Comparative study of the ichthyological production of two hydrosystems, one under protection and the other free of access in Aby lagoon, Ivory Coast

ABSTRACT

The main objective of this study is to compare the productivity of the reserves with that of the open-access portion of Aby Lagoon in order to learn more about the importance of fisheries management in this natural ecosystem. The study ran from December 2020 to May 2021 and from December 2021 to May 2022. Sampling was carried out on catches from an artisanal fishery using purse seines in both fishing environments. The results for the reserves showed a reduction in fishing effort in year 2 compared with year 1. In terms of profit per fishing trip in the reserves. The highest Catch Per Unit Effort (CPUE) was recorded in Ehoussou (3,526.87 kg) and Abiaty (2,624 kg) during the first year, and in Bèdoubegnin/Mauricekro (1,774 kg), Abiaty (1,288.88 kg), Aby (1,283.57 kg) and Eplemlan (1,240 kg) during the second year. The largest quantities of fish caught per reserve were observed at Ehoussou (56,430 Kg) and Abiaty (39,360 Kg) during year 1, and at Aby (17,970 Kg) and Bèdoubegnin/Mauricekro (17,740 Kg) during year 2. On the portion of the Aby lagoon to which access is free, the fishing effort amounted to 2,315 trips (year 1), compared with 1,812 trips in year 2. In this free-fishing zone, the CPUE was 291.12 kg in year 1, compared with 193.17 kg in year 2. The quantity of fish produced annually in this unprotected portion was 673,935 kg in year 1, and 350,029 kg in year 2. These results showed that for the small amount of fishing effort made in the reserves (250 trips) over the sampling period, the average profit from one fishing trip was as high as possible (1,177.31 kg). The opposite was observed in the lagoon portion with free access, since with an effort of 4,127 fishing trips over the entire survey period, the average gain from one fishing trip was only 248.11 kg.

Keywords: Aby lagoon, protected reserve, fishing effort, Catch per Unit effort, Ivory Coast.

1. INTRODUCTION

Protecting aquatic ecosystems is essential for the ecological balance of fish species and for a healthy diet for local populations (Dovonou et al., 2011). These ecosystems include brackish waters, which are very rich in terms of species diversity. These habitats potentially serve as spawning grounds, nurseries and biological resting places for many aquatic species (Ruiz et al., 2006). These ecosystems are naturally vulnerable and their ecological balance can be rapidly altered under the influence of natural and/or anthropogenic factors (Kouassi, 2005). The Aby lagoon is not immune to these nuisance factors. In the 1980s, the high productivity of capture fisheries led to an influx of fishermen who settled all along the shore of the Aby lagoon (Koulaï & Amalatchy, 2020; Ahoulou et al., 2024), resulting in strong fishing pressure on biological resources (Koulaï, 2014). This influx of fishermen from a variety of backgrounds has encouraged the use of fishing techniques that are unsuited to the rational exploitation of fishery resources. This combination of factors has led to cases of biological over-exploitation of certain species. In response to this worrying situation, the Adiaké Departmental Fisheries Directorate, in collaboration with the chiefdoms and the prefectural authority, has shown the political will to implement a management plan known as "protected reserves in the Aby lagoon". Since the establishment of these protected reserves, no study has been undertaken to assess their importance in terms of fish production. It is in this context that this study is endeavouring to carry out research work under the theme "Comparative study of fish production in two hydrosystems, one under protection and the other free of access in the Aby lagoon, Ivory Coast". Its main objective is to compare the productivity of protected reserves with that of the open access zone in the Aby lagoon.

2. MATERIAL AND METHODS

2.1 Study area

A total of 22 protected reserves have been set up on the Aby lagoon (Fig. 1). This lagoon is located in the south Comoé region, in the extreme south-east of Ivory Coast, precisely between longitudes East 2°51 and 3°21 and latitudes North 5°05 and 5°22. It serves as a natural border to the south and east

between Ivory Coast and Ghana, and encompasses the Tendo and Ehy lagoons (Kambiré et al., 2014).

