Tagging Sharks, Informing Policy, and Conservation: Streamlining Best Practices for the Isle of Man's Tagging Initiatives for Sustainable Shark Management

By

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Abstract

Sharks and rays are key predators in marine ecosystems, playing an important role in maintaining ecological system function (Dedman *et al*., 2024). These species face severe threats from overfishing, habitat degradation, and climate change (Frisk *et al.*, 2005; García *et al.*, 2007). Here, we focused on the population metrics and conservation challenges of small sharks and rays around the Isle of Man, specifically through the Manx Wildlife Trust's (MWT) Small Shark Tagging Programme (SSTP). Initiated in 2013, the SSTP gathers essential data on the distribution, movement, and population dynamics of species including bull huss (*Scyliorhinus stellaris*), spurdog (*Squalus acanthias*), thornback ray (*Raja clavata*), and tope (*Galeorhinus galeus*).

These species face varying levels of threat: bull huss is 'Near Threatened' in Europe (Ellis *et al.,* 2015) and 'Vulnerable' globally (Finucci *et al*., 2012), with significant population declines over the past 48 years. Spurdog, listed as 'Vulnerable' globally (Finucci *et al*., 2020) and 'Endangered' in Europe (Ellis *et al*., 2015), has complex migratory patterns, making accurate population assessments difficult without tagging data. Thornback ray, also 'Near Threatened' (Ellis *et al*., 2016) requires further monitoring due to high pre-maturity catch rates. Tope, categorised as 'Critically Endangered' globally (Walker *et al*., 2020) and 'Vulnerable' in Europe (McCully *et al*., 2015), suffers from population fragmentation, making tagging crucial for conservation insights.

The study had two primary objectives: first, to conduct a comprehensive review of global shark tagging technology to identify best practices for the SSTP; and second, to analyse a decade's worth of SSTP data to assess population structures including age, size, and sex distribution. Key findings show that 75 % of tagged tope and 94 % of tagged spurdog are females, indicating that Manx waters may serve as critical nursery grounds. However, discrepancies in length-mass relationships, particularly for spurdog, highlight the need for improved data accuracy.

These findings underscore the importance of targeted conservation strategies, such as establishing marine protected areas (MPAs) and updating fisheries regulations. This research supports the development of proactive conservation policies in the Northeast Atlantic and contributes to global efforts to protect vulnerable elasmobranch species and sustain marine ecosystems.

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Chapter 1. Synthesis Review of Elasmobranch Tagging Devices

1. Introduction

Historically, studying animal movements in marine environments has been challenging due to primarily due to their high mobility and the obscuring nature of the marine environment (Myrberg, 1987; Klimley *et al*., 1992; Bres, 1993; Martin *et al*., 2009). Both external and internal tags have been utilised to facilitate identification and the retrieval of information from marine and freshwater fish (Kohler and Turner, 2001). Initial tagging efforts primarily focused on salmonids using simple mark and recapture techniques by marking caudal fins with coloured wool ribbons to record their return to natal rivers following marine phases (McFarlane *et al.*, 1990; Kohler and Turner, 2001). These methods saw minimal advancement for nearly 340 years, providing little information beyond the locations and times of tagging and recapture.

A breakthrough occurred with the introduction of archival tags in the early 1990s. In addition to recording environmental data encountered by host animals, these tags also allowed migration routes from tagging to recapture to be calculated (Gunn and Block, 2001; Bradford *et al.*, 2011). Notably, these tags detach from the host at specified times and transmit a summary of archived data, eliminating the need for recapture (Block *et al.*, 1998; Gunn, 2000; Bradford, 2011).In addition to satellite tags, low-cost acoustic technology was developed for tracking the movements of Chinook salmon, approximately 300 years after the first tagging studies on Atlantic salmon (Johnson, 1957; Welch, 2003). The earliest acoustic tags were remarkably large compared to modern devices, measuring approximately 6.4 cm in length and 2.3 cm in diameter, with heavy and labour-intensive tracking equipment (Welch, 2003). The miniaturisation of components and the advancement of electronics over the past 50 years has significantly enhanced the usefulness of acoustic technology (Hussey *et al.*, 2015). Modern acoustic tags are smaller, more powerful, have longer operational lives, and can host a variety of sensors (Bradford *et al.*, 2011). The introduction of autonomous or passive acoustic monitoring systems has significantly decreased the labour involved in tracking tagged fish, while greatly enhancing the ability to scale monitoring effort (Heupel *et al.*, 2006; Bradford *et al.*, 2011).

Elasmobranchs have been studied using conventional tagging methods since the 1930s (Steven, 1936). By 1936, roughly 700 skates and rays had been tagged and released around the British Isles, and by 1940, the number of tagged individuals in all European waters had reached 1,005 (Olsen, 1953). The 1940s signalled the commencement of shark tagging activities, primarily on species including *S. acanthias* and *G. galeus* in both the Pacific and Atlantic Oceans (Kohler and Turner, 2001). Recently, the tagging of elasmobranchs (sharks, skates, and rays) has seen notable progress (Kohler and Turner, 2001). Critical information on shark behaviour and ecology that was previously difficult to obtain, has been made available by the rapid expansion of tagging studies (Burke, 2023), including life cycle characteristics, migration routes, stock status, and behavioural and distribution patterns (Kohler and Turner, 2001). Tagging fish to track their spatiotemporal presence offers fishery managers a crucial tool for conservation management (Hammerschlag *et al.*, 2011), providing a cost-effective and reliable method for gathering data on fish populations (Everhart & Youngs 1981, Gordon 1990).

2. Methods

To review current literature on elasmobranch tagging efforts, the Google Scholar database was used to access peer-reviewed articles, theses, books, and conference papers. The search strategy included keywords specifically selected to find relevant studies on elasmobranch conservation, spatial ecology, and tagging methods, which included "*elasmobranch**", "*habitat suitab**", "*tag**", "*spatial ecology*", "*mark recapture*", and "*recap**". These terms were carefully chosen to ensure a broad yet focused search, ensuring the most relevant aspects for the study's goals were targeted.

This search strategy yielded 2,650 results, which were continually monitored for new literature until the writing phase. To ensure a rigorous and systematic approach, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework (Figure 1) was utilised to screen, filter, and assess the relevance and quality of the studies. PRISMA's structured process facilitated the identification of key studies, with results manually reviewed for eligibility. This process led to the retention of 78 peer-reviewed papers that met the inclusion criteria, focusing on *methodology* (tagging methods), *organism* (elasmobranchs), and *region* (Atlantic Ocean).The exclusion principle was applied to further refine the selection to studies directly relevant to the research aims were included. Papers that did not meet specific criteria, such as those not addressing elasmobranchs, lacking robust methodological details, or focusing on unrelated regions, were excluded. Studies that met criteria 3-4 (as outlined in Figure 2) were retained, emphasising the importance of methodology, organism, and regional focus in the analysis.

In addition to the initial search results, 12 references were incorporated from the bibliographies of seminal works, bringing the total to 90 publications. This approach ensured a comprehensive and focused literature review, providing a solid foundation for the study's analysis of elasmobranch population dynamics, habitat suitability, and tagging methods. The structured framework for exclusion, depicted in Figure 2, illustrates the targeted data collection and analysis process, aligning with the study's goals and ensuring the relevance and quality of the included studies.

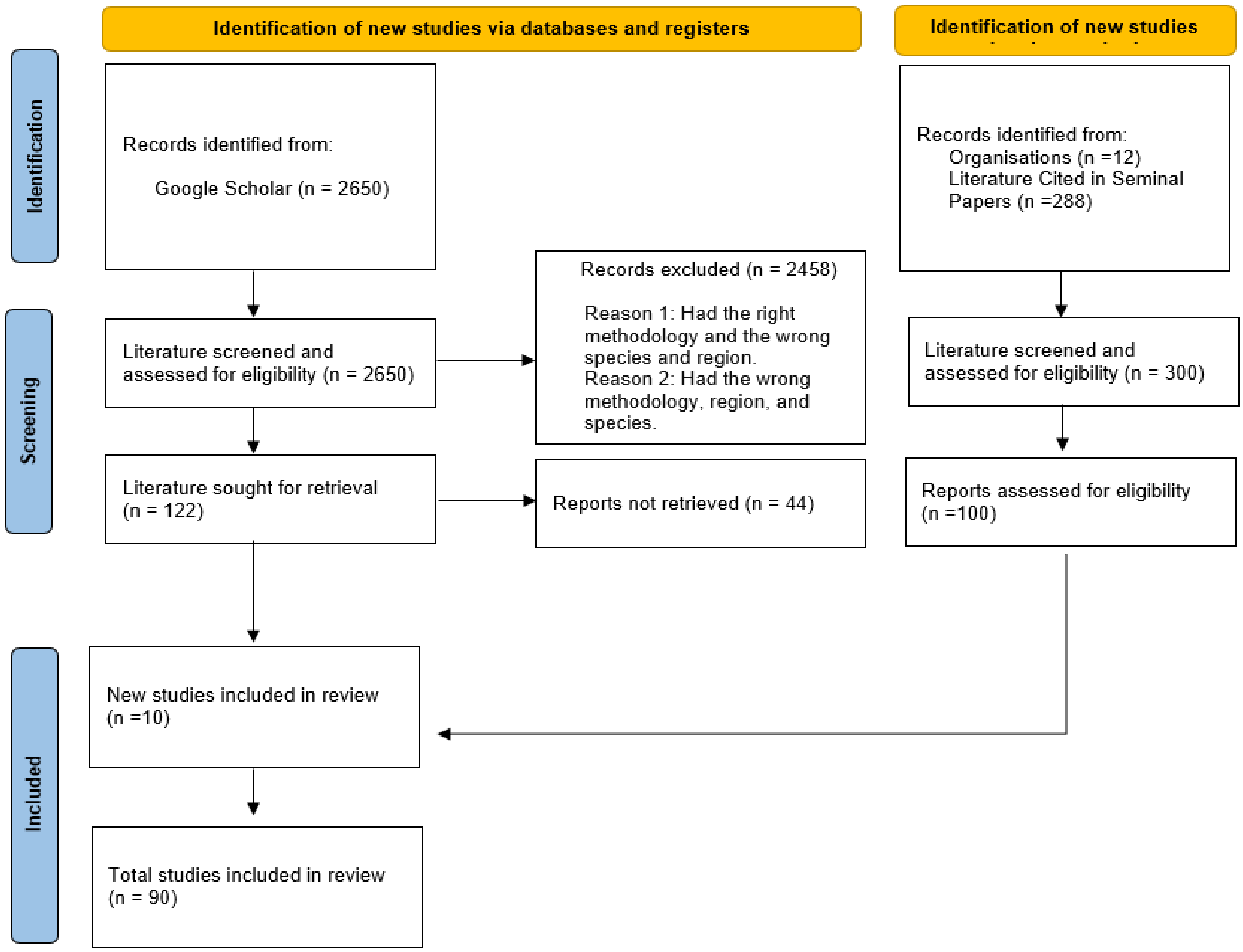

Figure 1. **PRISMA Framework.** Adapted from Page et al., 2021.

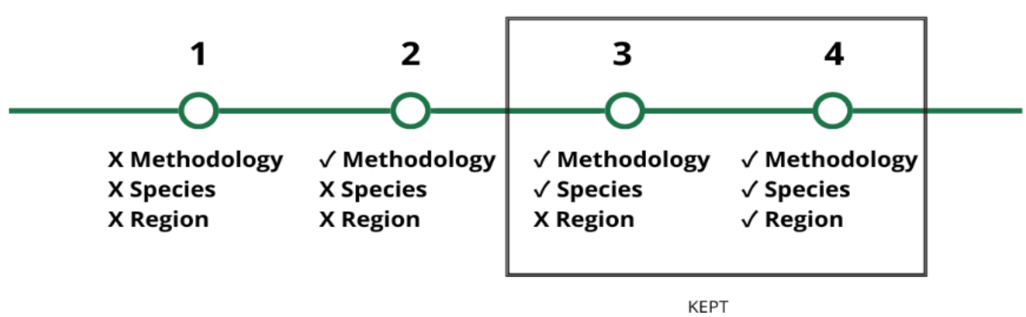

Figure 2. **Framework for the Exclusion Principle for the Literature Review.** Outline of the framework applied to the exclusion principle in the study, featuring key components: *Methodology* (tagging methods), *Organism* (elasmobranchs), and *Region* (Atlantic Ocean). The framework illustrates the structured approach used to focus the research scope and ensure targeted data collection and analysis.

3. Results

The literature was categorised into the following themes: Tagging Technique, Movement and Habitat, Movement Patterns, Tagging Programme, Life History, Stock Assessment, and Growth Rates & Movement (Figure 3). The predominant theme, comprising 43 % of the peer-reviewed papers, was Tagging Technique. The second most prevalent theme, at 23 %, was Movement & Habitat, and the third most frequent theme, Movement Patterns, accounted for 9 % of the literature. The abundance of papers on Tagging Technique likely result from the keyword search bias, emphasising terms such as "tags" and "mark recapture," as well as “spatial ecology”, which is reflected in the themes Movement & Habitat and Movement Patterns.

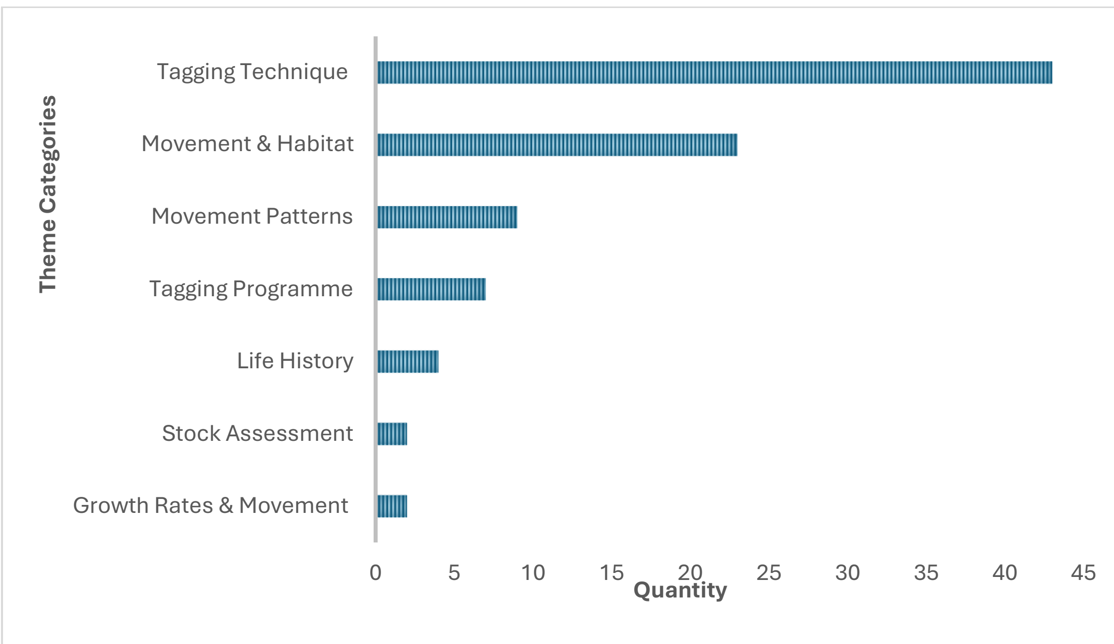

Figure 3. **Distribution of Research Themes of Selected Literature** (N=90). Tagging Technique is the predominant focus (43 %), followed by Movement & Habitat (23 %), and Movement Patterns (9 %). Other themes include Tagging Programmes (7 %), Life History (4 %), and both Stock Assessment and Growth Rates & Movement (2 % each).

Regarding publication trends, the literature selected (from 1984 to 2024) for this review indicates a peak in publications in 2022, with nine papers published. The years 2014, 2020, and 2023 each followed closely with eight publications (Figure 5).

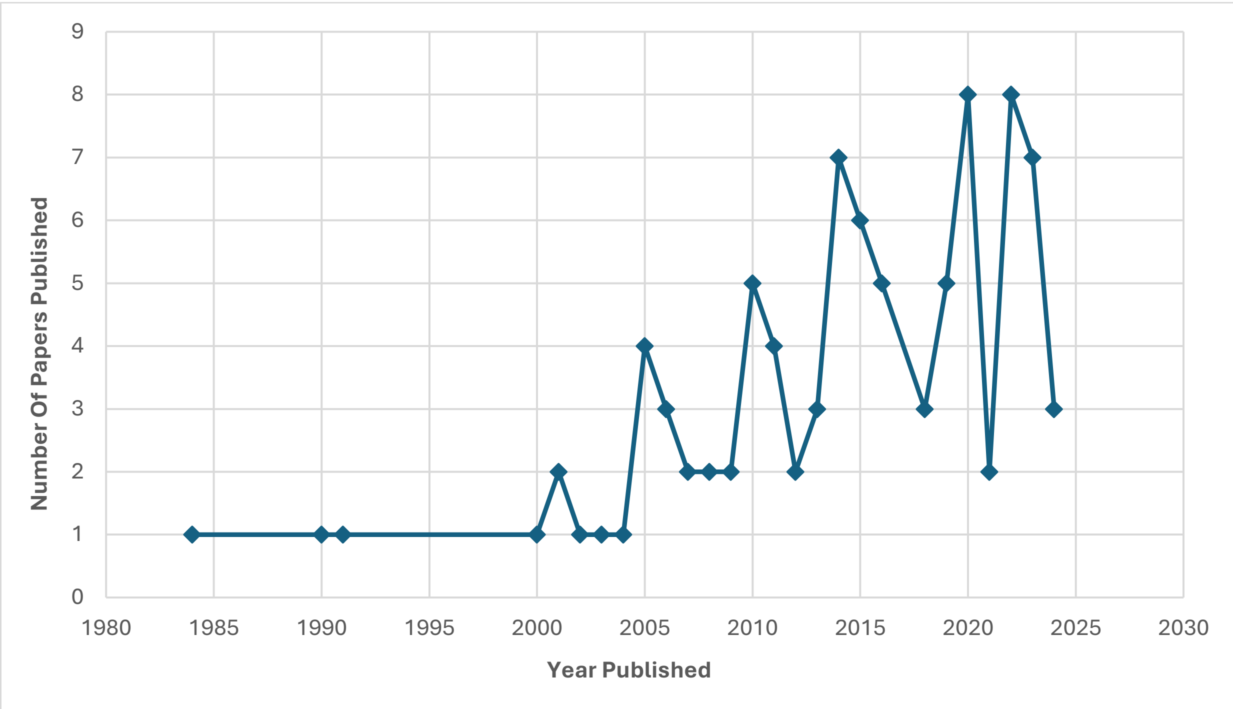

Figure 4. **Annual Publication Trends.** The number of shark conservation-related papers (N=90) published annually from 1984 to 2024.

The reviewed literature encompassed chapters from books, peer-reviewed journal articles (including experimental studies, secondary analyses, and reviews), governmental and institutional reports, as well as theses (comprising both doctoral and master's level work). The predominant category within the literature was journal articles, accounting for 56 selections. This was followed by a total of 18 reports, 10 theses entries, and 6 book chapters (Figure 5).

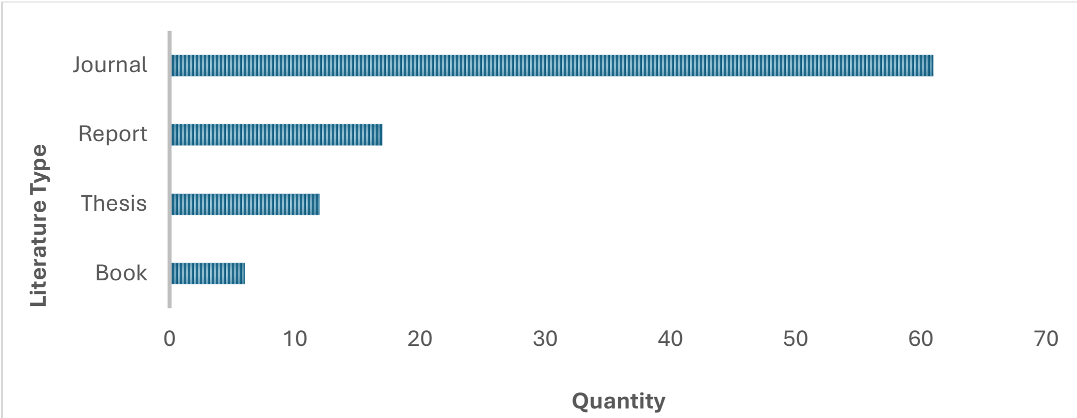

Figure 5. **Thematic Distribution of Publications.** A bar chart showing the distribution of publications (N=90) categorised by theme, highlighting the diversity of research topics within the field of shark conservation.

An analysis of 45 journal articles was used to interrogate the number of scientific publications per species (Figure 6) . Reports and review articles were generally excluded from this analysis, except for three reviews in which the species were clearly stated. The exclusion was due to the difficulty in extracting species-specific information from these sources, or the extensive number of species mentioned, which would have been beyond the scope of this dissertation's time constraints. From the reviews that were included, the top three shark species were identified and incorporated into the list (Appendix I).

The literature showed spiny dogfish (*S. acanthias*) had the highest number of publications (N=5), The blue shark (*Prionace glauca*) followed with four papers. The flapper skate (*Dipturus intermedius*), broadnose sevengill shark (*Notorynchus cepedianus*), and white shark (*Carcharodon carcharias*) each have three publications. The graph covers a diverse range of species, including both pelagic (e.g., White Shark, Blue Shark) and demersal (e.g., Spiny Dogfish, Thorny Skate) sharks, as well as skates.

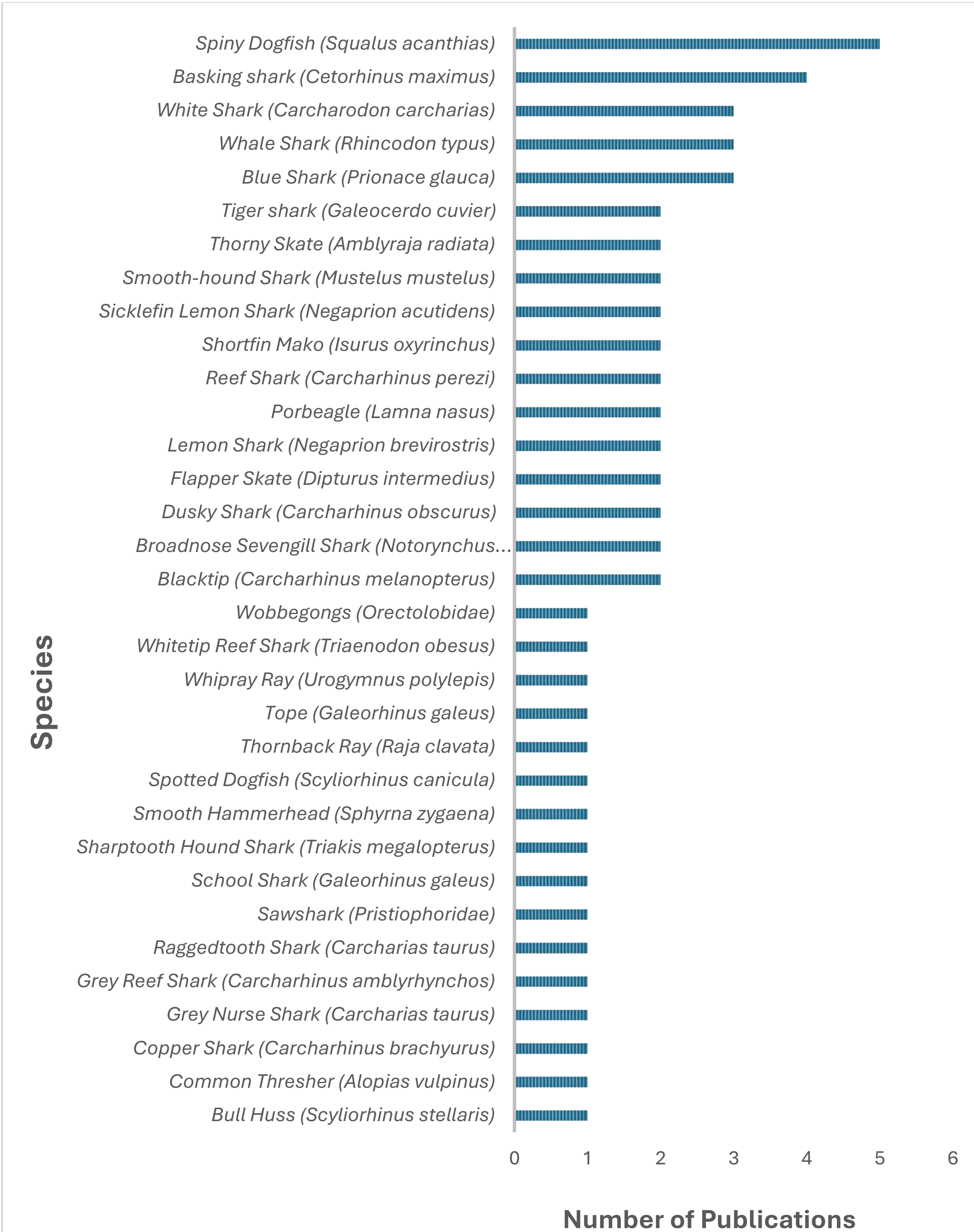

Figure 6. **Number of Scientific Publications by Species of Elasmobranchs**. Analysis of 45 journal articles showing the number of publications per elasmobranch species, excluding review articles due to difficulty in extracting species-specific information. The top three species from the included three reviews are also highlighted.

Figure 7 illustrates the spatial distribution of publications, created using peer-reviewed literature that explicitly indicated their locations. Additionally, 21 reviews were included, further details can be found in the cited reviews (Appendix II). The United States had the highest number of publications (7), followed by Australia with 5, with Latin America, Africa, and Asia being highly underrepresented.

Figure 7. **Geographic Distribution of Experimental Elasmobranch Studies** (Source: Datawrapper). World map showing the geographic distribution of experimental peer-reviewed studies on elasmobranchs.

A heatmap analysis was conducted using data from 41 publications (Appendix III; Figure 8), categorising sharks by size, with small being <1.5 m, medium 1.51-3 m, and large >3.1m. Sizes were determined by using the total length (TL) reported from FishBase (FishBase, 2024). Rays and skates were excluded due to the low count of publications and the difficulty in categorising by size. Categories include different tagging methods (e.g., conventional, satellite, acoustic) and factors influencing tagging procedure (e.g., size, mass, handling time, mortality), publication themes (e.g., spatial ecology, stock assessment, life history), study area (e.g., coastal or pelagic), policy aspects (e.g., recommended/ supported policies), and fisheries focus (conversation perspective or stock assessment). The theme of "Movement & Habitat" encompasses studies focusing on migrations and habitat usage, while "Movement Patterns" addresses broader movement trends and migration patterns. These two themes are grouped under the broader umbrella of spatial ecology, which is reflected in the heatmap (Figure 8) for simplification purposes. The "Growth Rates & Movement" theme includes studies that primarily discuss methodologies for measuring growth rates and consider overall animal movement, incorporated within spatial ecology.

The "Tagging Programme" theme pertains to papers describing tagging programmes and propose best practices for tagging. The "Tagging Technique" theme includes papers that critically analyse and discuss various elasmobranch tagging techniques, often proposing improved practices, contrasting and comparing different methods, providing reviews, and discussing future research directions. Lastly, the "Life History" theme, encompasses foundational biological factors such as nurseries, mortality rates, and population genetics, in addition to addressing movement and habitat aspects.

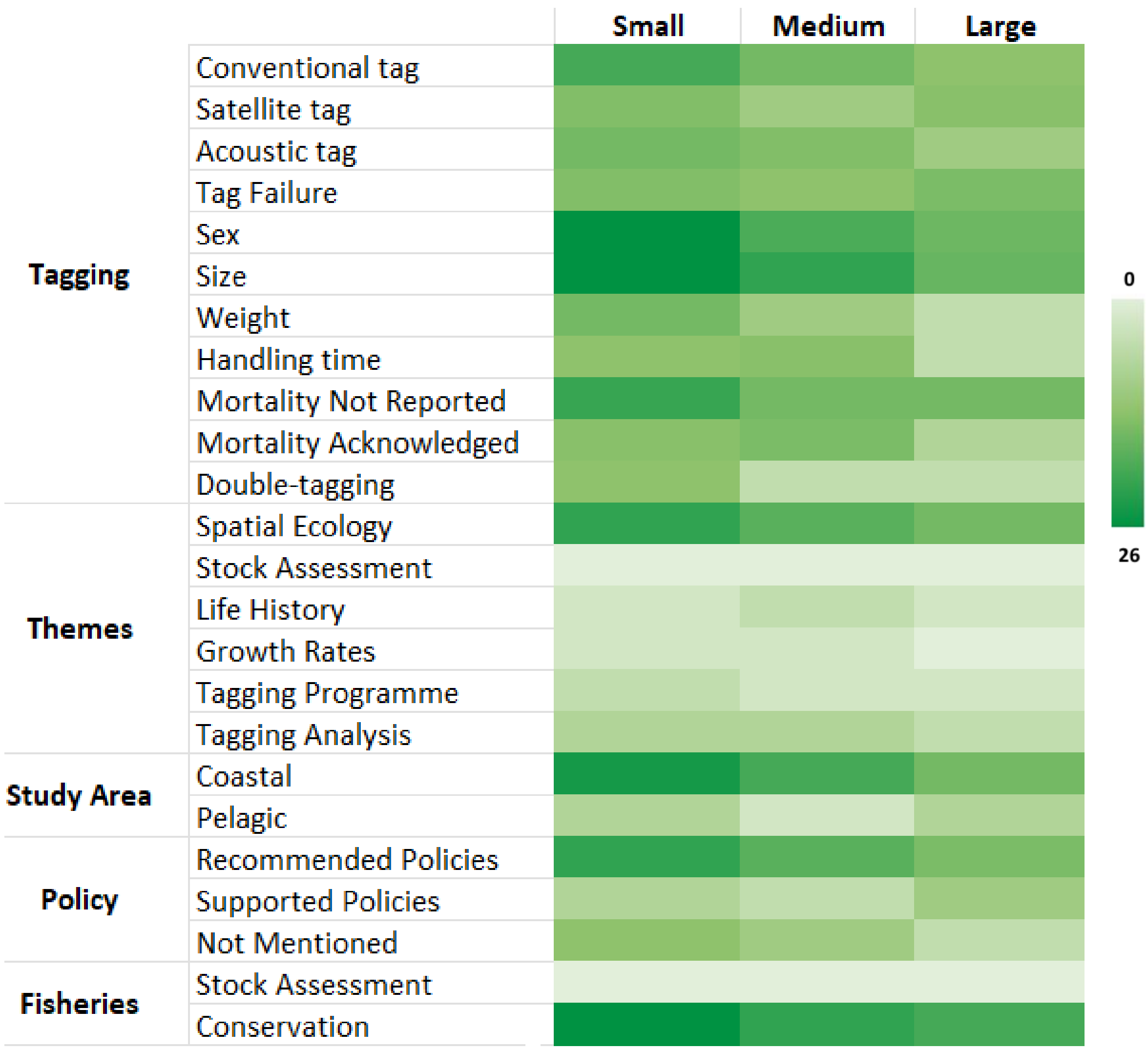

Figure 8. **Heatmap of Research Focus Across Shark Size Categories and Key Themes**. Distribution of publications (N=41) categorised by fish size (Small: ≤1.5m, Medium: 1.51-3m, Large: ≥3.1m) across various research themes, including Tagging, Study Area, Policy, and Fisheries. Darker green shades indicate a higher number of publications within each category.

4. Literature Review Discussion

Regarding publication trends, the literature selected for this review indicates a peak in publications in 2022, with nine papers published. The years 2014, 2020, and 2023 each followed closely with eight publications (Figure 5). These peaks coincide with significant legislative and regulatory developments or initiatives, which likely encouraged increased research interest. For example, in 2013, five shark species were added to Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; CITES, 2023), requiring international trade to be sustainable and traceable. Additionally, 2019 saw the adoption of the Shark Fin Sales Elimination Act in the U.S. SFSEA; SFSEA, 2019), addressing the sale of shark fins, and the inclusion of rays and skates in the Seafood Traceability Programme which requires data reporting and recordkeeping at the time of entry for imported fish or fish products entering U.S. commerce.

In 2022, the publication peak could be related to the increased global attention on marine conservation driven by the United Nations Decade of Ocean Science for Sustainable Development (2021-2030; UNESCO n.d.). This initiative, launched in 2021, aims to promote science-based management of the oceans (Guan *et al.,* 2023) and likely incentivised further research into shark conservation as part of global management efforts. The overall higher number of publications in 2023 may reflect the ongoing impact of these legislative and regulatory measures or initiatives; In addition to technological advancements in tagging equipment, which enhance data accuracy, extend tracking periods, enable miniaturisation, improve transmission capabilities, and make the technology more accessible (Hammerschlag *et al.*, 2011; Harcourt *et al.*, 2019; Renshaw *et al.*, 2023). Although not correlative, these initiatives likely stimulated research into the effectiveness of stock management as a result of these regulations, as well as alternative potential conservation strategies.

Analysis of research output by species showed spiny dogfish (*S. acanthias*) had the highest number of publications (N=5), potentially due to their significant population declines from overfishing and their Vulnerable status on the IUCN Red List (Ellis *et al*., 2015; Finucci *et al*., 2020).

Other species like basking sharks (*Cetorhinus maximus*), great white sharks (*Carcharodon carcharias*), and whale sharks (*Rhincodon typus*) also receive significant research focus possibly due to their roles as apex predators or filter feeders, their high extinction risk, unique life cycles, and wide spatial distribution (Sims *et al*., 2003; Domeier and Nasby-Lucas, 2013; Pikesley *et al*., 2014; Pierce and Norman, 2016). Their vulnerability to human impacts makes them critical for conservation, driving extensive scientific study to better understand their biology and behaviour. The inclusion of both common and lesser-known species can indicate an attempt to cover a broad spectrum of elasmobranch biodiversity within a wide range of topics (trophic-levels, life cycles, predator-prey interactions, etc).

The spatial distribution of shark research reveals significant underrepresentation in Latin American, Africa, and Asia (Figure 7), despite these regions' crucial roles in global shark populations (Kroese and Sauer, 1998; Bornatowski *et al*., 2018; Espinoza *et al*., 2020; Clark-Shen *et al*., 2023). Language barriers and limited research infrastructure contribute to this disparity. While Asia plays a significant role in shark consumption, research output is relatively low, likely due to varying levels of research funding and collaboration (Dent and Clarke, 2015). Collaborative international research networks are essential to address these gaps and enhance understanding of elasmobranch spatial ecology and conservation strategies (Oliver *et al*., 2015; Kohler and Turner, 2018).

As evidenced by the heatmap (Figure 8), a notable gap in the literature is the limited discussion on shark mortality associated with the tagging process. Understanding mortality rates is crucial for assessing the ethical and ecological impacts of tagging studies (Arlinghaus *et al.*, 2007; Cameron *et al.*, 2023). Despite the underrepresentation of small-bodied sharks in telemetry literature (Ducatez, 2019), the findings of this review shows that sharks measuring less than 1.5 meters in length were the most frequently studied, followed by medium-bodied sharks (Figure 8). This trend may be attributed to the methodology used, which categorised individuals based on overall size rather than species-specific size, thereby including juvenile and early life stages in the small-bodied category. For example, the white shark (*C. carcharias)* as a juvenile (1.75-3.0 m) would fall into the “medium” category but during its adult (>3.6 m) life stage it would be categorised as “large” (Bradford *et al.*, 2011). This data deficiency does not necessarily reflect a lack of data, potentially signally that this deficiency lies in reporting, rather than in the lack of available data. As further evidenced by the lack of transparency in presenting study methodologies and analyses, potentially affecting study reproducibility and comparability.

The heatmap shows conventional tags were the most frequently used for small-bodied sharks (Figure 8), likely due to smaller sharks being unable to support larger satellite tags, which would impede movement (Hammerschlag *et al.*, 2011). In contrast, mass was recorded least frequently for large-bodied sharks, likely because it is challenging to weigh them, especially if needed to be brought aboard a ship. Coastal regions had a significantly higher number of publications compared to pelagic regions. This trend can be attributed to the accessibility and convenience of conducting tagging procedures near the coast. Additionally, many targeted species either prefer coastal habitats or are reef-associated (Papastamatiou *et al.*, 2009; Speed *et al.*, 2010, 2011), contributing to the higher publication count for coastal areas.

Spatial ecology emerged as the most prevalent theme, significantly outnumbering other study themes, aligning with many tagging programmes objectives to investigate movement patterns, habitat usage, nursery areas, and feeding grounds (Barker *et al.*, 2005; Dureuil, 2013; Engelbrecht *et al.*, 2020; Burke, 2023), all components of spatial ecology. Additionally, conservation was a prominent theme, as tagging programmes are widely used as part of marine conservation efforts (e.g. CSTP, the Australian Shark Tagging and Tracking Program, the United Kingdom (UK) Shark Tagging Programme, the Global Shark Movement Project (GSMP), etc). In contrast, stock assessment was the least represented theme, likely due to the high costs and extended study periods required for tagging studies, as well as the fact that stock assessments often focus on different objectives and employ alternative methods like modelling, which may not have been captured in the literature search.

Most papers concluded with recommendations for implementing policies and regulations for species protection and conservation. Yet almost none of these studies led to the direct or indirect development of legislation, with this mismatch likely due to complex sociopolitical factors such as competing economic interests, lack of political will, and the challenges of international cooperation in marine conservation efforts (Agardy *et al.,* 2011; Redpath *et al*., 2015; Dulvey *et al*., 2021).

4.1 Elasmobranch Tagging Methods

Shark tagging enables the study of movement patterns, habitat use, and behaviour (Edwards *et al.*, 2024), with multiple tagging methods utilised, each offering distinct advantages and limitations. Conventional tagging has long been a fundamental tool in fisheries research, involving tagging individuals that can later be visually identified without special detection equipment, yielding data on growth rates, movement patterns, and mortality (Kohler and Turner, 2001; Galuardi and Lam, 2014). This method provides crucial information on the life history, migrations, and population dynamics of various marine species (Galuardi and Lam, 2014), yet despite its usefulness, conventional tagging requires careful and well-organised study designs to ensure data accuracy and reliability (Kohler and Turner. 2001; Heupel *et al*., 2006).

Telemetry techniques are primarily facilitated by three categories of electronic devices: acoustic transmitters, satellite transmitters, and archival tags, which provide a fishery-independent (not reliant on commercial and recreational fishing activities) means of gathering information about individuals within a population (Hazen *et al.*, 2012; Matley *et al.*, 2022). Data obtained from telemetry offers valuable biological insights, providing a comprehensive view of population-level activities (Galuardi and Lam, 2014). Telemetry requires the tagged individual to carry either a receiver or transmitter, which can be broadly categorised into acoustic and non-acoustic methods. While acoustic telemetry is well-suited for monitoring coastal, riverine, and certain oceanic areas (e.g., fish aggregating devices), it is limited by factors such as detection range and field logistics (Heupel and Webber, 2012). Non-acoustic tagging methods can be divided into two categories: data storage (archival) tags and satellite-linked radio transmitting (SLRT) tags. The primary distinction lies in the data delivery method; archival tags store data for later retrieval, while SLRTs can transmit data in real time (Hussey *et al*., 2015). The application of these emerging technologies is still being investigated, as telemetry data is contingent upon the scale at which the individual can be observed. Further, species physiology ultimately determines the type of telemetry possible and, consequently, the breadth of data applicability (Hammerschlag *et al.*, 2011; Hussey *et al.*, 2015). The positioning and analysis techniques used for archival and SLRT tags directly affect the level of detail and accuracy of the inferences that can be drawn from the movement data.

Despite significant advancements in telemetry studies, technological and logistical constraints continue to determine the spatiotemporal scales that can be investigated using these techniques (Galuardi and Lam, 2014; Harcourt *et al.*, 2019). Factors such as tag size, battery life, and data resolution and recovery are crucial considerations when selecting appropriate techniques for specific research questions and species (Matley *et al.*, 2023).The following subsections provide a brief overview of the applications, advantages, considerations and limitations, and advancements for the two dominant tagging methods: conventional and telemetry (acoustic, satellite, and archival).

4.2 Conventional Tagging

4.2.1 Applications

Conventional tagging is essential for estimating growth rates and understanding both natural and fishing-induced mortality (Galuardi and Lam, 2014). Researchers can examine differences between tagging and recapture locations to infer movement rates and population structures (Hammerschlag *et al.*, 2011; Hussey *et al.*, 2015). Nonetheless, these studies must tag large numbers of individuals, often ranging from hundreds to thousands, to ensure representative data (Hall, 2014). These extensive tagging efforts generally span over many years, and the reliability of the data on mortality and movement rates is dependent on the proportion of tagged individuals compared to total population size (Pine *et al.*, 2003).Tag-recovery models play a critical role in this approach, but they often rely heavily on fisheries, introducing potential biases from fishing activities and regulatory frameworks (Schwarz, 2005). To address these biases, fishery-independent data collection methods are preferred, allowing for more accurate assessments of fish movement and population dynamics (Galuardi and Lam, 2014).

4.2.2 Advantages

Conventional tagging remains the most affordable and commonly utilised approach for addressing environmental aspects (e.g. distribution and movement) at both individual and population levels (Kohler and Turner, 2001; Dunlop *et al.*, 2013). The success of tagging studies is greatly influenced by the type of tag used (McFarlane *et al.*, 1990), for example, Petersen discs emerged as the preferred option for skates, utilised in 69 % of releases because of their high retention rates and minimal biofouling (Bird *et al.*, 2020). Studies have also shown that stainless-steel dart tags outperform single-barb tags in terms of retention performance and ease of application for large pelagic sharks (Mas *et al.*, 2022). The shedding rate, ease of application, visibility, and impact of tags on behaviour and survival can differ significantly across various tag types, depending on the species, body size, and tagging method used (Latour, 2005; Pine *et al.*, 2013). Studies have shown that double-tagging is a straightforward method to compare the performance and shedding rate of different tags (Mas *et al.*, 2022), thereby providing insights into the suitability of tag types in relation to the study's objectives. For instance, using both internal and external tags can increase return rates, as demonstrated by the tagging of *G. galeus* (Olsen, 1984). A study by Mas *et al*. (2022) revealed that without double-tagging, the overall recapture rate drops from 1.4 % to 1.0 %, and over half of all long-term (≥ 1 year) and large-scale (≥ 1000km) recaptures are lost due to the shedding of single-barb plastic tags.

4.2.3 Challenges and Considerations

A significant limitation of conventional tagging is the reliance on the recapture of tagged individuals to draw meaningful conclusions about their movements and behaviour (Hammerschlag *et al.*, 2011). This dependence necessitates deploying a large number of tags, which can be resource-intensive (Kohler and Turner, 2001). Accumulating a sufficient sample size of tag reports to support analyses and policies can take many years, further restricting the applicability of these studies (Byrne *et al.*, 2017). Shark tagging studies often have low re-sighting or recapture rates, for example, Housiaux (2016) tagged over 50 sevengill sharks (*Notorynchus cepedianus*) with dart tags, but only two

(3.7 %) were re-sighted. Similarly, 2,378 spiny dogfish (*S. acanthias)* were tagged across Pierre Bank and in Newfoundland coastal waters between 1963-65, with only 9.4 % reported recaptures (Templeman, 1984). Due to the low recapture rates of conventional tags, Kneebone *et al.,* (2020) found it necessary to use satellite technology to track the horizontal movements of thorny skates in a fishery-independent context (Kneebone et al., 2020). In a review of 52 shark tagging studies, Kohler & Turner (2001) found that > 50 % had a recapture rate < 5 %. Factors such as tag shedding, bio-fouling, mortality, migration, fishing pressure, and human error in identification contribute to these low re-sight rates (Pepperell, 1990; Schwarz & Arnason, 1990; Tiedemann *et al.*, 1990; Kohler & Turner, 2001). Moreover, conventional tagging methods do not always provide the detailed data needed to inform policy, highlighting a gap that current methodologies cannot easily bridge (Kohler and Turner, 2001).

Unfortunately, many anglers fail to report all the requested information, limiting data analysis (Kohler *et al.,* 1998). To improve the reporting rate of tag recoveries, tagging programmes have been advertised in newspaper articles, posters, radio interviews, and distributed information pamphlets (Dicken *et al.*, 2007). The Oceanographic Research Institute even held a series of workshops at fishing clubs throughout South Africa, encouraging fishermen to record and report tag recaptures. Collaborating with the public in elasmobranch population studies is a widely used technique to increase awareness of study species (Barker *et al.*, 2011; Marshall and Pierce, 2012). Oher strategies to improve return rates include promoting the programme objectives to anglers to dispel misconceptions, offering incentives to encourage tag returns, and educating the fishing community about the importance of accurate data collection through media, workshops, and public forums (Tiedemann *et al.*, 1990).

4.2.4 Advancements

A common limitation of conventional tagging is the low recapture rate, however cooperative programmes offer an effective solution to this challenge (Kohler and Turner, 2018). The Cooperative Shark Tagging Programme (CSTP), a collaboration among recreational anglers, the commercial fishing industry, and National Oceanic and Atmospheric Administration (NOAA) Fisheries, aims to study Atlantic sharks' life history. Since its inception in 1962 with fewer than 100 participants, the CSTP has expanded to involve thousands of people along the Atlantic and Gulf coasts, tagging >295,000 sharks across 52 species (CSTP, 2019). The programme focused on enhancing the design and implementation of tagging studies, increasing angler participation, and ensuring high-quality data collection. Additionally, by integrating conventional tagging with other methodologies, such as electronic tagging, the programme aimed to provide a more comprehensive understanding of fish movements and population dynamics (Mas *et al.*, 2022).

