Saving the last Angel Sharks of the Mediterranean Sea: X-ray report on spatial protection for Angel Sharks with a focus on the Adriatic Sea.

Developed by the Zoological Society of London on behalf of the Angel Shark Project; contracted by WWF Mediterranean

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Executive Summary

Three angel shark species are found in the Mediterranean Sea, *Squatina squatina* (Angelshark), *S. aculeata* (sawback Angelshark), and *S. oculata* (smoothback Angelshark) all of which are classified as Critically Endangered on the International Union for the Conservation of Nature's (IUCN) Red List of Threatened Species. A Regional Action Plan for Angel Sharks in the Mediterranean (MedRAP) was published in 2019 to focus efforts on coordinated conservation action for these species, with specific Sub-Regional Action Plans (SubRAPs) to be developed to facilitate this. This study aimed to identify possible angel shark hotspots; evaluate the overlap of angel sharks with designated Marine Protected Areas (MPAs) and Fisheries Restricted Areas (FRAs); provide recommendations to improve angel shark protection; and act as a baseline to develop the Adriatic SubRAP. Although some outputs span the Mediterranean Sea, this study and recommendations focus on the Adriatic Sea.

Angel shark occurrence data were gathered from the Angel Shark Sightings Map and a Local Ecological Knowledge (LEK) case study conducted in Croatia by WWF Adria. These data were analysed in the context of the existing network of MPAs and FRAs designated in the Mediterranean Sea. 27.8 % of angel shark records in the Mediterranean Sea were found to occur within a designated MPA, and 97 % of these were *S. squatina.* None of the MPAs had a management plan or an implemented management plan, and the majority were designated as Natura 2000 sites.

In the Adriatic Sea, only *S. squatina* records were reported, adding to the documented uncertainty of whether *S. oculata* remains extant in this part of its historic range. The LEK case study provided a substantial number of new *S. squatina* records, with the majority caught and landed. Recent records (2010–2020 inclusive) were mainly distributed in the northern Adriatic Sea, with a potential hotspot identified in the Molat Island archipelago. Distribution of *S. squatina* records supported published literature on habitat preference, with 62 % of sightings located shallower than 50m depth on soft sediments. Presence of juvenile *S. squatina* and anecdotal evidence of females aborting pups when accidentally caught, suggest a potential *S. squatina* nursery area located in the Molat Island archipelago.

Six recommendations to improve understanding and conservation of angel sharks in the Adriatic Sea were developed:

1. Work with the Government of the Republic of Croatia and Natura 2000 management officials to improve understanding of angel shark presence in the region, and where appropriate, account for this in management plans.
2. Further angel shark research at possible hotspots to strengthen baseline knowledge of angel sharks in the region.
3. Train fishers in best-practice guidance to safely release angel sharks and work with communities around Molat Island archipelago.
4. Develop a sub-regional action plan for the Adriatic Sea.
5. Develop angel shark LEK case study template to replicate research in other countries.
6. If Angelshark hotspots are confirmed with further study, identify mechanisms to develop MPAs to protect these habitats (see Recommendation 2 & 3).

Contents

Background

Biodiversity in the Mediterranean Sea:

The Mediterranean Sea is a biodiversity hotspot, of significant cultural and economic importance (Bianchi & Morri 2000, Myers *et al*. 2000, Abdulla *et al*. 2009, Claudet & Fraschetti 2010, Coll *et al.* 2010, 2012). Approximately 7 % of the worlds marine biodiversity is found in the Mediterranean Sea, which is substantial for a water body covering just 0.82 % of the global marine area (Bianchi & Morri 2000, Coll *et al.* 2010, Micheli *et al*. 2013). The Mediterranean Sea is under intense pressure from various human impacts, including unsustainable exploitation and habitat loss, and threats have accelerated and diversified with a growing human population (Claudet & Fraschetti 2010, Coll *et al*. 2010, 2012, Lotze *et al*. 2011).

Elasmobranchs in the Mediterranean:

Elasmobranchs (sharks, skates and rays) are particularly susceptible to overfishing and habitat degradation, and there is evidence of severe declines in large predatory sharks throughout the Mediterranean Sea (Ferretti *et al*. 2008, Dulvy *et al*. 2014). Many elasmobranchs have a life history characterised by slow growth, long life, late maturity, and low fecundity, which increases risk of human induced mortality at a population wide scale (Stevens *et al*. 2000, Ferretti *et al*. 2008). Sharks are often top predators, and reduction within a community can cause cascading trophic effects, altering ecosystem structure and function (Stevens *et al*. 2000, Ferretti *et al*. 2008, Lotze *et al*. 2011).

Angel Sharks in the Mediterranean Sea:

There are at least 22 species of angel sharks in the family Squatinidae, identified as the third most threatened family of elasmobranchs in the world (Dulvy *et al.* 2014, Kyne *et al*. 2019). Three angel shark species are found in the Mediterranean Sea, *Squatina squatina* (Angelshark), *S. aculeata* (sawback Angelshark), and *S. oculata* (smoothback Angelshark); all are classified as Critically Endangered on the International Union for the Conservation of Nature's (IUCN) Red List of Threatened Species (Morey *et al*. 2019*a,b,c*). It is estimated that the ranges of these species have declined between 48 % to 58 % in the last century (Lawson *et al*. 2020). The fact that angel sharks inhabit shallow coastal areas, coupled with their extended life history, make them particularly vulnerable to the combined impact of habitat loss and mortality from incidental capture (Barker *et al.* 2016, Gordon *et al*. 2017, Giovos *et al*. 2019, Lawson *et al*. 2020).

Angel sharks are protected under various legislations within the Mediterranean Sea. Including; the EU Common Fisheries Policy Council Regulation (EC) 43/2009 and Council Regulation (EC) 43/2014, on the Barcelona Convention Annex II of the Protocol concerning Specially Protected Areas and Biological Diversity (SPA/BD Protocol), and more specifically in Spanish waters through the Spanish List of Species Under Special Protection in the Mediterranean (LESPRE) Orden AAA/75/2012 (Fortibuoni *et al*. 2016, Gordon *et al*. 2017). *S. squatina* is listed under the Convention of Migratory Species (CMS) Appendix I and II, as well as on Annex I of the CMS Sharks MOU. In addition, concerted actions for angel sharks have been adopted by CMS at the 12th Conference of the Parties (CMS 2017). Migratory species listed under CMS benefit from internationally coordinated conservation throughout their migratory range, through agreements between Range States that are parties to CMS (Gordon *et al*. 2019).

A Regional Action Plan for Angel Sharks in the Mediterranean (MedRAP) has been published to focus efforts for coordinated, collaborative conservation action (Gordon *et al*. 2019). Under this framework, Sub-Regional Action Plans (SubRAPs) for the Mediterranean will be developed to better facilitate action in each respective subregion (Gordon *et al*. 2019). Identified threats to angel sharks categorised

within the MedRAP include: Agriculture and aquaculture, biological resource use, climate change, human intrusion and disturbance, invasive species and diseases, pollution, transportation and service corridors, and development (Gordon *et al*. 2019). Within these categories, fishing activity and habitat destruction were identified as the priority threats (Gordon *et al*. 2019).

Marine Protected Areas:

Establishing a representative network of Marine Protected Areas (MPAs) is an essential tool for conservation of marine ecosystems (Abdulla *et al*. 2009). Protecting a range of habitats allows natural systems to continue to function, with reduced disturbance, enabling the ecosystem to provide associated services from which humans benefit (Abdulla *et al*. 2009, Gomei *et al*. 2019). MPAs have the potential to be a useful tool for elasmobranch conservation, if their design and management is informed by scientific understanding of movement, biology, and habitat (Rigby *et al*. 2019). Gomei *et al*. (2019) assessed progress in the Mediterranean Sea towards implementing an effective network of MPAs. Actions were evaluated in the context of MPA targets included in Aichi target 11 set by the Convention on Biological Diversity (CBD) and signed by Mediterranean countries, to protect 10 % of coastal and marine waters by 2020 (Gomei *et al*. 2019). It was found that 9.68 % of the surface of the Mediterranean Sea was covered by designated MPAs (Gomei *et al*. 2019). However, MPAs with a management plan only covered 2.48 % of the surface, and MPAs where actions within the management plan were actually being implemented covered an even smaller surface area, only 1.27 % (Gomei *et al*. 2019). These findings revealed that a large proportion of designated MPAs are not performing effectively, and that countries are failing to ensure proper management and monitoring of designated areas (Gomei *et al*. 2019).

Geographic focus – The Adriatic Sea:

The Adriatic Sea sits between Italy and the Balkans, covering a surface area of around 138,600 km^2 (Danovaro & Boero 2019). The basin is split into northern, central, and southern Adriatic, with depth increasing from a north to south gradient to a maximum of over 1200 m (Danovaro & Boero 2019). The continental shelf covering the north and central Adriatic is the most extensive of the Mediterranean Sea and occurs between depths of 10 and 200 m, making it ideal for coastal species such as the angel shark, and demersal fisheries (Pinardi *et al*. 2006, Coll *et al*. 2007, Holcer and Lazar 2017, Lotze *et al*. 2011, Fortibuoni *et al.* 2016, Danovaro & Boero 2019). The basin is semi-enclosed, composed of a muddy/sandy substratum, and receives the largest freshwater influx of all the Mediterranean Sea (Pinardi *et al*. 2006, Fortibuoni *et al.* 2016, Danovaro & Boero 2019). Exchange of water between the Adriatic and Ionian Sea occurs through the Strait of Otranto (Pinardi *et al*. 2006, Danovaro & Boero 2019). Threats to the Mediterranean Sea are reflected in the Adriatic, and depletion of large consumers and predators through intensive exploitation has resulted in simplified and therefore more unstable food webs and reduced ecosystem function (Lotze *et al*. 2011). Elasmobranchs have undergone severe declines in the region throughout the twentieth century (Lotze *et al*. 2011).

Both *S. squatina* and *S. oculata* were once common throughout the Adriatic Sea, but have undergone substantial declines, and there is uncertainty as to whether *S. oculata* remains extant in this part of its range (Gordon *et al*. 2017, Holcer & Lazar 2017, Morey *et al*. 2019*b,* Lawson *et al*. 2020). Presence of angel sharks has been well documented in this region; historically *S. squatina* sustained a large fleet of commercial fishing boats in the Adriatic Sea, which used targeted nets named “squaenere” or “sklatare” to land angel sharks, amongst other fish (Holcer & Lazar 2017). Landings of *S. squatina* declined dramatically after the 1960s, causing them to become considered “economically extinct” (Raicevich & Fortibuoni 2013, Fortibuoni *et al*. 2016). Although scientific surveys occasionally found of

S. squatina during sampling in the Adriatic Sea between 1948 and 1958, they were not present in surveys occurring after this time, suggesting extirpation from the area (Ferretti *et al*. 2013, Fortibuoni *et al*. 2016, Maynou *et al*. 2011). However, more recently, new angel shark records have been reported, demonstrating that at least *S. squatina* was still present (Fortibuoni *et al*. 2016, Holcer & Lazar 2017, Dragicevic & Ugarkovic, unpublished data). It is therefore vital that effective conservation measures are developed to secure the future of this species in the Adriatic.

Project Aims:

The major aim of this study was to identify possible angel shark hotspots in the Adriatic Sea and evaluate the potential effectiveness of designated MPAs[1] and Fisheries Restricted Areas (FRAs) for these species across the Mediterranean Sea. Angel shark occurrence data were gathered from the Angel Shark Sightings Map and fisher surveys conducted in Croatia by WWF Adria. Gomei *et al*. (2019) was used to evaluate the occurrence of angel shark records in the existing network of MPAs, categorised by their management status. Results will be used as a baseline to help develop the Adriatic SubRAP and provide recommendations on the next steps to improve protection of angel shark habitat.