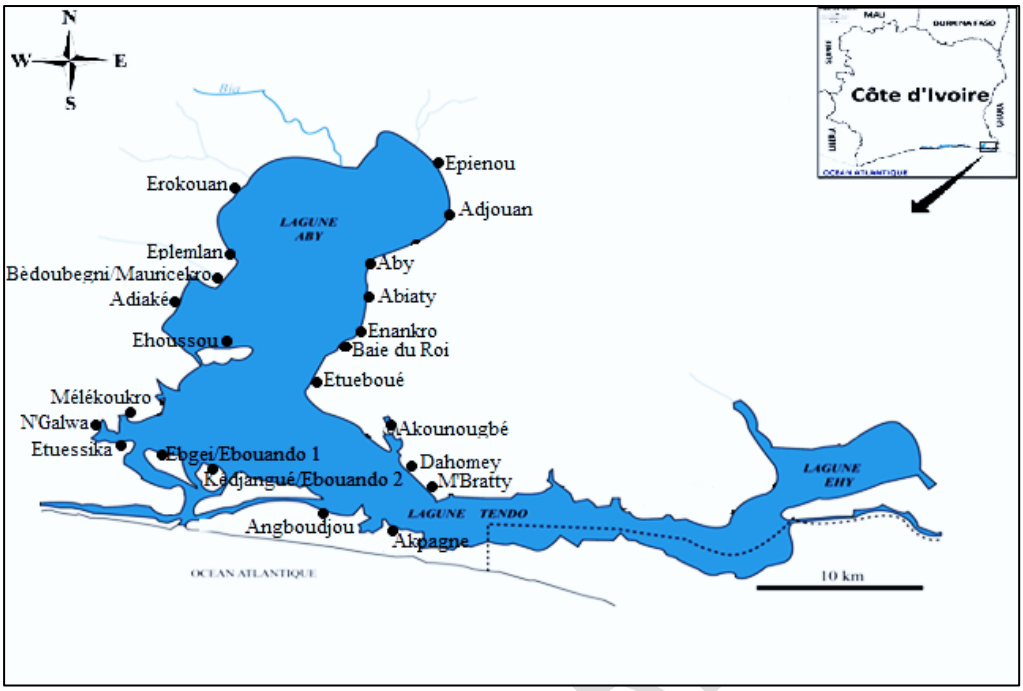

Fig. 1. Map of the Aby lagoon showing the location of the protected reserves (•) (Ahoulou et al., 2024, modified)

2.2 Data collection

The fishing surveys were carried out over two semesters. The first runs from December 2020 to May 2021 (Semester 1 in Year 1) and the second from December 2021 to May 2022 (Semester 2 in Year 2). The failure to cover the entire year with data collection is due to the closure of the reserves to all fishing activity for the rest of the months of the year. The research activities were carried out on the total production of all the protected reserves as well as on the total production of fish landed in the open access lagoon. The fishing gear used to catch the fish is a purse seine commonly known as an Aly net (Fig. 2).

Fig. 2. Purse seine (Aly net) used to catch fish

2.3. Estimated total production

Total production was obtained by summing the weight catches made in each of the reserves, as well as in the portion of the Aby lagoon to which there is no access. This production is evaluated using a bowl whose empty weight is known. Once filled with fish, after subtracting the empty weight, we obtain a weight of 30 kg, which corresponds to the weight of the contents (fish). So, the number of filled trays multiplied by 30 Kg corresponds to the total quantity of fish landed per reserve. The number of fish per tank was also estimated by counting the fish in a full tank. This number of fish per tank gives an idea of the total number of fish caught in a given area. The same applies to the portion of the Aby lagoon that is open to the public. Total production was estimated in two phases:

- The first phase consisted of counting and weighing catches from protected waters, with the support of agents from the Adiaké Departmental Fisheries Directorate.

- The second phase concerned only catches made in the open waters of the Aby lagoon. The aim was to count and weigh every day all the catches made in this part of the lagoon, which is free from any fishing activity.

2.4 Data processing

Based on data from fishing activities in protected reserves and in the open waters of the Aby lagoon, certain production indices have been calculated.

2.4.1 Choice of Fishing effort unit

Fishing effort is a management parameter which measures the accumulation of catching resources used by fishermen to exploit a stock over a unit of time (Gascuel, 1993). It also corresponds to the quantification of the exploitation of a stock during a given time interval, and in its evaluation takes into account the quantification of the effort for the fishing units sampled, extrapolated to the units active in the area and for the period considered. This total effort quantifies the fishing pressure exerted by a fleet on a stock (Laurec & LE Guen, 1981). The fishing effort considered in this study is the number of fishing trips per year over the two sampling periods.

2.4.2 Evaluation of Total Production (TP) and Catch Per Unit Effort (CPUE)

Total Production (TP) is the total quantity of fish landed during the study period in the protected reserves and in the open waters of Aby lagoon. Total Production is expressed in Kg of fish.

The CPUE of each environment (reserves and open access areas), expressed in Kg/number of fishing trips per year, was evaluated for the two sampling periods using the following formula from Soro et al. (2018).

$$\mathrm{CPUE} = \frac{\mathrm{TP}}{\mathrm{Fe}}$$

TP = Total Production per year (kg)

Fe = Fishing effort (number of fishing trips per year).

2.5 Statistical analysis

The data collected was processed using Excel 2016 software, which was used to plot the various histograms.

3. RESULTS

3.1 Protected reserves

3.1.1 Fishing effort in terms of number of fishing trips per year and per reserve

Fishing effort, estimated as the number of fishing trips per year, is shown in Fig. 3. In the first year, the Ehoussou, Abiaty and Aby reserves recorded the highest number of fishing days, with 16, 15 and 12 fishing trips respectively. The lowest Fishing effort was observed in the Adjouan, Akpagne and Dahomey reserves, with one (1) fishing trip each. To these reserves with high Fishing effort should be added Angbougjou and Eplemlan (11 Fishing trips/year each), Kédjangué/Ebouando 2 with 9 fishing trips/year, Adiaké and Bèdoubegnin/Mauricekro (8 fishing trips/year each), M'Braty with 6 fishing trips/year and N'Galwa with 5 fishing trips/year. During the second year, fishing effort decreased slightly in the Ehoussou (12 fishing trips/year) and Abiaty (9 fishing trips/year) reserves, with the

exception of the Aby reserve, which showed a slight increase in fishing effort (14 fishing trips/year) in contrast to year 1. The reserves with the lowest fishing effort values (Ep ≤ 2 fishing trips/year) in both years are: Adjouan, Akpagne and Dahomey. To these reserves should be added Akounougbe, Baie du roi, Etueboué, Etuessika and Melekoukro. On the other hand, the Adiaké, M'Braty and Bèdoubegnin/Mauricekro reserves recorded a fishing effort of more than 2 fishing trips/year during the second year, compared with the previous year.