4.3 Passive Acoustic Telemetry

4.3.1 Applications

Passive acoustic telemetry involves attaching transmitters to animals that emit unique acoustic signals detected by strategically placed receivers in aquatic environments. This technology tracks fish movements across different habitats, providing insights into their spatial ecology and behaviour (Heupel and Webber, 2012; Matley *et al.*, 2023). The lifespan of tags ranges from ~100 days for small transmitters used in juvenile fish, to up to ~10 years for larger tags (Edwards *et al.*, 2022; Lingard *et al.*, 2023). Studies that use acoustic telemetry offer high-resolution, fishery-independent data compared to traditional mark-recapture methods (Heupel *et al.*, 2006).

Many studies have been conducted using acoustic telemetry, from understanding the residency behaviours of Caribbean reef sharks (*Carcharhinus perezi*; Kohler *et al.*, 2023), migrations patterns of lemon sharks (*Negaprion acutidens*; Pillans *et al.*, 2021), investigating the seasonal residency of Greenland sharks (*Somniosus microcephalus*) in an Artic fjord (Edwards *et al.*, 2022), studying movement patterns of whale sharks (*Rhincodon typus*; Norman, 2016; Perry *et al.*, 2020), multi-year tracking studies of habitat usage (Farmer and Ault, 2018), to first-of-its-kind studies about the giant freshwater whipray (*Urogymnus polylepis*; Haetrakul *et al.*, 2023).

Acoustic positioning methods, such as synchronisation tags combined with time-difference-of-arrival or time-of-arrival models, allow for precise localisation in specific areas, but they require a dense array of closely situated receivers and detailed prior knowledge of the target species' fine-scale residency (Baktoft *et al.*, 2017; van der Knaap *et al.*, 2021; Orrell and Hussey, 2022; Lennox *et al.*, 2023).

In contrast, broader detection data from receiver arrays are used to understand fish presence, migration patterns, mortality rates, and passage success over larger areas (Chaput *et al.*, 2019; Larocque *et al.*, 2020). These configurations help analyse animal presence concerning temporal cues like diurnal, seasonal, or interannual variations in environmental conditions (Edwards *et al.*, 2024).

Presence-absence arrays, such as grids, effectively demonstrate habitat selection, coastal residency, and site fidelity over broader study areas (Able *et al.*, 2014; Novak *et al.*, 2020; Reyier *et al.*, 2023). In each of these methods, while acoustic detections confirm an individual's presence within a receiver's range, the exact position of the animal is not accurately determined (Edwards *et al.*, 2024). Additionally, detection ranges fluctuate considerably over time and space due to numerous factors influencing the transmission and reception of acoustic signals (Kessel *et al.*, 2014).

4.3.2 Advantages

A key advantage of acoustic telemetry is autonomous operation, reducing the need for continuous human presence and minimising disturbance(Heupel *et al.*, 2006). This method allows for the simultaneous monitoring of multiple individuals, providing comprehensive data on species' behaviours and interactions (Clements *et al.*, 2005). Moreover, the data collected does not require the physical recapture of tagged animals, as information is logged by the receivers for later retrieval (Hueter *et al.*, 2004; Heupel *et al.*, 2006). The advancement, and widespread adoption, of telemetry equipment capable of monitoring both environmental data and specific behavioural information over extended periods will enable a transition from habitat-specific monitoring to a comprehensive life-stage approach (Speed *et al.*, 2010).

Passive acoustic telemetry is less labour-intensive than active tracking methods, involving tracking tagged individuals', often influencing behaviour (Heupel *et al.*, 2006; Matley *et al.*, 2023). Passive acoustic monitoring allows for continuous data collection, even during adverse weather conditions, eliminating observational biases associated with human presence (Heupel *et al.*, 2006). Additionally, long-life acoustic tags (i.e. with sufficient battery) enable multi-year data collection, essential for understanding the long-term movements and behaviours of marine species (Hueter *et al.*, 2004; Heupel, unpublished data). This technological advancement enables a shift towards longer-term studies, allowing researchers to quantify changes in habitat use over time (Speed *et al.*, 2010).

Acoustic telemetry's reliance on fixed receivers with limited detection ranges (<1000m) has primarily directed research towards coastal, estuarine, and freshwater ecosystems in developed regions (Heupel, 2006). Despite this, the swift growth of acoustic telemetry networks in coastal areas and on offshore and mobile platforms now offers a cost-effective method for extensive, long-term monitoring of numerous individuals (Hussey *et al.*, 2015). The advancements in acoustic telemetry have been quick and substantial, with current systems including receivers capable of wireless data communication or satellite linkage, enhancing the efficiency of data collection (Heupel, 2006). For example, Vemco's VR3 units with underwater modems allow *in situ* data downloading, while surface buoys can relay data to ARGOS satellites or cellular networks, facilitating remote data access (Heupel, 2006; Vemco, 2007).

4.3.3 Challenges and Considerations

Transmission and detection ranges of acoustic signals can vary due to environmental factors such as water temperature, depth, and wind-entrained bubbles in the water column (Kessel *et al.*, 2014), or occasionally resulting in the loss of the acoustic tags (Perry *et al.*, 2020). Ensuring that tagged individuals pass within range of a receiver is crucial for data collection, therefore the placement of receivers must consider anthropogenic activities and natural obstacles that may interfere with signal reception (Clements *et al.*, 2005). As acoustic networks only detect presence within their coverage area, unlike the global detection capabilities of satellites, reconstructing movements is confined to the relatively short range of these acoustic receivers (Sippel *et al.*, 2015).

Tags cannot indicate when they have been shed, so scientists must rely on assumptions when encountering anomalous data. For example, investigations into the distribution patterns of whale sharks *(R. typus)* saw that their receiver recorded 938 detections (81.9 % of all detections) of a single tagged individual over 31 hours (Perry *et al.*, 2020). These detections occurred every few minutes, suggesting that the transmitter had shed near the receiver, leading to continuous detections over that period and thus resulting in the exclusion of that individual from further analysis, and the loss of that tag (Perry *et al.*, 2020).

The technology also requires significant initial investment, deploying and maintaining an extensive network of receivers can be costly and labour-intensive, particularly in large-scale or long-term studies (Hammerschlag *et al.*, 2011a; Matley *et al.*, 2023; Renshaw *et al.*, 2023). For example, during a sampling season of whale sharks (*R. typus*) in St. Helena, Perry (2020) noted that acoustic receivers were not retrieved for maintenance, leading to uncertainty around battery life and that tagged individuals in 2018 were likely not detected due to low battery. Downloading data from submerged receivers often requires bringing the units to the surface, posing logistical challenges in certain environments where retrieval might be difficult due to weather and accessibility. Innovations such as the previously mentioned VR3 units with underwater modems help mitigate some of these issues by allowing remote data retrieval (Heupel *et al.*, 2006).

4.3.4 Advancements

Key innovations include the miniaturisation of tags and the extension of battery life, facilitating the long-term tracking of smaller individuals (Bradford *et al.*, 2011). Improvements in underwater acoustic communication and transmission techniques have minimised false detections and signal collisions (Awan et al., 2019). Additionally, new methods such as autonomous underwater gliders for data collection, and robust acoustic release systems have streamlined the deployment and retrieval of receivers. The coupling of a passive acoustic receiver with satellite communication (Iridium modem) has shown promise in addressing the limitation of having to manually download data, which delays detection and analysis, by creating a two-way communication with the receiver (see Bradford *et al.*, 2011). The integration of advanced sensors into transmitters and the development of smart transmitters capable of identifying specific behaviours or physiological states are also particularly noteworthy, as they enable real-time data acquisition without the need for tag retrieval (Hellström *et al.*, 2022).

The success and widespread adoption of passive acoustic telemetry has led to the creation of several large-scale collaborative networks of acoustic receivers worldwide (Murray *et al.*, 2022) including the Ocean Tracking Network (Iverson *et al.*, 2018), European Tracking Network (Abecasis *et al.*, 2018; Reubens *et al.*, 2019), Florida Telemetry Network (Young *et al.*, 2020), Integrated Marine Observing System's Animal Tracking Facility in Australia (Steckenreuter *et al.*, 2016; Hoenner *et al.*, 2018; Huveneers *et al.*, 2021), Atlantic Cooperative Tracking Networks (Block *et al.*, 2016), and South Africa's Acoustic Tracking Array Platform (Cowley *et al.*, 2017). These networks enhance the ability to study highly migratory species across vast distances and different jurisdictional boundaries. This creates a global resource for tracking animal movements (Abecasis *et al.*, 2018) and extending the scope of acoustic tracking studies by linking independent arrays to facilitate international data sharing (Abecasis *et al.*, 2018; Hoenner *et al.*, 2018; Iverson *et al.*, 2018; Young *et al.*, 2020).

4.4 Non-Acoustic Tags

4.4.1 Satellite

4.4.1.1 Application

Satellite tags are invaluable in the study of animal ecology, providing detailed insights into horizontal and vertical movements, habitat fidelity, and migration patterns (Hammerschlag *et al.*, 2011b). Different types of satellite tags exist to accommodate various research needs. For instance, SPOT tags offer location estimates using Argos satellite data, while

SPLASH tags not only provide location data but also transmit sensor information like depth and temperature readings, and the Fastloc-GPS tags capture high-precision GPS data, which is then relayed to the ARGOS satellite network (Meyer *et al.*, 2016). Originally one-way, ARGOS has evolved since 2002 to include two-way communication, enabling applications like adjusting sensor data sampling rates and conserving battery by activating transmitters only when satellites are nearby (Berrow and O’Connor, 2013).

These tags are particularly effective for air-breathing or water-breaking animals, as they transmit position information when the tag has a clear path to the orbiting satellites upon surfacing (Meyer *et al.*, 2016). The ARGOS system, using NOAA's weather satellites and ground receivers, helps locate surfacing animals and transmit limited data (Hazen *et al.*, 2012). With over 8,000 active platforms worldwide, ARGOS is the standard for global environmental monitoring (Berrow and O’Connor, 2013). To improve location accuracy (meters for GPS versus kilometres for ARGOS), GPS receivers are often integrated into ARGOS tags, or data can be stored on the device for later retrieval for regularly surfacing animals (Hazel, 2009; Costa *et al.*, 2010; Hazen *et al.*, 2012; Edwards *et al.*, 2024). Fastloc GPS receivers have enhanced GPS use in marine animals by capturing data in under a second, allowing precise tracking even during brief surfacing events (Costa *et al.*, 2010; Sims, 2010; Witt *et al.*, 2010). Transmitting tags must have their antennae fully above water to transmit, with each transmission taking 0.5 to 1.0 seconds, and requiring at least four transmissions per satellite pass for location calculation (Berrow and O’Connor, 2013).

Comprehensive reviews by Hammerschlag *et al.* (2011) and Renshaw *et al.* (2023) highlighted the contributions of satellite tagging studies, knowledge gaps, and future research directions. Renshaw *et al.* (2023) noted that <17 % of studies directly produced management or conservation outcomes, underscoring the need for telemetry studies with clearly defined goals and objectives to yield relevant findings for conservation. Further, Renshaw *et al.* (2023) found that between 2010 to 2020 saw a threefold increase in shark satellite tagging studies compared to previous periods, with researchers tracking twice as many species.

4.4.1.2 Advantages

Studying the responses of highly mobile or pelagic species to environmental changes over extended periods offers valuable insights into their spatial and environmental preferences (Southall *et al.*, 2006; Sequeira *et al.*, 2014). Satellite tags enable near real-time monitoring of tagged animals, providing logged dive behaviour and location data each time the individual surfaces (Hammerschlag *et al.*, 2011b; Renshaw *et al.*, 2023) . Although larger than acoustic tags and thus limited to larger animals, satellite tags can record fine-scale time series data on depth, temperature, and location over thousands of kilometres (Hussey *et al.*, 2015). This data can inform evaluations of species climate change vulnerability and species usage in protected versus unprotected areas (Sequeira *et al.*, 2014; Dedman *et al.*, 2015; Boucek *et al.*, 2017).

The global coverage of the ARGOS satellite system allows researchers to track animal movements over vast spatial scales, including the open ocean and across political jurisdictions (Hussey *et al.,* 2015). This technology enables researchers to accurately track previously difficult-to-monitor species with minimal invasiveness, providing data without the need for recapture (Berrow and O'Connor, 2013). For instance, studies on basking sharks (*Cetorhinus maximus*) in the Isle of Man (IoM) have been used to delineate spatiotemporal hotspots and assess site fidelity (Dolton *et al.*, 2019). Similarly, monitoring of the porbeagle shark (*Lamna nasus*) in the Northwest Atlantic improved management and conversation (Anderson, 2024).

4.4.1.3 Considerations and Limitations

Battery life and attachment success determine tag longevity, typically set for > 1 year (Hammerschlag et al., 2011), this limitation restricts their application for studying long-term migration cycles or repeated movements over extended periods (Edwards *et al.*, 2024). Satellite tracking data often have significant gaps due to irregular surfacing of tagged animals and variable satellite coverage, leading to potential autocorrelation and spatial biases (Anderson, 2024). Meyer *et al.* (2016) demonstrated the utility of multiple tag types (SPOT, SPLASH, and Fastloc GPS) in tracking shark movements in Hawaii, addressing the challenges posed by limited satellite coverage, which averages only 6-12 minutes per hour. The equator also poses a challenge for data transmission, resulting in variable positional accuracy due to lower satellite density (Friedlander *et al.*, 2008).

Signal loss can occur due to several factors, including battery exhaustion, salt-water switch failure, antenna breakage, animal mortality, or premature detachment of tags (Hays *et al.*, 2007). The high cost of satellite tags, ranging from $3,000 to $5,000, also limits their widespread use (Berrow and O'Connor, 2013; Whoriskey and Hindell, 2016). Additionally, the large size of these tags typically confines their application to aquatic animals larger than 50 cm in length, or with a mass greater than 1 kg (Whoriskey and Hindell, 2016). Satellite tags have also been known to accumulate bio-fouling (Hammerschlag *et al.*, 2014), with one study coating the device before deployment with two types of antifouling compounds (Propspeed™ and C-Spray) to extend their functional lifespan (Meyer *et al*., 2016).

4.4.1.4 Advancements

Innovations in software and hardware have led to the development of smaller, more complex tags that can record a broader range of physical and physiological variables. These include magnetic field strength and dip, acceleration and tail-beat frequency, heart rate and cardiac output, feeding rate and behaviour, growth rate, gonad development, and water chlorophyll concentrations (Census of Marine Life, 2024). Recent advancements, such as the inclusion of solar power cells and improved attachment designs, have extended the observation periods of individual animals to multiple years (Domeier and Nasby-Lucas, 2013).

Improved methods of tag application, geolocation, data transmission, and the analysis, integration, and visualisation of biological and environmental information are continually enhancing the field (Census of Marine Life, 2024). These advancements increase the ability to answer complex ecological questions, such as predator-prey interactions, migration patterns, and habitat use, while also aiding in conservation planning and management (Hussey *et al.*, 2015). For example, integrating satellite-derived sea surface temperature data with tag data can refine animal position estimates, particularly for pop-up tags using light-based geolocation (Lam *et al.*, 2010). Satellite telemetry has significantly broadened the scope of ecological research, offering increased capacity to unravel ecological questions, monitor species for global assessments, and contribute to conservation efforts (Hammerschlag *et al.*, 2011b; Hussey *et al.*, 2015; Renshaw *et al.*, 2023).

4.4.2 Archival

4.4.2.1 Applications

Archival tags, also known as data storage tags or bio-loggers, are widely utilised for tracking environmental conditions (depth, light levels, temperature, and pressure) and physiological data (acceleration, heart rate, stomach temperature) in marine animals (Berrow and O'Connor, 2013; Harcourt *et al.*, 2019). Archival tags are small data logging devices designed to be either attached externally to a fish or surgically implanted, typically in the peritoneal cavity (Galuardi and Lam, 2014). They are especially suitable for species that do not surface frequently, such as smaller fish and deep-diving marine mammals (Harcourt *et al.*, 2019). Given their ability to store data for extended periods without the need for constant transmission, they are ideal for long-term studies on species with a high probability of recapture, such as commercially targeted fish, or species with predictable distribution patterns (Watanabe and Papastamatiou, 2023).

Archival tags actively log time-series data from multiple sensors, storing this information within the device. Researchers can access the data either by recovering the tag or, for those with transmitting capabilities (such as Pop-up satellite archival tags; PSATs), upon its detachment (Block *et al.*, 1998; Hammerschlag *et al.*, 2011b; Hussey *et al.*, 2015). PSATs transmit summarised data after detachment after a predetermined period and float to the surface, where it transmits data to a satellite in the ARGOS network. This is particularly useful for tracking the movement and environmental preferences of highly mobile species (Block *et al.*, 1998; Skomal *et al.*, 2009; Hammerschlag *et al.*, 2011). The collected data is utilised to estimate the tag's location throughout the deployment (Teo *et al.*, 2004).

4.4.2.2 Advantages

One significant advantage of archival tags is their capability for multi-year deployment without the energy costs associated with data transmission, allowing comprehensive long-term data collection (Harcourt *et al.*, 2019). These tags can record high-frequency environmental data, such as depth and temperature, which can reveal detailed individual environmental preferences and facilitate the modelling of movement trajectories (Braun et al., 2018; Thygesen et al., 2009).

Contrary to conventional satellite tags that track an animal's location solely upon surfacing and communicating with orbiting satellites, PSATs can estimate positions based on light intensity even while fully submerged (Nielsen *et al.*, 2006). Horizontal and vertical movements can also be tracked (Carlson *et al.*, 2014). They can also provide PSATs further enhance the utility of archival tags by providing fisheries-independent data retrieval, meaning the animal does not need to be recaptured for data recovery (Campana *et al.*, 2009). Yet, if the tag is recovered, it provides a complete archival record with detailed data, similar to conventional archival tags, and many have been unexpectedly retrieved by beachcombers and fisheries personnel (Berrow and O'Connor, 2013).

PSATs offer valuable insights into post-release behaviour and mortality, which are crucial for conservation planning and fisheries management (Hammerschlag *et al.*, 2011b). PSATs have allowed researchers to understand salmon-shark niche expansion (*Lamna ditropis,* Weng *et al.*, 2005); the migration patterns of white sharks (*C. carcharias*, Domeier and Nasby-Lucas, 2008, 2013; Jorgensen *et al.*, 2012); blue sharks (*P. glauca*) in the northeast Atlantic were tracked for the first time (256 tracking days recorded, with an estimated minimum distance of 11,432km covered; Queiroz *et al.*, 2010); and the investigation of broad-scale movements of large juvenile dusky sharks *(Carcharhinus obscurus)* off Southern Australia (Rogers *et al.*, 2013).

4.4.2.3 Considerations and Limitations

Archival tags and PSATs must be physically recovered to access the stored data, making their utility dependent on the likelihood of recapturing the tag to obtain the full dataset stored (Hammerschlag *et al.*, 2011b). This recovery requirement can be challenging for species with low recapture rates or unpredictable movements (Watanabe and Papastamatiou, 2023). Additionally, light-based geolocation in PSATs becomes unreliable in high latitudes, during equinoxes when day length is uniform, or when the animal dives deep enough to leave the photic zone (Whoriskey and Hindell, 2016).

PSATs face issues such as difficulties related to attachment to the host, premature detachment, positional inaccuracies, and high cost (Hammerschlag *et al.*, 2011b; Musyl *et al.*, 2011). For instance, Perry (2020) found that tracking horizontal movements away from the island was challenging due to the deep-diving behaviour of whale sharks (R. typus), which either damaged the archival satellite tags or caused them to detach prematurely. Of the fifty satellite tags deployed, only thirty provided reliable data for evaluating horizontal movements, and some tags detached early due to depth, while others were in poor satellite coverage areas, resulting in incomplete data transmission (Perry, 2020).

The data transmission via the ARGOS satellite system is limited by message size (bandwidth ~32 bytes/message), which means there needs to be more messages to convey more data (Skubel *et al.*, 2020); and satellite availability, leading to potential gaps in the transmitted data (Musyl *et al.*, 2011). Data compression techniques and predetermined algorithms are often employed to mitigate these limitations, but they can result in loss of detail and potential biases in the data (Skubel *et al.*, 2020).

4.4.2.4 Advancements

Modern archival tags now incorporate additional data sources, such as sea surface temperature and magnetic field data, to enhance geolocation accuracy (Teo *et al.*, 2004; Royer *et al.*, 2005; Nielsen *et al.*, 2006). These improvements have reduced the location errors traditionally associated with light-based geolocation, making archival tags more reliable for tracking animal movements (Whoriskey and Hindell, 2016).

Additionally, longer deployments risk incomplete record transmission due to high battery usage, but current PSATs address this by having a separate dedicated memory for storing a complete high-frequency archival record (Galuardi and Lam, 2014). The development of life history transmitters designed for long-term deployment and automatic data transmission upon the animal's death has extended the utility of archival tags to studying vital rates over the life span of marine animals (Horning and Hill, 2005). These advancements have broadened the scope of research applications for archival tags, enabling more detailed and accurate studies of marine animal behaviour and ecology.

4.5 Animal Oceanographers

Using satellite tags for oceanographic sampling has proven an important tool, particularly through the contributions of "animal oceanographers" such as sea lions and seals (Whoriskey and Hindell, 2016). These animals navigate regions that are otherwise challenging for human researchers to access, such as areas under Antarctic ice, significantly enhancing our understanding of global oceanography (Fedak, 2004; Block, 2005). The integration of logging and telemetry equipment on marine animals has yielded extensive data on their movements and behaviours, enabling predictions about their migratory patterns and the environmental conditions they encounter (Block, 2005; Hussey *et al.*, 2015). This information is crucial not only for understanding the biology and population dynamics of these species but also for comprehending the environments they navigate and the potential threats they face. Additionally, real-time monitoring of oceanic processes is essential for long-term climate and weather forecasting (Fedak, 2004).

Physiological ecologists have demonstrated the importance of animals equipped with oceanographic instruments in global ocean observation efforts (Hussey *et al.*, 2015). Marine mammals equipped with satellite-linked transmitters can collect time series data on temperature, salinity, fluorescence, light, and partial pressure of oxygen, all correlated with the animals' location and depth within the various water bodies they meet (Lydersen *et al.*, 2002). These animal-borne sensors not only reflect the animals' environmental preferences but also map ocean conditions in four dimensions (X, Y, Z, Time), offering critical data for calibrating satellite observations (Block, 2005). For instance, northern elephant seals (*Mirounga angustirostris*) undertake extensive foraging migrations across the northeastern Pacific, diving to depths of up to 1,600m and providing large volumes of environmental data (DeLong and Stewart, 1991; Delong *et al.*, 1992; Le Boeuf *et al.*, 2000). Programmes like the Tagging of Pacific Predators have leveraged these capabilities to generate extensive datasets, possibly surpassing the data collection capacity of traditional methods such as the Argo float system (Block, 2005).

Telemetered animals have been instrumental in enhancing regional oceanographic models. For instance, Narwhals (*Monodon monoceros*) and beluga whales (*Delphinapterus leucas*) equipped with transmitters have generated over 200,000 temperature and salinity profiles, significantly enhancing our understanding of the Arctic Ocean (Grist *et al.*, 2011). Similarly, seals and sea lions have contributed to near-circumpolar sampling of the Southern Ocean, with a significant portion of profiles originating from south of 60°S, where traditional methods are hindered by ice (Fedak, 2013; Roquet *et al.*, 2013). These high-resolution hydrographic profiles are refining our understanding of Southern Ocean circulation (Roquet *et al.*, 2013), basal ice shelf melting processes (Padman *et al.*, 2012), and coastal upwelling dynamics (Lowther *et al.*, 2013). Encouraged by these successes, researchers are expanding the deployment of oceanography-capable telemetry tags to non-mammalian species such as tuna and sharks, promising further enhancements to ocean-atmosphere observation platforms and ocean forecasting (Hussey *et al.*, 2015). By harnessing the remarkable abilities of marine animals, particularly sharks, as integral participants in oceanographic research, we not only advance our understanding of the oceans but also foster a future where collaboration with nature and technological innovation achieves unprecedented scientific achievements.

Chapter 2: Tagging Sharks, Informing Policy, and Conservation: Streamlining Best Practices for the Isle of Man's Tagging Initiatives for Sustainable Shark Management

1. Introduction

The chondrichthyan (cartilaginous) fishes, including skates and chimaeras, are among the oldest extant vertebrates, having existed for over 400 million years (Awruch, 2018). With more than 1,200 species, these fishes are distributed in tropical, subtropical, and temperate waters (Compagno, 1990; Kriwet *et al.*, 2007). Elasmobranchs, a subclass encompassing both sharks and rays, are important predators within marine ecosystems, holding significant influence on the structure and function of their habitats (Stedman and Garner, 2018). These species are characterised by *k*-selected life history, exhibiting long lifespans, slow growth rates, delayed sexual maturity, and low reproductive outputs, making them particularly susceptible to various anthropogenic pressures such as overfishing, bycatch, pollution, and habitat degradation (Frisk *et al.*, 2005; García *et al.*, 2007), especially in key spawning and nursery areas (Winter and Batsleer, 2023). Sharks play a crucial role in marine ecosystems, and their decline could lead to significant disruptions in the structure, function, and stability of marine food webs (Stevens *et al.*, 2000; Myers *et al.*, 2007; Baum and Worm, 2009; Ferretti *et al.*, 2010). Despite their ecological importance, global elasmobranch populations have plummeted, with approximately one-third of species facing the threat of extinction and global shark populations declining by 71 % since 1970 (Dulvy *et al.*, 2021; Pacoureau *et al.*, 2021).

Over the past 50 years, the commercial exploitation of elasmobranchs has intensified, with landings increasing continuously due to declining teleost fish catches and the high value of shark fins, which are worth an estimated at $400-550 million USD annually (Dent and Clarke, 2015). Despite the stabilisation of global catch statistics at 520,000 tonnes per annum since 2005 (FAO, 2014), true mortality rates are likely substantially higher (3 to 4 times greater) due to misidentification, underreporting, and discards at sea, exacerbated by increasing demand for shark meat (Clarke *et al.*, 2006; Dhaneesh and Zacharia, 2013; Worm *et al.*, 2013; Bornatowski *et al.*, 2014). Twenty-four per cent of shark, skate, and ray species are classified as Threatened with extinction by the IUCN

Red List's Shark Specialist Group (Dulvy *et al.*, 2021). Sharks and rays in the Northeast Atlantic and Mediterranean are more threatened than the global average, with one fifth of Europe's species classified as Data Deficient (Walls and Dulvy, 2020). Estimates suggest that between 63 - 273 million sharks were killed in 2010 alone, far surpassing their population's natural rebound capacity (Worm *et al.*, 2013). One of the most lucrative economic commodities in the seafood industry is shark finning, the practice of removing fins at sea and discarding the remainder of the body (Clarke *et al.*, 2006; Rodenbiker *et al.*, 2023). The demand for shark fins, primarily for shark fin soup, a delicacy in Asian cultures, remains a major driver of shark fishing, alongside markets for meat, jaws, cartilage, and liver oil (Cunningham-Day, 2001; Spiegel, 2001; Clarke *et al.*, 2007; Davidson *et al.*, 2016). Given sharks' conservative life-history strategies, conventional fisheries management approaches have limited success in reversing population declines even under low mortality scenarios (García *et al.*, 2007; Ward-Paige *et al.*, 2012).

Accurate estimates of population parameters are crucial for successful fisheries management and conservation, especially for highly mobile pelagic shark species (Byrne *et al.*, 2017). Tagging initiatives are crucial for understanding the behaviour, migration patterns, and habitat use of shark species, providing essential data to inform conservation strategies (Renshaw *et al.*, 2023). These efforts not only enhance scientific knowledge but also support the development of evidence-based management policies vital for the sustainable preservation of shark populations and broader marine ecosystems (Hammerschlag *et al.*, 2011b; Fortuna *et al.*, 2024). For decades, various, mark-recapture, telemetry, and bio-logging technologies have been employed to study elasmobranchs, offering insights into species migrations, population connectivity, habitat preferences, movement patterns, and spatial interactions with fisheries (Hammerschlag *et al.*, 2011b, 2014). These tracking studies have resulted in significant management and conservation achievements, such as providing evidence for establishing marine protected areas (MPAs) and advocating for the protection of vulnerable elasmobranch species (Chapman *et al.*, 2005; Espinoza *et al.*, 2015; Byrne *et al.*, 2017). Tagging research and cooperative shark tagging programmes are essential for advancing conservation efforts and bridging the gap between scientific research and effective policy implementation in a setting where multi-jurisdictional challenges are common (Kohler and Turner, 2001; Shiffman and Hammerschlag, 2016).

1.1 Marine Protected Areas for Elasmobranch Conservation

Few shark fisheries are effectively managed today, largely due to the inadequate application of traditional teleost management models to elasmobranchs, heightened by challenges such as insufficient quality data, lack of appropriate management tools, and limited political will (Camhi *et al*., 1998). Effective conservation of shark populations requires a combination of strategies, including the establishment of protected areas and the setting of sustainable exploitation rates (Camhi *et al*., 1998). Research has shown that effective fishery management can be achieved through a mix of catch restrictions and habitat protection (Worm *et al*., 2009). To rebuild shark stocks and ensure their sustainable use, it is crucial to have reliable reference points, identify critical areas, and understand both current and historical exploitation levels, as well as trends in abundance (Dureuil, 2013). Conventional fisheries management techniques often fall short in reversing shark population declines, particularly due to their conservative life-history strategies, which make these species highly vulnerable even under low mortality scenarios (García *et al.*, 2007; Ward-Paige *et al.*, 2012). The increasing trend of expanding MPA coverage presents opportunities to maximise benefits, particularly for highly mobile shark species, in regions with adequate enforcement (Lascelles *et al.*, 2014; Green *et al.*, 2015). Many MPAs are often too small to provide adequate protection at a population level, as sharks can traverse large distances, sometimes exceeding 110km (Claudet *et al.*, 2008; Lascelles *et al.*, 2014; Green *et al.*, 2015). Despite these challenges, studies have demonstrated that coastal shark abundances are generally higher within no-take MPAs compared to areas outside them, with significant increases in biomass observed when MPAs are large and isolated (Bond *et al.*, 2012; Ruppert *et al.*, 2013; Edgar *et al.*, 2014; Espinoza *et al.*, 2014). Tracking studies have highlighted that habitat connectivity, resource dependency, life stage, and sex influence the extent of shark mobility, with males dispersing more widely than females (Papastamatiou *et al.*, 2009; Speed *et al.*, 2011; Barnett *et al.*, 2012; Espinoza *et al.*, 2015; Chin *et al.*, 2016).

Identifying patterns of habitat use linked to specific life history stages, such as pupping or nursery areas, can significantly enhance conservation planning at local scales (Heupel and Simpfendorfer, 2005). The growing body of information from tracking studies is increasingly guiding MPA design, making them more effective for coastal shark conservation (Oh, 2016).

1.2 Isle of Man (IoM) Conservation Network

The IoM, a self-governing Crown Dependency located in the Irish Sea, extends its jurisdiction 12 nautical miles into the surrounding sea (IoM Government, 2024). The island's unique geographical and ecological features support diverse marine life, leading to its designation as a UNESCO Biosphere Reserve in 2016 (UNESCO, n.d.). Environmental governance on the IoM is managed by the Department for Environment, Food, and Agriculture (DEFA) through a stakeholder partnership (Russell, 2023). Central to its conservation strategy is the designation of MPAs, which cover 52 % of its coastal territorial sea, protecting critical habitats such as maerl beds, horse mussel reefs, and seagrass meadows (DEFA, 2018; Watson and Howe, 2022).

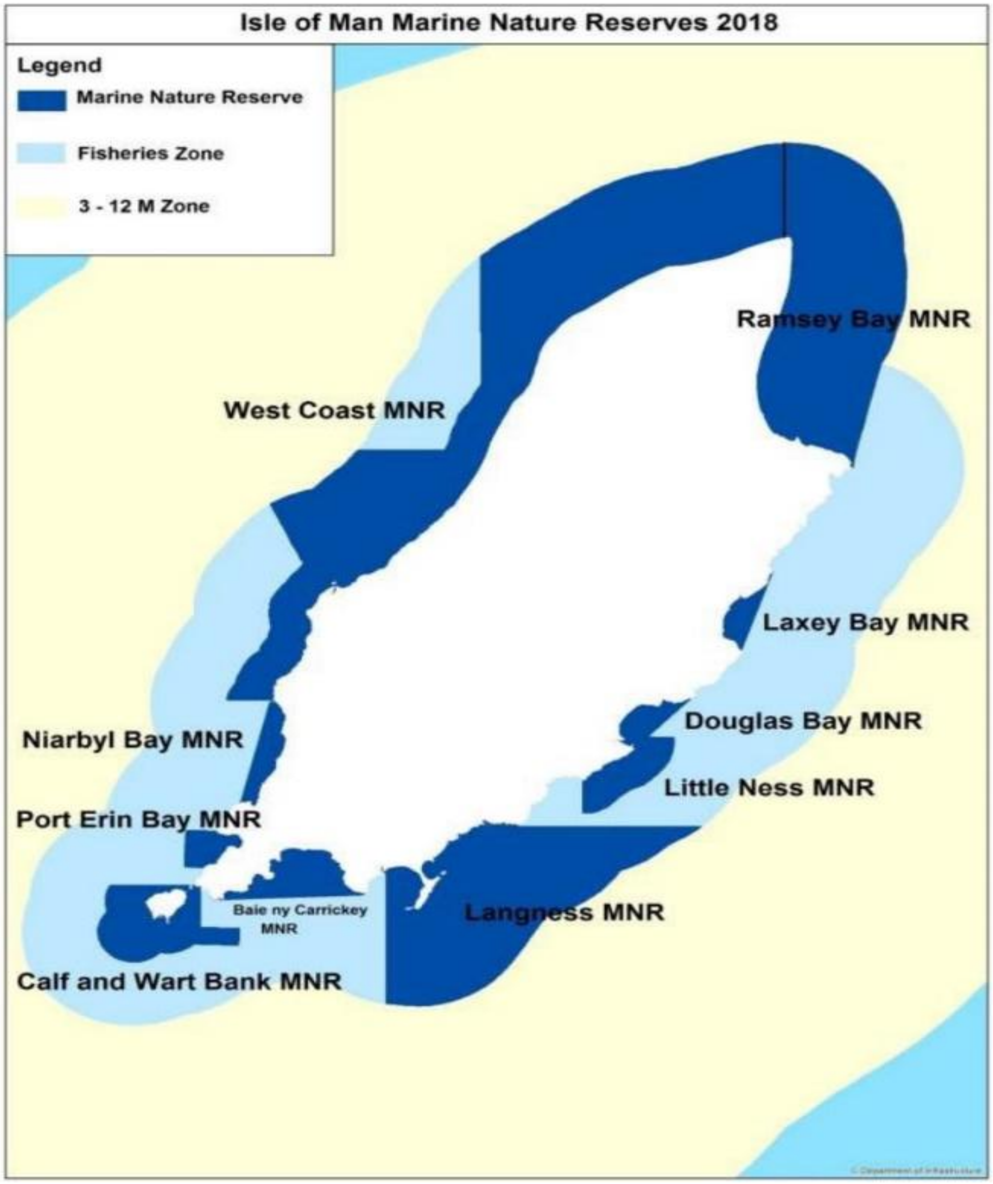

Figure 9. **Marine Nature Reserves in the Isle of Man as of 2018** (Source: Government of the Isle of Man).

The IoM's marine conservation framework includes legislation for Marine Nature Reserves (MNRs; Figure 9) established under the Wildlife Act since 1990, with the first MNR, Ramsey Marine Nature Reserve, created in 2011, and internationally recognised under OSPAR (IoM Government, 2015). Although not specifically designated to protect small shark species, these MNRs play a crucial role in their conservation by preserving diverse habitats and imposing restrictions on damaging activities and fishing practices (Watson and Howe, 2022). Additionally, the island has implemented a network of closed and restricted areas for fisheries management and research, contributing to sustainable fisheries and marine ecosystem conservation (IoM Government, 2024). These critical habitats are estimated to have an annual economic value of at least £42 million (Brander and McEvoy, 2012). As a participant in the Convention on Biological Diversity, the IoM developed its Biodiversity Strategy, committing to protect at least 10 % of its waters by 2020 (IoM Government, 2015). This led to the re-designation of all MPAs as MNRs in 2018, aiming to provide consistency, specific habitat and species protection under the Wildlife Act, and future management opportunities within a statutory framework (IoM Government, 2024a). The island also protects several Areas of Special Scientific Interest (ASSI) and a National Nature Reserve (NNR) along its coast, including Ballaugh Curragh, the first Ramsar wetland of international importance on the IoM (IoM Government, 2024b). Despite this, the fishing industry, significant to the IoM's economy, faces challenges such as overfishing, bycatch, and climate change, making sustainable practices and stringent regulations essential for balancing economic interests with marine biodiversity preservation (Watson and Howe, 2022).

1.3 Manx Wildlife Trust (MWT) Small Shark Tagging Programme (SSTP)

The MWT is a leading conservation organisation on the IoM, dedicated to protecting the island's natural heritage (MWT, 2024). Since May 2013, the MWT has been collaborating with the DEFA to run the SSTP, aimed at gathering crucial data on the distribution, movement, and population sizes of small shark species in Manx waters (Watson and Howe, 2022). The primary goal of the SSTP is to work with local anglers to tag small sharks and rays with identification tags or streamers, operating on a catch-and-release basis. This initiative not only promotes public awareness about the importance of shark conservation but also engages the local community in scientific research (Watson and Howe, 2022). The data gathered helps to establish population dynamics, such as abundance and distribution, of the four key elasmobranch species currently tagged in Manx waters: the spurdog (*S. acanthias*), tope (*G. galeus*), bull huss (*S. stellaris*), and thornback ray (*R. clavata*). Although these species are the most frequently tagged, the SSTP also tags every species of skate, ray, and shark that can be captured, except for small spotted catsharks, as their abundance is already well-documented. Currently, small sharks have been tagged in several MNRs including West Coast, Calf and Wart Bank, Baieny Carrickey, Langness, Little Ness, and Ramsey Bay. These sites only cover up to the 3 nautical miles boundary of Manx waters and are not formally designated to protect small shark species (Watson and Howe, 2022). This is in part due to small shark species not receiving formal protection in the IoM currently. However, small sharks will benefit from these MNRs due to restrictions against damaging protected habitats and fishing (Watson and Howe, 2022).

Since its inception, the programme has successfully tagged 593 elasmobranchs and trained 101 local anglers in tagging techniques, significantly expanding the scope of the research (Watson and Howe, 2022). Due to the tagging efforts the SSTP has seen notable recaptures reported in France, the Netherlands, Spain, and Portugal. The recapture of tagged individuals has provided valuable data on the movements and distribution of these species, contributing to a broader understanding of their ecology (Watson and Howe, 2022). The programme's success has been furthered by collaborations with other international tagging initiatives, such as the Centre for Environment, Fisheries and Aquaculture Science (Cefas) and the Scottish Shark Tagging Programme (STP). These partnerships have enhanced the programme's capabilities through shared knowledge, resources, and training.

1.4 Tagged Elasmobranch Species for the SSTP

1.4.1 Tope

The tope shark, *G. galeus* (Linnaeus 1758), also known by various names such as school shark, soupfin shark, and oil shark, is a highly prized species among anglers (Riede, 2004, British Sea Fishing, 2024). Typically growing up to six feet in length and weighing around 45 kg, smaller specimens are more commonly encountered (British Sea Fishing, 2024). This species is easily recognisable by its streamlined body, long pointed snout, sharp teeth, and the distinct greyish upper body with a white underside, sometimes tinged with brown, with males further distinguished by claspers near the anal fin (Compagno, 1984; British Sea Fishing, 2024). This species is a generalist feeder, primarily consuming crustaceans and small bony fish like sardines, anchovies, flatfish, skates, crabs, shrimp, lobsters, octopuses, and sponges (Compagno, 1984).

Typically found in temperate waters, inhabiting bentho-pelagic zones on continental and insular shelves, as well as upper to mid slopes, ranging from shallow coastal areas to depths of up to 826m, though they are most commonly found at depths of up to 200m (Walker, 1999; Weigmann, 2016; Thorburn *et al.*, 2019). Some larger individuals are known to undertake long-distance oceanic migrations far from the continental shelves and slopes, although they do not traverse entire ocean basins (Walker, 1999; Walker *et al.*, 2009; Colloca *et al.*, 2019). Within the UK, they are prevalent along the south and west of England, in Welsh waters, and along Scotland's west coast (British Sea Fishing, 2022). Additionally, tope sharks exhibit diurnal movement patterns, often migrating from shallow waters at night to deeper waters during the day (Walker *et al.*, 2009).

The biological characteristics exhibit significant regional variation, which is crucial for understanding its population dynamics and informing conservation strategies (Jennings *et al.*, 1998). This species shows a range of maximum sizes depending on the region, with the largest individuals reaching up to 200 cm in total length (TL) in the Mediterranean Sea (Capapé and Mellinger, 1998) and the smallest reaching up to 155 cm TL in the Southwest Atlantic (Peres and Vooren, 1991). Additionally, the size-at-maturity varies by location, in the NE Atlantic males mature about approximately 121cm TL and females around 15 cm TL (Dureuil, 2013).

Reproduction in this species is aplacental viviparous (live birth without a placenta), with litter sizes ranging between 6 - 52 pups, depending on the female's size (Cox and Francis, 1997; Capapé and Mellinger, 1988). The reproductive cycle can be annual or triennial, with more detailed studies indicating a triennial cycle, and the gestation period lasts around 12 months (Walker, 1999; Walker *et al.*, 2005; Ebert *et al.*, 2013). Females reach reproductive maturity between the ages of 10 and 15 years, with an average of 12.5 years, and males between 12-17 years (Vooren and Ferreira, 1991; Francis and Mulligan, 1998). In the Northeast Atlantic, tope sharks exhibit remarkable longevity, with some individuals living up to 55 years (Dureuil, 2013). Understanding these life history traits is essential for conservation efforts, as the species' slow reproductive rate, delayed maturation, and long lifespan make it particularly susceptible to overfishing and other anthropogenic impacts, underscoring the need for targeted management and protection strategies (Dulvy *et al.*, 2021).

The IUCN lists the tope as Critically Endangered (Walker *et al*., 2020) globally and Vulnerable (McCully *et al*., 2015) in Europe, due to dramatic declines in their population. Tope sharks are under significant threat due to their long history of being captured in various global fisheries, including industrial, small-scale, and recreational operations; they are commonly caught using methods such as demersal and pelagic gillnets, longlines, trawls, hook-and-line, troll lines, trammel nets, and traps. (Walker *et al*., 2020). They are generally kept for their meat, fins, and liver oil, which are valued in different markets (Dent and Clarke, 2015). In cases where tope are captured as bycatch, they are often retained as a byproduct; however, when released, the mortality rates at the vessel vary depending on the fishing gear used, ranging from 2–73 % in gillnets and reported as 0 % in longlines (Ellis *et al.*, 2017).

In the Northeast Atlantic, tope is primarily caught as bycatch and occasionally discarded, though they are retained in certain fisheries, while also holding significant value in recreational fisheries where they are often targeted by anglers (International Council for the Exploration of the Sea (ICES), 2019). Despite this, there are considerable challenges in monitoring tope populations due to incomplete landings data, with reports often aggregated under broader categories such as “Dogfish and Hounds” (Walker *et al*., 2020). The annual reported species-specific tope landings in the Northeast Atlantic between 2005 and 2018 ranged from 542- 715 tonnes, though ICES recommended limiting landings to 376 tonnes annually in 2018 and 2019, and further reduced this recommendation to 302 tonnes for 2021 (ICES, 2019).

In European waters, tope is now protected under various regulations, including the Tope (Prohibition of Fishing) Order 2008, which prohibits direct targeting of the species. English commercial fishermen are permitted to retain up to 45 kg of tope per day, provided they are not directly targeting the species, and all tope caught by recreational anglers must be released alive (ICES, 2019). Despite these protections, the commercial value of tope remains significant in regions like Spain, where they are used in traditional dishes, and in Asia for shark fin soup, contributing to their continued decline. The critical conservation status, combined with ongoing exploitation, underscores the urgent need for enhanced conservation efforts to prevent further population declines and ensure the long-term survival of this vulnerable populations (Dulvy *et al.*, 2014).

In Manx waters, tope is collected through various methods, such as charter angling, long lining, and rod and line fishing from both shore and boats (Hanley, 2013). Several recreational angling competitions throughout the year attract both local and visiting anglers from the UK, Ireland, and beyond. Recreational angling for small shark species, such as tope, has gained popularity on the IoM, often practiced as catch and release (Hanley, 2013). This activity also supports UK-based shark tagging projects that study the distribution, behaviour, and growth rates of these species. The IoM collaborates closely with the Scottish Shark Tagging Programme and the MWT, in partnership with the DEFA, coordinates these efforts on the island (Hanley, 2013; Watson and Howe, 2022).

1.4.2 Spurdog

The spurdog, *S. acanthias* (Linnaeus, 1758), also known by various names such as spiny dogfish, spiked dogfish, cape shark, and piked dogfish, is a slender shark species that typically reaches a size of up to 11 kg (Compagno, 1984), with UK shore-caught specimens usually weighing between 2- 4.5 kg (British Sea Fishing, 2024a). They are easily identified by their grey to brown colouration, white-spotted backs, prominent pectoral fins, and distinctive venomous spines on their dorsal fins (Compagno, 1984). The venom from their dorsal spines can cause swelling and discomfort in humans (Compagno, 1984), making them as one of the few venomous fish in UK waters (British Sea Fishing, 2024a). Spurdogs are adaptable to various depths, often found from intertidal to deep waters (approximately 900m), moving to shallower areas to feed (Compagno, 1984) and making them accessible to shore anglers. These sharks feed on a variety of fish and typically hunt near the seabed for bottom-dwelling fish, though they will venture into midwater for prey like herring and sand eels, especially during summer months (Compagno, 1984; British Sea Fishing, 2024a).

