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FEED THE FUTURE GHANA FISHERIES RECOVERY ACTIVITY

2022 CLOSED SEASON IMPACT ASSESSMENT REPORT

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Feed the Future Ghana Fisheries Recovery Activity
Biological and Socioeconomic Assessment of 2022 Close Season

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COVER PHOTO: Positioning of fish to measure its folk length.

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CECAF	Fishery Committee for the Eastern Central Atlantic
CFS	Canoe Frame Survey
CPUE	Catch-Per-Unit-Effort
CSO	Civil Society Organization
DA	District Assembly
EEZ	Economic Exclusive Zone
FAO	Food and Agricultural Organization
FC	Fisheries Commission
FMOC	Fisheries Management Operational Committee
FSSD	Fisheries Scientific Survey Division
GFRA	Ghana Fisheries Recovery Activity
GSI	Gonadosomatic Index
IEC	Information Education and Communication
MOFAD	Ministry of Fisheries and Aquaculture Development
MSY	Maximum Sustainable Yield
NGO	Non-Governmental Organization
SFMP	Sustainable Fisheries Management Project
STC	Scientific and Technical Committee
STWG	Scientific and Technical Working Group
USAID	United States Agency for International Development

EXECUTIVE SUMMARY

Since 2019, the annual fisheries closed season is one of the fisheries management measures taken by the Ministry of Fisheries & Aquaculture Development (MoFAD) and the Fisheries Commission (FC) towards the recovery of the depleted small pelagic fish stocks of Ghana. The 2022 closed season occurred between July 1 - 31, 2022 for all artisanal and industrial fishing vessels (except for licensed tuna vessels) in the maritime economic exclusive zone (EEZ) of Ghana, and an additional month from August 1 – 31, 2022 for industrial fishing vessels. The purpose of this management measure is to prevent further decline of the small pelagic fish stocks by giving fish the ability to breed during their annual peak spawning period before fishermen can harvest them.

The USAID Feed the Future Ghana Fisheries Recovery Activity (GFRA) supported the FC to develop and implement a monitoring plan to assess the biological and socioeconomic impact of the 2022 closed season. Data was collected to assess the impact before and after the closed season. For the biological assessment, sampling was done three months before the closure (April, May, June) and three months after the closure (August, September, October). For the socioeconomic assessment, data collection was done one month before the closure (June), one month during the closure (July), and one month after the closure (August). This report summarizes the main results of the biological and socioeconomic impact assessments of the 2022 closed season and presents recommendations for the successful implementation of the 2023 closed season.

The biological assessment showed that fish catches were relatively higher after the closed season and mean sizes of all the three species (round sardinella, flat sardinella, and anchovies) showed a significant increase after the closure. The assessment also confirmed that the peak reproductive season for these fisheries was likely in August and September. The biological assessment showed higher proportions of immature ovaries were observed before the closed season while more matured ovaries were observed after the closure. Ovaries that have released their eggs, also known as spent ovaries, were also generally observed after the seasonal closure. These findings confirm that fish stocks indeed did receive a break from fishing pressure during the closed season which allowed them to reproduce and release their eggs, thereby giving the stocks a short rebound through the addition of young fish into the fishery.

The socioeconomic assessment revealed that fishers have limited aspirations for and access to livelihood during the closed fishing season. The majority of fishers (76% and 62% of the fishermen and fish traders respectively) interviewed before the closed season said they did not intend to engage in any other economic activity during the closed season. The remaining who wanted to look for work preferred non-skilled livelihood options such as petty trading, including selling of sachet water or food vending. When asked about employability, the majority of respondents (80%) felt that they had no other employable skills outside of fishing nor did they have access to social networks to help them find jobs.

The socioeconomic assessment also examined the effect of the closed season on income and food security. The closed season had a positive effect on respondents' dietary diversity, and by correlation, their income. The closed season had no effect on food poverty, meaning that it did not make food insecure households worse off or better off. This contradicts the commonly held perspective among fishers that the closed season negatively affects their ability to feed their families. Instead, the study identifies other important determinates of fisher household food poverty – namely large household sizes and income levels prior to the closed season. Finally, respondents from Greater Accra were the anomaly, registering negative impacts of the closed season on both dietary diversity and food poverty. As a result, the assessment recommends more research to better understand the unique socio-economic characteristics and circumstances facing fishers in that Region.

The closed season is just one of many tools in a fisheries managers' toolkit to reduce fishing pressure. The Fisheries Management Plan (2022-2026) outlines a number of actions that must be taken to sustain Ghana fisheries, including limiting the number of boats through a moratorium on new canoes in the fishery and enforcing the nation's existing fisheries rules to reduce illegal fishing. Now that the closed season has become a regular annual rest period to allow pregnant fish to spawn, it is time to focus on implementation of these additional fisheries management measures to fully recover Ghana's fisheries. Most importantly, reducing illegal fishing methods that target juvenile fish will ensure new fish entering the fishery during the closed season are not immediately caught when fishers return to sea.

1.0 BACKGROUND

On March 24, 2022, the Minister of Fisheries and Aquaculture Development (MoFAD) announced Ghana's 2022 closed fishing season for July 1 – August 31, 2022. The monthlong closure in July applies to all forms of fishing including the artisanal, semi-industrial, industrial fishing vessels and beach seines from shore, while the monthlong closure in August applies only to industrial fishing vessels. The purpose of this management measure is to prevent further decline of the small pelagic fish stocks by allowing fish to reproduce during the fisheries annual peak spawning, or breeding, period before fishermen can harvest them. The scientific evidence and the identification of the peak spawning season of the small pelagics was provided by the Fisheries Scientific Survey Division (FSSD) of the Fisheries Commission in their research on the biological and socioeconomic impact of the 2021 closed season. This research and its implications on the 2022 closed season were presented at a national stakeholder consultation to ensure all stakeholders were aware of the results and engaged on next steps. The research suggested that implementation of the closed season should coincide with the major upwelling period (July to September), which provides the greatest spawning activity for the small pelagic and demersal species. This informed the decision to instate a one-month closure for all species and two months for demersal species.

