World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Check for updates

Growth and stock exploitation parameters of *Sphyrna lewini* (Griffith & Smith, 1834) living in the Ivorian coastal water

Abdoulaye KONE [1,*], Christian Bernard TIA [1], Diomandé LOUA [1] and Konan N'Da [2]

[1] *University of San Pedro, Marine Sciences Training and Research Unit, 01 BP1800 San Pedro 01, San Pedro, Côte d'Ivoire.*
[2] *University Nangui Abrogoua, Animal Biology and Cytology Laboratory, 02 BP 801Abidjan 02, Abidjan, Côte d'Ivoire.*

World Journal of Advanced Research and Reviews, 2025, 28(01), 1913-1923

Publication history: Received on 18 August 2025; revised on 22 October 2025; accepted on 25 October 2025

Article DOI : https://doi.org/10.30574/wjarr.2025.28.1.3333

Abstract

In Côte d'Ivoire, data on shark exploitation are limited to landing records. The high demand for fins in Asian markets has led to an increase in shark catches. Yet many species are threatened with extinction, despite their crucial role in maintaining the balance of marine ecosystems. This study aims to determine the growth parameters of *Sphyrna lewini* and to assess the level of stock exploitation off the Ivorian coast, in order to improve resource management. Between January 2019 and December 2020, the total length of 774 specimens between 90 and 235 cm was measured. From the length frequency data, growth and exploitation parameters were evaluated using FiSAT II software. The estimate reveals growth rate (K) at 0.17 year^{-1}, asymptotic length (L∞) at 266.75 cm, and growth performance index (Ø') at 4.083. The species undergoes total mortality (Z) of 0.92 year^{-1}, natural mortality (M) of 0.29 year^{-1}, and fishing mortality (F) of 0.63 year^{-1}, resulting in an exploitation rate (E) of 0.68. The specimens caught are mostly small in size, with a higher catch abundance during the major cold season. The species is slow-growing. *Sphyrna lewini's* stock in a state of overexploitation. Maintaining the current fishing pressure could lead to stock collapse. Further study on reproduction and ecology of *Sphyrna lewini* in Côte d'Ivoire is necessary to identify the periods and areas of reproduction, with a view to creating marine protected area.

Keywords: *Sphyrna lewini*; Growth; Exploitation; Stocks; Côte D'Ivoire

1. Introduction

Tropical oceans harbor rich biodiversity, including numerous shark species. Most of these sharks are apex predators that exert a significant impact on prey population sizes, as well as on the structure and composition of marine ecosystems [1]. Moreover, sharks are among the most threatened groups of marine fishes globally, mainly due to overfishing and habitat degradation [2; 3]. Furthermore, out of 134 species of sharks and rays associated with coral reefs, approximately two-thirds (59%) are threatened with extinction [4]. One of the greatest threats to the sustainability of shark populations is overexploitation, due to high global market demand for fins, meat, skin, and cartilage [5; 6]. This excessive pressure not only threatens the survival of shark populations but also disrupts the trophic levels of marine ecosystems [7]. Yet, sharks belonging to the subclass Elasmobranchii are considered the most vulnerable group of marine vertebrates [8; 9; 10]. Indeed, their life-history traits such as slow growth rates, late sexual maturity, and generally low reproductive potential make them particularly susceptible to overexploitation by both targeted and non-targeted fisheries [11; 12]. Hammerhead sharks are the second most abundant group in the international fin trade [13]. Among them, *Sphyrna lewini* stands out due to the high value of its fins, which contain a large number of ceratotrichia (fin rays), making it one of the most frequently traded species on the Hong Kong market [13 ;14]. *Sphyrna lewini* is a coastal and oceanic shark with a circum global distribution in tropical and temperate waters [15]. Following drastic population declines observed in several regions of the world, *Sphyrna lewini* has been classified

* Corresponding author: KONE Abdoulaye

as 'Critically Endangered' on the IUCN Red List of Threatened Species [16]. In Côte d'Ivoire, sharks are caught as bycatch in artisanal fisheries, whose catches mainly consist of tunas [17]. The increasing exploitation of sharks in Côte d'Ivoire raises serious concerns about stock sustainability and the conservation of these vulnerable species. *Sphyrna lewini* is among the most commonly landed shark species by artisanal marine fishers in Abidjan [1]. However, in Côte d'Ivoire, information on the biological parameters, population structure, and exploitation levels of *Sphyrna lewini* remains very limited. Therefore, a study of growth parameters (size at maturity, growth rate, longevity) and exploitation rates is essential to fill these gaps. This study will help assess the status of *Sphyrna lewini* stocks in order to formulate regulatory management measures for the sustainable exploitation.

2. Material and methods

The study area corresponds to the Ivorian artisanal fishing zone, which extends from Cape des Palmes (8°W) to Cape Three Points (2°30'W). It is located 5 to 10 nautical miles offshore, beyond the continental shelf. The Ivorian artisanal fishing zone extends from Cape of Palms (8°W) to Cape of the Three Points (2°30'W), located 5 to 10 nautical miles offshore, beyond the continental shelf. Data were collected at the port of Abidjan and the Abobodoumé landing site, two key locations for fish landings.

2.1. Material

The biological material consists of *Sphyrna lewini*, commonly called the scalloped hammerhead shark. These sharks were obtained from artisanal fishery landings in Abidjan. The artisanal fishermen use motorized canoes and drift gillnets for fishing. Taxonomic keys were used to identify the different specimens [15; 18]. A measuring tape was used to measure the total length of each shark. The FiSAT II software was used to analyze the different size-frequency distributions recorded.

