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Local Ecological Knowledge, Catch Characteristics, and Evidence of Elasmobranch Depletions in Western Ghana Artisanal Fisheries

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Abstract
We relied on local knowledge of fishers in five coastal communities in Ghana to investigate ecological factors that affect fishing for elasmobranchs (sharks and rays) and the changes in the abundance of sharks and rays from 1980 to 2020. We gathered data using participant observation, interviews, focus group discussions, and participatory rural appraisal techniques. The results revealed fisher's understanding of six main ecological conditions, which have been applied over the years to improve fishing and maximize fisher catch: season and weather conditions, lunar phase, bait type, presence of seabirds and fish movement, the color of seawater, and sea current. Most elasmobranch species were abundant in 1980 but became severely depleted as of 2020, except Blue Shark (*Prionace glauca)* and Devil rays (*Mobula* spp.), shared by the fishers. We found fishers' local ecological knowledge consistent with scholarly knowledge and call for its inclusion in research, decision-making, and management interventions by biologists and policymakers.

Keywords Artisanal fisheries · Abundance trend · Marine management · Sharks · Rays · Ghana · Western Africa

Introduction

The data needed for managing artisanal fisheries exploitation, like population trends and catch efforts, have traditionally been acquired from scientific surveys and monitoring methods (Castillo-Géniz et al., 1998; Lunn & Dearden, 2006). However, in developing countries with high biodiversity and mixed-species fisheries, these time-consuming and relatively expensive methods may be challenging to implement (Anadón et al., 2009; Johannes et al., 2000). With these difficulties, researchers have to depend on alternative knowledge from local fishers to understand biological and ecological processes in the artisanal fishery setting (Colloca et al., 2020; Johannes et al., 2000; Leduc et al., 2021; Moore et al., 2010). There has also been increasing recognition that wildlife and fisheries management can no longer depend solely on empirical scientific data (Mangel et al., 1996; McCool & Guthrie, 2001; Riley et al., 2002; Wang et al., 2019). Therefore, incorporating the social dimension in developing relevant management protocols is widely advocated (McCleery et al., 2006; Miller, 2009).

Local ecological knowledge (LEK) has been described as practical, behavior-oriented, structured, dynamic, and based on long-term empirical observations (Ruddle, 2000). Ens et al. (2015) posit that people close to natural resources have a profound and comprehensive understanding of conservation and sustainable utilization and rely on LEK to protect their environment. LEK is gained through learning, imitating, and observing from experience (Mavhura & Mushure, 2019) and has been used to sustain local livelihoods, culture, forest, and wildlife resources for centuries (Parrotta & Agnoletti, 2007). The application of LEK in fisheries management has attracted public interest (Berkes et al., 2008; Olsson & Folke, 2001). It has been extensively used in fishery studies to characterize gear types and fishing efforts (Lam & Sadovy de Mitcheson,

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2011), estimate bycatch (Silver & Campbell, 2005), and provide biological data such as reproduction and fish diet (Grant & Berkes, 2007; Rasalato et al., 2010). LEK has also been used to study the population status and trends of fishes (Taylor et al., 2011), lobsters (Eddy et al., 2010), fisheries dynamics (Ainsworth et al., 2008), trends in ecological processes (Poizat & Baran, 1997), and to detect extinctions (Colloca et al., 2020; Dulvy & Polunin, 2004; Leduc et al., 2021). Sáenz-Arroyo and Revollo-Fernández (2016) compared long-term fishery data on catches with fishers' memories in the Baja's abalone (Haliotis spp.) fishery California, Mexico. They found that historical landings and fishers' memories strongly concur with the history of how this fishery has collapsed over the last 60 years. McClenachan et al. (2012) postulate that oral history, LEK, surveys, and historical documents are some of the few tools available to understand the trajectory of impacts on marine species and ecosystems. Further, Silvano and Valbo-Jorgensen (2008) hypothesize that LEK of fishers may have the potential to improve fishery management through the provision of new information about the ecology, behavior, and abundance trends of fishes and other aquatic animals.

In contrast to specialized industrial fleets that have finite fishing seasons and are regulated mainly by policies, artisanal fisheries are generally flexible and dynamic and operate almost all year round, with few or no management structures (Salas et al., 2007; Moore et al., 2010). Artisanal fisheries contribute 60% of animal protein consumed in Ghana, with average per-capita consumption between 20–25 kg per annum (Nunoo et al., 2014; Ministry of Fisheries and Aquaculture Development, 2015). Ghana's fishery sector provides direct and indirect employment to 10% of Ghanaians, which translates into 2.6 million people of the current population (Finegold et al., 2010; Nunoo et al., 2014). Ghana has a 550 km coastline with about 90 lagoons and associated wetlands (deGraft-Johnson et al., 2010). The extensive coastline, lagoons, and rivers support many artisanal fisheries. Ghanaian artisanal fisheries range from subsistence to small-scale commercial fishing, part-time to full-time, sedentary to migrant fishers, non-advanced and non-differentiated, to highly specialized and differentiated fishing operations (Aheto et al., 2012; Demuynck, 1994). According to census data, about 12,000 artisanal canoes with over 124,000 fishers operating in 300 landing sites along Ghana's coastline (Amador et al., 2006; CRC, 2013). This figure is likely to be underestimated since many fishers and canoes are not registered, operate illegally, and may not have been counted in the census (CRC, 2013). Artisanal fishery contributes 80% to the total national annual marine fish landings by volume (CRC, 2013).

There is a growing awareness of the decline of shark and ray populations, and efforts are underway to provide relevant data on their status and develop strategies to halt and reverse their decline (Bräutigam et al., 2015; Dulvy et al., 2014). Nevertheless, few data exist regarding shark and ray catches and their status in West Africa (Fowler et al., 2005). A recent conservation strategy highlighted the urgent need to improve the collection, reporting, and analysis of information on sharks and rays throughout most of their range in West Africa, including Ghana, to guide improved fisheries management (Bräutigam et al., 2015; Dulvy et al., 2017). However, the small sizes of artisanal boats or canoes make an onboard observation of catches and record keeping logistically impossible, as there is no room to accommodate observers (Moore et al., 2010). Under such conditions, in-situ monitoring and estimates of vessel catch, effort, bycatch, and operations may not be applicable in artisanal fisheries. These fisheries are typically data-poor (Kelleher, 2005; Salas et al., 2007; Moore et al., 2010).

Additionally, discards at sea are largely unaccounted for, leading to information related to dead removals of bycatch (dead discards plus declared landings) being largely unavailable from artisanal fishers (Bonfil, 1994). Accordingly, national and global statistics on catch stock and fishing capacity may not yield accurate scientific data (Moore et al., 2010). As a result of these challenges, the current and historical status of sharks and rays in Ghana, including their catch characteristics, composition, threats, and operations of fishers targeting these species, are limited (Seidu et al., 2022b). We used local knowledge of fishers in Western Ghana to ascertain ecological factors that affect fishing operations and historical and current records of the status of sharks and rays in Ghana.

Here we tackle the following questions: (i) How do elasmobranch fishers learn, understand, and apply ecological features to enhance their fishing operations? (ii) How have catch composition and sizes of target species changed over time? (iii) How has fishers' abundance of commercially important shark and ray species changed since the 1980s?

We first present an overview of the regulatory framework for fishery activities in Ghana, followed by a description of the research settings, data collection, and analysis. In the discussion, we suggest management implications and the use of our findings.