3.1.2 Catch Per Unit Effort (CPUE) of protected reserves

The Catch Per Unit Effort, expressed in Kg/Number of fishing trips, is shown in Fig. 4. The highest CPUE values were recorded in the Ehoussou reserve (3,526.87 kg/Number of trips) and the Abiaty reserve (2,624 kg/Number of trips) during the first year. In the second year, the Bèdoubegnin/Mauricekro (1,774 kg/No. of outlets), Abiaty (1,288.88 kg/No. of outlets), Aby (1,283.57 kg/No. of outlets) and Eplemlan (1,240 kg/No. of outlets) reserves posted high CPUEs. The other reserves all had CPUEs above 200 kg/Number of fishing trips, with the exception of the Erokouan and Dahomey reserves in year 1 and Melekoukro, Etuessika, Baie du Roi and Akpagne in year 2. It should be noted that during year 2, there was a drop in the Catch per Unit Effort at the Ehoussou (986.66 kg/Number of trips) and Abiaty (1,288.88 kg/Number of trips) reserves, compared with 3,526.87 kg/Number of trips and 2,624 kg/Number of trips respectively at Ehoussou and Abiaty during year 1.

3.1.3 Total weight intake per reserve

The total quantity of fish landed per number of fishing trips and per reserve gives an idea of the productivity of the reserves in the lagoon. The average weight catch per fishing trip was 1,177.31 kg for the reserves. The largest total fish catches per reserve were recorded at Ehoussou (56,430 Kg) and Abiaty (39,360 Kg) in year 1 and at Aby (17,970 Kg) and Bèdoubegnin/Mauricekro (17,740 Kg) in year 2 (Fig. 5). Relatively large catches by weight, i.e. over 10,000 kg in the first year, were observed in Aby (16,500 kg), Bèdoubegnin/Mauricekro (14,310 kg) and Eplemlan (11,070 kg) respectively. During the second year, these large catches were observed in Adiaké (13,930 Kg) and Ehoussou (11,840 Kg). The other reserves with cumulative catches of less than 10,000 Kg are: Adiaké (7,920 Kg) and Kédjangué/Ebouando 2 (6,030 Kg) during the first year and M'Braty (9,618 Kg), Eplemlan (8,680 Kg) and N'Galwa (6,030 Kg) during the second year. The rest of the reserves recorded low fishing yields of less than 5,000 kg of fish.

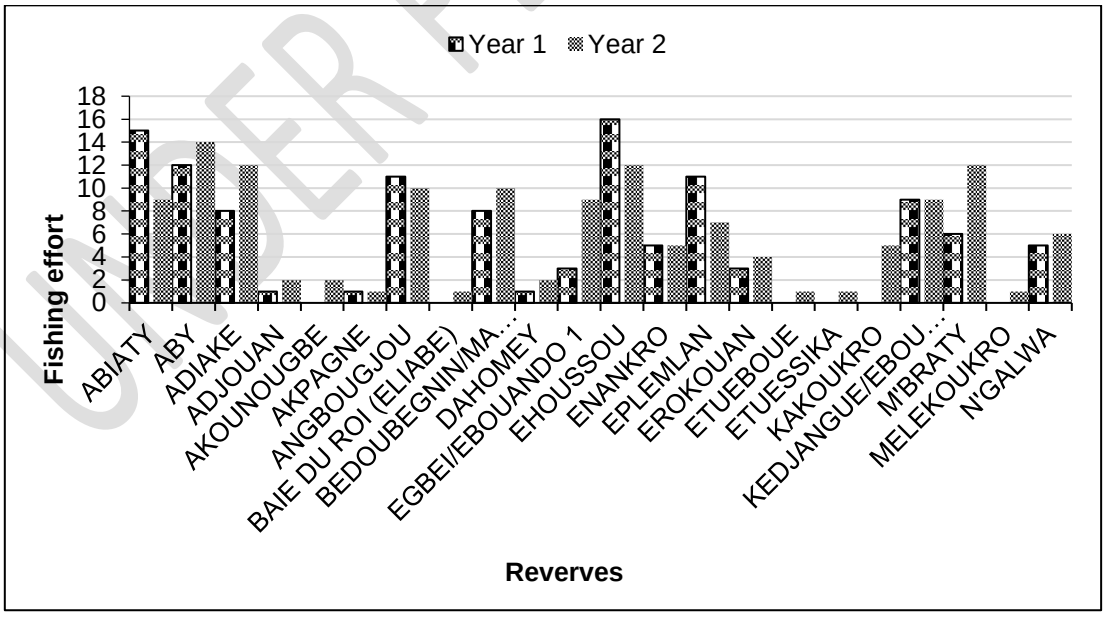

Fig. 3. Fishing effort per number of trips and per reserve from December 2020 to May 2021 (Year 1) and from December 2021 to May 2022 (Year 2)