The announcement of the seasonal closure is a comprehensive management measure, fair and equitable in its implementation to all segments of small pelagic and demersal fisheries, except for large pelagics/tuna fishery. Implementation of a closed season is backed by Ghana's fishery regulatory framework and fully described in sub-part VII-84 of the 2002 Fisheries Act-625. The objective of the closed season is to rebuild depleted fish stocks and maximize the spawning, or reproductive, potential of the stock. The long-term goal is to increase the total biomass and yield of the small pelagic fisheries and improve the artisanal fishery sector for the benefit of more than 3 million Ghanaians that depend on this resource for its livelihood and food security.

Policymakers recognize that any fishery closure will have a short-term negative impact on fishers, especially those that cannot find other sources of income when they are not fishing. However, business as usual is no longer an option for Ghana's fisheries development and food security. The small pelagic fishery is an extremely important economic activity for the country's coastal communities and a key source of protein for many Ghanaians. However, this fishery is currently facing a near collapse status due to overfishing caused by lack of

managed access and excess fishing capacity. Available data (fig. 1) shows a continuous decline in total landings resulting in the loss of income for thousands of fishermen and fish processors.

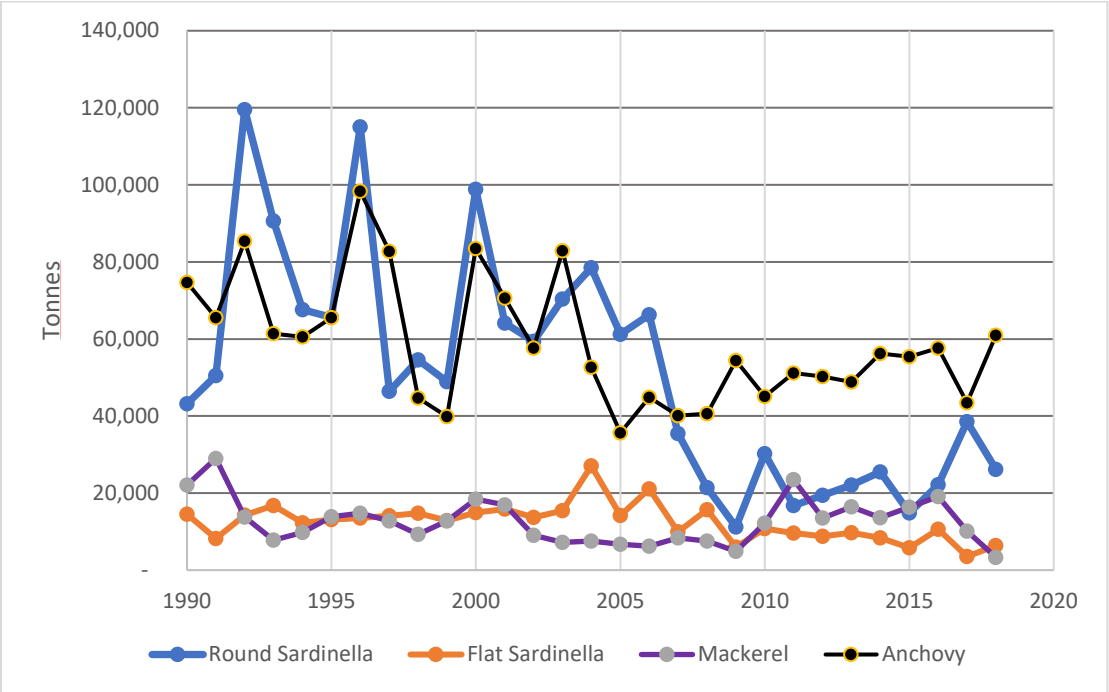

Figure 1 Annual landings of small pelagic stocks (FC, 2019)

A 2019 report produced by the Science and Technical Working Group (STWG) revealed that annual landings of small pelagic species, consisting of round sardine (*Sardinella aurita),* flat sardine (*Sardinella maderensis),* anchovies (*Engraulis encrasicolus)* and mackerel (*Scomber colias),* have declined to the lowest level in the time series between 1990 and 2019. The total landings recorded in 2019 represented about 41% of the highest recorded landings in 1993. These results spurred MOFAD and FC into action in 2019, resulting in the first closed season in Ghana's waters and the management measure has been implemented continuously since, with the exception of 2020 when it was suspended as a COVID 19-related economic relief measure.

2.0 OBJECTIVE

No fisheries management measure is effective without good data to understand the impact of the measure and guide adjustments that might be needed to improve the measure's efficacy. Thus, with GFRA support, the FC instituted a closed season monitoring and evaluation plan to provide a systematic assessment of its implementation, measure its outcomes, and guide modifications to the design of future seasonal closures. The plan took the form of two

assessments – a biological assessment of the impact the closed season had on fish populations and a socio-economic assessment of the impact of the closed season on fishers and fish traders. The biological study specifically monitors fish size distribution to understand the impact of the closed season on fish growth and monitors the size of fish gonads (reproductive organs) to ascertain the fishery's peak reproductive activity and the impact on growth. The socio-economic assessment specifically investigates livelihoods opportunities for fishermen and fish traders in fishing communities during and outside of the closed season, how these opportunities affect fishing households' support for the closed season and analyzes the effect of the closed season on hunger and food poverty dynamics among fishing households.

