A fisher's perspective: Using half a century of local fisher knowledge to identify socio-economic, ecological, and legislative trends influencing angelshark (*Squatina squatina*) records in Wales.

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Keywords: Fisheries Changes, Historical Records, Local Ecological Knowledge, Fisher Knowledge, Fisheries, *Squatina squatina*, Wales.

Abstract

1. The evolution of marine fisheries has broadly influenced the ecology, distribution, and abundance of coastal elasmobranchs. However, quantifying these interactions remains a challenge due to the scarcity of historical records.
2. Fishers' local ecological knowledge (LEK) is an essential tool in fisheries research, providing an avenue to regain scarce information on rare or cryptic species and contextualise modern observations and trends.
3. LEK was collected from 27 semi-structured interviews with commercial, recreational and charter fishers to better understand the ecology and temporal population trends for the Critically Endangered angelshark (*Squatina squatina*) within Wales, United Kingdom. Questions were designed to identify fisher perceptions of socio-economic, ecological, and legislative factors that drove changes in fishing effort for vessels operating within the 'Welsh Zone' between 1968 to 2019.
4. Understanding how fleet-wide spatiotemporal changes to fishing effort and capacity within commercial, recreational and charter fisheries have influenced historical records and sightings of *S. squatina* is an important consideration for assessing its status in Wales and designing appropriate actions to safeguard the species.
5. Our findings identify structural changes to fisheries in Wales and key driving factors that likely decreased fishers' likelihood of encountering *S. squatina* over a 51-year period. Therefore, we suggest recent published estimates of population declines may be overstated.
6. Furthermore, we highlight the importance of quantifying and incorporating changes in fishing effort at a regional scale into future modelling approaches for elasmobranchs and advocate for the increased consideration of LEK in the development of management strategies.

Introduction

Globally, industrial fishing in nearshore regions has resulted in widespread declines for many important fish stocks, contributing to functional changes in community structure (Jackson et al. 2001; Myers and Worm 2003). Yet, determining the effect of historical sea fishing (herein "fisheries" and "sea fishing" refers to all marine sectors (commercial, recreational and charter boat) unless specified) on species distribution and abundance presents a formidable challenge, given ecological records documenting these interactions rarely extend beyond the preceding decades (Thurstan et al. 2022; Engelhard et al. 2016). For non-commercially targeted species and those that rarely overlap spatially with fisheries, deciphering historical population trends is especially difficult as these species are often absent or deficient in available fisheries-derived data sets, therefore our ability to characterise spatiotemporal changes to populations is limited (Ovando et al. 2022; Pinto et al 2019; Rufener et al 2021). Considering this, alternative approaches and fisheries-independent datasets should be utilised alongside landing data, to enhance the monitoring of data-deficient stocks (Robinson and Frid 2008; Mesnil et al. 2009; Hilborn and Walters, 2013).

The incorporation of historical marine ecology (HME) (e.g., palaeoecological, archaeological, and historical records), particularly the integration of local ecological knowledge (LEK) and/or fisher knowledge (FK) has provided a much-needed avenue to understand the past state of marine environments and historical changes to fish populations (Kittinger et al. 2015; Thurstan et al. 2015). Standardised social science methodologies provide a systematic process to obtain important species-specific information from commercial, recreational and charter fishers (herein referred together as "fisher(s)" unless specified), on the distribution, abundance, and behaviour of data-poor fish populations, enabling researchers to address crucial knowledge gaps that cannot be addressed through empirical approaches alone (Silvano and Valbo-Jørgensen 2008; Pantin et al. 2015). Integrated methodologies that combine LEK with quantitative fisheries data, alternative survey methodologies (e.g., eDNA, satellite imagery) and statistical modelling (e.g. LEK-derived catch-per-unit-effort (CPUE)) can yield more robust historical baselines and abundance estimations (Dunn et al. 2025; Early-

Capistrán et al. 2020; Exeter et al. 2021). Despite the evident advantages of incorporating HME for understanding and managing fisheries, there remains a critical need for broader implementation of these integrated approaches in marine conservation and policymaking particularly in data-poor regions.

Fishing is an important industry and recreational activity for coastal communities in Wales, United Kingdom, for generations, with many regions today (e.g., Milford Haven and Holyhead) still heavily reliant on aquatic resources to support livelihoods, local economies, and wellbeing (Peirson et al. 2001; Monkman et al. 2015; Moore et al. 2024) (Fig. 1). Historically, commercial sea fishing, specifically bottom trawling, is believed to date back to at least the 14th century in England, before later expansion of the industry to Wales occurred in the 17th - 19th centuries (Jones 2018; Thurstan 2010). The late 19th century witnessed the most rapid increase in Welsh fishing capacity, driven by the development of industrial-scale fishing and fleet modernisation (e.g. steam-powered vessels) (Hernvann and Gascuel 2020; Knauss 2004; Thurstan 2010). This likely resulted in significant, yet potentially undocumented, impacts on fish stocks due to increased demand for marine resources and improved access to fishing grounds (Hernvann and Gascuel 2020; Thurstan 2010). Presently, most of the Welsh commercial fishing fleet is comprised of smaller polyvalent vessels (< 10 m) fishing close to home ports, with larger vessels commonly based out of Milford Haven, Holyhead and Saundersfoot (Marine Management Organisation 2021). Over the past half century, the nature and scale of commercial fisheries operating within the UK Exclusive Economic Zone (EEZ) has changed considerably, primarily due to the gradual introduction of legislation and policies like the Common Fisheries Policy in 1983 and its subsequent reforms (EU Commission 2013). These measures introduced quotas, licensing systems, and stricter regulations on marine resource extraction in response to stock depletions, resulting in significant impacts on fishing capacity (Daw and Gray 2005; Hatcher and Read 2001). For example, from 1991 to 2021, there has been a 49% decline in the number of active UK registered commercial fishing vessels within the UK EEZ (Marine Management Organisation 2021; Uberoi et al. 2021). There has also been a documented decline in the number of charter boat operators in Wales, from at least 72 boats operating in 1973 to 40 in 2019 (Barker et al. 2022). While recreational angling has historical records dating back to the 17th century, as evidenced by George Owen of Henllys' 'Description of Penbrokshire' (1603) and Izaak

141 Walton's "The Compleat Angler" (1653), the origins of charter fisheries remain poorly understood
142 (Winfield 2016). Furthermore, trends in recreational charter fishing effort and catches over the past half-
143 century have not been comprehensively assessed in Wales due to a scarcity of data (Goudge and Morris
144 2011; Monkman et al. 2015; APBmer Ltd 2020).
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Figure. 1. Historical photos depicting fishing in Wales a) The Dog and Partridge Angling Club from Eccles, Manchester with a catch of 87 Thornback Ray in 1983 (Photography by Vic Haigh), b) Unknown fisherman unloading catch (year unknown) c) The Endeavour Charter Boats leaving port in Aberystwyth d) Hollington Club Members on Endeavour Charter Boat out of Aberystwyth. Pictures provided by the Peoples Collection of Wales licenced under Creative Archive Licence.

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148 Sharks, skates, and rays (subclass: Elasmobranchii herein “elasmobranchs”) are vital components of
149 marine ecosystems, often exhibiting slow life history strategies (e.g., slow growth, low fecundity, and
150 late maturity) and behavioural adaptations (e.g., long migrations, aggregation, philopatry) that make
151 them vulnerable to overexploitation and habitat loss (Stevens et al. 2000; Dulvy et al. 2021).

Traditionally, understanding elasmobranch abundance trends has been heavily dependent on historical catch records from mixed commercial fisheries (Fowler et al. 2004; Ellis et al. 2005; Hareide et al. 2007). However, prior to the mid-late 1990s and the start of fishery-independent monitoring, there was no requirement for commercial fisheries in the UK to record elasmobranch catches (FAO 2000; Fowler et al. 2004; Ellis et al. 2005). Elasmobranchs were often recorded and grouped as 'miscellaneous' or as generic categories (i.e. 'skates and rays') in mixed fisheries, resulting in insufficient and non-species-specific landing data (Martin et al. 2010; Lawson et al. 2020). In addition, fishery-dependent datasets can often be considered biased due to non-standardised factors (e.g., changing gear type and methods) and spatiotemporal changes in fishing locations that are often not accounted for or recorded (Simpfendorfer et al. 2002). Understanding these nuances in fishing effort and catch trends is important to ensure the long-term sustainability of fisheries resources and associated livelihoods.

The Celtic Sea Ecoregion, including the Welsh coastline, is an important area for the angelshark, *Squatina squatina* - an elasmobranch species listed as Critically Endangered on the IUCN Red List of Threatened Species - whose geographic range historically extended from the southwest coast of Norway (62° N) to northwest Africa (21° N) (Morey et al. 2019; Barker et al. 2022). Found in coastal waters and on continental shelves up to 200 m depth, *S. squatina* occupies a wide range of benthic habitats including reef, mud, sand, and gravel (Meyers et al. 2017; Ellis et al. 2021). In recent years, there has been considerable effort to better understand the ecology, habitat preference, abundance, and distribution of *S. squatina* (Jiménez-Alvarado et al. 2020; Barker et al. 2022; Moore and Hiddink 2022). Yet, due to a lack of baseline information for *S. squatina* populations within the Celtic Sea Ecoregion, current understanding of the species is primarily based on populations from the Canary Islands and the Mediterranean (Meyers et al. 2017; Ellis et al. 2021). Records from the 19th and 20th centuries identify historical commercial fisheries for this species existing in Spain, France, Italy, and Croatia (Fortibuoni et al. 2016; Lawson et al. 2020), yet there is no documented evidence of a commercial fishery targeting *S. squatina* in Wales, thus alternative approaches are required.