Regulatory Structures Governing Fishery Activities in Ghana

The Ghanaian marine fishery encompasses the artisanal, semi-industrial, and industrial sectors, whose management falls under the Ministry of Fisheries and Aquaculture Development (MoFAD). MoFAD delegates functions, including implementation, to a semi-autonomous body, the Fisheries Commission. The Fisheries Commission was established under the Fisheries Act of 2002 (Act, 625), and it uses the Fisheries Regulations (L. I. 1968) and the Fisheries Law

(PNDCL 256, 1991) to regulate all the fishery sub-divided sectors.

The Fisheries Act, 2002 (Act 625) is the primary regulatory tool of the fisheries sector of Ghana, which application is intended through the Fisheries Regulation, 2010 (L.1. 1968). Act 625 consolidates all the preceding laws on fisheries, decrees, legislative instruments, and other subsidiary/subordinate legislation on the fisheries sector that are still in force. The Act seeks to integrate international agreements into the country's national legislation. It sets out provisions for the regulation and management of fisheries, the development of the fishing industry, and the sustainable exploitation of fishery resources. Details of the regulatory structures for managing fishery activities in Ghana are listed in Table 2.

Study Sites

We conducted this study in five coastal communities, the hotspots of elasmobranch fisheries in the Western Region of Ghana (Fig. 1, Table 1). These communities were selected based on three main reasons: (i) fishing is exclusive to artisanal fishers; (ii) sharks and/or rays form a significant component of the catch; and (iii) fishers were willing to cooperate with the researchers for the interview data. The communities are located on West Coast (≈95 km) and extend from the Ghana-Côte d'Ivoire border to the Ankobra River estuary (deGraft-Johnson et al., 2010). Because Tuesday is the day of the sea god, there is a prohibition on fishing in many coastal communities in Western Ghana (Alexander et al., 2017). Fishers in these communities observe fishing holidays and use Tuesdays to mend their gear and equipment, resolve conflicts, and carry out other social activities.

Methods

Data were collected through participant observations, face-to-face interviews with 33 respondents, five focus group discussions, and participatory rural appraisal methods. Data collection commenced in June 2019 and ended in July 2020. We used participant observation to understand the primary social dynamics in the study communities and became familiar with the various activities and fishing practices in the

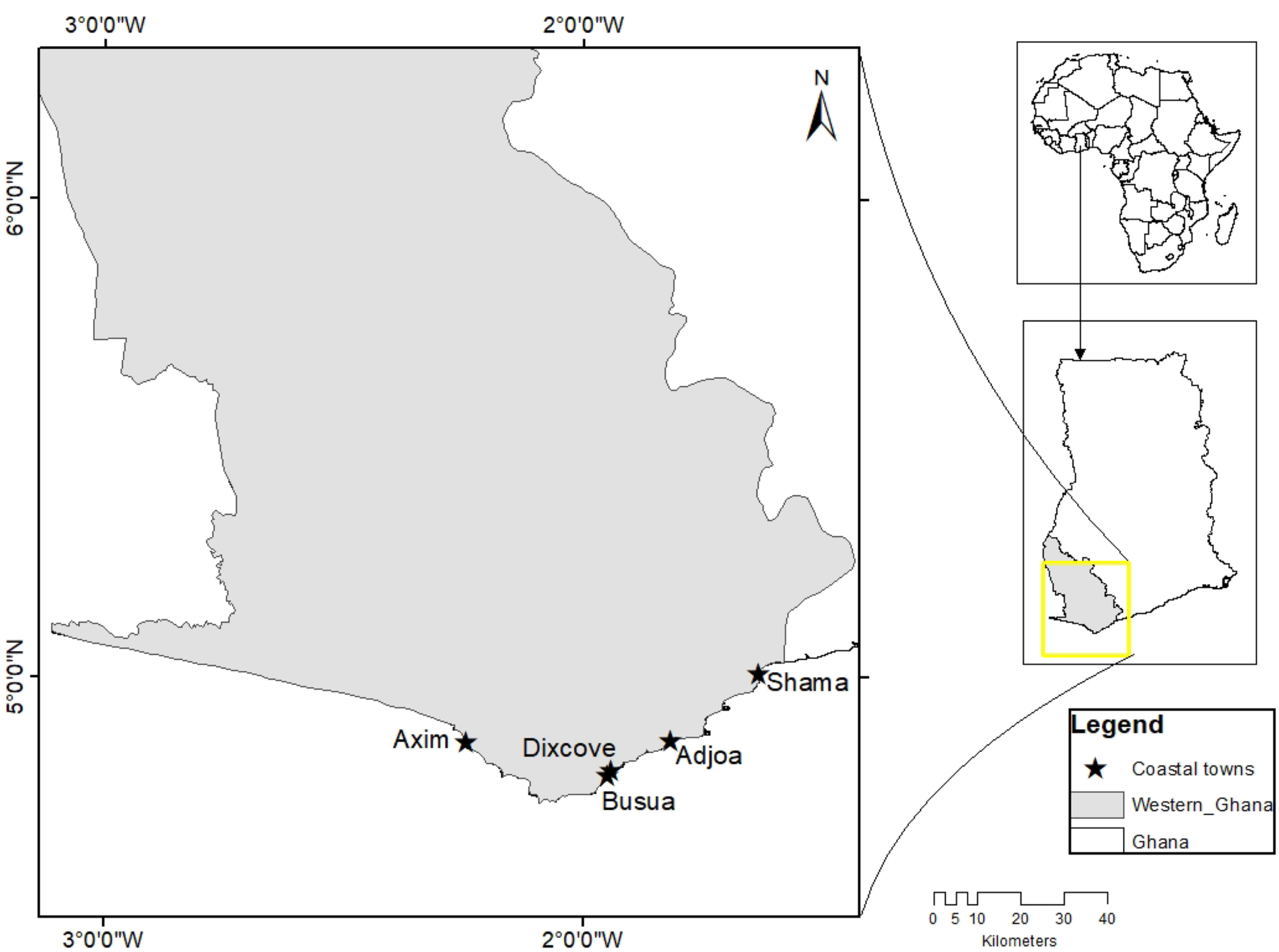

Fig. 1 Map of Western Ghana showing the five study communities

Table 1 Characteristics of study communities

Community	District assembly	Population	Number of canoes	Festival	Major ethic group
Adjoa	Ahanta West District	2,665	68	Kundum	Fante and Ahanta
Axim	Nzema East Municipal	27,719	220	Kundum	Nzema and Fante
Busua	Ahanta West District	1,667	81	Asa Baako	Ahanta
Dixcove	Ahanta West District	30,000	201	Kundum	Ahanta
Shama Apo	Shama District	23,699	265	Pra Nye-Eyi	Fante

Source of population data: Ghana Statistical Services (2014); Source of canoes data: CRC (2010)

communities. The first author also participated in community fishing activities, which included hauling marine megafauna ashore, butchering catch, and mending nets. He participated in all these activities to build trust with fishers in the various communities. Several meetings were held in small groups of fishers and chief fishers to explain the research's aim and rationale and garner their support for the research in their landing sites. The questions and interview guides were pre-tested in March 2020 in the communities of Axim and Shama, with eight respondents (four from each community).