These sharks are known for their ability to travel in schools, covering large distances in search of food (Compagno, 1984). They are highly migratory, forming large, dense aggregations segregated by size and sex, which can complicate population assessments (Pawson and Ellis, 2005). Their distribution is extensive, covering regions from Scandinavia to the Mediterranean, and extending to North Africa, Greenland, Iceland, and various parts of North and South America, as well as off the coasts of Australia, New Zealand, and East Asia (Compagno, 1984). Spurdog populations are also prevalent in temperate waters around the UK, particularly along the western coasts of England, Scotland, and Ireland (British Sea Fishing, 2024a). Population studies have shown that spurdogs in European waters are divided into three distinct subpopulations with little genetic mixing, with only one distinct stock thought to exist for the Northeast Atlantic region (Pawson and Ellis, 2005). Despite their wide distribution, spurdog populations have significantly declined due to overexploitation (Ellis and Keable, 2008).

The age is commonly determined by counting annual growth rings on the fin spines, although this method's effectiveness can be limited by spine wear in larger individuals (Compagno, 1984; Henderson *et al.*, 2002). Regional variations in the age of maturity have been reported, with females maturing between 10- 20 years and males at 11 years or older, while the maximum age is at least 40 years (Fahy, 1989), with some estimates suggest they could approach 100 years (Compagno, 1984). Reproduction in spurdog is a long process, they are ovoviviparous (where the eggs hatch inside mother; live birth), with mating occurring every other year in winter and females carrying fertilised eggs from 18- 24 months before giving birth (Holden and Meadows, 1962; Compagno, 1984). Spurdog fecundity is positively correlated with maternal length, typically showing a linear relationship between these two factors (Gauld, 1979; Compagno, 1984). Geographical variations in fecundity are observed, with studies showing up to 15 pups in the Northwest Atlantic (Nammack *et al.*, 1985), up to 16 in the Northeast Atlantic (Henderson *et al.*, 2002) and off New Zealand (Hanchet, 1988), up to 32 in the Aegean and Black Seas (Kirnosova, 1989), and up to 17 and 25 in the Northeast and Northwest Pacific, respectively (Ketchen, 1972). These variances may be partly due to differences in spurdog length, which can reach 121cm in the Northeast Atlantic (Ellis *et al.*, 2005), 136 cm in the Black Sea (Avsar, 2001), and 130-135 cm in the North Pacific (Ketchen, 1972). The central Irish Sea has been suggested as a key mating site (Dureuil, 2013), with females maturing at 74-92.5 cm TL and males at 57.5-64 cm TL (Henderson *et al.*, 2002). Young spurdogs are born with a yolk sac that provides nutrients until they can fend for themselves (Compagno, 1984). The extended gestation period, combined with the late sexual maturity of females, means that population recovery is a prolonged process (Camhi *et al.*, 1998). These life characteristics underscore the need for strict conservation efforts to ensure the survival and recovery of spurdog populations.

Historically, one of the most common sharks in British waters, the spurdog faced intense commercial fishing pressure in the European market, leading to severe population declines since the 1970s (Hammond and Ellis, 2004). This species is heavily harvested for its flesh, fins, and liver oil, with the majority of Atlantic-derived products being sold in the European Union market (Dell'Apa *et al.*, 2013), often under generic names to hide their endangered status (ICES-WGEF 2018). It is used in various ways, such as fresh, frozen, smoked, boiled, marinated, dried, salted, and in fish cakes for human consumption, as well as in the production of liver oil, pet food, fishmeal, fertiliser, and leather (Compagno, 1984). The IUCN lists spurdogs as Vulnerable globally (Finucci et al., 2020) and Endangered in Europe (Ellis *et al*., 2015) due to declining populations and fragmented habitats. Conservation efforts have led to a zero Total Allowable Catch (TAC) in European waters since 2010, prohibiting commercial retention of spurdog (ICES-WGEF 2018). The principal threat to this valuable commercial species is over-exploitation from target and bycatch fisheries worldwide, primarily caught using bottom trawls, gillnets, line gear, and rod and reel (Fordham *et al*., 2016). Post-release mortality rates differ based on handling methods and gear types, with trawl fisheries causing up to about 30 % mortality and gillnet fisheries exhibiting at-vessel mortality rates as high as roughly 39 % (Ellis *et al.*, 2017). The species' slow growth, late maturity, and long gestation periods, combined with sexual dimorphism where females are larger than males, exacerbate their vulnerability to overfishing and make recovery slow even with protective measures in place (Compagno, 1984; Hammond and Ellis, 2004). Additionally, habitats essential for spurdog and their prey are negatively affected by coastal development, pollution, dredging, and bottom trawling (ASMFC 2008, Fordham *et al.,* 2016), threatening their survival.

In the Northeast Atlantic, the European Union (EU) introduced a 100 cm maximum landing length for Spiny Dogfish in 2009, drastically reduced the Total Allowable Catch (TAC) by 90 % in 2010, and set it to zero in 2011, while also banning the targeting, retaining, transhipping, and landing of the species by all vessels in ICES areas 2 through 10 and requiring reporting of discards over 50 kg (ICES-WGEF 2018; Shark Trust 2019, Finucci *et al*., 2020). By 2016, a TAC of 270 tonnes was allocated for bycatch avoidance programmes, with a 2-tonne monthly limit per vessel (Finucci *et al*., 2020). Yet, following ICES advice that the spurdog stock is recovering and can support increased landings, the UK and EU have agreed to reopen the fishery for 2023 and 2024, with the UK Statutory Instrument The Sea Fisheries (Amendment) Regulations 2023, effective from April 1, 2023, setting TACs of 2,781 tonnes for the North Sea and 4,825 tonnes for Western waters, including the IoM territorial sea, managed through sectorial Fixed Quota Allocation (FQA) and monthly licence limits, respectively (ICES, 2022; IoM Government, 2023).

In the IoM, according to the Government's website, spurdog fishing practices are governed by the Fisheries Management Agreement 2012 (FMA 2012), which aligns with UK Fisheries Authorities on managing quotas in Area VIIa (which covers all the IoM's territorial waters; Figure 10). Following consultations under the Trade and Cooperation Agreement (TCA) in late 2022, the UK and EU established fishing opportunities for 2023 and certain deep-sea stocks for 2023 and 2024, including spurdog (DEFRA, 2023).

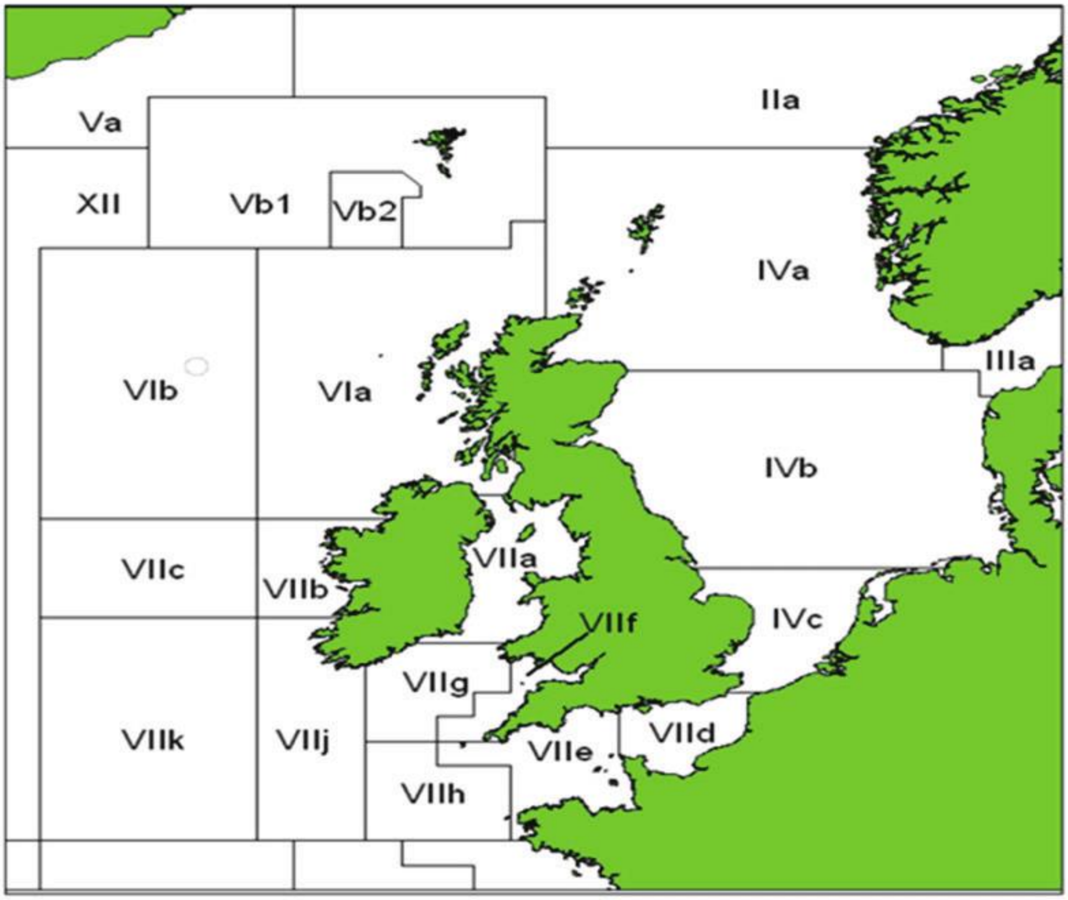

Figure 10. Map showing the Statistical Fishing Areas of the ICES.
Source (Anbleyth-Evans and Williams, 2018).

As a result, the spurdog fishery was reopened in UK and in the EU waters based on ICES advice that the Northeast Atlantic spurdog stock is recovering (ICES, 2022). The Sea Fisheries (Amendment) Regulations 2023, effective from April 1, 2023, set the TACs for spurdog at 2,781 tonnes for the North Sea and 4,825 tonnes for Western waters, including the IoM's territorial sea (DEFRA, 2023). In the IoM, regulations require the landing of spurdog specimens 100 cm or less, while larger ones must be released and catch reporting must follow specific guidelines for the region (IoM Government, 2023). Quota management is handled through unallocated monthly tonnage limits, starting at 5 tonnes and subject to adjustments (DEFRA, 2023). These rules are included in the IoM Sea Fishing Licence, ensuring quotas apply concurrently with UK vessel licenses (IoM Government, 2023). Given the species' vulnerability to overfishing, the DEFA has adopted a cautious approach to reopening the spurdog fishery and may implement additional measures as necessary to ensure sustainable management and will engage with stakeholders to review and potentially enhance these practices (IoM, 2023).

1.4.3 Bull Huss

The bull huss, *S. stellaris*, commonly known as the greater-spotted dogfish, large-spotted catshark, nursehound, or rough hound (British Sea Fishing, 2024b). Predominantly found along the southern and western coasts of the British Isles, with its distribution extending from Scandinavia to the Mediterranean and along the northern African coast (Compagno, 1984; British Sea Fishing, 2024b). This species can grow up to 162 cm TL, with the average adult size being around 125 cm TL (Finucci *et al*., 2021). The bull huss is identifiable by its elongated body, prominent pectoral fins, and distinctive large spots, with two dorsal fins positioned far back on its brownish to yellow body and a pale underside (Compagno, 1984).

Primarily nocturnal, the bull huss preys on small fish, sand eels, cuttlefish, crabs, prawns, marine worms, and shellfish, often hiding in rocky crevices or resting on the seabed during the day (Compagno, 1984; British Sea Fishing, 2024b). Although it generally inhabits deeper, rockier waters, it will venture into shallower areas when food is abundant (British Sea Fishing, 2024b). Reproduction is oviparous, with females laying eggs in protective cases known as mermaid's purses during spring and summer, with an incubation period of 7- 12 months (Compagno, 1984; British Sea Fishing, 2024b) and a size-at-birth of approximately 11 cm TL (Soares and Carvalho, 2019). Males mature at 77 cm TL and females at 79 cm TL, particularly in the Mediterranean (Bauchot, 1987). Little else is known about its biology, with maximum age and age-at-maturity inferred from the small spotted catshark *(S. canicula),* a related species, due to a lack of direct data (Finucci *et al*., 2021). The small spotted catshark reaches female maturity at nine years with a maximum age of 17 years (Rodríguez-Cabello *et al.*, 2005), while the nursehound's generation length is estimated to be around 16 years due to its larger size (Finucci *et al*., 2021).

The bull huss faces significant threats, many of which are exacerbated by its frequent confusion with the more abundant small spotted catshark, potentially skewing reported landing (Finucci *et al*., 2021). Species-specific population trends in the Northeast Atlantic, analysed using standardised CPUE data, indicate a 4.7 % annual increase in populations around the British Isles, suggesting local abundance (ICES-WGEF, 2019; Sherley *et al*., 2020; Winker *et al.,* 2020). However, the nursehound has been assessed by the IUCN as globally Vulnerable (Finucci *et al*., 2021) and Near Threatened in Europe (Ellis *et al*., 2015), with a 30-49 % population decline over the past three generations due to high exploitation and fragmented populations, particularly in the Mediterranean (Finucci *et al*., 2021; Sherley *et al.,* 2020). The species is often caught incidentally in various fisheries, but its true vulnerability is hard to gauge due to being frequently grouped with other elasmobranchs (Finucci *et al*., 2021). Despite some local population increases, the overall threats highlight the urgent need for targeted conservation efforts. No information regarding landing requirements, quotas, or other fisheries regulations specific to bull huss in the IoM could be found.

1.4.4 Thornback Ray

The thornback ray, *R. clavata,* commonly referred to as the Roker, is one of the most prevalent skate species in North European coastal waters (Ellis, 2016). Reaching up to 4 feet in wingspan and approximately 16 kg, though typically smaller when caught from the shore in the UK, these rays are characterised by a kite-shaped body with a long tail, a light orange/brown marbled pattern with pale spots on their back, and a central body covered with horns and spikes that become more pronounced with age (British Sea Fishing, 2024c). Thornback rays have a relatively long lifespan, reaching up to 12 years of age, and they grow to a maximum length of about 118 cm for females and 98 cm for males (Walker, 1998). The species has a prolonged breeding season from February to September, with peak egg-laying occurring in May and June (Holden, 1975). Despite the species current abundance in some areas, its long life cycle and late maturity make it vulnerable to overfishing (Ellis, 2016). Although the thornback ray has not experienced the severe population declines seen in other rajids, such as the common skate (*Dipturus* *batis*), ongoing monitoring and the development of more comprehensive management strategies are necessary to ensure its long-term sustainability (Ellis, 2016).

It is widely distributed from Iceland and Norway down to the North Sea, where its presence has diminished in some southeastern areas (Walker, 1998). Beyond this, the species extends its range to the Mediterranean, the western Black Sea, and the Atlantic coasts of Africa, reaching as far south as South Africa and the southwestern Indian Ocean (Stehmann, 1995). The thornback ray typically inhabits demersal coastal environments with a variety of substrates, including mud, sand, gravel, and rocky areas, predominantly at depths of 10-60m but sometimes as deep as 300m (Wheeler, 1969; Stehmann and Buerkel, 1984). Their diet primarily consists of crustaceans and crabs, but they also consume small fish, especially flatfish (British Sea Fishing, 2024c). Its adaptability to different benthic habitats makes it a significant component of the demersal elasmobranch assemblage in regions such as the Bristol Channel, where it constitutes a notable percentage of the elasmobranch biomass (Ellis, 2016).

Crucial for both commercial and recreational fisheries, the thornback ray is commonly caught as bycatch in trawl and gillnet fisheries, though there has been limited directed fishing (Ellis, 2016). Despite the importance of the thornback ray in these fisheries, precise landings data are difficult to obtain since rajid landings are often recorded collectively rather than by species (ICES, 1958-1987). The IUCN list thornback rays as Near Threatened, with stable population numbers reported in European Waters (Ellis, 2016; Ellis *et al*., 2016). The population ecology of skate species around the British Isles is poorly understood, revealing a critical gap in knowledge (McAllister *et al.*, 2023). The species' population trends have been assessed using standardised CPUE data, with recent analyses indicating localised increases in the Irish Sea and Bristol Channel, where the population appears to be abundant and stable (ICES-WGEF, 2019). Still, the species still faces significant pressures, particularly in areas where habitat degradation and intensive fishing occur. Catches in the North Sea between 2000 and 2006 found that 38 % of thornback rays were caught before reaching sexual maturity, and if current fishing practices continue, the population could decline by up to 90 % within the next 30 years (Wiegand *et al.*, 2011; Watson and Howe, 2022). While some local fisheries management measures, such as minimum landing sizes, have been implemented in parts of the UK, these efforts are often insufficient to protect regional populations effectively (Ellis, 2016). In the IoM, DEFA's 2019 landing obligation guidance permits fishermen to discard skates and rays caught in ICES area VIIa (Figure 10) without further criteria, but specific gear configurations are required depending on whether haddock, cod, skates, and rays make up more or less than 10 % of the catch (IoM Government, 2019).

1.4 Dissertation Aims and Objectives

This thesis aims to enhance the understanding and conservation of small sharks and rays in Manx waters by analysing population metrics and promoting sustainable fishery practices. The study supports the MWT by analysing tagging data and potentially expanding the SSTP to strengthen conservation efforts. The two primary objectives are:

- to conduct a comprehensive literature review on shark tagging technology, covering its applications, benefits, limitations, and advancements;
- to analyse data from the MWT SSTP to investigate shark population dynamics in Manx waters.

The findings will assist the MWT in making informed decisions about fishing practices, contributing to the protection of sharks and the broader marine ecosystem. Additionally, this research aims to inform government policies, promote sustainable fishing practices, and raise public awareness through online platforms and educational materials about the importance of conserving small sharks in the IoM.

2. Methods

2.1 Shark Tagging

To participate in the shark tagging programme, local anglers targeting small sharks were recruited through public advertisements. A total of 101 anglers received training since the programme's inception. Trained anglers were provided with a minimum landing size crib sheet, recording cards, and tagging equipment. Prior to tagging, each shark was visually assessed for normal appearance and compliance with the minimum landing size (Table 1). Sharks that were injured, abnormally appearing, or below the minimum size were excluded from tagging. Relevant data, including species, location, date, length, girth, sex, and condition, were recorded.

Table 1. **Minimum Landing Size and Mass for Micro-Tag Application According to the MWT SSTP.** Outline of the minimum landing size and mass requirements for the application of micro-tags in elasmobranchs, as specified by the MWT SSTP. The species included are tope, spurdog, bull huss, and various ray species, with specific size and mass thresholds to ensure compliance with tagging protocols.

Species	Minimum Size (cm)	Minimum Mass (kg)
Tope (*Galeorhinus galeus*)	65	1.27
Spurdog (*Squalus acanthias*)	65	1.04
Bull Huss (*Scyliorhinus stellaris*)	65	1.13
Rays (wingspan)	35	0.95

Each shark received one external tag with a unique identification number, which was documented on the recording card. After tagging, sharks were released, and their post-capture behaviour was monitored to ensure normalcy. Data are currently maintained by the MWT and were previously stored with the SSTP. For more information visit www.mwt.im/.

2.2 Data Preparation

This dissertation in conducted under the Ethics ID: 141/2024/UniGib.

The dataset utilised in this study was provided by the MWT, encompassing tagging data from 2003 to 2022. Initial inspection of the dataset revealed significant knowledge gaps, particularly missing mass data points. To address these gaps and ensure the reliability of the analyses, a data cleaning process was undertaken. This process involved identifying and excluding incomplete entries, as well as using formulas to calculate missing mass points and estimate age, creating a robust dataset for subsequent analyses. Data analysis was conducted exclusively for tope and spurdog, as these species had sufficient data entries. Bull huss and thornback rays were excluded from the analysis due to insufficient data.

2.3 Data Supplementation

To enhance the dataset and provide additional population metrics information, supplementary mass and age data were calculated for tope and spurdog.

2.3.1 Mass

The Bayesian length-mass formula was sourced from FishBase for both species. The formula used was:

Tope: a= 0.00479 (0.00363 - 0.00631), b= 2.99 (2.91 - 3.07)

Spurdog: a= 0.00275 (0.00237 - 0.00320), b= 3.08 (3.04 - 3.12)

Formula: W = aL b (Log W = Log a + b Log L),

Where: 'L' is the Total Length,

'W' is the Total Body Mass,

a and b are the intercept and slope of the power equation.

The predicted mean, upper, and lower mass for each tagged individual was calculated. For individuals with recorded mass, these values served as a benchmark to validate the calculated mass. The percent difference between the (actual) recorded and expected mean mass were computed to assess the accuracy of the calculated mass.

To analyse and visualise the predicted mass distribution of the tagged tope and spurdog, forest plots were created using calculated mean, upper, and lower mass derived from the Bayesian length-mass formula. In these plots, the dot in the middle represents the mean calculated mass in kilograms, while the standard deviation is indicated by the lower and upper calculated mass values. The average length for both species is represented by a red line. For the tope, a significant percentage difference was observed between the predicted and actual recorded mass of smaller individuals. These discrepancies were highlighted with a red box for visual identification and was examined in further detail in the discussion section.

2.3.2 Age

The age of chondrichthyans is often modelled using the von Bertalanffy growth function (Cailliet *et al.*, 2007). To analyse the potential of the IoM serving as a nursing ground, age estimates were calculated to investigate the sexual maturity of the tagged individuals. Age estimation for tope was based on the von Bertalanffy growth curves presented by Dureuil (2013), which depict the growth of female and male tope sharks within the Northeast Atlantic. For spurdogs, age estimation was based on the von Bertalanffy growth curves from Avasr (2001), representing the growth of female and male spurdogs in the southeastern Black Sea. Both sets of growth curves use total length (TL) in centimetres as a parameter, consistent with the measurements in the present dataset. The von Bertalanffy growth curves can be found in Appendix IV and V.

Each tagged individual's age was estimated using their TL (cm) and sex. This allowed for a detailed analysis of age distribution within the population. To visualise the variation in age over time, histograms (Appendix VI and VII) and summary tables were created to show population variation on a weekly, monthly, and yearly basis . Age was categorised into groups (0-5, 5.1-10, 10.1-15, 15.1-20, 20.1-25, and 25.1-30 years) to account for the frequency of these age groups per year.

2.3.3 Length-Mass and Length-Width Relationship Analysis

To explore the relationships between length, mass, and width, linear regression analyses were conducted. For tope, length versus mass regressions were performed separately for males and females and further segmented by size class to mitigate the effect of size variation on the regression outcomes. Length versus width regressions were also conducted for tope by year without size class differentiation.

For spurdogs, length versus width regressions were performed separately for males and females, by year. Due to limited data, it was not feasible to analyse the relationship between size and mass for this species. Additional data from FishBase was used to supplement the dataset, and the accuracy of calculated mass was validated against recorded mass.

Additionally, a scatter plot was created for each species to see how they relate to each other, showing individual data points and the corresponding linear regression lines for length-width relationship. The regression equations and R^2 values for each species were determined. The R^2 value measures how well the data points fit the trend line, with values closer to 1 indicating a better fit and values closer to 0 indicating a weaker fit.

2.3.4 Timeseries

A time series analysis was conducted to illustrate the length of tagged individuals over time. This analysis included the creation of a bar chart displaying data for all years combined for both the tope and spurdog, as well as individual yearly graphs for each species (Appendix VIII and IX). The mean length of individuals was calculated on a weekly basis for the yearly graphs and monthly basis for the multiyear graphs. Additionally, the number of individuals tagged each month was superimposed on the bars to assess potential changes in abundance or tagging effort over time.

2.3.5 GIS

A map was created to visually represent the tagging effort relative to geographic locations. The figure was developed by mapping the latitude and longitude data provided in the MWT dataset, allowing for a clear spatial analysis of tagging activities across different regions.

3. Results

3.1 Overall Dataset

To justify the focus on the tope and spurdog datasets, a Tagging Effort table was created (Figure 11). These two species had the highest number of tagged individuals, with tope accounting for 392 tags and spurdog for 171 tags; in comparison to bull huss and thornback rays which had 23 and 7, respectively. This made them the primary candidates for analysis, as they provided the most substantial datasets. The data were categorised into two primary measurements: length-mass (L&M) and length-width (L&W). The dataset quality was assessed using a color-coded scale to represent the percentile of usable entries: Green indicated a percentile of 75 %-100 %, Orange indicated 30 %-74.9 %, and Red indicated 0 %-29.9 %. The analysis shows that both tope and spurdog had sufficient data for length and width measurements. Specifically, tope had 118 entries for L&M, constituting 30.1 % of the total data, and 337 entries for L&W, which constituted 86.0 % of the total data. Spurdog had 4 entries for L&M (2.3 %) and 165 entries for length and width (96.5 %). The limited percentile of L&M data for spurdog was mitigated using a Bayesian length-mass formula from FishBase to ensure meaningful analyses could still be conducted. In contrast, Bull Huss (*S. stellaris*) and Thornback Ray (*R. clavata*) had very limited data, making statistical analysis impractical for these species, however, some results are discussed where possible. Additionally, tagging effort was broken down by year and sex, and this detailed information is available in the Appendix X.

A)

Species	L&M	L&W	%L&M	%L&W
Tope (*Galeorhinus galeus*)	118	337	30,1	86,0
Spurdog (*Squalus acanthias*)	4	165	2,3	96,5
Bull Huss (*Scyliorhinus stellaris*)	2	8	8,7	34,8
Thornback Ray (*Raja clavata*)	3	7	42,9	100,0

B)

Species	Tagged	Length	Mass	Width	Sex
Tope (*Galeorhinus galeus*)	392	376	126	337	387
Spurdog (*Squalus acanthias*)	171	171	4	165	170
Bull Huss (*Scyliorhinus stellaris*)	23	23	2	8	20
Thornback Ray (*Raja clavata*)	7	7	3	7	7

Scale	
Green	100% - 75%
Orange	74.9% - 30%
Red	29.9% - 0

Figure 11. **Summary of Data Collection and Tagging Efforts for Tope (*Galeorhinus galeus*), Spurdog (*Squalus acanthias*), Bull Huss (*Scyliorhinus stellaris*), and Thornback Ray (*Raja clavata*).** Panel A indicates, for each species, the number of individuals with Length and Mass measurements (L&M), the number with Length and Width measurements (L&W), and the corresponding percentages of the dataset. Panel B provides a breakdown of the tagging efforts, showing the number of tagged individuals for each category (Length, Mass, Width, and Sex). The percentage scale is defined as follows: green (100 %-75 %) representing a good dataset for analysis, orange (74.9 %-30 %) indicating data that is usable in some cases, and red (29.9 %-0 %) representing data that is unanalysable.

3.2 Overall Sex Distribution

Out of the 387 tope with sex data, 74.68 % are females (289 individuals) and 25.32 % are males (98 individuals). The spurdog population consists of 94.12 % females (160 individuals) and 5.88 % males (10 individuals) out of 170. For Bull Huss, 40.0 % are females (8 individuals) and 60.0 % are males (12 individuals) out of a total of 20. The Thornback Ray data shows 28.57 % females (2 individuals) and 71.43 % males (5 individuals) out of a total of 7.

3.3 Overall Length-Width Relationship

To analyse the relationship between length and width for all species, a scatter plot was created showing individual data points and the corresponding linear regression lines. The regression equations and R^2 values for each species are as follows: bull huss ($y = 0.2724x + 10.283$, $R^2 = 0.3948$), spurdog ($y = 0.0339x + 40.214$, $R^2 = 0.0463$), thornback ray ($y = 0.3759x - 1.9628$, $R^2 = 0.4931$), and tope ($y = 0.4018x - 6.2686$, $R^2 = 0.671$). These values indicate varying degrees of correlation between length and width across the different species, with tope being the most abundant and the largest in size, followed by spurdog, bull huss, and the thornback ray. The number of tagged individuals per species is as follows: tope (337), spurdog (165), bull huss (8), and thornback ray (7).

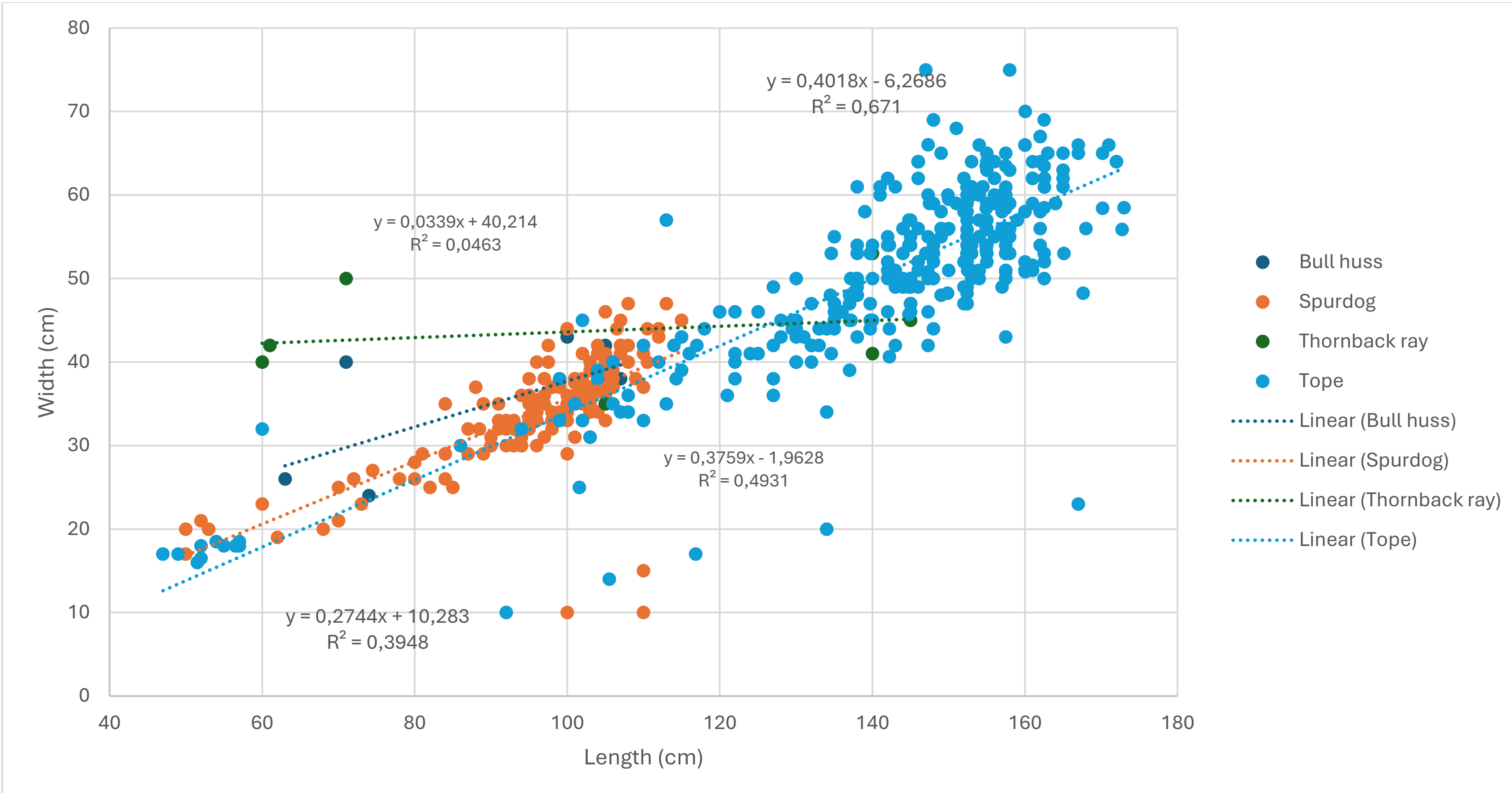

Figure 12. **Relationship between Length and Width for Tope (*Galeorhinus galeus*), Spurdog (*Squalus acanthias*), Bull Huss (*Scyliorhinus stellaris*), and Thornback Ray (*Raja clavata*).** Scatter plot illustrating the relationship between length and width for Bull huss (dark blue, N=8), Spurdog (orange, N=165), Thornback ray (green, N=7), and Tope (blue, N=337). Linear regression lines are included for each species with their corresponding equations and R^2 values. The regression lines are as follows: Bull huss ($y = 0.2724x + 10.283$, $R^2 = 0.3948$), Spurdog ($y = 0.0339x + 40.214$, $R^2 = 0.0463$), Thornback ray ($y = 0.3759x - 1.9628$, $R^2 = 0.4931$), and Tope ($y = 0.4018x - 6.2686$, $R^2 = 0.671$).

3.4 Tope Data Results

3.4.1 Mass

The scatter plot illustrates the relationship between length (cm) and mass (kg) for tope, comparing predicted calculated mean mass from FishBase (blue points) with recorded mass (orange points) over multiple years, specifically 2006, 2007, 2009, 2011, 2013, 2015, 2017, 2018, 2022, and 2023, for both females and males. For larger individuals (length >100 cm), predicted calculated and recorded mass align closely, indicating the accuracy of the FishBase Bayesian formula in predicting the mass of larger tope. For smaller individuals (length <100 cm), calculated mass is consistently lower than recorded mass. Recorded mass exhibit greater variability, especially for lengths between 120 cm and 160 cm, with a notable clustering around the 140-160 cm range.

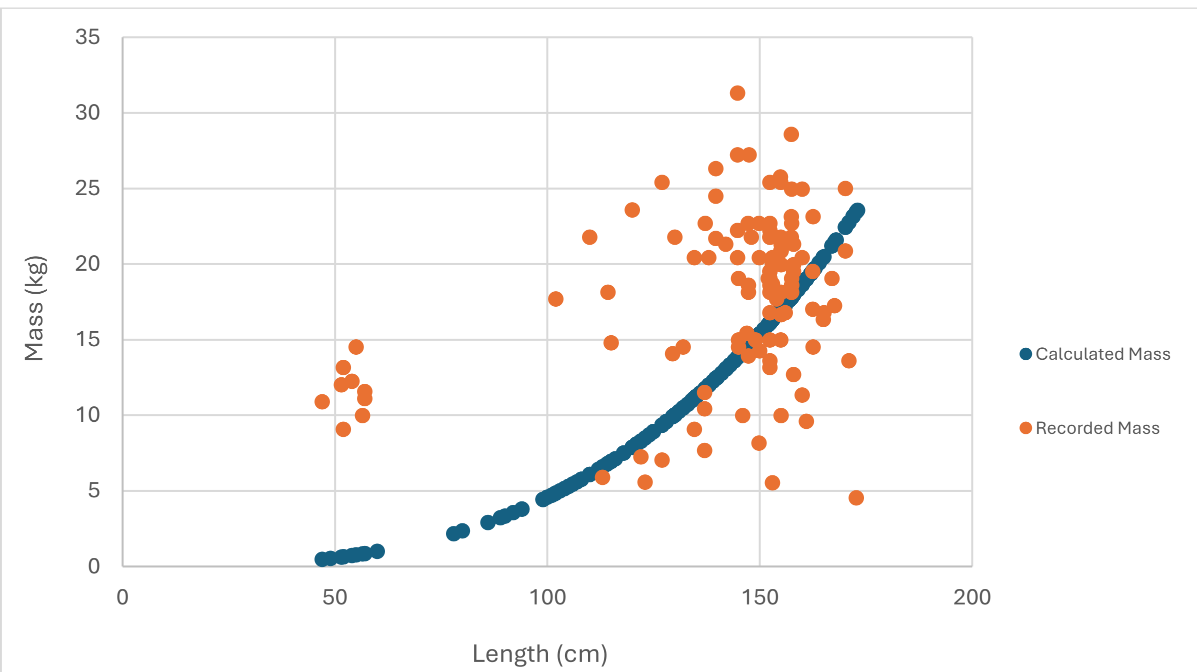

Figure 13. **Relationship between Length and Mass for Tope (*Galeorhinus galeus*).** Scatter plot comparing predicted calculated mean mass from FishBase (blue points) with recorded mass (orange points) over multiple years (2006-2023).

From 2009 to 2023, a total of 392 tope sharks were tagged in the IoM, with 118 individuals having both length and mass measurements recorded (Table 2). The measured lengths of these 118 topes ranged from 47-172.72 cm. Predicted calculated mean mass varied from 0.48-23.44 kg, while actual recorded mass spanned from 3.18-31.30 kg. There was a significant range between the calculated mean mass and the actual recorded mass, with percentage differences varying from -161.08 % to 95.02 %. A negative percentage difference occurs when the recorded mass is significantly lower than what the predictive model estimates.

The colour scale indicating overweight, expected mass, and underweight is used to categorise the percentage difference between predicted calculated mean mass and actual recorded mass. Results reveal that all individuals caught in 2007, and one individual caught in 2006 were extremely overweight, with a range of 93-95 % over the expected mass. Additionally, two females caught in 2022 (-161.08 %) and 2023 (-122.16 %) were severely underweight. Individuals with a percentage difference range of -27 % to 45 % were deemed healthy or satisfactory. Complete table with all individuals is provided in Appendix V.

Table 2. **Summary of Tope (*Galeorhinus galeus*) Data Collected from the Isle of Man with Length and Mass Measurements (2006-2023).** Data represents tagged tope sharks in the Isle of Man over the years 2006-2023, focusing on individuals with recorded lengths and masses (N= 118). Measurements include the length (cm), predicted calculated mass (mean, upper, and lower values in kg), actual recorded mass (kg), percentage difference between predicted calculated mean and actual mass, predicted ages (years), sex (M for male, F for female), and the year of data collection. The percentage difference indicates if the sharks were underweight (red), overweight (green), or within the expected mass range (yellow).

Tag Number	Measured Length (cm)	Calculated Mass (Kg) from Fishbase (mean)	Calculated Mass (kg) from Fishbase (upper)	Calculated Mass (kg) from Fishbase (lower)	Actual Recorded Mass (Kg)	% difference	Predicted Age (Years)	Sex	Year
22132	122,00	8,29	16,04	4,28	3,18	-161,08	12,0	F	2023
21741	152,40	16,12	31,75	8,17	7,26	-122,16	19,9	F	2022
3	161,00	19,00	37,58	9,59	14,97	-26,93	27,4	M	2011
5900	137,00	11,73	22,90	5,99	9,60	-22,11	16,0	F	2017
5716	127,00	9,35	18,14	4,81	7,67	-21,80	13,2	M	2013
13551	123,00	8,49	16,45	4,38	7,03	-20,82	12,2	M	2015
13549	113,00	6,59	12,68	3,42	5,58	-18,16	10,2	M	2015
5622	115,00	6,95	13,38	3,60	5,90	-17,82	10,5	M	2013
5733	153,00	16,31	32,14	8,27	14,78	-10,39	20,0	F	2017
15360	110,00	6,08	11,67	3,16	5,53	-9,92	10,0	F	2015
22609	172,72	23,44	46,63	11,76	21,77	-7,67	29,0	F	2022
3	102,00	4,85	9,26	2,54	4,54	-7,00	8,7	M	2009
22647	160,02	18,66	36,88	9,42	17,69	-5,46	22,0	F	2022
19892	137,00	11,73	22,90	5,99	11,34	-3,40	16,0	F	2017
5709	137,00	11,73	22,90	5,99	11,52	-1,81	16,0	F	2013
5818	132,00	10,49	20,43	5,38	10,43	-0,57	13,2	F	2017
22259	147,32	14,57	28,61	7,41	14,52	-0,37	19,0	F	2023
13546	145,00	13,89	27,25	7,07	13,93	0,23	17,9	F	2015
5304	147,00	14,47	28,42	7,36	14,52	0,28	19,0	F	2013
5714	150,00	15,38	30,24	7,80	15,42	0,30	19,7	F	2013
5705	146,00	14,18	27,84	7,21	14,26	0,52	18,4	F	2013
22140	129,50	9,91	19,26	5,09	9,98	0,71	12,8	F	2023
5761	145,00	13,89	27,25	7,07	14,06	1,19	17,9	F	2013
5618	148,00	14,77	29,02	7,51	14,97	1,32	19,4	F	2013
22626	167,64	21,44	42,55	10,79	21,77	1,53	26,0	F	2022
5724	155,00	16,96	33,45	8,59	17,24	1,61	20,3	F	2013
13564	153,00	16,31	32,14	8,27	16,65	2,00	20,0	F	2015
22118	162,50	19,53	38,67	9,85	19,96	2,13	23,7	F	2022
5621	154,00	16,63	32,79	8,43	17,01	2,20	20,2	F	2013

5623	156,00	17,29	34,11	8,75	17,69	2,27	20,6	F	2013
5615	153,00	16,31	32,14	8,27	16,78	2,80	20,0	F	2013
12668	158,00	17,96	35,47	9,08	18,69	3,89	21,0	F	2018
22133	165,10	20,48	40,60	10,32	21,32	3,92	25,0	F	2023
22128	152,40	16,12	31,75	8,17	16,78	3,93	19,9	F	2022
22308	157,50	17,79	35,13	8,99	18,60	4,34	20,8	F	2023
19891	155,00	16,96	33,45	8,59	18,14	6,53	20,3	F	2017
22116	162,50	19,53	38,67	9,85	21,32	8,37	23,7	F	2022
22126	155,00	16,96	33,45	8,95	18,60	8,80	21,5	M	2022
21966	157,50	17,79	35,13	8,99	19,50	8,79	20,8	F	2022
22300	157,50	17,79	35,13	8,99	19,96	10,86	20,8	F	2023
22136	155,00	16,96	33,45	8,59	19,05	10,98	20,3	F	2023
22137	152,40	16,12	31,75	8,17	18,14	11,14	19,9	F	2023
22304	154,90	16,93	33,38	8,57	19,05	11,15	20,2	F	2023
12667	171,00	22,75	45,22	11,43	25,76	11,67	28,5	F	2018
5860	138,00	11,98	23,41	6,12	13,61	11,94	16,4	F	2017
22119	158,00	17,96	35,47	9,08	20,41	12,01	21,0	F	2022
22305	134,60	11,12	21,69	5,69	12,70	12,43	13,5	F	2023
21964	157,50	17,79	35,13	8,99	20,41	12,84	20,8	F	2022
22303	152,40	16,12	31,75	8,17	18,60	13,30	19,9	F	2023
22139	137,20	11,78	23,00	6,02	13,61	13,46	16,0	F	2023
22613	162,56	19,56	38,71	9,86	22,68	13,78	23,7	F	2022
22251	139,70	12,43	24,31	6,34	14,52	14,37	16,5	F	2023
21743	170,18	22,43	44,56	11,27	26,31	14,76	28,0	F	2022
12666	167,00	21,20	42,05	10,67	24,99	15,19	26,0	F	2018
22125	152,40	16,12	31,75	8,17	19,05	15,37	19,9	F	2022
22622	149,86	15,33	30,16	7,78	18,14	15,49	19,5	F	2022
22142	114,30	6,82	13,13	3,54	8,16	16,45	10,5	F	2023
19893	149,00	15,07	29,63	7,65	18,14	16,93	19,5	F	2017
22143	139,70	12,43	24,31	6,34	14,97	16,96	16,5	F	2023
12669	158,00	17,96	35,47	9,08	21,68	17,16	21,0	F	2018
22648	152,40	16,12	31,75	8,17	19,50	17,34	19,9	F	2022
22258	152,40	16,12	31,75	8,17	19,50	17,34	19,9	F	2023
22301	152,40	16,12	31,75	8,17	19,50	17,34	19,9	F	2023
22148	144,80	13,84	27,14	7,04	16,78	17,56	17,4	F	2023
22616	170,18	22,43	44,56	11,27	27,22	17,60	28,0	F	2022
22121	155,00	16,96	33,45	8,59	20,87	18,72	20,3	F	2022
22112	155,00	16,96	33,45	8,59	20,87	18,72	20,3	F	2022
22625	154,94	16,94	33,41	8,58	20,87	18,81	20,2	F	2022
22115	165,00	20,45	40,52	10,30	25,40	19,51	25,0	F	2022
22149	142,00	13,05	25,56	6,65	16,33	20,07	17,2	F	2023
22113	155,00	16,96	33,45	8,59	21,32	20,45	20,3	F	2022
5366	120,00	7,89	15,24	4,08	9,98	20,93	11,5	M	2013

22302	160,00	18,65	36,87	9,42	23,59	20,94	22,0	F	2023
22307	152,40	16,12	31,75	8,17	20,41	21,01	19,9	F	2023
22111	157,50	17,79	35,13	8,99	22,68	21,56	20,8	F	2022
22107	157,48	17,78	35,12	8,99	22,68	21,59	20,8	F	2022
22644	154,94	16,94	33,41	8,58	21,77	22,19	20,2	F	2022
22134	152,40	16,12	31,75	8,17	20,87	22,73	19,9	F	2023
21744	162,56	19,56	38,71	9,86	25,40	23,02	23,7	F	2022
22646	157,48	17,78	35,12	8,99	23,13	23,12	20,8	F	2022
22619	157,48	17,78	35,12	8,99	23,13	23,12	20,8	F	2022
22114	145,00	13,89	27,25	7,07	18,14	23,42	17,9	F	2022
22306	147,32	14,57	28,61	7,41	19,05	23,53	19,0	F	2023
22253	144,80	13,84	27,14	7,04	18,14	23,74	17,4	F	2023
22257	154,94	16,94	33,41	8,58	22,23	23,78	20,2	F	2023
5812	153,00	16,31	32,14	8,27	21,69	24,79	20,0	F	2017
22144	149,90	15,35	30,18	7,79	20,41	24,82	19,5	F	2023
22614	149,86	15,33	30,16	7,78	20,41	24,88	19,5	F	2022
22611	154,94	16,94	33,41	8,58	22,68	25,31	20,2	F	2022
22255	152,40	16,12	31,75	8,17	21,77	25,95	19,9	F	2023
22117	152,00	16,00	31,50	8,11	21,77	26,53	19,9	F	2022
22600	144,78	13,83	27,13	7,04	19,05	27,40	17,4	F	2022
22252	147,30	14,56	28,60	7,40	20,41	28,65	19,0	F	2023
22254	152,40	16,12	31,75	8,17	22,68	28,91	19,9	F	2023
21742	127,00	9,35	18,14	4,81	13,15	28,94	12,5	F	2022
22309	157,50	17,79	35,13	8,99	25,40	29,96	20,8	F	2023
22615	154,94	16,94	33,41	8,58	24,95	32,10	20,2	F	2022
5360	130,00	10,02	19,49	5,15	14,97	33,04	15,0	M	2013
22612	147,32	14,57	28,61	7,41	21,77	33,08	19,0	F	2022
22250	139,70	12,43	24,31	6,34	18,60	33,16	16,5	F	2023
22621	152,40	16,12	31,75	8,17	24,49	34,17	19,9	F	2022
22146	147,50	14,62	28,72	7,43	22,23	34,21	19,0	F	2023
22605	157,48	17,78	35,12	8,99	27,22	34,65	20,8	F	2022
22256	160,02	18,66	36,88	9,42	28,58	34,72	22,0	F	2023
22608	152,40	16,12	31,75	8,17	24,95	35,37	19,9	F	2022
22311	144,80	13,84	27,14	7,04	21,77	36,45	17,4	F	2023
19894	158,00	17,96	35,47	9,08	31,30	42,62	21,0	F	2017
22310	134,60	11,12	21,69	5,69	19,96	44,27	13,5	F	2023
19916	51,50	0,63	1,14	0,35	9,07	93,07	2,9	F	2007
19924	56,50	0,83	1,51	0,46	12,02	93,10	3,4	F	2007
21199	52,00	0,65	1,17	0,36	9,98	93,51	2,9	F	2006
19921	57,00	0,85	1,55	0,47	13,15	93,52	3,8	F	2007
19923	54,00	0,72	1,31	0,40	11,57	93,73	3,0	F	2007
19919	55,00	0,77	1,39	0,42	12,25	93,75	3,2	F	2007
19917	57,00	0,85	1,55	0,47	14,52	94,13	3,8	F	2007

19918	52,00	0,65	1,17	0,36	11,11	94,17	2,5	M	2007
19922	47,00	0,48	0,86	0,27	9,072	94,73	2,0	M	2007
19920	49,00	0,54	0,97	0,30	10,89	95,02	2,5	F	2007

The forest plot below (Figure 14) shows the ranked distribution (y axis) of predicted mass from heaviest to lightest (x axis) throughout all tagged sharks based on length measurements (N = 376). The error bars denote the lower and upper calculated mass. Most recorded mass cluster between 5 kg and 25 kg, with fewer individuals at the extremes of the spectrum. In the analysis, the red line indicates the overall average length of 140.45 cm and the mean mass of 12.51 kg. The brackets mark the upper and lower mass limits, 24.47 kg and 6.38 kg, respectively. Additionally, the orange box emphasises smaller individuals that exhibit a significant percentage difference between their predicted and actual mass, possibly indicating human error in recoding or in calculating the mass.

