

# Identifying critical habitat with archives: 275-year-old naturalist's notes provide high-resolution spatial evidence of long-term core habitat for a critically endangered shark

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## **Biological Conservation**

DOI: 10.1016/j.biocon.2022.109621

Published: 01/08/2022

Peer reviewed version

Cyswllt i'r cyhoeddiad / Link to publication

*Dyfyniad o'r fersiwn a gyhoeddwyd / Citation for published version (APA):* Moore, A., & Hiddink, J. G. (2022). Identifying critical habitat with archives: 275-year-old naturalist's notes provide high-resolution spatial evidence of long-term core habitat for a critically endangered shark. Biological Conservation, 272, Article 109621. https://doi.org/10.1016/j.biocon.2022.109621

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## 1 Abstract

Historical sources can provide important data for modern-day threatened species conservation, 2 3 such as identifying formerly important habitat on which to focus recovery efforts. Here we reveal unique written archival material from the 1740s that provides reliable first-hand 4 observations of the Critically Endangered angel shark Squatina squatina, extending modern 5 knowledge of this species in Welsh waters back by over half a century. These sources clearly 6 7 identify small-scale and spatially explicit locations areas of abundance (including of juveniles) around specific reefs that align with more recent data, further strengthening evidence that these 8 9 areas are of long-term importance that should be prioritised for the global conservation of this species, which has become extinct across much of its former range. These contemporary 10 sources also describe fisheries for angel shark and high desirability, economic value and export 11 trade of their meat, which could suggest that population declines of this intrinsically vulnerable 12 species commenced centuries before modern science detected this. These unique contemporary 13 observations highlight the value that historic material can provide in prioritising resource-14 limited conservation efforts, as well as helping to reframe our temporal understanding of 15 elasmobranch fish declines. 16

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18 Key words: historical ecology, conservation, fisheries, elasmobranch, nursery, marine19 protected area

20 Running head: Historic sources reveal core shark habitat

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22 1. INTRODUCTION

Restoring biodiversity is a major global policy target. However, this is constrained by the fact 23 that modern scientific research or monitoring often started long after declines commenced, 24 resulting in only a partial understanding of past distribution, suitable habitat, and abundance. 25 Historical data sources such as archives can reveal new spatially explicit information on the 26 former distribution and critical habitat of threatened marine species which can inform their 27 conservation, such as humpback whale feeding grounds, shark nursery areas, and turtle nesting 28 29 beaches (Reeves et al. 2004, McLenachan et al. 2006, 2012, Moore 2018, Thurstan et al. 2022). Historical sources are also gaining broader acknowledgement for their ability to inform 30 31 ambitious species recovery initiatives like the IUCN Green List of Threatened Species (Grace et al. 2019). As archival material or old texts can by their nature be unique, valuable or fragile, 32 they can be difficult to access, but this is changing with open-access digitisation of resources, 33 such as the Biodiversity Heritage Library (https://www.biodiversitylibrary.org/). 34

The angel shark (Squatina squatina, Squatinidae) is a medium-sized (ca. 2.44 m total length, 35 TL) shark, with a historic range across shallow seas of the northeast Atlantic. Formerly 36 common, its demersal nature, affinity for sedimentary habitat, and relatively large size make it 37 highly susceptible to a range of fishery gear types. Combined with intrinsic biological 38 vulnerabilities of slow growth and low productivity, this has resulted in widespread local 39 extirpations, and it is now considered Critically Endangered with extinction; it is now only 40 regularly observed in the Canary Islands, and occasionally in Wales and Ireland (Morey et al., 41 2019). 42

In British waters the decline of *S. squatina* has been known for some time, based on 20<sup>th</sup> century trawl surveys (Rogers and Ellis 2000). Within Welsh waters, two recent studies have compiled data, including from historical sources, on angel sharks. Hiddink et al. (2019) collated 1860 records between 1970 and 2016, and from this estimated a 70% decline in abundance, with a contraction in range to Cardigan Bay. These authors noted a concentration of records in the

area around three parallel shingle reefs or causeways (Welsh 'sarn', pl. 'sarnau') extending 48 northeast-southwest from the coast, across a distance of approximately 40 km from north-south 49 in the northern half of Cardigan Bay, particularly around the Cynfelyn Patches (also known as 50 Sarn Gynfelyn) (Figure 1). Hiddink et al. (2019) suggested these reefs may comprise essential 51 habitat which could be the focus of conservation efforts, such as spatial restrictions on net 52 fisheries to minimise unintended bycatch. The Angel Shark: Wales project gathered additional 53 54 unique records around the Welsh coast dating back to 1812, and similarly reported the highest concentration in coastal waters of the northern half of Cardigan Bay (Figure 1)(Barker et al. 55 56 2020). This area included the central reef, Sarn-y-Bwch, which extends from the coast approximately 13 km south-southwest of the town of Barmouth (Figure 1). Here we report on 57 how archive material significantly extends our understanding of angel shark in Welsh waters. 58