Methods

Data collection

Angel Shark Sightings Map:

The Angel Shark Sightings Map (ASSM) is an interactive map that allows citizen scientists to report their angel shark sightings: www.angelsharkproject.com/map. Sightings information includes species, sex, depth, size, location and type of record. The ASSM is hosted by the Zoological Society of London (ZSL) on behalf of the Angel Shark Project (a collaboration between Universidad de las Palmas de Gran Canarias (ULPGC), Zoologisches Forschungsmuseum Alexander Koenig (ZFMK) and ZSL) and Angel Shark Conservation Network, led by the following partners: IUCN Shark Specialist Group, Shark Trust, Submon, ULPGC, ZFMK and ZSL. Sightings data in the Mediterranean Sea were downloaded from the ASSM on 18/06/2020; there were a total of 67 sightings with 94 angel shark records.

Local Ecological Knowledge surveys in Croatia:

In 2017 and 2018, the Institute of Oceanography and Fisheries gathered records of *S. squatina* through contacting fishers, fish markets, universities and divers directly and via social media. This broad-scale approach gathered data from both Croatia and Montenegro. In June and July 2020, a Local Ecological Knowledge (LEK) case-study was conducted by WWF Mediterranean, WWF Adria, and the Institute of Oceanography and Fisheries in order to complement these data (Dragičević & Ugarkovic *in prep*.). This involved asking fishers from across the coast of Croatia to complete an online survey to better understand recent interactions with angel sharks, including information on date, location, size, depth, and gear type for each angel shark record. The survey was made available to fishers through various online platforms, relevant to both commercial and recreational fishing sectors, and a total of 368 surveys were collected.

From these data sources, a total of 106 sightings and 147 angel shark records were used in the analysis presented here. These data were given a confidence score in relation to GPS point accuracy: a 'specific' confidence value referred to points within the radius of a 1–2 km area; 'medium' up to 20 km; and 'broad' anything larger than this.

[1] See methods for which MPAs are included in the analysis.

MPAs and FRAs:

Shapefiles of 1,228 MPAs, designated under the following legislation were used in this analysis: nationally designated MPAs, Natura 2000 sites, the marine part of Ramsar sites (wetlands of international importance under the Ramsar Convention), the marine part of UNESCO Biosphere reserves, and internationally designated Specially Protected Areas of Mediterranean Importance (SPAMIs) (Gomei *et al.* 2019). MPAs have a range of protected status, i.e. can include fully protected no-take zones, but also areas where monitoring and management is not taking place ("paper parks") (Gomei *et al.* 2019).

The analysis also includes eight Fisheries Restricted Areas (FRAs). A consensus has not yet been reached on whether to consider FRAs (designated under the General Fisheries Commission for the Mediterranean) as MPAs in the region (Gomei *et al*. 2019). As a result of this, they are considered separately within this report.

GIS shapefiles for MPAs and FRAs in the Mediterranean Sea were provided by WWF Mediterranean to be used in this analysis. Environmental data were gathered from open access sites; modelled substrate was downloaded from EMOD.net (EMODnet 2020), and bathymetry data was downloaded from Bio-ORACLE (Tyberghein *et al.* 2012).

Analysis

Analysis of data was conducted using QGIS 3.10 (QGIS.org 2020). All data were analysed as point records, but results were visualised as grid squares to hide the specific location of records. Grids were constructed for both the Mediterranean Sea (60 x 60 km) and for the Adriatic at varying scales (20 x 20 km, 10 x 10 km, 5 x 5 km). Using the combined data for both the Mediterranean Sea and Adriatic Sea, the 'count points within polygon' function was used to identify the number of sightings within each grid square. This method was conducted firstly using number of occurrence points only, giving a value for the number of **'sightings'** and secondly using number of points weighted to the number of angel sharks recorded within the sightings[2]. This gave a value for the specific number of **'angel shark records'**, accounting that there could be multiple angel sharks within one sighting. At the Mediterranean Sea scale, analysis was split by species (*S. squatina*, *S. aculeata*, *S. oculata*), and by time. For temporal analyses, the data were split into 'recent' sightings (2010–2020) and 'historic' sightings (1947–2009 inclusive). One angel shark generation length (GL), an average of 11 years, was used to delineate the threshold between these categories.

The 'count point within polygon' function was used to identify the number of sightings, and number of angel sharks, overlapping designated MPAs or FRAs in the Mediterranean Sea, with a focus on the Adriatic Sea. To better understand the overlap between sightings and differently managed MPAs in the Mediterranean Sea, the designated MPAs were further split into those that had a management plan, and those that had a management plan in force, *i.e.* those MPAs where actions within the management plan are being implemented ("implemented management plan"). For visualisation, the MPAs and FRAs were coloured according to this overlap. Pink indicated that an angel shark record occurred within the boundary of the MPA or FRA ("overlapping sightings"), and yellow indicated that there were no records within the boundary ("not overlapping sightings").

[2] Weighting the records by number of angel sharks automatically assumes all the sharks within that record are the same size (length or weight). Errors in the following size analysis therefore had to be manually corrected, for records where multiple sharks were observed in a single sighting, but size was only given related to the mother, and not the pups.

Size analysis was also conducted for the Adriatic Sea, where records were split by size categories for both length and weight. ASSM records have pre-determined length categories (<30 cm, 31–100 cm, >100 cm), whereas specific lengths and weights were given in the LEK case study. These were transformed into the pre-determined length categories using corresponding weight category estimates assigned based on anecdotal information (<0.5 kg, 0.6–18 kg, >19 kg) (Angel Shark Project, unpublished data).

Angel shark occurrence data in the Adriatic Sea was compared against open access environmental data. For modelled substrate type (EMODnet 2020), the 'count points within polygon' function was used to identify potential habitat types being utilised by angel sharks in the Adriatic. For bathymetry (Tyberghein *et al*. 2012), the 'sample raster values' function in QGIS was used to assign each occurrence point a depth value.

Results

Mediterranean Sea

27.8 % (n = 67) of angel shark records in the Mediterranean Sea (n = 241), were found to occur within a designated MPA (Fig. 1). Of these angel shark records found within MPAs, 29.9 % (n = 20) were historic records, and 70.2 % (n = 67) were recent records (Fig. 2a and 2b respectively). Almost all of these were *S. squatina* (n = 65), with one record of *S. oculata*, one record of an *angel shark* not identified to species level and no records of *S. aculeata*.

A large proportion of the MPAs found to overlap recent angel shark records were designated Natura 2000 sites (Table 1). Nine angel shark records also occurred within two MPAs with different designations: Sitsko-žutska otoèna skupina, a nationally designated site within the Adriatic Sea; and the Pelagos Sanctuary for The Conservation of Marine Mammals, protected under the Barcelona Convention spanning waters of France, Italy, and Monaco (Table 1). None of the MPAs overlapping angel shark records were found to have a management plan, or an implemented management plan.

A singular record of *S. squatina* was found to overlap a FRA, this occurred in the boundaries of Jabuka Pit FRA in the Adriatic Sea (Fig. 3, Table 1). Locations of MPAs and FRAs overlapping recent angel shark records in the Mediterranean Sea are highlighted in Fig. 4.

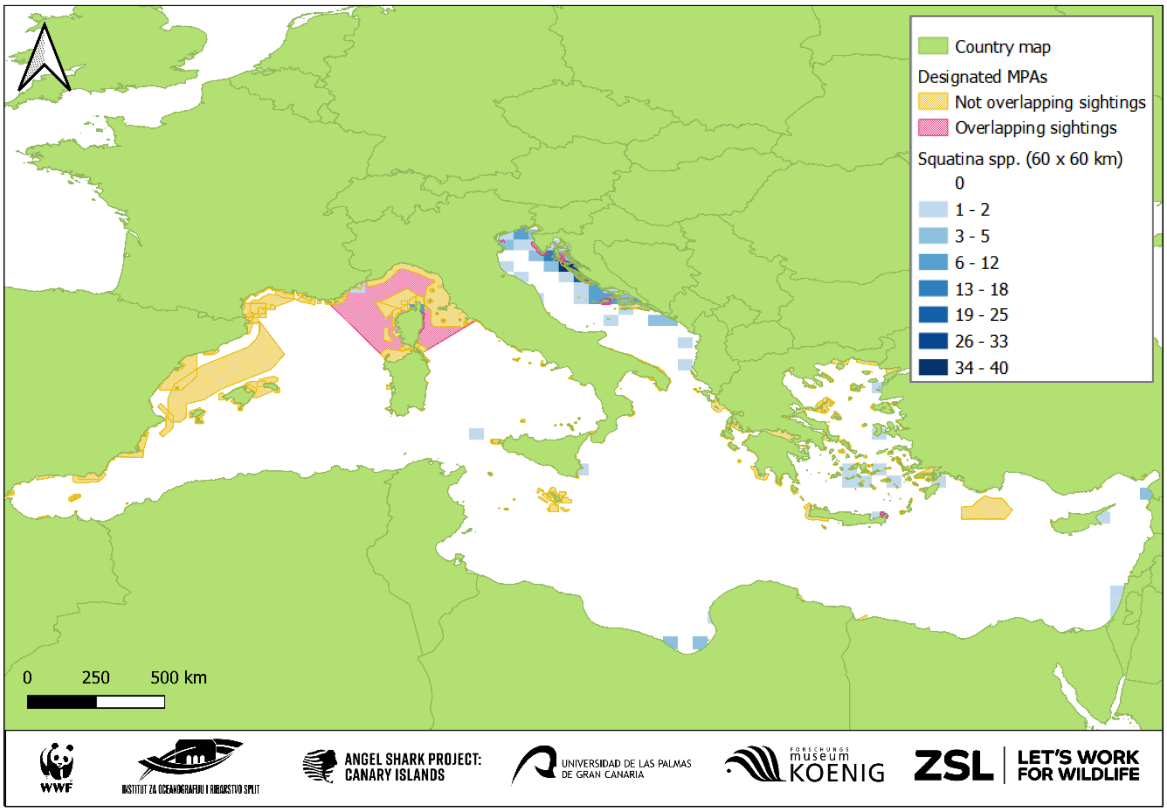

Figure 1 - Angel shark records (*Squatina* spp.) at 60 x 60 km resolution, in relation to **designated Marine Protected Areas (MPAs)** in the Mediterranean Sea .

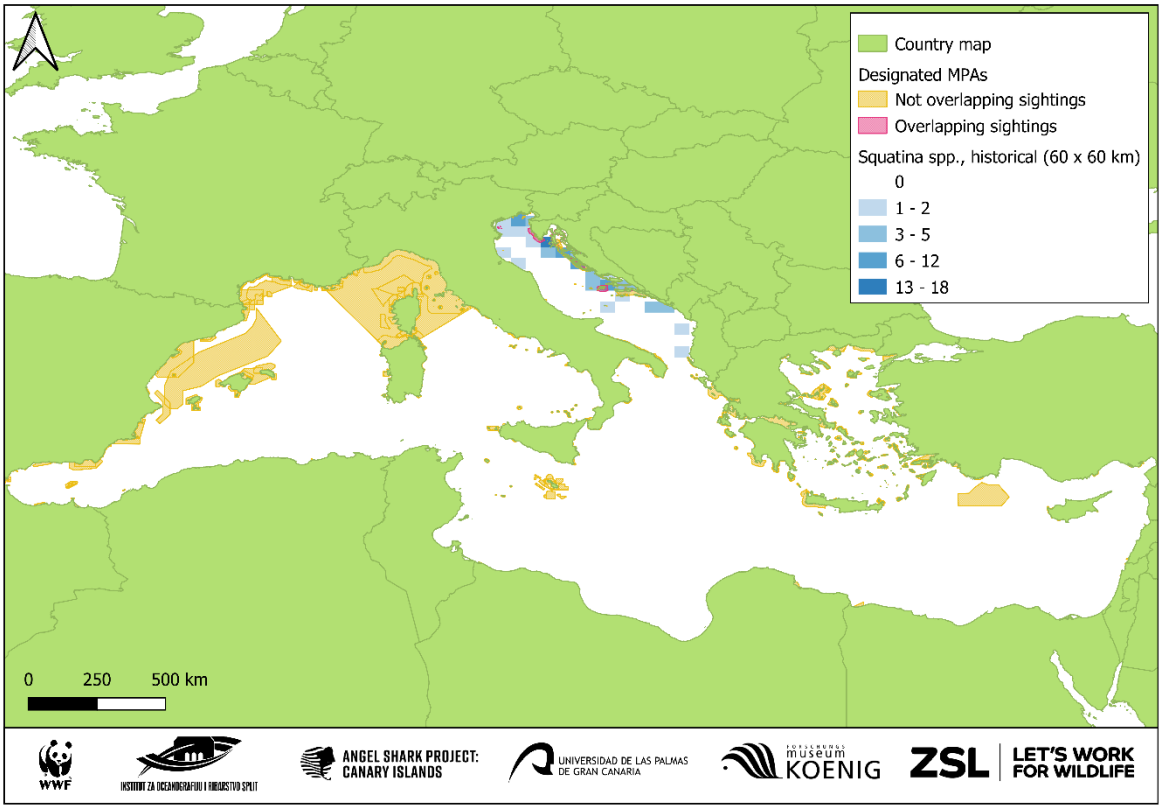

Figure 2a - **Historic** (1947–2009 inclusive) angel shark records (*Squatina* spp.) at 60 x 60 km resolution, in relation to **designated MPAs** in the Mediterranean Sea.