As a bottom-dwelling coastal species, *S. squatina* are particularly susceptible to incidental capture by commercial fisheries that interact with the seabed, especially those operating large mesh nets or bottom trawls; recreational fisheries due to spatial overlap (Lawson et al. 2020; Ellis et al. 2021); and habitat degradation due to proximity to anthropogenic activities along coastlines (Gordon et al. 2019; Barker et al. 2020). These threats have resulted in reported declines in *S. squatina* populations across their geographic range (Rogers and Ellis 2000; Hiddink et al. 2019). Notably, a recent study by Hiddink *et al.* (2019) utilised LEK quantitative data on *S. squatina* catches collated from interviews and opportunistic records (e.g. charter skipper logbooks and online databases) to infer population abundance trends for the species across Wales, on the assumption that fishing effort had stayed constant. The study estimated that abundance had declined by 70% between 1970 to 2016, yet did not explore how wider socio-economic fishing practices have evolved in Wales over the past century and how these may have influenced the degree and nature of fishing effort and historical sightings and records of *S. squatina* (Hiddink et al. 2019).

As a prohibited species under the UK Wildlife and Countryside Act (1981), with further protection in Wales under the Section 6 Biodiversity and Resilience of Ecosystems duty, Environment (Wales) Act (2016), concerted efforts to safeguard this species in Wales led to the development of Angel Shark Project: Wales and the Wales Angelshark Action Plan ('Action Plan') (Barker et al. 2020). Led by the Zoological Society of London and Natural Resources Wales, the Action Plan was co-developed with a network of NGOs, Government Agencies, fishers, and universities to address critical knowledge gaps for this species (Barker et al. 2020).

Here, we used interviews with fishers operating along the Welsh coast, to identify potential socio-economic, ecological, and legislative drivers of spatiotemporal changes in fishing effort in the Welsh Zone. We then used the collated LEK to investigate how these explanatory factors might have influenced historical records and sightings of *S. squatina*, in Wales.

Methods

2.1 Geographical Scope

For this study, data collection targeted individuals fishing within the 'Welsh Zone' (ICES Divisions VII a, e-h) (Fig. 2). In 2006, the implementation of the Government of Wales Act and the amendment to the Marine and Coastal Access Act in 2009, allowed for the devolution and separation of fisheries in England and Wales and the creation of a 'Welsh Zone' within the UK EEZ (Government of Wales Act 2006; Marine and Coastal Access Act 2009; Williams et al. 2020). The majority of participants in this study (n=21) were based out of harbours in North and West Wales including Aberdyfi, Barmouth and Porthmadog, and predominantly fish along the coast of the Llŷn Peninsula and within Cardigan Bay. Of the remaining participants, three fished the Bristol Channel, two in Swansea Bay and one in Carmarthen Bay.

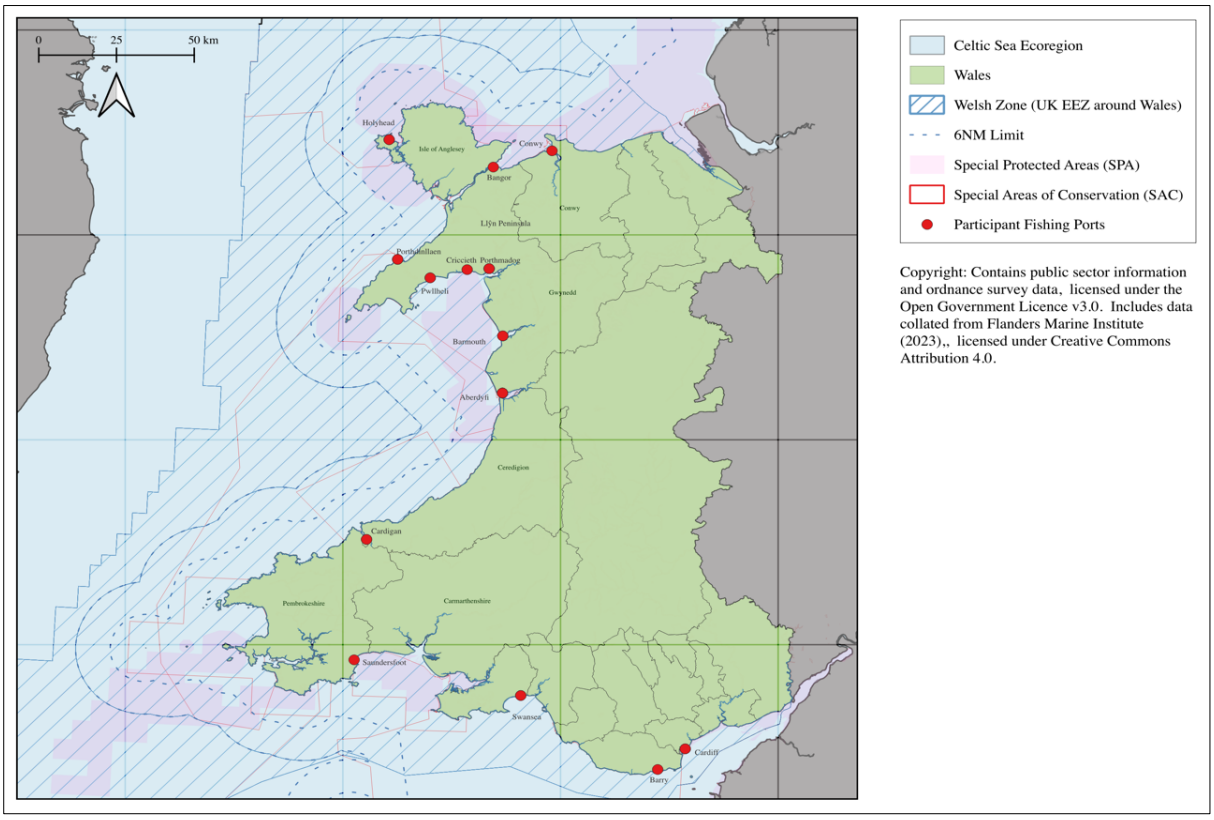

Figure 2. Geographical scope of this study. Boundaries for the UK EEZ around Wales (blue hashed area), six-mile limit (blue dashed line) and 12 mile limit the 'Welsh Zone' (blue line). Map indicates a 'general' location where fishers were based between 1969 – 2019[1] (red points).

2.2 Data collection

This study was co-designed in collaboration with Angling Cymru Sea Anglers and Welsh Fishermen's Association. As representatives of fishers in Wales, both organisations were involved with the project at the development stage and were involved throughout delivery through supporting methodological design, sharing contacts, providing iterative feedback, and co-developing next steps.

Participatory Interviews

Participants all fished between 1968 and 2019 within the Welsh Zone, including inshore waters (0-12 nm) and offshore waters (12-200 nm). We categorised fishers into three distinct groups: commercial (primarily engaged in landing fish for commercial sale), charter (skippers and/or charter crew that operate vessels hired by groups or individuals for fishing trips for recreational purposes) and recreational (fishing for personal enjoyment or leisure only).

Our methodology used semi-structured interviews consisting of five prompts designed to collect data on: a) *S. squatina* sightings and historical catch records, b) *S. squatina* ecology and distribution, c) fisher background (fisher category, location, active fishing years), d) information on other elasmobranch catches and e) observed changes in the fishing industry over time (fishing areas, gear type, changes in gear type and target species) (Supplementary Information S1). To aid recall, personal timelines and

[1] Fishers indicated that fishing locations and home ports changed over the years, therefore it was not always possible to allocate a fisher to a single home port (i.e. some fishers operated out of Aberdyfi and Aberystwyth). In addition, some fishers only provided information on general fishing location i.e. Cardigan Bay. Red points reflect available data.

participatory mapping exercises were carried out concurrently to provide a contextual timeframe and support the interview process (Connelly et al. 2000; Mundia, 2016). Fishers were presented with timelines that included key historical events that had been identified during previous informal interactions with fishers, such as significant national or fisheries-related events (e.g., Sea Empress oil spill in 1996) (Supplementary Information S2). Nautical maps were provided to allow visualisation of spatiotemporal fishing effort and to identify areas where *S. squatina* were encountered (Supplementary Information S3), although only nine fishers out of 27 provided spatial fishing data, due to the confidential nature of personal fishing locations. In addition, focused grey literature was collated for documents and reports explaining fishing changes in Wales (e.g., official fisheries statistics collected by the Ministry of Agriculture, Fisheries and Food (MAFF), Marine Management Organisation (MMO) Reports). This included a review of fisheries policy and legislation (documents compiled from MMO, MAFF, European Commission) (Fig. 3).