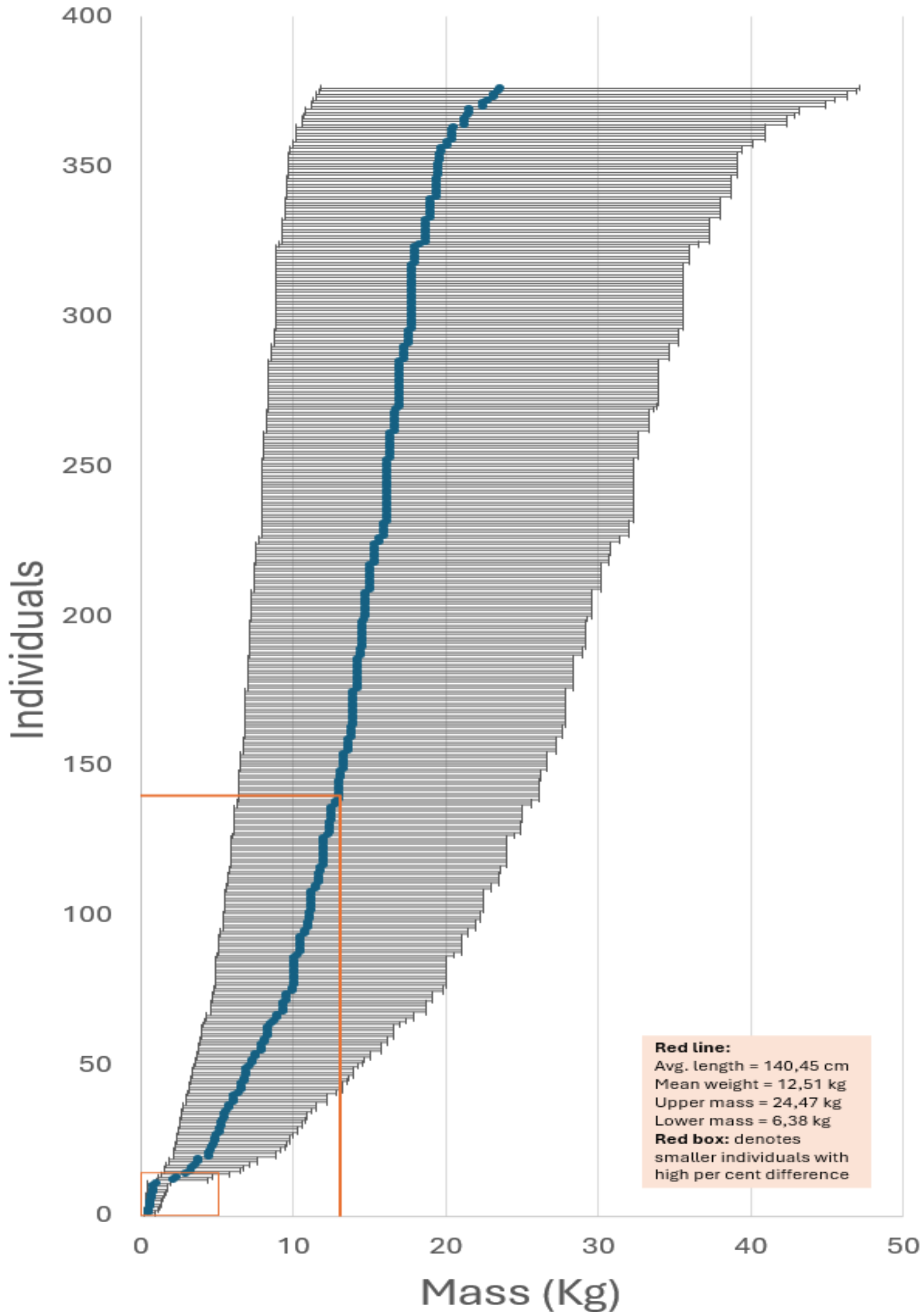

Figure 14. **Tope (*Galeorhinus galeus*) Mass Distribution Based on Length Measurements (2003 – 2023).** The forest plot illustrates the ranked distribution (y axis) of predicted mass for all tagged spurdog sharks (N = 376), ranging from heaviest to lightest (x axis). Error bars represent the calculated lower and upper mass estimates. Most of the recorded mass fall between 5 kg and 25 kg, with fewer individuals observed at both the lower and upper extremes of the mass range. The red line represents the average length (140.45 cm) and mean mass (12.51 kg), with the upper mass (24.47 kg) and lower mass (6.38 kg) denoted by the brackets. The red box highlights smaller individuals with a high percentage difference between predicted and actual mass.

3.4.2 Age

The table below illustrates the distribution of tagged individuals across various age classes (0-5, 5.1-10, 10.1-15, 15.1-20, 20.1-25, and 25.1-30 years) from 2006 to 2023. A total of 376 individuals are analysed, with the most represented age class being 15.1-20 years, accounting for 156 individuals (41.5 % of the total). The least represented age class was 25.1-30 years, with only 14 individuals (3.7 %). By 2007, the 0-5 age class saw an increase to nine individuals. From 2009 to 2015, the tagging programme expanded, notably in 2013 when 18 individuals in the 15.1-20 age class were tagged. This trend continued, with the 10.1-15 and 15.1-20 age classes seeing consistent tagging. The years 2016 to 2023 showed the 15.1-20 age class remaining dominant, particularly in 2017 with 22 individuals tagged. In 2022, there was a significant rise in the 20.1-25 age class, with 56 individuals tagged. Histograms for each year and an overall histogram displaying all tagged individuals can be found in Appendix XI, providing a visual representation of these age trends.

Table 3. **Distribution of Tagged Individuals by Predicted Age Class from 2006 to 2023 for Tope (*Galeorhinus galeus*).** Table presents total of 376 individuals analysed across various age classes from 2006 to 2023. The predicted age classes are divided into six groups: 0-5, 5.1-10, 10.1-15, 15.1-20, 20.1-25, and 25.1-30 years. The total number of individuals tagged each year is displayed, as well as the cumulative totals for each age class over the entire period.

Age	2006	2007	2009	2011	2013	2014	2015	2016	2017	2018	2019	2021	2022	2023	All Years
0-5	1	9	0	0	0	0	1	0	0	1	0	1	0	0	13
5.1-10	0	0	1	0	1	4	3	3	1	2	1	5	5	1	27
10.1-15	0	0	0	0	5	8	4	1	9	1	2	6	15	11	62
15.1-20	0	0	0	0	18	9	4	4	22	12	2	6	49	30	156
20.1-25	0	0	0	0	4	0	0	2	7	11	4	3	56	17	104
25.1-30	0	0	0	1	0	0	0	0	1	3	1	1	7	0	14

3.4.3 Length vs Mass Relationship

The length-mass relationship for tope sharks was analysed using linear regression, with separate analyses for individuals larger than 95 cm and those smaller than 95 cm. For tope sharks larger than 95 cm, the dataset comprised 99 females and 10 males. The linear regression equation for females was $y = 0.3511x - 34.002$, with an R^2 value of 0.6036, indicating that approximately 60.36 % of the variation in mass is explained by the variation in length. The linear regression equation for males was $y = 0.2329x - 19.659$, with an R^2 value of 0.7827, indicating that approximately 78.27 % of the variation in mass is explained by the variation in length. For tope sharks smaller than 95 cm, the dataset included 8 females and 2 males. The linear regression analysis for this class size was only performed for females due to the limited data for males. The linear regression equation for females was y = 0.4666x - 13.52, with an R^2 value of 0.6279, indicating that approximately 62.79 % of the variation in mass is explained by the variation in length.

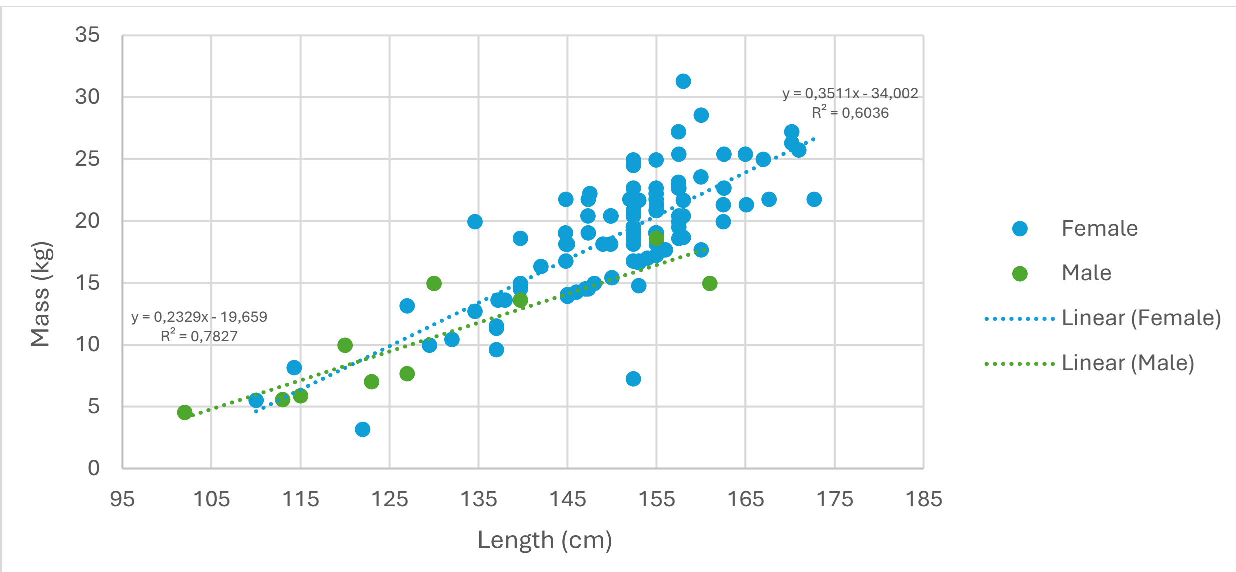

Figure 15. **Length vs Mass Relationship for Tope (*Galeorhinus galeus*) Sharks Larger than 95 cm.** The scatter plot illustrates the relationship between length and mass for tope sharks larger than 95 cm. Data points are differentiated by sex, with females (N=99) shown in blue and males (N=10) in green. Linear regression lines for each sex are included, with females showing an R^2 value of 0.6036 and males showing an R^2 value of 0.7827. These values indicate that a significant proportion of the variation in mass can be explained by the length for both sexes, with the relationship being stronger in males.

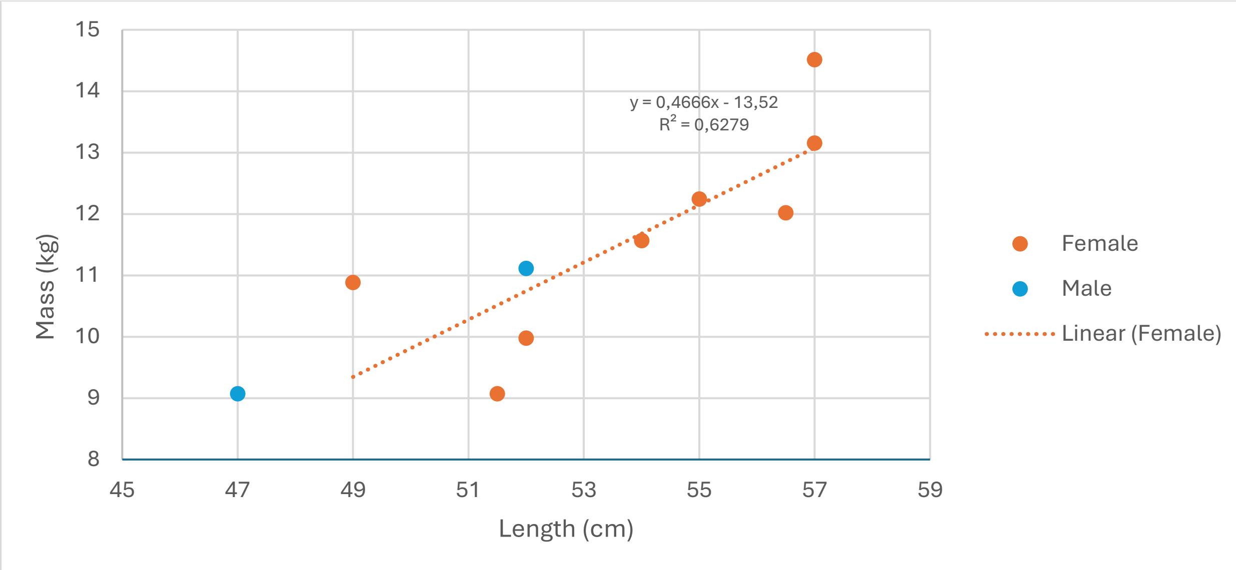

Figure 16. **Length vs Mass Relationship for Tope (*Galeorhinus galeus*) Sharks Smaller than 95 cm.** The scatter plot depicts the relationship between length and mass for tope sharks smaller than 95 cm. Females (N=8) are represented in orange and males (N=2) in blue. A linear regression line is provided for females, with an R^2 value of 0.6279, indicating a moderate correlation between length and mass. A linear regression line could not be made for males due to limited data.

3.4.4 Length vs Width Relationship

The length-width relationship for tope sharks was analysed using linear regression for individuals larger than 65 cm and those smaller than 65 cm. For tope sharks larger than 65 cm, the dataset comprised 259 females and 67 males. The linear regression equation for females was $y = 0.4594x - 14.619$, with an R^2 value of 0.5093, indicating that approximately 50.93 % of the variation in width is explained by the variation in length. For males, the linear regression equation was $y = 0.35x - 0.5134$, with an R^2 value of 0.6411, suggesting that 64.11 % of the variation in width is explained by the variation in length. For tope sharks smaller than 65 cm, the dataset comprised 9 females and 2 males. The linear regression equation for females was $y=0.2397x+4.6204$ with an R^2 value of 0.5588, indicating that 55.88 % of the variation in width is explained by the variation in length. Due to the small sample size for males, a reliable linear regression equation and R^2 value could not be determined for this group. In Appendix XII, a scatter plot of length-width by year is shown, for males and females.

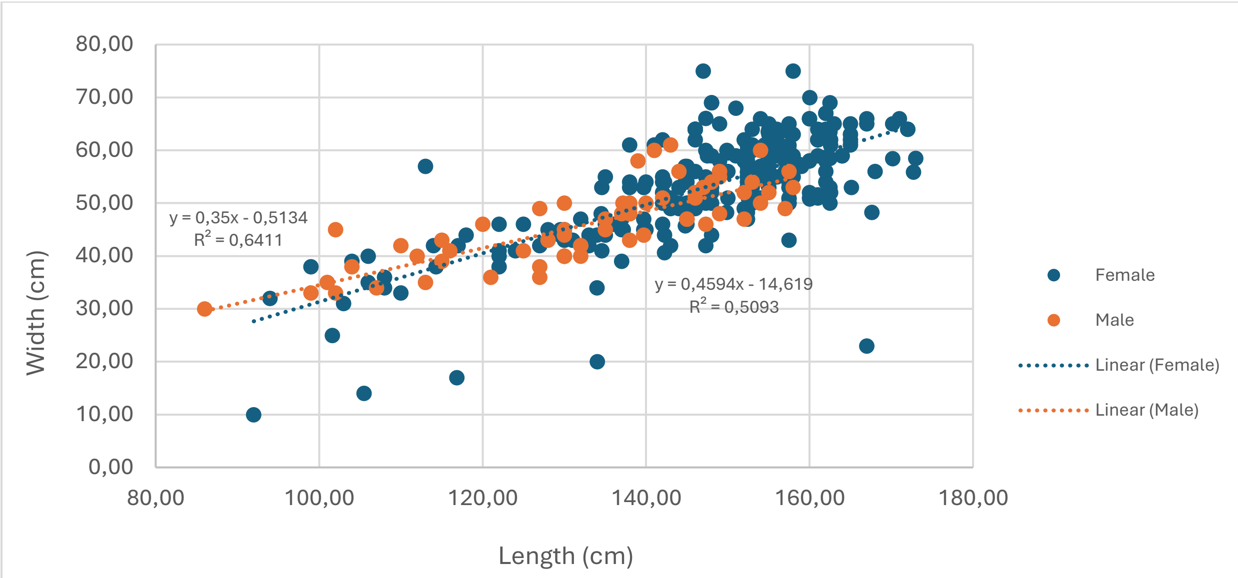

Figure 17. **Length vs Width Relationship for Tope (*Galeorhinus galeus*) Sharks Larger than 65 cm (2013-2023).** This scatter plot shows the relationship between length and width for tope sharks larger than 65 cm. Females (N=259) are indicated in blue and males (N=67) in red. The linear regression line for females has an R^2 value of 0.5093, while the line for males has an R^2 value of 0.6411. These R^2 values suggest a moderate to strong correlation between length and width, with the relationship being stronger in males.

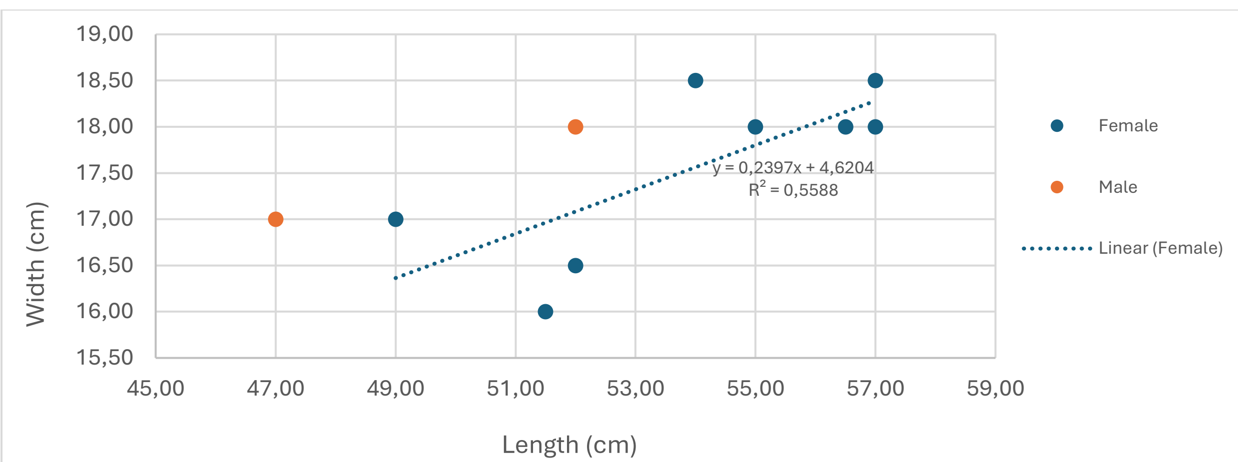

Figure 18. **Length vs Width Relationship for Tope (*Galeorhinus galeus*) Sharks Smaller than 65 cm.** The scatter plot shows the relationship between length and width for tope sharks smaller than 65 cm. Females (N=9) are indicated in blue and males (N=2) in orange. The linear regression line for females has an R^2 value of 0.5588, indicating a moderate correlation between length and width.

3.4.5 Length Over Time

The time series below illustrates the mean total length of tope across different months and years from 2006 to 2023. Over this period, 375 individuals were measured, with sample sizes varying significantly between months, as indicated by the numbers above the bars. The mean total length shows fluctuations over time, with some months exhibiting higher variability, as evidenced by larger standard deviations. The trend line suggests a potential change in the average size over the years. Data from 2006 to 2011 indicates the period when the MWT was a part of the STP, with the MWT SSTP commencing officially in 2013, when we see more consistent data. The mean length for each week per month throughout the years is provided in Appendix VI. The R^2 value of 0.246 indicates a weak positive correlation, meaning only about 24.6% of the variation in the mean values is explained by the passage of years, suggesting other factors (i.e. environmental, tagging effort, seasonality, etc.) significantly influence the data.

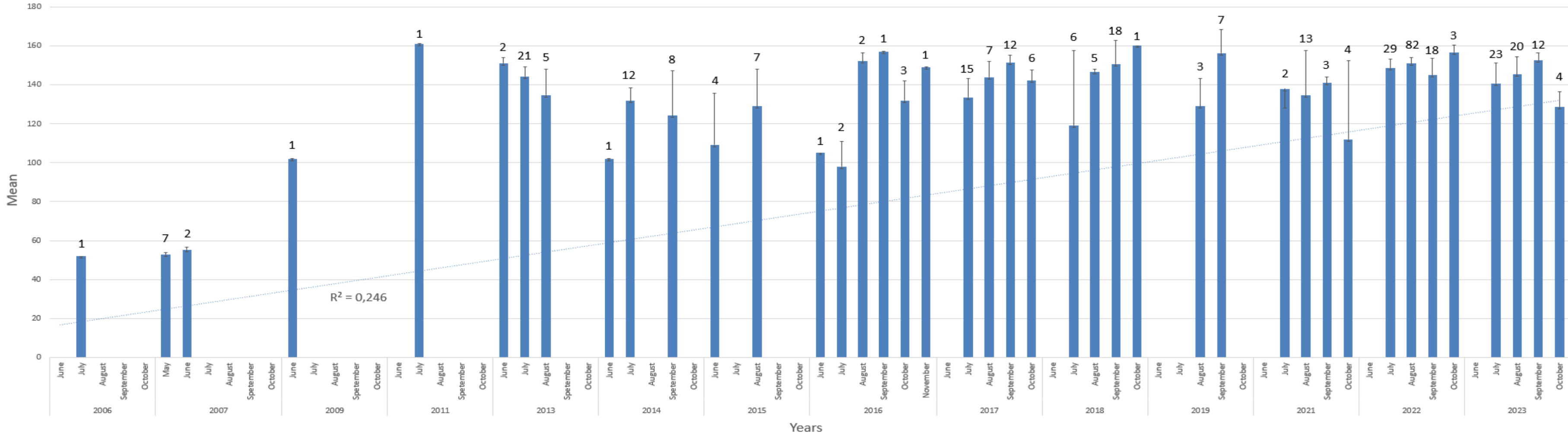

Figure 19. **Time Series Analysis of Mean Total Length of Tope (*Galeorhinus galeus*) from 2006 to 2023**. Monthly variation in the mean total length (mm) of tope (*Galeorhinus galeus*) from 2006 to 2023. Error bars represent the standard deviation. The numbers above each bar denote the sample size (n) for each month. A total of 375 individuals were analysed during the study period.

3.5 Spurdog Data Results

3.5.1 Mass

From 2013 to 2023, a total of 171 spurdog sharks were tagged in the IoM. Of these, only 4 individuals had both length and mass measurements recorded. The measured lengths of these 4 spurdogs ranged from 95 cm to 107 cm. Predicted calculated mean mass varied from 2,68 kg to 4,90 kg, while actual recorded mass spanned from 2,50 kg to 5,50 kg. There was a significant range between the calculated mean mass and the actual recorded mass, with percentage differences ranging from -8,52 % to 11.02 %. A negative percentage difference occurs when the recorded mass is significantly lower than what the predictive model estimates.

Table 4. **Summary of Spurdog (*Squalus acanthias*) Data Collected from the Isle of Man with Length and Mass Measurements (2013).** This table presents the data collected from tope sharks in the Isle of Man in 2013, focusing on individuals with recorded lengths and masses (N=4). Measurements include the length (cm), predicted calculated mass (mean, upper, and lower values in kg), actual recorded mass (kg), percentage difference between calculated mean and actual mass, predicted ages (years), sex (M for male, F for female), and the year of data collection. The percentage difference indicates if the sharks were underweight (red), overweight (green), or within the expected mass range (yellow).

Tag Number	Measured Length (cm)	Calculated Mass (kg) from Fishbase (mean)	Calculated Mass (kg) from Fishbase (upper)	Calculated Mass (kg) from Fishbase (lower)	Actual Recorded Mass (kg)	% difference	Predicted Age	Sex	Year
9335	95,00	3,39	4,74	2,44	3,11	-8,92	7,2	M	2013
9337	88,00	2,68	3,73	1,93	2,50	-7,28	5,5	M	2013
9336	106,00	4,76	6,67	3,40	5,33	10,84	6,8	F	2013
5707	107,00	4,90	6,87	3,50	5,50	11,02	6,9	F	2013

The colour scale indicating overweight, expected mass, and underweight is used to categorise the percentage difference between calculated mean mass and actual recorded mass. The percent differences between the actual recorded mass of spurdogs and the predicted mean calculated mass show a range of deviations. For Tag Number 9335 and Tag Number 9337, the percent differences were -8.26 % and -6.72 %, respectively, indicating that their actual mass were slightly lower than the predicted mean calculated mass. In contrast, Tag Numbers 9336 and 5707 exhibited positive percent differences of 11.98 % and 12.24 %, respectively, signifying that their actual mass exceeded the predicted mean calculated mass. All individuals fall within a healthy and satisfactory mass range. A scatterplot could not be made due to the low recorded mass data. Complete table with all individuals is provided in Appendix XIII.

The forest plot below shows the ranked distribution (y axis) of predicted mass from heaviest to lightest (x axis) throughout all tagged sharks based on length measurements (N= 171). The error bars denote the lower and upper calculated mass. Most recorded mass cluster between 4 kg and 6 kg, with fewer individuals at the extremes of the spectrum. A red line is included in the plot to mark the average length of the sampled sharks, which is 97.02 cm. This average length corresponds to a mean mass of 3.62 kg. Additionally, the upper and lower calculated mass estimates associated with this average length are 5.06 kg and 2.06 kg, respectively.

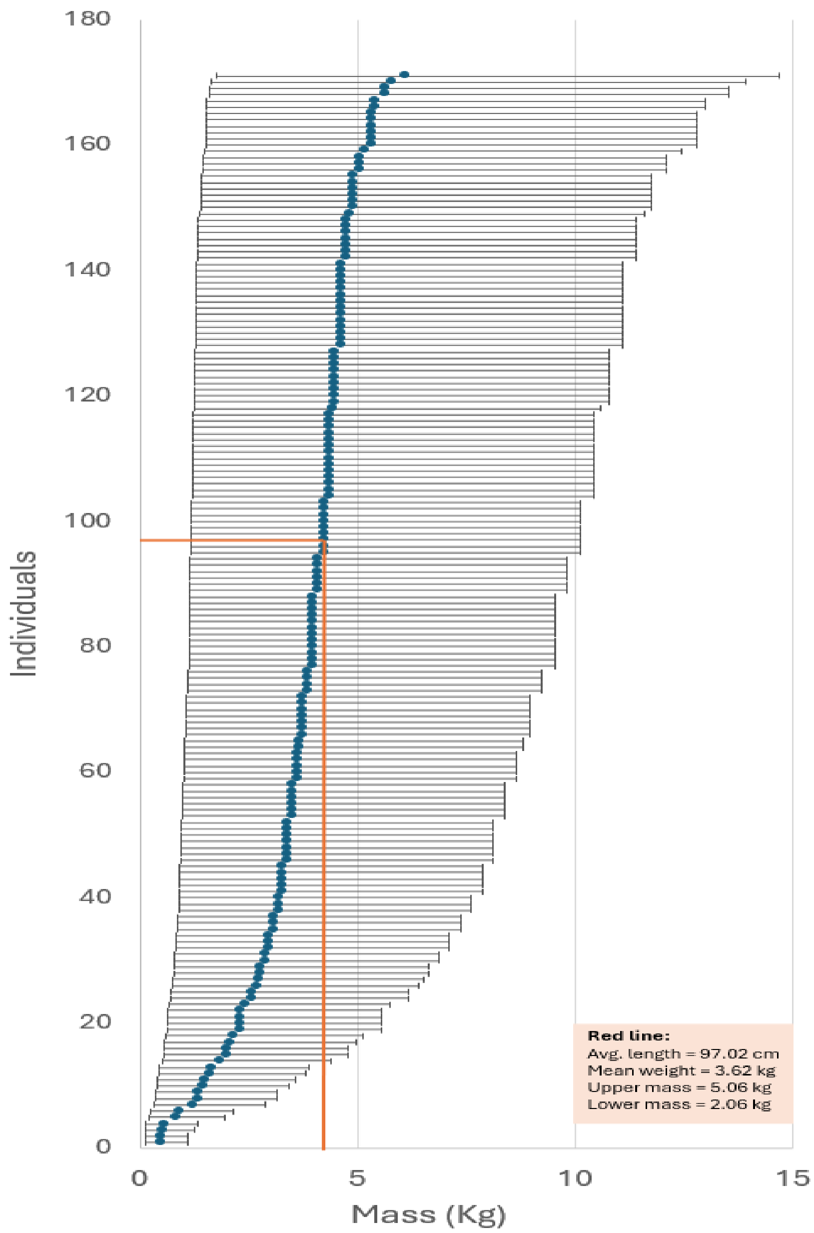

Figure 20. **Spurdog (*Squalus acanthias*) Mass Distribution Based on Length Measurements (2013 – 2023).** The forest plot illustrates the ranked distribution (y axis) of predicted mass for all tagged spurdog sharks (N = 171), ranging from heaviest to lightest (x axis). Error bars represent the calculated lower and upper mass estimates. Most of the recorded mass fall between 4 kg and 6 kg, with fewer individuals observed at both the lower and upper extremes of the mass range. A red line indicates the average length of 97.02 cm, with corresponding predicted mean mass, upper mass, and lower mass estimates of 3.62 kg, 5.06 kg, and 2.06 kg, respectively.

3.5.2 Age

Table 4 illustrates the distribution of spurdogs across various age classes from 2013 to 2023. A total of 165 spurdogs were recorded, with the most represented age class being 5.1-10 years, accounting for 141 individuals (85.5 %). No individuals were recorded in the 10.1-15, 15.1-20, 20.1-25, and 25.1-30 years age classes. Histograms for each year and a multiyear histogram displaying all recorded spurdogs can be found in Appendix VII, providing a visual representation of these age trends.

In 2013, only the 5.1-10 years age class had individuals recorded, with 5 spurdogs. By 2014, this number decreased to 1 individual. A significant increase was observed in 2017, with 85 spurdogs recorded in the 5.1-10 years age class and 5 spurdogs in the 0-5 years age class. In 2018, the numbers dropped to 14 in the 5.1-10 years age class and 0 in the 0-5 years age class. In 2019, 8 spurdogs were recorded in the 5.1-10 years age class. In 2021, there was an increase in the 0-5 years age class with 15 spurdogs, while the 5.1-10 years age class had 16 spurdogs. The subsequent years, 2022 and 2023, showed fluctuating numbers. In 2022, 1 spurdog was recorded in the 0-5 years age class and 11 in the 5.1-10 years age class. In 2023, there were 3 spurdogs in the 0-5 years age class and 1 in the 5.1-10 years age class.

Table 5. **Distribution of Tagged Individuals by Predicted Age Class from 2013 to 2023 for Spurdog (*Squalus acanthias*)**. The table illustrates the distribution of spurdogs across various age classes from 2013 to 2023. A total of 165 spurdogs were recorded, with the majority in the 5.1-10 years age class (141 individuals, 85.5 %). The 0-5 years age class had 24 individuals (14.5 %), while no spurdogs were recorded in the older age classes (10.1-30 years) throughout the study period. Notable peaks include 2017 with 85 individuals in the 5.1-10 years age class and 2021 with 15 individuals in the 0-5 years age class.

Age	2013	2014	2015	2016	2017	2018	2019	2021	2022	2023	All Years
0-5	0	0	0	0	5	0	0	15	1	3	24
5.1-10	5	1	1	4	85	14	8	16	11	1	141
10.1-15	0	0	0	0	0	0	0	0	0	0	0
15.1-20	0	0	0	0	0	0	0	0	0	0	0
20.1-25	0	0	0	0	0	0	0	0	0	0	0
25.1-30	0	0	0	0	0	0	0	0	0	0	0

3.5.3 Length vs Width Relationship

The length-width relationship for spurdog was analysed using linear regression. The dataset comprised 154 females and 10 males. The linear regression equation for females was $y = 0.3774x - 2.0994$, with an R^2 value of 0.4306, indicating that approximately 43.06 % of the variation in width is explained by the variation in length. For males, the linear regression equation was $y = 0.3503x - 0.1142$, with an R^2 value of 0.6894, suggesting that 68.94 % of the variation in width is explained by the variation in length. In Appendix XIV, a scatter plot of length-width by year is shown, for males and females.

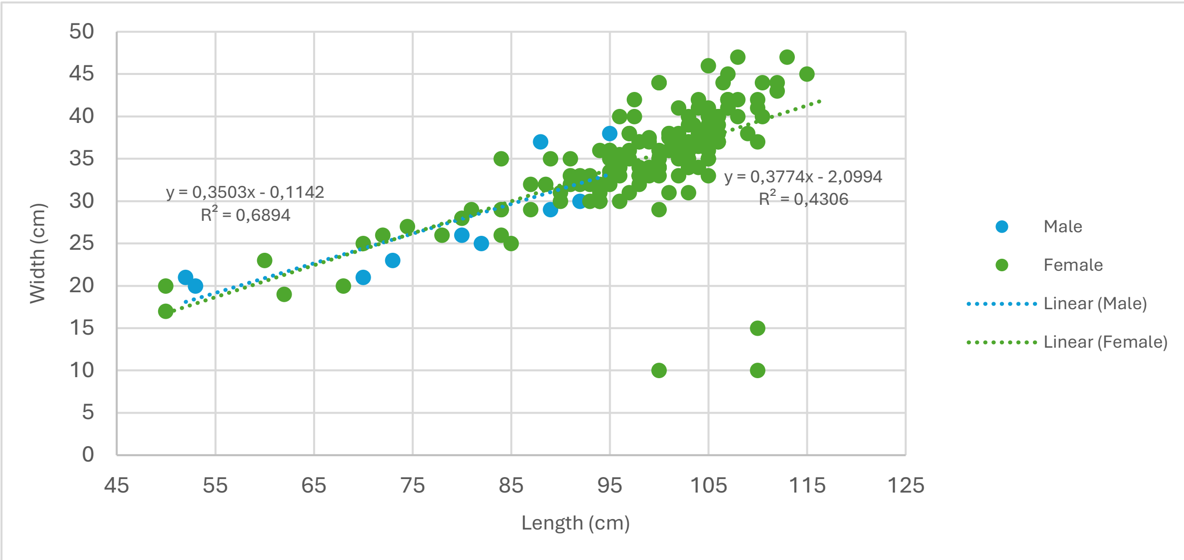

Figure 21. **Length vs Width Relationship for Spurdog (*Squalus acanthias*) (2013-2023).** The scatter plot shows the relationship between length and width for spurdog. Females (N=154) are indicated in green and males (N=10) in blue. The linear regression line for females has an R^2 value of 0.4306, while the line for males has an R^2 value of 0.6894.

3.5.4 Length Over Time

The time series below illustrates the mean total length of spurdog across different months and years from 2013 to 2023. Over this period, 171 individuals were measured, with sample sizes varying significantly between months, as indicated by the numbers above the bars. The mean total length shows fluctuations over time, with some months exhibiting higher variability, as evidenced by larger standard deviations. The trend line in the figure shows a slight downward trend in mean total length over time, although the R^2 value suggests that this trend is not strongly predictive. The mean length for each week per month throughout the years is provided in Appendix IX. The R^2 value of 0.003 suggests an extremely weak correlation between the variable and the years. This indicates that the passage of years explains only 0.3% of the variation in the mean values, implying that other factors (i.e. environmental, tagging effort) are overwhelmingly influencing the data.

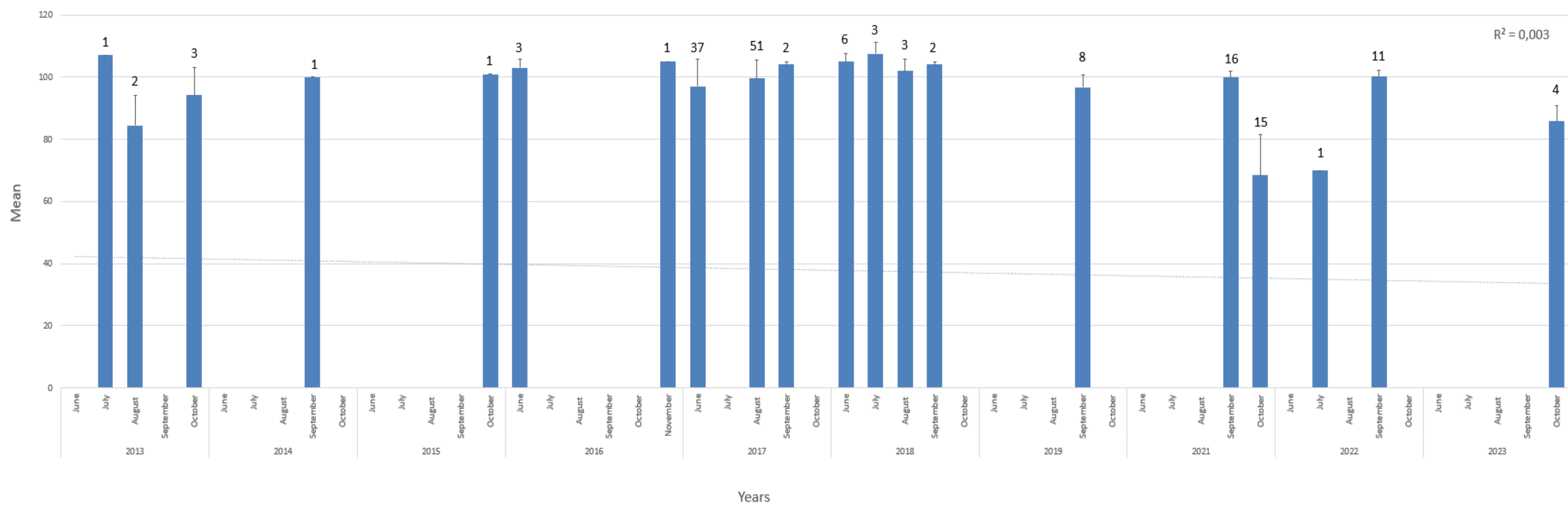

Figure 22. **Time Series Analysis of Mean Total Length of Spurdog (*Squalus acanthias*) from 2013 to 2023**. Monthly variation in the mean total length (mm) of spurdog (*Squalus acanthias*) from 2013 to 2023. Error bars represent the standard deviation. The numbers above each bar denote the sample size (n) for each month. A total of 171 individuals were analysed during the study period.

4. Discussion

Tagging efforts are predominantly concentrated along the southern and eastern coastal regions, which according to the MWT, these areas are either more accessible, or where anglers report a higher presence of sharks. Tope is the most commonly tagged species, which could possibly be attributed to the focus on regions where Tope is more prevalent compared to bull huss, spurdog, and thornback ray. The underrepresentation in the northern part of the region highlights a gap in the current tagging programme that could be addressed in future efforts. By broadening the geographic scope of tagging activities, a different composition of species might be revealed, providing a more comprehensive understanding of shark populations around the island.

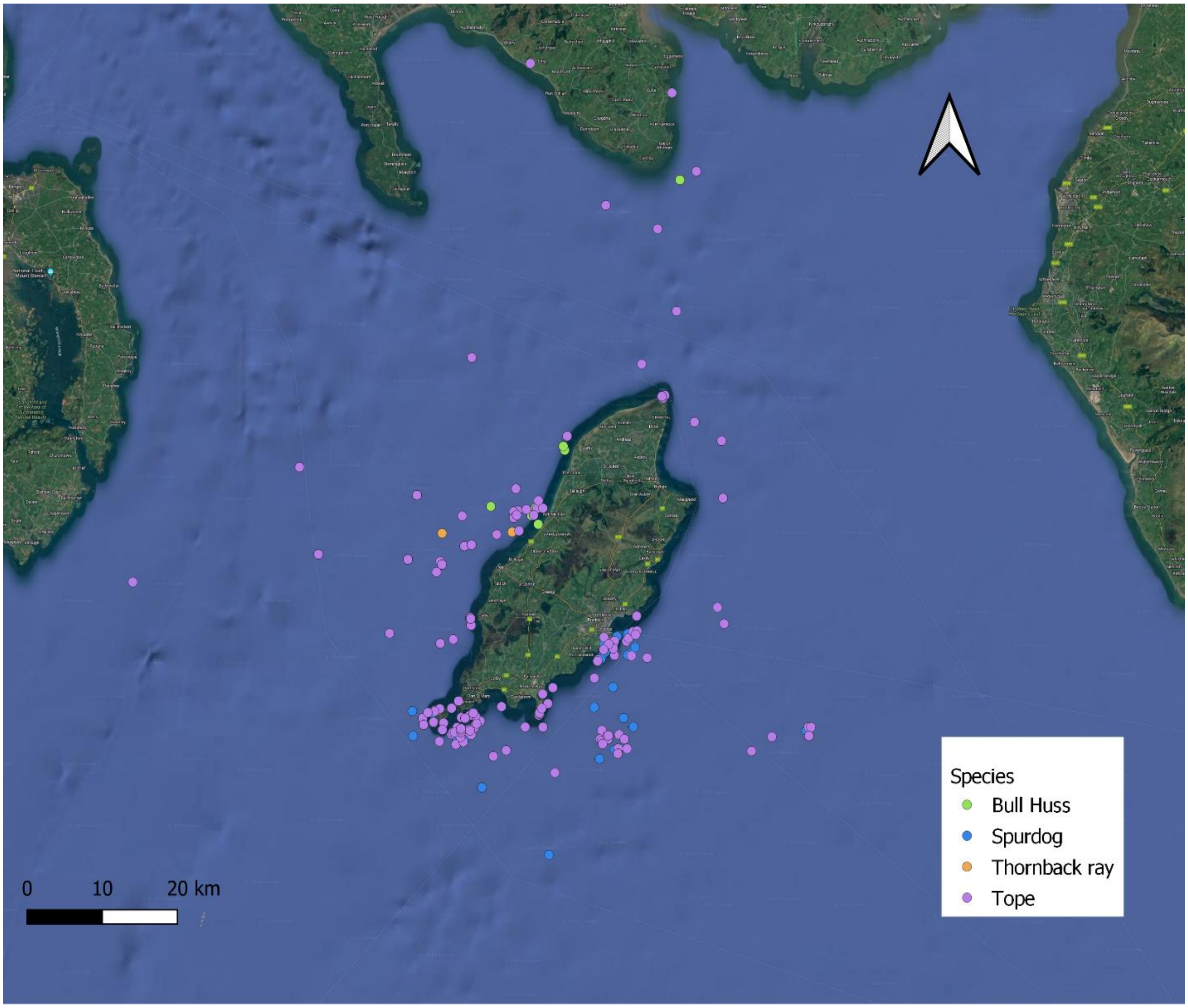

Plate 1. **Tagging Effort and Species Distribution Around the Ise of Man**. Map showing tagging efforts (N=541) around the island, with Bull Huss (green), Spurdog (blue), Thornback ray (orange), and Tope (purple) concentrated mainly in the southern and eastern regions.

4.1 Tope *(Galeorhinus galeus)*

The data from the present study indicates an average length of 140.45 cm and a mean calculated mass of 12.51kg. For males, the average length was recorded at 130.33 cm TL, with a predicted age of 15.1 years, indicating a mature population, given that maturity is reached at 121 cm TL and 12-17 years (Vooren and Ferreira, 1991; Francis and Mulligan, 1998). The analysis shows that females, with an average length of 143.72cm, are nearing the 50% maturity threshold, which is typically around 155 cm TL in the Northeast Atlantic (Dureuil, 2013). Interestingly, despite not reaching this threshold length, the average predicted age of 18.2 years (von Bertalanffy growth curve; Dureuil, 2013) suggests that these females are mature, given that the age of maturity for tope females ranges from 10 to 15 years. Although the tagged individuals are generally smaller than the 50% maturity threshold, they are still considered mature based on their mean age. The reason for this discrepancy is unclear, but it may indicate that tope sharks are maturing at a smaller size due to factors such as fishing pressure or environmental changes. This pattern is consistent with other species, like the northern cod, where fishing pressure has led to earlier maturation in smaller individuals (Olsen *et al.*, 2004). To confirm whether this is a fisheries pressure-related phenomenon, future studies should include blood sample analysis to further investigate the estimated length of maturity.