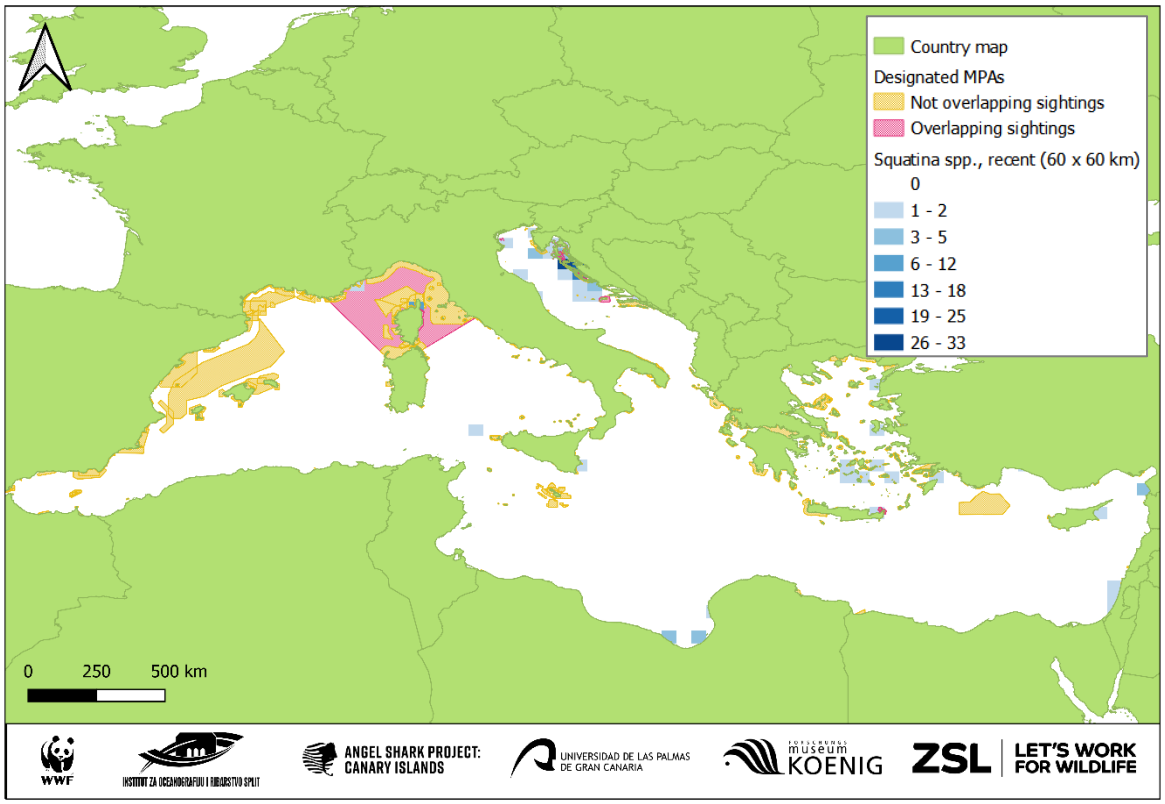

Figure 2b - **Recent** (2010–2020) angel shark records (*Squatina* spp.) at 60 x 60 km resolution, in relation to **designated MPAs** in the Mediterranean Sea.

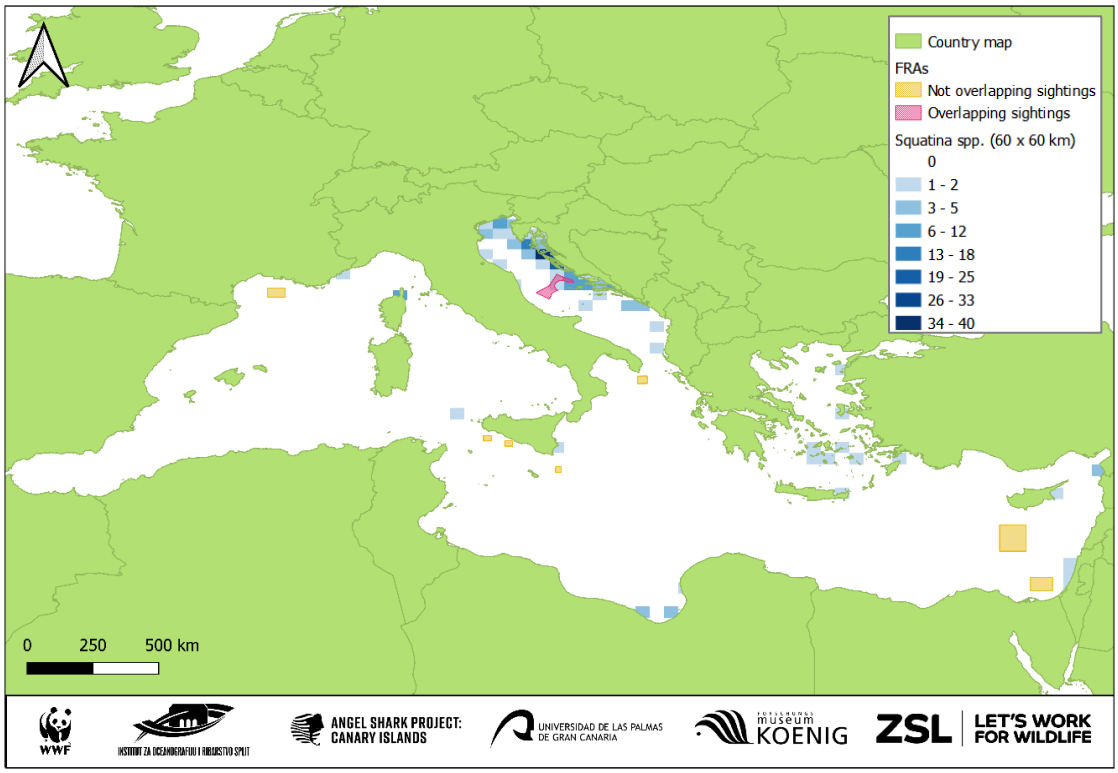

Figure 3 - Angel shark records (*Squatina* spp.) at 60 x 60 km resolution, in relation to **Fishery Restricted Areas (FRAs)** in the Mediterranean Sea.

Figure 4 – Locations of **MPAs and FRAs** overlapping **recent** (2010–2020) angel shark records.

Table 1 – **Designated MPAs and FRAs** overlapping recent (2010–2020) angel shark records (*Squatina* spp.) in the Mediterranean Sea. See Fig. 4 for their location.

	MPA name	Designated	Country	Year	MgtPlan[3]	MgtImp[4]	Sightings[5]	Angel sharks[6]
Adriatic Sea	J. Molat-Dugi-Kornat-Murter-Pašman-Ugljan-Rivanj-Sestrunj-Molat	Natura 2000	Croatia	2013	N	N	11	17
	JI dio o. Molata	Natura 2000	Croatia	2013	N	N	3	13
	Srednjedalmatinski otoci i Pelješac	Natura 2000	Croatia	2013	N	N	2	2
	Rivanjski kanal sa Sestricama	Natura 2000	Croatia	2013	N	N	2	2
	Tegnùe di Chioggia	Natura 2000	Italy	2010	N	N	1	1
	Sitsko-žutska otoèna skupina	National designation	Croatia	1967	N	N	1*	1*
	Kvarnerski otoci	Natura 2000	Croatia	2013	N	N	1*	1*
	Viški akvatorij	Natura 2000	Croatia	2013	N	N	1	1
	Cres - Lošinj	Natura 2000	Croatia	2013	N	N	1*	1*
	Badija i otoci oko Korčule	Natura 2000	Croatia	2013	N	N	1	1
	Cres - rt Suha - rt Meli	Natura 2000	Croatia	2013	N	N	1*	1*
	Silba - podmorje	Natura 2000	Croatia	2013	N	N	1*	1*
	Jabuka Pit	FRA	Croatia, Italy	2018	n/a	n/a	1	1
Outside the Adriatic	VOREIOANATOLIKO AKRO KRITIS: DIONYSADES, ELASA KAI CHERSONISOS SIDERO (AKRA MAVRO MOURI - VAI - AKRA PLAKAS) KAI THALASSIA ZONI	Natura 2000	Greece	2011			1	1
	DIONYSADES NISOI	Natura 2000	Greece	1997			1	1
	Pelagos Sanctuary For The Conservation Of Marine Mammals	Specially Protected Area of Mediterranean Importance (Barcelona Convention)	France, Italy, Monaco	1999	N	N	7	8
	Grand herbier de la côte orientale	Natura 2000	France	2015	N	N	6*	7*

* Shows duplicated sightings / angel sharks where some MPAs overlap each other. This has been accounted for within the analysis.

[3] "MgtPlan" is whether there is a management plan for an MPA.

[4] "MgtImp" is whether the management plan is in force, whether actions within the plan are being implemented.

[5] "Sightings" means the number of sighting provided to ASSM or LEK study.

[6] "Angel sharks records" is the total number of angel sharks counted within those sighting records, i.e. accounting that there may be multiple sharks observed in a single sighting.

Adriatic Sea

Of the records provided by the LEK study, 48.1 % were caught in gillnets, 22.6 % from trawls, 8.5 % from divers/spearfishers, 7.5 % from longlines, 1.8 % from harpoon or hook and 11.3 % did not record the source. 28.7 % (n = 58) of Adriatic *S. squatina* records (n = 202) occurred within a designated MPA (Fig. 5). Of these *S. squatina* records found within MPAs, 34.5 % (n = 20) were historic records, and 65.5 % (n = 38) were recent records (Fig. 6a and 6b respectively). Analysis of historic and recent *S. squatina* records were visualised at northern (Fig. 7a and 7b respectively), central (Fig. 8a and 8b respectively), and southern (Fig. 9a and 9b respectively) Adriatic scale. Historic *S. squatina* records accounted for just over half (n = 107) of all Adriatic records (n = 202), and these records covered a greater area of the Adriatic Sea than those from recent years. This is particularly apparent in the central and southern Adriatic, where there are little to no recent records of *S. squatina* (Fig. 8b & 9b). Hotspots of recent *S. squatina* records in the Adriatic were identified around the northern Croatian Islands, specifically the Molat island archipelago (Fig. 10a and 10b respectively).