Table 2 Regulatory structures governing Ghanaian fisheries

Laws and regulations	Brief description
Fishery Act 2002 (Act 625)	Prohibits the use of local, industrial or semi-industrial fishing vessel and the use of canoes without license and stipulates the process, application and qualification of acquiring a license. Regulates artisanal fishery Ban large semi-industrial vessels or industrial fishing vessels from fishing inside the Inshore Exclusive Zone (IEZ). Declaration of closed seasons, including their duration for fishing in specified areas of the coastal waters. Specified the types and sizes of devices and nets that are prohibited for fishing activities. Ban the use of any fishing method that aggregate fish either by light attraction, use of bamboo for purposes of aggregating fish, or use of explosives, or any obnoxious chemicals for fishing, or operating pair trawling. Ban the use of un-prescribed mesh net sizes for fishing
Fishery Regulation 2010	Regulates fishing vessels, gears and equipment and the issuing of fishing licenses. Prohibits fishing methods such as light attraction, portable generators, switchboards, and paired trawling. Bans all multifilament set-nets and monofilament set-nets of mesh size of less than 50 mm and 75 mm, respectively, in stretched diagonal length in the marine waters. Stipulates minimum landing size of commercially important species
Fisheries Amendment Act of 2014 (ACT 880)	An Act to amend the Fisheries Act, 2002 (Act 625) to give effect to international conservation and management obligations, to empower the Minister of Fishery and Aquaculture Development to make Regulations to combat Illegal, Unreported and Unregulated fishing in accordance with the international obligations of the Republic and to provide for related matters
Ministerial Directives in 2016	Directs all fishing vessels to maintain a minimum sanitary condition on board the fishing vessels
Ministerial Directives in 2016	Declared closed seasons for industrial trawlers for the periods 1st – 30th November 2016 and 1st February – 31st March 2017
Fisheries Amendment Regulation 2015 (L.I. 2217)	Stipulates the various requirements for the registration of a fishing vessel as a Ghanaian fishing vessel
Fisheries Management Plan of Ghana, 2015	Imposes license conditions to reduce the number of fishing days of various vessels available. Declares closed seasons for two months, up to four months from May- June and/ or November- December (to be determined). Increase the traditional one day fishing holiday per week to two days. Controls new entrants to the fishery sector. Implement co-management for artisanal fishery. Strict compliance with the International Commission for the Conservation of Atlantic Tuna (ICCAT). Strict adherence to licensing and monitoring of vessels. Stipulates the creation of marine habitat protection areas to protect nursery areas and spawning grounds, mainly in estuaries and mangrove areas
Ministerial Directives in 2021	Declared closed seasons for artisanal and inshore fleets for periods of 1st to 30th July, 2021 and industrial fleets from 1 to 31st August, 2021

Adapted from Seidu et al. (2022a)

We selected only retired and active fishers for this study because they have more direct interactions with elasmobranchs and other marine resources and are primary stakeholders in fisheries in Ghana. Further, the retired fishers have gained much experience in fishery activities and possess a wealth of retrospective knowledge of shark fisheries and operations. In contrast, active fishers possess current knowledge of fisheries, elasmobranch catch dynamics, and composition. A non-probability convenience sampling approach (Alexander et al., 2017) was used to select active fishers for the interview. The convenience sampling scheme also referred to as availability sampling, is based on the availability and willingness of respondents to participate in the interview (Naderifar et al., 2017; Newing, 2010). The snowball sampling scheme was employed to track down retired fishers who doubled as canoe owners. This sampling scheme is where research participants recruit other respondents for the study (Naderifar et al., 2017). The snowball sampling technique was selected as a referral or chain sampling is used where potential participants are difficult to find (Newing, 2010). These sampling schemes were used to select respondents as most fishers are aware of the global controversies surrounding sharks, particularly the shark fin trade, making it challenging to get fishers willing to participate in such interviews and open up to researchers.

Face-to-face interviews formed the primary data source. We interviewed 33 respondents comprising 17 retired fishers and 16 active fishers. We also interviewed three officials of the Fisheries Commission to validate some essential information from the fishers. Interviews were conducted at landing sites for active fishers and mainly at the homes of retired fishers and lasted between 60 and 80 min. The interviews were conducted mainly in the local languages used by each respondent. The first author conducted these interviews with the assistance of local volunteers fluent in English and Fante, Ahanta, Nzima, or Twi. The volunteers assisted the first author in translating information from Nzima and Ahanta languages to Twi or English when necessary. The purpose of the research was explained to all respondents, and their consent was sought before the interview. Respondents were also assured anonymity and their right to omit uncomfortable questions or withdraw from the interview.

Almost all questions used for the interviews were semi-structured, which allowed the researcher to probe further issues raised by the respondents. The researcher used the same questions for the interview in all five communities, with some questions adapted to suit the local context. For example, some questions were asked explicitly in communities where fishers used bottom-set or drift gillnet gears. Interviews were guided by sets of questions categorized into themes to understand the ecological factors influencing fishing operations and changes in shark and ray stock status. After conducting a series of interviews, it became clear that they use six major ecological categories to enhance their fishing operations. Specifically, questions were intentionally designed to generate comprehensive information regarding how well fishers understand these ecological factors and their influence on fishing operations. Interview questions provided an understanding of i) bait types and how they influence the catch of sharks; ii) seasons and weather conditions; iii) the effect of lunar phase on fishing activity; iv) the presence of sea birds and fish movement; v) color of seawater; vi) sea currents on fishing operations. In addition, interview questions were designed to collect data on the species targeted, seasons with the most elasmobranch catch, and changes in catch location. Changes in stock status focused on body sizes, species composition, and decadal changes in the abundance of well-known commercially essential sharks and rays since 1980. Factors causing the changes were also collected using trend analysis. This included a qualitative ranking of the abundance of ten commercial shark and seven ray species, which are well-known to fishers. Fishers were asked to characterize the abundance of each shark and ray species into one of four qualitative categories (abundant, common, depleted, and severely depleted) for each period – that is, the 1980s, 1990s, 2000s, 2010s, and 2020s. Fishers were asked to quantify the abundance categories of each species using ten stones. Seven to 10 stones indicated abundance, 5–6 indicated common, 3–5 indicated depleted, and 1–2 indicated severely depleted.

In addition, five focus group discussions (one per community) were organized for active and retired fishers in the various communities to validate the interview data. Each focus group discussion comprised six to nine participants. We slightly adapted the interview questions and used similar protocols for the focus group discussions to collect data on changes in shark and ray catch abundance, size, and composition.

Data Analysis

Content or thematic analysis was the principal protocol used for analyzing the data. The data were coded and analyzed using descriptive statistics and presented in tables or figures where necessary. Interview notes, field records, and focus group discussion (FGD) summaries were first written in the descriptive form and transcribed from spoken format to formal English. Categories from the interview data and FGD summaries were identified and aggregated manually.

For the decadal changes in abundance of commercially important shark and ray species, we assigned the abundant ordinal categories (i. e., abundant, common, depleted, and severely depleted) a category weight of 1, 0.75, 0.5, and 0.25, respectively. The weighted score for each species in a given decade was then calculated using the formula;

$$\text{Weight score} = \frac{\text{Category weight} \times \text{Percent value}}{100}$$

The percent value is the percentage of all respondents reporting abundance, common, depleted, and severely depleted for a species in a given decade.

The datasets generated during and/or analysed during the current study are available from the corresponding author upon reasonable request.

Results

Demographic Characteristics of Respondents

All 33 respondents were males, as women are barred from fishing due to traditional beliefs (Adjei & Sika-Bright, 2019). However, many women in the study communities are fish traders and processors who own canoes and thus control the selling price of fish. Of the 33 respondents, 52% (n = 17) were retired fishers who doubled as canoe owners and 48% (n = 16) were active fishers. The mean age of respondents was 45.9 ± 15.0. The fishing experience of both retired and active fishers ranged from 6–58 years. Many of the respondents (64%) had no education. Most of them belong to the Fante ethnic group (Table 3).