2.2. Methods

To assess the growth and exploitation parameters of *Sphyrna lewini* caught in Ivorian waters, the adopted methodology was based on the collection of size-frequency data and the analysis of fishing pressure. Data were collected monthly between January 2019 and December 2020 during artisanal fishery landings in Abidjan. A total of 774 specimens were sampled from catches made by fishermen using motorized canoes and drifting gillnets. These specimens were identified using taxonomic keys [15; 18]. Each shark was measured for total length to the nearest centimeter. Length frequencies were grouped into 5 cm size classes by month. The FiSAT II software was used to estimate the growth and exploitation parameters of Sphyrna lewini [19]. The seasonal abundance of the catches was also analyzed.

The growth parameters were calculated using the mathematical model implemented in the FiSAT II software [19]. The asymptotic length ($L\infty$) and the growth coefficient (K) were estimated using the ELEFAN I module of FiSAT II, version 1.2.2 [20]. Individual growth was modeled using Von Bertalanffy equation, which expresses fish length as a function of age. The equation is as follows:

- $Lt = L\infty [1 – e^{-K (t - to)}]$, Where:
- Lt = total length of the fish at age t (in cm);
- $L\infty$ = asymptotic length (in cm),
- the length the species would reach if it continued to grow indefinitely;
- K = growth coefficient ($year^{-1}$), representing the rate at which the species approaches $L\infty$;
- t_0 = theoretical age at which the fish would have zero length (in years);
- t = age of the fish at time t (in years).

Based on the obtained values of K and $L\infty$, the growth performance index (Ø') was calculated using the equation of Pauly and Munro (1984): $Ø' = \log k + 2 \log L\infty$

The theoretical age at zero length (t_0) was calculated using the empirical Equation [21]: $\log10(-to) = -0,3922 - 0,2752\log10\ L\infty - 1,038\ \log10K$

Longevity (t_{max}), indicating the age at which 95% of the asymptotic length ($L\infty$) is reached, was estimated using the next equation [22]: $t_{max} = 5(\ln 2) / K$.

The age at first maturity (t_m) was calculated using the next formula [23]:

$Log(t_{max}) = 0.5496 + 0.957 \log(t_m)$.

Regarding mortality parameters and the exploitation rate, these were estimated from the length-converted catch curve using the ELEFAN I module of the FiSAT II software. Total mortality (Z) was calculated using the following equation [20]:

$$\ln\left(N/\Delta t_i\right) = a + bt_i$$

Were

- N = number of fully recruited fish in length class i;
- Δti = time required for the fish to grow through length class i;
- t = average age of the fish in the length class with abundance N;
- b = slope representing total mortality, with a change in sign.

Natural mortality (M) was calculated using the following empirical equation [24]:

Log(M)= -0,0066) - 0,279Log(L∞) + 0,6543Log(K)+ 0,4634Log(T)

- M: natural mortality rate
- F: fishing mortality rate
- Z: total mortality rate; With an average annual water temperature of T = 26°C.
- Based on the values of M and Z, the fishing mortality rate (F) was estimated using the next relationship [25]: Z = M + F.

The fishing mortality was calculated using the formula: F = Z - M.

The exploitation rate was calculated using Gulland's formula: E = F / Z.

The exploitation rate (E) is used to assess the status of a stock based on its different values [26]. When the exploitation rate (E) equals 0,5, it indicates a stock in equilibrium, with maximum sustainable yield. If E < 0.5, the stock is underexploited, and if E > 0.5, it is overexploited.

The ELEFAN I module, integrated into the FiSAT II software, was used to determine the recruitment pattern of Sphyrna lewini based on the collected length-frequency data [27]. The relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R), at different levels of fishing mortality, were estimated using yield-per-recruit analysis [28].

3. Results

3.1. Size frequency distribution

The histogram (Figure 1) shows the size-frequency distribution of *Sphyrna lewini* caught off the Ivorian coast between 2019 and 2020. The size-frequencies of the captured individuals range from 90 cm to 235 cm, with an average size of 160 cm. The overall frequency distribution shows a concentration of catches around the size classes between 150 cm and 170 cm, with a total of 373 individuals, representing 48.19% of the landed sharks. The modal class is [150–155 cm [with a maximum of 109 individuals, followed by the [155–160 cm [class with 94 individuals, the [160–165 cm[class with 89 individuals, and the [165–170 cm[class with 81 individuals. In contrast, the numbers are very low at the extremes of the distribution, particularly for small individuals (less than 120 cm) as well as for those measuring 200 cm or more. The largest observed size of *Sphyrna lewini* was 235 cm, while the smallest was 90 cm.