The trend of a steadily increasing average number of tagged females, contrasted with the more variable annual number of tagged males, suggests that females may predominantly use Manx waters as a potential nursery ground; however, more evidence is needed to confirm this hypothesis. The tagging periods, primarily between June and October, coincide with the pupping season (early spring and summer), supporting the idea that these waters may play a significant role in the reproductive cycle of tope sharks (Capapé *et al.*, 2005; Walker et al., 2006).

The sex distribution, with females comprising 74.68% of the tagged population and males 25.32%, aligns with known patterns of partial segregation by size and sex in tope sharks (Walker *et al.,* 2008). This segregation might explain the observed differences in tagging data, suggesting that males and females occupy different depths or areas in Manx waters (Watson and Howe, 2022).

The trends in tagging (Figure 19) reveal variability in consistency, with less consistent tagging from 2006 to 2011, potentially due to coordination with the STP. A significant increase in the number of individuals tagged in 2022 and 2023 could indicate either an increase in tagging efforts or a higher presence of tope around southern IoM.

There are discrepancies in predicted mass estimations (Table 2), particularly for smaller tope (length <100cm), where the Bayesian formula tended to underestimate mass. This discrepancy suggests potential biases in the formula or measurement errors. For example, it is unlikely that a 51cm tope weighs 9.07kg, indicating a probable data recording error. Most discrepancies with the largest predicted and recorded mass differences occurred before the MWT SSTP commenced, during coordination with the STP. This period likely involved resolving tagging and recording methodologies. Once the MWT SSTP was established, the predicted and recorded mass became more consistent, overall indicating a healthy population. Two individuals (22132 and 21741) appeared underweight based on the Bayesian formula compared to their recorded mass, possibly due to recording errors or malnourishment. The analysis also revealed significant clustering of recorded mass around the 140-160 cm length range (Figure 14), reflecting a common size class within the population and indicating mature and healthy individuals.

The length-mass relationship analysis revealed that the linear regression model provided more predictive results for males ($R^2 = 0.7827$) than for females ($R^2 = 0.6036$) for tope sharks larger than 95cm. However, this could be influenced by the unequal sample size, with 99 females and only 10 males analysed. For sharks smaller than 95cm, the relationship remains moderately strong for females ($R^2 = 0.6279$), though there is insufficient data to draw reliable conclusions for males in this category. These findings underscore the importance of collecting more comprehensive data, particularly for smaller sharks and males, to better understand growth dynamics and improve the accuracy of length-mass models.

Table 6. **Summary Table of Reproductive and Morphological Characteristics of Tope (*Galeorhinus galeus*) and Spurdog (*Squalus acanthias*) in the Present Study**. Summary of key reproductive traits, maturity parameters, and morphometric data for Tope and Spurdog, including comparisons with findings from the current study and established literature.

Species	Pup Litter	Characteristics	Present Study
Tope (*Galeorhinus galeus*)	Average litter of 20 to 35 pups (Ebert, 2003)	**Breeding**: once a year to triannual (Walker *et al*., 2006; Ebert *et al*., 2013). **Ovulation**: early summer (Capapé *et al*., 2005; Walker *et al*., 2006). **Parturition**: spring and early summer (Capapé *et al*., 2005; Walker *et al*., 2006). **Gestation**: 12 months (Capapé *et al*., 2005; Walker *et al*., 2006). **Maturity Size:** Females: 155 cm TL, Males: 121 com TL (Dureuil, 2013) **Maturity Age:** Females: 10-15 years; Males: 12-17 years (Vooren and Ferreira, 1991; Francis and Mulligan, 1998).	**Average age class (N=376)**: 15.1-20 years (41.4%) **Average predicted age:** Female (N=284): 18.2 years Male (N=92): 15.1 years **Average length (TL)**: Overall (N=376): 140.45 cm Female (N=284): 143.72 cm Male (N=92): 130.33 cm **Average width**: Overall (N=337): 50.65 cm Female (N=268): 52.03 cm Male (N=69): 45.30 cm **Average predicted mean mass**: Overall (N=376): 13.56 kg Female (N=284): 14.41 kg Male (N=92): 10.93 kg
Spurdog (*Squalus acanthias*)	Average litter of ~16 pups (Gauld, 1979; Henderson *et al*., 2002)	**Breeding**: every two years (Holden and Meadows, 1962; Sosinski, 1978; Fahy, 1989). **Ovulation**: winter (between December and January) (Compagno, 1990). **Parturition**: August to December/January (Holden and Meadows, 1962; A. Henderson *et al*., 2002). **Gestation**: 18-24 months (Compagno, 1990). **Maturity Size:** Females: 74 - 92.5 cm TL;	**Average age class (N=165)**: 5.1-10 years (85.5%) **Average predicted age:** Female (N=160): 6.1 years Male (N=10): 4.7 years **Average length**: Overall (N=170): 97.04 cm Female (N=160): 98.40 cm Male (N=10): 77.40 cm **Average width**: Overall (N=165): 34.46 cm Female (N=154): 34.94 cm Male (N=10): 27 cm **Average mean calculated mass**: Overall (N=171): 2.72 kg

		Males: 57.5 - 64 cm TL (Henderson *et al.*, 2002; Pawson and Ellis, 2005). **Maturity Age:** Females: 10-20 years; Males: 11+ years (Compagno, 1984).	Female (N=154): 2.80 kg Male (N=10): 1.44 kg

4.2 Spurdog *(Squalus acanthias)*

The data from the present study indicate that the average spurdog length is 97.04 cm, with females averaging 98.40 cm. Given that the maturity size for spurdogs ranges from 74- 92.5 cm TL for females (Henderson *et al.*, 2002; Pawson and Ellis, 2005), this suggests that the tagged individuals are predominantly mature females. However, the length-age data presents a conflicting picture, with 85.5% of individuals falling within the 5.1-10 year age class, which under length-age predictions indicates that these are not yet mature females and males. Females are typically considered mature at 10-20 years of age and males at 11 years or older (Compagno, 1984), suggesting that the population is predominantly juvenile. Modelling data from this study further indicates that individuals 100 cm and below correspond to an age range of 2-6.4 years, which are considered juvenile.

According to ICES guidelines, spurdogs below 100cm can be landed, which, based on this study's data, suggests that all landed spurdogs would be juveniles. While this may be sustainable in the short term, given the recovering Northeast Atlantic stock, it is crucial to maintain strict quotas and closely monitor the population to ensure that enough juveniles are left to mature and sustain the species. The observed juvenile dominance in the population indicates successful recruitment, meaning that new young individuals are entering and surviving within the population. A healthy and sustainable population structure includes a strong representation of younger age classes, ensuring continuity as these individuals mature and eventually reproduce.

The EU's regulatory changes, particularly the introduction of a 100 cm maximum landing size in 2009, have likely contributed to this recovery. This regulation protects larger, mature individuals from being caught, allowing them to contribute to the gene pool and sustain the population through reproduction. As larger, mature spurdogs are often the most fertile, their protection is crucial for the long-term stability of the species. Thus, the observed juvenile dominance, along with protective regulations, suggests that the population is not only stable but potentially increasing. These regulations likely prevent the overfishing of mature individuals, ensuring that enough adults remain to breed and support population growth. The recent decision by the UK and EU to reopen the fishery for 2023 and 2024 seems supported by this data. However, continued monitoring and adherence to landing limits are essential to ensure that the population continues to recover and that mature individuals are not overexploited.

As evidenced in Figure 20, the mass distribution of spurdogs shows that 66% are larger individuals (approaching 10kg or more), while 34% are smaller, weighing less than 5 kg. The study also highlighted discrepancies between predicted mean mass and actual recorded mass, similar to findings for tope sharks. This discrepancy, especially given the limited sample size of only four individuals with both length and mass measurements, suggests potential inaccuracies in mass estimations or recording, or variability in individual spurdog conditions.

The analysis of the length-width relationship for spurdog reveals significant differences in the strength of this relationship between males and females. For females, the R^2 value of 0.4306 indicates a moderate correlation between length and width, suggesting that other factors may also contribute to width variation. In contrast, the R^2 value for males is higher at 0.6894, indicating a stronger correlation, possibly due to the smaller sample size resulting in a more pronounced linear relationship.

4.3 Fisheries Recommendations

Managing fisheries and promoting sustainable practices align with the IoM's First Biodiversity Strategy (2015-2025), which includes the goal that "*By 2025, demonstrate that all marine fishing activity and aquaculture, whether commercial or recreational, is sustainable based on the ecosystem approach*". The ecosystem approach, as defined by the Convention on Biological Diversity (CBD), is a "*strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way. It recognises that humans, with our cultural diversity, are an integral component of ecosystems*".

The study's findings reveal notable differences in the life history and population structure of tope and spurdog sharks around Manx waters. The tope population is characterised by a significant proportion of mature individuals, as suggested by their average age, despite being slightly below the typical size threshold for maturity. In contrast, the spurdog population predominantly comprises juveniles, as indicated by both age and length data. These distinct population structures suggest the need for tailored management strategies for each species, considering the higher maturity levels in tope sharks and the younger demographic observed in spurdogs.

For spurdog, the existing EU measures such as a 100cm maximum landing size, appear to be effective, as indicated by the population's recovery and the significant presence of juveniles. It is important that these regulations continue to be enforced rigorously, with close monitoring to prevent premature reopening of fisheries from undoing the conservation gains achieved so far. As the population continues to recover, implementing seasonal closures could further support these efforts. According to the ICES OSPAR Assessment (2021), spurdog status within Region IV (Figure 10) is still considered poor, with the last comprehensive OSPAR assessment conducted over a decade ago (ICES, 2018). In addition, most of the population tagged within Manx waters, with an average age of 5.1-10 years (85.5%), falls within the harvestable range as defined by ICES (2022). Despite indications that the Northeast Atlantic stock has improved over the past decade, the population remains low compared to historic levels, and bycatch continues to pose a significant threat (ICES, 2022).

In contrast, there is an absence of specific fisheries management for tope, management recommendations include implementing size limits to protect larger, breeding females and establishing seasonal closures during peak breeding periods to safeguard reproductive individuals (Hooker and Gerber, 2004; Chilvers, 2008; White and Kyne, 2010). Further work is required to evaluate the benefits of these measures, including determining the size ranges where tope can be fished sustainably and identifying the most effective timing for seasonal closures through consultation with stakeholders and fisheries management. Additionally, setting catch quotas could help maintain a healthy population by maintaining a balanced age structure within the population. Improving data accuracy on smaller sharks would also contribute to sustainable fisheries management.

Establishing a MPA targeting small sharks in Manx waters could provide important benefits beyond what traditional fisheries management offers. MPAs protect critical habitats essential for survival and reproduction, offering a more holistic approach that encompasses entire ecosystems rather than just regulating catches and accounts for the complex ecological interactions within marine ecosystems (Lester *et al*., 2009; Bond *et al*., 2012; Heupel *et al*., 2014). Additionally, MPAs can create spill-over effects, where protected populations expand into adjacent areas, potentially boosting local fisheries (Gell & Roberts, 2003; Lester *et al*., 2009). Although current tagging data shows an abundance of small sharks in the southern waters of the IoM, establishing an MPA solely based on current data may overlook the potential future importance of northern regions. Future planning should also consider climate change impacts, which may shift shark populations northward, requiring predictive models and adaptive management strategies (Hooker and Gerber, 2004; Dulvy *et al*., 2008, McLeod et al., 2009; Edgar *et al*., 2014). While fisheries management can regulate specific threats, MPAs provide broader protection, helping ensure the long-term sustainability of shark populations and marine ecosystems (Davidson and Dullvy, 2017; Dulvy *et al*., 2017; Gaines *et al*., 2010).

4.4 SSTP Recommendations

To enhance the effectiveness SSTP, several critical recommendations should be considered. First, the programme should transition towards incorporating telemetry studies, including the use of acoustic and satellite tags, to address the limitations of traditional tagging methods (Hammerschlag *et al.*, 2011b; Carlson *et al.*, 2014; Renshaw *et al.*, 2023). The current recapture rate of only seven individuals over a ten-year period underscores the need for more advanced tracking techniques, which would provide more robust data on shark migration patterns and behaviour (Matley *et al.*, 2022, 2023). Additionally, to improve the likelihood of recaptures, it is recommended that the programme implement an incentive system for anglers (Taylor *et al*., 2022). Offering rewards, such as recognition, merchandise, or financial incentives, could boost participation and data collection in tagging programs (Taylor *et al*., 2006, 2022). Ethical concerns, including the risk of incentivising inaccurate or biased data reporting and the possibility of participants engaging for rewards rather than genuine scientific contribution, must be carefully managed to ensure that the integrity of the study is not compromised (Jenkins *et al*., 2000; Taylor *et al*., 2022). Evidence from successful initiatives (i.e. CSTP and the FACT Network) suggests that ethically implemented rewards can effectively motivate participants while maintaining data integrity (Dunlop *et al*., 2013; Kohler and Turner, 2018, Young *et al*., 2020).

While the expansion into advanced tagging technologies such as PSATs and satellite tags is a promising future direction, it is recognised that financial constraints may make immediate investment challenging. In the short term, upscaling current programme using the current micro-tags, particularly in under-represented northern areas, and incorporating new analytical techniques can significantly enhance the understanding of species' spatial distribution, improve population estimates, support the development of more effective and data-driven conservation strategies while providing crucial baseline data for future studies.

When funding becomes available, it may be advisable to consider investing in a limited number of advanced tags, such as 3-4 PSATs or satellite tags, to assess their efficacy within the specific research context. While these advanced tags offer cutting-edge tracking capabilities, they are associated with significant costs, typically ranging from $3,000 to $5,000 per tag, which also limits their widespread use (Berrow and O'Connor, 2013; Whoriskey and Hindell, 2016).

It is imperative that the programme ensures the consistent and accurate recording of key biometric data, including mass, length, sex, location, and width for all tagged individuals. These metrics are not only essential for understanding population dynamics but are also critical inputs for reliable population modelling. This can be facilitated by utilising smartphone applications (apps) to document fishing trips and catches can significantly streamline data collection, making it more consistent, accurate, and facilitate data-sharing (Garvy, 2015; Venturelli *et al*., 2016).

Furthermore, accurate determination of maturity and sex is crucial for the interpretation of population metrics. The programme should consider the collection of blood samples to verify age, particularly considering conflicting evidence from predictive models regarding length and mass. This additional data could enhance the precision of maturity assessments and support more informed conclusions.

Environmental monitoring should be integrated into the tagging programme to account for external factors that may influence shark populations. Regular recording of variables such as water temperature, salinity, and habitat changes (including plankton blooms, pollution events, and areas of high tourist activity) would provide valuable context for interpreting tagging data and understanding broader ecological impacts. Additionally, the programme must address the apparent lack of mortality reporting. Establishing a protocol for recording mortality events is essential to assess the impact of tagging on shark survival and to refine methodologies to minimise harm.

Engagement with local communities is crucial for increasing public awareness and support for conservation programmes (Falk *et al*., 2007; Ballantyne *et al*., 2011). Educational workshops for both adults and children can foster a deeper understanding of shark ecology and conservation (Falk *et al*., 2007). Additionally, leveraging social media, news outlets, and educational materials can help disseminate information widely (Brossard & Scheufele, 2013; Bergman *et al*., 2022). However, while such initiatives have been successful in other conservation efforts, like the "Adopt a Dolphin" programme by the Whale and Dolphin Conservation Society (Ocean Conservation Society, 2024), they come with challenges. Significant time investment is needed to organise and maintain these programmes, requiring dedicated staff and resources (Waylen *et al*., 2010; Brooks *et al*., 2012). Furthermore, public perception may vary, with some viewing the initiatives as more commercial than conservation-driven, potentially undermining their credibility (Smith *et al*., 2009; Leader-Williams *et al.,* 2011). These potential drawbacks should be carefully considered, and strategies should be developed to address them effectively.

Lastly, establishing collaborations with universities, research institutions, and conservation organisations is crucial for enhancing the programme's scientific capabilities. These partnerships would facilitate the sharing of resources, data, and expertise, ensuring that the programme remains at the forefront of shark research and conservation. By implementing these scientifically grounded recommendations, the shark tagging programme can significantly improve its data quality, expand its research impact, and contribute more effectively to the long-term conservation of shark populations.

4.5 Future Studies

Future research should build on the findings of this study by exploring several key areas to enhance the understanding and conservation of small shark species in the IoM's waters. One critical area is the integration of GIS mapping with other datasets, such as environmental variables and historical catch data, which would refine and optimise the overall tagging strategy. This multilateral approach would allow for a deeper analysis of shark distribution and behaviour, aiding in the development of more effective conservation measures.

For both species, there is a pressing need to address the robustness of input data used in assessments, particularly given the lack of reliable catch data. Future studies should focus on updating growth parameters and providing more accurate estimates of natural mortality. Additionally, identifying the locations and significance of pupping and nursery grounds is essential for effective spatial management of this species. Utilising shark egg case data can serve as an efficient initial step in identifying potential correlations. Further research into the impacts of pollutants and habitat degradation on spurdog populations will also be critical in informing conservation efforts.

Another important area for future research is the investigation of shark responses and abundance in relation to abiotic factors, such as temperature, especially in the context of climate change. Spurdogs are known to favour a temperature range between 7 to 15°C (Compagno, 1984), and tope a range between 6.7 to 23°C (Froese, 2020). Understanding how their migration patterns and temperature preferences interact with changing climate conditions could provide valuable insights into their future distribution and abundance.

Exploring the underrepresented northern part of the IoM is also necessary to gain a more complete understanding of shark distribution across the region. This could fill current knowledge gaps caused by the focus on areas of known shark abundance. Additionally, future research should aim to strengthen collaborations with other shark tagging programmes in the Northeast Atlantic. Sharing data and insights across regions could lead to more robust findings and help in the development of broader conservation strategies.

Finally, creating public guidance notes and educational materials, such as the infographics produced for the MWT SSTP and displayed in Appendix XV, XVI, and XVII, could help raise awareness and support for shark conservation. This would also facilitate the dissemination of best practices in commercial fishing and other activities that impact shark populations. By addressing these areas, future studies can significantly contribute to the ongoing efforts to protect and conserve shark species in Manx waters and beyond.

5. SWOT Analysis

The SWOT analysis gives a clear view of the study's strengths, weaknesses, opportunities, and threats, summarising key points about the research.

Strengths

- The study uses a solid foundation of a decade's worth of tagging data and reviews global shark tagging instruments.
- The findings are directly useful to the MWT and can have a real impact on local conservation efforts.
- The involvement of citizen science through the SSTP highlights the value of working with local communities and anglers.
- The study bridges the gap between research and real-world conservation by combining ecological analysis with policy recommendations.
- Modelling age and mass for tope and spurdog adds to the baseline knowledge of these species in Manx waters, helping future studies.
- The study provides a strong starting point for future research and offers valuable data for stakeholders like MWT and DEFA.

Weaknesses

- The tight timeline (May 14th to August 14th) limited how deep the analysis could go.
- There was no chance to visit the IoM, meet stakeholders or anglers in person, or take part in the tagging process, which could have added important context.
- The data is biased, as it was collected in areas with known shark abundance, so it doesn't fully represent the entire shark population.
- There was missing data (i.e. weight).
- The recommendations may not be easily applied to other shark tagging programmes.

Opportunities

- The literature review brings attention to gaps in knowledge and points out areas needing more research.
- Future studies could dive into advanced tagging techniques, GIS mapping, and long-term monitoring to better understand shark behaviour and migration.
- The study's infographic can be shared on the MWT's website and social media to spread the word about the programme.
- There's an opportunity to create educational materials in Manx Gaelic, expanding the reach of conservation efforts. Additionally, a Guidance Note can also be made to aid anglers in sustainable fisheries for small sharks around the island.
- Collaborating with universities, conservation groups, and tech companies could improve future research through better data collection and analysis.
- The findings could help push for stronger regulations and more Marine Protected Areas (MPAs).
- Adding environmental factors like temperature and salinity to the analysis could refine population abundance models.
- Exploring the less-studied northern part of the IoM could provide new insights.
- Counting mermaid purses could help investigate the idea that these waters are nursery areas.
- Modelling future MPA sites with climate change in mind could guide conservation efforts.
- Partnering with other shark tagging programmes in the NE Atlantic could lead to better data sharing and insights.

Threats

- There's a risk that the MWT or other stakeholders might not fully take on the study's recommendations, which could limit its impact.
- Environmental changes like climate change, habitat loss, and overfishing could make conservation efforts less effective.

- Inconsistent or changing regulations, like reopening fisheries, might undo some of the positive effects of the research.
- Persistent data gaps, especially for less-studied species and age groups, could make it harder to develop strong conservation strategies.

6. Conclusion

The findings of this study provide valuable insights into the life history and population structure of tope and spurdog sharks around the Isle of Man. The data suggest that the tope population is predominantly mature, with an average length of 140.45 cm and an average predicted age of 18.2 years, despite being below the 50 % maturity threshold typically observed in the Northeast Atlantic. This indicates that tope sharks in these waters may be maturing at smaller sizes, potentially due to environmental factors or fishing pressures. In contrast, the spurdog population appears to be primarily juvenile, with 85.5 % of individuals falling within the 5.1-10 year age class, despite their lengths suggesting maturity. This discrepancy highlights the importance of considering both length and age data when assessing the maturity and sustainability of shark populations.

The broader implications of this research are significant, as the data gathered can inform both local and global conservation efforts. Locally, the findings underscore the need for more robust fisheries management practices, including the implementation of size limits, catch quotas, and seasonal closures to protect breeding individuals and maintain population balance. Globally, the study enhances the understanding of shark conservation, offering data that could be useful for similar initiatives in other regions. The establishment of MPAs based on these findings could also help enhance local biodiversity and promote sustainable tourism.

The study faced some limitations, including a sample size that may not fully represent the overall population. Additionally, gaps in the dataset, such as missing weight measurements and insufficient data for bull huss and thornback ray, limited the scope of the analysis. Despite these challenges, the results provide a strong foundation for future research and conservation efforts. The observed trends in tope and spurdog populations offer valuable insights for developing targeted conservation strategies, ensuring the long-term viability of these species in Manx waters.

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Appendix

Appendix I. Literature excluded from the species ranking frequency list (Figure 6).

Table 1. **List of Literature Excluded from the Elasmobranch Species Ranking.** Summary of the literature excluded (N=46) due to difficulties in extracting species-specific data when comprising the comprehensive analysis of elasmobranch species frequency per publication. Three review articles (highlighted in yellow) were included in the analysis and the top three shark species from each review were incorporated into the list.

Title	Year	Author
An assessment of tag-and-release in the northeast region.	1990	Tiedemann, John
Increasing Angler Participation In Marine Catch/tag-And-Release Fishing Programs: Workshop Summary, Program Outlines, And Angler Survey Results	1991	Lucy, Jon
Southern Shark Tag Database Project	2000	Walker, Terence
Electronic Tagging and Tracking in Marine Fisheries	2001	Sibert
Shark tagging: a review of conventional methods and studies	2001	Kohler and Turner
Tagging Methods for Stock Assessment and Research in Fisheries	2002	Thorsteinsson
Physiological Ecology in the 21st Century: Advancements in Biologging Science	2005	Block, Barbara
Stock Identity of Elasmobranchs in the Northeast Atlantic in Relation to Assessment and Management	2005	Pawson and Ellis
Passive Acoustic Telemetry Technology: Current Applications and Future Directions	2005	Heupel, Michelle

Automated acoustic tracking of aquatic animals: scales, design and deployment of listening station arrays	2006	Heupel, Michelle
Measuring devices on wild animals: what constitutes acceptable practice?	2006	Wilson and McMahon
Emerging Technologies for Reef Fisheries Research and Management	2006	Taylor, Christopher
Why do Argos satellite tags deployed on marine animals stop transmitting?	2007	Hays
Enhancing catch-and-release science with biotelemetry	2008	Donaldson, Michael
Tools for Studying Biological Marine Ecosystem Interactions—Natural and Artificial Tags	2009	Gillanders
Advances in conservation oceanography: new tagging and tracking technologies and their potential for transforming the science underlying fisheries management	2009	Greene
Tracking and Analysis Techniques for Understanding Free-Ranging Shark Movements and Behavior	2010	Sims
Biologging technologies: new tools for conservation. Introduction	2010	Bograd, Steven
Complexities of coastal shark movements and their implications for management	2010	Speed
Electronic tagging of marine animals	2010	Census of Marine Life
A Review of Approaches to Assess Survival of Released Catch from Canadian Large Pelagic Longline Fisheries	2011	Neilson, John
A review of shark satellite tagging studies	2011	Hammerschlag
Considerations for tagging and tracking fish in tropical coastal habitats: lessons from bonefish, barracuda, and sharks tagged with acoustic transmitters	2012	Murchie, Karen
Ontogeny in marine tagging and tracking science: technologies and data gaps	2012	Hazen
A review of the Oceanographic Research Institute's Cooperative Fish Tagging Project: 27 years down the line	2013	Dunlop

Telemetry Analysis of Highly Migratory Species	2014	Galuardi and Lam
Considering the fate of electronic tags: interactions with stakeholders and user responsibility when encountering tagged aquatic animals	2014	Hammerschlag
Making connections in aquatic ecosystems with acoustic telemetry monitoring	2014	Donaldson, Michael
A review of detection range testing in aquatic passive acoustic telemetry studies	2014	Kessel, Steven
Aquatic animal telemetry: A panoramic window into the underwater world	2015	Hussey, Nigel
The use of external electronic tags on fish: an evaluation of tag retention and tagging effects	2015	Jepsen, Niels
Tonic immobility as an anaesthetic for elasmobranchs during surgical implantation procedures	2015	Kessel and Hussey
Using movement data from electronic tags in fisheries stock assessment: A review of models, technology and experimental design	2015	Sipple, Tim
Developments in Tagging Technology and Their Contributions to the Protection of Marine Species at Risk	2016	Whoriskey and Hindell
Comparative assessment of pelagic sampling methods used in marine monitoring.	2018	Bouchet, Phil
Detecting, counting and following the giants of the sea: a review of monitoring methods for aquatic megavertebrates in the Caribbean	2019	Castelblanco-Martínez
The Cooperative Shark Tagging Program (CSTP) Tagging Guide	2019	NOAA's National Marine Fisheries Service
A scalable, satellite-transmitted data product for monitoring high-activity events in mobile aquatic animals	2020	Skuble, Rachel
The FACT Network: Philosophy, Evolution, and Management of a Collaborative Coastal Tracking Network	2020	Young, Joy
Fish identification, marking and tagging methods	2020	Axelsson, Michael

Chapter Two - Discovering marine biodiversity in the 21st century	2022	Rogers, Alex
A biologging database of juvenile white sharks from the northeast Pacific	2022	O'Sullivan, John
Feasibility of tagging deepwater sharks in New Zealand	2022	Finucci
Best practices for catch-and-release shark angling: current scientific understanding and future research	2023	Horton, Thomas
Global tracking of shark movements, behaviour and ecology: A review of the renaissance years of satellite tagging studies, 2010–2020	2023	Renshaw, Samantha
A multi-scale tracking approach for conserving large migratory fish in an open coastal environment	2024	Edwards

Appendix II. List of the literature used to produce the world map showcasing publication regions (Figure 7).

Table 2 . **Reviews Incorporated into the World Map.** List of peer-reviewed reviews (N=21) included in the world map, where the literature explicitly states the locations of the studies. These reviews were selected to ensure accuracy in representing the geographic distribution of experimental research.

Paper Title	Author	Location
Acoustic tracking of a threatened juvenile shark species, the smooth hammerhead (*Sphyrna zygaena*), reveals vulnerability to exploitation at the boundary of a marine reserve	Albano *et al.*, 2023	De Hoop MPA, South Africa
Spatial and ontogenetic variation in growth of nursery-bound juvenile lemon sharks, *Negaprion brevirostris*: a comparison of two age-assigning techniques	Barker *et al.*, 2005	Bimini, Bahamas Marquesas Keys, USA
An Evaluation of Passive Acoustic Monitoring Using Satellite Communication Technology for Near Real-Time Detection of Tagged Animals in a Marine Setting	Bradford *et al.*, 2011	Norfolk Bay, Tasmania North Neptune Islands, South Australia Perth, Western Australia
The Use of Satellite Tags to Redefine Movement Patterns of Spiny Dogfish (*Squalusacanthias*) along the U.S. East Coast: Implications for Fisheries Management	Carlson *et al*., 2014	Gulf of Maine, USA North Carolina, USA
Assessing the importance of Isle of Man waters for the basking shark *Cetorhinus maximus*	Dolton *et al.*, 2020	Isle of Man
Accounting for detection gaps when evaluating reef fish habitat use in an acoustic array	Farmer and Ault, 2018	Florida, USA
Assessing the Movements, Habitat Use, and Site Fidelity of the Giant Freshwater Whipray (*Urogymnus polylepis*) with Acoustic Telemetry in the Maeklong River, Thailand	Haetrakul *et al.*, 2023	Maeklong River, Thailand

Using conventional and pop-up satellite transmitting tags to assess the horizontal movements and habitat use of thorny skate (*Amblyraja radiata*) in the Gulf of Maine	Kneebone *et al.*, 2020	Gulf of Maine, USA
Individual residency behaviours and seasonal long-distance movements in acoustically tagged Caribbean reef sharks in the Cayman Islands	Kohler *et al.*, 2023	Cayman Islands
Movement patterns of a Critically Endangered elasmobranch *(Dipturus intermedius*) in a Marine Protected Area	Lavender *et al.*, 2021	Loch Sunart, Scotland
Behavioural Responses of a Large, Benthic Elasmobranch to Catch-and-Release Angling	Lavender *et al.*, 2022	Loch Sunart, Scotland
To catch or to sight? A comparison of demographic parameter estimates obtained from mark-recapture and mark-resight models	Lee *et al*., 2014	Cabbage Tree Bay Aquatic Reserve, Sydney, Australia
Spatial Dynamics of Tiger Sharks (*Galeocerdo cuvier*) Around Maui and Oahu	Meyer *et al*., 2016	Maui and Oahu, USA
St. Helena: An Important Reproductive Habitat for Whale Sharks *(Rhincodon typus)* in the Central South Atlantic	Perry *et al.*, 2020	Saint Helena
Long-Term Acoustic Monitoring Reveals Site Fidelity, Reproductive Migrations, and Sex Specific Differences in Habitat Use and Migratory Timing in a Large Coastal Shark (*Negaprion acutidens*)	Pillans *et al*., 2021	Ningaloo, Australia
Short-term movements and diving behaviour of satellite-tracked blue sharks Prionace glauca in the northeastern Atlantic Ocean	Queiroz *et al*., 2010	English Channel South Portugal South Azores
Regional-Scale Migrations and Habitat Use of Juvenile Lemon Sharks (*Negaprion brevirostris*) in the US South Atlantic	Reyier *et al*., 2014	Cape Canaveral, USA
Broad-scale movements and pelagic habitat of the dusky shark *Carcharhinus obscurus* off Southern Australia determined using pop-up satellite archival tags	Rogers *et al.*, 2013	Spencer Gulf, Australia

Spatial and temporal movement patterns of a multi-species coastal reef shark aggregation	Speed *et al.*, 2011	Ningaloo, Australia
Winter residency and site association in the Critically Endangered Northeast Atlantic spurdog *Squalus acanthias*	Thorburn *et al.*, 2015	Loch Etive, Scotland
An open spatial capture-recapture framework for estimating the abundance and seasonal dynamics of white sharks at aggregation sites	Winton *et al.*, 2023	Cape Cod, Massachusetts, USA

Appendix III. Literature used to produce publication theme/effort heatmap (Figure 8).

Table 3. **Publications Used to Generate the Heatmap of Shark Species.** List of publications (N=41) used to create the heatmap, excluding literature on rays and skates due to their low publication count and the challenges in categorising them by size

Title	Year	Primary Author
Migrations of Spiny Dogfish, *Squalus acanthias*, and Recapture Success from Tagging in the Newfoundland Area, 1963-65	1984	Templeman, Willfred
Mark-recapture population estimate and movements of Grey Nurse Sharks	2004	Otway and Burke
Spatial and ontogenetic variation in growth of nursery-bound juvenile lemon sharks, *Negaprion brevirostris*: a comparison of two age-assigning techniques	2005	Barker, Michael
Spatial and seasonal distribution patterns of juvenile and adult raggedtooth sharks (*Carcharias taurus*) tagged off the east coast of South Africa	2007	Dicken
Ecology and predator-prey dynamics of Fishes at Palmyra and Kingman Atolls NWR	2008	Friedlander, Alan
Short-term movements and diving behaviour of satellite-tracked blue sharks *Prionace glauca* in the northeastern Atlantic Ocean	2010	Queiroz, Nuno
An Evaluation of Passive Acoustic Monitoring Using Satellite Communication Technology for Near Real-Time Detection of Tagged Animals in a Marine Setting	2011	Bradford
Spatial and temporal movement patterns of a multi-species coastal reef shark aggregation	2011	Speed
Marine Mammals and Megafauna in Irish Waters - Behaviour, Distribution and Habitat Use. Biotelemetry of Marine Megafauna in Irish Waters	2013	Berrow and O'Connor
Broad-scale movements and pelagic habitat of the dusky shark Carcharhinus obscurus off	2013	Rogers, Paul

Southern Australia determined using pop-up satellite archival tags		
A review of the Oceanographic Research Institute's Cooperative Fish Tagging Project: 27 years down the line	2013	Dunlop
The Use of Satellite Tags to Redefine Movement Patterns of Spiny Dogfish (*Squalus acanthias*) along the U.S. East Coast: Implications for Fisheries Management	2014	Carlson, Amy
Regional-Scale Migrations and Habitat Use of Juvenile Lemon Sharks (*Negaprion brevirostris*) in the US South Atlantic	2014	Reyier, Eric
To catch or to sight? A comparison of demographic parameter estimates obtained from mark-recapture and mark-resight models	2014	Lee, A
Incorporating Migration and Local Movement Patterns into Management Strategies for Spiny Dogfish (*Squalus acanthias*)	2015	Cudney, Jennifer
Winter residency and site association in the Critically Endangered Northeast Atlantic spurdog *Squalus acanthias*	2015	Thorburn
Spatial Dynamics of Tiger Sharks (*Galeocerdo cuvier*) Around Maui and Oahu	2016	Meyer, Carl
Integrating citizen science and telemetry techniques in understanding the movement patterns of the whale shark (*Rhincodon typus*)	2016	Norman, Bradly
Exploring the murky world of the sevengill shark, *Notorynchus cepedianus*, in southern New Zealand	2016	Housiaux, Jordan
Seasonal migration of the starry smooth-hound shark *Mustelus asterias* as revealed from tag-recapture data of an angler-led tagging programme	2016	Breve
Accounting for detection gaps when evaluating reef fish habitat use in an acoustic array	2018	Farmer and Ault

Biology, Movement Behaviour and Spatial Dynamics of An Exploited Population of Smoothhound Shark *Mustelus Mustelus* Around a Coastal Marine Protected Area in South Africa	2018	da Silva, Charlene
Predicting habitat suitability for basking sharks (*Cetorhinus maximus*) in UK waters using ensemble ecological niche modelling	2019	Austin, Rebecca
Evaluating vital components of elasmobranch assessment and spatial conservation	2019	Dureuil, Manuel
Assessing the importance of Isle of Man waters for the basking shark *Cetorhinus maximus*	2020	Dolton, Haley
St. Helena: An Important Reproductive Habitat for Whale Sharks *(Rhincodon typus)* in the Central South Atlantic	2020	Perry, Cameron
Novel Tools and Techniques to Investigate and Reduce the Impacts of Capture-and-Handling	2020	Knotek, Ryan
Using conventional and pop-up satellite transmitting tags to assess the horizontal movements and habitat use of thorny skate (*Amblyraja radiata*) in the Gulf of Maine	2020	Kneebone, Jeff
Movements and growth rates of the broadnose sevengill shark *Notorynchus cepedianus* in southern Africa: results from a long-term cooperative tagging programme	2020	Engelbrecht
Long-Term Acoustic Monitoring Reveals Site Fidelity, Reproductive Migrations, and Sex Specific Differences in Habitat Use and Migratory Timing in a Large Coastal Shark (*Negaprion acutidens*)	2021	Pillans, Richard
Shedding rates and retention performance of conventional dart tags in large pelagic sharks: Insights from a double-tagging experiment on blue shark (*Prionace glauca*)	2022	Mas, Frederico
The Isle of Man Shark Tagging Programme	2022	Watson and Howe
Estimated life-history traits and movements of the Caribbean reef shark (*Carcharhinus*	2022	Talwar, Brendan

perezi) in The Bahamas based on tag-recapture data		
Diving into the vertical dimension of elasmobranch movement ecology	2022	Andrzejaczek, Samantha
Assessing the Movements, Habitat Use, and Site Fidelity of the Giant Freshwater Whipray (*Urogymnus polylepis*) with Acoustic Telemetry in the Maeklong River, Thailand	2023	Haetrakul
An open spatial capture-recapture framework for estimating the abundance and seasonal dynamics of white sharks at aggregation sites	2023	Winton
Acoustic tracking of a threatened juvenile shark species, the smooth hammerhead (*Sphyrna zygaena*), reveals vulnerability to exploitation at the boundary of a marine reserve	2023	Albano, Patricia
The Biology and Ecology of Mesopredatory Sharks Revealed Through a Multidisciplinary Approach	2023	Burke, Patrick
Individual residency behaviours and seasonal long-distance movements in acoustically tagged Caribbean reef sharks in the Cayman Islands	2023	Kohler, Joanna
Acoustic Telemetry Suggests the Lesser Spotted Dogfish *Scyliorhinus canicula* Stays and Uses Habitats within a French Offshore Wind Farm	2024	Labourgade, Pierre
Using Satellite Tagging Technologies to Improve Management and Conservation of the Northwest Atlantic Porbeagle Shark *Lamna nasus*	2024	Anderson, Brooke

Appendix IV. Von Bertalanffy Growth Curves for tope (male and female).

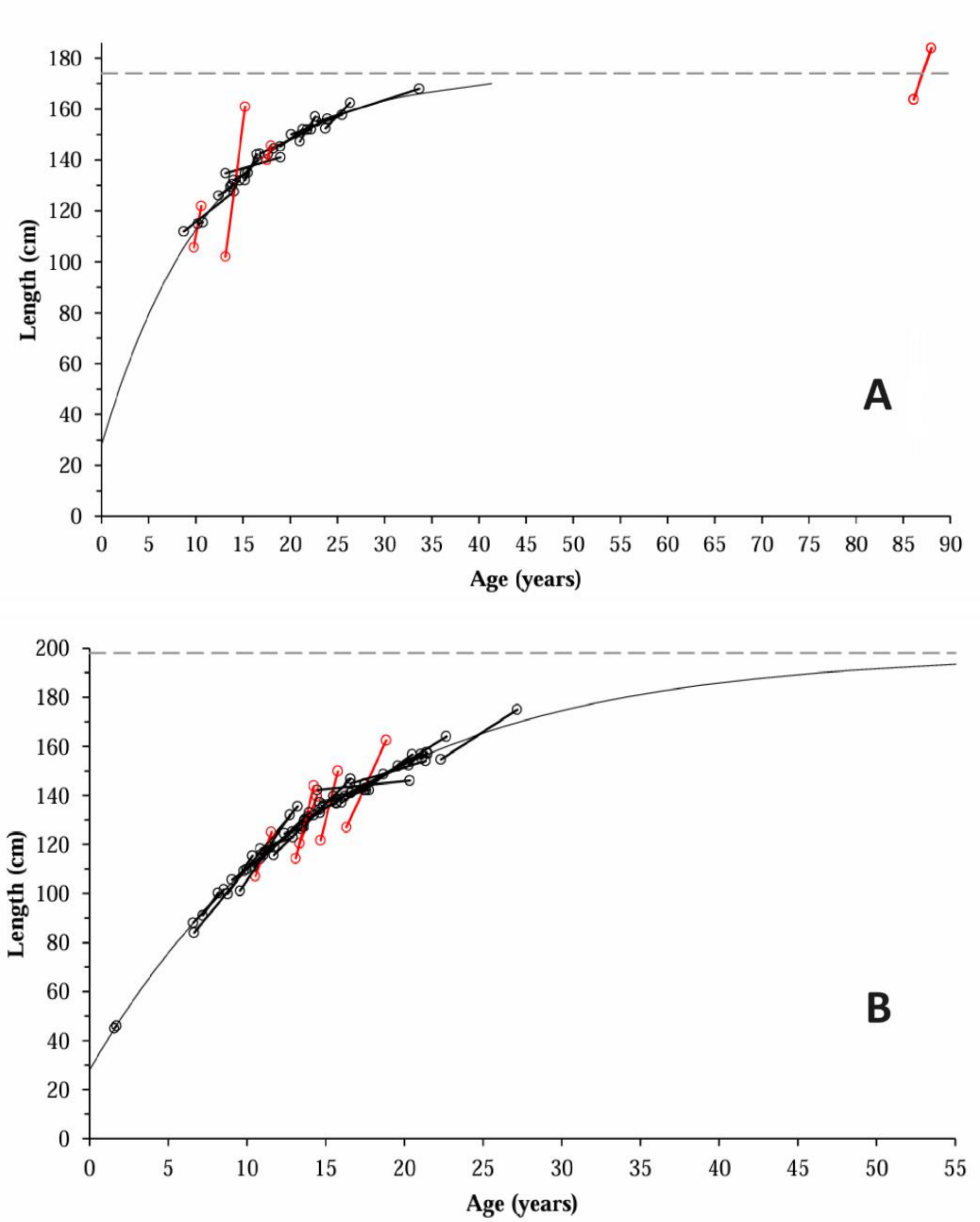


Figure 1. **Von Bertalanffy Growth Curves for Male and Female Tope *(Galeorhinus galeus)* Sharks in the Northeast Atlantic** (Adapted from Dureuil, 2013). (A) Von Bertalanffy growth curve for male Tope sharks in the Northeast Atlantic. (B) Von Bertalanffy growth curve for female Tope sharks in the Northeast Atlantic. This figure is adapted from Dureuil (2013) and is used to estimate the age and growth patterns of Tope sharks in the region.

Appendix V. Von Bertalanffy Growth Curves for spurdog (male and female).