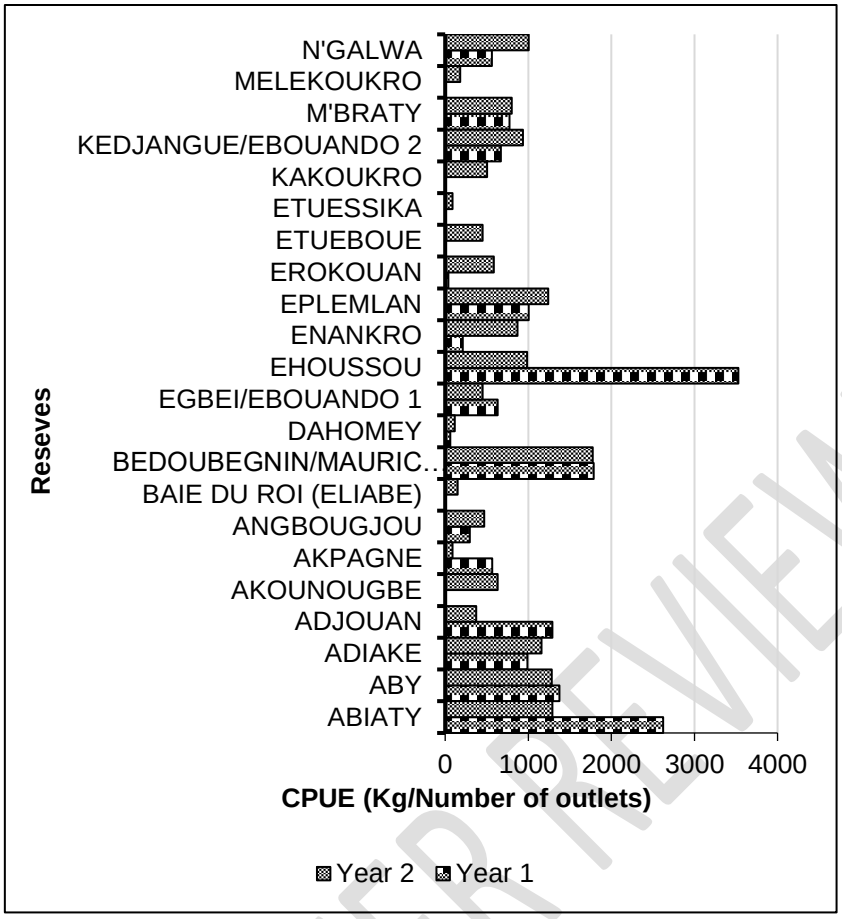

Fig. 4. Catch Per Unit Effort per reserve from December 2020 to May 2021 (Year 1) and from December 2021 to May 2022 (Year 2).

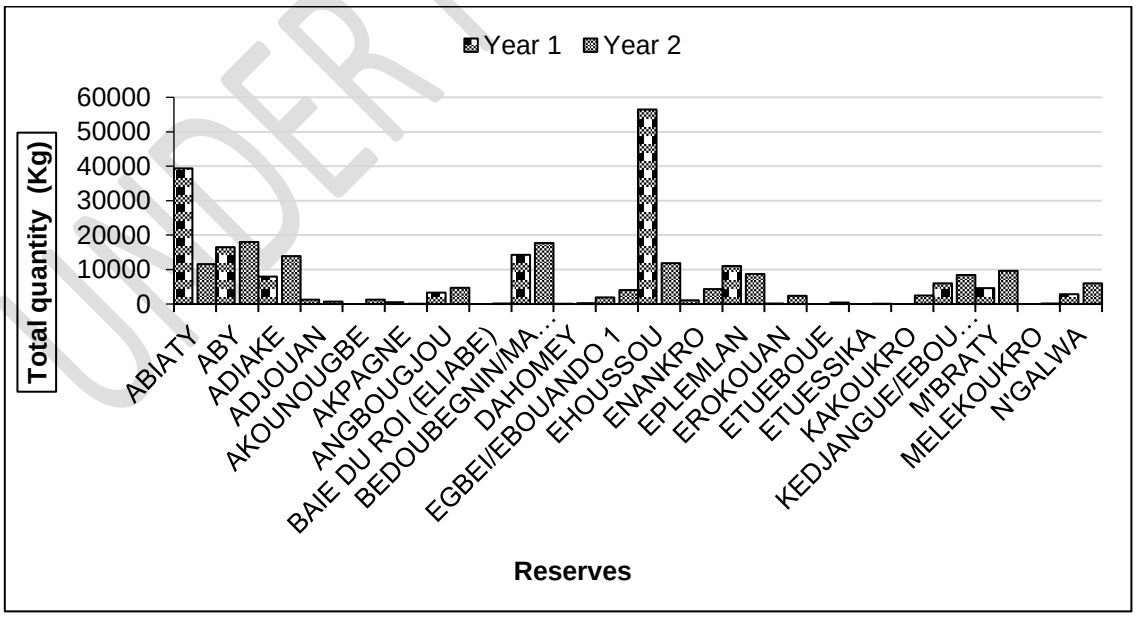

Fig. 5. Total quantity of fish landed per village (Kg) from December 2020 to May 2021 (Year 1) and from December 2021 to May 2022 (Year 2)

3.2 Portion of the Aby lagoon open to access

3.2.1 Fishing effort in terms of number of fishing trips per year in open waters

Fig. 6 shows the fishing effort in terms of the number of trips over the course of a year in the open waters of Aby lagoon. The fishing effort recorded in the first and second years is 2,315 and 1,812 trips respectively. The average fishing effort over the two years was 2,063.5 trips. From the first to the second year, there was a decrease in fishing effort of around 503 trips.