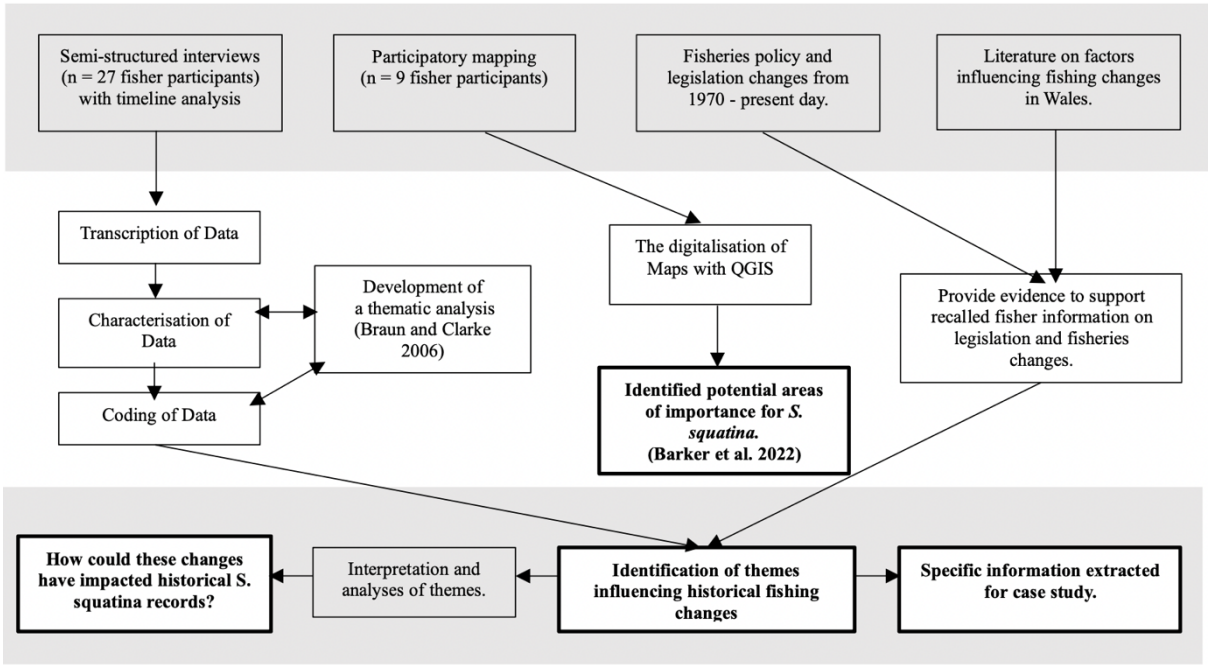

Figure. 3. Schematic workflow diagram outlining the methodological approach used to collate and extract qualitative data on historical changes to the changing fishing landscape in Wales from 27 semi-structured interviews with commercial, charter and recreational fishers.

Confirmation processes

All interviews were transcribed from notes taken during the in-person interviews and later verified by the interviewee. Furthermore, subsequent meetings were organised for respondents to read and verify the interview transcripts to ensure they fairly represented their testimony and wider views. All respondents were invited to co-author the paper, provide either verbal or written feedback and input in the final draft. Free prior informed consent (FPIC) processes were undertaken for all participants. Validity checks, and bias considerations were consistently addressed throughout the design and process of this study and authors involved in data collection and analysis have provided individual positionality statements (Supplementary Information S4) (Maxwell 2012; Holmes 2020). All methods were approved by the Zoological Society of London's human ethics committee (ZSLHEC-001).

2.3 Data Analysis

Data collected from fisher interview notes were compiled, transcribed and verified before coding within NVivo software using thematic analysis (NVivo 2020). An inductive six-step framework approach was used, as described by Braun and Clarke (2006), consisting firstly of data familiarisation, before identifying initial data-driven themes without the use of prior theoretical assumptions, allowing for underlying meanings to emerge from the data organically (Braun and Clarke 2006; Kiger and Varpio 2020). Once initial codes were generated, overarching themes and recurring patterns in the data were investigated before refinement and hierarchical arrangement into final themes (herein referred to as 'drivers') (Braun and Clarke 2006; Newing et al. 2011). Through this thematic analysis, we identified important socio-economic, ecological, and legislative explanatory factors perceived by fishers, that resulted in changes to the fishing landscape around Wales. Results were used to determine whether these changes could have increased or decreased the likelihood of fishers to interact with *S. squatina.*

292 3. Results

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294 3.1 Participants and Vessel Size

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296 Overall, 27 participants were interviewed, comprising of 10 commercial fishers, eight charter skippers
297 or crew on charter boats, five recreational anglers, while three participants worked on both commercial
298 and charter boats and one individual had experience working as crew on a charter boat, but mainly
299 fishes recreationally (Table. 1). Participants had been actively fishing for between one and 51 years,
300 with a mean of 28 years, spanning from 1968 to 2019. Eleven participants are still actively fishing in
301 the Welsh Zone, with 48% (n=13) of participants employed full-time by the fisheries sector, mainly
302 those currently employed or previously employed on commercial vessels. Many participants had
303 complex work histories and were employed in different fishing sectors and vessels over time (part-time
304 or full-time). Three fishers alternated between working on commercial vessels during the winter months
305 and on charter boats during the summer months. Of the charter fishers interviewed, most operated, and
306 employed seasonal crew during the charter summer season, which runs from April to October. In
307 contrast, shore and boat-based recreational anglers often fished all year round, although fishing effort
308 (number of days fished) was often heavily dependent on weather and fisher availability (i.e., weekends,
309 after-work excursions) (Table. 1).

310

311 The majority of fishers interviewed 82% (n=22) worked on fishing vessels less than 10 m in length.
312 However, many commercial fishers emphasised how vessel size has changed over the past several
313 decades with the modernisation of the Welsh commercial fishing fleet, reflecting changes in target
314 species, governance and the implementation of quota and non-quota species by the EU Common
315 Fisheries Policy. Out of the 10 commercial fishers, 90% worked on polyvalent fishing vessels operating
316 multiple gear types that varied seasonally and annually dependent on target species. Tangle nets or other
317 static nets (e.g., gillnet), together referred to as ‘netting’, were used historically by all respondents
318 working on commercial vessels, with 80% using pots and traps, 40% trawling, 20% deploying longlines,
319 and 10% dredging. Of the three fishers who combined commercial and charter boat fishing, all fished

using rod and line while also operating additional gear types; one fisher used to tangle net for thornback rays, *Raja clavata*, one potted for crustaceans and one used to work on a trawler. Out of the charter boat and recreational fishers interviewed (n=17), the majority (94%) fished using a rod and line, except for one recreational fisher who spearfished (Fig. 4.).

Table. 1. Vessel attributes and respondent characteristics for all fishers interviewed in this study.

Participant Categories	Fisher Backgrounds			Vessel Characteristics		
	Active Fishing Years	Mean (± SD) Years Fished	Employment status	Vessel Size	Season Fished	Fishing Location
Total (n= 27)	1968 - 2019	26 (± 16)	Active: 11 Retired: 16	82% (n=22) <10m Vessel 7% (n=2) <24m Vessel 11% (n=3) Unknown	48% (n=13) All Year 33% (n=9) April - Oct 11% (n=3) Summer 4% (n=1) Autumn 4% (n=1) April - Nov	56% (n=15) Cardigan Bay 11% (n=3) Caernarfon Bay 11% (n=3) Bristol Channel 7% (n=2) Swansea Bay 7% (n=2) Tremadog Bay 4% (n=1) Carmarthen Bay 4% (n=1) Constable Bank
Commercial (n=10)	1977- 2019	23 (± 15.4)	Active: 5 Retired: 5	<10m Vessel (n=9) <24m Vessel (n=1)	All Year (n=9) Summer (n=1)	Cardigan Bay (n=4) Caernarfon Bay (n=2) Tremadog Bay (n=2) Carmarthen Bay (n= 1) Constable Bank (n=1)
Charter (n= 8)	1968 – 2019	25 (± 19.1)	Active: 3 Retired: 5	<10m Vessel (n=7) <24m Vessel (n=1)	April – Oct (n=8)	Cardigan Bay(n=6) Bristol Channel (n=2)
Recreational (n=5)	Late 1960s – 2019	24 (± 17.7)	Active: 2 Retired: 3	<10m Vessel (n=2) Unknown (n=3)	All Year (n=1) April – Oct (n=1) Summer (n=2) Autumn (n=1)	Cardigan Bay (n=3) Caernarfon Bay (n=1) Bristol Channel (n=1)
Commercial/ Charter (n=3)	1968-2017	36 (± 11)	Retired: 3	<10m Vessel (n=3)	All Year (n=2) April – Nov (n=1)	Cardigan Bay (n=1) Swansea Bay (n=2)
Charter/ Recreational (n =1)	1980 - 2019	39	Active: 1	<10m Vessel (n=1)	All Year (n=1)	Cardigan Bay (n=1)

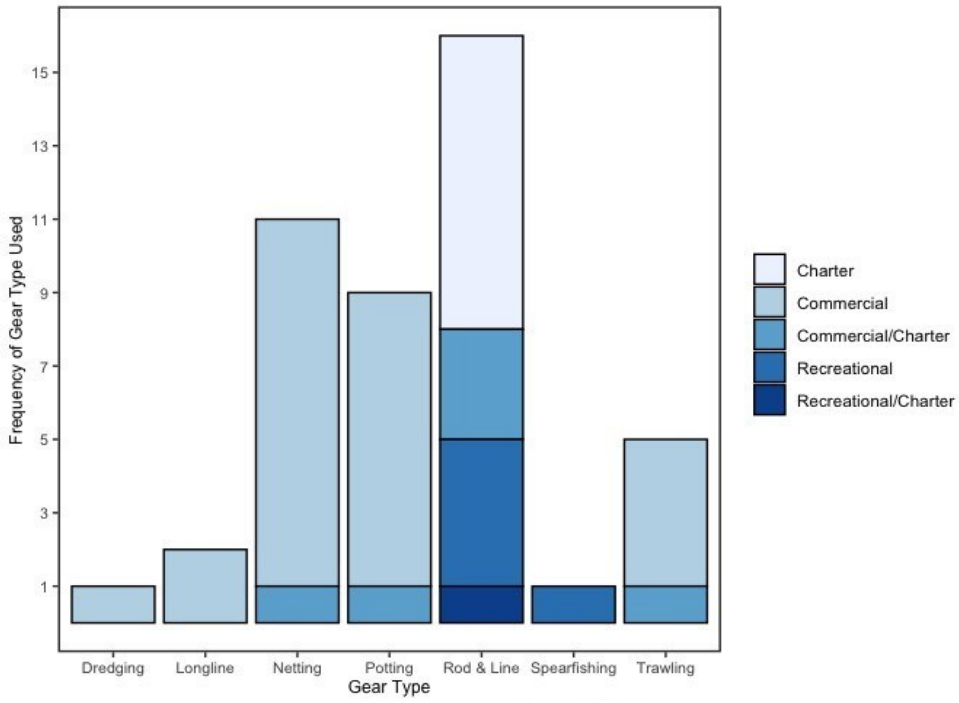

Figure. 4. Gear types used by the fishers interviewed in this study. Of the commercial fishers, gear type varied between static and towed gear, while charter and recreational fishers predominately fished using rod and line specifically.