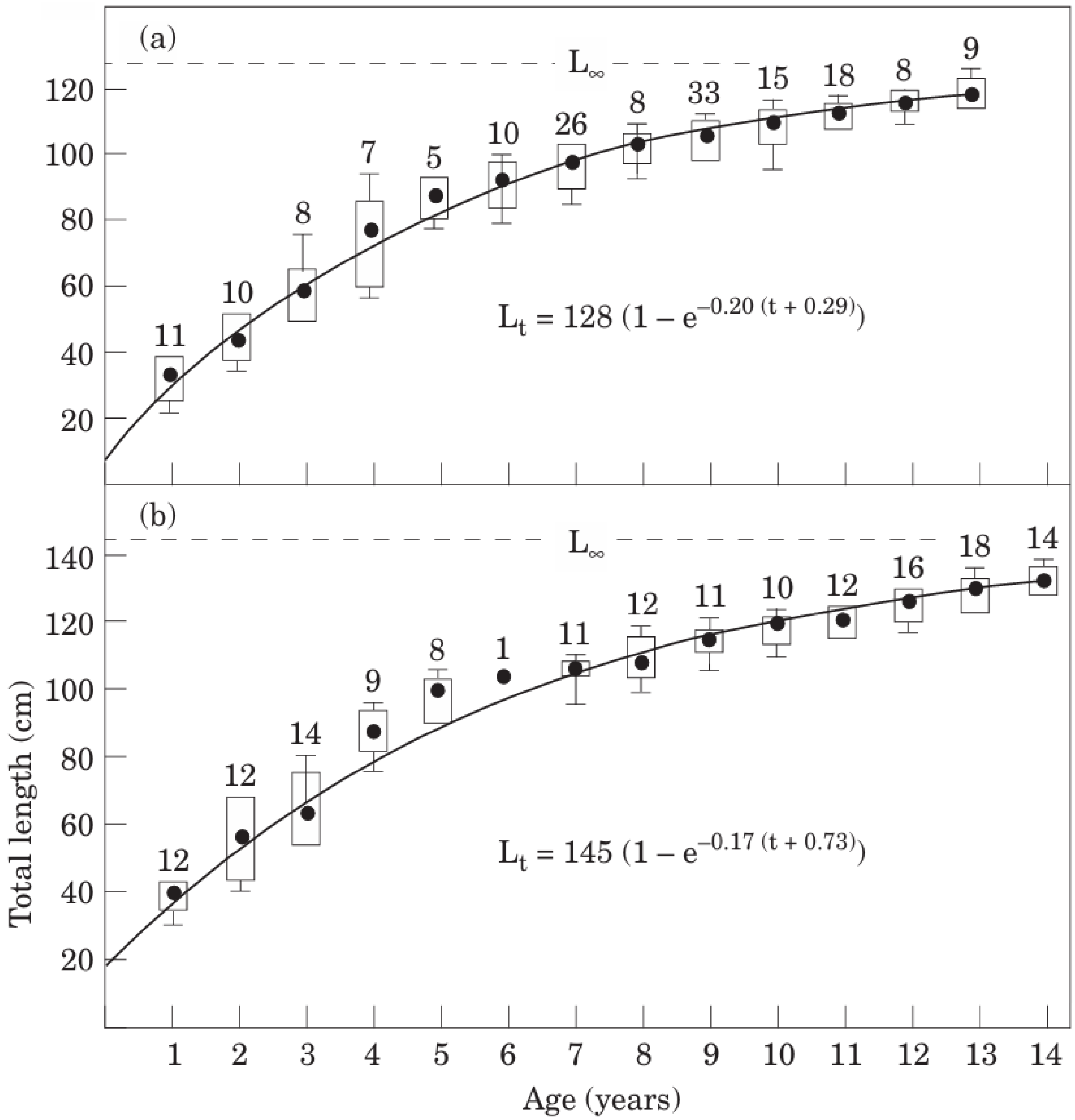
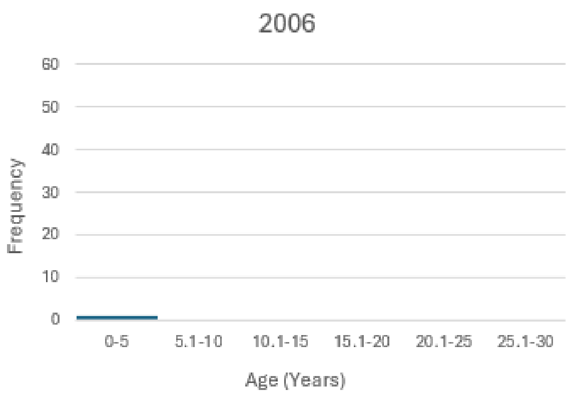
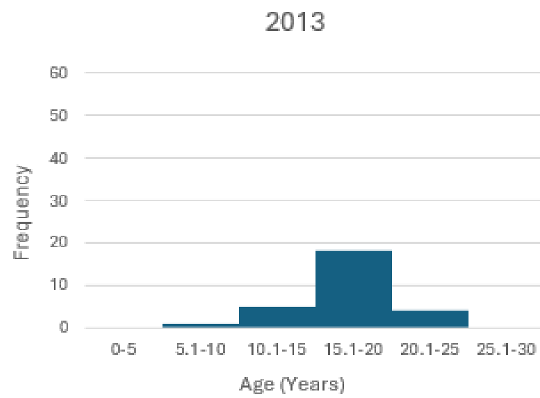
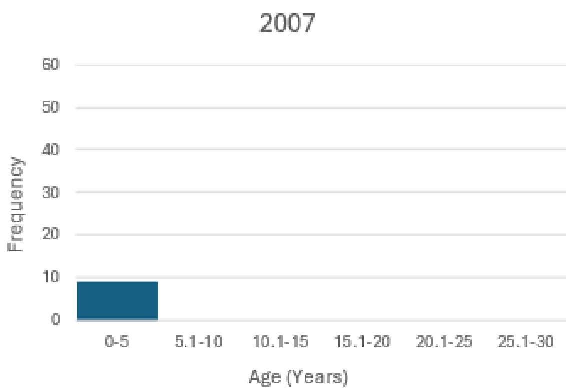


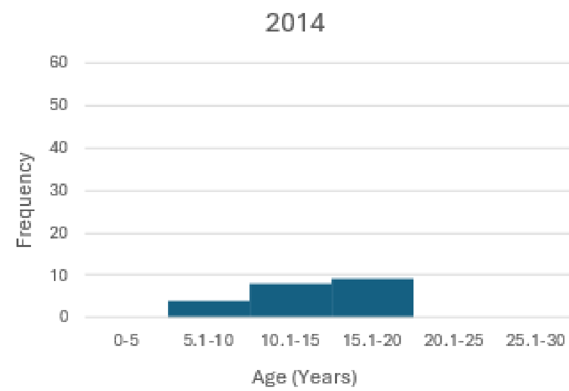
Figure 2. **Von Bertalanffy Growth Curves for Male and Female Spurdog *(Squalus acanthias*) in the Southeast Black Sea** (Adapted from Avsar, 2001). (A) Von Bertalanffy growth curve in length for male Spurdog in the Southeast Black Sea. (B) Von Bertalanffy growth curve in length for female Spurdog in the Southeast Black Sea. This figure is adapted from Avsar (2001) and is used to estimate the growth patterns of Spurdog in this region.

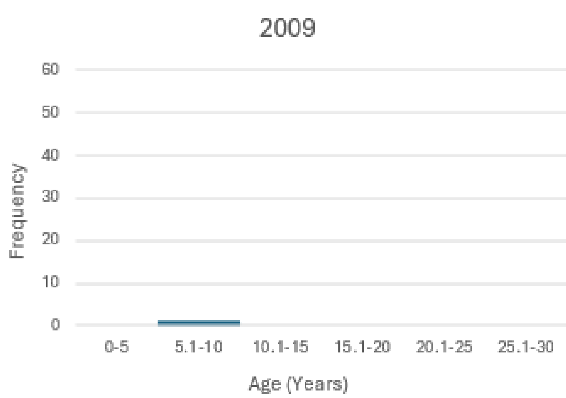
Appendix VI. Histogram time-series showing age distribution for tope from 2006 to 2023.

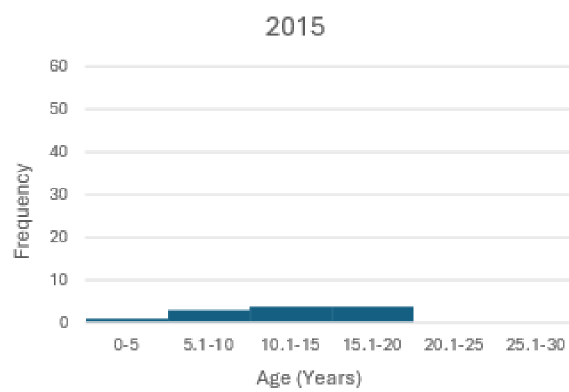


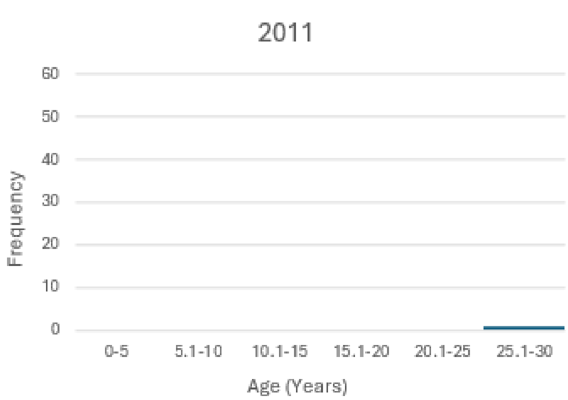


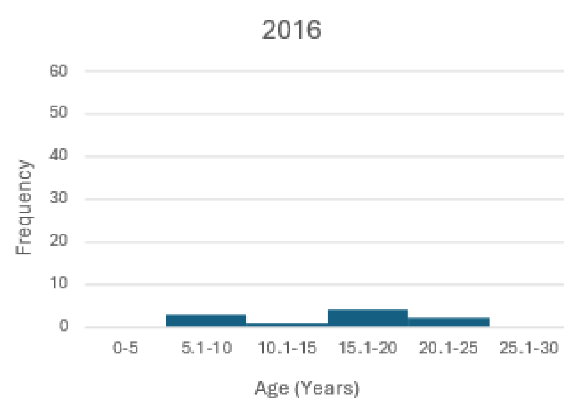












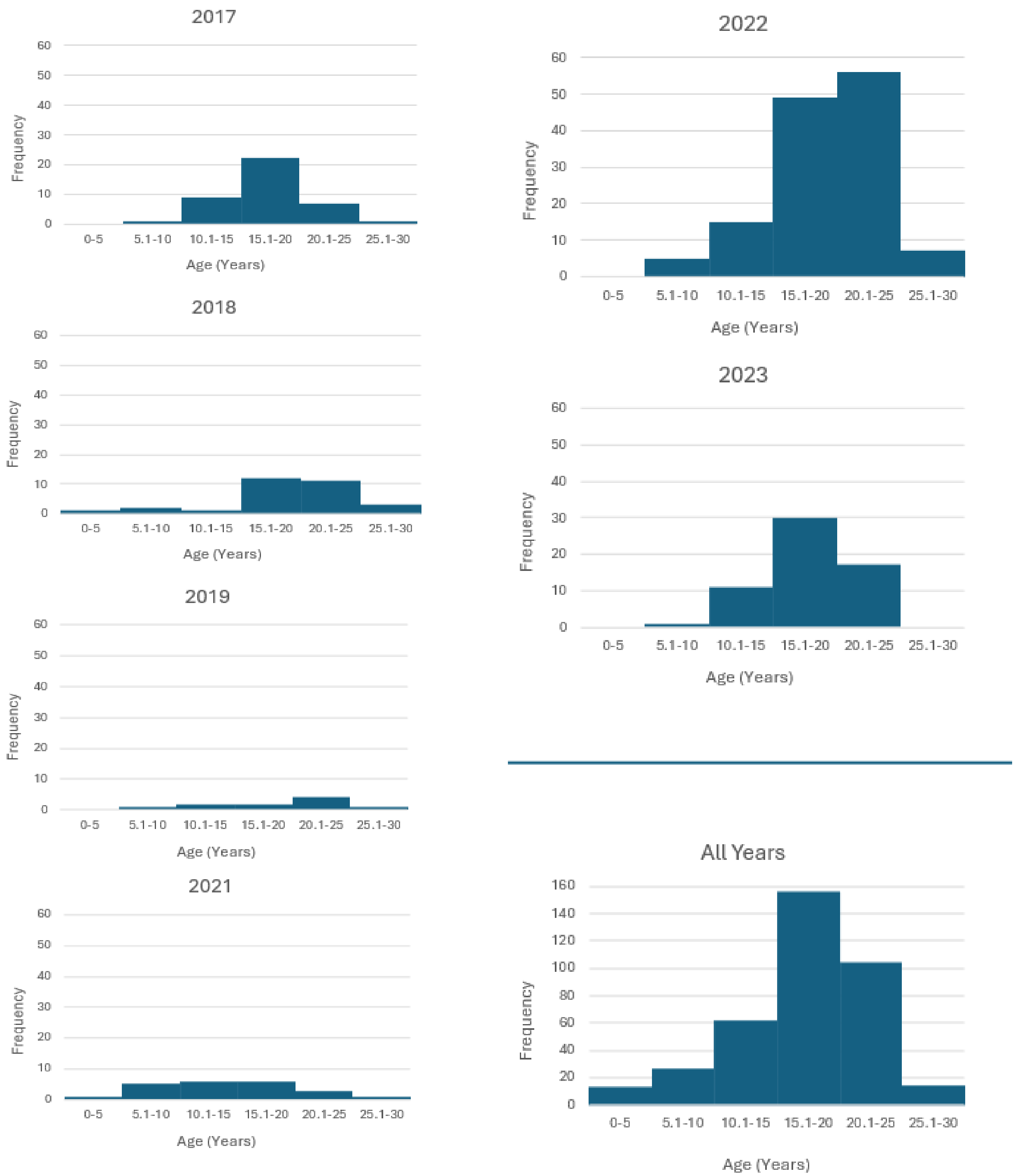
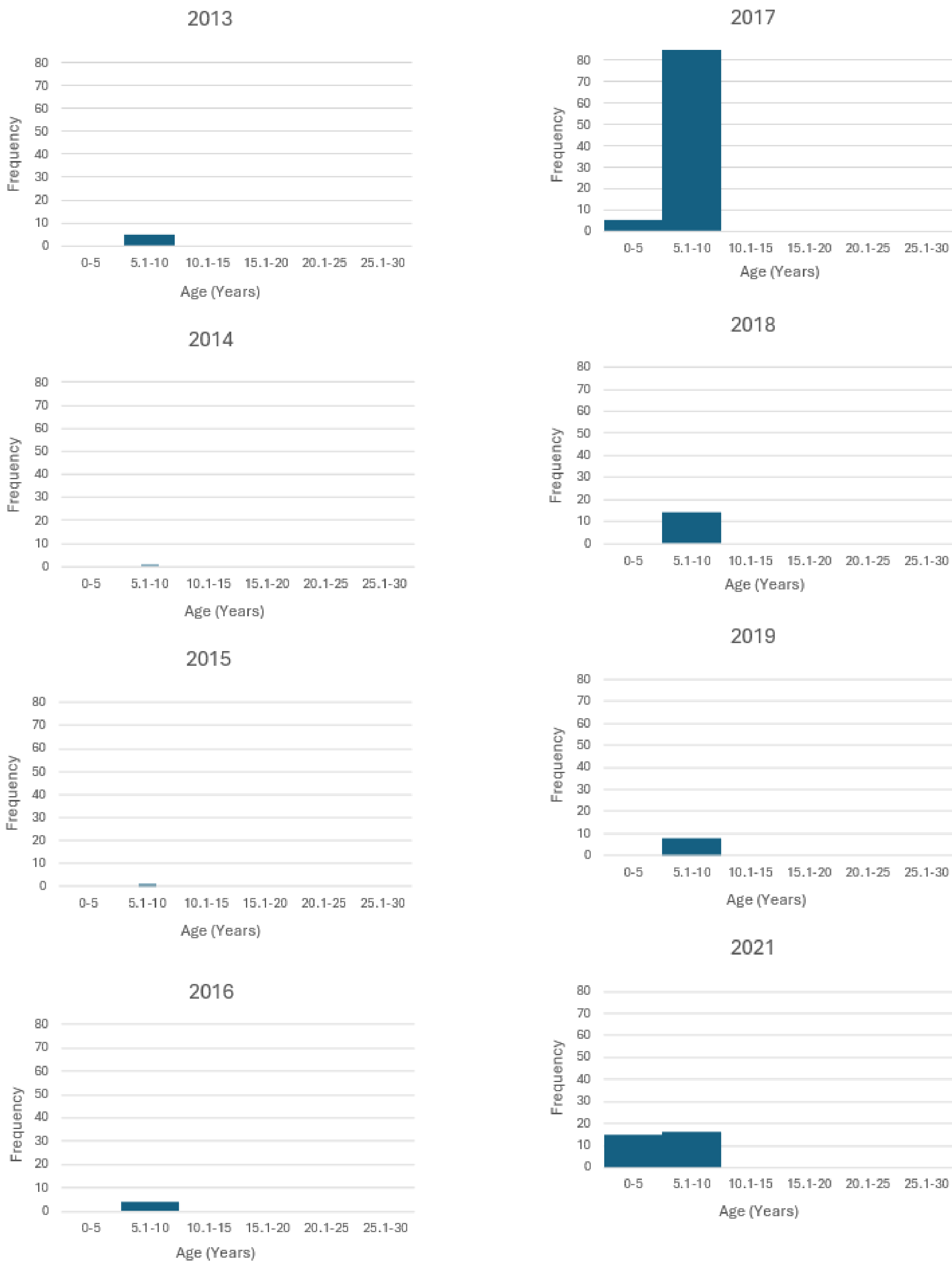


Figure 3. **Annual Histograms of Tope *(Galeorhinus galeus)* Frequency by Age Class (2006-2023).** Display the annual frequency distribution of Tope sharks, classified by age classes (0-5, 5.1-10, 10.1-15, 15.1-20, 20.1-25, 25.1-30 years) from 2006 to 2023. The data combines both males and females, providing insights into the age structure of the population over time.

Appendix VII. Histogram time-series showing age distribution for spurdog from 2013 to 2023.



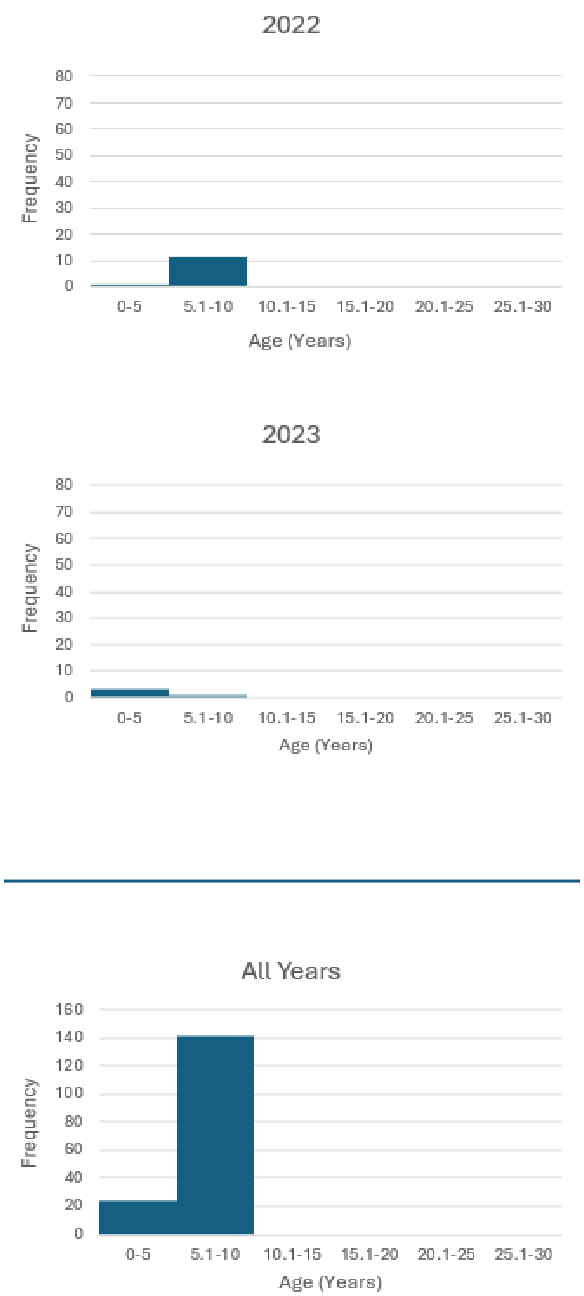
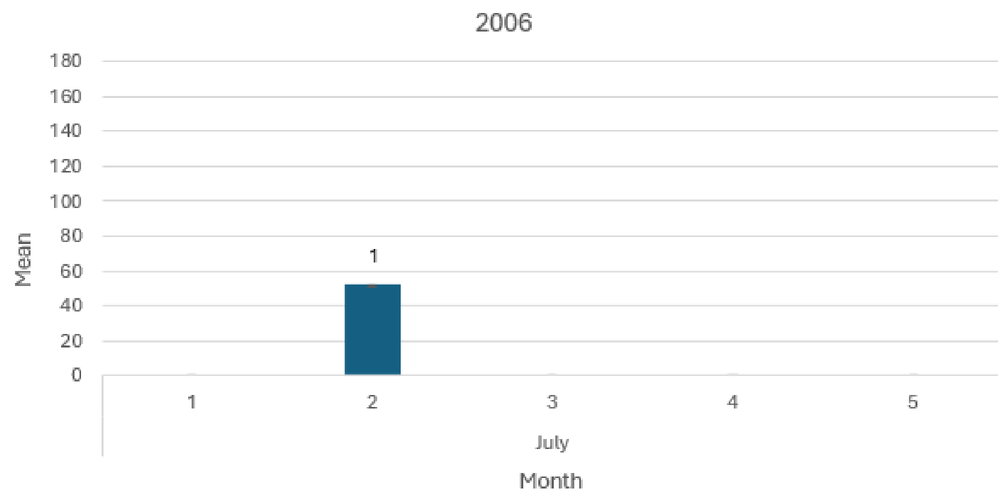
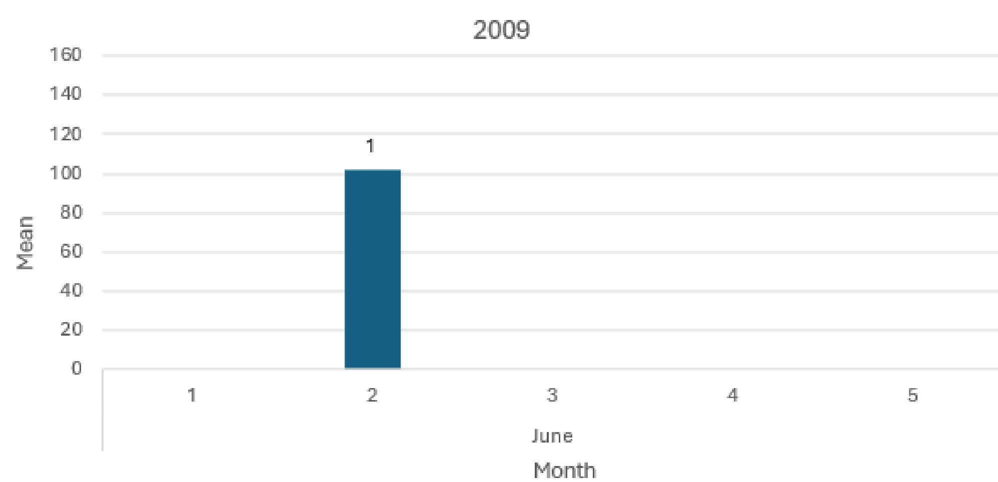
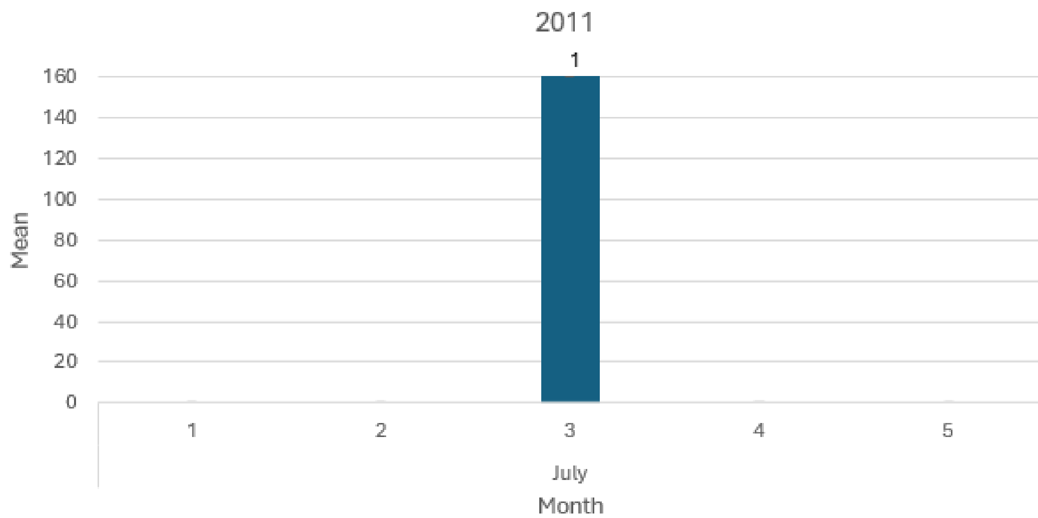


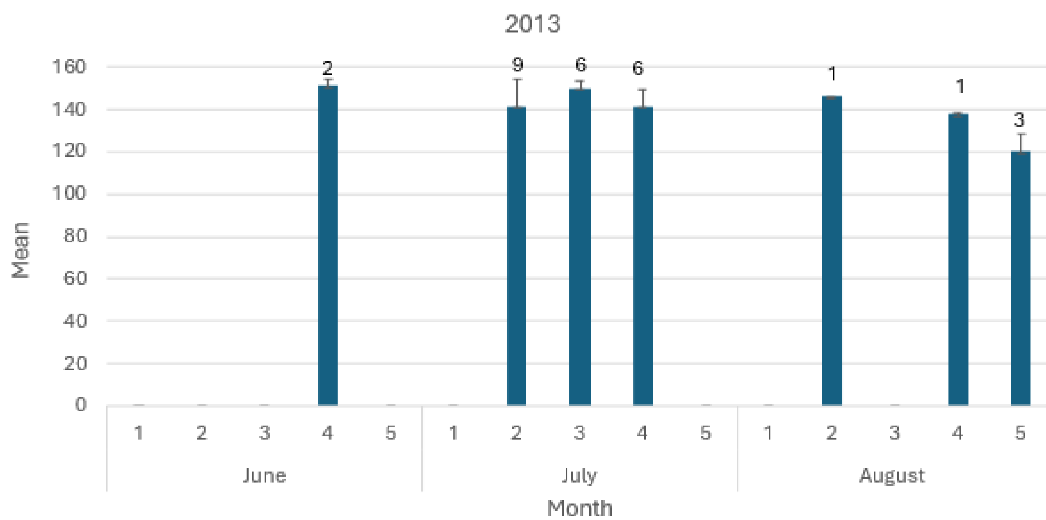
Figure 4. **Annual Histograms of Spurdog *(Squalus acanthias*) Frequency by Age Class (2013-2023).** Display the annual frequency distribution of Spurdog sharks, classified by age classes (0-5, 5.1-10, 10.1-15, 15.1-20, 20.1-25, 25.1-30 years) from 2013 to 2023. The data combines both males and females, providing insights into the age structure of the population over time

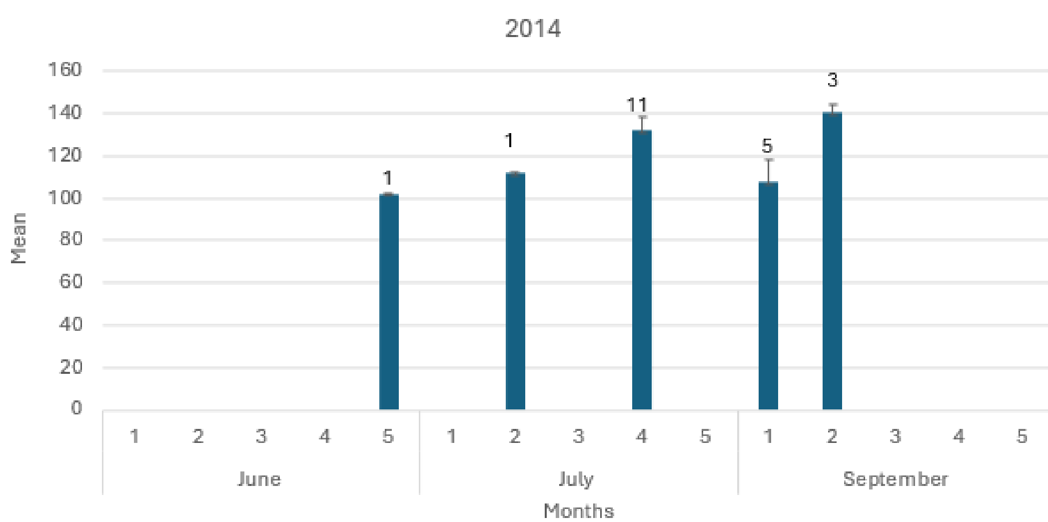
Appendix VIII. Time-series showing mean length over time (2006-2023) for tope.






2011
Mean
160
140
120
100
80
60
40
20
0
1
1
2
3
4
5
July
Month


2013
Mean
160
140
120
100
80
60
40
20
0
2
9
6
6
1
1
3
1 2 3 4 5
1 2 3 4 5
1 2 3 4 5
June
July
August
Month


2014
Mean
160
140
120
100
80
60
40
20
0
1
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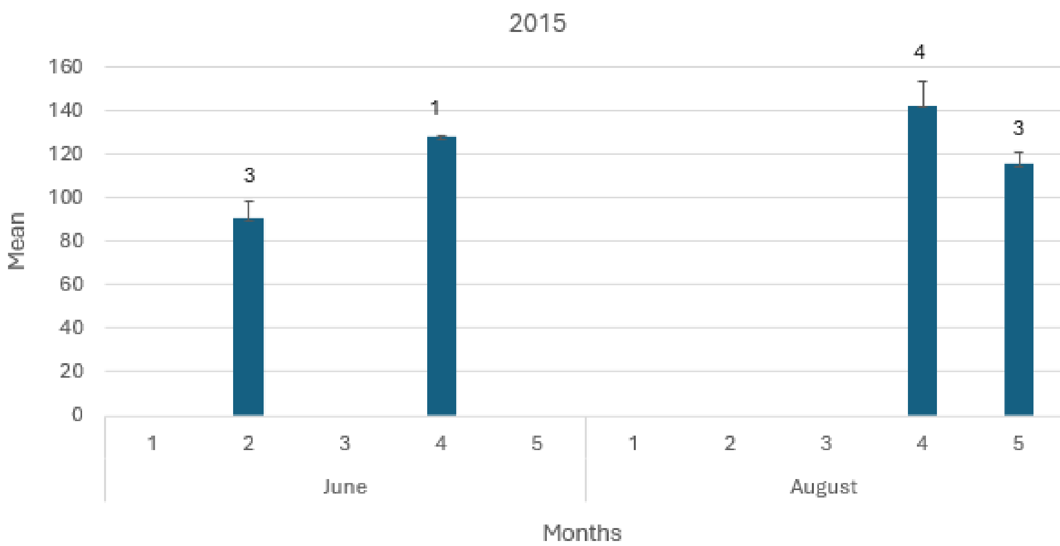
11
5
3
1 2 3 4 5
1 2 3 4 5
1 2 3 4 5
June
July
September
Months


2015
Mean
160
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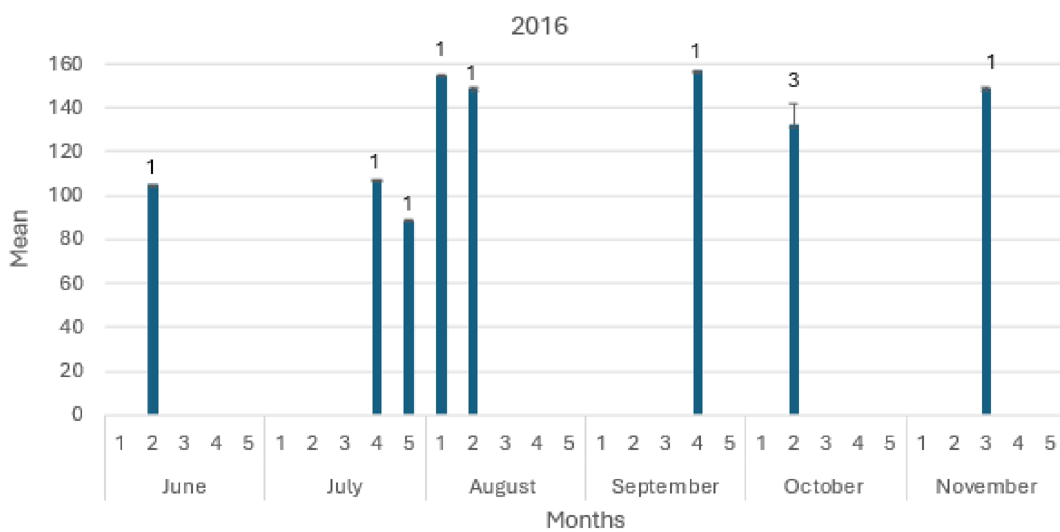
1 2 3 4 5 1 2 3 4 5
June
August
Months


2016
Mean
160
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120
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80
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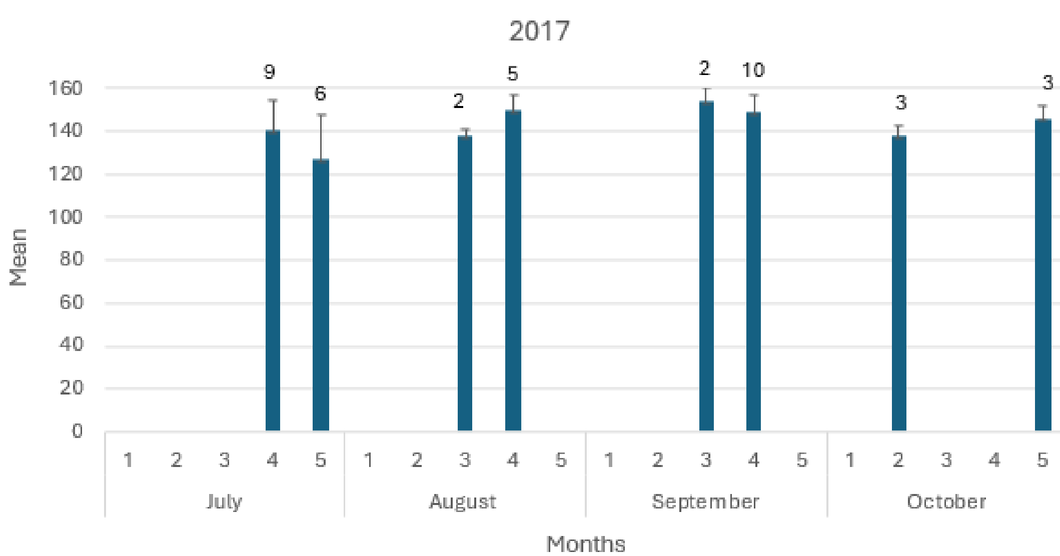
0
1 1 1 1 1 1 3 1
1 2 3 4 5 1 2 3 4 5 1 2 3 4 5 1 2 3 4 5 1 2 3 4 5 1 2 3 4 5
June
July
August
September
October
November
Months


2017
Mean
160
140
120
100
80
60
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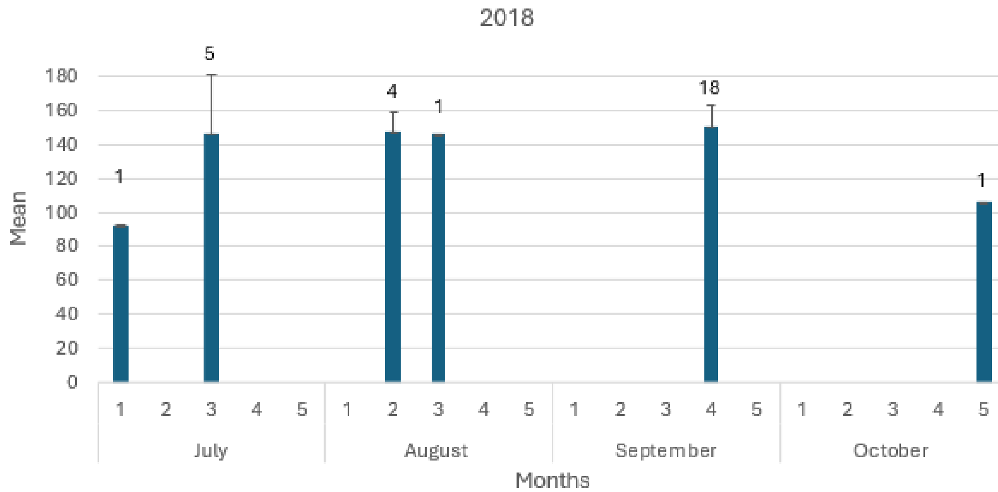
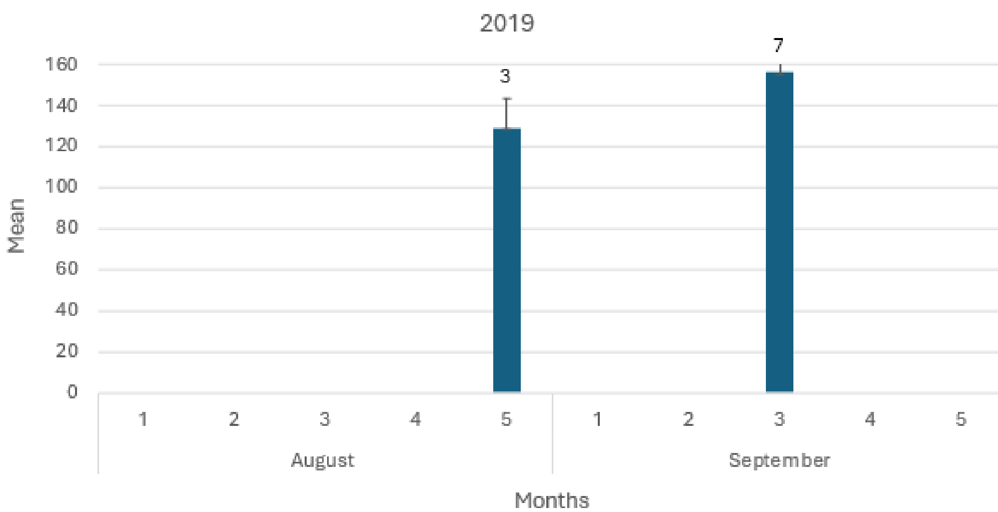
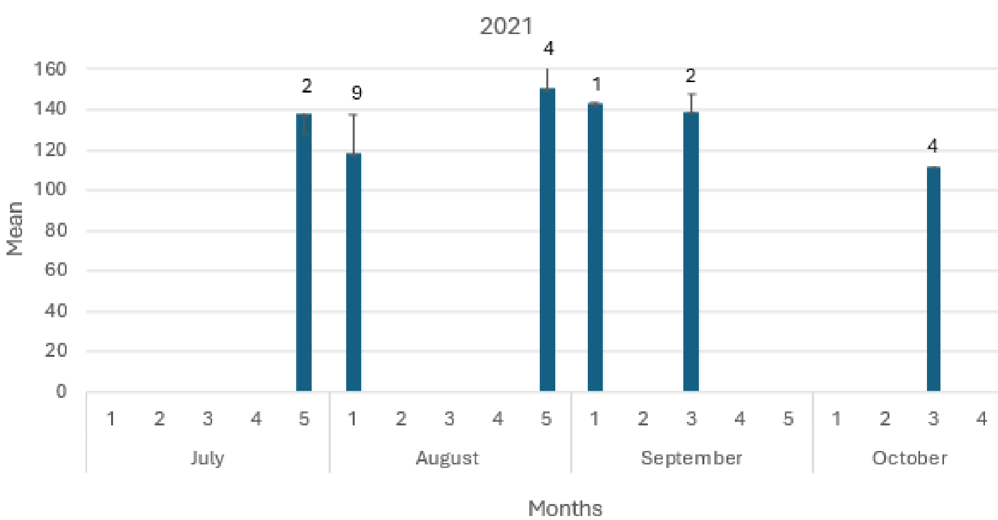
9 6 2 5 2 10 3 3
1 2 3 4 5 1 2 3 4 5 1 2 3 4 5 1 2 3 4 5
July
August
September
October
Months


2018
Mean
Months
July
August
September
October


2019
Mean
Months
August
September


2021
Mean
Months
July
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September
October

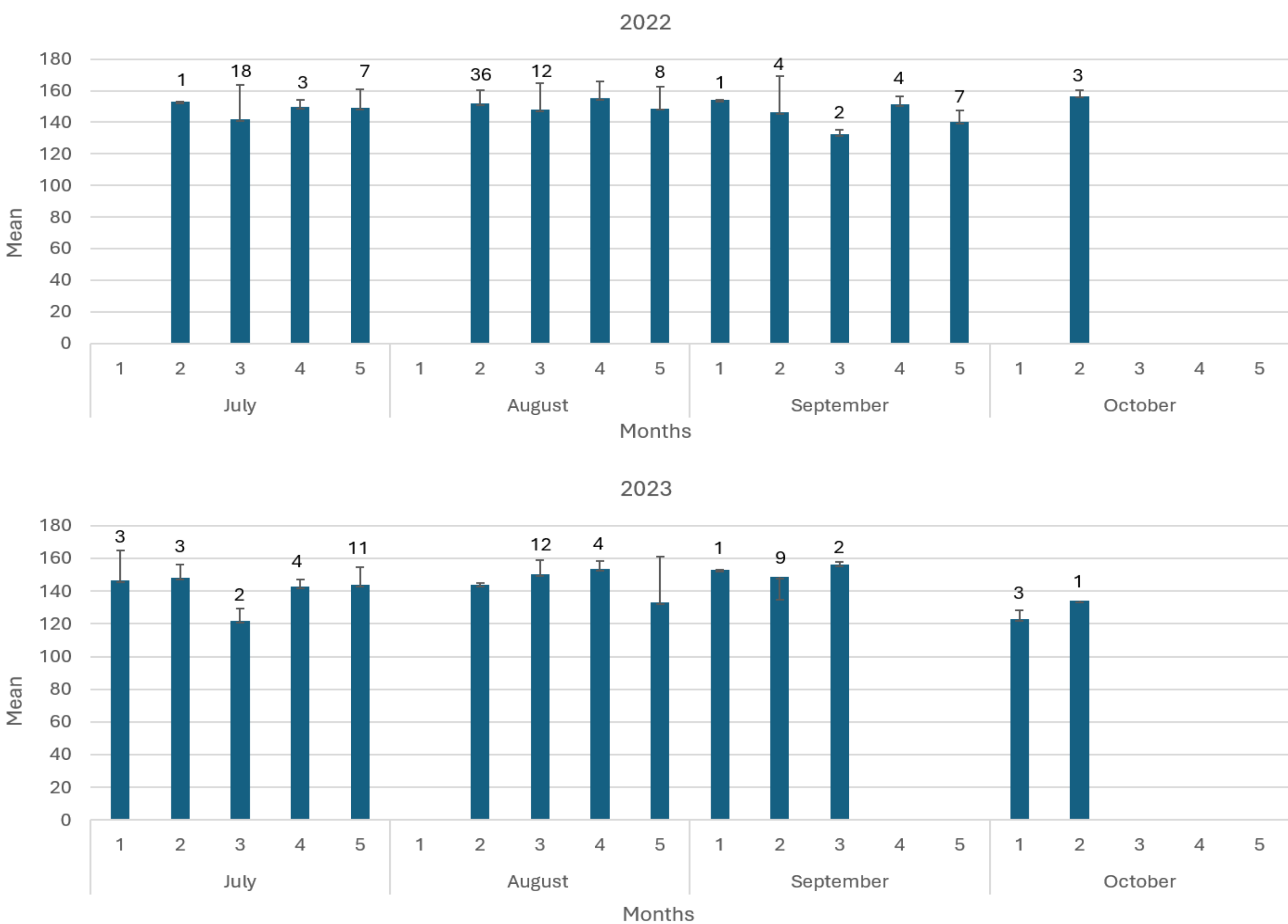
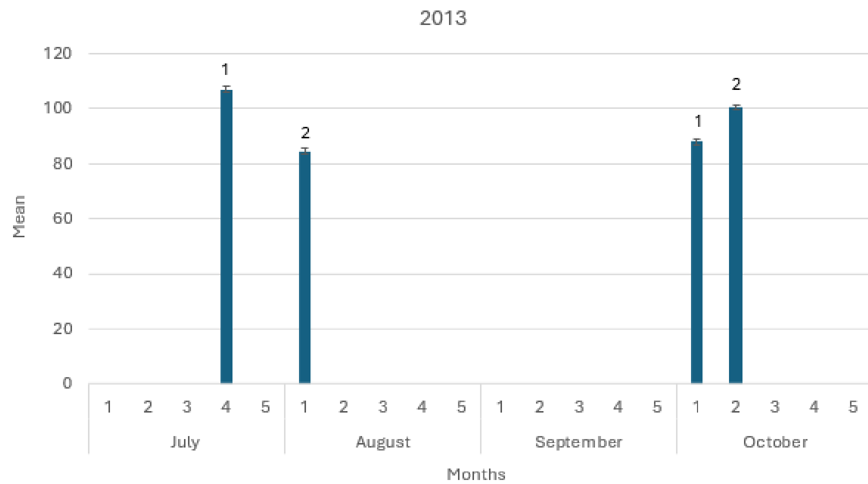
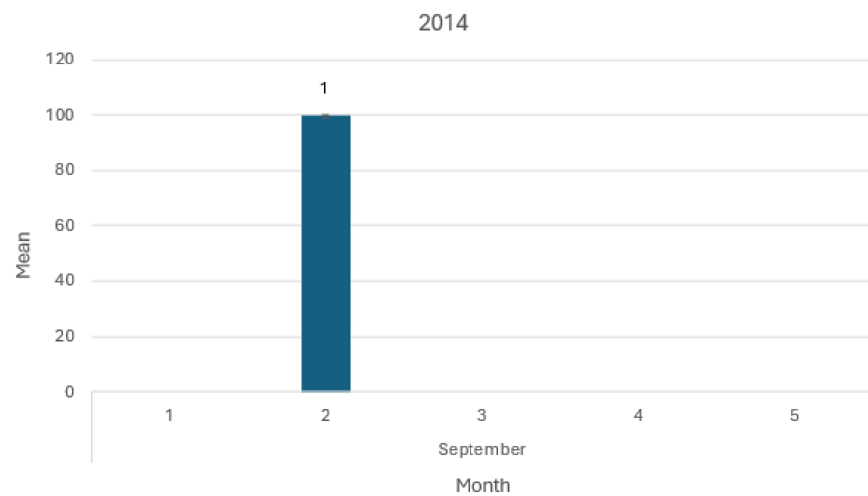
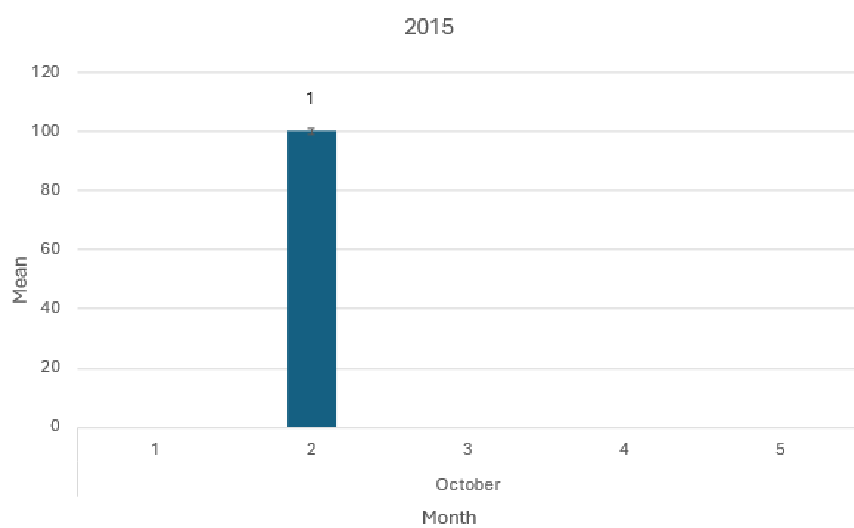


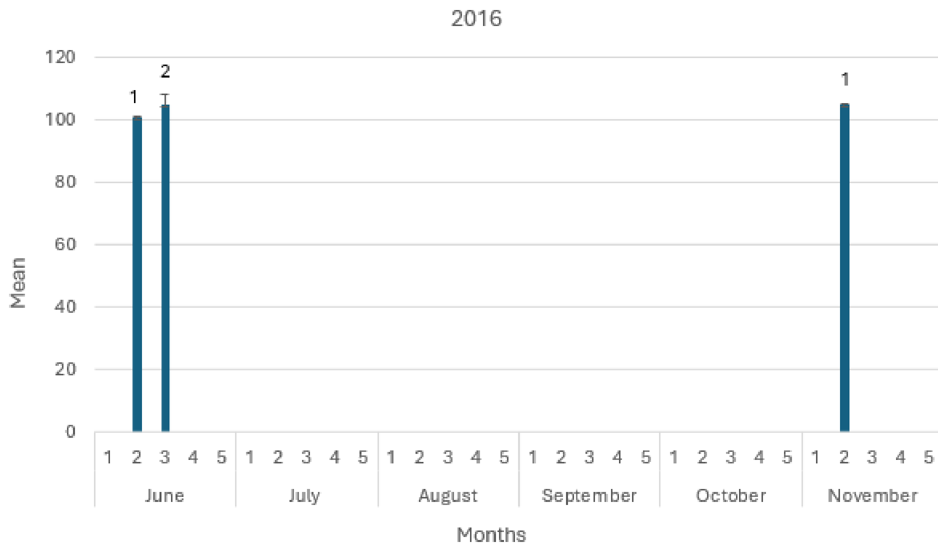
Figure 5. **Mean Length of Tagged Tope *(Galeorhinus galeus)* by Week per Month (2006-2023).** The mean length of Tope (males and females) tagged each week and month from 2006 to 2023. Standard deviations are represented, and the number of tagged individuals per week is displayed above each bar, providing insight into size trends and tagging frequency over time.