3.2.2 Catch Per Unit Effort (CPUE) in open water

Catch per Unit Effort in open water was 291.12 kg/number of trips in year 1, compared with 193.17 kg/number of trips in year 2 (Fig. 7). CPUE fell by around 100 kg/number of trips during this period.

3.2.3 Total landed weight in open waters

The total catch by weight landed in open waters is shown in Fig. 8. The total catch by weight landed during the first six (6) months (Year 1) is 673,935 Kg, while it is 350,029 Kg during the second year.

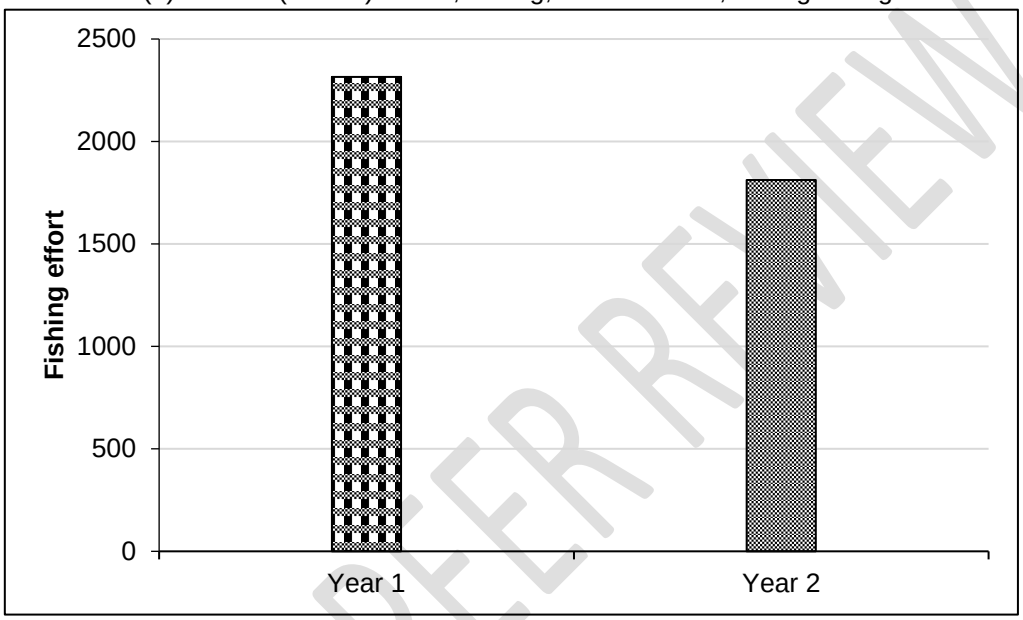

Fig. 6. Fishing effort in number of trips per six-month period in open waters from December 2020 to May 2021 (Year 1) and from December 2021 to May 2022 (Year 2)

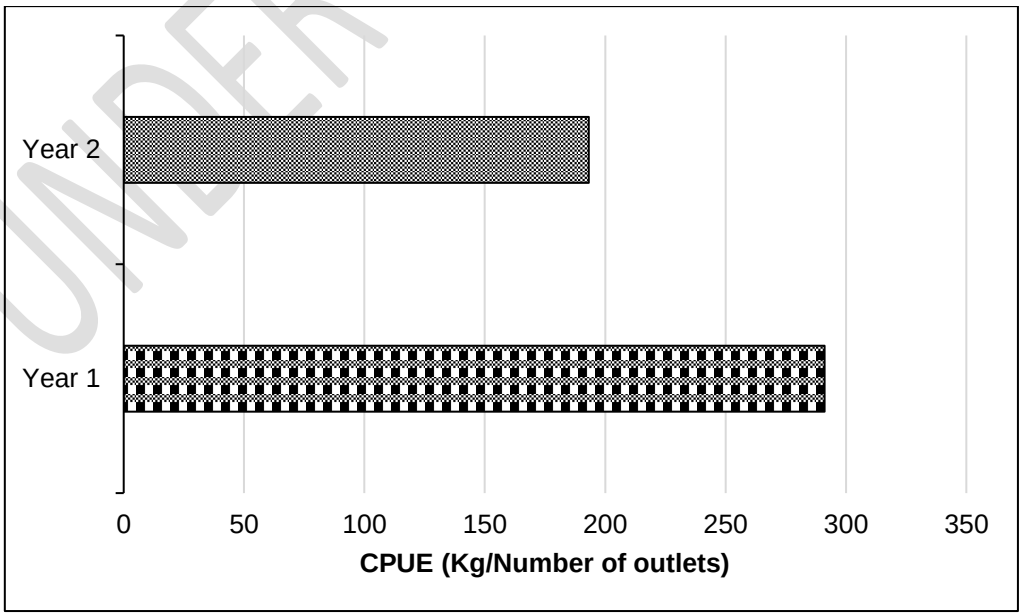

Fig. 7. Catch Per Unit Effort in open waters from December 2020 to May 2021 (Year 1) and from December 2021 to May 2022 (Year 2)