3.2 Angelshark, *Squatina squatina*

The following names, ‘monkfish’, ‘monks’, ‘big uglies’ and ‘fiddler fish’ were used to refer to *S. squatina* by fishers. All fishers interviewed recalled catching *S. squatina* before 2000, while 19% (n=5) discussed sightings post 2000. Additionally, 74% (n=20) of fishers noted that *S. squatina* was often caught incidentally by those targeting *R. clavata. S. squatina* were reported to be caught by the following gear types: tangle nets, rod and line, demersal trawls, and gillnetting. A commercial/charter fisher used to refer to *S. squatina* catches as a “*nuisance*” due to the species' lack of commercial value and the implication that they would often “*mess up”* fishing gear. Furthermore, 56% (n = 15) of fishers recalled that *S. squatina* were mainly sighted or caught between April and November, coinciding with the charter fishing season.

3.3 Social and Economic Drivers.

Fishers identified six potential overarching social and economic drivers that resulted in spatiotemporal changes to fishing effort (Table. 2). Under these, 16 sub-categories were identified, referred to as ‘factors’; 10 factors linked with a decreased likelihood of fishers interacting with *S. squatina*; two factors linked with increased likelihood; and four factors had an unknown impact. Changes in vessel size and characteristics, were the most frequently mentioned factor (n=19, 70% of respondents), followed by reductions in charter fleet size (n=8, 30%), market value and competition (n=8, 26%), non-UK vessels fishing within the Welsh Zone (n=5, 19%), inland industry collapses (n=2, 7%), and operating costs of fishing (n=2, 7%), respectively (see Table 2 for further definitions).

In addition, reduced profitability in commercial fisheries and reduced demand for recreational fisheries may have also driven decreases in overall fishing effort. In the commercial sector, seven fishers commented that often markets would buy catches from the first boat to land its catch, with increased competition driving prices down. In addition, five fishers explained that non-UK vessels increasingly operating in Welsh zone drove market competition and impacted on value of landings.

Notably, fishers within the recreational sector, 30% (n= 8) commented that they have observed a reduction in the number of angling clubs visiting Wales over the past half a century, resulting in reduced demand for charter trips, directly impacting fishers' livelihoods and annual income. Thus, declines in the number of charter boats would have resulted in reduced fishing effort and could inadvertently influence the likelihood of fishers interacting with *S. squatina* and/or the number of records. Two fishers mentioned that collapses in inland industries, for example, coal mining and factory closures, had important negative implications for revenue generated by the charter industry, suggesting a link between industrial workers and recreational angling. Furthermore, two fishers commented that operational costs associated with charter fishing have increased over time, resulting in many leaving the sector for more secure employment opportunities. Specifically, the increase in fuel costs in 1978 and increased licencing costs in the 1980s were listed as two major factors for the reduction in charter boats. The social and economic reasons for the reduction in fishing effort in Wales was highlighted by participant p60 (Supplementary Information S5: Case Study 1).

Table. 2. Potential explanatory socio-economic factors impacting fishing capacity and effort in Wales, identified from thematic analysis of qualitative data collected from fisher interviews (n=27).

Driver	Factors	Evidence from fisher interviews	Implication for fisheries	Predicted impact on *S. squatina* records.	Supporting Evidence
Changes in vessel size or characteristics (n=19, 70%)	Fisher backgrounds indicated that the size of vessels (over or under 10m) varied over the past three decades.	*'The Viking left from Barmouth but carried 94 people and underwent 15-hour trips in the 1960s'.*	The fishing capacity of a fleet is measured by vessel size in gross tonnage (GT) and engine power (kW). Quotas given to commercial vessels depend on vessel size, and characteristics. Changes to the size and characteristics of vessels in the Welsh fleet are difficult to quantify.	Temporal changes to the number of vessels and size of vessels operating in Wales could either increase or decrease the probability of sighting *S. squatina* depending on the vessel category and type of fishery. Overall, this has an unknown impact on *S. squatina* records.	(Gray. 1995; Hatcher and Read 2001; Ota and Just 2008)
	Fishers also worked on different vessel categories (i.e., commercial, recreational or charter).	82% (n=22) of fishers worked on vessels <10m.	Fisher respondents owned and/or worked on different vessels over time.	Overall, this has an unknown impact on *S. squatina* records.	Derived from Primary data
	Temporal changes to vessel/fisher characteristics (i.e., number of rods, time at sea).	*'1976 Started fishing on a boat that had 10 rods with a 3-mile licence. 1978 Boat IP23 called Nissan. 8 people with a 3-mile licence offshore and 15 miles North & South. 1981 got a new boat Aquastore, an offshore vessel that was able to go 10-12 miles out with a 10 - 12 rod licence.'*	Vessel fishing effort (a standardised unit) is measured by either the number of days or hours at sea and/or the gear type used on the vessel. With many fishers working on polyvalent fleets.	These changes could either increase or decrease the probability of fishers sighting *S. squatina,* dependent on the number of hours spent fishing and the gear used to catch *S. squatina*. While angling effort targeting *S. squatina* may have reduced, understanding the interactions between commercial fishing activity on *S. squatina* populations is still poorly understood. Given the complexity surrounding these changes, overall, we conclude that there is an unknown impact on *S. squatina* records.	(Gray. 1995; Hatcher and Read 2001; Lawson et al. 2020; O)
	Full/Part-time employment and fishing activity is dependent on vessel category and seasonality.	48% (n=13) of fishers interviewed were employed full-time. Charter fishers mainly fished between April and November.	Fishing effort does not stay constant throughout the year. The majority (n = 11, 92%) of charter fishers interviewed were only employed during the summer months.	Charter fishing effort is higher during the summer months increasing the probability of fishers sighting *S. squatina* during seasons that align with postulated *S. squatina* movements.	(Barker et al. 2022)
Reduction in charter vessels (n=8, 30%)	Fishers explained there has been a reduction in charter trip demand from anglers and angling clubs.	*"The Viking fished every day weather permitting but took out clubs on longer 'deep sea' trips on Sat, Sun and Weds. Trips stopped due to reduced demand."*	Overall reduction in the number of charter vessels taking out guests targeting elasmobranchs. Reduction in angling effort (rod & line) in inshore fishing locations.	Decrease the probability of sighting *S. squatina.* The reduction in the number of days at sea would reduce the number of active recreational anglers fishing for elasmobranchs by boat.	(Hutton et al. 2008)
	Since 1968, there has been a gradual decline in the number of charter vessels operating in Wales due to regulations, licencing, and operating costs.	*"In the mid- 1980s, used to be 87 boats from Aberystwyth (charter & commercial), today there are no charter boats in Aberystwyth."*	Reduction in angling effort (number of charter vessels, hours spent at sea, reduction in the number of anglers on charter boats).	Decrease the probability of recreational anglers sighting *S. squatina.*	(Pitcher and Hollingworth 2008; Marine Management Organisation 2021)
		'23 charter boats in the early 80s. The late 80s was a coal strike that caused a reduction in the number of charter boats.'	Social and economic loss to coastal communities.		
	Increase in private boat ownership.	*'While private boats and recreational anglers increased this wasn't reflected in charter boats, as the industry decreased.'*	More private boats on the water. Catch data unknown unless fishers reported 'trophy' catches to angling magazines.	Unknown impact on *S. squatina* records.	Derived from primary data.