Fishing Gear Used in the Communities

The study sites have a multi-gear fishery. However, sharks and rays are caught with two major gear types; drift gillnets complemented with longlines and bottom-set gillnets. Baited hooks are deployed as secondary longline gears, which are set alongside the drift gillnet in the same fishing grounds and directions. The gears used by fishers were dependent on the size of the canoe, fishing grounds (oceanic or coastal), and in many instances, the finances of the canoe owners. All fishers interviewed from Shama, Dixcove, and Axim used drift gillnets complemented with longlines gear (n = 23), while fishers from Adjoa and Busua used bottom-set gillnets (n = 10) for their fishing operations. Both gear types were made of monofilament fishing lines. The gears are deployed and retrieved manually by the fishers.

Learning, Understanding, and Use of Ecological Variables in Fishing Operations

Fisher's knowledge of fishery activities and practices generally stems from older generations and their continued interactions with their surroundings, especially during fishing trips. Half of the interviewed fishers (48%) learned fishing practices and ecological factors from their families (grandfathers, fathers, and uncles), as apprentices in a crew (16%), or

Table 3 Demographic characteristics of respondents

Variables	Adjoa	Axim	Busua	Dixcove	Shama	Sum/ average
No. of retired fishers	2	4	2	4	5	17 (52%)
No. of active fishers	3	4	3	1	5	16 (48%)
Total no. of respondents	5 (15%)	8 (24%)	5 (15%)	5 (15%)	10 (30%)	
Mean age	42.0 ± 16.8	43.0 ± 12.2	42.0 ± 18.3	54.6 ± 11.6	47.7 ± 16.8	45.9 ± 15.0
Minimum age	26	22	20	42	27	
Maximum age	64	56	62	65	70	
Educational level						
Illiterate	4	5	4	3	5	21 (64%)
Junior school	0	1	1	0	2	4 (12%)
Senior High	1	0	0	2	1	4 (12%)
Tertiary	0	2	0	0	2	4 (12%)
Years of fishing experience	23.8 ± 12.0 (11- 41)	28.3 ± 12.4 (10–43)	27.2 ± 17.6 (16–50)	33.6 ± 14.2 (20–50)	31.4 ± 18.0 (10–58)	29.2 ± 14.7 (6–58)
Ethnic groups						
Fante	0	6	0	3	10	19 (58%)
Ahanta	4	1	4	0	0	9 (27%)
Nzima	1	1	1	2	0	5 (15%)

% represents percent of total respondents for each variable in some cases through observation (36%) in their communities. These ecological clues have been applied to enhance fishing operations and maximize fisher catch. Fishers could identify and name the species they target, their composition, and their abundance. They rely on local ecological knowledge to assess potential fishing locations, timing, and protocols for their fishing activities. The interviewed fishers described six categories of ecological factors they use as clues and their understanding of how these clues affect their mode of operations on the sea. The stated clues are subdivided into two main sections, which are presented below.

Fishers' Knowledge Regarding Timing and Protocols of Fishing

Knowledge about periods and the practice of fishing gave fishers opportunities to know when and how to fish. Such knowledge includes seasons, weather conditions, lunar phase, and bait type.

Seasons and Weather Conditions

All interviewed fishers agreed that knowledge about the bumper and lean seasons and the reproductive seasons for pelagic and demersal species are indispensable in preparing and targeting particular fish taxa. According to them, harvesting seasons for pelagic and demersal species vary considerably. Most drift gillnet-operated fishers (87%) stated that the harvesting season for sharks, billfish, and most types of tunas is from July to September. The lean seasons for these species are December to February. Fishers recounted that the breeding season for most tuna, including Frigate Mackerel (*Auxis thazard*), Skipjack (*Katsuwonus pelamis*), Yellowfin Tuna (*Thunnus albacares*), and Bigeye Tuna (*Thunnus obesus*) is from May to July and that of sharks is March to June. This is the period they mostly catch and see neonates. Most of the interviewed bottom-set gillnet fishers recounted that the harvesting season for rays, especially Stingrays (*Fontitrygon* spp.), Cassava Fish (*Micropogonias undulates*), and Threadfin Fish (Polynemidae), is from August to October.

Considering weather conditions, 82% of fishers reported that the primary rainy season (May to July) was not good for fishing. They recounted that this period is characterized by high fog, which makes navigation tricky. Heavy rainfall is usually accompanied by intense storms, which can capsize canoes and displace fishing nets. Many of the respondents (73%) mentioned the minor rainy season (August to November) and dry season (November to March) as the best periods for fishing.

Lunar Phase

Most fishers (94%) reported that the moon affects their ability to catch fish species of all kinds. These include large pelagic species like Sharks, Swordfish, Sailfish, and Tuna, and demersal species like Stingrays, Guitarfishes, and Anchovies in large quantities. Fishers reported that a full moon makes the water more transparent for these species to see and avoid the gears. To fishers, the best periods to go fishing are when there is partial or no moon. They said this allows them to get substantial catch because of the opaqueness of the water.

Bait Type

All the interviewed fishers operating with drift gillnets, which are complemented with longline gears, recounted that the type of bait used significantly influences the catch of large pelagic fish species. They mostly use freshly caught dolphins, Flying Fish, Tuna, and Sardinella as bait (Table 4). All respondents regarded Dolphins as the best and most effective bait for catching sharks, followed by Flying Fish. To fishers, dolphins' bright and shiny skin attracts sharks more quickly than any other bait. Further, all respondents reported that Dolphins and Flying Fish have a powerful odor and are characterized by high oil and blood content, which are good attractants for sharks. Dolphins are mostly bought from Dixcove in the Western Region, Tema in the Greater Accra Region, and Apam in the Central Region. Flying Fish and Tuna are harvested mainly by the local fishers operating with drift gillnets, while

Table 4 Species used as bait in drift gillnet fisheries in the study communities of West Ghana

Species	Common name	Scientific name	Local name	No. of respondents
	Atlantic Humpback	*Sousa teuszii*		
Dolphins	Common Bottlenose	*Tursiops truncates*	Etwui	23 (100%)
	Oceanic Dolphins	*Stenella* spp.		
Flying fish	Unspecified	Exocoetidae (family)	Epoanomaa	19 (83%)
	Frigate Mackerel	*Auxis brachydorax*	Apaku	
Tuna	Atlantic Little Tuna	*Ethynnus alleteratus*	Apakuwona	14 (61%)
	Chub Mackerel	*Scomber japonicas*	Akowona	
Sardinella	Round Sardinella	*Sardinella aurita*	Eban	8 (35%)
	Flat Sardinella	*Sardinella maderensis*		

Sardinella is caught by the fishers using ring net gears. The respondents mentioned that in desperate situations where all these baits are unavailable, they mostly rely on cold-store Sardinellas, Herrings, beef, and pork as baits.

Fishers' Knowledge Regarding Oceanographic Conditions

Knowledge of oceanographic conditions provided fishers with clues about fishing locations. These factors included sea birds and fish movement, the color of seawater, and sea currents.