3.0 METHODOLOGY

A basic non-experimental sampling procedure using a *before-and-after* statistical design (OxO) was used for evaluating the biological and socio-economic impacts of the closed season (fig. 2). This method is most useful in demonstrating the immediate impacts of short-term management measures. With this design, data collection begins at least two months before the seasonal closure to establish a solid "before" situation and continues for at least two months after the seasonal closure to establish the "after" situation. The duration of monitoring efforts should be the same during the before and after situation to allow for equitable comparisons. However, the biological assessment data collection design allowed for a rapid assessment for the three months after the closed season and a full impact evaluation for the six month period after the closed season. The six-month period is important because it links the monitoring to the time period for recruitment of fish species to the fishery, which is 6 months for sardines and anchovies.

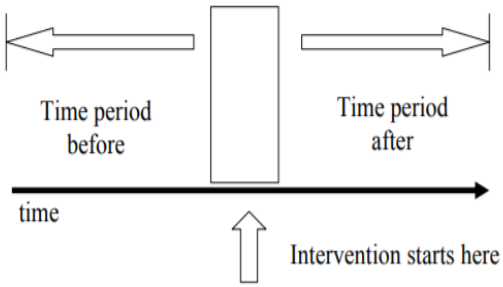

Figure 2: Before and after design diagram.

GFRA organized training for enumerators on the sampling protocols to enhance their skills in data collection. Whereas skilled volunteer enumerators were used for the socio-economic assessment, FC enumerators were used for the biological assessment of the closed season. Separate trainings on the biological and socio-economic sampling protocols were conducted

for different sets of enumerators using a similar training style combining classroom and field-based learning. Enumerators were guided to pre-test the protocols during the field training.

Figure 3: An enumerator pre-testing socio-economic questionnaire with a fisher (left). Enumerators trying to identify the gonadal stage of a fish during training on biological data collection protocol (right).

3.1 Biological Impact Assessment Methodology

To assess the biological impacts of the closed season, fish samples were collected and analyzed in each of Ghana's coastal regions at four major landing sites, Keta, Tema, Elmina and Sekondi. A bi-weekly sampling regime was deployed to collect biological parameters indicative of growth and reproductive patterns needed to ascertain the size distribution and the maturity stages of fish ovaries on the four key small pelagic species. The parameters measured were fish length (cm), fish weight (g), sex of fish, gonad (ovaries/testes) weight (g) and maturity stage of gonad. Fish specimens were classified into three maturity stages based on macroscopic gonadal characteristics. Specimen with gonads within stages I and II were classified as immature, stage III and IV as matured and stage V as spent. The spawning periods of the species were ascertained using a gonadosomatic index (GSI = (GW/W) x 100) as the indicator for the species reproductive activity and to determine the peak spawning period. Data on canoe fish catch and effort (Catch per trip), value per trip and mean price of fish per kg were also collected for further analysis.

3.2 Socioeconomic Impact Assessment Methodology

The socioeconomic assessment of the closed season involved primary data collection via a questionnaire administered to fishermen and fish traders in all four fishing regions in the country. The first round of data collection was before the closed season in June, the second was in July during the closed season, and the final round was in August when the fishing season opened. The targeted sample size was 663 respondents, based on population size of fishermen and fish processors (107,518 fishermen and about 20,000 fish traders). However, a total of 800 respondents (560 fishermen and 240 fish traders) were targeted to accommodate the potential for non-responses and attrition across the data collection period given that

Figure 4: A fisherman observing the collection of simple biological protocols in Tema (Left) and an enumerator collecting data in Sekondi (Right)

migration among artisanal fisherfolks is quite high. The study covered six fishing districts: Keta, Tema, Elmina, Mfatsiman, Shama, and Nzema. The selection of districts and landing beaches were based on the relative fishers' population size.

The questionnaire included questions on respondent's demographic characteristics, their acceptance of the timing and duration of the closed fishing season, alternative income sources, employability opportunities, household dietary diversity, household food and non-food expenditures, food security, household assets, savings, child labor and gender-based violence.

To analyze the diversity of food intake by fishers after and before the closed season, researchers employed the Shannon diversity index and a model for the food poverty line developed by Greer and Thorbecke (1985). These models are discussed in Annex A.

4.0 RESULTS

4.1 Biological Assessment

4.1.1 Changes in Catch Rate and Value

The landings of small pelagics, especially round sardinella and anchovy, increased post closed season. Anchovy is the dominant pelagics species found in these landings. The mean catch rate of round sardinella, and anchovy increased after the closed season whilst that of flat

sardinella deceased after the closed season (fig. 5). However, this cannot be attributed to the closed season as flat sardinella reproduction generally lags behind round sardinella and the data is showing this natural pattern.