Market value & competition (n=7, 26%)	Historically, local markets were oversaturated with commercial fishers in competition to sell catches. Only profitable to the first commercial vessels to arrive.	*"Price of rays decreased as everyone started fishing rays. Problem for the market, as more fishers fished certain species there was competition that drove market price down. Had implications for whether fishing certain species was economically viable."*	Market drove which species was targeted. Competition for catches had implications for the value of fish.	As market value for *R. clavata* declined, this would reduce the probability of commercial fishers sighting *S. squatina,* as *S. squatina* were frequently caught by fisheries targeting *R. clavata.*	(Ellis, Cruz-Martinez, et al., 2005; Silva and Ellis 2019)
	S. squatina has no commercial value (in regard to a historical commercial fishery in Wales) however, catches would be sold to local restaurants.	*"No value in the markets for angelshark (called angelshark 'fiddler fish')"*	*S. squatina* catches historically were sold to local markets, if caught accidently. However, the species had no real commercial market value.	Not commercially targeted in the UK, decreasing the probability of fishers sighting *S. squatina* and/or recording the catch.	(Lawson et al. 2020)
	Charter fishing competitions had implications for fishing effort targeting elasmobranch species.	*"The 1980s used to have large fishing festivals such as the Tope festival with 30/40 fishing boats in attendance."*	Increase in recreational sea angling effort targeting elasmobranchs.	Increase probability of anglers sighting *S. squatina.*	Primary data
Non- Welsh Vessels (n=5, 19%)	Non-UK registered vessels (i.e., beam trawlers) and vessels from other UK administrations (i.e., Scotland, England, Northern Ireland) and EU member states used to fish within the Welsh Zone.	*"1989-1993 much bigger Dutch beam trawlers were around Cardigan Bay impacting seabed."*	Competition for catches with foreign vessels. Ecological ramifications for habitats within the Welsh Zone.	Decrease probability of sighting *S. squatina*. Large beam trawlers could have negative impacts on seabed habitats that are important for *S. squatina* in Cardigan Bay, reducing, displacing, or fragmenting populations in the impacted regions.	(Hutton et al. 2008)
	In 1980s, non-UK based angling clubs used to visit coastal towns for large fishing festivals (e.g., tope festival)	*"The 1980s used to have large fishing festivals such as the Tope festival with 30-40 fishing boats in attendance. A Belgium fishing group were a big group that regularly attended."*	Economic contribution to coastal communities reduced. As the number of non-UK based angling clubs reduced fishing effort targeting elasmobranchs would have decreased.	Decrease in the number of recreational anglers potentially sighting *S. squatina.*	Derived from primary data.
Inland industry collapses (n =2, 7%)	Coal mine strikes and industry collapse in the midlands resulted in fewer angling club trips with charter boats.	*"Factories disappeared in the midlands around 1979, so, a lot of angling clubs stopped coming to Wales because they couldn't afford prices, so had fewer holidays – this had a huge impact on charter vessels."*	Collapse of industry and closure of factories had implications for charter trip demand, contributing to the reduction in operational charter vessels.	Decrease probability of sighting *S. squatina* due to a reduction in charter fishing effort.	(Huggins 2020; Hyder et al. 2020)
	Fishers suggested a potential link between industrial workers and recreational angling.	*"The late 1980s coal strike caused a reduction in the number of charter boats."*	Reduction in fishing effort due to declines in trip demand by industrial workers.	Decrease probability of sighting *S. squatina* due to a reduction in charter fishing effort.	(Shorney 2004; Mordue 2009)
Cost of fishing (n=2, 7%)	Increase in fuel prices resulting in shorter trips (fishing effort reduction).	*"...due to fuel prices in 1978 had to fish closer to shore."*	Fishing effort reduction due to fewer boats out fishing. Time on the water changed from longer fishing trips in the 1970s to shorter trips closer to shore.	Decrease probability of sighting *S. squatina*, due to spatiotemporal changes in fishing location dependent on operational costs and reduction in time spent fishing.	Derived from primary data. (Shorney 2004)
	Passenger licencing costs increased contributing to reductions in the number of charter vessels.	*"Changes in regulations over the years and licencing costs have resulted in a reduction of charter vessels operating."*	Licencing costs contribute to overall operational costs of charter vessels. Fishers suggested this was the reason for the overall	Decrease probability of sighting *S. squatina* due to a reduction in charter fishing effort.	Derived from primary data.

reduction in the size of the charter fleet in Wales.

404

405 3.3 Ecological Drivers

406

407 Overall, 16 ecological factors were identified by fishers and grouped into five drivers; nine factors could
408 potentially decrease the probability of fishers sighting *S. squatina*; four factors could increase the
409 likelihood; and three factors remained indeterminate (Table. 3). Many of the ecological points discussed
410 in the interviews were related directly to *S. squatina* sightings by fishers and therefore are examined
411 from that perspective. Of the fishers interviewed, 81% (n=22) mentioned *R. clavata* populations. Most
412 (74%, n= 20) identified *R. clavata* as a popular target species in commercial and recreational fisheries,
413 where *S. squatina* were often caught as bycatch. Importantly, 52% of fishers (n=14) mentioned the
414 decline of *R. clavata* populations in the 1990s having potential localised impacts on fisheries operating
415 in Wales, specifically in Cardigan Bay. One fisher suggested the lack of quotas for catching *R. clavata*
416 in the 1980- 90s was the reason so many were landed, resulting in the fishery collapsing (Fig. 2).
417 Changes to target species and fisheries were the second most popular ecological factor mentioned by
418 respondents (48% of interviewed fishers, n=13), gear selectivity (44% of interviewed fishers, n=12)
419 followed by spatiotemporal changes in fishing location and habitat (33% of interviewed fishers, n=9)
420 and species composition changes (22% of interviewed fishers, n= 6).

421

422 Tangle netting in commercial fisheries and sea angling by recreational anglers (shore and charter boat
423 based) was suggested by fishers as gear that most frequently caught *S. squatina*. Fishers commented
424 that the reduction in *R. clavata* populations in Cardigan Bay had negative ecological consequences for
425 species composition in the region. For example, one fisher anecdotally implied that the decline in *R.*
426 *clavata* abundance in the 1990s, contributed to *M. brachydactyla* numbers increasing, resulting in
427 potential trophic level changes within Cardigan Bay. In response to these changes, many fishers changed
428 fishing locations and target fisheries to more offshore habitat (see Supplementary Material S5: Case
429 Study 2). Another commonly recurring theme from the interviews was how spatiotemporal changes in

fishing locations impacted target catches. Given that fishing effort changed seasonally, many fishers indicated that Cardigan Bay during the summer season was considered an important area for both *R. clavata* and *S. squatina* catches. Of the respondents, 56% (n=15) noted that fishers were more likely to catch *S. squatina* during the summer season between April and November, suggesting a crossover between seasonal charter boat fisheries and the species' distribution in Cardigan Bay. Consequently, it was further inferred that changes to species composition (i.e., the decline of *R. clavata* in the 1990s) within Cardigan Bay, shifted target fishing areas for charter fishers, to reef or wreck habitats, reducing the chances of fishers encountering or sighting *S. squatina*. Moreover, 44% (n=12) of interviewed fishers highlighted how gear type changed seasonally or depending on targeted species, with many vessels operating multiple fishing methods (i.e., potting and netting) concurrently. A fisher commented on how the introduction of monofilament in the 1970s significantly increased catch rates of *R. clavata*, potentially also increasing the catchability of *S. squatina*.

Table. 3. Potential ecological explanatory factors impacting the fishing capacity and effort in Wales identified from thematic analysis of qualitative data collected from fisher interviews

Driver	Factors	Evidence from fisher interviews	Implication for fisheries	Predicted impact on *S. squatina* records.	Supporting Evidence
Thornback ray *(R. clavata)* population (n=22, 81%)	Popular target species by commercial and recreational fishers. 74% (n=20) of all fishers interviewed mentioned they caught *S. squatina* while actively targeting *R. clavata.*	*"1990s thornback rays declined and were outfished."*	Reduction of *R. clavata* populations by fisheries in the 1980s-1990s.	Decrease the probability of fishers sighting *S. squatina* after 1990s, as *R. clavata* populations were overfished and fewer vessels would try and catch *R. clavata.*	(Enever et al. 2009)
	52% (n= 14) of fishers interviewed mentioned in the late 1980s/1990s, *R. clavata* populations declined, due to targeted and non-target fishing pressures (tangle netting, rod & line, bycatch in demersal fisheries).	*"Charter was out targeting thornback rays and tope when they caught the angelsharks."* *"Tangle netting effort for rays increased in 1995 in Aber, caused changes in bottom fishing because of the reduction in rays,"*	*R. clavata* are caught in multiple fisheries. Population declines in the 1990s, resulted in changes to target fisheries in the Welsh fleet. Reduced fishing effort targeting *R. clavata.*	Decrease the probability of sighting *S. squatina.* Increased fishing pressure on *R. clavata* could have negatively Impacted *S. squatina* population(s). The resulting shift in target fisheries would have further reduced the probability of a fisher sighting *S. squatina.*	(Whittamore and McCarthy 2005; Chevolot et al. 2006; Amelot et al. 2021)
	Reductions in the abundance of *R. clavata* resulted in target species and habitat changes for both commercial and charter fishers operating in Cardigan Bay.	*"Saw a decrease in thornback rays during the 1990s due to tangle netting in the bay. Fishing areas changed due to changes in species i.e., fewer thornbacks. Fishing areas changed as a result of decreased thornbacks to fishing on reefs for bream and tope."*	The steep decline in the population of *R. clavata* resulted in a Wales-wide change in target species and habitats, which shifted to more offshore and wreck fishing in the late 1990s.	Decrease the probability of sighting *S. squatina.* Changes to target species and habitat to offshore, wreck fishing and potting would reduce the probability of fishers encountering *S. squatina* due to a lack of spatial overlap.	(Chevolot et al. 2006; Ellis et al. 2010; Silva et al. 2012)
	No commercial fishing quota for targeting *R. clavata* locally in the 1980s/90s. Fishers suggested that this was the reason so many were landed during this period.	*"No quota for thornback rays and that was the reason for landing so many in the 80s/90s."*	Implications for species composition. Increased fishing effort had implications for the abundance of *R. clavata.*	Decrease the probability of sighting *S. squatina* after the decline in abundance of *R. clavata* reducing in fishing effort in locations that overlap with *S. squatina* predicted habitat use.	(Silva et al. 2012; Amelot et al. 2021)
Changes in target species and fisheries. (n=13, 48%)	Spatiotemporal changes to target fisheries. Today majority of commercial fishing is potting compared to nomadic fisheries in the 1970s.	*"The reason for switching target species was due to decline in the number of rays because of tangle netting in the bay. Switched target species but still caught thornbacks up to 2008."*	Fishing effort has not stayed constant over the past three decades.	The probability of sighting *S. squatina* is dependent on target species, location and fishing gear used. This decreased as commercial fishers changed target species to fisheries that rarely overlapped with *S. squatina.*	(Marine Management Organisation 2021)
	Commercial fishers implied that fleets were dynamic. Reductions in populations of target species would result in changes to fisheries. However, gear used (e.g. tangle netting) was not always species specific.	*"Tangle nets to target thornback rays and spurdog till 1993. Then potting for crustaceans and whelk."*	Likelihood of catching target species is dependent on gear type used, commercial fishing effort and fleet capacity.	*S. squatina* often caught as bycatch in mixed demersal fisheries and targeted commercial fisheries. Fleet-wide changes in target fisheries to more offshore, wreck and reef, decreased the probability of sighting *S. squatina.*	(Marine Management Organisation 2021)
	Quotas would influence commercial fisheries and preferred target species.	*"1970s - No real Quotas"*	Introduction of catch limits had implications for what fish were targeted and commercial fishing effort.	Increased the likelihood of sighting *S. squatina* in the 1970s – 1980s due to limited fisheries management.	(Hatcher and Read 2001a; Hatcher and Read 2001b)