Seabirds and Fish Movement

Most interviewed fishers (88%) reported that seabirds are good indicators for the presence of fish and potential fishing areas. Fishers reported that some birds could see deep below the water surface to hunt and feed on smaller fishes such as Anchovies and Sardinellas, which invariably serve as foods for large pelagic species, including sharks and billfishes. Hence, the presence of a large flock of birds hovering close to the surface of the seawater and dipping their beaks in the water indicates that there are fish, and the fishers set their nets along that particular area. Fishers further stated that knowledge regarding the movements of seabirds combined with understanding the rippling effect of seawater and fish movement are essential clues for identifying a prospective fishing location. According to respondents, a faster movement of fish from a particular area, or when seen jumping out the water, indicates that setting a net in that location may not yield a good catch. However, fishes moving in circular motions indicate to fishers that they are stable within that particular location. They, therefore, have a high possibility of getting abundant catch should they set their nets there.

Seawater Color

Interviewed fishers reported five different colors of seawater – deep blue, light blue, yellow, red, and light green (Table 5). The deep blue color, referred to as "Adomnsuo" in the local dialect, literally means "divine water" and was listed as the preferred color by all respondents (100%). It was followed by light blue/sea blue (91%). Yellow color (33%) was the least preferred seawater color for fishers and occurred intermittently at any period within the year. Fishers stated that Cassava Fishes, Herrings, and Bill fishes are primarily caught in yellow water whenever it occurs. Most respondents (78%) stated that deep blue water occurs unpredictably once a year between July and October at any location in the sea and does not last for more than two weeks. Deep blue water provides a bountiful catch of all kinds of fish to both drift gillnet and bottom-set gillnet fishers. Light green water provides suitable conditions for larger fish such as sharks, tunas, and Bill Fishes, and according to fishers, it can occur randomly at any period within the year. Red color occurs intermittently from June to July and is mainly associated with tunas (Frigate Mackerel, Skipjack), Guitarfishes, Whiprays, Cassava Fish, and Octopus. Light blue water occurs all year round whenever they go fishing and can get almost all kinds of pelagic and demersal fishes.

Sea Current

Most respondents (85%) reported that sea currents significantly impact fishing. Strong currents obstruct fish's movement and further carry them away from a particular area, while slow currents provide suitable conditions for fish to stay in one area. Fishers described the two main current directions they rely on while fishing on the sea – eastward and westward currents. Fishers stated that the eastward currents are primarily slow and provide favorable conditions for fish to stay in a particular area, thus being best for catching more fish. The westward currents were powerful and tended to transport fish away from the area.

Catch Composition and Abundance of Target Species

Fishers reported that they target multiple species in response to the seasonal changes and fluctuating abundance of most fish species. All interviewed fishers said they fish all year round, and the number of trips per annum depends on the canoe owners' financial capacity and the premix fuel availability. Most respondents (91%) stated that July to September was their 'bumper' season when the most excellent catches were taken. Fishers were quick to add that their fish stocks

Table 5 Fishers' perception of colors of seawater and associated favored fish species

Water color	Local names	Most favored species	No. of respondents
Deep blue	Adomnsuo	All kinds of fish, both demersal and pelagic	33 (100%)
Light blue	Sea blue	All kinds of fish, both pelagic and demersal	30 (91%)
Light green	Green water	Sharks, Tuna, and Bill Fish	24 (73%)
Red	Red water	Frigate Mackerel, Skipjack, Guitarfishes, Whip Rays, Cassava Fish, and Octopus	19 (58%)
Yellow	Yellow water	Cassava Fish, Herrings, and Bill Fish	11 (33%)

have been severely depleted presently and that there is no longer a guarantee of getting bumper harvests in these periods. All fishers are now generalists who target several species of fish. Drift gillnet fishers target large pelagic species but occasionally catch smaller ones, while the bottom-set gillnet fishers target demersal fishes and occasionally catch some pelagic species (Table 6). When asked about the most uncommon species of fish, most drift gillnet fishers stated that all shark species, except Blue Shark (*Prionace glauca*) (87%), Devil rays (*Mobula* spp.) (78%), and Marlins (Istiophoridae) (74%), are now becoming increasingly difficult to catch. Many interviewed fishers (65%) further listed tunas (Frigate Mackerel, Skipjack, Yellowfin, and Bigeye Tuna) as species dominating their catch. However, most bottom-set gillnet fishers (80% of 10 respondents) stated guitarfish and herrings as the rarest fish they catch. Fishers stated cassava fish and rays are the most common species they catch.

Table 6 Fish species targeted in bottom-set gillnet (BSN) and drift gillnet (DGN) gears in the study communities

Gears	Common name	Scientific/ family name	Local name
BSN	Rays/Guitarfishes	Unspecified	Tantra
	Threadfin Fish	Polynemidae	Ankasakasa
	Cassava Fish	*Micropogonias undulates*	Ekan
	Rock Sole	*Lepidopsetta bilineata*	Abrawan
	Tongue Sole	Cynoglossidae	Futfutu
	Lobsters	Nephropidae	Sessew
	Ribbon Fish	Trachipteridae	Nwanyan
	Sergeant Fish	*Abudefduf saxatilis*	Alatablade
	Pink Dentex	*Dentex gibbosus*	Wiriwirii
	Red Pandora	*Pagellus bellotti*	Wiriwirri
	Angola Dentex	*Dentex angolensis*	Wiriwirri
	Longfin Herring	*Pristigasteridae*	Kanfla
	Roncador Fish	*Roncador stearnsii*	Ebueakwoa
	Sardinella	Sardinella	Nkankraba
	Anchovy	Engraulidae	Ntare
DGN	All kinds of shark	Unspecified	Semin
	Frigate Mackerel	*Auxis thazard*	Apaku
	Skipjack	*Katsuwonus pelamis*	Anful
	Yellowfin Tuna	*Thunnus albacares*	Edei
	Atlantic Sailfish	*Istiophorus albicans*	Ekyirikyiri
	Swordfish	*Xiphias gladius*	Ekyirikyiriprako
	Blue Marlin	*Makaira nigricans*	Kwatwe
	Bigeye Tuna	*Thunnus obesus*	Edei
	Dolphin Fish	*Coryphaena hippurus*	Lifee
	Wahoo	*Acanthocybium solandri*	Eposurosafo
	Butterfish	Stromateidae	Kokotea
	Jack Mackerel	*Trachurus symmetricus*	Epei
	Doctor Fish	*Garra rufa*	Doctor
	Trigger Fish	Balistidae	Ewuraefua
	Crevell Jack	*Caranx hippos*	Epei
	Chub Mackerel	*Scomber japonicas*	Apaku

Changes in Elasmobranch-specific Catch Composition and Sizes

Fishers in the study communities have had a long-standing history of catching sharks since the early 1970s. Retired fishers recounted that they used to target small pelagic and demersal species with bottom-set gillnets and paddle canoes, setting their nets in coastal zones and retrieving them the next day. Fishers recounted the ongoing destruction of their gear by sharks and other bigger fishes, which motivated some of them to develop nets to suit the sizes of these big fishes in the early 1970s. Fishers reported that sharks and rays became a major target in the 1980s, when Ghanaians residing in the neighboring West African countries, including Guinea, Gambia, Senegal, and Mali, returned home and started trading shark fins, which afforded them much profit. A retired fisher in Shama recounted that:

> "When we started fishing about 50 years ago, our intention was never to catch sharks. Sharks were not valuable at all. Many fishers were not actually involved in shark fisheries. Most fishers were interested in tunas, anchovies, and sardinellas and were catching more in the coastal habitats. I started targeting sharks when I got much profit on my first fin trade in the late 1980s." (Retired fisher, Shama, 06/2020)

Interviewed fishers recalled their knowledge about the elasmobranch species they catch, their abundance, and their composition. The respondents' most well-known and valuable species were Blue Shark (*Prionace glauca*) and Devil rays (*Mobula* spp.), which were mentioned by all drift gillnet fishers. In contrast, Whale Shark (*Rhincodon typus*) was mentioned the least by respondents (17%) (Table 7). Fishers reported that Blue Sharks were the most common shark species caught in drift gillnet gears. This assertion was confirmed by the participants in the focus group discussions and during participant observation.