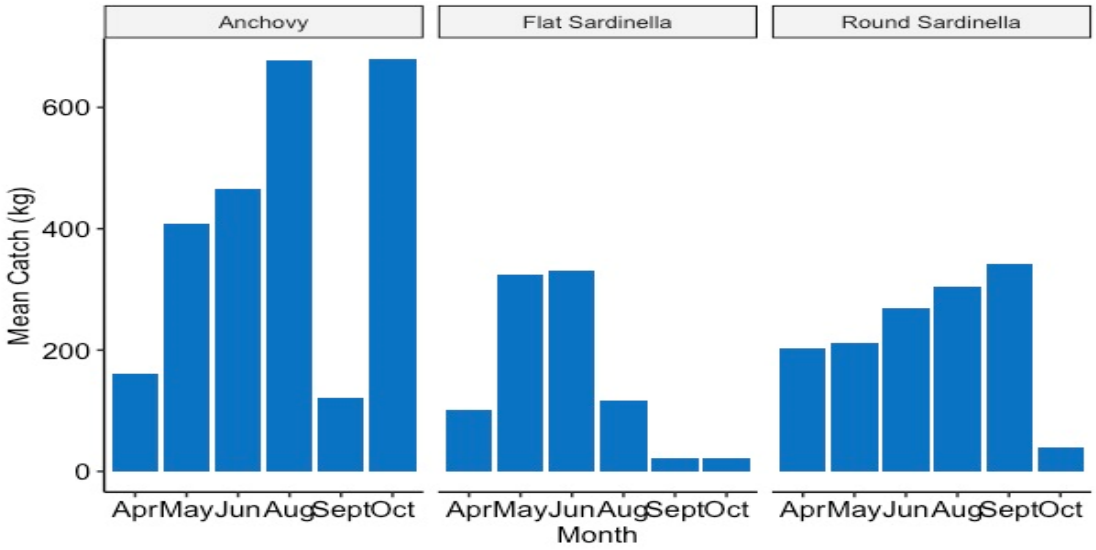

Figure 5 Mean catch rate of the small pelagics.

The mean price per Kg of all small pelagic species increased after the closed season (Table 1). The average price index increased by 2.8% for round sardinella, 23% for flat sardinella, and significantly increased by 96% for anchovy. With this data, it is clear that the closed season has an impact on fish prices.

Species	Catch (Kg)/Trip		Value/Trip (GHS)		Mean Price (GHS)\Kg	
	Before	After	Before	After	Before	After
Round sardinella	223.9	287.2	2140.8	3013.6	11.38	11.7
Flat sardinella	222.1	73.8	1401.1	736.7	10	12.3
Anchovy	269.3	400.3	672.9	713.8	2.8	5.5

Table 1. Catch Rate, Price, and Value per Kg of round sardinella, flat sardinella and anchovy before and after closed season.

4.1.2 Mean Length Distribution

The mean sizes of round sardine, flat sardine and anchovies observed after the closed season were significantly higher than sizes before the closed season (fig. 6).

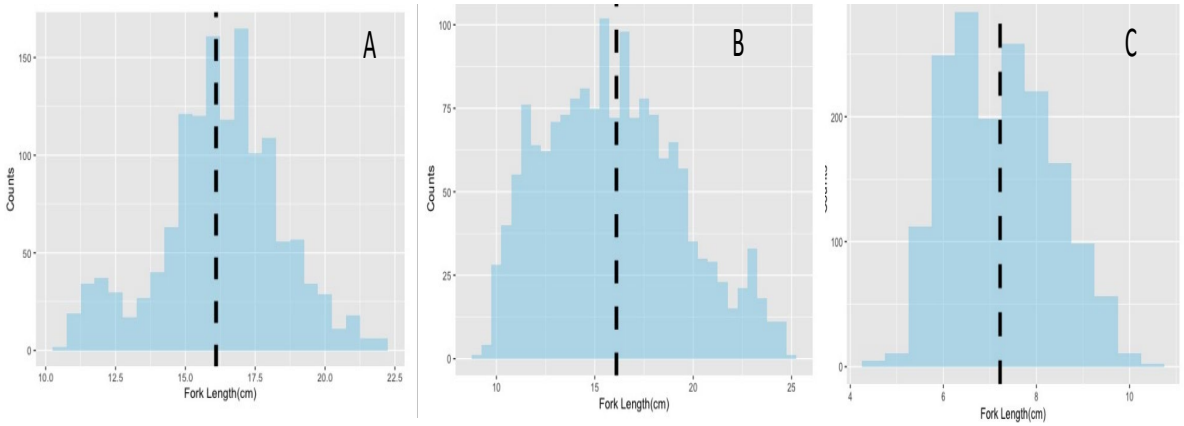

Figure 6 Length frequency distribution of round sardines (A), flat sardines (b) and anchovies (c) across the coastal waters of Ghana

This indicates that the stocks had the opportunity to rest from fishing pressure and experienced a short-term rebound. For all months, however, round, and flat sardines recorded mean sizes below the minimum landing size of 18 cm (Table 2). This suggests that fishers are still catching too many small fish, by deploying gears with smaller mesh sizes or by using light fishing, making the benefits of the closed season short lived.

	Anchovy	Round Sardine	Flat Sardine
April	6.7±0.9	15.6±1.6	15.8±4.2
May	7±0.9	15.0±2.5	16.7±2.8
June	6.3±0.3	15.1±2.3	16.3±1.6
August	7.7±0.6	16.8±1.3	16.5±4.2
September	7.9±1.2	16.1±1.0	17.9±2.3
October	7.5±0.6	18.0±0.7	16.8±3.6

Table 2 Mean lengths of small pelagics recorded before and after the closed season.

4.1.3 Proportion of Matured gonads and Spawning Periods

The biological assessment deployed the Gonodosomatic Index (GSI)[1] as an indicator of a fish reproductive activity. The GSI assessment for all three species showed a significant increase after the closed season. (fig. 7), confirming earlier observations that the spawning period for small pelagics peaks during August and September. Analysis of the gonadal developmental

[1] GSI is the ratio between the gonad weight and the total weight of the individual.

stage of the collected fish samples revealed that a higher proportion of immature gonads were found in the period before the closed season (April to June). Spent gonads were mostly encountered during August after the season closure. This is an indication that the closed season represented a rest period for these species, allowing more of the gonads to mature and therefore increasing recruitment of juveniles into the fishery. However, it also suggests that an August closed season for all fishing sectors would be more effective for ensuring high levels of spawning than July.