Size analysis found only 37.6 % (n = 76) of all Adriatic *S. squatina* records had information relating to the length or weight of the angel shark. Of these records, 10.5 % (n = 8) were juveniles of less than 30 cm or less than 0.5 kg; 69.7 % (n = 53) were between 31 and 100 cm in length or 0.6 and 18 kg in weight; and 19.7 % (n = 15) were adults of a length greater than 100 cm or weight of 19 kg (Fig. 11).

Within the LEK case study data, it was found that some records contained qualitative information where a female angel shark had aborted pups during the fishing procedure. After identification of these records, further size analysis was conducted for juvenile angel sharks, which included these records, in conjunction with sightings of juvenile *S. squatina* described as less than 30 cm in length and less than 0.5 kg in weight (Fig. 12). Analysis indicated a cluster of points (n = 4) around the islands off Zadar, including Molat, Sestrunj, Rivanj, and Tun Veli. Three of the four sightings within this area were given a 'specific' confidence value and the remaining record was given a 'medium' value, suggesting the area is relatively accurate. This hotspot could be important for *S. squatina* juveniles, as a breeding and/or nursery area. Using modelled substrate data (EMODnet 2020*a*), three of the points were identified to fall on infralittoral sandy mud, and one on infralittoral coarse and mixed sediment.

S. squatina records were analysed in relation to modelled substrate type for the Adriatic Sea (EMODnet 2020). *S. squatina* records mostly occurred on 'sandy mud' substrate type, followed by 'muddy sand', 'sand', 'coarse and mixed sediment', and 'fine mud' (Table 2). Some of the *S. squatina* records from the Adriatic Sea had no substrate type due to being records from fish markets, and others due to the GIS raster layer not covering the area of the point. Most *S. squatina* records occurred in either infralittoral or circalittoral biozones, although three records were within the bathyal zone.

Table 2 – *S. squatina* records in relation to substrate type for the Adriatic Sea

Substrate	Number of *S. squatina* records	%
Sandy mud	66	32.7
Muddy sand	40	19.8
Sand	38	18.8
Coarse and mixed sediment	24	11.9
Fine mud	19	9.4

Sightings of *S. squatina* were also analysed in relation to depth of the sea floor (bathymetry) for the Adriatic Sea (average depth of sea floor, 30 arcsecond spatial resolution) (Tyberghein *et al*. 2012) (Figure 13). *S. squatina* sightings mostly occurred at depths shallower than 50 m (Table 3), with the deepest sighting recorded at 867 m from a trawling vessel. Data collected from the bathymetry layer

may not accurately reflect the depths at which angel sharks were caught as some of the GPS coordinates of the sightings were not accurate. For example, for the sighting recorded at 867m on the bathymetry layer, the fisherman who provided the sighting recorded a depth of 154–276 m. There were also sightings that occurred at +2 m, even though the points were located in the Adriatic Sea. This may have been a result of tides or an error within the bathymetry layer.

Depth was recorded by the observer for 92 angel shark records, within the ASSM sightings these depths were categorised, whereas they were specific within the LEK data. LEK data was therefore split into the depth categories of the ASSM. 52.2 % (n = 48) of these angel shark records occurred below depths of 40 m, 29.3 % (n = 27) between 41 and 100m, and 18.5 % (n = 17) at depths greater than 100 m. The deepest recorded specific depth from the LEK study was between 305–377 m.

Table 3 - Sightings of *S. squatina* in relation to depth of sea floor (bathymetry) for the Adriatic Sea

Bathymetry (m)	*S. squatina* sightings	%
+ 2	3	2.2
- 0–25	48	34.5
- 25.1–50	35	25.2
- 50.1–100	33	23.7
- 100.1–150	7	5
- 150.1–200	3	2.2
- >200	7	5

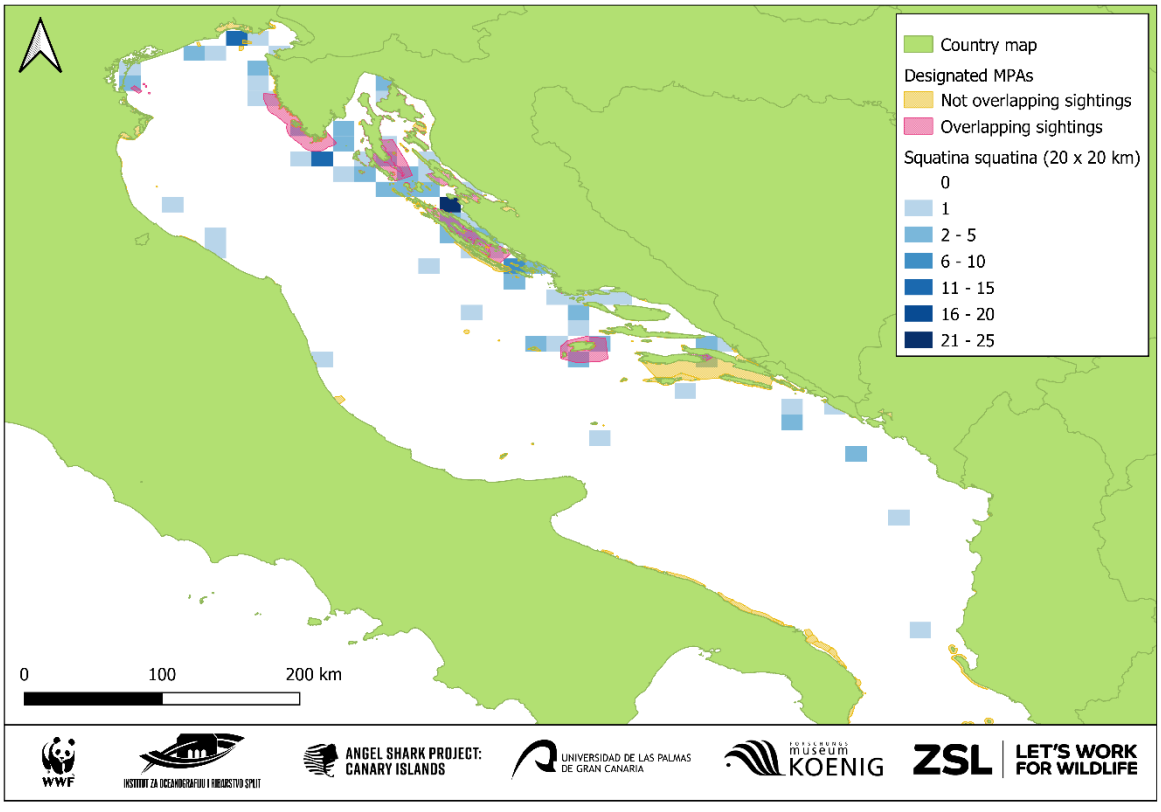

Figure 5 - *S. squatina* records at 20 x 20 km resolution, in relation to **designated MPAs** in the Adriatic Sea.

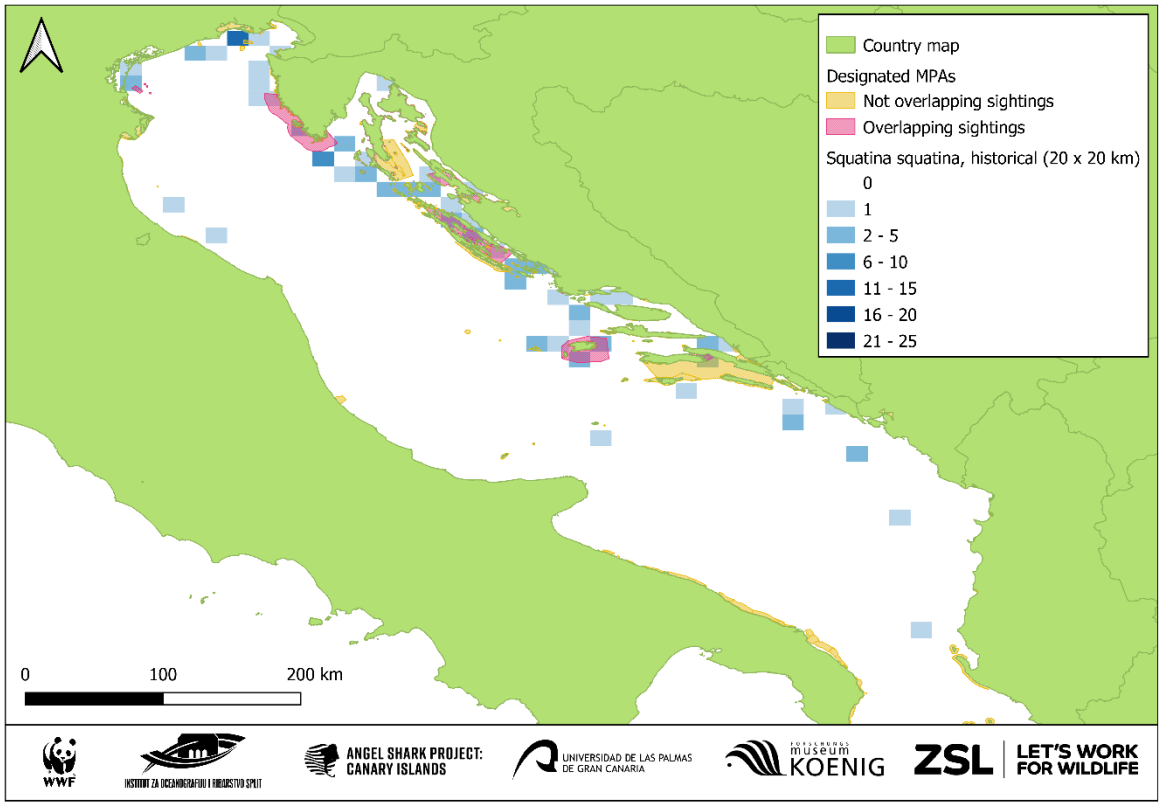

Figure 6a - **Historic** (1947–2009 inclusive) angel shark records (*S. squatina*) at 20 x 20 km resolution, in relation to **designated MPAs** in the Adriatic Sea.

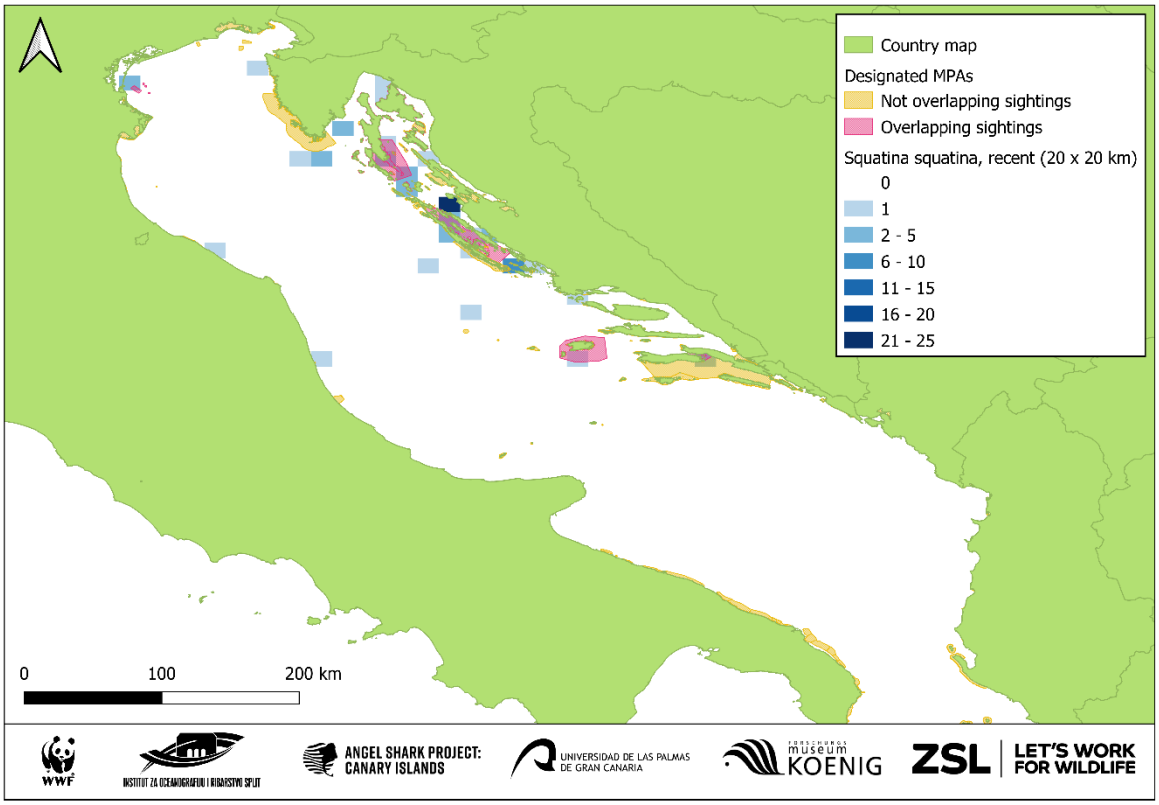

Figure 6b - **Recent** (2010–2020) angel shark records (*S. squatina*) at 20 x 20 km resolution, in relation to **designated MPAs** in the Adriatic Sea.