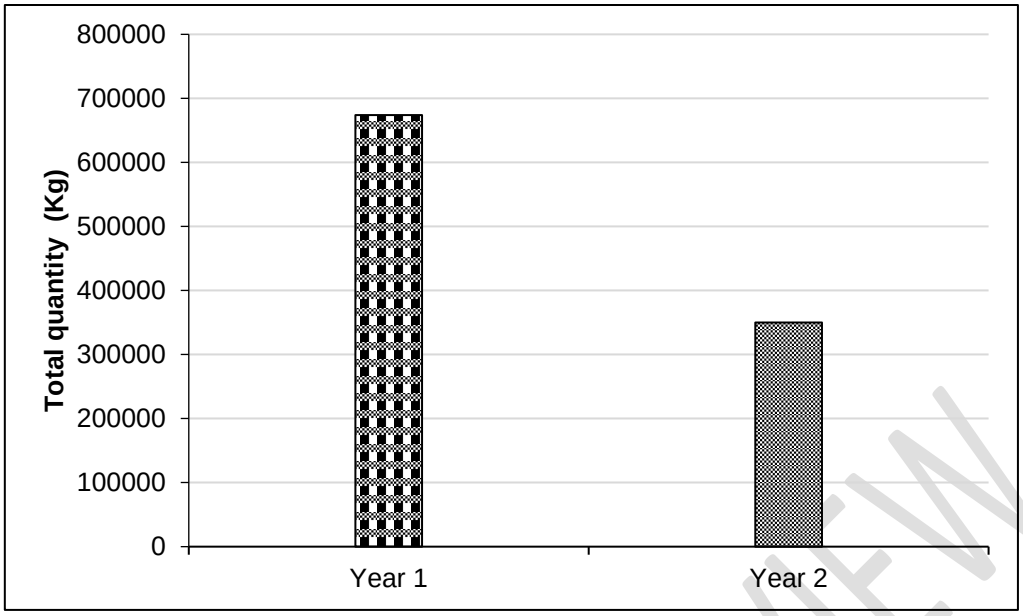

Fig. 8. Total quantity of fish (Kg) landed in open waters from December 2020 to May 2021 (Year 1) and from December 2021 to May 2022 (Year 2)

3.3 Comparative study of fishing activities in the reserves and open waters of the Aby lagoon

3.3.1 Fishing effort in reserves and open waters

During the study period, 250 fishing trips were recorded in protected reserves, while 4,127 fishing trips were recorded in open waters (Fig. 9).

3.3.2 Catch Per Unit Effort (CPUE) in protected reserves and open waters

The Catch Per Unit Effort (CPUE) of fishing in protected reserves and open waters is shown in Fig. 10. In reserves, the CPUE is 1,177.31 Kg/number of trips, compared with only 248.11 Kg/number of trips in open waters.

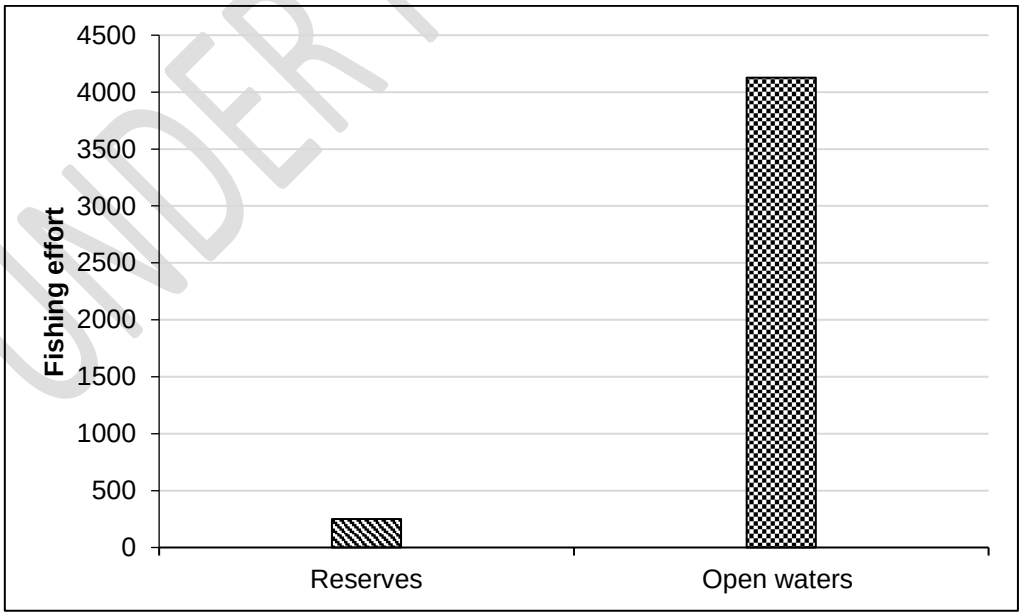

Fig. 9: Fishing effort in reserves and open waters from December 2020 to May 2021 and from December 2021 to May 2022.