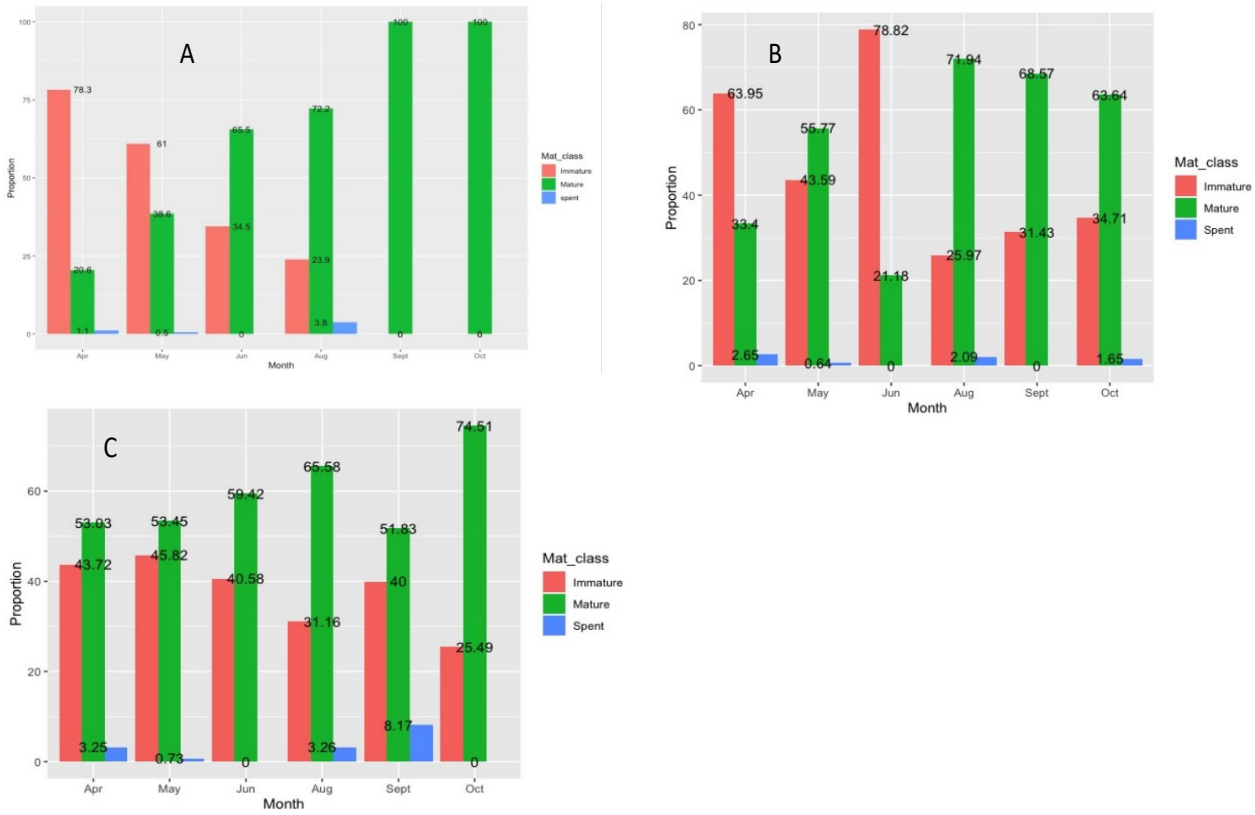

Figure 7 Maturity stages of gonads of round sardine (A) flat sardine (B) and anchovies (C) before and after the close season

4.2 Socioeconomic

A total of seven hundred and twenty-two (722) fishers were interviewed. A third (33%) of the respondents were females and the remainder were fishermen. On average, slightly more than one-half (51%) did not agree with the closed fishing season policy. Yet, a majority (88% of fish traders and 78% of fishermen) agreed that the closed season should be adhered to when in effect. Among both groups, July was indicated as the preferred month for the closed season. A majority of the respondents (78%) agreed with the one-month closure while a few (6%) opted for an extended period.

This indicates that although fishers do not like the management measure because it will deprive them of their livelihood during the period of implementation, they recognize that the closed season will contribute to the rebuilding of the fish stocks. It is also interesting to note that a majority of fishers (fig. 8) see IUU fishing as the main driver of the decline in fish stocks.

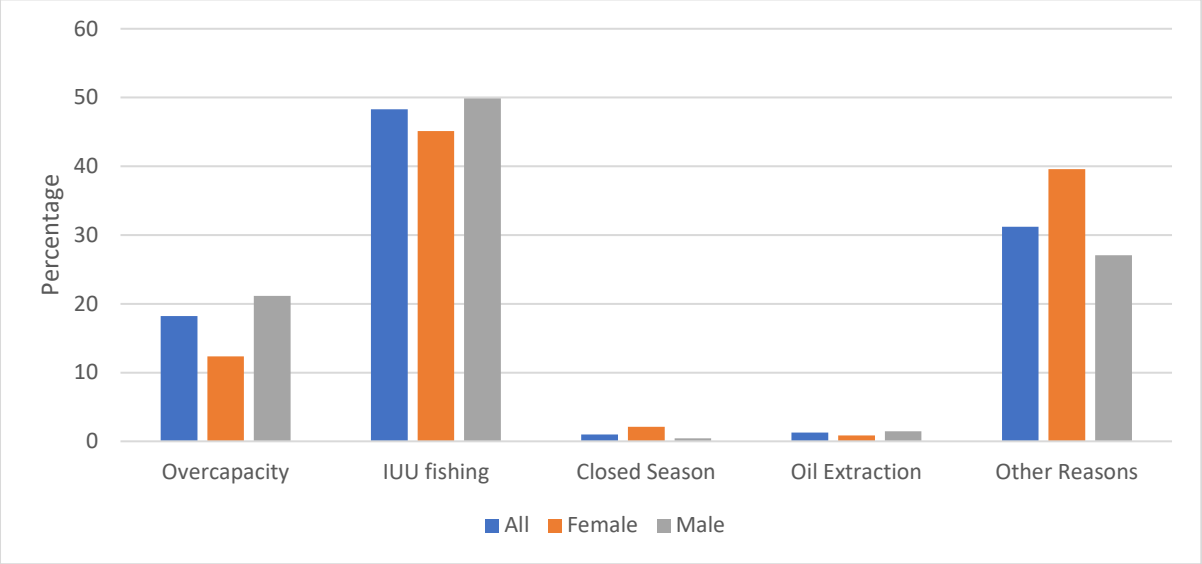

Figure 8 Reasons given by respondents for stock decline over the last five years.