Fishing gear selectivity (n=12, 44%)	Commercial fishing fleet was mostly polyvalent, utilising multiple gear types to seasonally target different species.	48% (n=13) of all fishers interviewed operated different gear types to target different species.	Potential catches of *S. squatina* dependent on gear type. Rod & Line recreational fishing effort was higher in summer months.	Probability of fishers catching S. *squatina* is dependent on gear selectivity. *S. squatina* are most likely to be caught in fisheries operating gear that interact with the seabed: static nets, trawling, rod & line. Overall, we suggest there is an unknown impact, as further analysis is needed to assess the impact of gear type on *S. squatina* catchability.	(Gray. 1995)
	Introduction of monofilament in 1970s.	*"Used to fish twine and then brought monofilament from St. Johns in Canada. Monofilament increased catch rates of thornback rays.*	Increased catch rates due to advancement in gear type/design, increasing fishing efficiency.	Introduction of new gear types improves selectivity of fisheries and increases catch rates of elasmobranchs. Could likely increase the likelihood of a fisher catching *S. squatina* when targeting other elasmobranchs.	Derived from primary data.
	Multiple gear changes between 1968 and 2019. Today, the majority of the Welsh commercial fishing fleet is potting, with shellfish and whelk (*Buccinum undatum)* being the main commercial fisheries.	48% (n=13) of all fishers operated multiple gear types.	Modernisation of the Welsh commercial fishing fleet. Often species-specific gear type used to catch target species (i.e., leaders, monofilament, bait).	Overall decrease the probability of fishers sighting *S. squatina,* as the majority of the fleet has shifted to potting. Little overlap of *S. squatina* with commercial shellfish fisheries.	(Seafish 2022)
Spatiotemporal changes in fishing location and target habitat (n=9, 33%)	Fishing effort changes depending on location impacting species caught.	*A charter fisher - "Since 2005 changed fishing grounds, now fishes more east of Constable bank and doesn't pick up angelsharks.* "	Fishers commonly said they changed to target wreck and reef habitat instead of sand, mud & gravel.	Decrease in the probability of sighting *S. squatina* due to a reduction in fishing effort in locations of importance for *S. squatina* populations.	Participatory mapping.
	Fishing effort in different locations is dependent on seasons. For example, charter fishers are mainly active during April- October.	48% (n=13) of all interviewed fishers were employed all year, 33% (n=9) were active between April and October.	Reduced fishing effort by charter fishers in winter months, still limited knowledge about seasonal habitat/space use of *S. squatina.*	Increase probability of sighting *S. squatina* during summer months due to spatiotemporal overlap of charter boat fisheries with *S. squatina* space use.	(Barker et al. 2022)
	Spatial overlap of fisheries with *S. squatina* habitat use.	*"In the 1990s there was a decline in thornback rays in the bay. In the late 80s anglers changed their fishing locations and therefore less likely to catch rays and angels."*	Demersal trawls, static nets and rod & line fishing often in targeted species in sand/gravel/mud habitats.	*S. squatina* distribution is still poorly understood, predicted habitat space use has identified Cardigan Bay as an important area. Fishers operating in that region are more likely to sight *S. squatina*.	(Hiddink et al. 2019; Barker et al. 2022)
	Fishing effort and targeted fishing areas for charter fishers change due to passenger licence regulations.	*"Changes in fishing efforts and targeted fishing areas (overall changes in the fishing fleet) were due to regulation changes."*	Fishing effort for recreational fishers in different locations is heavily dependent on permits (i.e. passenger licences) granted by local authorities or council.	Charter & recreational fishing effort not constant across Wales. Can either increase or decrease the probability of sighting *S. squatina* depending on fishing location and local authority or councils Overall, unknown impact on *S. squatina* records.	Derived from primary data.
Species composition changes (n=6, 22%)	In the 1990s, commercial fishers noticed an increase in spider crab (*Maja brachydactyla)* population.	*"Noticed an increase in spider crab numbers as thornback rays decreased in the 1990s."*	Fishers suggested that reduction of *R. clavata* resulted in an increase in *M. brachydactyla* populations.	Decrease probability of sighting *S. squatina* due to little overlap with shellfish fisheries.	Derived from primary data.
	Fishers suggested that spurdog (*Squalus acanthias)* populations decrease in the 1980-90s.	*"The early 1980s - early 1990s, boom and bust due to the decline of spurdog in the area"*	Changes to target fisheries that caught *S. squatina*.	Unknown impact on probability of sighting *S. squatina*.	(Rogers and Ellis 2000; Silva and Ellis 2019)

458

459 Overall, 13 factors were identified by fishers and grouped into four drivers; six factors could potentially
460 decrease the probability of fishers sighting *S. squatina*; one factor could increase the likelihood; and six
461 factors remain indeterminate (Table. 4). Of the legislative drivers mentioned by fishers, the most
462 mentioned factor referred specifically the charter industry, with 26% (n= 7) charter fishers citing
463 governance and passenger licencing changes becoming more restrictive from 1960-1990s by certain
464 local authorities (e.g., Barmouth). These made it more challenging to get permits to fish in certain areas,
465 directly shaping the number of charter vessels actively fishing. For charter vessels, increases in
466 passenger licence costs often contributed to rising operational costs, which fishers believed to be a
467 major economic driver of reducing the Welsh charter fleet. Furthermore, most charter fishers implied
468 that charter operations overlapped spatially with *S. squatina* during the summer months. Thus, a
469 reduction in charter operations over the years likely reduced the probability of sighting of *S. squatina*
470 within Welsh waters. Interestingly, one charter boat fisher commented about how increasingly stringent
471 and expensive insurance was, which played a pivotal role in the decline of the charter fishing industry
472 in Wales. Additionally, seasonal crew and skippers were expected to undergo training and vessels had
473 to acquire costly certificates, contributing to overall operating costs and leading to declines in the
474 industry. Collectively, these may have resulted in a reduced probability of sighting *S. squatina*.

475

476 For commercial vessels, three commercial fishers indicated that shifting quotas and limits had important
477 implications for landings. In the early 1970s, commercial fisheries legislation was introduced by the
478 European Commission, but it was only in 1983 that catch limits were introduced for the first time under
479 the CFP. In the early 1970s, no real national quotas for fish stocks existed in the UK, until the enactment
480 of early commercial fisheries management strategies under the CFP in 1983. Furthermore, it was only
481 in 2008 that *S. squatina* received protection in the UK when it was listed on Schedule 5 of the Wildlife
482 Countryside Act 1981. Thus, historical catches of *S. squatina* are likely underreported by commercial
483 fishers.

484 Table. 4. Potential legislative & political explanatory factors impacting the fishing capacity and effort
485 in Wales identified from thematic analysis of qualitative data collected from fisher interviews.