Regarding bottom-set gillnet fisheries, fishers could reveal knowledge about seven rays they caught in their gears. These included African Brown Skate (*Raja parva*, 90%), Electric Ray (*Torpedo torpedo,* 80%), and Stingrays (*Fontitrygon* spp., 80%), while Blackchin Guitarfish (*Glaucostegus cemiculus*, 30%) was the least caught ray species (Table 7). Most respondents (70%) stated African Brown Skate and Stingrays as the most common ray species caught. Focus group discussions and participant observation confirmed that these species were relatively common catches in bottom-set gillnet gears.

When asked about the best seasons to catch sharks, fishers gave a wide range of answers. This is because fishing

Table 7 Shark and ray species listed by drift gillnet (DGN) and bottom-set gillnet (BSN) fishers in the study communities

Gear	Common name	Scientific/ family name	Local name	No. of respondents
BSN	African Brown Skate	*Raja parva*	Enuanan	9 (90%)
	Stingray	*Fontitrygon* spp.	Dandze tantra	8 (80%)
	Eyed Electric Ray	*Torpedo torpedo*	Opusu	8 (80%)
	Butterfly Ray	*Gymnura sereti*	Tantra pa	7 (70%)
	Marbled Stingray	*Dasyatis marmorata*	Kwamankwa	6 (60%)
	Spineback Guitarfish	*Rhinobatos irvinei*	Esene	6 (60)
	Blackchin Guitarfish	*Glaucostegus cemiculus*	Esenetuntum	3 (30)
DGN	Blue Shark	*Prionace glauca*	Gogorow	23 (100%)
	Devil rays	*Mobula* spp.	Mbadie	23 (100%)
	Mako sharks	*Isurus* spp.	Edu	17 (74%)
	Hammerhead sharks	*Sphyrna* spp.	Anto	22 (96%)
	Thresher sharks	*Alopias* spp.	Polley	21 (92%)
	Bull Shark	*Carcharhinus leucas*	Esuoa	20 (87%)
	Lemon Shark	*Negaprion brevirostris*	Finpong	18 (78%)
	Tiger Shark	*Galeocerdo cuvier*	Epoagyinamoah	16 (69%)
	Sand Tiger Shark	*Carcharias taurus*	Ewiabere	13 (5%)
	Milk Shark	*Rhizoprionodon acutus*	Semin	8 (35%)
	Whale Shark	*Rhincodon typus*		4 (17%)

continues all year round. Only 39% of fishers reported that the best season for catching sharks is from October to December, especially immediately after the bumper season (July to September). One fisherman stated that he catches more sharks in November because they travel farther to the oceanic zone during this period, as most sharks are found in the deep sea. In response to the question "which location is best to catch more sharks or rays," over 96% of fishers operating with drift gillnets stated that oceanic habitats are where they catch more sharks. Bottom-set gillnetters fished only in coastal habitats and reported that they catch all their ray species in this particular habitat. Most fishers (91%) reported that the areas they used to fish in have changed significantly and that they must travel farther to reach their fishing grounds. The respondents attributed light fishing (88%) and foreign vessels (91%) as the reasons for depleting fish stocks.

In addition to assessing the species composition of elasmobranch catch, we asked fishers to state the species of shark and ray that are now very uncommon in their catch. Participants in the focus group discussions confirmed that Lemon Sharks, Tiger sharks, Hammerhead sharks, and Bull sharks were the rarest species caught presently. Lemon Sharks (*Negaprion brevirostris*, 83%), Tiger Sharks (*Galeocerdo cuvier*, 78%), Thresher sharks (*Alopias* spp., 73%), Hammerhead sharks (*Sphyrna* spp., 65%), Bull Shark (*Carcharhinus leucas*, 61%), and Sand Tiger Shark (*Carcharias taurus*, 54%) were most frequently stated by fishers (n = 23) as uncommon species. Most fishers have never caught or observed Whale Sharks, and only two have done so in over a decade. An active fisher stated that:

> "Lemon Shark and Hammerhead sharks have always been very rare even though their fins are valuable. Our hopes have always been dashed anytime we aspired to catch some. It is 11 years now since I caught a Lemon Shark." (Active fisher, Dixcove, 07/2020)

Most of the interviewed bottom-set gillnet fishers recalled that guitarfishes were the rarest species of fish they catch. All respondents had never seen or caught sawfish (*Pristis* spp.), except a retired fisher who claimed he saw one specimen 16 years ago at the Apam landing site in 2004. Most fishers (76% of 33) stated that the sizes of sharks and rays they used to catch have decreased over the years. Respondents recollected reductions in the sizes of sharks since the 2000s and rays since the 2010s. Similarly, when asked about the observed changes in the abundance of sharks and rays, most fishers (85%) stated that the number of sharks and rays they caught had significantly declined compared to when they began fishing. Only two fishers reported catching more sharks now than when they started fishing, but this is because they have increased the number of nets and hooks deployed in the waters. Most fishers also expressed concern about reducing the composition of the sharks they catch. Fishers stated that they now catch fewer shark or ray species (73%) and less valuable sharks or rays (67%) compared to previous years when they started fishing. Focus group discussions confirmed that shark and ray species composition has changed over the years. The focus group discussions also confirmed that Stingrays, Devil rays, Blue sharks, and African Brown skates have the least valuable meat, although these species dominate their catch. An active fisher narrated:

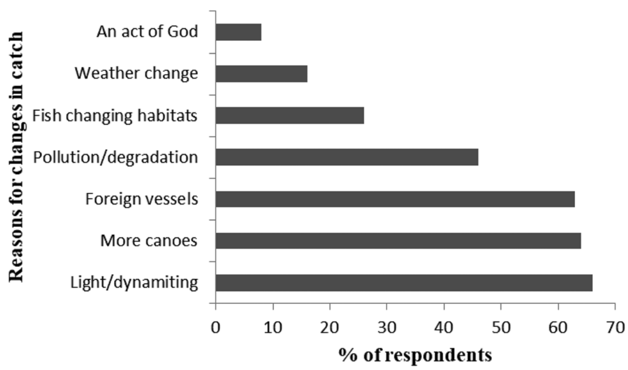

Fig. 2 Perception of fishers on reasons for changes in shark and ray species catch composition. The figure contains multiple responses

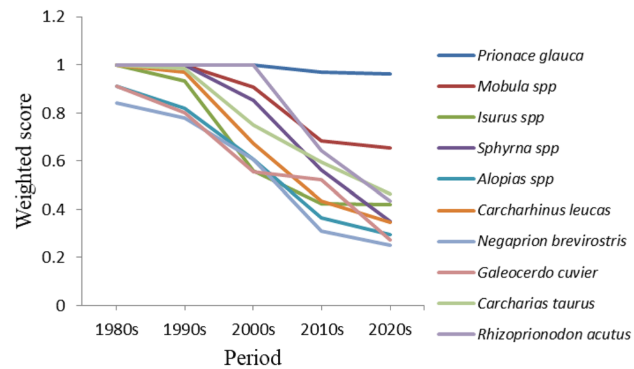

Fig. 3 Perceived changes in abundance or otherwise of sharks/rays by drift gillnet fishers (n = 23) from 1980 to 2020