4.2.1. Livelihoods

Regarding supplemental livelihoods, less than a third of the fishers had alternate sources of income while fish traders had more options. During the interviews that took place before the closed season, fishermen and fish traders were asked to identify an economic activity they intended to engage in during the closed fishing season. In response, 76% of fishermen and 62% of fish traders said they did not intend to engage in any economic activity. For those few who were interested in engaging in other livelihoods, petty trading was the most preferred among the fish traders. The fishermen also indicated petty trading, including selling of sachet water; masonry; factory work; and crop farming. Interestingly, when interviewed during the closed season almost all fishermen interviewed did not engage in any economic activity, while approximately 22% of fish traders engaged in other livelihoods (fig. 9).

Interviewees were also asked a series of questions regarding their employability outside of the fishing sector. Four out of every five (80%) of fisherman and fish traders perceive no options outside of their current fishing occupations. Only 5% had other job offers at the time

of the survey. In addition, a similar proportion of the respondents specified that they do not have social networks that could assist them in finding other jobs. This indicates that fishers indeed have limited options for earning an income during the closed fishing season.

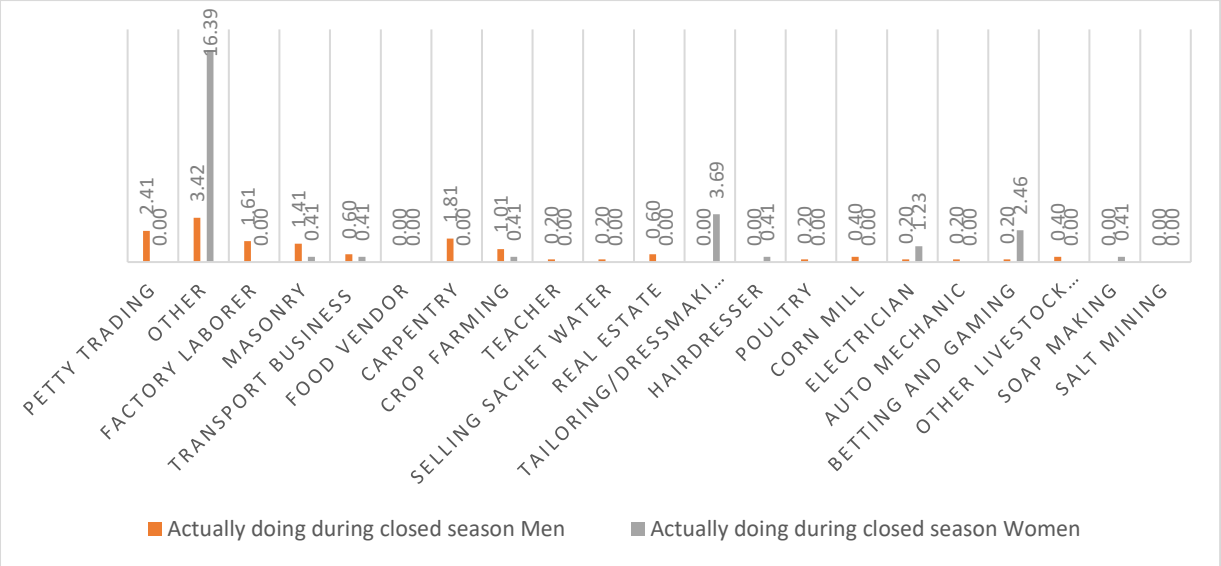

Figure 9 Economic Activities that fishermen and fish traders engaged in during the closed season.

4.2.2. Dietary Diversity and Food Poverty Dynamics

The socioeconomic assessment also examined the household "food basket" (food expenditures) before and after the closed season as an indication of dietary diversity. Research shows that a household's food basket is usually positively correlated with income because with additional income families are more likely to buy a range of food items. While the socioeconomic assessment results show some variation by region and gender, in general, household food baskets reported by fishermen and fish traders were more diversified after the closed season (fig. 10). Since dietary diversity is positively correlated with income, this suggests that improvements to fishing household dietary diversity after the closed season resulted from the catch of more and bigger fish and receiving higher prices for those fish (see Table 1 previous section).

The Greater Accra region was the anomaly, were households of both fisherman and fish traders registered a decline in the diversity of their food baskets after the seasonal closure. This decline in dietary diversity is likely due to lower income generated from fishing activities in Greater Accra after the closure. Given this finding, additional research to understand why fisher in Greater Accra are not earning as much as fishers in other regions and other unique

Figure 10 Dietary diversity amongst fishers

socioeconomic conditions affecting fishers in the Greater Accra Region and how this affects their resilience in the face of fisheries management is warranted.

The socioeconomic assessment also examined food poverty by computing a food poverty expenditure line based on food expenditure and calorie consumption (Table 3). A household that falls below this food poverty line is considered "food poor."