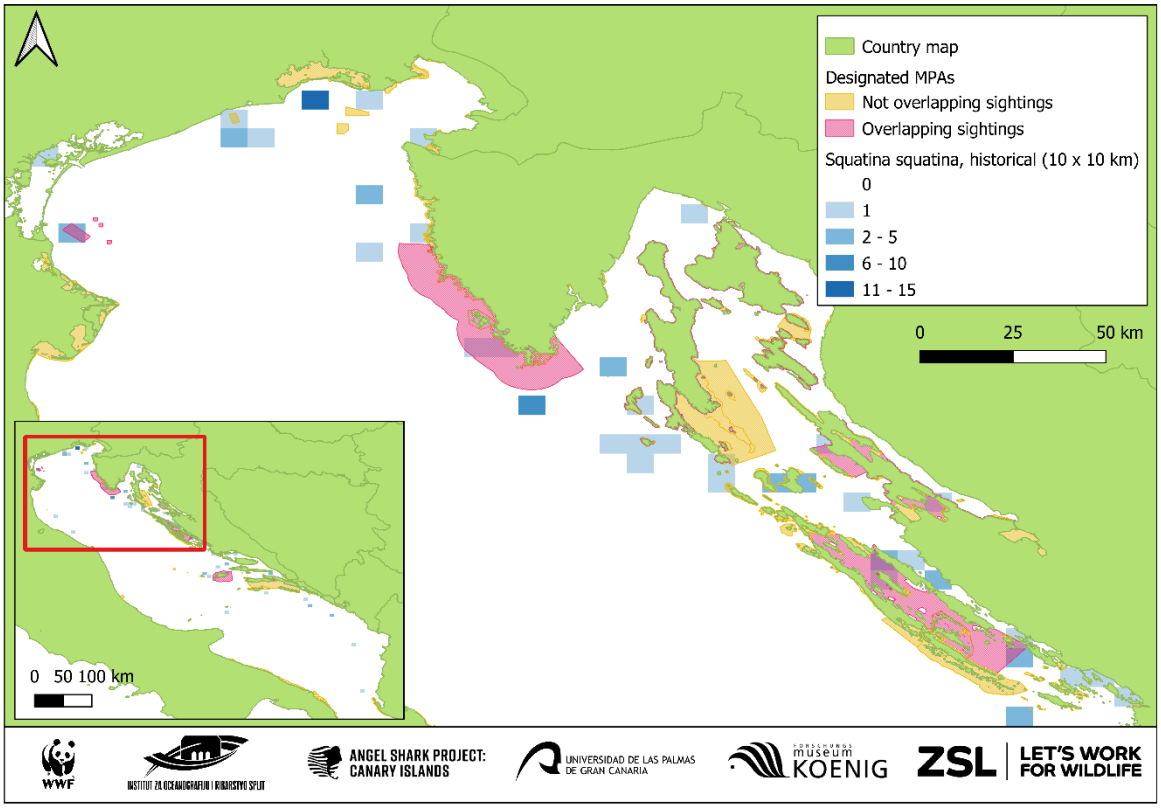

Figure 7a – Northern Adriatic visualisation of **historic** (1947–2009 inclusive) angel shark records (*S. squatina*) at 10 x 10 km resolution, in relation to **designated MPAs** in the Adriatic Sea.

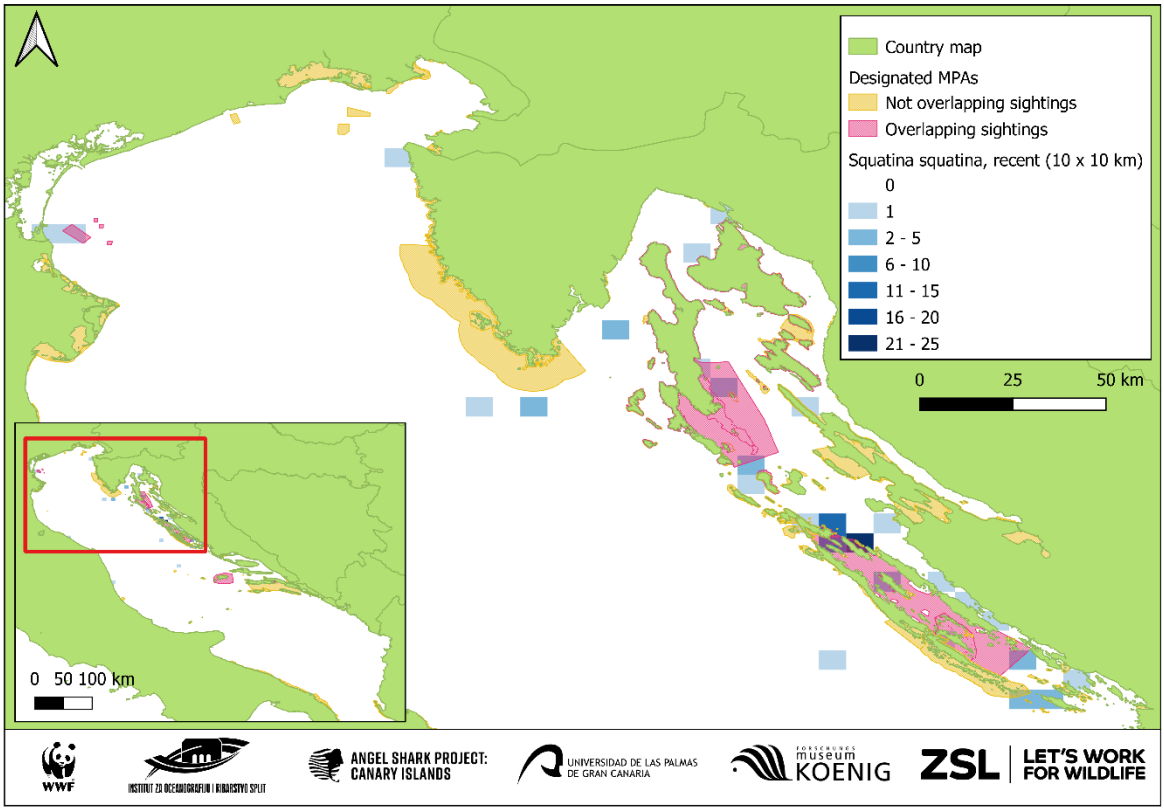

Figure 7b – Northern Adriatic visualisation of **recent** (2010–2020) angel shark records (*S. squatina*) at 10 x 10 km resolution, in relation to **designated MPAs** in the Adriatic Sea.

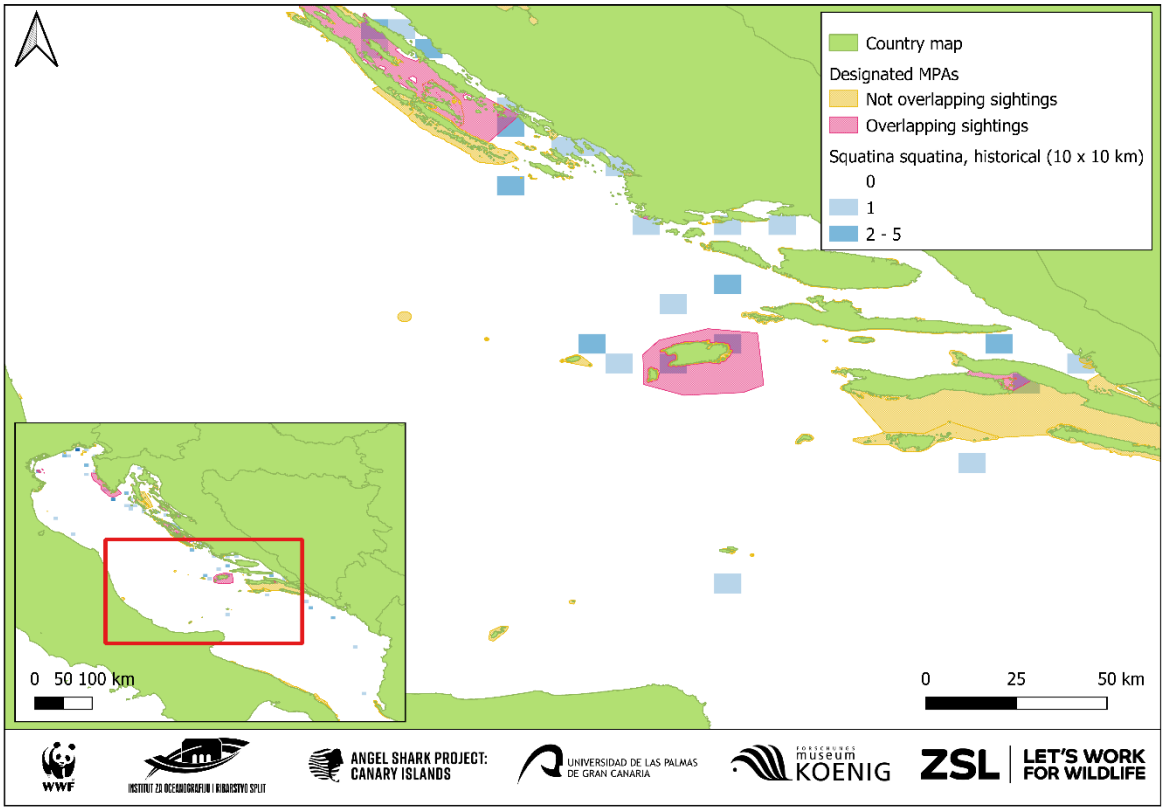

Figure 8a – Central Adriatic visualisation of **historic** (1947–2009 inclusive) angel shark records (*S. squatina*) at 10 x 10 km resolution, in relation to **designated MPAs** in the Adriatic Sea.