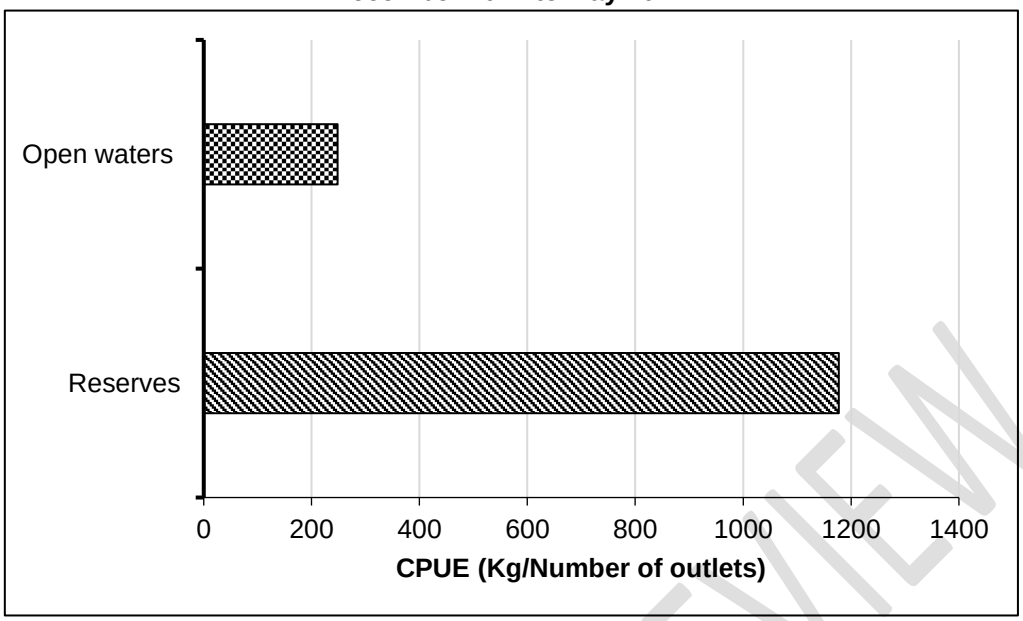

Fig. 10. Catch per Unit Effort in reserves and in open waters from December 2020 to May 2021 and from December 2021 to May 2022

4. DISCUSSION

4.1 Fishing effort and CPUE in reserves

The results of the studies carried out on the exploited reserves showed a slightly higher fishing effort in the first year compared to the second year. This drop in fishing effort is thought to be due to a conflict of interest between young people and the chiefdoms of certain reserves (Abiaty, Ehoussou and Eplemlan). In these reserves, the young people of the villages concerned say that they do not receive any of the money earned from fishing. In terms of fishing effort per reserve, the greatest fishing pressure was recorded in the Ehoussou, Abiaty and Aby reserves, certainly linked to the fact that these reserves are more accessible or more productive. In contrast, low fishing effort was observed in the Adjouan, Akpagne, Dahomey, Akounougbe, Baie du roi, Etueboué, Etuessika and Melekoukro reserves. One of the reasons for the low presence of fishermen in these areas is the fact that these reserves were set up during the present study. It is possible that these reserves are difficult to access or unknown to all the fishermen.

The high CPUE recorded in certain reserves such as Ehoussou, Abiaty, Bèdoubegnin/Mauricekro, Aby and Eplemlan is justified by the fact that these reserves have been in existence for more than 10 years. This high CPUE value could also be explained by the increased surveillance of young local residents and the configuration of these reserves. For the other reserves, the drop in average catches could be linked to clandestine exploitation by some young local residents. This assertion is supported by Koulaï & Amalatchy (2020) who claim that fishermen exploit the reserves clandestinely in collaboration with the surveillance committee and even with the approval of certain village chiefs.

On all the reserves in the Aby lagoon, the quantities of fish landed per fishing trip are significant. This is justified by the effective preservation of these habitats and their resources. The temporary closure of an ecosystem to fishing is biologically very beneficial to the organisms that live there, as they take the opportunity to reproduce, feed properly and reach marketable sizes. Differences in tonnage between reserves are thought to be linked to non-compliance with fishing deadlines, the abundance of fish in certain reserves and the ease of access to certain sites, unlike others. However, fluctuations in fishing effort expressed in terms of the number of fishing trips per year are closely linked to increased surveillance of the reserves and strict compliance with fishing deadlines. Thus, non-compliance with the fishing deadline and lack of surveillance are characterised by low catches correlated with an intense catching effort.

4.2 Fishing effort and CPUE in open waters

The fishing effort deployed by fishermen on the portion of the lagoon to which access is free fell by around 503 fishing trips between the first and second years. This decline is thought to be linked to the intensification of illegal gold panning upstream of the Aby lagoon. This activity not only attracts a large number of fishermen, but above all pollutes the Aby lagoon with mining waste. These pollutants, which are of various kinds, have an impact on the quality of the water and the organisms that live there. All these factors combine to make fishing unprofitable at local level.