Appendix IX. Time-series showing mean length over time (2013-2023) for spurdog.








2016
120
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Mean
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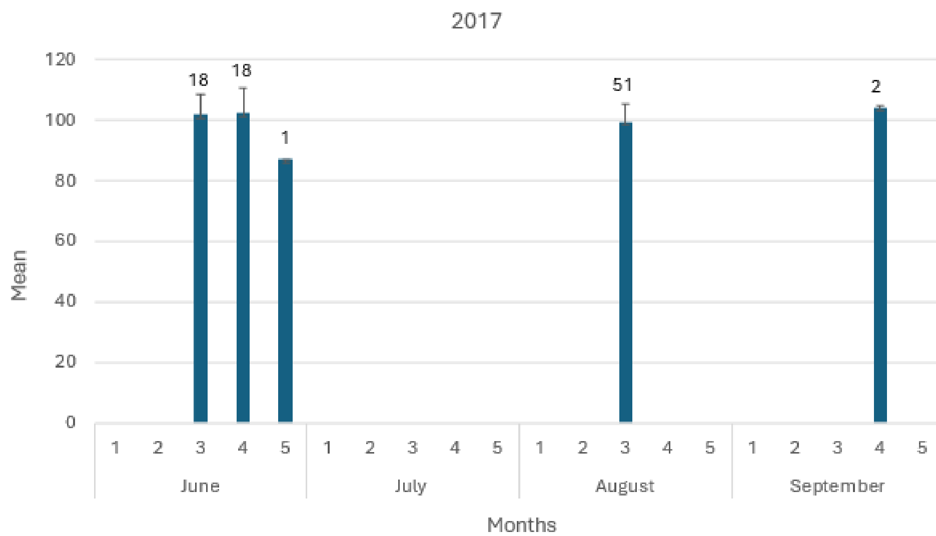
1 2 3 4 5 1 2 3 4 5 1 2 3 4 5 1 2 3 4 5 1 2 3 4 5 1 2 3 4 5
June
July
August
September
October
November
Months


2017
120
100
80
60
40
20
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Mean
18
18
1
51
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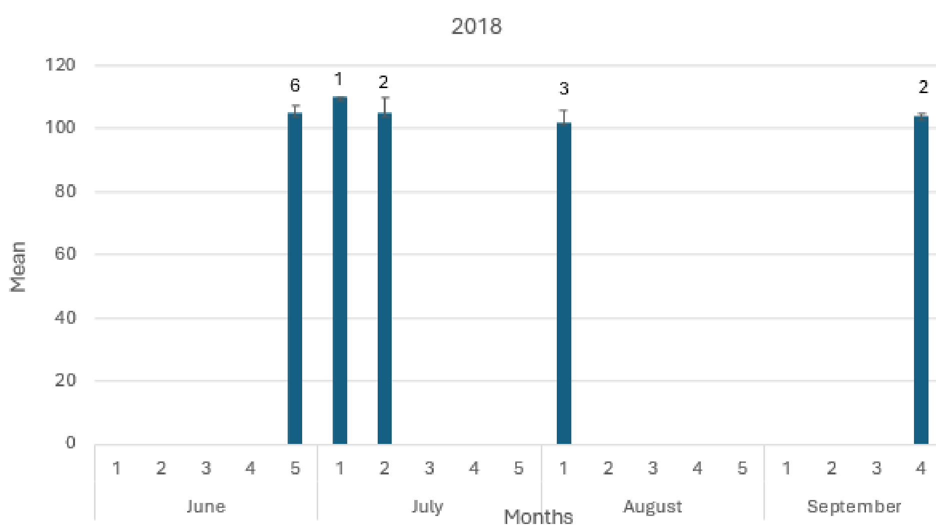
1 2 3 4 5 1 2 3 4 5 1 2 3 4 5 1 2 3 4 5
June
July
August
September
Months


2018
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Mean
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June
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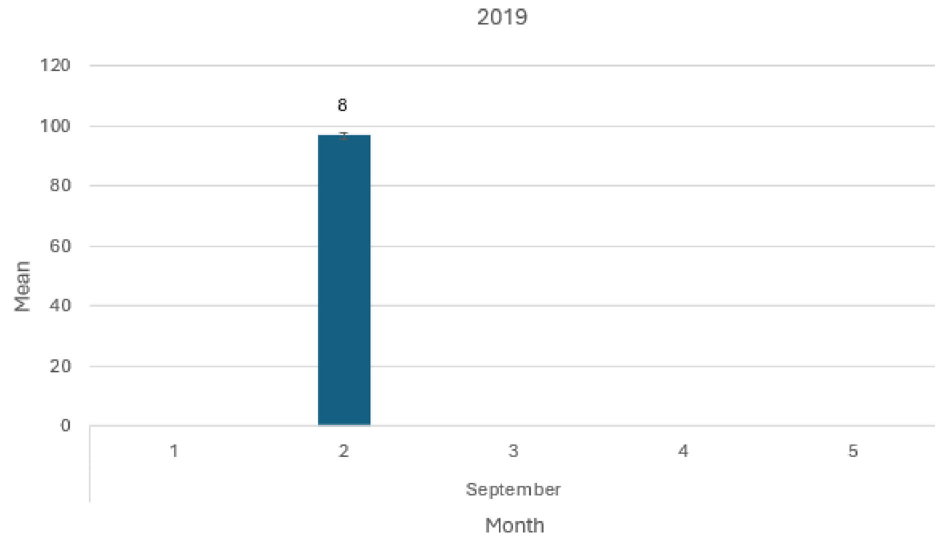
August
September
Months



2019
Mean
120
100
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20
0
8
1
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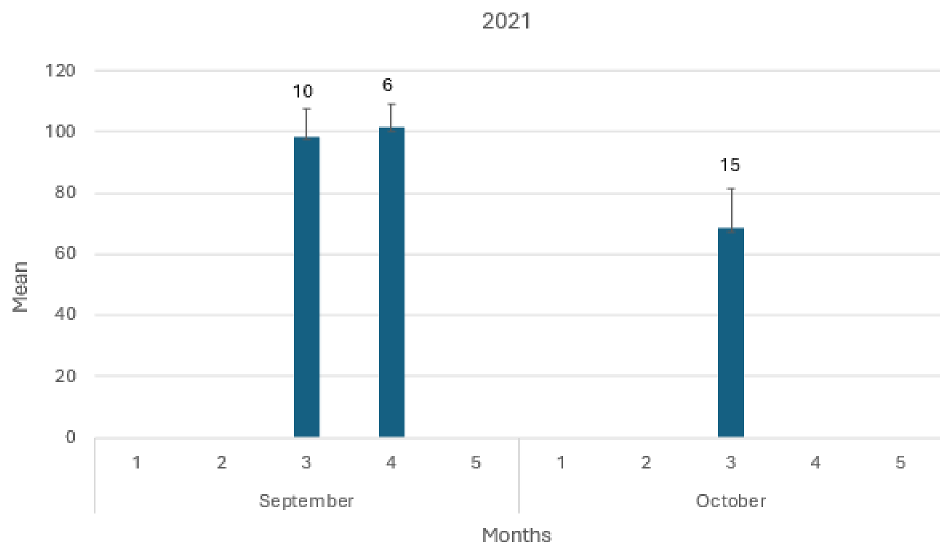
September
Month



2021
Mean
120
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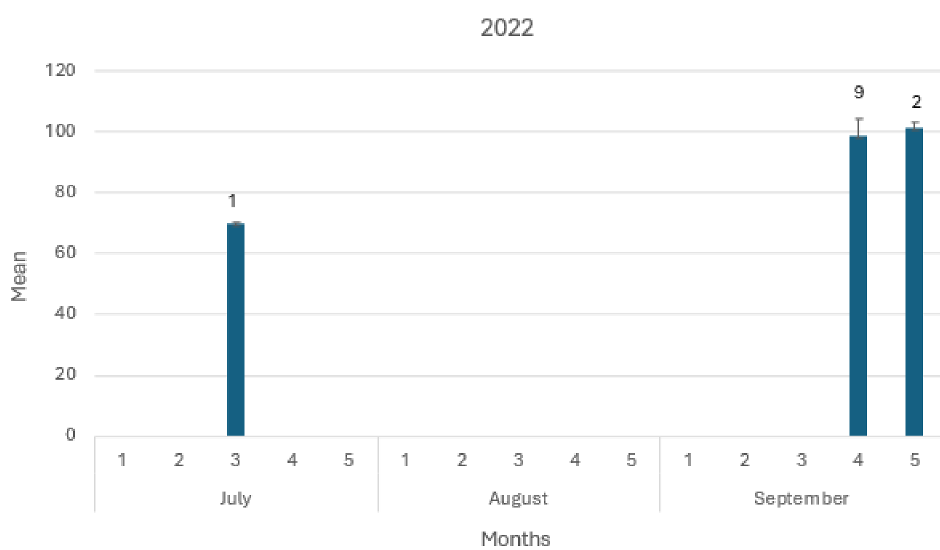
September
October
Months



2022
Mean
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Months

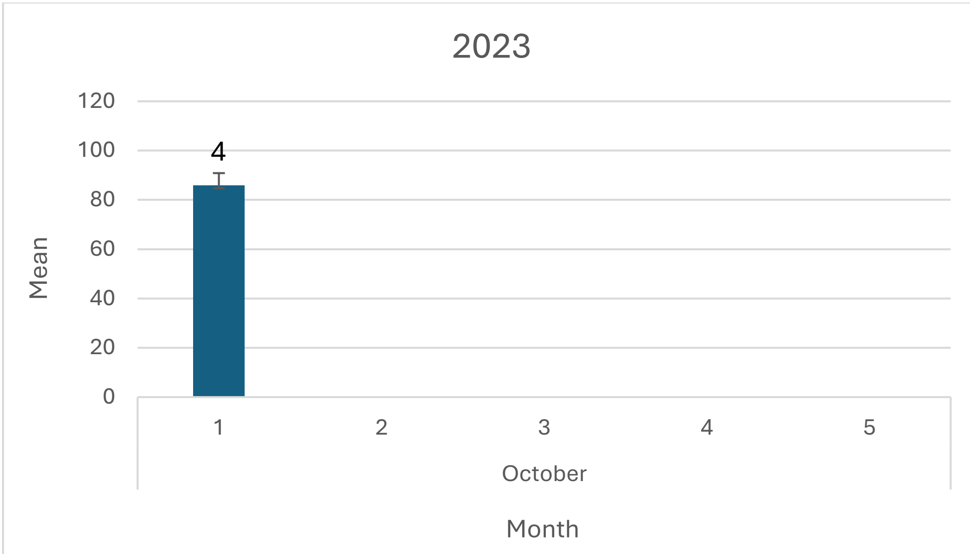

Figure 6. **Mean Length of Tagged Spurdog *(Squalus acanthias*) by Week per Month (2013-2023).** The mean length of Spurdog (males and females) tagged each week and month from 2013 to 2023. Standard deviations are represented, and the number of tagged individuals per week is displayed above each bar, providing insight into size trends and tagging frequency over time.

Appendix X. Frequency of tagging effort broke down by species, from 2003 to 2023, divided by male and female.

Table 4. **Frequency of Tagged Individuals by Sex for Tope, Spurdog, Bull Huss, and Thornback Ray by Year (2003-2023).** Summary of tagged individuals by species, categorised by males and females, from 2003 to 2023. The data provides a year-by-year breakdown, highlighting trends in tagging efforts over two decades.

Species	Sex	2003	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total	Comments	
Tope (*Galeorhinus galeus*)	Female	1	2	7	0	0	0	1	0	16	5	8	4	25	23	9	0	15	116	57	289	1 recapture in 2006 1 recapture in 2011 1 recapture in 2022	*5 without sex
	Male	0	0	3	1	1	0	1	0	12	16	8	8	15	7	1	0	7	16	2	98	1 recapture in 2008 1 recapture in 2011	
Spurdog (*Squalus acanthias*)	Female	0	0	0	0	0	0	0	0	3	1	1	4	90	14	8	0	24	12	3	160		
	Male	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	7	0	1	10		
Bull Huss (*Scyliorhinus stellaris*)	Female	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	4	1	8	*3 without sex	
	Male	0	0	0	0	0	0	0	0	10	1	0	0	0	0	0	0	0	0	1	12		
Thornback Ray (*Raja clavata*)	Female	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2		
	Male	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	5		

Appendix XI. Complete table showing predicted mass and age for tope, from 2009 to 2023.

Table 5. **Detailed Breakdown of Tagged Tope *(Galeorhinus galeus)* Sharks in the Isle of Man (2009-2023).** Comprehensive breakdown of tagged Tope sharks (N=376) in the Isle of Man from 2009 to 2023. Data includes length (cm), predicted calculated mass (mean, upper, and lower values in kg), actual recorded mass (kg), percentage difference between predicted mean and actual mass, predicted age (years), sex (M for male, F for female), and year of data collection. The percentage difference is color-coded to indicate whether the sharks were underweight (red), overweight (green), or within the expected mass range (yellow).

Tag Number	Measured Length (cm)	Calculated Mass (g) (mean)	Calculated Mass (Kg) (mean)	Calculated Mass (g) (upper)	Calculated Mass (kg) from Fishbase (upper)	Calculated Mass (g) from Fishbase (lower)	Calculated Mass (kg) from Fishbase (lower)	Actual Recorded Mass (lbs)	Actual Recorded Mass (g)	Actual Recorded Mass (Kg)	% difference	Predicted Age	Sex	Year
21199	52,00	647,42	0,65	1169,93	1,17	357,66	0,36	22,00	9979,20	9,98	93,5	2,9	F	2006
19922	47,00	478,53	0,48	857,77	0,86	266,51	0,27	20,00	9072,00	9,07	94,7	2,0	M	2007
19920	49,00	542,03	0,54	974,84	0,97	300,87	0,30	24,00	10886,40	10,89	95,0	2,5	F	2007
19916	51,50	628,98	0,63	1135,74	1,14	347,75	0,35	20,00	9072,00	9,07	93,1	2,9	F	2007
19918	52,00	647,42	0,65	1169,93	1,17	357,66	0,36	24,50	11113,20	11,11	94,2	2,5	M	2007
19923	54,00	724,76	0,72	1313,65	1,31	399,18	0,40	25,50	11566,80	11,57	93,7	3,0	F	2007
19919	55,00	765,63	0,77	1389,77	1,39	421,08	0,42	27,00	12247,20	12,25	93,7	3,2	F	2007
19924	56,50	829,78	0,83	1509,45	1,51	455,37	0,46	26,50	12020,40	12,02	93,1	3,4	F	2007
19917	57,00	851,92	0,85	1550,83	1,55	467,20	0,47	32,00	14515,20	14,52	94,1	3,8	F	2007
19921	57,00	851,92	0,85	1550,83	1,55	467,20	0,47	29,00	13154,40	13,15	93,5	3,8	F	2007
3	102,00	4853,44	4,85	9256,18	9,26	2540,58	2,54	10,00	4536,00	4,54	-7,0	8,7	M	2009
3	161,00	18999,62	19,00	37582,42	37,58	9588,93	9,59	33,00	14968,80	14,97	-26,9	27,4	M	2011
5375	110,00	6082,75	6,08	11670,91	11,67	3164,90	3,16					10,0	M	2013
5622	115,00	6947,40	6,95	13377,40	13,38	3601,95	3,60	13,00	5896,80	5,90	-17,8	10,5	M	2013
5366	120,00	7890,19	7,89	15244,59	15,24	4076,84	4,08	22,00	9979,20	9,98	20,9	11,5	M	2013
5310	125,00	8914,49	8,91	17279,97	17,28	4591,08	4,59					12,4	F	2013
5716	127,00	9347,78	9,35	18142,90	18,14	4808,12	4,81	16,92	7674,91	7,67	-21,8	13,2	M	2013
5360	130,00	10023,66	10,02	19491,06	19,49	5146,14	5,15	33,00	14968,80	14,97	33,0	15,0	M	2013
5709	137,00	11725,46	11,73	22896,10	22,90	5994,65	5,99	25,39	11516,90	11,52	-1,8	16,0	F	2013

9262	138,00	11983,23	11,98	23413,06	23,41	6122,87	6,12					15,8	M	2013
5364	138,00	11983,23	11,98	23413,06	23,41	6122,87	6,12					15,8	M	2013
9253	144,00	13609,41	13,61	26681,01	26,68	6930,13	6,93					17,4	F	2013
9623	145,00	13893,95	13,89	27253,93	27,25	7071,11	7,07					17,9	F	2013
5761	145,00	13893,95	13,89	27253,93	27,25	7071,11	7,07	31,00	14061,60	14,06	1,2	17,9	F	2013
5712	145,00	13893,95	13,89	27253,93	27,25	7071,11	7,07					17,9	F	2013
5705	146,00	14182,43	14,18	27835,09	27,84	7213,96	7,21	31,43	14256,65	14,26	0,5	18,4	F	2013
9264	146,00	14182,43	14,18	27835,09	27,84	7213,96	7,21					19,2	M	2013
5304	147,00	14474,86	14,47	28424,55	28,42	7358,68	7,36	32,00	14515,20	14,52	0,3	19,0	F	2013
9252	147,00	14474,86	14,47	28424,55	28,42	7358,68	7,36					19,0	F	2013
9254	147,00	14474,86	14,47	28424,55	28,42	7358,68	7,36					19,5	M	2013
5618	148,00	14771,28	14,77	29022,37	29,02	7505,30	7,51	33,00	14968,80	14,97	1,3	19,4	F	2013
5311	148,00	14771,28	14,77	29022,37	29,02	7505,30	7,51					19,8	M	2013
5706	149,00	15071,71	15,07	29628,60	29,63	7653,83	7,65					19,5	F	2013
9261	149,00	15071,71	15,07	29628,60	29,63	7653,83	7,65					19,9	M	2013
5714	150,00	15376,18	15,38	30243,32	30,24	7804,27	7,80	34,00	15422,40	15,42	0,3	19,7	F	2013
5615	153,00	16314,09	16,31	32138,98	32,14	8267,20	8,27	37,00	16783,20	16,78	2,8	20,0	F	2013
5621	154,00	16634,99	16,63	32788,23	32,79	8425,43	8,43	37,50	17010,00	17,01	2,2	20,2	F	2013
5323	154,00	16634,99	16,63	32788,23	32,79	8425,43	8,43					21,0	M	2013
5724	155,00	16960,06	16,96	33446,27	33,45	8585,62	8,59	38,00	17236,80	17,24	1,6	20,3	F	2013
5623	156,00	17289,33	17,29	34113,15	34,11	8747,81	8,75	39,00	17690,40	17,69	2,3	20,6	F	2013
5374	94,00	3801,79	3,80	7203,31	7,20	2003,13	2,00					7,6	M	2014
5357	100,00	4574,41	4,57	8710,22	8,71	2398,32	2,40					8,8	F	2014
5316	102,00	4853,44	4,85	9256,18	9,26	2540,58	2,54					8,7	M	2014
5364	105,00	5292,87	5,29	10117,67	10,12	2764,19	2,76					9,2	M	2014
5734	112,00	6419,44	6,42	12334,70	12,33	3335,27	3,34					10,2	M	2014
5835	115,00	6947,40	6,95	13377,40	13,38	3601,95	3,60					10,5	M	2014
13553	120,00	7890,19	7,89	15244,59	15,24	4076,84	4,08					11,8	F	2014
13570	120,00	7890,19	7,89	15244,59	15,24	4076,84	4,08					11,8	F	2014
5838	130,00	10023,66	10,02	19491,06	19,49	5146,14	5,15					15,0	M	2014
5846	130,00	10023,66	10,02	19491,06	19,49	5146,14	5,15					15,0	M	2014
5827	130,00	10023,66	10,02	19491,06	19,49	5146,14	5,15					15,0	M	2014

5844	130,00	10023,66	10,02	19491,06	19,49	5146,14	5,15					15,0	M	2014
5838	132,00	10491,84	10,49	20426,38	20,43	5379,93	5,38					15,2	M	2014
5840	132,00	10491,84	10,49	20426,38	20,43	5379,93	5,38					15,2	M	2014
5832	135,00	11221,05	11,22	21885,38	21,89	5743,52	5,74					14,0	F	2014
5829	135,00	11221,05	11,22	21885,38	21,89	5743,52	5,74					15,4	M	2014
5355	136,00	11471,41	11,47	22386,89	22,39	5868,20	5,87					15,5	M	2014
5850	138,00	11983,23	11,98	23413,06	23,41	6122,87	6,12					15,8	M	2014
13552	140,00	12510,03	12,51	24470,48	24,47	6384,68	6,38					15,9	M	2014
5843	143,00	13328,78	13,33	26116,26	26,12	6791,01	6,79					17,3	F	2014
13567	145,00	13893,95	13,89	27253,93	27,25	7071,11	7,07					19,0	M	2014
9333	80,00	2347,33	2,35	4390,52	4,39	1252,85	1,25					5,0	M	2015
9334	90,00	3338,26	3,34	6303,10	6,30	1765,03	1,77					7,4	F	2015
9330	101,00	4712,55	4,71	8980,41	8,98	2468,78	2,47					8,5	M	2015
15360	110,00	6082,75	6,08	11670,91	11,67	3164,90	3,16	12,20	5533,92	5,53	-9,9	10,0	F	2015
13549	113,00	6592,35	6,59	12675,94	12,68	3422,67	3,42	12,30	5579,28	5,58	-18,2	10,2	M	2015
13551	123,00	8494,77	8,49	16445,16	16,45	4380,57	4,38	15,50	7030,80	7,03	-20,8	12,2	M	2015
5895	124,00	8702,95	8,70	16859,08	16,86	4485,01	4,49					12,4	F	2015
5894	128,00	9569,59	9,57	18585,06	18,59	4919,12	4,92					13,3	M	2015
13546	145,00	13893,95	13,89	27253,93	27,25	7071,11	7,07	30,70	13925,52	13,93	0,2	17,9	F	2015
5804	148,00	14771,28	14,77	29022,37	29,02	7505,30	7,51					19,4	F	2015
14945	149,00	15071,71	15,07	29628,60	29,63	7653,83	7,65					19,5	F	2015
13564	153,00	16314,09	16,31	32138,98	32,14	8267,20	8,27	36,70	16647,12	16,65	2,0	20,0	F	2015
13574	89,00	3228,58	3,23	6090,55	6,09	1708,57	1,71					7,0	M	2016
9329	105,00	5292,87	5,29	10117,67	10,12	2764,19	2,76					9,2	M	2016
5884	107,00	5600,06	5,60	10721,06	10,72	2920,21	2,92					9,5	M	2016
13545	118,00	7503,48	7,50	14477,95	14,48	3882,25	3,88					11,5	F	2016
13547	138,00	11983,23	11,98	23413,06	23,41	6122,87	6,12					15,8	M	2016
13573	140,00	12510,03	12,51	24470,48	24,47	6384,68	6,38					15,9	M	2016
14945	149,00	15071,71	15,07	29628,60	29,63	7653,83	7,65					19,5	F	2016
14941	149,00	15071,71	15,07	29628,60	29,63	7653,83	7,65					19,9	M	2016
5768	155,00	16960,06	16,96	33446,27	33,45	8585,62	8,59					20,3	F	2016
13548	157,00	17622,82	17,62	34788,95	34,79	8911,99	8,91					23,0	M	2016

19804	99,00	4439,00	4,44	8445,58	8,45	2329,19	2,33					8,1	M	2017
19800	113,00	6592,35	6,59	12675,94	12,68	3422,67	3,42					10,2	M	2017
18468	115,00	6947,40	6,95	13377,40	13,38	3601,95	3,60					11,0	F	2017
19803	121,00	8088,42	8,09	15637,97	15,64	4176,50	4,18					12,0	M	2017
19801	127,00	9347,78	9,35	18142,90	18,14	4808,12	4,81					13,2	M	2017
13556	128,00	9569,59	9,57	18585,06	18,59	4919,12	4,92					13,3	M	2017
18451	132,00	10491,84	10,49	20426,38	20,43	5379,93	5,38					13,2	F	2017
5818	132,00	10491,84	10,49	20426,38	20,43	5379,93	5,38	23,00	10432,80	10,43	-0,6	13,2	F	2017
18473	132,08	10510,86	10,51	20464,41	20,46	5389,43	5,39					13,2	F	2017
19839	134,00	10974,35	10,97	21391,49	21,39	5620,59	5,62					13,5	F	2017
19857	135,00	11221,05	11,22	21885,38	21,89	5743,52	5,74					15,4	M	2017
19892	137,00	11725,46	11,73	22896,10	22,90	5994,65	5,99	25,00	11340,00	11,34	-3,4	16,0	F	2017
5900	137,00	11725,46	11,73	22896,10	22,90	5994,65	5,99	21,17	9602,71	9,60	-22,1	16,0	F	2017
5860	138,00	11983,23	11,98	23413,06	23,41	6122,87	6,12	30,00	13608,00	13,61	11,9	16,4	F	2017
17444	138,00	11983,23	11,98	23413,06	23,41	6122,87	6,12					16,4	F	2017
19873	138,00	11983,23	11,98	23413,06	23,41	6122,87	6,12					15,8	M	2017
19835	140,00	12510,03	12,51	24470,48	24,47	6384,68	6,38					17,0	F	2017
14930	141,00	12779,11	12,78	25011,06	25,01	6518,30	6,52					17,1	F	2017
13554	144,00	13609,41	13,61	26681,01	26,68	6930,13	6,93					18,9	M	2017
19872	145,00	13893,95	13,89	27253,93	27,25	7071,11	7,07					19,0	M	2017
19802	146,00	14182,43	14,18	27835,09	27,84	7213,96	7,21					18,4	F	2017
19848	146,00	14182,43	14,18	27835,09	27,84	7213,96	7,21					18,4	F	2017
19809	146,00	14182,43	14,18	27835,09	27,84	7213,96	7,21					19,2	M	2017
19871	148,00	14771,28	14,77	29022,37	29,02	7505,30	7,51					19,4	F	2017
18469	148,00	14771,28	14,77	29022,37	29,02	7505,30	7,51					19,8	M	2017
19893	149,00	15071,71	15,07	29628,60	29,63	7653,83	7,65	40,00	18144,00	18,14	16,9	19,5	F	2017
17439	149,00	15071,71	15,07	29628,60	29,63	7653,83	7,65					19,5	F	2017
57221	149,00	15071,71	15,07	29628,60	29,63	7653,83	7,65					19,9	M	2017
18460	150,00	15376,18	15,38	30243,32	30,24	7804,27	7,80					20,4	M	2017
19806	151,00	15684,71	15,68	30866,59	30,87	7956,64	7,96					19,8	F	2017
5733	153,00	16314,09	16,31	32138,98	32,14	8267,20	8,27	32,58	14778,29	14,78	-10,4	20,0	F	2017
5812	153,00	16314,09	16,31	32138,98	32,14	8267,20	8,27	47,82	21691,15	21,69	24,8	20,0	F	2017

19891	155,00	16960,06	16,96	33446,27	33,45	8585,62	8,59	40,00	18144,00	18,14	6,5	20,3	F	2017
18474	155,00	16960,06	16,96	33446,27	33,45	8585,62	8,59					21,5	M	2017
19894	158,00	17960,57	17,96	35473,71	35,47	9078,18	9,08	69,00	31298,40	31,30	42,6	21,0	F	2017
19870	160,00	18648,94	18,65	36870,39	36,87	9416,64	9,42					22,0	F	2017
19849	161,00	18999,62	19,00	37582,42	37,58	9588,93	9,59					22,2	F	2017
19847	162,00	19354,65	19,35	38303,68	38,30	9763,27	9,76					23,7	F	2017
13568	162,00	19354,65	19,35	38303,68	38,30	9763,27	9,76					23,7	M	2017
18472	168,00	21577,95	21,58	42828,10	42,83	10853,17	10,85					27,0	F	2017
5893	78,00	2176,20	2,18	4062,19	4,06	1163,86	1,16					5,0	M	2018
12795	92,00	3565,01	3,57	6743,07	6,74	1881,61	1,88					7,5	F	2018
14964	106,00	5445,03	5,45	10416,42	10,42	2841,49	2,84					9,5	F	2018
19897	114,00	6768,32	6,77	13023,49	13,02	3511,56	3,51					10,4	F	2018
19873	138,00	11983,23	11,98	23413,06	23,41	6122,87	6,12					15,8	M	2018
19877	139,00	12244,75	12,24	23937,83	23,94	6252,87	6,25					15,9	M	2018
19875	141,00	12779,11	12,78	25011,06	25,01	6518,30	6,52					16,0	M	2018
19879	142,00	13052,02	13,05	25559,63	25,56	6653,74	6,65					17,2	F	2018
19876	143,00	13328,78	13,33	26116,26	26,12	6791,01	6,79					16,4	M	2018
19872	145,00	13893,95	13,89	27253,93	27,25	7071,11	7,07					19,0	M	2018
19878	146,00	14182,43	14,18	27835,09	27,84	7213,96	7,21					18,4	F	2018
19802	146,00	14182,43	14,18	27835,09	27,84	7213,96	7,21					18,4	F	2018
19848	146,00	14182,43	14,18	27835,09	27,84	7213,96	7,21					18,4	F	2018
19846	146,00	14182,43	14,18	27835,09	27,84	7213,96	7,21					18,4	F	2018
19809	146,00	14182,43	14,18	27835,09	27,84	7213,96	7,21					19,2	M	2018
19871	148,00	14771,28	14,77	29022,37	29,02	7505,30	7,51					19,4	F	2018
19895	155,00	16960,06	16,96	33446,27	33,45	8585,62	8,59					20,3	F	2018
18581	156,00	17289,33	17,29	34113,15	34,11	8747,81	8,75					20,6	F	2018
12668	158,00	17960,57	17,96	35473,71	35,47	9078,18	9,08	41,20	18688,32	18,69	3,9	21,0	F	2018
12669	158,00	17960,57	17,96	35473,71	35,47	9078,18	9,08	47,80	21682,08	21,68	17,2	21,0	F	2018
19898	158,00	17960,57	17,96	35473,71	35,47	9078,18	9,08					21,0	F	2018
19870	160,00	18648,94	18,65	36870,39	36,87	9416,64	9,42					22,0	F	2018
19849	161,00	18999,62	19,00	37582,42	37,58	9588,93	9,59					22,2	F	2018
19847	162,00	19354,65	19,35	38303,68	38,30	9763,27	9,76					23,7	F	2018

19896	162,00	19354,65	19,35	38303,68	38,30	9763,27	9,76					23,7	F	2018
19899	162,00	19354,65	19,35	38303,68	38,30	9763,27	9,76					23,7	F	2018
19845	165,00	20446,20	20,45	40523,32	40,52	10298,76	10,30					25,0	F	2018
12666	167,00	21196,19	21,20	42050,28	42,05	10666,25	10,67	55,10	24993,36	24,99	15,2	26,0	F	2018
12799	167,00	21196,19	21,20	42050,28	42,05	10666,25	10,67					26,0	F	2018
12667	171,00	22750,65	22,75	45219,67	45,22	11426,82	11,43	56,78	25755,41	25,76	11,7	28,5	F	2018
10051	110,00	6082,75	6,08	11670,91	11,67	3164,90	3,16					10,0	F	2019
10050	133,00	10731,29	10,73	20905,18	20,91	5499,39	5,50					13,4	F	2019
17396	135,00	11221,05	11,22	21885,38	21,89	5743,52	5,74					14,0	F	2019
17398	140,00	12510,03	12,51	24470,48	24,47	6384,68	6,38					17,0	F	2019
10052	144,00	13609,41	13,61	26681,01	26,68	6930,13	6,93					18,9	M	2019
17394	160,00	18648,94	18,65	36870,39	36,87	9416,64	9,42					22,0	F	2019
17397	162,00	19354,65	19,35	38303,68	38,30	9763,27	9,76					23,7	F	2019
17395	165,00	20446,20	20,45	40523,32	40,52	10298,76	10,30					25,0	F	2019
17399	165,00	20446,20	20,45	40523,32	40,52	10298,76	10,30					25,0	F	2019
17393	167,00	21196,19	21,20	42050,28	42,05	10666,25	10,67					26,0	F	2019
21882	60,00	993,13	0,99	1815,32	1,82	542,41	0,54					3,9	F	2021
21895/21894	86,00	2913,98	2,91	5482,01	5,48	1546,31	1,55					6,7	M	2021
21956	94,00	3801,79	3,80	7203,31	7,20	2003,13	2,00					7,5	F	2021
21951	104,00	5143,58	5,14	9824,75	9,82	2688,27	2,69					9,5	F	2021
21952	104,00	5143,58	5,14	9824,75	9,82	2688,27	2,69					9,0	M	2021
21957	108,00	5758,01	5,76	11031,65	11,03	3000,34	3,00					9,7	F	2021
21955	116,00	7129,60	7,13	13737,74	13,74	3693,85	3,69					10,6	M	2021
21950	118,00	7503,48	7,50	14477,95	14,48	3882,25	3,88					11,5	F	2021
21954	125,00	8914,49	8,91	17279,97	17,28	4591,08	4,59					13,0	M	2021
21923	128,00	9569,59	9,57	18585,06	18,59	4919,12	4,92					12,7	F	2021
21962	130,00	10023,66	10,02	19491,06	19,49	5146,14	5,15					13,0	F	2021
22050	130,00	10023,66	10,02	19491,06	19,49	5146,14	5,15					15,0	M	2021
21953	137,00	11725,46	11,73	22896,10	22,90	5994,65	5,99					15,7	M	2021
21963	143,00	13328,78	13,33	26116,26	26,12	6791,01	6,79					17,3	F	2021
16945	145,00	13893,95	13,89	27253,93	27,25	7071,11	7,07					17,9	F	2021
21959	146,00	14182,43	14,18	27835,09	27,84	7213,96	7,21					18,4	F	2021

21921	148,00	14771,28	14,77	29022,37	29,02	7505,30	7,51					19,4	F	2021
21907	148,00	14771,28	14,77	29022,37	29,02	7505,30	7,51					19,4	F	2021
21887	157,00	17622,82	17,62	34788,95	34,79	8911,99	8,91					23,0	M	2021
21961	159,00	18302,61	18,30	36167,50	36,17	9246,39	9,25					21,5	F	2021
21958	160,00	18648,94	18,65	36870,39	36,87	9416,64	9,42					22,0	F	2021
21960	168,00	21577,95	21,58	42828,10	42,83	10853,17	10,85					27,0	F	2021
21751	99,00	4439,00	4,44	8445,58	8,45	2329,19	2,33					8,8	F	2022
22106	101,60	4796,76	4,80	9145,20	9,15	2511,70	2,51					9,0	F	2022
21701	103,00	4997,11	5,00	9537,61	9,54	2613,74	2,61					9,4	F	2022
21700	106,00	5445,03	5,45	10416,42	10,42	2841,49	2,84					9,5	F	2022
22218	108,00	5758,01	5,76	11031,65	11,03	3000,34	3,00					9,7	F	2022
21847	121,00	8088,42	8,09	15637,97	15,64	4176,50	4,18					12,0	M	2022
21877	122,00	8289,94	8,29	16038,14	16,04	4277,73	4,28					12,2	F	2022
22124	122,00	8289,94	8,29	16038,14	16,04	4277,73	4,28					12,2	F	2022
21742	127,00	9347,78	9,35	18142,90	18,14	4808,12	4,81	29,00	13154,40	13,15	28,9	12,5	F	2022
22127	127,00	9347,78	9,35	18142,90	18,14	4808,12	4,81					13,2	M	2022
21705	129,54	9917,98	9,92	19280,10	19,28	5093,33	5,09					12,8	F	2022
22077	130,00	10023,66	10,02	19491,06	19,49	5146,14	5,15					13,0	F	2022
21702	130,00	10023,66	10,02	19491,06	19,49	5146,14	5,15					15,0	M	2022
21740	131,00	10255,97	10,26	19955,02	19,96	5262,18	5,26					13,2	F	2022
22130	132,00	10491,84	10,49	20426,38	20,43	5379,93	5,38					15,2	M	2022
22655	133,00	10731,29	10,73	20905,18	20,91	5499,39	5,50					13,4	F	2022
22656	134,00	10974,35	10,97	21391,49	21,39	5620,59	5,62					13,5	F	2022
22122	134,50	11097,24	11,10	21637,48	21,64	5681,83	5,68					13,5	F	2022
22053	135,00	11221,05	11,22	21885,38	21,89	5743,52	5,74					14,0	F	2022
22664	135,00	11221,05	11,22	21885,38	21,89	5743,52	5,74					14,0	F	2022
21727	135,00	11221,05	11,22	21885,38	21,89	5743,52	5,74					15,4	M	2022
22661	136,00	11471,41	11,47	22386,89	22,39	5868,20	5,87					14,5	F	2022
22110	137,16	11766,46	11,77	22978,29	22,98	6015,04	6,02					15,7	M	2022
21708	138,00	11983,23	11,98	23413,06	23,41	6122,87	6,12					16,4	F	2022
22050	140,00	12510,03	12,51	24470,48	24,47	6384,68	6,38					15,9	M	2022
21779	142,00	13052,02	13,05	25559,63	25,56	6653,74	6,65					17,2	F	2022

21709	142,00	13052,02	13,05	25559,63	25,56	6653,74	6,65					17,2	F	2022
10096	142,00	13052,02	13,05	25559,63	25,56	6653,74	6,65					17,2	F	2022
21780	142,00	13052,02	13,05	25559,63	25,56	6653,74	6,65					16,0	M	2022
21796	142,24	13118,09	13,12	25692,49	25,69	6686,52	6,69					17,2	F	2022
22108	142,24	13118,09	13,12	25692,49	25,69	6686,52	6,69					17,2	F	2022
22109	142,24	13118,09	13,12	25692,49	25,69	6686,52	6,69					17,2	F	2022
21846	143,00	13328,78	13,33	26116,26	26,12	6791,01	6,79					17,3	F	2022
22651	143,00	13328,78	13,33	26116,26	26,12	6791,01	6,79					17,3	F	2022
22051	144,00	13609,41	13,61	26681,01	26,68	6930,13	6,93					17,4	F	2022
22654	144,00	13609,41	13,61	26681,01	26,68	6930,13	6,93					17,4	F	2022
22600	144,78	13831,02	13,83	27127,18	27,13	7039,93	7,04	42,00	19051,20	19,05	27,4	17,4	F	2022
22114	145,00	13893,95	13,89	27253,93	27,25	7071,11	7,07	40,00	18144,00	18,14	23,4	17,9	F	2022
21738	147,32	14569,28	14,57	28614,94	28,61	7405,39	7,41					19,0	F	2022
21739	147,32	14569,28	14,57	28614,94	28,61	7405,39	7,41					19,0	F	2022
22612	147,32	14569,28	14,57	28614,94	28,61	7405,39	7,41	48,00	21772,80	21,77	33,1	19,0	F	2022
21797	147,32	14569,28	14,57	28614,94	28,61	7405,39	7,41					19,0	F	2022
22102	147,32	14569,28	14,57	28614,94	28,61	7405,39	7,41					19,0	F	2022
21749	147,32	14569,28	14,57	28614,94	28,61	7405,39	7,41					19,5	M	2022
22667	148,00	14771,28	14,77	29022,37	29,02	7505,30	7,51					19,4	F	2022
22219	149,00	15071,71	15,07	29628,60	29,63	7653,83	7,65					19,9	M	2022
22622	149,86	15333,31	15,33	30156,75	30,16	7783,09	7,78	40,00	18144,00	18,14	15,5	19,5	F	2022
22614	149,86	15333,31	15,33	30156,75	30,16	7783,09	7,78	45,00	20412,00	20,41	24,9	19,5	F	2022
18591	150,00	15376,18	15,38	30243,32	30,24	7804,27	7,80					19,7	F	2022
21945	150,00	15376,18	15,38	30243,32	30,24	7804,27	7,80					19,7	F	2022
22223	151,00	15684,71	15,68	30866,59	30,87	7956,64	7,96					19,8	F	2022
21703	152,00	15997,34	16,00	31498,45	31,50	8110,95	8,11					19,8	F	2022
22117	152,00	15997,34	16,00	31498,45	31,50	8110,95	8,11	48,00	21772,80	21,77	26,5	19,9	F	2022
22668	152,00	15997,34	16,00	31498,45	31,50	8110,95	8,11					19,9	F	2022
21733	152,00	15997,34	16,00	31498,45	31,50	8110,95	8,11					20,6	M	2022
22650	152,00	15997,34	16,00	31498,45	31,50	8110,95	8,11					20,6	M	2022
21795	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17					19,9	F	2022
21747	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17					19,9	F	2022

22103	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17					19,9	F	2022
21741	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17	16,00	7257,60	7,26	-122,2	19,9	F	2022
22621	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17	54,00	24494,40	24,49	34,2	19,9	F	2022
22648	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17	43,00	19504,80	19,50	17,3	19,9	F	2022
22608	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17	55,00	24948,00	24,95	35,4	19,9	F	2022
22125	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17	42,00	19051,20	19,05	15,4	19,9	F	2022
22128	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17	37,00	16783,20	16,78	3,9	19,9	F	2022
22104	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17					19,9	F	2022
22105	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17					19,9	F	2022
22123	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17					19,9	F	2022
21777	152,50	16155,20	16,16	31817,63	31,82	8188,83	8,19			0		19,9	F	2022
21736	153,00	16314,09	16,31	32138,98	32,14	8267,20	8,27					20,0	F	2022
21947	153,00	16314,09	16,31	32138,98	32,14	8267,20	8,27					20,0	F	2022
22660	153,00	16314,09	16,31	32138,98	32,14	8267,20	8,27					20,8	M	2022
22219	154,00	16634,99	16,63	32788,23	32,79	8425,43	8,43					20,2	F	2022
22214	154,00	16634,99	16,63	32788,23	32,79	8425,43	8,43					20,2	F	2022
21735	154,00	16634,99	16,63	32788,23	32,79	8425,43	8,43					21,0	M	2022
21785	154,50	16797,00	16,80	33116,15	33,12	8505,28	8,51					20,2	F	2022
22615	154,94	16940,43	16,94	33406,54	33,41	8575,96	8,58	55,00	24948,00	24,95	32,1	20,2	F	2022
22611	154,94	16940,43	16,94	33406,54	33,41	8575,96	8,58	50,00	22680,00	22,68	25,3	20,2	F	2022
22625	154,94	16940,43	16,94	33406,54	33,41	8575,96	8,58	46,00	20865,60	20,87	18,8	20,2	F	2022
22644	154,94	16940,43	16,94	33406,54	33,41	8575,96	8,58	48,00	21772,80	21,77	22,2	20,2	F	2022
22112	155,00	16960,06	16,96	33446,27	33,45	8585,62	8,59	46,00	20865,60	20,87	18,7	20,3	F	2022
22113	155,00	16960,06	16,96	33446,27	33,45	8585,62	8,59	47,00	21319,20	21,32	20,4	20,3	F	2022
22121	155,00	16960,06	16,96	33446,27	33,45	8585,62	8,59	46,00	20865,60	20,87	18,7	20,3	F	2022
22126	155,00	16960,06	16,96	33446,27	33,45	8585,62	8,59	41,00	18597,6	18,60	8,8	21,5	M	2022
22221	156,00	17289,33	17,29	34113,15	34,11	8747,81	8,75					20,6	F	2022
22652	156,00	17289,33	17,29	34113,15	34,11	8747,81	8,75					20,6	F	2022
21948	157,00	17622,82	17,62	34788,95	34,79	8911,99	8,91					20,8	F	2022
22220	157,00	17622,82	17,62	34788,95	34,79	8911,99	8,91					20,8	F	2022
22669	157,00	17622,82	17,62	34788,95	34,79	8911,99	8,91					20,8	F	2022
21704	157,48	17784,41	17,78	35116,51	35,12	8991,51	8,99					20,8	F	2022