Table 3. Food Expenditure Poverty Lines for the Coastal Regions of Ghana

Region	Min Food Exp (GHS)
Greater Accra	114.48
Volta	82.28
Central	92.69
Western	85.69

Source: Socioeconomic Assessment Authors' Calculations from Field Data

The food poverty results are summarized in Figure 11 and show no clear pattern of escape from food poverty. On the aggregate, 60% of respondents did not experience a change in their poverty status from before the close to after the closure. Thus, the assessment concludes that the closed season has no negative effect on fishing community's food poverty levels, contradicting the commonly held position among fishers that the closed season makes them worse off.

Interestingly, fisherman in Great Accra were least likely to escape food poverty as a result of the closed season, reinforcing the concept that fishers in Greater Accra are face unique socio-economic challenges. Given the positive effect the closed season has on dietary diversity, we would assume to see similar positive results on food poverty. However, a secondary regression analysis of the underlying factors that determine household food poverty status show that the largest determinates were household size and household income levels.

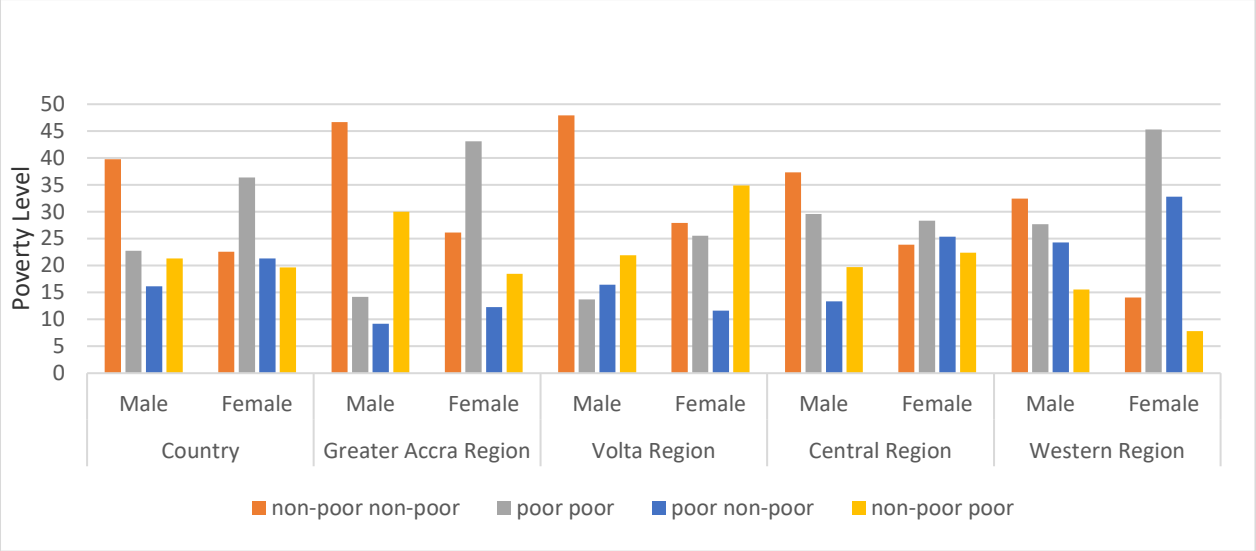

Figure 11 Food Poverty Dynamics among Fishing Households in Ghana

5.0 COMPLIANCE

The FC Monitoring Control and Surveillance Division (MCSD) reported 98% of fishers complied with the closed season. Data on compliance was gathered during MCSD beach combing[2] activities. Arrests of fishers for violating the closed season were minimal and only observed by the MCSD during the first five days of the closure. However, there were reported cases of violations of the management measure at night by fishers at the border towns in the Volta and Western. GFRA, during its own independent monitoring, also observed fishing activities in the border town between Ghana and Côte d'Ivoire. The non-compliant fishers were predominantly Ghanaians who had migrated to Côte d'Ivoire before the closed season came into force. This resulted in conflict amongst fishers who lived in such areas, who threatened to go fishing if the perpetrators were not arrested.

[2] In the fisheries sector, beach combing is conducted by the FEU to recover illegal fishing gears and prevent activities that can affect the fisheries industry, or community, negatively.

Figure 12 A canoe violating the 2022 closed season at the Ghana-Togo boarder.

6.0. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

Assessment results show that the closed fishing season is an effective management measure for the recovery of the small pelagic fish stocks. Biological data demonstrates improved productivity of the stocks, evidenced by a general increase in the mean catches of the small pelagic species after the closure. The mean sizes of the species also increased after the closed season, indicating that the measure is allowing fish to grow bigger during that period of rest. The abundance of spent ovaries observed in the data from all the three species suggests that pregnant fish were able to release their eggs, adding more juvenile fish to the fish stock. However, the overall trend of fish being landed at sizes below the ideal size of 18 cm means that fishers are still catching fish that are too small. Thus, for the measure to be completely effective, it needs to be combined with management measures that stop fishers from landing small or juvenile fish.

The socioeconomic assessment of the closed season provides insight into the nuanced effects of the closed season on people's livelihoods and food security. Although approximately half of the population supports the closed season, the majority agreed that with the measure in place, adherence is essential and recognized its potential positive impact on sustaining the fishery. However, fishers are completely dependent on fishing as a source of income and have no other options during the closed season. This points to the urgent need for short term stop-gap measures to support fishers during the closed season while in the long term

promoting supplementary livelihood amongst fishers to help them absorb the 'shocks' that comes with such key management measures.

Fishers often complain that the closed season has a negative effect on their income and ability to feed themselves and their families. However, the results of the socioeconomic assessment show otherwise. Regarding the impact of the closure on household income and hence food diversity, the assessment shows that at the aggregate level, the household diet was more diverse, hence more prosperous, after the seasonal closure. Furthermore, concerning food poverty dynamics, comparing the situation before the season closure to that after the closure, it was found that the closed season had no effect – negative or positive. Those respondents who were poor remained poor and those who were non-poor maintained their status after the closure. Respondents in the Greater Accra region were an anomaly, experiencing both a decrease in dietary diversity and an increase in food poverty. This suggests that management measures are having a negative effect mostly on fishers in this region and further research must be done to better understand their unique socio-economic conditions and how to address them, especially during the closed season.