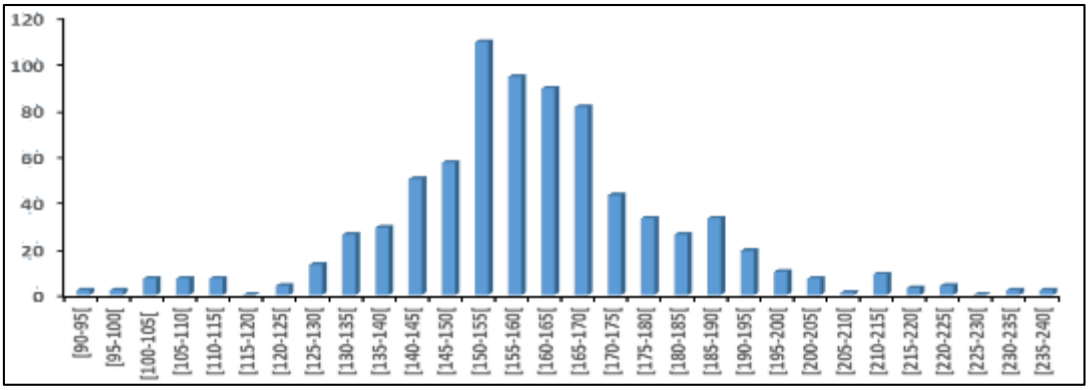

Figure 1 Histogram of size-frequencies of *Sphyrna lewini* caught off the Ivorian coast between 2019 and 2020

3.1.1. Seasonal variation of catches

The histogram (Figure 2) shows the number of *Sphyrna lewini* caught off the Ivorian coast according to the marine seasons. The highest numbers were recorded during the major cold season (MCS), from July to October, in 2019 and 2020, with respective counts of 205 and 198 specimens. The warm seasons were the least productive. The lowest abundances were observed during the PSC (November and December), with 31 individuals in 2019 and 21 in 2020.

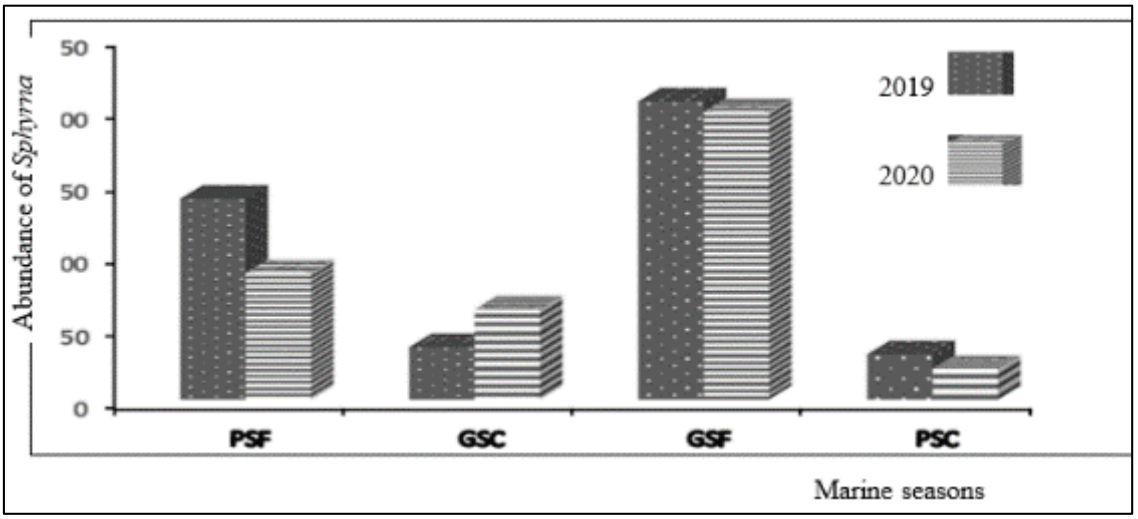

Figure 2 Histogram of *Sphyrna lewini* numbers caught off the Ivorian coast according to marine seasons

The parameters were calculated from size-frequency data of 774 *Sphyrna lewini* specimens. The main estimated growth parameters ($L\infty$, K, t_0, t_{max}, t_m, and Ø') are presented in Table 1. The asymptotic length ($L\infty$) is 266.75 cm. The growth coefficient (K) is 0.17 year^{-1}, with a model fit score (Rn) of 0.354 (Figure 3). The theoretical age at birth (t_0) is estimated at -0.549 years. These obtained parameters allow the following Von Bertalanffy equation to be derived:

$$Lt = 266{,}75\ [1 - e^{-0{,}17\ (t + 0\ ;549)}].$$

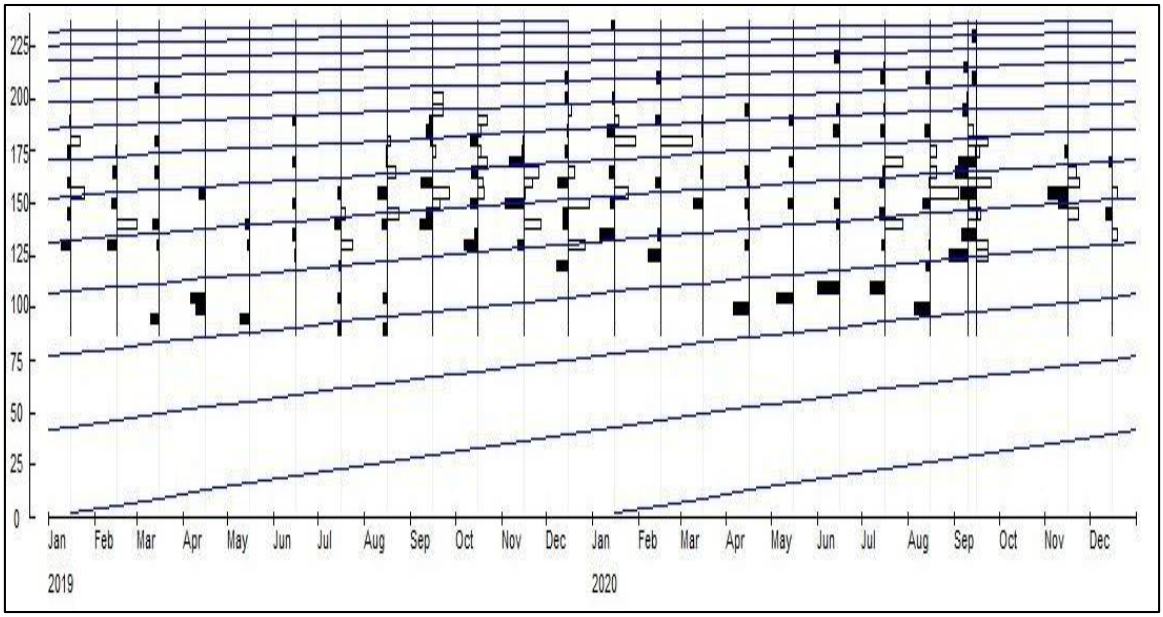

Figure 3 Growth curves of *Sphyrna lewini* caught between January 2019 and December 2020 off the Ivorian coast, based on the Von Bertalanffy growth model estimated using the ELEFAN I method in the FiSAT II software. L∞ = 266.75 cm, K = 0.17 year^{-1}, Rn = 0.345

The theoretical initial age (t_0) of *Sphyrna lewini* is estimated at -0.549 years. The species has a growth performance index (Ø') of 4.083 and reaches sexual maturity at approximately 6.22 years of age. Its theoretical longevity is estimated at 20.39 years.

Table 1 Growth parameters of *Sphyrna lewini* caught between January 2019 and December 2020 off the Ivorian coast

Parameters	Values
L∞ (Cm)	266.75
K (year^{-1})	0.17
Ø'	4.083
Rn	0.345
t_0(year^{-1})	-0.549
Tmax (years)	20.39
Tm (years)	6.22

3.2. Exploitation parameters and mortality coefficients

The mortality parameters and the exploitation rate determined in this study are presented in Table 2. The total mortality (Z) is estimated at 0.92 year^{-1}, while fishing caused a mortality (F) of 0.63 year^{-1}, and natural mortality (M) is estimated at 0.29 year^{-1}. These mortality rates yielded an exploitation rate of E = 0.68, which is higher than E_{50} (0.385) as well as the reference threshold of 0.5 proposed by Gulland (Figure 4). The assessment of exploitation parameters of *Sphyrna lewini* in Ivorian waters reveals a high fishing pressure on the population.

Table 2 Mortality and exploitation parameters of *Sphyrna lewini* specimens sampled between January 2019 and December 2020 off the Ivorian coast

Parameters	Values
Natural mortality (M) per year	0.29
Fishing mortality (F) per year	0.63
Total mortality (Z) per year	0.92
Exploitation rate (E)	0.68

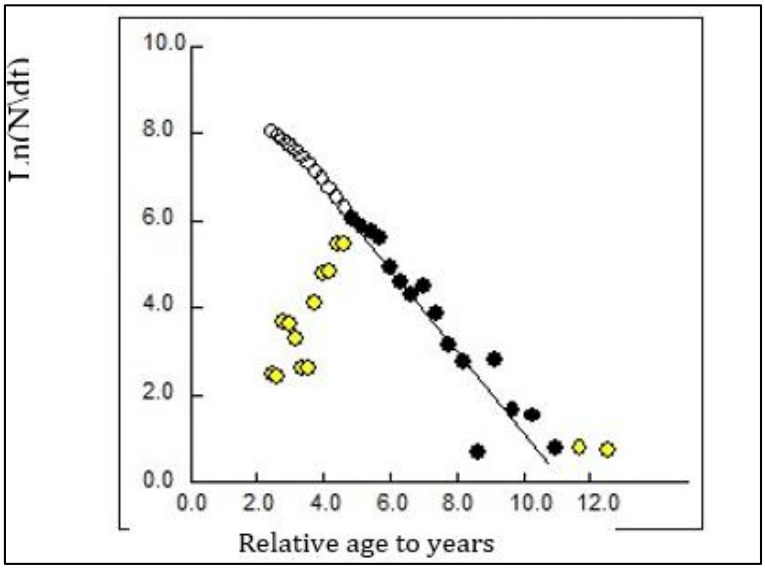

Figure 4 Catch curve of *Sphyrna lewini* caught off the Ivorian coast based on length

The selectivity curve of *Sphyrna lewini* reveals a size at first capture (Lc or L_{50}) estimated at 151.07 cm (Figure 5). The size L_{25}, at which 25% of individuals are caught, is estimated at 139.26 cm, while the size L_{75}, corresponding to 75% of captures, is 162.89 cm.