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# 2. MATERIALS & METHODS

Lewis Morris (1701-1765) was a Welsh polymath whose life included surveying the entire 61 coast of Wales to produce detailed and accurate maps, and working as a customs officer in 62 Welsh ports, notably the north Wales settlements of Holyhead and Beaumaris (Jenkins, 1959). 63 Morris owned and annotated a copy of the second edition of De Historia Piscium, Francis 64 Willughby's seminal ichthyological work of 1686, a digitised copy of which is available from 65 the National Library of Wales; it is thought Morris made these notes between 1740 and 1747 66 67 (Morris 1740-1747). In this, Morris provides numerous handwritten observations on fish and fisheries around northern Wales which are often both spatially explicit and accurate based on 68 modern knowledge (Moore, in prep.). Morris also owned a 'commonplace book' (undated, but 69 70 text dates within range from 1736-1754) which included further observations of fish; we examined this in the National Library of Wales. We also examined an original text of Morris' 71 published coastal maps of Wales ("Plans, harbours and roads of St. George's Channel..."), 72

which included notes on 'natural commodities' at each location (Morris 1748) in Bangor
University Archives and Special Collections. Spellings in quotes are verbatim.

# **3. RESULTS**

Within the section of De Historia Piscium dealing with elasmobranch fishes, digitised page 76 435 of Morris (1740-1747) presents an unmistakeable image of an angel shark Squatina 77 squatina, the only species of this family to occur in British waters. In handwriting above this, 78 Morris notes: "The monkfish or angelfish. In Wales called Maelgi. They are found in plenty 79 about Sarn y Bwch and in Barmouth Bay". On the same page, Morris also notes, sketches the 80 ventral surface of, and provides measurements for what is also clearly an angel shark "...which 81 I took A.D. 1739. It was 20 inches [51 cm] long" (Figure 2a). He goes on to note that angel 82 83 shark were sizeable ("...generally of the size of a man"), highly desirable as food ("...delicious 84 eating, said to have 3 sorts of fish on it, a ray, a salmon, and a sturgeon"), and caught either in targeted or bycatch net fisheries ("They take them in nets with meshes 10 inches [25 cm] or 85 a foot [30 cm] square."). 86

In his commonplace book, Morris then provides further additional detail on angel sharks 87 88 (Morris, undated, p. 5). Along with a reliable description (inc. "It is rough on the back like the common dogfish, & of ash colour. The belly is soft, white and tender. The eyes very small & 89 near its snout"), he notes "These fish breed in great plenty about Sarn y Bwch & Llwyn Gwryl 90 91 on the coast of Merionethshire [historic county name]". He then elaborates on utilisation, trade and fisheries: "The wings [pectoral fins] of it are exceeding tender, eating like a maiden ray 92 [rajid skate, typically thornback ray Raja clavata]. The tail like a dogfish, the main body like a 93 94 sturgeon, for which latter fish it is often sold in England by the Welsh fishermen who make great gain of it. They are commonly about the bigness of a man, and are taken in nets whose 95 mashes [sic] are squares of 10 inches side & sometimes are found entangled in herring nets". 96

Morris (undated) also sketches and provides details of what is apparently the same juvenile
already mentioned (Figure 2b), but this time provides both ventral and dorsal views (Figure
2b) and a capture location: "*The fish by which I took this draught was taken in Holyhead, 1739*and was but a young one of 20 inches [51 cm] long i.e. 8 inch [20 cm] tail, 12 inch [30 cm]
body. 11 inch [28 cm] broad at the main wings".

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Lastly, in *Plans and harbours*, under Cardigan Bay, Morris (1748, p. 11) has a subheading
entitled 'Of the monk-fish'. The first sentence of this provides yet further location data: "This
fish breeds in plenty about Sarn Gynfelyn and Sarn y Bwch; and is called by the natives
Maelgi.". He also reiterates his observation on fisheries and desirability: "It is taken in nets
made of small ropes, with about ten inches mash [sic], and is reckoned a delicious dish."

#### 108 **4. DISCUSSION**

109 These contemporary observations extend modern knowledge of the Critically Endangered angel sharks in Wales by at least 64 years (cf. 1812 in Barker et al. 2020). Morris can be taken 110 as a reliable source for first-hand observations: his nautical charts of detailed bathymetry 111 112 demonstrate he had intimate knowledge of the coast, including the sarnau in Cardigan Bay (Morris, 1748). His identifications can also be regarded as accurate based on his sketches and 113 descriptions; possible confusion with the teleost fish Lophius piscatorius, sometimes also 114 called 'monkfish', can be discounted, as he accurately sketched this species quite separately 115 from S. squatina (Morris, undated). His Welsh name for angel shark, maelgi, also aligns with 116 current usage (Barker et al., 2020). 117

The most important aspect of these sources for modern-day conservation is the high-resolution spatial information they provide on core habitat. Collectively, Morris' notes from nearly 300 years ago, and based on his knowledge of the entire Welsh coast, provide information on a specific area of local abundance around two of the sarnau (Sarn-y-Bwch and the Cynfelyn
Patches/Sarn Gynfelyn) and two nearby coastal settlements (Barmouth and Llwyngwril, Figure
1). Combined with more recent records of Hiddink et al. (2019) and Barker et al. (2020), these
therefore significantly strengthen evidence that this relatively small area is of long-term
importance to this species.