With regard to Catch Per Unit Effort (CPUE) in open waters, the highest production was observed in year 1 (291.12 kg/fishing trip), compared with 193.17 kg/fishing trip in year 2. The decrease in CPUE of around 100 kg in the second year could be explained by the scarcity of fish in the area, following uncontrolled exploitation of this stretch of water. When a body of water is freely accessible, fishing effort increases steadily, while CPUE peaks before falling steadily. At critical CPUE thresholds, fishermen withdraw to other, more profitable locations. In the open access portion of the Aby lagoon, the biomass produced fell from 673,935 kg in year 1 to 350,029 kg in year 2. This drop in production can be explained in part by a decline in fishing activity following illegal gold panning. In addition, free access to the resource could lead to the depletion of large fish, resulting in the capture of juveniles with a low biomass.

4.3 Comparative Fishing effort and CPUE in the two fishing zones

A comparison of the fishing effort recorded in the reserves is 250 fishing trips, compared with 4,127 fishing trips in the open waters. This large difference in fishing pressure between the reserves and the rest of the open Aby lagoon is due to the management plan applied to the reserves. For management reasons, the reserves are periodically closed to fishing activities, thus reducing the number of fishing trips, unlike the rest of the open water area where the effort is constantly increasing.

The Catch Per Unit Fishing Effort recorded in the reserves is much higher than that calculated for open access waters. This significant difference is reflected in the abundance of fish, especially large fish, in the reserves. This result once again confirms the need to manage bio-ecologically important ecosystems effectively so as to increase fishermen's profits. In the reserves, fishermen make little effort for greater profit, unlike in the open waters where they fish every day to catch just a few small fish of no commercial value. According to Laë & Lévêque (2006), the low CPUE recorded in open access waters is the result of strong fishing pressure, which ends up drastically reducing the stocks exploited.

5. CONCLUSION

The study shows that fish production in the protected reserves is more abundant than in the lagoon section with free access. Also, the CPUE, which is synonymous with the gain per fishing team, is greater in the reserves than in the open access zone. On the other hand, the fishing effort deployed to catch these fish is much greater in the open access waters than in the reserves under periodic protection. This confirms once again the importance of undertaking and ensuring sustainable and efficient management of exploited resources, through closed periods for certain habitats of bio-ecological and socio-economic interest.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors(s) hereby declare that NO generative Al technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Ahoulou, E. J., Soro, Y., Diaha, N. C., Doffou, C. Y., & Edoukou, A. (2024). Diversity of fish fauna in some protected reserves in the Aby lagoon, Côte d'Ivoire. *Journal of Applied Biosciences*, 197, 20838-20853.

Dovonou, F., Aina, M., Boukari, M., & Alassane, A. (2011). Physicochemical and bacteriological pollution of an aquatic ecosystem and its ecotoxicological risks: the case of Lake Nokoué in southern Benin. *International Journal of Biological and Chemical Sciences*, 5 (4), 1590-1602.

Gascuel, D. (1993). Fishing effort and power: redefining concepts and examples of application, 159-181.

Kambiré, O., Adingra, A. A., Eblin, S. G., Aka, N., Kakou, A. C., & Koffi-Nevry, R. (2014). Characterisation of the waters of an estuarine lagoon in Côte d'Ivoire: the Aby lagoon. *Larhyss Journal*, 20, 95-110.

Kouassi, A. M. (2005). Hydrochemistry and water quality of two tropical lagoons in Côte d'Ivoire (Ebrié, Grand-Lahou). Doctoral thesis, Université Félix Houphouët- Boigny: 147 p.

Koulaï-Djedje E. (2014). Current fishing situation in the Aby 30 lagoon after the collapse of fish stocks 1980-1981 (Côte d'Ivoire), Géotrope *(journal of tropical geography and the environment)*, 1, 75-82.

Koulaï-Djedje, E., & Amalatchy, J. N. (2020). Local communities and sustainable fisheries management in the Aby lagoon: the case of "artificial bays » (Côte d'Ivoire), Spatial Dynamics and Development: *Biannual journal of the Laboratoire d'Etudes des Dynamiques Urbaines et Régionales (Urban and Regional Dynamics Laboratory)*, 4-20.

Laë, R., & Lévêque, C. (2006). Fishing. In: Levêque C. and Paugy D. (Eds). The fish of African continental waters: diversity, ecology, use by man. *IRD Editions*, Paris, 415-456.

Laurec, A., & Le Guen, J. C. (1981). Dynamics of exploited marine populations. Volume I: concepts and models. Rapp. *Science et Technology*, CNEXO, 45, 117 p.

Ruiz, F., Abad, M., Galan, E., Gonzalez, I., Aguila, I., Olias, M., Gomez, A. J. L. & Cantano M. (2006). Le scénario environnemental actuel de la lagune d'El Melah (NE Tunisia and its evolution to a future sabkha. *Journal of African Earth Sciences,* 44, 289-302.

Soro, Y., Diaha, N. C., Ahoulou, E. J., Amande, M. J., Konan, K. J., Bahou, L. & N'DA, K. (2018). Upwelling and distribution density of rouvet (*Ruvettus pretiosus*, cocco, 1833) in the marine waters of Côte d'Ivoire. *Journal of Chemical, Biological and Physical Sciences*, 8 (3), 669-679.