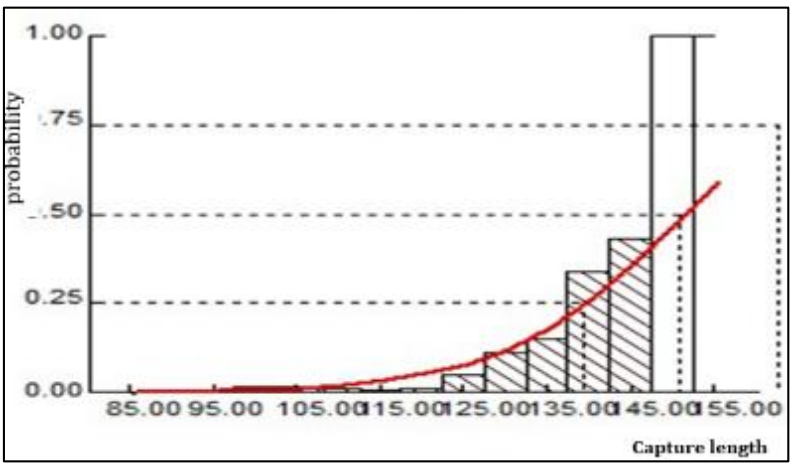

Figure 5 Capture probability (L_{25} = 139.26 cm; L_{50} = 151.07 cm; L_{75} = 162.89 cm) of *Sphyrna lewini* off the Ivorian coast

3.2.1. Recruitment

Two recruitment periods occur during the year (Figure 6). The first recruitment peaks at 12.96% of individuals being replaced by new recruits in April. The second, larger recruitment takes place in June, with a maximum of 15.85% of individuals replaced by new recruits.

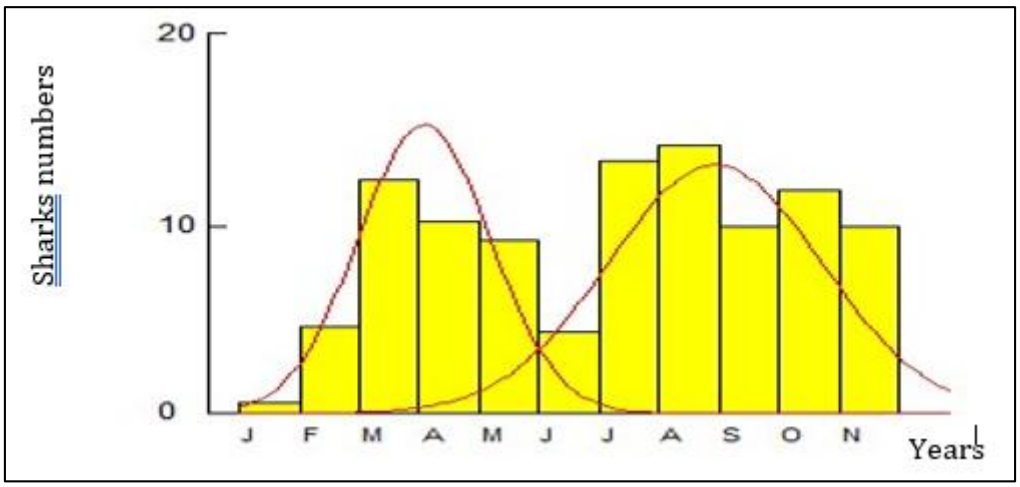

Figure 6 Estimation of the recruitment rates of *Sphyrna lewini* of the coast of Côte d'Ivoire.

3.3. Stock assessment

The analysis of the relative yield-per-recruit (Y'/R) curve for *Sphyrna lewini* reveals that the maximum Y'/R ratio is obtained at an Emax of 0.859(Figure 7). The marginal exploitation rate E_{10} is 0.655. The exploitation rate (E_{50}) at which the relative biomass per recruit (B'/R) is reduced to 50% of the virgin stock is estimated at 0.385. The current exploitation rate remains slightly below the estimated maximum rate (Emax = 0.859).

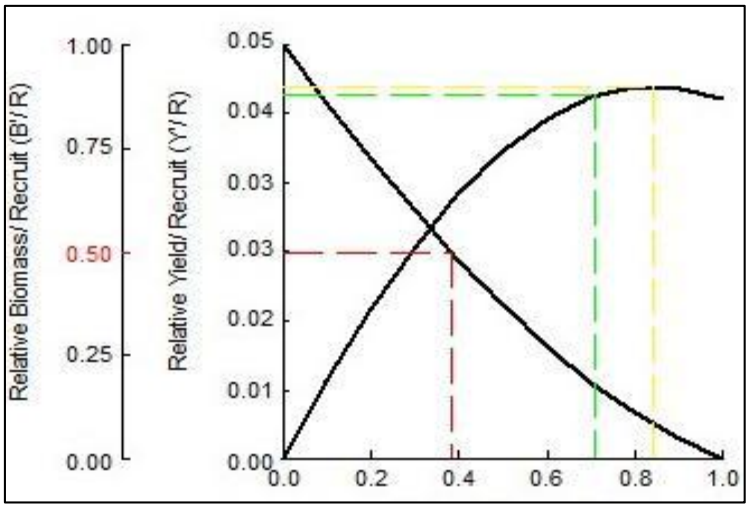

Figure 7 Catch curve according to the lengths of *Sphyrna lewini* of the coast of Côte d'Ivoire.