These records also reveal new insights into the life history of angel shark in Welsh waters. The 126 individual Morris reported and accurately sketched from Holyhead would have been within its 127 first few years of life, given that the birth size is 20-30 cm TL (Morey et al. 2019). Morris 128 (undated) clearly knew this ("...a young one"). To our knowledge, this is the earliest record of 129 a young angel shark in Welsh waters and possibly much wider, or even of the species as a 130 whole. It also provides valuable rare supporting evidence that young occur in Welsh waters, as 131 only 4% of the records collected by the Angel Shark: Wales project were juveniles (Zoological 132 Society of London 2021). 133

Two of Morris' observations from northern Cardigan Bay around the sarnau specifically mention breeding ("*breeds in plenty*, "*breeds in great plenty*"; Morris undated, 1748). As Morris was clearly familiar with what a young angel shark looked like, and the entire Welsh coast, this could indicate a nursery area. If so, this is of direct conservation interest, because northern Cardigan Bay was also where the underwater footage of a young angel shark – the first of this species in Welsh waters - was recently captured and reported to media globally (Davies 2021, Zoological Society of London 2021).

141 Collectively these data add further weight to the importance of inshore waters of northern 142 Cardigan Bay, and specifically the relatively small areas around the sarnau, as a global priority 143 for the conservation of this species of angel shark, given its disappearance from much of its 144 former range as a priority for conservation. Having evidence of long-term importance,

including as a possible nursery area, provides confidence in the focused targeting of resource-145 limited conservation efforts, such as research and angler education. The spatially explicit nature 146 of the 'hotspot' and the highly threatened status of angel shark, would make this an ideal 147 candidate for an Important Shark Area, an initiative that aims to provide an easily accessible 148 overview of globally recognised, criteria-based selections to further conservation and 149 sustainable management (Moore & Fowler, 2022). In the context of severe declines elsewhere, 150 151 the reasons for the relative abundance and/or persistence of angel shark in this area are unknown, but it may be that the shallow reef features may have provided a refuge from fisheries 152 153 interactions, especially the historic trawl fisheries that operated in Cardigan Bay (Moore, unpublished data). 154

Morris' notes also provide new insights on fisheries, utilisation and trade that significantly 155 extend our temporal understanding of the exploitation of this elasmobranch fish. Angel shark 156 was apparently highly desirable ("delicious", "exceeding tender") and commercially valuable 157 for export trade as counterfeit sturgeon meat ("often sold in England by the Welsh fishermen 158 who make great gain of it"). Combined with their relatively large body size this would have 159 made them a valuable catch, and Morris' mention of large-mesh nets suggests they may have 160 been targeted or semi-targeted, in addition to their bycatch in herring nets. Angel sharks were 161 also being caught long before Morris' time, in Dutch fisheries of the 1500s, and possibly in 162 163 Scottish fisheries in the 1600s (Bennema & Rijnsdorp 2015, Raye 2018). Combined with their inherent biological vulnerability (e.g. low productivity) already noted, this could suggest that 164 fisheries-induced declines of angel shark commenced long before it was formally documented 165 by modern science around 250 years later (e.g. Rogers & Ellis 2000). This may help re-frame 166 the conventional narrative that declines in elasmobranch abundance are a phenomenon that 167 largely commenced in the 20th century (Brander 1981, Rogers & Ellis 2000, Ferretti et al., 168 2010, Pacoureau et al., 2021). 169

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- 232

# 233 FIGURES





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Figure 1. Left (top): British Isles (inset: Wales); left (bottom): Wales (inset: Cardigan Bay). Blue circle shows Holyhead, site of 1739 record of young angel shark *Squatina squatina* (see Figure 2). Right (main image): map of northern Cardigan Bay showing shallow reef ('sarn') features and isobaths (10 and 15 m). Green shading shows areas of angel shark breeding habitat and/or abundance recorded by Lewis Morris in the mid-1700s around Sarn y Bwch, Sarn Gynfelyn (Cynfelyn Patches), Barmouth Bay and Llwyngwril (see text). . Recent angel shark records from 1970-2016 compiled by Hiddink et al., (2019) are shown in red, with density of

colour increasing with number of records. All records are jittered (normal distribution with SD
= 2000 m). Thick black lines surround the approximate area containing the highest density of
angel shark records, Wales-wide, compiled by Barker et al. (2020).

Figure 2. A (left) Sketch of ventral surface of young angel shark *Squatina squatina* extracted
from Morris (1740-1747) "*which I took A.D. 1739. It was 20 inches* [51 cm] *long*". B) (centre
and right). Sketch apparently of the same individual, from Morris (undated) "...*taken in Holyhead, 1739, and was but a young one of 20 inches* [51 cm]".



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