Drivers	Factors	Evidence from fisher interviews	Implication	Predicted impact on *S. squatina* records.	Supporting Evidence
Licencing changes (n=7, 26%)	Local authorities were responsible for passenger licencing activities at its respective port.	*"Licences were available from the local council to dock at the harbour."*	Licences were required to take out passengers and fishers were required to obtain permits to Fish. However, these were dependent on local authorities. This had implications for the number of passengers onboard and distance from port.	Charter fishing effort impacting *S. squatina* populations will vary depending on location due to differences in licencing requirements and local by-laws. Decrease or increase the probability of sighting *S. squatina* due to more stringent protocols in certain areas. Overall, unknown impact on S. *squatina*	(Hatcher and Read 2001a; Hatcher and Read 2001b)
	Council was responsible for licencing charter boats to take out paying guests.	*"Licences were given from the tourist board to take out guests, but Health and Safety became a big concern. This was council dependent with some areas tougher than others. "*	Certain council licences were more restrictive than others (e.g., Barmouth). Impacted the number of charter boat vessels actively fishing.	Decrease the probability of sighting *S. squatina* by influencing charter boat fishing effort in certain regions.	(Hatcher and Read 2001a; Hatcher and Read 2001b)
	Licencing costs increased for charter boats.	*"Changes in regulations over the years and licencing costs have resulted in a reduction of charter vessels operating."*	Reduction in the number of charter boats due to operational cost increases.	Decrease the probability of sighting *S. squatina* due to a reduction in charter fishing effort.	(Maritime and Coastguard Agency, 2012)
Shifting quotas (n=3, 11%)	Quota limits for commercial vessels (total allowable catch (TAC)) are set annually by The European Commission under Common Fisheries Policy based on area.	*"Shifting quotas (allocated to Welsh fishermen) changed every year. If the quota went down, effort went down.'*	Catch limits determine species-specific commercial fishing effort which changed annually. If TAC limits are reduced, commercial fishing effort in the respective commercial fishery is reduced. Thus, commercial fishing effort doesn't stay constant over time.	The probability of fishers sighting *S. squatina* is dependent on the type of commercial fishing activity. Catch limits imposed on bottom trawlers would either increase or decrease the probability of sighting *S. squatina* dependant on fishing effort and capacity. Overall, unknown impact on S. *squatina.*	(Hatcher 1997; Squires et al. 1998; Hatcher and Read 2001b)
	Quotas allocated to commercial fishing vessels (over 10m) by UK administrations. Vessels (under 10m) have an entitlement under an administrative level for pooled resources.	*"Shifting quotas (allocated to Welsh fisherman) changed every year.*	Quotas traded between commercial fishers in different locations, however this mainly applies to commercial fishing vessels over 10m. Quotas for Welsh commercial fisheries are subject to change annually and influence our understanding of landing records and species-specific commercial fishing effort.	The lack of quotas and reporting requirements for elasmobranch catches under the early CFP regulations could result in inaccuracies the number of historical *S. squatina* sightings. Overall, unknown impact on *S. squatina.*	(Hatcher 1997; Squires et al. 1998)
	Non-quota species for commercial fisheries are regulated by the Member States and do not have limits set at the EU level. This includes many species including shellfish (the main fishery in Wales). No quota restrictions for *R. clavata* meant there was no limit to the number caught annually.	*"No quota for thornback rays and that was the reason for landing so many in the 80s/90s."*	Local by-laws apply for certain species within specific commercial fishing areas.	Increased probability of commercial fishers sighting *S. squatina* when targeting *R. clavata* in the 1980s/90s.	Primary data
			Article 15 of the CFP landing obligation for demersal commercial fishing quota species (also referred to as 'discard ban') has potential implications for non-commercially targeted species that are caught as bycatch. Non quota species that are undersized fish would have to be returned to sea.	Overall, the introduction of the quotas for elasmobranchs in commercial fisheries, discard bans and commercial fisheries management plans for vulnerable elasmobranchs would decrease the likelihood of fishers sighting *S. squatina*. However, it would have also improved the reporting of elasmobranch catches, with reporting leading to more accurate records than historical datasets.	(EU Commission 2013; EU Commission 2015; EU Commission 2019)

Fisheries legislation and jurisdiction (n=3, 11%)	The first EU wide commercial fisheries regulations were introduced under the Common Fisheries Policy (CFP) and its reforms in 1992, 2002 and 2013.	*"In the 1980s Common Fisheries Policy introduced - impact on quotas/catch limits. Lots of sea committee by-laws. Introduction of minimum landing sizes for certain species.* "	CFP responsible for commercial fisheries quotas and which species were targeted commercially including many non-quota species (i.e. Bass, Turbot). Has direct implications for commercial fishing effort and target species in Wales.	Decrease probability of sighting *S. squatina* as CFP reforms introduced catch limits, and commercial fishing effort reduced in fisheries catching S. *squatina* (i.e., tangle netting for thornback rays in the 1990s)	(EU Commission 2013)
	Implementation of Exclusive Economic Zones (EEZ) in 1976.	———	Implementation of EEZ, and 6 -12 nautical limits had implications for the number of non-UK vessels fishing around the Welsh and English Coast.	Unknown impact on *S. squatina.*	
	Devolution of UK fisheries and establishment of the Welsh Zone.	———	The devolution of UK fisheries has direct ramifications for our understanding of historical catch records and the capacity of the Welsh commercial fishing fleet, especially given that landing data for England and Wales was recorded together historically.	Implications for the number of *S. squatina* records, current records likely under report the actual number of a *S. squatina* sightings. Overall, unknown impact on *S. squatina*.	Marine and Coastal Access Act (2009) Government of Wales Act (2006).
	"Protection of *S. squatina*" as it relates to all fishers/fisheries. "Commercial fisheries landing records" as it relates just to commercial fishers/fisheries	*"2008 - Wildlife and Countryside Act 1981 (angelshark some rays). After this no records of angelsharks/rays. (Fisher opinion) once these species were put on this act, was there compliance? Did commercial fishers' throwback angelsharks and not record it?"* *"Commercial operations didn't used to report sharks and rays. If an angelshark was caught it was normally labelled under 'misc.'. Up till more reliable the implementation of the Wildlife Countryside Act 1981 (listed 2008) records were not species- specific."*	Under national and international legislation, it is prohibited to target, land, retain, or transhipangelsharks (*Squatina squatina*). If accidentally caught, specimens must be immediately released, and estimated discards should be recorded. According to Technical Measure Regulation (EU) No. 2015/812 and Article 15 (4) and (5) of Regulation (EU) No. 1380/2013 of the European Parliament, commercial fishing vessels over 10 meters in length are required to record all accidental catches (released) and estimated discards of *S. squatina* in their logbooks. Prior to 2020, European Union Regulation No. 2019/1241 did not mandate logbook records for under 10-meter commercial vessels	After 2008, decreased probability of fishers sighting *S. squatina,* due to their prohibited status. Prior to this, records for *S. squatina* likely underreported the number of actual sightings. Depending on commercial fishing vessel compliance, records for *S. squatina* in commercial operations likely underestimate historical catches due to grouped/unreliable labelling. *S. squatina* are exempt from the landing obligation, all accidental catches must be released unharmed, with estimated discards recorded. Overall, unknown impact on *S. squatina* due to difficulties in extracting species-specific information from these records.	The Wildlife and Countryside Act (GovUK. 1981; EU Commission 2018) (EU Commission 2013; EU Commission 2015 ; EU Commission 2019)
Insurance (n=1, 4%)	Insurance for charter boats was only licenced from April-September.	*"Insurance for charters was only licenced from April-September."*	Reduction in annual charter boat fishing effort due to seasonal insurance window.	Potential overlap of charter fishing season with *S. squatina* sightings in the summer months. Increased probability of charter fishers sighting *S. squatina.* However, overall constraints to fishing activity could reduce the probability of fishers sighting *S. squatina* over the past three decades.	Primary data
	Health & Safety Certificates needed for crews and licences on charter boats (cost associated).	*"Accidents could have tightened up regulations by certain authorities, Health & Safety was a big concern for insurance reasons."*	A requirement that might have reduced the number of experienced charter boat skippers/crew due to costs associated with training.	Reduction in the number of anglers and charter boat vessels would decrease probability of sighting *S. squatina.*	(Maritime and Coastguard Agency, 2012)

Insurance costs for charter fishing boats	*"Certificates need for crews and licences on charter boats, had a cost associated."*	Contributed to overall to the increase in operating costs for charter vessels. Potentially a reason for the decline charter boats.	Decrease probability of sighting *S. squatina* due to a reduction in the number of charter vessels operating.	Primary data

4. Discussion

To effectively conserve species, management decisions need to be based on the best data available data. For cryptic or rare elasmobranch species, this is primarily from fisheries. However, traditional fisheries derived data for such species are often limited and scarce. Thus, inferences made upon them alone can be misleading without holistically considering the wider context and the coinciding changes in fisher behaviours that may have influenced interaction rates with these animals. Drawing on 51 years of fisher knowledge, this study offers a novel perspective on the complex narrative behind changes to the fishing landscapes in the United Kingdom from 1968 to 2019, and the potential impact these changes could have had on *Squatina squatina* sightings in Welsh coastal waters, drawing examples from underrepresented fisher voices. We identified 45 factors that potentially had an impact on the likelihood of fishers interacting with *S. squatina*. Of the factors identified, 16% (n =7) inferred increasing likelihood of sighting *S. squatina*, 56% (n= 25) factors inferred decreased likelihood, and 29% (n= 13) factors could not be inferred (unknown impact). Whilst we acknowledge and agree with the consensus that *S. squatina* is now a relatively rare and elusive species within Welsh waters, 56% of identified changes to fishing effort were inferred to have reduced the likelihood of fishers sighting individuals. As such, we suggest that the postulated population declines for *S. squatina* may be over-exaggerated due to a net reduction in the detectability of the species over the past several decades. We therefore suggest that the wide range of socio-economic, ecological, and legislative factors should be incorporated into future trend-based analyses for *S. squatina* populations in Wales.