4. Discussion

The sizes of *Sphyrna lewini* specimens landed ranged from 90 to 235 cm, with a modal size class between 150 and 155 cm. These results are consistent with observations of sizes ranging from 100 to 225 cm for Sphyrna lewini specimens caught between 2008 and 2011 in Ivorian waters [1]. The findings reveal that 48.19% of the landed Sphyrna lewini specimens measured between 150 and 170 cm. These individuals are generally smaller than those observed in the Northwest Pacific Ocean, where sizes ranged from 130 to 250 cm for females and from 140 to 200 cm for males [29]. This result indicates strong fishing pressure mainly on medium-sized individuals, accompanied by a scarcity of large specimens in the catches. The presence of individuals of subadult to adult size is frequent in artisanal or semi-industrial

fisheries targeting or accidentally capturing coastal and pelagic sharks [1; 13]. Peak catches of *Sphyrna lewini* occur during the major cold season (MCS). This abundance results from favorable environmental conditions associated with coastal upwelling, which enhances marine primary productivity and increases prey availability [30; 31]. In fact, this period corresponds to the species' seasonal migrations toward coastal areas, driven by feeding or reproductive needs [32; 33. In contrast, the decline in catches during warmer seasons could be explained by the migration of individuals to deeper waters, making them less accessible to fishing gear. The asymptotic length (L∞) of *Sphyrna lewini* observed in Ivorian waters exceeds that of specimens from tropical regions, estimated at 211.9 cm [34]. However, the asymptotic length (L∞) is lower than that of individuals from temperate zones, reaching up to 319.9 cm, as well as that of specimens from the east coast of Australia [34]. The scarcity of large specimens in the landings could explain this lower asymptotic length. Indeed, Ivorian artisanal fishers operate only along the coast. However, large individuals, particularly females, are likely to be found in deeper and/or offshore waters [35]. Estimation of the growth coefficient of *Sphyrna lewini* living in Ivorian waters reveals that this species grows slowly. Low growth rates have also been observed in *Sphyrna lewini* [36; 37]. In contrast to individuals from tropical areas (0.163 $year^{-1}$), specimens from temperate regions displayed a substantially lower growth rate of 0.093 $year^{-1}$ [35]. The growth performance index (Ø' = 4.083) indicates that *Sphyrna lewini* exhibits slow growth, typical of large coastal sharks. This value is consistent with those reported for specimens in Indonesia [38]. The present study estimates the natural mortality of *Sphyrna lewini* at 0.29 yr^{-1}, compared to a fishing mortality of 0.63 yr^{-1}. This high fishing pressure more than twice the natural mortality indicates potential overexploitation of the species. Increased vigilance is therefore necessary to prevent the extinction of this species. The size at first capture (L_{50} = 132.45 cm) is lower than the various sizes at sexual maturity of *Sphyrna lewini* reported in several studies. Males reach sexual maturity at 198 cm total length (TL) and females at 210 cm TL [39]. Furthermore, the size at maturity has also been estimated at 181 cm TL for males and 199 cm TL for females [40]. These findings indicate that the specimens captured in Ivorian waters are mostly immature individuals. Such exploitation is likely to reduce the species' reproductive potential and compromise stock replenishment. This raises concerns regarding the sustainability of the population, as *Sphyrna lewini* is listed as "Endangered" by the IUCN due to its late maturity and low resilience [40]. The two main recruitment peaks, recorded in April (12.96%) and especially in June (15.85%), could indicate a seasonal reproductive strategy. However, in Kaneohe Bay, Hawaii, births occur throughout the year, although an increased intensity is also observed between April and October [41]. Moreover, a higher presence of juveniles was observed in coastal areas between May and July [42]. These recruitment peaks should be considered critical periods for the survival of juvenile cohorts and for the development of appropriate management strategies. Given the exploitation rate (E = 0.68), which exceeds the optimal exploitation threshold (E=0.5) defined [26]. This study highlights a situation of overexploitation that may compromise the natural replenishment of the *Sphyrna lewini* population.

5. Conclusion

Catches of *Sphyrna lewini* in Ivorian waters consist of medium-sized individuals, reflecting targeted fishing pressure likely to cause a demographic imbalance. These catches show seasonality, with peak abundances during the major cold season (July to October), and significantly lower numbers during the warm season, particularly in November and December. The species is characterized by slow growth and displays two annual recruitment periods, with a first peak in April, followed by a second, more pronounced one in June. Furthermore, the species experiences fishing mortality that is twice as high as natural mortality, indicating intense exploitation pressure. The *Sphyrna lewini* population is in a state of overexploitation, with an exploitation rate exceeding the estimated maximum sustainable rate off the Ivorian maritime coast.

Compliance with ethical standards

Disclosure of conflict of interest

All authors have no conflict of interest to declare.

No conflict of interest to be disclosed.

This case report was conducted in accordance with ethical guidelines.

References

[1] Konan KJ, Diaha NC, Sylla S, Amandè MJ, Tapé GTJ. Importance des requins dans les captures de la peche artisanale aux filets maillants derivants de Côte d'ivoire, Collective Volume of Scientific Papers. ICCAT.2014; 70(5): 2446-2451.

[2] Dulvy NK, Fowler SL, Musick JA, Cavanagh RD, Kyne PM. Harrison LR, Carlson JK, Davidson LNK, Fordham SV, Francis MP, Pollock CM, Simpfendorfer CA, Burgess GH, Carpenter KE, Compagno LJV, Ebert DA, Gibson C, Heupel MR, Livingstone SR, Sanciangco JC, Stevens JD, Valenti S, White WT. Extinction risk and conservation of the world's sharks and rays, eLife. 2014 ; 3 :1–34.

[3] Nance HA, Klimley P, Galván-Magaña F, Martínez-Ortíz J, Marko PB. Demographic Processes Underlying Subtle Patterns of Population Structure in the Scalloped Hammerhead Shark, *Sphyrna lewini*. PLOS ONE. 2011 ; 6(7) : e21459.