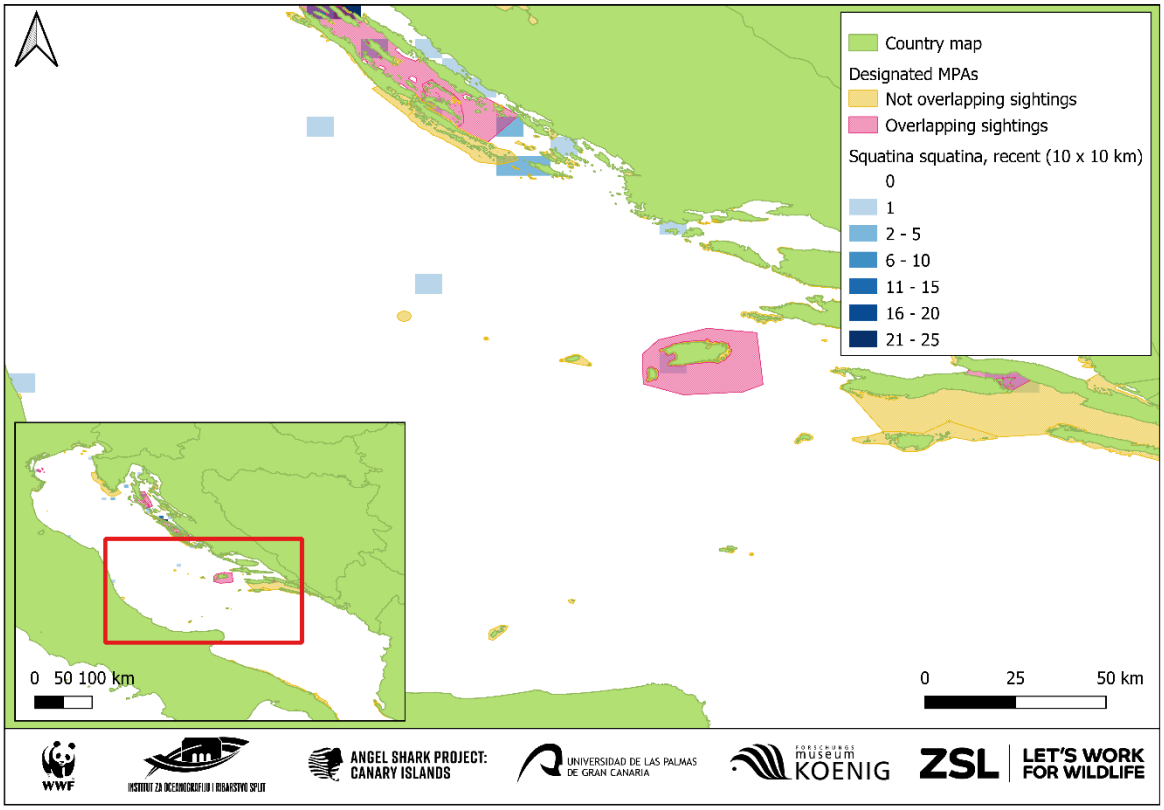

Figure 8b – Central Adriatic visualisation of **recent** (2010–2020) angel shark records (*S. squatina*) at 10 x 10 km resolution, in relation to **designated MPAs** in the Adriatic Sea.

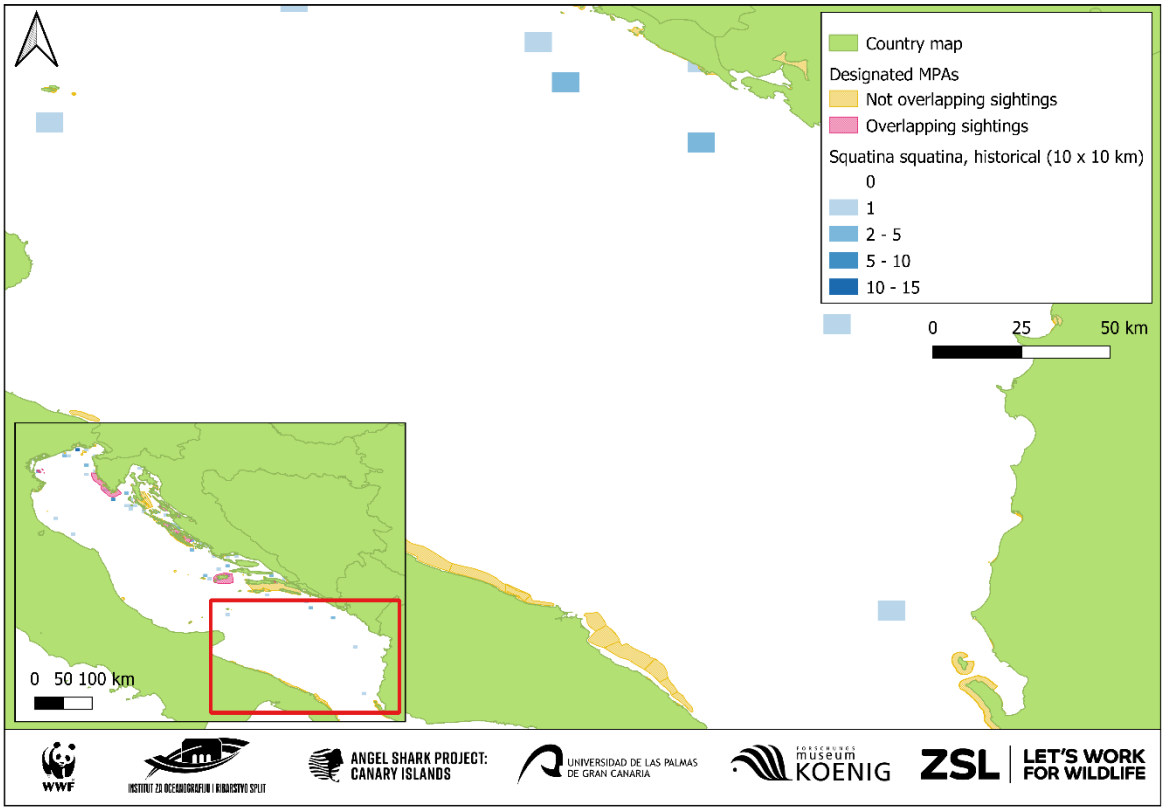

Figure 9a – Southern Adriatic visualisation of **historic** (1947–2009 inclusive) angel shark records (*S. squatina*) at 10 x 10 km resolution, in relation to **designated MPAs** in the Adriatic Sea.

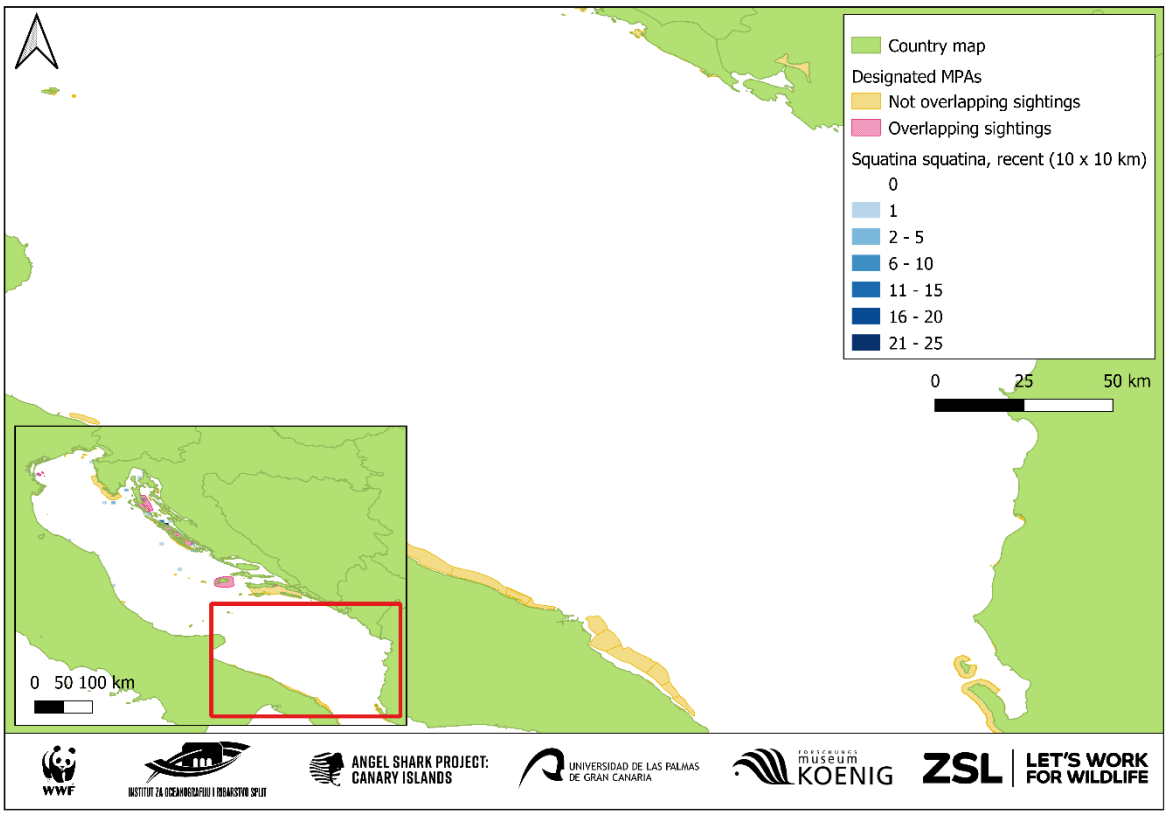

Figure 9b – Southern Adriatic visualisation of **recent** (2010–2020) angel shark records (*S. squatina*) at 10 x 10 km resolution, in relation to **designated MPAs** in the Adriatic Sea.

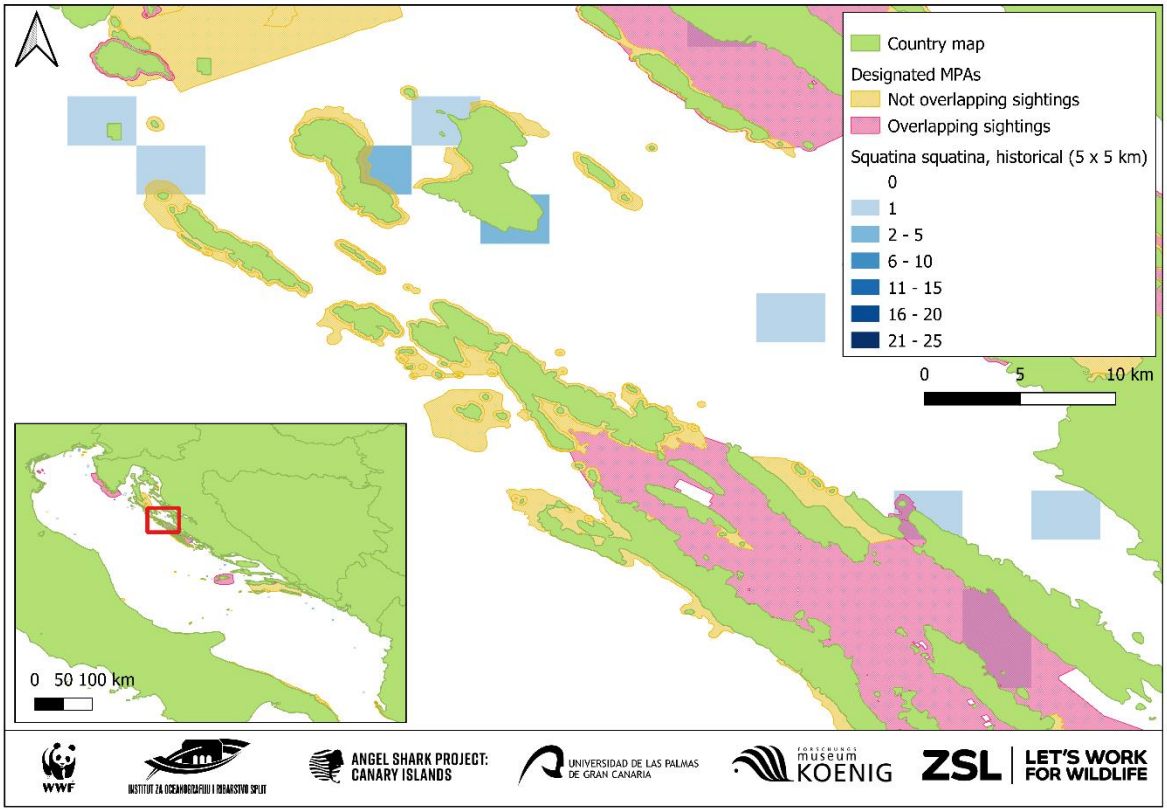

Figure 10a – Visualisation of Molat island, showing **historic** (1947–2009 inclusive) angel shark records (*S. squatina*) at 5 x 5 km resolution, in relation to **designated MPAs** in the Adriatic Sea.