509 Considering that *S. squatina* populations have declined throughout its geographic range, calculating the
510 rate and magnitude of these declines with charter boat fishing effort requires further reflection,
511 especially given the notable spatial overlap between historical charter fisheries and *S. squatina* in Wales.
512 A population trajectory for *S. squatina* estimated a 70% (1.5% per year) decline in abundance for the
513 species in Wales over a 46-year period (Hiddink et al. 2019), yet this estimate fails to sufficiently
514 incorporate the reduction in angling effort (both recreational shore and boat-based effort) and
515 commercial activity overlapping with *S. squatina* predicted space use over time (Hiddink et al. 2019).
516 Thus, opportunistic records of *S. squatina* catches and sightings used to model these changes could
517 underestimate the underlying population abundance, resulting in inflated declines for this species. Our
518 analysis indicates that charter boat fishing effort has declined over the past three decades. While no
519 validated complete data sets exists for the number of charter boats actively fishing in Wales across our
520 study time period, online searches for advertised charter trips estimate that approximately 37 boats are
521 still in operation today, representing a 46% decrease over the last 50-years (compared to Gammon
522 1974). Given this, fishers implied that the frequency of trips has reduced over the past few decades -
523 due to a decline in demand, operational costs and bureaucratic changes that govern the sector -
524 contributing to substantial shifts in angling effort in localised regions. *S. squatina* were commonly
525 caught by charter boat fishers prior to their inclusion as a protected species, with all interviewees
526 indicating that they had seen or caught *S. squatina* prior to 2008. Gradual declines in the number of
527 active vessels, frequency of trips, and the number of guests fishing, from 1968 to 2008 would result in
528 a net decrease in sightings of *S. squatina*, reducing the likelihood of a fisher sighting an individual. For
529 example, The Endeavour charter group, a collective group of three vessels based out of Aberystwyth
530 was mentioned in three separate interviews as a notable operation specialising in catching *S. squatina*,
531 with there being 38 records of *S. squatina* catches from the group in the Sea Angler magazine from
532 1968 until the charter business closed in the late 1990s (Angler 1996). Today there are no remaining
533 charter boats in Aberystwyth, which at one time had 14 charter boats fishing in Cardigan Bay,
534 highlighting how changes to the number of charter boats vary depending on the region.
535

The reported decline of *R. clavata* in the late 20th century, may have had substantial impacts on species composition and fishing effort within Cardigan Bay, Wales (Ellis et al. 2005; Enever et al. 2009; Silva et al. 2012; Walker and Heessen 1996). As a valuable commercial fishery in the late 20th century and a popular target species for recreational anglers, there were limited management plans or catch limits for the species (Fowler et al. 2004). *R. clavata* populations were commonly targeted in inshore commercial longline and static net fisheries in coastal waters around Wales, in addition to the species being an important bycatch component in mixed demersal trawls (Enever et al. 2009; Amelot et al. 2021; Whittamore et al. 2005). This commercial fishery also recorded sightings of *S. squatina* (Silva and Ellis 2019). Fisher narratives indicate that in response to this decline, many charter boat operations that targeted *R. clavata*, switched fishing locations to deeper offshore waters or to fish wreck and reef habitats, selectively targeting species including bass (*Dicentrarchus labrax*) and tope (*Galeorhinus galeus*). This resulted in sector-wide changes in the spatial locality and target species that may have reduced the probability of charter boat fishers encountering *S. squatina*. To understand historical declines of R. *clavata*, surplus-production models have been used to model data-deficient landing data of skates from demersal trawls (commercial fishing activity), corroborating the reported decline of this fishery by fishers and providing evidence to support these historical accounts (Dulvy et al. 2000; Sguotti et al. 2016; Silva et al. 2012; Pedersen and Berg 2017). Furthermore, species-specific survey data gathered from the Irish Sea and Bristol Channel, noted an important decline in abundance for *R. clavata*, during the latter half of the 20th century, alongside other large, bodied skates (Dulvy et al. 2000; Stevens et al. 2000; Whittamore and McCarthy 2005).

It is generally agreed that both *S. squatina* and *R. clavata* may occupy a similar niche within Wales, with both species vulnerable to overexploitation by the same mixed demersal commercial fisheries (Ellis et al. 2010; Silva et al. 2012). Considering this, in accordance with conclusions by Hiddink et al., (2019) it could also be perceived that *S. squatina* populations might have also been impacted in the 1990s, alongside *R. clavata*. Without species-specific data for *S. squatina*, understanding localised and regional declines for other elasmobranchs caught in the same fisheries may allow for future comparative analyses, providing an ecosystem-based approach for determining the impact of fishing activity on

564 species composition. Our study proposes that historical recreational fishing effort targeting *S. squatina*
565 was much higher in the 1970s to early 1990s, supporting the current postulations that fishing, and
566 observation effort varies over time for elasmobranchs. We highlight how nuanced and intertwined the
567 relationship between seasonality, fishing location and gear types were on the likelihood of a fisher
568 landing target species. Historically *S. squatina* was commonly caught as bycatch in mixed demersal
569 fisheries with 74% (n = 20) of the fishers specifying that the species was often caught while targeting
570 *R. clavata* in both commercial and recreational fisheries (Ellis et al. 2010; Silva et al. 2012). Given that
571 historical records for both *R. clavata* and *S. squatina* are considered data-deficient, understanding
572 whether there is a potential overlap in the distribution, prey preference, and habitat use of the two
573 species may warrant further investigation and aid in the interpretation of stock assessments and
574 population trends.
575
576 A suite of legislative changes has occurred over the past half a century, which have had arguably
577 widespread impacts on coastal fisheries in Wales and the likelihood of encountering *S. squatina.* The
578 establishment of the South Wales, Northwestern and North Wales Sea Fisheries Committees (SFC)
579 under the Sea Fisheries Regulation Act 1966 ("the 1966 Act"), saw the first introduction of commercial
580 fisheries by-laws in different regions across Wales, with the SFC responsible for regulating the inshore
581 (0-6nm) fishing zones until the committee's dissolution in 2010 (Terry et al. 2017). In the 1970s, there
582 were very limited regulations on commercial fishing activity within Welsh waters. Consequently, from
583 1970 to the mid/late 1990s there were no set quotas or catch limits for elasmobranchs within Wales, and
584 commercial fishers were under no obligation to keep species-specific records on sightings, landings, or
585 discards of these species (Fowler et al. 2004; Silva and Ellis 2019). Considering that the compiled
586 historical records for *S. squatina* analysed in this study span a 51-year period, elucidating the influence
587 of legislative changes on these records is crucial for gauging the accuracy of past catch reporting across
588 Wales.
589
590 Gradual decadal reforms of the CFP policy in 1992, 2002 and 2013 have resulted in significant changes
591 to fisheries management (EU Commission 2013). The successes and failures of the policy's gradual

592 reforms have been widely debated and critiqued by fisheries biologists, fishers and elected officials,
593 with extensive studies detailing how early legislation and management efforts failed to protect
594 vulnerable stocks from overexploitation by fisheries (see Daw and Gray 2005; Jensen 1999; Churchill
595 and Owen 2010). Despite the direct impact of CFP policies and its reforms on commercial fisheries
596 operating within Wales, only three fishers highlighted the importance of it or referred to 'quotas' more
597 generally. While investigating the impacts of specific regulations on commercial fishing fleet
598 characteristics and behaviour within Wales is beyond the scope and purpose of this study, commercial
599 fishers highlighted that the implementations of legislation had broadscale impacts on the composition
600 and behaviour of fleets operating within the Welsh Zone.
601
602 Commercial landings data for *S. squatina* catches collated by the International Council for the
603 Exploration of the Sea (ICES) Working Group on Elasmobranch Fisheries have indicated decadal
604 declines of species records across the Northeast Atlantic (ICES, 2017). Yet, detailed fishery-dependent
605 datasets for commercial fisheries targeting *S. squatina* within the Welsh Zone are scarce. It is highly
606 likely that *S. squatina* were commonly caught as bycatch in historical mixed demersal commercial
607 fisheries. However, pulling species-specific *S. squatina* data from historical records is challenging, as a
608 plethora of identification labels in commercial fisheries have been used to refer to the species. Given
609 that 'monkfish' is also a moniker for a popular commercially targeted teleost fish, *Lophius piscatorius*,
610 it is likely that these records are under-recording the true number of *S. squatina* caught. Whilst some
611 fishers reported voluntarily, until recently, commercial vessels had no statuary obligation to record
612 bycatch or discards despite the large volume of unreported species being extracted (harvested or
613 released) in these fisheries (Barker and Schluessel 2005; CEC 2009; DEFRA 2011; Fischer et al. 2012;
614 ICES 2017). While *S. squatina* are exempt from the landing obligation due to their inclusion as a
615 protected species on Wildlife and Countryside Act 1981 and auxiliary protections afforded under
616 international legislations (see, EU Commission 2013; ICES 2017) it is probable that historical landing
617 data is underestimating the number of records.
618

Although this study aimed to shed light on the nuanced changes in fishing practices across Wales, it is important to note the unavoidable bias associated with our analysis. For one, due to the snowball sampling methods used to recruit fishers for this study and the willingness of fishers to contribute (Miles and Huberman 1994), there is a considerable bias towards North Wales where most of the project's engagement is highest. Nonetheless, we argue that the complex behaviours of both commercial and recreational fisheries need to be better characterised and considered in elasmobranch population assessments and incorporated into sustainable management initiatives, particularly for non-commercially targeted species. Finally, we advocate for the greater inclusion of fisher perspectives into traditional quantitative approaches within fisheries research and highlight the innovative value of LEK and narratives in regaining data on historical fish populations.

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