[4] Sherman CS, Simpfendorfer CA, Pacoureau N, Matsushiba JH, Yan HF, Walls RHL, Rigby CL, VanderWright WJ, Jabado RW, Pollom RA, Carlson JK, Charvet P, Bin Ali A, Fahmi, Cheok J, Derrick DH, Herman KB, Finucci B, Eddy TD, Palomares MLD, Avalos-Castillo CG, Kinattumkara B, Blanco-Parra MD, Dharmadi, Espinoza M, Fernando D, Haque AB, Mejía-Falla PA, Navia AF, Pérez-Jiménez JC, Utzurrum J, Yuneni RR, Dulvy NK. Half a century of rising extinction risk of coral reef sharks and rays. Nature Communications. 2023 ; 17 ;14(1) :15.

[5] Partin, T. G., Alberto J. Gonzalez & Mary K. Burnham-Curtis. Sharks on a plane: Large shark fin seizure shines light on shark exploitation. Forensic Science International: Animals and Environments. 2022; 2:100055.

[6] Gallucci VF, Taylor IG, Erzini K. Conservation and management of exploited shark populations based on reproductive value. Canadian Journal of Fisheries and Aquatic Sciences. 2006 ; 63 : 931–942.

[7] Irsan A, Wijayanti F, Assyuti Y M, Yuneni R R. Fisheries and biological aspects of Dusky Shark Carcharhinus obscurus (Lesueur, 1818) in Muncar Fishing Port, Banyuwangi, Indonesia. Acta Aquatica Turcica. 2021; 17(4): 463-473.

[8] Cardeñosa D, Shea SK, Zhang H, Fischer GA, Simpfendorfer CA, Chapman DD. Two thirds of species in a global shark fin trade hub are threatened with extinction: conservation potential of international trade regulations for coastal sharks, Conservation Letters. 2022; 15 (5): e12910.

[9] Dulvy NK, Pacoureau N, Rigby CL, Pollom RA, Jabado RW, Ebert DA, Finucci B, Pollock CM, Cheok J, Derrick DH. Overfishing drives over one-third of all sharks and rays toward a global extinction crisis Current Biology. 2021;31(21): 4773–4787.e4778.

[10] Talwar BS, Anderson B, Avalos-Castillo CG, del Pilar Blanco-Parra M, Briones A, Cardeñosa D, Carlson JK, Charvet P, Cotton CF, Crysler Z. Extinction risk, reconstructed catches and management of chondrichthyan fishes in the Western Central Atlantic Ocean. Fish and Fisheries. 2022 ; 23(5) : 1150–1179.

[11] Dulvy NK, Baum JK, Clarke S, Compagno LJV, Cortés E, Domingo A, Fordham S, Fowler S, Francis MP, Gibson C, Martinez J, Musick JA, Soldo A, Stevens JD, Valenti S. You can swim but you can't hide: the global status and conservation of oceanic pelagic sharks and rays. Aquatic Conservation: Marine and Freshwater Ecosystems. 2008 ;18(5) : 459–482.

[12] Pardo SA, Kindsvater HK, Reynolds JD, Dulvy NK. Maximum intrinsic rate of population increase in sharks, rays, and chimaeras: the importance of survival to maturity. Canadian Journal of Fisheries and Aquatic Sciences. 2016; 73(8): 1159–1163.

[13] Clarke SC, McAllister MK, Milner-Gulland EJ, Kirkwood GP, Michielsens CGJ, Agnew DJ, Pikitch EK, Nakano H, Shivji M.S. Global estimates of shark catches using trade records from commercial markets, Ecology Letters. 2006; 9:1115-1126

[14] Cardeñosa D, Fields AT, Babcock EA, Shea SK H, Feldheim K A, Chapman DD. Species composition of the largest shark fin retail-market in mainland China, Scientific Reports. 2020; 10, 1–10.

[15] Compagno LJV. FAO Species Catalogue. Sharks of the world: An annotated and illustrated catalogue of shark species known to date. Part 2 : Carcharhiniformes. FAO Fisheries Synopsis. 1984a ;125 (4/2). p. 251–655.

[16] Rigby CL, Dulvy NK, Barreto R, Carlson J, Fernando D, Fordham S, Francis MP, Herman K, Jabado RW, Liu KM, Marshall A, Pacoureau N, Romanov E, Sherley RB, Winker H. *Sphyrna lewini*. The IUCN Red List of Threatened Species. 2019 : e.T39385A2918526. Accessed on August 8, 2025, from https://www.iucnredlist.org/species/39385/2918526

[17] N'Goran YN, Kouassi Y, Barrigah B. Quantités et tailles des requins capturés par la pêcherie de filet maillant dérivant en côte d'ivoire, Collective Volume of Scientific Papers, ICCAT. 2005 ; 58(3) : 1087-1095.

[18] Compagno LJV. FAO species catalogue, Sharks of the world: an annotated and illustrated catalogue of shark species known to date. Part 1: Hexanchiformes to Lamniformes FAO, Fisheries Synopsis. 1984b;125(4). P. 249

[19] Von Bertalanffy LV. A quantitative theory of organic growth, Human Biology. 1938;10: 181–213.

[20] Gayanilo FC Jr, Sparre P, Pauly D. The FAO-ICLARM Stock Assessment Tools (FISAT) User's Guide. FAO Computerized Information Series (Fisheries). Rome: Food and Agriculture Organization of the United Nations.1996 ; p. 128

[21] Pauly D. Gill size and temperature as governing factors in fish growth: a generalization of von Bertalanffy's growth formula. Berichte des Instituts für Meereskunde an der Universitat Kiel. 1979 ; 63(xv). p.156

[22] Cailliet GM, Mollet HF, Pittenger GG, Bedford D, Natanson LJ. Growth and demography of the Pacific angel shark (Squatina california), based upon tag returns off California. Australian Journal of Marine and Freshwater Research.1992 ;43 :1313–30.