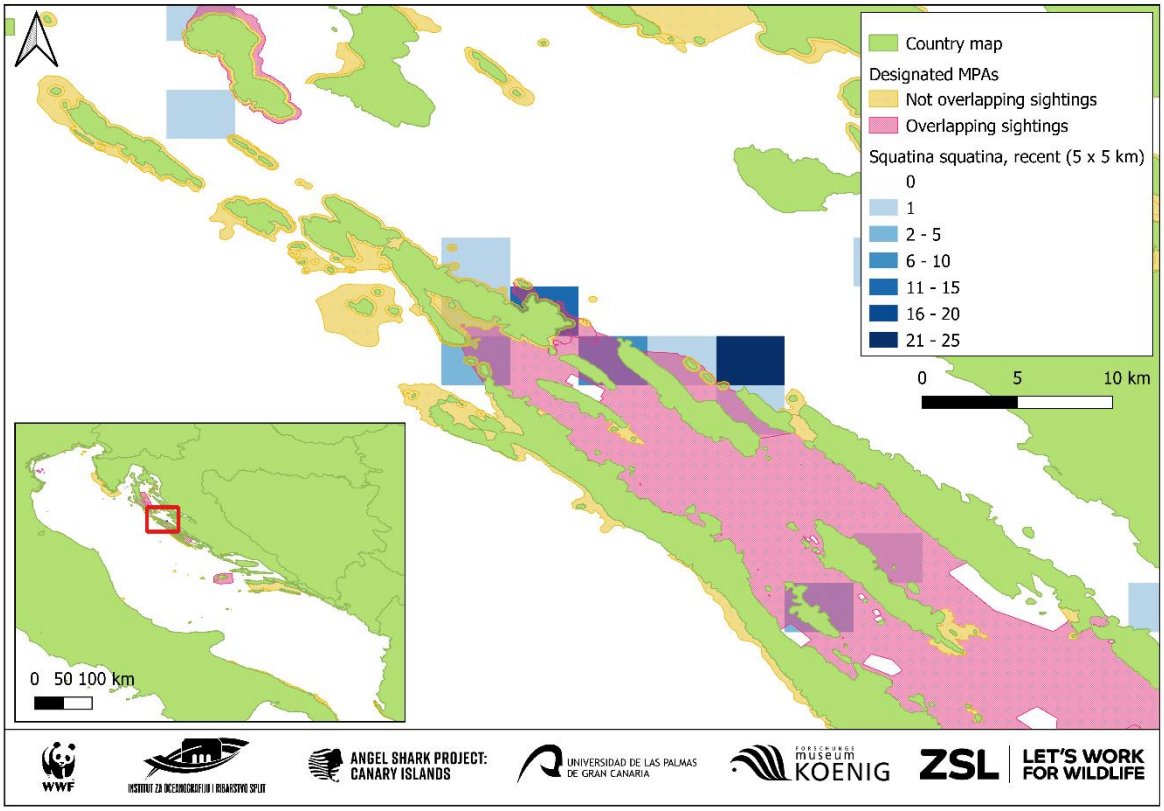

Figure 10b – Visualisation of Molat island, showing **recent** (2010–2020) angel shark records (*S. squatina*) at 5 x 5 km resolution, in relation to **designated MPAs** in the Adriatic Sea.

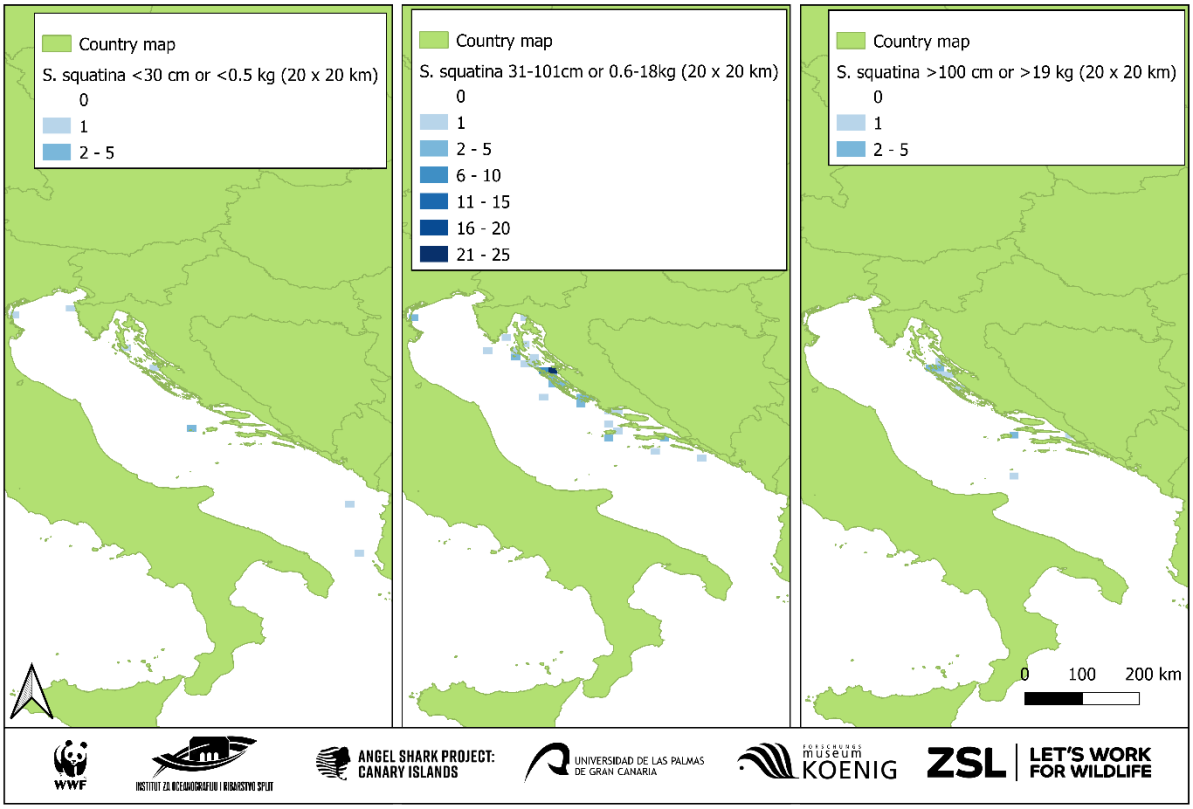

Figure 11 – Size analysis showing *S. squatina* records described as either less than 30 cm in length or less than 0.5 kg in weight, between 31–100 cm or 0.6–18kg, and greater than 100 cm or 19 kg, at 20 x 20 km resolution (where information was available).

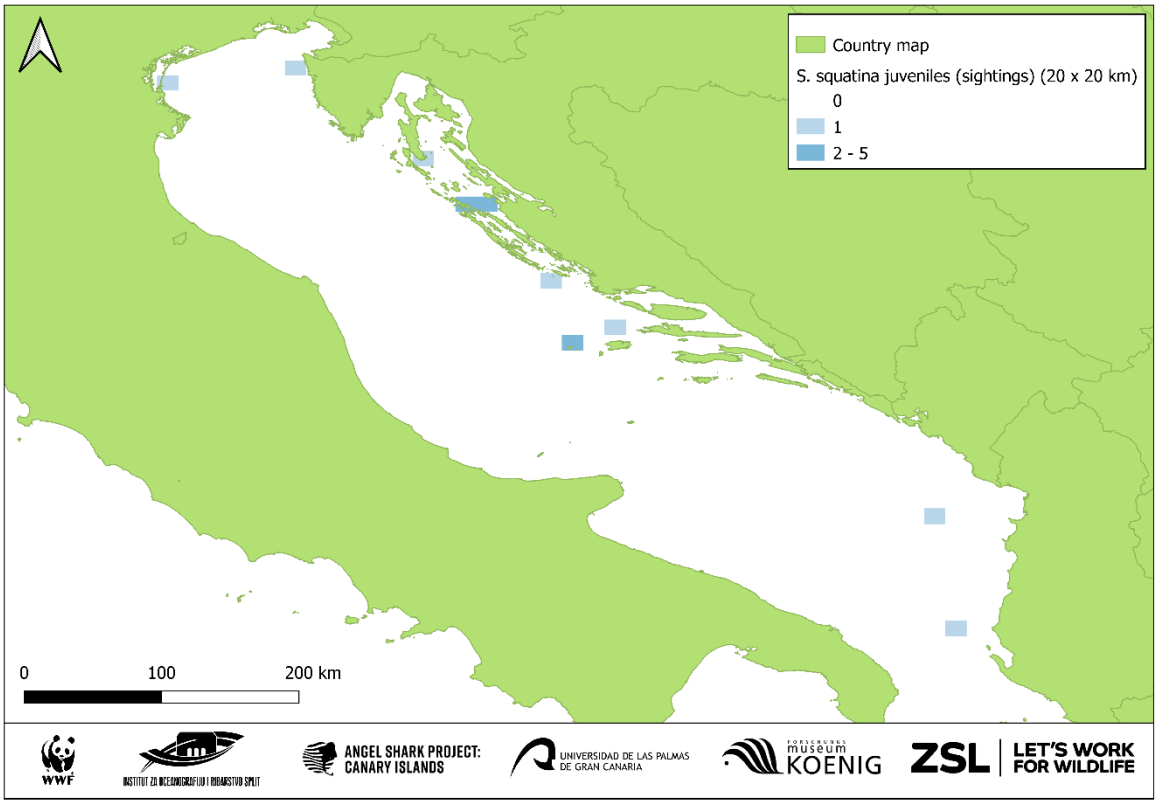

Figure 12 – Size analysis showing sightings of juvenile *S. squatina* described as either less than 30 cm in length, less than 0.5 kg in weight, or records within the LEK study where size was given for an adult *S. squatina*, but there was a note to describe that the sighting also included juveniles of which the size was not recorded, at 20 x 20 km resolution.

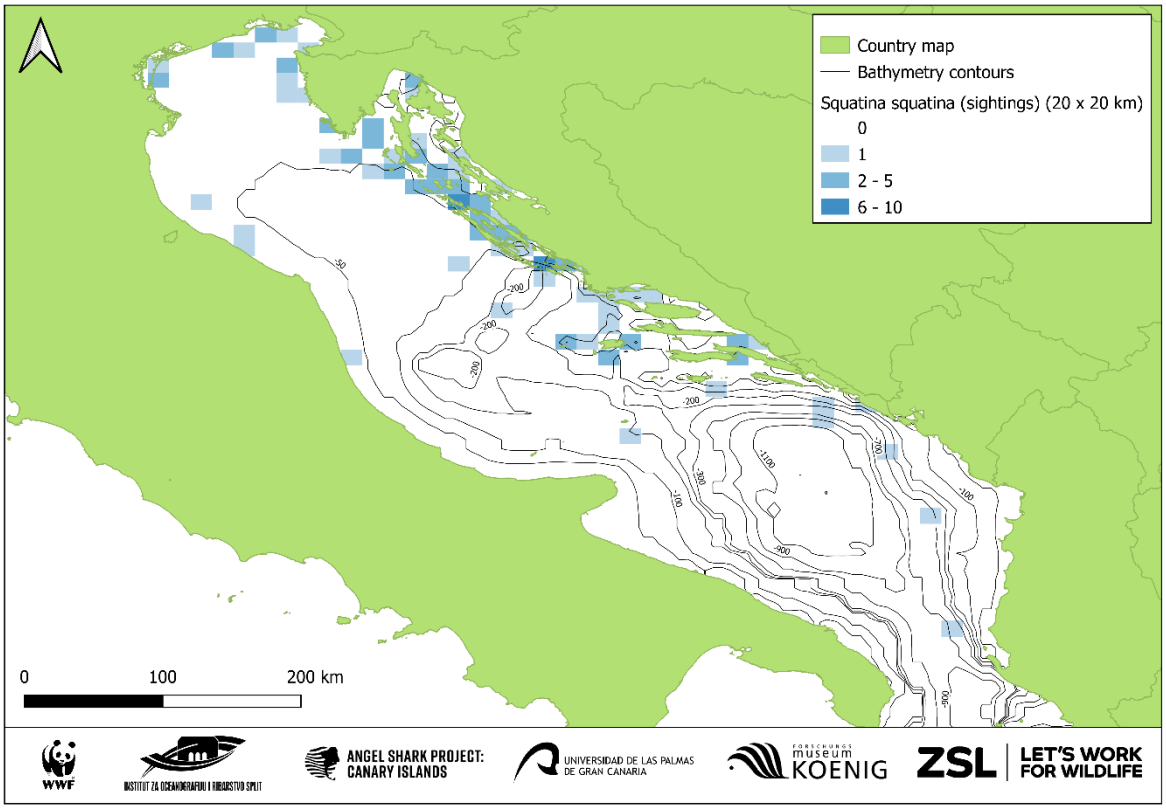

Figure 13 – Sightings of *S. squatina* at 20 x 20 km resolution, in relation to depth of sea floor (bathymetry) for the Adriatic Sea (average depth of sea floor, 30 arcsecond spatial resolution).

