} estimates across regions and years may reflect differences in sampling strategy, population structure or reproductive plasticity in response to environmental changes. Oceanographic conditions, particularly upwellings, can modulate growth and energy allocation, thereby influencing maturity schedules. Ndiaye (2022) also suggested that inconsistencies in the reproductive dynamics of this species may vary geographically due to ecological factors and fishing pressure.

Furthermore, it should be noted that the estimation of L_{50} in this study is subject to certain limitations. The use of data from all months rather than restricting the analysis to reproductive periods may have biased ogives, as females in resting stages could have been misclassified as immature. This issue was especially evident in Côte d'Ivoire, where the ogive shows signs of irregularity. In addition, reliance on macroscopic staging can lead to misidentification of resting adults (Brown-Peterson et al. 2011). These methodological limitations underscore the need for cautious interpretation of the L_{50} estimates and for future histological validation. Further research is also needed to assess the potential influence of fishing pressure on maturation patterns.

A synthesis of regional studies (Table 4) highlights the variability in reproductive traits across West African populations of *P. bellottii*. L_{50} values ranged from 12.2 to 22.4 cm TL and spawning peaks were generally biannual, with major and minor periods. Hermaphroditism was confirmed only in Senegalese populations (Ndiaye 2014). These findings emphasize the importance of localized studies for accurate biological assessments and fisheries management.

Table 4. – Comparative summary of reproductive parameters of *P. bellottii* in West African countries, organized by country and year. TL =total length; FL=fork length; * When not directly estimated, L_{50} was calculated as 2/3 × L_∞, following Hoggarth et al. (2006); † FL.

Study	Country	Year (data)	N	Length Range (TL cm)	Sex Ratio (M: F)	Spawning Peak	Spawning Periods	Hermaphroditism	L_{50} (cm TL)
Gandega et al. 2022	Mauritania	2020	516	11–30 FL	1:0.88	August (GSI ♀)	Jul–Dec ♀ / Aug–Nov ♂	–	19.6 ♀ / 20.04 ♂
Ndiaye 2014	Senegal	1992–1993, 2004, 2008–2014 (punctualy)	581	12–31	–	March, Oct (GSI ♀)	Jan–Jun / Aug–Dec	Yes (16–22 cm)	16.75 ♀ / 16.76 ♂
Ndiaye et al. 2022	Senegal	2019–2020	360	11.2–32.6	1:0.82	April (GSI ♀)	Mar–Jun	–	18.0 ♀ / 17.8 ♂ TL
Mansaray and Konoyima 2020	Sierra Leone	2018	135	9–28.5	1:0.4	–	–	–	–
Konoyima and Seisay 2021	Sierra Leone	2016	8216	–	–	–	–	–	22.4*
Kouame et al. 2018	Côte d'Ivoire	2016–2017	386	9–25 FL	1:0.9	June (GSI ♀)	Apr–Sep / Dec–Feb	Not confirmed	12.41 ♀ / 13.33 ♂ †
Present study	Côte d'Ivoire	2020–2021	1422	10.7–32.5	1:0.6	June (GSI ♀)	May–Sep / Dec–Jan	Not confirmed	17.8 ♀
Rijavec 1973	Ghana	1969–1970	5059	–	Predominant males	Jun, Jan (GSI ♀)	Year–round	–	12.22 ♀ / 13.06 ♂
Asabere–Ameyaw 2000	Ghana	1993–1995	–	–	–	Jun–Sep / Jan–Feb	Major and minor periods	–	20.0 ♀ / 21.0 ♂
Amponsah et al. 2016	Ghana	2014–2015	440	–	–	July (GSI)	–	–	13.0 *
Amponsah 2024	Ghana	2019	933	7–33.9	1:0.7	May, July (GSI ♀)	Mar–Sep / Nov–Jan	–	20.0 ♀ / 20.8 ♂
Present study	Ghana	2019–2021	1323	10.0–28.0	1:0.8	June (GSI ♀)	May–Aug / Nov–Feb	Not confirmed	17.8 ♀

Ecological and fishing context also shape population traits. Sampled individuals were larger in Côte d'Ivoire than in Ghana, likely due to the predominant fishing techniques used in each country for exploiting sparids, including *P. bellottii*. In Ghana, fishing is primarily undertaken by the artisanal sector using hooks and lines, bottom-set nets, and a gear known as *ali/poli/watsa*, which is a combination of materials from the *ali*, *poli* and *watsa* nets. This gear has been specifically developed for use by artisanal fishers and is known loosely as a "mixed net" (Ferraris et al. 1995, Koranteng 1995, Amponsah et al. 2016). In contrast, the majority of fish in Côte d'Ivoire are exploited by semi-industrial and industrial fleets operating with bottom trawls (FAO 2019). This indicates that fish from the two countries are exploited at different depth ranges inhabited by different fractions of the population: smaller individuals in or near the estuaries, where they are fished by artisanal fleets, and larger individuals in deeper waters, where they are fished by bottom trawls.

In this region, *P. bellottii* is regarded as a relatively sedentary species, manifesting only seasonal inshore migrations to shallower waters (approximately 25 m depth) during the upwelling season and remaining in deeper zones (45–55 m) during periods of hydrographic stability and strong thermoclines (Rijavec 1973). The variability observed in reproductive traits across regions may reflect local ecological influences, such as differences in upwelling intensity in Ghana and overall habitat productivity in Côte d'Ivoire (Djagoua et al. 2011). However, given the geographic proximity and shared biological characteristics of these populations, such ecological influences likely modulate rather than define population differences. Variability within populations is probably greater than that between countries. Thus, while environmental context may shape certain reproductive parameters, our results should not be overinterpreted as evidence of population-specific adaptations.

In conclusion, this study provides essential, updated and regionally comparable biological data for *P. bellottii* in two key fishing areas of the Gulf of Guinea. While some reproductive traits, such as the timing of spawning peaks and the estimated length at first maturity, showed similarities, other parameters, including length-weight relationship, condition factor, sex ratio and GSI trends, revealed differences likely reflecting local environmental and fishing conditions. Our work provides valuable inputs for stock assessments and a scientific basis for the refinement of fisheries management strategies. The implementation of region-specific management strategies, in conjunction with continuous biological monitoring, is imperative to ensure the long-term sustainability of *P. bellottii* stocks and the livelihoods they support in West Africa.

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DECLARATION OF COMPETING INTERESTS

The authors of this article declare that they have no financial, professional or personal conflicts of interest that could have inappropriately influenced this work.

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Blanca Partida: Data Curation, Formal analysis, Investigation, Methodology, Visualization, Writing - original draft, Writing - review and editing. **Eva García Isarch:** Conceptualization, Data Curation, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing - review and editing. **Coulibaly Bakari:** Data curation, Investigation, Resources, Writing - review and editing. **Ivone A. Czerwinski:** Formal Analysis, Investigation, Methodology, Visualization. **Ernest Ansong:** Data curation, Investigation, Resources. **Joanny Tapé:** Funding acquisition, Investigation, Resources. **Julius Afetorgbor:** Data curation, Investigation, Resources. **Jorge Landa:** Investigation, Methodology.

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