"We used to get guitarfishes and I mean the bigger ones in large quantity. These days, even getting one individual in a fishing trip is a problem. The ones we get are not big enough, and we do not even get fins from them to sell." (Active fisher, Adjoa, 06/2020)

Fishers who had noticed changes in their catch were asked why this occurred. The primary reason cited by fishers (66% of 32 fishers) for the changes in sizes, abundance, and composition of sharks was the practice of illegal, unreported, and unregulated fishing (IUU) (Fig. 2). Fishers were also increasingly concerned about the activities of foreign vessels on the sea, which invade their territories engaging in illegal fishing practices and catching more bycatch that exceeds their quotas sanctioned by the Ghanian law. Sixty-three percent of fishers mentioned competition with foreign vessels as a possible cause of the decline in abundance and composition of sharks and rays. Fishers attributed shark species abundance and size reduction to the escalating rate of light fishing and dynamiting, depleting smaller fishes such as Anchovies and Sardinellas. Fishers stated that these species are food for sharks, and once they are depleted, sharks will also travel far into the deep and oceanic waters to find other food sources. Most fishers believe that the smaller sharks that cannot travel far remain and feed on the remaining food, which is why they get smaller sharks and rays these days. Another reason was overfishing, which was attributed to the increasing number of canoes and nets in the sea (64%).

Changes in Abundance of Elasmobranch Since 1980

We used trend analysis to rank the abundance of each genus or species of shark and ray from 1980 to 2020 (Figs. 3 and 4 and supplementary information 1 and 2). In general, most shark and ray species were abundant in 1980 but have been severely depleted as of 2020. Most shark and ray species got depleted in the 2010s with a weighted score of less than 0.75, while other species started depleting in the 2000s. Shark and ray species that were depleted in the 2010s were *Sphyrna* spp., *Carcharhinus leucas*, *Carcharias taurus*, *Dasyatis marmorata*, *Fontitrygon* spp., and *Rhinobatos irvinei*. Species such as *Alopias* spp., *Galeocerdo cuvier, Glaucostegus cemiculus, Isurus* spp., and *Negaprion brevirostris* were depleted in the 2000s. All shark species (except *Negaprion brevirostris*, *Alopias* spp., and *Galeocerdo cuvier*) and all ray species were abundant in the 1980s. While no shark and ray species were abundant in the 2010s, *Prionace glauca* and *Mobula* spp. were reported to be common.

Discussion

Our findings that fishers know about the diverse distribution and abundance of sea life from season to season based on habitat, weather, lunar phase, currents, and other environmental factors agree with Johannes and Neis (2007). Fishers invariably master these environmental variables that repeatedly occur based on learning and experience, which guide to facilitate and improve the effectiveness of their fishing

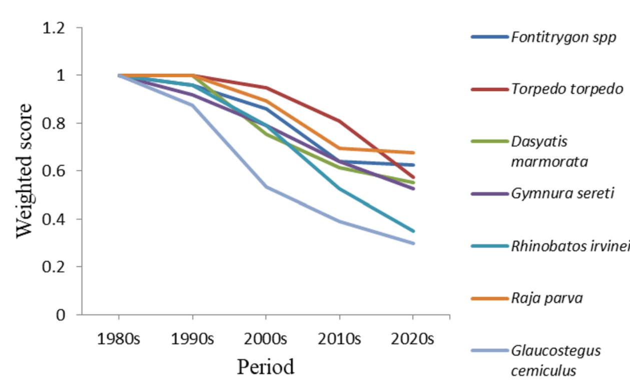

Fig. 4 Perceived changes in abundance or otherwise of rays from by bottom-set gillnet fishers (n = 10) from 1980 to 2020

operations while at sea (Silva, 2005). Some local ecological variables described by fishers in the study communities are consistent with published scientific data. These include the use of birds as fish indicators (Gomes et al., 1998; Vlietstra, 2005), harvesting and spawning seasons of large pelagic species (Oxenford, 1999), and the influence of the Amazon on seawater color in the eastern Caribbean (Gomes et al., 1998). In addition, several studies have revealed how fisher's understanding of ecological and biological variables influences their fishing operations. For example, fishers in Patos Lagoon, Brazil, have observed that Silver White Croaker (*Pennahia argentata*) catches are hindered by the brightness or fullness of the moon and attributed this phenomenon to the playful nature of these species during this lunar phase (Kalikoski & Vasconcellos, 2007). Ocean color is influenced by chlorophyll concentration, algal blooms, and coastal pollution. Ocean color data are used to monitor the distribution, movement, and migration of whales, dolphins, pinnipeds, penguins, and sea turtles (Clapham, 2004). Satellite measurements of sea surface temperature and ocean color were used to improve both management strategies and predict the location of the right whale congregation (Kenney et al., 2020). Further, the identified local ecological variables of fishers in the present study are consistent with those from Gouyave, Eastern Caribbean (Grant & Berkes, 2007). The Gouyave fishers described the presence of seabirds, seawater color, weather conditions, and sea current, amongst other variables, as ecological factors influencing their longline fishing operations (Grant & Berkes, 2007).

The claim by fishers that sharks and rays became a significant target in the 1980s corroborates the study of Clarke (2005). He reported that elasmobranchs were primarily caught as bycatch until the rise in international demand for their products, particularly fins, in the mid-1980s. This incentivized many coastal communities to target sharks. The rise in fin trade was primarily attributed to the reforms of the economy and the increasing rate of the wealthy population in China, which led to the reintroduction of shark fin soup in the 1980s (Buckley & Hile, 2007; Cook, 1990; Fabinyi, 2012). This was also when marine biologists and conservationists realized that many shark populations were under severe threat (Manire & Gruber, 1990).

The results of this present study show that fishers have noticed changes in the abundance of *Negaprion brevirostris*, *Galeocerdo cuvier,* and Rhinobatidae, which had the most valuable meat and fins in the 2000s. A strong trend in fishers' responses indicates a depletion of *Dasyatis marmorata*, *Sphyrna* spp., and *Carcharhinus leucas* in the 2010s. At the same time, *Alopias* spp., *Galeocerdo cuvier, Glaucostegus cemiculus, Isurus* spp., and *Negaprion brevirostris* were reported to be severely depleted as early as the 2000s. It may be possible that most shark species reported to have changed in abundance in the 2000s were already showing signs of depletion in the 1990s, but most fishers overlooked that. This is because fishers reported that in the mid-1990s to 1998, fishing pressure on sharks was remarkably reduced, as most fishers using large canoes with drift gillnet gears migrated to Liberia, The Gambia, Benin, and Cote d'Ivoire to fish in their waters. A focus group discussion confirmed that most fishers had already started noticing depletions in several shark species in the early 1990s and were forced to move to these countries where shark catches were more abundant. Thus, the few fishers who remained fishing in Ghanaian waters in the 1990s had an abundant catch. This partly explains why fishers reported most sharks to be abundant in this period. Migrant fishers returned home and started their fishing operations in Ghanaian waters between 1999 and early 2000 when they noticed that the shark species in other countries were becoming increasingly depleted. This was when fishing for sharks and other pelagic species intensified.