6.2. Recommendations

The closed season is just one of a range of fisheries management measures to reduce fishing pressure. The Fisheries Management Plan (2022-2026) outlines several actions that must be taken to sustain Ghana fisheries, including limiting access to the fishery through a moratorium on new canoes and enforcing the nation's existing fisheries rules to reducing illegal fishing. Now that the closed season has become a regular annual rest period to allow pregnant fish to spawn, it is important to focus on implementation of these additional fisheries management measures to fully recover Ghana's fisheries. Most importantly, reducing illegal fishing methods that target juvenile fish will ensure that the new fish that have entered the fishery during the closed season are not immediately caught when fishers return to sea. This will allow the juveniles to grow to a reproductive size to replenish the stocks.

Considering the peak reproductive season of the small pelagic stocks spans July through September, the timing of the closed season should be critically reconsidered to cover the peak spawning seasons more effectively. Ideally the season should be extended to two months – July and August – for all of Ghana's fishery sectors. However, given the lack of income alternatives, this would be challenging. An alternative is to shift the closed season to August,

which will allow most gravid (pregnant) fish to expend the eggs before being harvested, with ripple impact on recruitment and abundance. This will ensure increased stock recovery rate.

Fishers oppose the close season because of its negative impact on their livelihoods. As a result, fishers should be encouraged and supported to acquire employable skills in the medium to long term. This presents an opportunity for the GFRA livelihood program which can increase intentional promotion that targets fishermen in order to admit more males into the program and ensure better economic resilience during future closed seasons. Also, fishers' lack of employable skills and supplementary livelihood options means that an early announcement of the closed season, with at least six months' notice, is highly recommended to allow fishers to prepare financially towards the closure. Finally, there is no straightforward evidence that all fishing communities across Ghana benefitted equally from the closed season, especially when it comes to diversification of household diets and escape from food poverty. As a result, expectations about potential immediate economic gains from the closed season should be managed.

Since the small pelagic stock is a shared stock between Ghana, Côte d'Ivoire, Togo and Benin, a regional-wide closure will ensure optimal gains towards the sustainable management of the fishery. Fishers from all four countries also migrate up and down the coast in search of fish, moving from Ghana's waters into neighboring countries to exploit their fisheries especially during Ghana's closed season. It is therefore recommended that a regional closed season should be observed by all the countries that share the small pelagic stocks with Ghana.

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ANNEX A

Shannon Diversity Index

To analyze the diversity of food intake by fishers after and before the closed season, the Shannon diversity index was employed. The index is used to characterize a community's species diversity (in our case, food type). It considers the richness and evenness of the food types. The richness or abundance refers to the absolute number of food groups present in a diet, while evenness denotes the relative distribution of the abundance of the food groups (Vadiveloo et al. 2014; Penafiel et al. 2019; Wertheim-Heck). Thus, the index accounts for the number of food groups available to the household and the abundance of each food group. The higher the computed index, the more diverse the food groups consumed by the fishing household. Following Hanley-Cook et al. (2022), the Shannon Index (H) is specified as follows:

$$H = -\sum_{i=1}^{s} p_i \ln p_i \text{ , with } 0 \le p_i \le 1, \sum_{i=1}^{s} p_i = 1$$

where p_i are the calories of food group i consumed divided by the total food calories available to the fishing household; and s is the number of food groups (i.e., $i = 1, 2, .., s$). Table 3 contains the five (i.e., $s = 5$) food groups and their components considered for this study.

Table 3 Food Groups and their Components

No	Food Group	Components
1	Fruit	Whole fruit and fruit juice
2	Grains	Whole grains and refined grains
3	Vegetables	Dark green vegetables, red and orange vegetables, beans and peas, starchy vegetables, and other vegetables
4	Dairy	Milk, yogurt, and cheese
5	Protein foods	Seafood, meat, poultry, eggs, nuts, seeds, and soy

Source: US Department of Agriculture[3].

Food Poverty Line

[3] Back to Basics: All About MyPlate Food Groups | USDA

A household is considered food (expenditure) poor if it lacks the resources for a nutritionally adequate diet (Greer and Thorbecke, 1985). Greer and Thorbecke (1985) was used to estimate the food poverty line. Their seminal work entails the estimation of a specific relationship between calorie consumption (c_j) and food expenditure (x_j), given as:

$$\ln x_j = a + bc_j \tag{2}$$

where a and b are parameters estimated from field data. Two fundamental assumptions underlie equation (2). These are: (1) all the fishing households face comparable prices, and (2) there is a typical dietary taste pattern among the households. After estimating these parameters, the food poverty line is calculated based on the cost of meeting a recommended daily allowance (RDA). Thus, FPL (Z) is specified as:

$$Z = e^{\left(\hat{a}+\hat{b}RDA\right)} \tag{3}$$

where, $\hat{a}$ and $\hat{b}$ are the estimated coefficient of a and b respectively. The RDA of 2,250 calories per adult equivalent is taken from the literature (e.g., Greer and Thorbecke, 1985). After estimating the poverty line (i.e., equation 3), the 'depth' (D_j) of poverty for household j is computed as:

$$D_j = \left(\frac{G_j}{Z}\right)^2 \text{ , where } G_j = Z - x_j \text{ if } x_j \le Z, \ = 0 \text{ if } x_j > Z \tag{4}$$

A higher value of D_j signifies a higher depth of food poverty.

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