[23] Froese R, Binohlan C. Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. Journal of Fish Biology. 2000 ; 56(4) :758–73.

[24] Pauly D. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. Journal du Conseil International pour l'Exploration de la Mer. 1980 ; 39 (3) :175–92.

[25] Pauly D. Studying single-species dynamics in a tropical multi-species context. In: Pauly D, Murphy GI. editors. Theory and management of tropical fisheries. ICLARM Conf Proc. 1982 ; 9 :33–70.

[26] Gulland JA. Manuel des méthodes d'évaluation des stocks d'animaux aquatiques. Première partie : Analyse des populations. Man Sci Halieut FAO. 1969 ; 4(FRS/M4) : p.160

[27] Moreau J, Cuende FX. On improving the resolution of the recruitment patterns of fishes. ICLARM Fishbyte. 1991 ; 9 :45–6.

[28] Beverton RH, Holt SJ. Manual of methods for fish stock assessment. Part II : Tables of yield functions. FAO Fisheries Biology Technical Paper. 1966 ; 38 :10–67.

[29] Huynh HH, Tsai W-P. Estimation of the population status of smooth hammerhead shark (Sphyrna zygaena) and scalloped hammerhead shark (*Sphyrna lewini*) in the Northwest Pacific Ocean: A data-limited approach. Journal of Sea Research. 2023 ;195 :102434.

[30] Peterson WT, Emmett R, Goericke R. Coastal upwelling and productivity in the Pacific : ecological implications. Progress in Oceanography. 2001 ; 49(1–4) :237–64.

[31] Ketchum JT, Hearn A, Klimley AP, Peñaherrera C, Espinoza E, Bessudo S, Soler G, Arauz R. Seasonal movements of *Sphyrna lewini* across the Eastern Tropical Pacific : a collaborative research and tagging program. Marine Biology. 2014 ;161(5) :939–951.

[32] Zanella I, López-Garro A, Cure C. Reproduction and abundance of the scalloped hammerhead shark *Sphyrna lewini* (Griffith & Smith, 1834) in Golfo Dulce, Costa Rica. Revista de Biología Tropical. 2006 ;54 (3) :105–16.

[33] Cuevas-Gómez JL, Pérez-Jiménez JC, Méndez-Tenorio FJ, Galván-Magaña FJ. Use of coastal habitats by juvenile scalloped hammerhead sharks (*Sphyrna lewini*) in the southern Gulf of Mexico. Environmental Biology of Fishes. 2020 ;103(7) :809–21.

[34] Harry AV, Macbeth WG, Gutteridge AN, Simpfendorfer CA. The life histories of endangered hammerhead sharks (Carcharhiniformes, Sphyrnidae) from the east coast of Australia. Journal of Fish Biology. 2011 ;78(6) :2026–51.

[35] Mollet HF, Cliff G, Pratt HL, Stevens JD. Reproductive biology of the female shortfin mako, Isurus oxyrinchus Rafinesque, 1810, with comments on the embryonic development of lamnoids. Fishery Bulletin. 2000 ; 98 :299–318.

[36] Frazier BS, Galloway AS, Natanson LJ, Piercy AN, Driggers WBDIII. Age and growth of scalloped (*Sphyrna lewini*) and Carolina (*Sphyrna gilberti*) hammerheads in the western North Atlantic Ocean. SEDAR 77-DW19. North Charleston, SC: SEDAR; 2021. p.11.

[37] Kotas JE, Mastrochirico V, Petrere M Jr. Age and growth of the scalloped hammerhead shark, *Sphyrna lewini* (Griffith and Smith, 1834), from the southern Brazilian coast. Brazilian Journal of Biology. 2011 ;71(3) :755–61.

[38] Sentosa AA, Dharmadi, Tjahjo DWH. Population parameters of scalloped hammerhead shark (*Sphyrna lewini,* Griffith & Smith, 1834) caught from southern Nusa Tenggara waters. Jurnal Penelitian Perikanan Indonesia. 2016 ;22(4) :253–62.

[39] Ichsan M, Simeon BM, Muttaqin E, Munawir. Size distribution and sex ratio of scalloped hammerhead shark (*Sphyrna lewini*) in Banda Aceh fisheries. IOP Conference Series : Earth and Environmental Science. 2019; 278: 012038.

[40] Alejo-Plata MD, Ahumada-Sempoal MA, de Guevara GCL, Gomez-Marquez JL. Population structure and reproductive biology of the hammerhead (Sphyrna lewini) (Carcharhiniformes: Sphyrnidae) caught in artisanal fisheries of Oaxaca, Mexico. Hidrobiologica. 2018 ; 28(3) :265–75.

[41] Clarke TA. The ecology of the scalloped hammerhead shark, Sphyrna lewini, in Hawaii. Pacific Science. 1971; 25: 133–144.

[42] White WT, Bartron C, Potter IC. Catch composition and reproductive biology of *Sphyrna lewini* (Griffith & Smith) (Carcharhiniformes, Sphyrnidae) in Indonesian waters. Journal of Fish Biology. 2008 ;72(7) :1675–89.