21706	157,48	17784,41	17,78	35116,51	35,12	8991,51	8,99					20,8	F	2022
21707	157,48	17784,41	17,78	35116,51	35,12	8991,51	8,99					20,8	F	2022
21793	157,48	17784,41	17,78	35116,51	35,12	8991,51	8,99					20,8	F	2022
21794	157,48	17784,41	17,78	35116,51	35,12	8991,51	8,99					20,8	F	2022
22100	157,48	17784,41	17,78	35116,51	35,12	8991,51	8,99					20,8	F	2022
22101	157,48	17784,41	17,78	35116,51	35,12	8991,51	8,99					20,8	F	2022
22605	157,48	17784,41	17,78	35116,51	35,12	8991,51	8,99	60,00	27216,00	27,22	34,7	20,8	F	2022
22619	157,48	17784,41	17,78	35116,51	35,12	8991,51	8,99	51,00	23133,60	23,13	23,1	20,8	F	2022
22646	157,48	17784,41	17,78	35116,51	35,12	8991,51	8,99	51,00	23133,60	23,13	23,1	20,8	F	2022
22107	157,48	17784,41	17,78	35116,51	35,12	8991,51	8,99	50,00	22680,00	22,68	21,6	20,8	F	2022
21748	157,48	17784,41	17,78	35116,51	35,12	8991,51	8,99					23,0	M	2022
21781	157,50	17791,16	17,79	35130,20	35,13	8994,83	8,99					20,8	F	2022
21750	157,50	17791,16	17,79	35130,20	35,13	8994,83	8,99					20,8	F	2022
21776	157,50	17791,16	17,79	35130,20	35,13	8994,83	8,99					20,8	F	2022
21778	157,50	17791,16	17,79	35130,20	35,13	8994,83	8,99					20,8	F	2022
21964	157,50	17791,16	17,79	35130,20	35,13	8994,83	8,99	45,00	20412,00	20,41	12,8	20,8	F	2022
21966	157,50	17791,16	17,79	35130,20	35,13	8994,83	8,99	43,00	19504,80	19,50	8,8	20,8	F	2022
22111	157,50	17791,16	17,79	35130,20	35,13	8994,83	8,99	50,00	22680,00	22,68	21,6	20,8	F	2022
22119	158,00	17960,57	17,96	35473,71	35,47	9078,18	9,08	45,00	20412,00	20,41	12,0	21,0	F	2022
21725	160,00	18648,94	18,65	36870,39	36,87	9416,64	9,42					22,0	F	2022
22647	160,02	18655,92	18,66	36884,54	36,88	9420,06	9,42	39,00	17690,40	17,69	-5,5	22,0	F	2022
22224	161,00	18999,62	19,00	37582,42	37,58	9588,93	9,59					22,2	F	2022
22670	161,00	18999,62	19,00	37582,42	37,58	9588,93	9,59					22,2	F	2022
21782	162,50	19533,82	19,53	38667,78	38,67	9851,22	9,85					23,7	F	2022
21752	162,50	19533,82	19,53	38667,78	38,67	9851,22	9,85					23,7	F	2022
22116	162,50	19533,82	19,53	38667,78	38,67	9851,22	9,85	47,00	21319,20	21,32	8,4	23,7	F	2022
22118	162,50	19533,82	19,53	38667,78	38,67	9851,22	9,85	44,00	19958,40	19,96	2,1	23,7	F	2022
22120	162,50	19533,82	19,53	38667,78	38,67	9851,22	9,85					23,7	F	2022
21712	162,56	19555,39	19,56	38711,62	38,71	9861,81	9,86					23,7	F	2022
21744	162,56	19555,39	19,56	38711,62	38,71	9861,81	9,86	56,00	25401,60	25,40	23,0	23,7	F	2022
22613	162,56	19555,39	19,56	38711,62	38,71	9861,81	9,86	50,00	22680,00	22,68	13,8	23,7	F	2022
21946	163,00	19714,08	19,71	39034,20	39,03	9939,68	9,94					24,0	F	2022

22216	164,00	20077,92	20,08	39774,06	39,77	10118,18	10,12					24,5	F	2022
22217	164,00	20077,92	20,08	39774,06	39,77	10118,18	10,12					24,5	F	2022
22115	165,00	20446,20	20,45	40523,32	40,52	10298,76	10,30	56,00	25401,60	25,40	19,5	25,0	F	2022
22626	167,64	21440,00	21,44	42546,98	42,55	10785,63	10,79	48,00	21772,80	21,77	1,5	26,0	F	2022
21743	170,18	22426,01	22,43	44557,26	44,56	11268,09	11,27	58,00	26308,80	26,31	14,8	28,0	F	2022
22616	170,18	22426,01	22,43	44557,26	44,56	11268,09	11,27	60,00	27216,00	27,22	17,6	28,0	F	2022
22222	172,00	23150,78	23,15	46036,44	46,04	11622,36	11,62					28,8	F	2022
8172	172,00	23150,78	23,15	46036,44	46,04	11622,36	11,62					28,8	F	2022
22609	172,72	23441,75	23,44	46630,62	46,63	11764,51	11,76	48,00	21772,80	21,77	-7,7	29,0	F	2022
21784	173,00	23555,56	23,56	46863,09	46,86	11820,09	11,82					29,4	F	2022
22078	105,5	5368,59	5,37	10266,31	10,27	2802,67	2,80					9,5	F	2023
22801	113,00	6592,35	6,59	12675,94	12,68	3422,67	3,42					10,3	F	2023
22142	114,30	6821,72	6,82	13128,99	13,13	3538,52	3,54	18,00	8164,80	8,16	16,4	10,5	F	2023
22071	116,84	7285,08	7,29	14045,44	14,05	3772,23	3,77					11,2	F	2023
22227	117,00	7314,95	7,31	14104,57	14,10	3787,28	3,79					11,3	F	2023
22132	122,00	8289,94	8,29	16038,14	16,04	4277,73	4,28	7,00	3175,20	3,18	-161,1	12,0	F	2023
22249	122,00	8289,94	8,29	16038,14	16,04	4277,73	4,28					12,0	F	2023
22140	129,50	9908,82	9,91	19261,83	19,26	5088,76	5,09	22,00	9979,20	9,98	0,7	12,8	F	2023
22820	130,00	10023,66	10,02	19491,06	19,49	5146,14	5,15					13,0	F	2023
22070	134,02	10979,25	10,98	21401,30	21,40	5623,03	5,62					13,5	F	2023
22305	134,60	11121,93	11,12	21686,91	21,69	5694,13	5,69	28,00	12700,80	12,70	12,4	13,5	F	2023
22310	134,60	11121,93	11,12	21686,91	21,69	5694,13	5,69	44,00	19958,40	19,96	44,3	13,5	F	2023
22139	137,20	11776,72	11,78	22998,87	23,00	6020,15	6,02	30,00	13608,00	13,61	13,5	16,0	F	2023
22812	138,00	11983,23	11,98	23413,06	23,41	6122,87	6,12					16,4	F	2023
22143	139,70	12430,05	12,43	24309,85	24,31	6344,95	6,34	33,00	14968,80	14,97	17,0	16,5	F	2023
22250	139,70	12430,05	12,43	24309,85	24,31	6344,95	6,34	41,00	18597,60	18,60	33,2	16,5	F	2023
22251	139,70	12430,05	12,43	24309,85	24,31	6344,95	6,34	32,00	14515,20	14,52	14,4	16,5	F	2023
22145	139,70	12430,05	12,43	24309,85	24,31	6344,95	6,34	30,00	13608	13,61		15,9	M	2023
22149	142,00	13052,02	13,05	25559,63	25,56	6653,74	6,65	36,00	16329,60	16,33	20,1	17,2	F	2023
Failed	142,00	13052,02	13,05	25559,63	25,56	6653,74	6,65					17,2	F	2023
22805	143,00	13328,78	13,33	26116,26	26,12	6791,01	6,79					17,3	F	2023
22148	144,80	13836,73	13,84	27138,69	27,14	7042,76	7,04	37,00	16783,20	16,78	17,6	17,4	F	2023

22253	144,80	13836,73	13,84	27138,69	27,14	7042,76	7,04	40,00	18144,00	18,14	23,7	17,4	F	2023
22311	144,80	13836,73	13,84	27138,69	27,14	7042,76	7,04	48,00	21772,80	21,77	36,4	17,4	F	2023
22803	145,00	13893,95	13,89	27253,93	27,25	7071,11	7,07					17,9	F	2023
22809	145,00	13893,95	13,89	27253,93	27,25	7071,11	7,07					17,9	F	2023
22814	145,00	13893,95	13,89	27253,93	27,25	7071,11	7,07					17,9	F	2023
22252	147,30	14563,36	14,56	28603,01	28,60	7402,47	7,40	45,00	20412,00	20,41	28,7	19,0	F	2023
22306	147,32	14569,28	14,57	28614,94	28,61	7405,39	7,41	42,00	19051,20	19,05	23,5	19,0	F	2023
22259	147,32	14569,28	14,57	28614,94	28,61	7405,39	7,41	32,00	14515,20	14,52	-0,4	19,0	F	2023
22146	147,50	14622,57	14,62	28722,41	28,72	7431,76	7,43	49,00	22226,40	22,23	34,2	19,0	F	2023
22144	149,90	15345,55	15,35	30181,47	30,18	7789,14	7,79	45,00	20412,00	20,41	24,8	19,5	F	2023
22134	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17	46,00	20865,60	20,87	22,7	19,9	F	2023
22137	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17	40,00	18144,00	18,14	11,1	19,9	F	2023
22254	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17	50,00	22680,00	22,68	28,9	19,9	F	2023
22255	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17	48,00	21772,80	21,77	25,9	19,9	F	2023
22301	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17	43,00	19504,80	19,50	17,3	19,9	F	2023
22303	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17	41,00	18597,60	18,60	13,3	19,9	F	2023
22307	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17	45,00	20412,00	20,41	21,0	19,9	F	2023
22258	152,40	16123,55	16,12	31753,62	31,75	8173,21	8,17	43,00	19504,80	19,50	17,3	19,9	F	2023
22807	153,00	16314,09	16,31	32138,98	32,14	8267,20	8,27					20,0	F	2023
22813	153,00	16314,09	16,31	32138,98	32,14	8267,20	8,27					20,0	F	2023
22811	154,00	16634,99	16,63	32788,23	32,79	8425,43	8,43					20,2	F	2023
22819	154,00	16634,99	16,63	32788,23	32,79	8425,43	8,43					20,2	F	2023
22304	154,90	16927,36	16,93	33380,07	33,38	8569,52	8,57	42,00	19051,20	19,05	11,1	20,2	F	2023
22257	154,94	16940,43	16,94	33406,54	33,41	8575,96	8,58	49,00	22226,40	22,23	23,8	20,2	F	2023
22136	155,00	16960,06	16,96	33446,27	33,45	8585,62	8,59	42,00	19051,20	19,05	11,0	20,3	F	2023
22802	156,00	17289,33	17,29	34113,15	34,11	8747,81	8,75					20,6	F	2023
22300	157,50	17791,16	17,79	35130,20	35,13	8994,83	8,99	44,00	19958,40	19,96	10,9	20,8	F	2023
22308	157,50	17791,16	17,79	35130,20	35,13	8994,83	8,99	41,00	18597,60	18,60	4,3	20,8	F	2023
22309	157,50	17791,16	17,79	35130,20	35,13	8994,83	8,99	56,00	25401,60	25,40	30,0	20,8	F	2023
22816	158,00	17960,57	17,96	35473,71	35,47	9078,18	9,08					23,4	M	2023
22302	160,00	18648,94	18,65	36870,39	36,87	9416,64	9,42	52,00	23587,20	23,59	20,9	22,0	F	2023
22256	160,02	18655,92	18,66	36884,54	36,88	9420,06	9,42	63,00	28576,80	28,58	34,7	22,0	F	2023

22806	161,00	18999,62	19,00	37582,42	37,58	9588,93	9,59					22,2	F	2023
22810	161,00	18999,62	19,00	37582,42	37,58	9588,93	9,59					22,2	F	2023
22815	162,00	19354,65	19,35	38303,68	38,30	9763,27	9,76					23,7	F	2023
22073	163,00	19714,08	19,71	39034,20	39,03	9939,68	9,94					24,0	F	2023
22133	165,10	20483,27	20,48	40598,77	40,60	10316,93	10,32	47,00	21319,20	21,32	3,9	25,0	F	2023

Appendix XII. Length-width relationship for male and female tope, from 2006 to 2023.

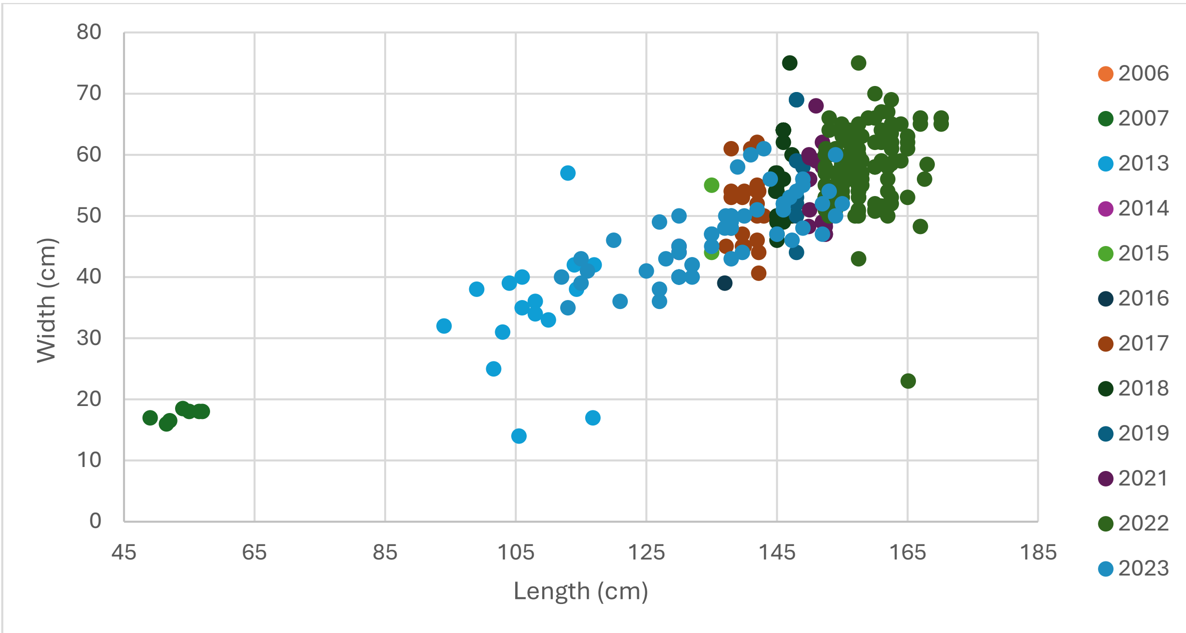

Figure 7. **Female Tope *(Galeorhinus galeus)* Length-Width by Year (2006-2023).** Illustration the relationship between length and width for female Tope from 2006 to 2023 (N=268). The data is plotted by year, providing a visual representation of size variation over time.

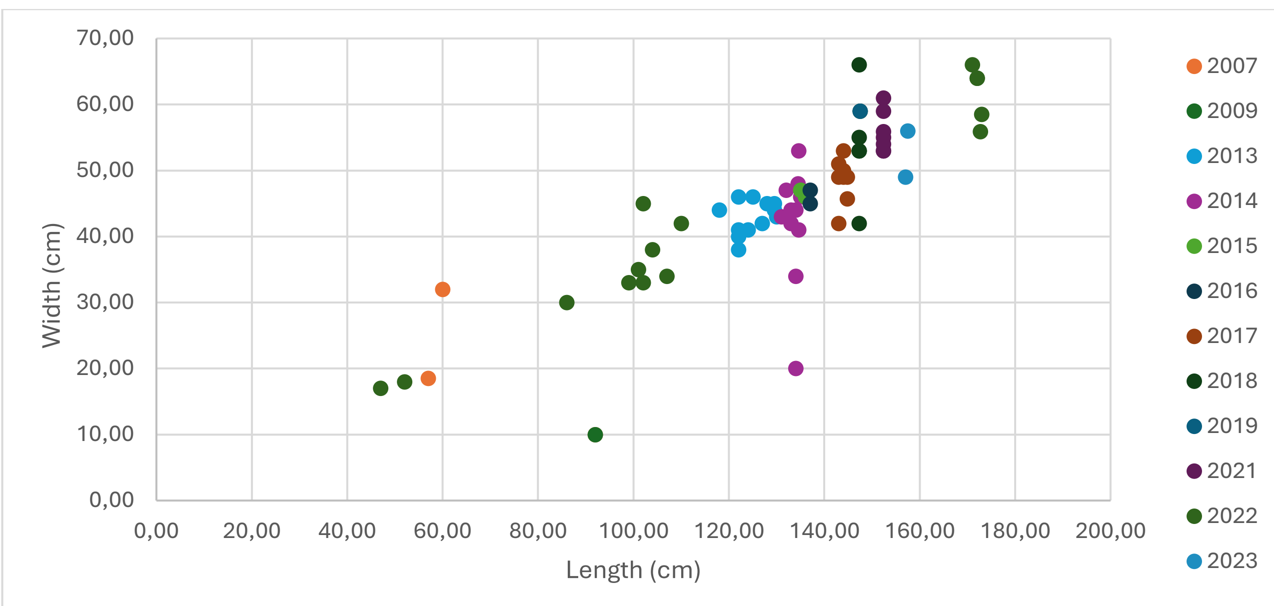

Figure 8. **Male Tope *(Galeorhinus galeus)* Length-Width by Year (2007-2023).** Illustration the relationship between length and width for male Tope from 2006 to 2023 (N=69). The data is plotted by year, providing a visual representation of size variation over time

Appendix XIII. Complete table showing predicted mass and age for spurdog, from 2013 to 2023.

Table 6. **Detailed Breakdown of Tagged Spurdog *(Squalus acanthias*) Sharks in the Isle of Man (2013-2023).** Comprehensive breakdown of tagged Spurdog sharks (N=171) in the Isle of Man from 2013 to 2023. Data includes length (cm), predicted calculated mass (mean, upper, and lower values in kg), actual recorded mass (kg), percentage difference between predicted mean and actual mass, predicted age (years), sex (M for male, F for female), and year of data collection. The percentage difference is color-coded to indicate whether the sharks were underweight (red), overweight (green), or within the expected mass range (yellow).

Tag Number	Measured Length (cm)	Calculated Weight (g) from Fishbase (mean)	Calculated Weight (kg) from Fishbase (mean)	Calculated Weight (g) from Fishbase (upper)	Calculated Weight (kg) from Fishbase (upper)	Calculated Weight (g) from Fishbase (lower)	Calculated Weight (kg) from Fishbase (lower)	Actual Recorded Weight (lbs)	Actual Recorded Weight (kg)	Actual Recorded Weight (g)	% difference	Predicted Age	Sex	Year
9338	75,00	1638,78	1,64	2266,42	2,27	1188,32	1,19							2013
9337	88,00	2681,26	2,68	3731,95	3,73	1931,86	1,93	5,51	2,50	2499,336	-7,3	5,5	M	2013
9340	94,00	3285,24	3,29	4584,68	4,58	2360,79	2,36					5,7	F	2013
9335	95,00	3394,07	3,39	4738,57	4,74	2437,97	2,44	6,87	3,11	3116,232	-8,9	7,2	M	2013
9336	106,00	4756,36	4,76	6669,67	6,67	3401,56	3,40	11,76	5,33	5334,336	10,8	6,8	F	2013
5707	107,00	4895,92	4,90	6867,95	6,87	3500,06	3,50	12,13	5,50	5502,168	11,0	6,9	F	2013
9341	100,00	3974,96	3,97	5560,96	5,56	2849,37	2,85					6,4	F	2014
9331	101,00	4098,67	4,10	5736,31	5,74	2936,87	2,94					6,5	F	2015
9330	101,00	4098,67	4,10	5736,31	5,74	2936,87	2,94					6,5	F	2016
9328	102,00	4224,95	4,22	5915,38	5,92	3026,17	3,03					6,6	F	2016
5889	105,00	4619,51	4,62	6475,31	6,48	3304,94	3,30					6,7	F	2016
9327	108,00	5038,23	5,04	7070,21	7,07	3600,45	3,60					7,0	F	2016
17854	74,50	1605,37	1,61	2219,61	2,22	1164,40	1,16					3,7	F	2017
10057	84,00	2323,34	2,32	3227,76	3,23	1677,09	1,68					4,5	F	2017
12259	84,00	2323,34	2,32	3227,76	3,23	1677,09	1,68					4,5	F	2017
17410	87,00	2588,52	2,59	3601,22	3,60	1865,89	1,87					4,8	F	2017
12263	87,00	2588,52	2,59	3601,22	3,60	1865,89	1,87					4,8	F	2017
17865	88,50	2728,46	2,73	3798,51	3,80	1965,42	1,97					5,2	F	2017

12250	89,00	2776,22	2,78	3865,87	3,87	1999,37	2,00	5,2	F	2017
17862	91,00	2972,90	2,97	4143,42	4,14	2139,12	2,14	5,6	F	2017
10061	92,00	3074,67	3,07	4287,14	4,29	2211,38	2,21	5,7	F	2017
12271	93,00	3178,78	3,18	4434,22	4,43	2285,26	2,29	5,7	F	2017
12274	93,00	3178,78	3,18	4434,22	4,43	2285,26	2,29	5,7	F	2017
12511	93,00	3178,78	3,18	4434,22	4,43	2285,26	2,29	5,7	F	2017
12513	94,00	3285,24	3,29	4584,68	4,58	2360,79	2,36	5,7	F	2017
17874	95,00	3394,07	3,39	4738,57	4,74	2437,97	2,44	5,8	F	2017
17724	95,00	3394,07	3,39	4738,57	4,74	2437,97	2,44	5,8	F	2017
10056	95,00	3394,07	3,39	4738,57	4,74	2437,97	2,44	5,8	F	2017
12256	95,00	3394,07	3,39	4738,57	4,74	2437,97	2,44	5,8	F	2017
17870	96,00	3505,32	3,51	4895,94	4,90	2516,82	2,52	5,9	F	2017
10058	96,00	3505,32	3,51	4895,94	4,90	2516,82	2,52	5,9	F	2017
12251	96,00	3505,32	3,51	4895,94	4,90	2516,82	2,52	5,9	F	2017
12273	96,00	3505,32	3,51	4895,94	4,90	2516,82	2,52	5,9	F	2017
17861	97,00	3619,01	3,62	5056,82	5,06	2597,37	2,60	6,0	F	2017
10059	97,00	3619,01	3,62	5056,82	5,06	2597,37	2,60	6,0	F	2017
12253	97,00	3619,01	3,62	5056,82	5,06	2597,37	2,60	6,0	F	2017
12270	97,00	3619,01	3,62	5056,82	5,06	2597,37	2,60	6,0	F	2017
17871	97,50	3676,77	3,68	5138,59	5,14	2638,29	2,64	6,0	F	2017
17723	97,50	3676,77	3,68	5138,59	5,14	2638,29	2,64	6,0	F	2017
17426	98,00	3735,16	3,74	5221,26	5,22	2679,63	2,68	6,2	F	2017
10054	98,00	3735,16	3,74	5221,26	5,22	2679,63	2,68	6,2	F	2017
12257	98,00	3735,16	3,74	5221,26	5,22	2679,63	2,68	6,2	F	2017
17863	99,00	3853,80	3,85	5389,29	5,39	2763,63	2,76	6,3	F	2017
17430	99,00	3853,80	3,85	5389,29	5,39	2763,63	2,76	6,3	F	2017
12262	99,00	3853,80	3,85	5389,29	5,39	2763,63	2,76	6,3	F	2017
15779	100,00	3974,96	3,97	5560,96	5,56	2849,37	2,85	6,4	F	2017
17857	100,00	3974,96	3,97	5560,96	5,56	2849,37	2,85	6,4	F	2017
10053	100,00	3974,96	3,97	5560,96	5,56	2849,37	2,85	6,4	F	2017
10055	100,00	3974,96	3,97	5560,96	5,56	2849,37	2,85	6,4	F	2017
12264	100,00	3974,96	3,97	5560,96	5,56	2849,37	2,85	6,4	F	2017

12265	100,00	3974,96	3,97	5560,96	5,56	2849,37	2,85	6,4	F	2017
12272	100,00	3974,96	3,97	5560,96	5,56	2849,37	2,85	6,4	F	2017
12512	100,00	3974,96	3,97	5560,96	5,56	2849,37	2,85	6,4	F	2017
12515	100,00	3974,96	3,97	5560,96	5,56	2849,37	2,85	6,4	F	2017
17853	101,00	4098,67	4,10	5736,31	5,74	2936,87	2,94	6,5	F	2017
19858	101,00	4098,67	4,10	5736,31	5,74	2936,87	2,94	6,5	F	2017
17868	102,00	4224,95	4,22	5915,38	5,92	3026,17	3,03	6,6	F	2017
12254	102,00	4224,95	4,22	5915,38	5,92	3026,17	3,03	6,6	F	2017
12258	102,00	4224,95	4,22	5915,38	5,92	3026,17	3,03	6,6	F	2017
12517	102,00	4224,95	4,22	5915,38	5,92	3026,17	3,03	6,6	F	2017
19850	102,00	4224,95	4,22	5915,38	5,92	3026,17	3,03	6,6	F	2017
15776	103,00	4353,83	4,35	6098,21	6,10	3117,26	3,12	6,6	F	2017
15778	103,00	4353,83	4,35	6098,21	6,10	3117,26	3,12	6,6	F	2017
17432	103,00	4353,83	4,35	6098,21	6,10	3117,26	3,12	6,6	F	2017
10060	103,00	4353,83	4,35	6098,21	6,10	3117,26	3,12	6,6	F	2017
12261	103,00	4353,83	4,35	6098,21	6,10	3117,26	3,12	6,6	F	2017
12268	103,00	4353,83	4,35	6098,21	6,10	3117,26	3,12	6,6	F	2017
12269	103,00	4353,83	4,35	6098,21	6,10	3117,26	3,12	6,6	F	2017
17436	103,00	4353,83	4,35	6098,21	6,10	3117,26	3,12	6,6	F	2017
17431	103,50	4419,25	4,42	6191,04	6,19	3163,49	3,16	6,6	F	2017
17867	104,00	4485,34	4,49	6284,84	6,28	3210,18	3,21	6,6	F	2017
17851	104,00	4485,34	4,49	6284,84	6,28	3210,18	3,21	6,7	F	2017
12267	104,00	4485,34	4,49	6284,84	6,28	3210,18	3,21	6,7	F	2017
19852	104,00	4485,34	4,49	6284,84	6,28	3210,18	3,21	6,7	F	2017
19854	104,00	4485,34	4,49	6284,84	6,28	3210,18	3,21	6,7	F	2017
19856	104,00	4485,34	4,49	6284,84	6,28	3210,18	3,21	6,7	F	2017
19859	104,00	4485,34	4,49	6284,84	6,28	3210,18	3,21	6,7	F	2017
17855	105,00	4619,51	4,62	6475,31	6,48	3304,94	3,30	6,7	F	2017
12252	105,00	4619,51	4,62	6475,31	6,48	3304,94	3,30	6,7	F	2017
12514	105,00	4619,51	4,62	6475,31	6,48	3304,94	3,30	6,7	F	2017
12516	105,00	4619,51	4,62	6475,31	6,48	3304,94	3,30	6,7	F	2017
19890	105,00	4619,51	4,62	6475,31	6,48	3304,94	3,30	6,7	F	2017

17435	105,00	4619,51	4,62	6475,31	6,48	3304,94	3,30	6,7	F	2017
17858	106,00	4756,36	4,76	6669,67	6,67	3401,56	3,40	6,8	F	2017
17872	106,00	4756,36	4,76	6669,67	6,67	3401,56	3,40	6,8	F	2017
12260	106,00	4756,36	4,76	6669,67	6,67	3401,56	3,40	6,8	F	2017
19851	106,00	4756,36	4,76	6669,67	6,67	3401,56	3,40	6,8	F	2017
19855	106,00	4756,36	4,76	6669,67	6,67	3401,56	3,40	6,8	F	2017
17427	106,50	4825,80	4,83	6768,32	6,77	3450,57	3,45	6,8	F	2017
17852	107,00	4895,92	4,90	6867,95	6,87	3500,06	3,50	6,9	F	2017
17428	107,00	4895,92	4,90	6867,95	6,87	3500,06	3,50	6,9	F	2017
20444	107,00	4895,92	4,90	6867,95	6,87	3500,06	3,50	6,9	F	2017
17850	108,00	5038,23	5,04	7070,21	7,07	3600,45	3,60	7,0	F	2017
12255	108,00	5038,23	5,04	7070,21	7,07	3600,45	3,60	7,0	F	2017
17869	109,00	5183,30	5,18	7276,47	7,28	3702,75	3,70	7,1	F	2017
15777	110,00	5331,17	5,33	7486,78	7,49	3806,99	3,81	7,2	F	2017
17433	110,00	5331,17	5,33	7486,78	7,49	3806,99	3,81	7,2	F	2017
19853	110,00	5331,17	5,33	7486,78	7,49	3806,99	3,81	7,2	F	2017
17859	110,50	5406,16	5,41	7593,47	7,59	3859,84	3,86	7,2	F	2017
17429	110,50	5406,16	5,41	7593,47	7,59	3859,84	3,86	7,2	F	2017
17434	112,00	5635,39	5,64	7919,73	7,92	4021,34	4,02	7,5	F	2017
17864	113,00	5791,81	5,79	8142,44	8,14	4131,49	4,13	7,6	F	2017
15455	98,00	3735,16	3,74	5221,26	5,22	2679,63	2,68	6,2	F	2018
7298	100,00	3974,96	3,97	5560,96	5,56	2849,37	2,85	6,4	F	2018
15451	102,00	4224,95	4,22	5915,38	5,92	3026,17	3,03	6,6	F	2018
15453	103,00	4353,83	4,35	6098,21	6,10	3117,26	3,12	6,6	F	2018
17436	103,00	4353,83	4,35	6098,21	6,10	3117,26	3,12	6,6	F	2018
9325	104,00	4485,34	4,49	6284,84	6,28	3210,18	3,21	6,7	F	2018
15450	105,00	4619,51	4,62	6475,31	6,48	3304,94	3,30	6,7	F	2018
5746	105,00	4619,51	4,62	6475,31	6,48	3304,94	3,30	6,7	F	2018
17435	105,00	4619,51	4,62	6475,31	6,48	3304,94	3,30	6,7	F	2018
15452	107,00	4895,92	4,90	6867,95	6,87	3500,06	3,50	6,9	F	2018
15454	107,00	4895,92	4,90	6867,95	6,87	3500,06	3,50	6,9	F	2018
5899	110,00	5331,17	5,33	7486,78	7,49	3806,99	3,81	7,2	F	2018

12796	110,00	5331,17	5,33	7486,78	7,49	3806,99	3,81	7,2	F	2018
7297	110,00	5331,17	5,33	7486,78	7,49	3806,99	3,81	7,2	F	2018
17380	90,00	2873,42	2,87	4003,01	4,00	2068,45	2,07	5,5	F	2019
17377	92,00	3074,67	3,07	4287,14	4,29	2211,38	2,21	5,7	F	2019
17379	96,00	3505,32	3,51	4895,94	4,90	2516,82	2,52	5,9	F	2019
17376	97,00	3619,01	3,62	5056,82	5,06	2597,37	2,60	6,0	F	2019
17378	98,00	3735,16	3,74	5221,26	5,22	2679,63	2,68	6,2	F	2019
17381	98,00	3735,16	3,74	5221,26	5,22	2679,63	2,68	6,2	F	2019
17382	101,00	4098,67	4,10	5736,31	5,74	2936,87	2,94	6,5	F	2019
17383	102,00	4224,95	4,22	5915,38	5,92	3026,17	3,03	6,6	F	2019
21885	50,00	470,07	0,47	639,64	0,64	346,43	0,35	2,0	F	2021
21890	50,00	470,07	0,47	639,64	0,64	346,43	0,35	2,0	F	2021
21886	52,00	530,42	0,53	722,90	0,72	390,30	0,39	2,0	M	2021
21883	53,00	562,47	0,56	767,17	0,77	413,57	0,41	2,0	M	2021
21884	60,00	824,21	0,82	1129,75	1,13	603,02	0,60	2,5	F	2021
21888	62,00	911,80	0,91	1251,45	1,25	666,22	0,67	2,5	F	2021
21891	68,00	1211,88	1,21	1669,47	1,67	882,22	0,88	2,7	F	2021
21892	70,00	1325,06	1,33	1827,49	1,83	963,49	0,96	3,5	M	2021
21896/21895	72,00	1445,16	1,45	1995,39	2,00	1049,64	1,05	3,0	F	2021
21893	73,00	1507,88	1,51	2083,13	2,08	1094,59	1,09	3,6	M	2021
21897	78,00	1849,20	1,85	2561,45	2,56	1338,80	1,34	3,9	F	2021
21917	80,00	1999,17	2,00	2771,98	2,77	1445,91	1,45	4,1	F	2021
21889	81,00	2077,14	2,08	2881,53	2,88	1501,56	1,50	4,2	F	2021
21898	82	2157,15	2,16	2993,98	2,99	1558,63	1,56	5,0	M	2021
21899	84	2323,34	2,32	3227,76	3,23	1677,09	1,68	4,5	F	2021
21903	89,00	2776,22	2,78	3865,87	3,87	1999,37	2,00	6,8	M	2021
21918	90,00	2873,42	2,87	4003,01	4,00	2068,45	2,07	5,5	F	2021
21897/21896	92,00	3074,67	3,07	4287,14	4,29	2211,38	2,21	6,5	M	2021
21911	94,00	3285,24	3,29	4584,68	4,58	2360,79	2,36	5,7	F	2021
21906	94,00	3285,24	3,29	4584,68	4,58	2360,79	2,36	5,7	F	2021
21908	95,00	3394,07	3,39	4738,57	4,74	2437,97	2,44	5,8	F	2021
21912	98,00	3735,16	3,74	5221,26	5,22	2679,63	2,68	6,2	F	2021

21914	101,00	4098,67	4,10	5736,31	5,74	2936,87	2,94	6,5	F	2021
21904	102,00	4224,95	4,22	5915,38	5,92	3026,17	3,03	6,6	F	2021
21910	103,00	4353,83	4,35	6098,21	6,10	3117,26	3,12	6,6	F	2021
21915	103,00	4353,83	4,35	6098,21	6,10	3117,26	3,12	6,6	F	2021
21916	105,00	4619,51	4,62	6475,31	6,48	3304,94	3,30	6,7	F	2021
21902	105,00	4619,51	4,62	6475,31	6,48	3304,94	3,30	6,7	F	2021
21900	106,00	4756,36	4,76	6669,67	6,67	3401,56	3,40	6,8	F	2021
21901	112,00	5635,39	5,64	7919,73	7,92	4021,34	4,02	7,5	F	2021
21913	115,00	6113,39	6,11	8600,57	8,60	4357,82	4,36	7,8	F	2021
21875	70,00	1325,06	1,33	1827,49	1,83	963,49	0,96	3,0	F	2022
22206	91,00	2972,90	2,97	4143,42	4,14	2139,12	2,14	5,6	F	2022
22207	91,00	2972,90	2,97	4143,42	4,14	2139,12	2,14	5,6	F	2022
22208	95,00	3394,07	3,39	4738,57	4,74	2437,97	2,44	5,8	F	2022
22200	96,00	3505,32	3,51	4895,94	4,90	2516,82	2,52	5,9	F	2022
22209	99,00	3853,80	3,85	5389,29	5,39	2763,63	2,76	6,3	F	2022
22665	100,00	3974,96	3,97	5560,96	5,56	2849,37	2,85	6,4	F	2022
22202	103,00	4353,83	4,35	6098,21	6,10	3117,26	3,12	6,6	F	2022
22659	103,00	4353,83	4,35	6098,21	6,10	3117,26	3,12	6,6	F	2022
22211	104,00	4485,34	4,49	6284,84	6,28	3210,18	3,21	6,7	F	2022
22203	105,00	4619,51	4,62	6475,31	6,48	3304,94	3,30	6,7	F	2022
22212	105,00	4619,51	4,62	6475,31	6,48	3304,94	3,30	6,7	F	2022
22228	80,00	1999,17	2,00	2771,98	2,77	1445,91	1,45	4,8	M	2023
22248	84,00	2323,34	2,32	3227,76	3,23	1677,09	1,68	4,5	F	2023
Failed	85,00	2409,59	2,41	3349,17	3,35	1738,53	1,74	4,6	F	2023
22225	94,00	3285,24	3,29	4584,68	4,58	2360,79	2,36	5,7	F	2023

Appendix XIV. Length-width relationship for male and female spurdog, from 2013 to 2023.

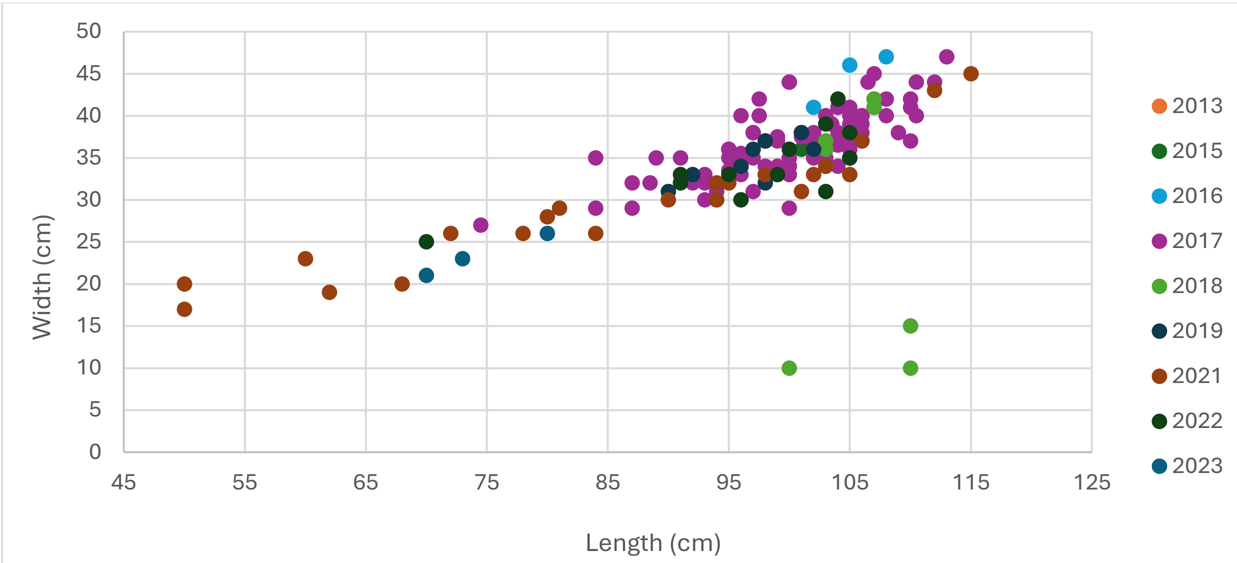

Figure 9. **Female Spurdog *(Squalus acanthias*) Length-Width by Year (2013-2023).** Illustration the relationship between length and width for female Spurdog from 2013 to 2023 (N=154). The data is plotted by year, providing a visual representation of size variation over time.

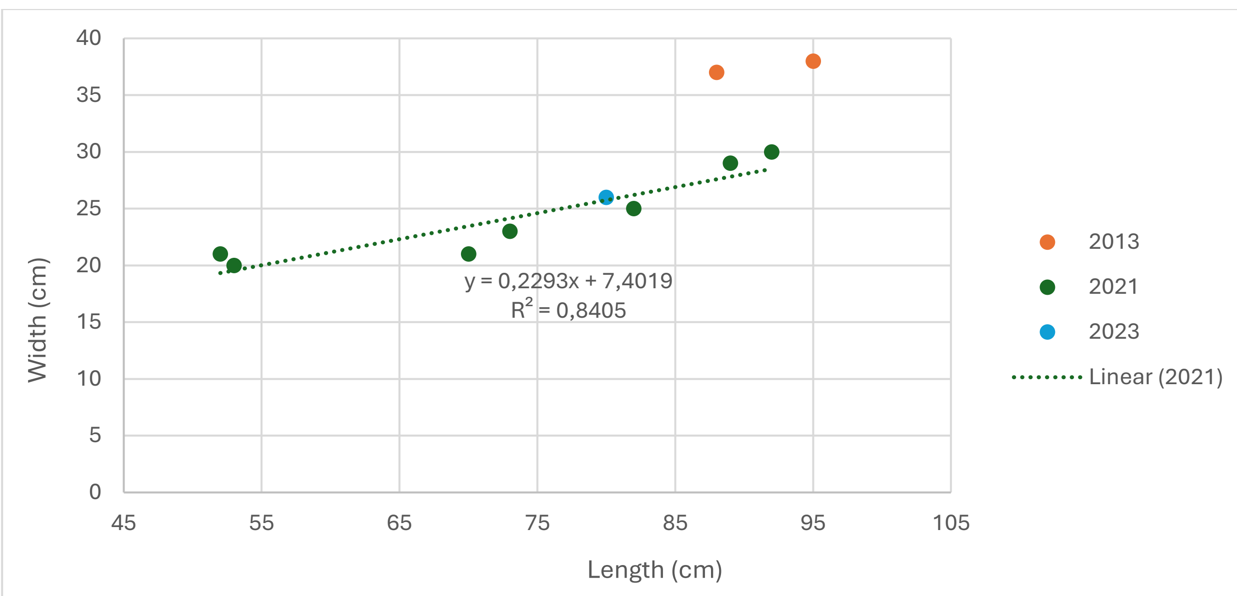

Figure 10. **Male Spurdog *(Squalus acanthias*) Length-Width for 2013, 2021, and 2023.** Illustration the relationship between length and width for male Spurdog in 2013, 2021, and 2023 (N=10). The data is plotted by year, providing a visual representation of size variation over time.

Appendix XV. Infographic summarizing the MWT SSTP and the present study.

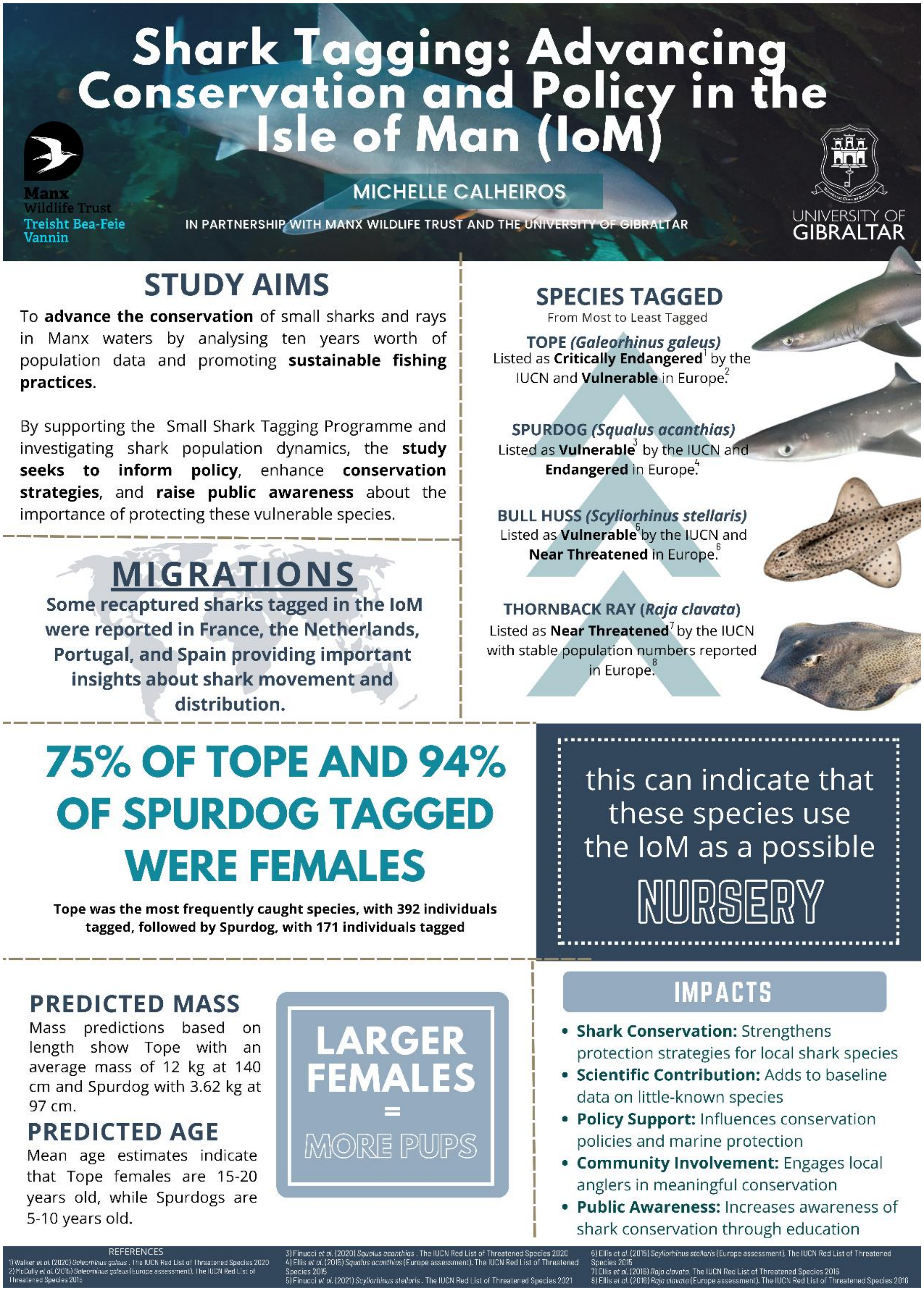

Plate 1. **Infographic of the Study's Key Highlights.** Can be utilised by the Manx Wildlife Trust on their website, social media platforms, and newsletters to effectively share and promote the study's findings.

Appendix XVI. Infographic summarizing the MWT SSTP.

Plate 2. **Infographic of the Manx Wildlife Trust Small Shark Tagging Programme.** Can be utilised by the MWT on their website, social media platforms, and newsletters to effectively promote and raise awareness of the programme.

Appendix XVII. Pamphlet MWT for general public engagement.

Plate 3. **Infographic of the Manx Wildlife Trust**. Can be used by the MWT on their website, social media platforms, and newsletters to effectively disseminate information about the Trust's initiatives and mission.