Fishers' catch in 2020 mostly encompassed species such as *Prionace glauca*, *Mobula* spp., and *Raja parva,* with other species remarkably declining. The results agree with Jaiteh et al. (2017), where Indonesian fishers also reported a decline of 16 shark and ray species, including *Sphyrna* spp., *Galeocerdo cuvier,* and Rhinobatidae between 1993 and 2013. Similarly, Ainsworth et al. (2008) also found that fishers reported a steep decline in shark catches in Raja Ampat, Indonesia, between 1990 and 2000. In West Africa, trend data are lacking, but there is evidence of severe declines of Wedgefishes across its range. Wedgefishes were moderately abundant across their former range in 1960 in West Africa but declined dramatically after that (Kyne et al., 2020). Similar to our findings, in southern areas of West Africa (Cameroon to Namibia), qualitative evidence seems to be stronger for the extinction of Sawfishes across their range than against, although uncertainty because of the absence of data in this sub-region (Fernandez Carvalho et al., 2014). Further, reviews of the current status of sawfishes from Mauritania to the Republic of Guinea in West Africa revealed that sawfishes, *Pristis pectinata,* and *Pristis pristis* (referred to as *Pristis microdon*) were relatively common in the past but are now rarely caught or observed (Ballouard et al., 2006; Robillard & Séret, 2006).

An indication of overfished stocks is the decline in abundance and sizes and changes to the composition of shark and ray species fishers used to catch. However, no retrospective data confirm this claim, which demands caution in interpreting the findings. The fact that fishers travel longer distances to fishing grounds indicates the decline in the catch of sharks and rays in the study communities. Other parallel studies have demonstrated that fishers traveling far distances to offshore zones are signs of overfishing and stock decline. For example, in China, a similar scenario has been reported with fishers moving further offshore and intensifying their fishing efforts, although their catch remains virtually the same (Lam & Sadovy de Mitcheson, 2011). Similarly, Wing and Wing (2001) found that the mean trophic level of reef fishes declined from the early to late occupation on each of the five studied islands. They further suggested that populations of reef fishes adjacent to occupation sites on these islands were heavily exploited in prehistoric times, which resulted in shifts in size structure and species composition among the reef fish fauna.

The perceived decrease in abundance encompasses species mainly exploited by fishers and regarded as commercially crucial in both the drift gillnet and bottom-set gillnet fisheries. Consequently, species such as Common Smoothhound (*Mustelus mustelus*) and Spiny Butterfly Ray (*Gymnura altavela*), occasionally observed in landing sites during participant observation, were unfamiliar to most fishers and thus not easily identified even when photo illustrations were shown to them. This may be partially explained by the rare nature of these species in fishers' catch or because fishers do not particularly value these species, as some of them may not attract a high enough market price.

The changes in abundance, size, and composition of shark and ray catches were attributed to several factors, including overfishing and illegal fishing practices. These factors, which fishers perceived as causing changes in shark and ray stock status, reflected the threats faced by sharks in Kenya (Temple et al., 2019) and the UAE (Jabado, 2014). Globally, overfishing is a significant threat to shark and ray species (Dulvy et al., 2014). The biological attributes of sharks, which generally include slow growth rates, late sexual maturity, low reproductive rates, and long life spans, make them exceptionally vulnerable to overfishing and population decline (Klimley, 2013; Myers & Ottensmeyer, 2005). Overfishing has already been reported to be the primary threat to marine fishery resources in Ghana (Overå, 2011). In Ghana, overfishing is influenced mainly by the over-capitalization of the fishing industry, the use of small mesh nets, human population pressure, increasing demand for fish products, and open-access regimes (Nunoo et al., 2014). The historic increase in the number of artisanal and industrial fleets in the early 2000s further worsened the depletion of Ghanaian fisheries resources (Lam et al., 2012). Within these periods, the number of industrial fleets in Ghana nearly doubled, while artisanal canoes increased to about 24% (Anon, 2003). Many fishers were also concerned about illegal, unreported, and unregulated (IUU) fishing practices, specifically stating light fishing and dynamiting as the primary cause of the decline in their target species. Ghana and other West African countries record over 40% of reported catches of IUU (Agnew et al., 2009; Doumbouya et al., 2017; Agyemang et al., 2021). The Fisheries Commission, in collaboration with the MoFAD and some local conservation NGOs, have instigated several interventions to mitigate IUU, which include harmonization of fisheries legislation, setting up national fishing registers, increased sanctions, deployment of vessel monitoring systems (VMS), and improving monitoring and cross-border patrols and public education and awareness creation of fishers on the demerit of these fishing methods. Despite the increasing efforts to mitigate the threats of IUU, most fishers still believe the only available remedy to get abundant catch is to use these methods (Afoakwah et al., 2018). Illegal fishing violates management efforts and is recognized as a severe threat to the sustainability of fisheries due to the adverse impact on the ecology of the oceans and the economy of fishing nations (Afoakwah et al., 2018; Okafor-Yarwood, 2019). Further, some fishers attributed much of the illegal, unreported, and unregulated fishing practices in the region to the actions of foreign vessels fishing in the exclusive economic zone of coastal zones in Ghana. At the same time, most fishers also recognized illegal, unreported, and unregulated fishing as standard practices in Ghanaian fishing vessels.

Conclusions and Management Implications

The study revealed that six main ecological variables shape the fishing operations of artisanal fishers in Ghana. These comprise the season and weather conditions, lunar phase, bait type, seabird presence and fish movement, the color of seawater, and sea current. Second, fishers have noticed a substantial decrease in shark and ray abundance and attributed the decline in numbers and size and the species composition of their catch to overfishing and IUU fishing. Finally, fishers noticed the depletion of some species as early as the 2000s, while sharks and rays depletion took place in the 2010s.

Few studies have considered how the use of LEK can support the development of management, climate change mitigation, land cover change, and forest conservation, in very data-poor regions of the world, such as West Africa (Adaawen, 2021; Aswani et al., 2018; Kupika et al., 2019; Paré et al., 2010). This study is unique in West Africa and demonstrates the importance of using LEK to gather fishers' retrospective, current, and holistic fisheries data. It shows that such data are consistent with published scientific data, highlighting the importance of local knowledge bases in fisheries and ocean management. Ecological knowledge is precious for risk assessment processes such as IUCN Red List Assessments. Further, these baseline data are particularly essential in designing and implementing policies and programs aimed at making elasmobranch fisheries economically and environmentally sustainable. Our data benefit data-poor fisheries research and management in Ghana and other countries with limited funds to conduct fishery research that relies on traditional scientific surveys.

Our results show that the abundance of numerous shark and ray species has significantly depleted, and fishers are aware of changes in the stock status. This calls for active management to mitigate this impact on sharks. Such management may require changes in and enforcement of gear regulations and effective monitoring of practices and activities of fishers, especially checking illegal, unreported, and unregulated practices in both artisanal and foreign fleets. We further recommend the collaboration between research scientists, policymakers, and artisanal fishers in any research, decision-making, and management interventions, as the latter possess much valuable information of which the former may not be aware.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10745-022-00371-z.

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Author Contributions Issah Seidu: Conceptualization, investigation, Methodology, formal analysis, fund acquisition, writing original draft, writing-review and editing. Lawrence K. Brobbey: Supervision, Methodology, writing original draft, writing-review and editing. Emmanuel Danquah: Supervision, Data curation, writing-review and editing. Samuel K. Oppong: Supervision, Data curation, writing-review and editing. David van Beuningen: Methodology, Writing -review & editing, supervision, formal analysis. Nicholas K. Dulvy: Supervision, Conceptualization, Methodology, Formal analysis, Writing -review & editing.

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Declarations

Informed Consent Written consent was not received from interviewees for each interview to go ahead, as many interview participants were unable to read. Permission to conduct the interview was requested verbally from each interviewee prior to starting the interview.

Competing Interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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