Discussion

Mediterranean Sea

Of the three species of angel shark found in the Mediterranean Sea, *S. squatina* was the most common species recorded to the ASSM. *S. squatina* presence was confirmed off the coast of Corsica, Sicily, Libya and Israel, and in the Aegean and Adriatic Seas. Records for *S. oculata* and *S. aculeata* in the Mediterranean Sea were sparse, with records occurring in the Aegean Sea, on the south eastern coast of Sicily and the southern coast of Turkey. This aligns with recently published research investigating the extant range of the three *Squatina* species in the Eastern Atlantic and Mediterranean Sea (Lawson *et al.* 2020) and the IUCN Red List assessments for *S. squatina* (Morey *et al.* 2019a), *S. oculata* (Morey *et al.* 2019b) and *S. aculeata* (Morey *et al.* 2019c). Further research could be targeted at these locations to better understand angel shark distribution and ecology.

Angel shark occurrence in MPAs and FRAs

Recent records of angel sharks were found to show overlap with some MPAs and FRAs in the Mediterranean Sea (Table 1). The most common type of MPA to overlap sightings was designated Natura 2000 sites, none of which were found to have management plan, or implemented management plan. One FRA, Jabuka Pit, overlapped angel shark records.

Natura 2000 sites cover both aquatic and terrestrial ecosystems across all EU countries (European Commission 2020). The network of Natura 2000 sites aim to protect rare species and habitats listed under the EU Birds Directive or EU Habitats Directive respectively (European Commission 2020). No elasmobranchs are included in the species list of these directives; thus Natura 2000 sites cannot be designated specifically for angel sharks. However, angel sharks could benefit from some level of de-

facto protection as habitats listed under the EU Habitats Directive have been shown to be used by this species: “1110 Sandbanks which are slightly covered by sea water all the time” (Akyol *et al*. 2015, Meyers *et al*. 2017, Morey *et al.* 2019*b,c*); “1130 Estuaries” (Morey *et al*. 2019*c*), “1140 Mudflats and sandflats not covered by seawater at low tide” (Morey *et al*. 2019*b,c*); “1150 Coastal lagoons” (Lapinski and Giovos 2019); “1160 Large shallow inlets and bays” (Morey *et al*. 2019*c*, Meyers *et al.* 2017, Barker *et al*. 2019, Jiménez-Alvarado *et al*. 2020); “1170 Reefs” (Meyers *et al.* 2017). In addition, an angel shark species could feature as a species of conservation interest within the management plan for the Natura 2000 site, if data shows that the species occurs within the designated area.

Within the Adriatic there were four Natura 2000 sites where two or more angel sharks had been sighted. These Natura 2000 sites occur in Croatia; three were listed under the Habitats Directive for reefs, *Posidonia oceanica* beds, sea caves (submerged or partially submerged) and bottlenose dolphins. The remaining site was listed under the Birds Directive. Outside of the Adriatic, there was one Natura 2000 site in France where over two angel sharks were sighted. This site was listed under the Habitats Directive for *P. oceanica* beds, sandbanks (slightly covered by seawater), mudflats and sandflats (not covered by seawater at low tide), and loggerhead turtles. None of these sites have a management plan or implemented management plan.

Less than 10 % of the Mediterranean Sea is covered by MPAs, meaning international targets have not been met by 2020. Within the context of the Post-2020 Global Biodiversity Framework, scientists and global leaders are calling for increasingly ambitious biodiversity targets, to effectively protect at least 30 % of the ocean to maintain and restore biodiversity. Gomei *et al*. (2019) found that MPAs with a management plan only covered 2.48 % of the surface of the Mediterranean Sea, and MPAs where actions within the management plan were actually being implemented only covered only 1.27 %, suggesting current levels of protection are not effective. The results of the current analysis reflect this shortcoming, and highlights the lack of spatial protection for threatened species, such as angel sharks. Findings of this report underline the urgency to expand and designate additional areas.

Adriatic Sea

Records from the LEK case study revealed gillnets to be the most common gear type interacting with angel sharks. Other studies show angel sharks are susceptible to gillnets as a result of their demersal nature (Lawson *et al*. 2020). Anecdotal evidence collected during this study found that 27.1 % of fishers did not return their angel shark catch, 8.2 % released the angel shark alive, and 64.7 % did not record the fate of their catch. This highlights the urgency of working with the fishing communities to educate in the protected status of angel sharks and train in how to safely release angel sharks encountered. LEK case study and ASSM records found only *S. squatina* to be present in the Adriatic Sea. Fortibuoni *et al.* (2016) suggested *S. squatina* underwent a collapse in the 1970s in the Adriatic Sea, although there were some records remaining from the area between 2000 and 2013. In this study, more historical records in the northern Adriatic occurred around the Italian coast between Venice and Trieste, whereas in recent years the records were clustered around the northern Croatian Islands. In the central and southern Adriatic, there were less recent records in comparison to historical records. The LEK case study was focussed mostly in Croatia, and so a comparable study conducted in other countries bordering the Adriatic may produce new records. This would allow better comparison across the Adriatic Sea to fully understand angel shark distribution.

In Croatian waters, the Molat Island archipelago was identified as a potential hotspot for *S. squatina*. This was apparent when mapping recent records and just juvenile sightings. The currents around Molat Island archipelago are some of the largest in Croatia and surrounding reef ecosystems mean there are fewer opportunities for fishing (D. Kanski *pers. comms*.). Thus, low levels of historic and

current fishing pressure in this area may provide an explanation for the location of this angel shark hotspot. Further research is needed to evaluate this.

Angel sharks bury themselves in soft sediment to camouflage from predators and prey (Compagno 1984). When overlaying angel shark records with modelled habitat data, the most common substrate types were sand and mud-based sediments. Around Molat Island archipelago, three of four juvenile records were on sandy mud substrate type, with one record occurring on coarse and mixed sediment. This supports research in the Canary Islands that show *S. squatina* presence was most commonly associated with sand habitat, close to reefs, although they were also found in reef habitat, and within seagrass beds (Meyers *et al*. 2017, Jiménez Alvarado *et al.* 2020). Angel sharks have also been linked with seagrass in Corsica (Lapinski & Giovos 2019), and three of the four Natura 2000 sites overlapping sightings in the Adriatic were found to have protections for *P. oceanica* beds. This habitat may therefore be important for *S. squatina*, and further study is needed to confirm this. However, in recent years there have been observed large decline in seagrass beds across the Mediterranean Sea, attributed to coastal development and construction, pollution, aquaculture, trawling, and rapid ocean warming which has been shown to trigger shoot mortality (Ruíz *et al*. 2009, Marba & Duarte 2010).

Depth has also been shown to be a factor in angel shark distribution, with shallower areas (< 25m) more commonly occupied by juvenile angel sharks, with adult angel sharks found at greater depths (Meyers *et al*. 2017, Jiménez Alvarado *et al.* 2020). In this study, most sightings occurred at depths shallower than 50 m. Juvenile angel shark presence in shallower areas may be due to protection from predators, greater prey abundance or higher temperatures to increase rate of development (Meyers *et al*. 2017). Molat Island archipelago is composed of many shallow inlets and bays, coupled with soft sediment and reef habitat, which may provide the environmental conditions needed for *S. squatina* to thrive. Further study in the Molat Island archipelago would be beneficial to confirm whether it is a potential nursery area for *S. squatina* in Croatia.

Recommendations

The following recommendations have been developed using the results of this study. They focus on improving understanding and conservation of angel sharks in the Adriatic Sea, specifically in Croatian waters where the most records were collected. As our understanding of angel sharks in the Adriatic Sea and wider Mediterranean Sea grows, these recommendations will need further development.

RECOMMENDATION 1: Work with the Government of the Republic of Croatia and Natura 2000 management officials to improve understanding of angel shark presence in the region, and where appropriate, account for this in management plans.

Firstly, contact officials that manage the specific Natura 2000 areas that overlap angel shark occurrences, to share the results of this study and increase understanding of angel shark ecology. Due to Natura 2000 site designation process, a specific designation for angel sharks would not be possible (see Discussion). However, angel sharks could feature as an additional species of conservation interest within management plans at these Natura 2000 sites, where appropriate.

Secondly, complete a consultation with the respective authorities, including the Ministry of Economy and Sustainable Development (Government of the Republic of Croatia), to discuss how angel sharks could be included in the development and implementation of management plans, with possible consideration of specific fishing restrictions or seasonal protection of specific habitat. This should focus on the following priority Natura 2000 sites:

- J. Molat-Dugi-Kornat-Murter-Pašman-Ugljan-Rivanj-Sestrunj-Molat
- JI dio o. Molata
- Srednjedalmatinski otoci i Pelješac
- Rivanjski kanal sa Sestricama

In the future, if research confirms that angel sharks depend on specific habitats listed under the EU Habitats Directive during a particular life stage, angel sharks could be added as a "typical species" or "notable species" for this habitat as part of the Natura 2000 framework. Significant additional data are needed for this.

RECOMMENDATION 2: Further angel shark research at possible hotspots to strengthen baseline knowledge of angel sharks in the region.

Resources should be secured to enable dedicated angel shark research in the Adriatic Sea to gather data on distribution, movement, ecology, and abundance to inform future conservation and management. The Angel Shark Project have suggested the following research techniques as a priority for Croatian waters:

- Continue to strengthen citizen science data collection to better understand angel shark distribution in Croatia.
- Conduct a systematic environmental DNA (eDNA) study at possible angel shark hotspots to investigate occurrence throughout the year.
- Complete visual surveys via scuba diving and snorkelling at possible hotspots (where conditions allow) to identify angel sharks and assess habitats present.
- Use results of the above techniques to assess whether an angel shark tagging study or genetic research could be viable in the Adriatic Sea, in order to understand movement and connectivity.

RECOMMENDATION 3: Train fishers in best-practice guidance to safely release angel sharks and work with communities around Molat Island archipelago.

Molat Island archipelago was identified within this study as a potential hotspot for *S. squatina*. Scoping work around this island is necessary to confirm this hypothesis, which should include pilot studies as outlined in Recommendation 2. As a first step, focused work alongside the fishing community should be conducted in this area to:

- Raise awareness of the conservation status and ecology of angel sharks.
- Educate fishers of the protected status of angel sharks, and that if caught, individuals must be released.
- Train fishers in best practise handling to ensure highest chance of survival for accidental angel shark catches.

In addition, a focused threat analysis could be conducted to assess possible threats to angel sharks in this area. It is important to closely involve fishing and local communities in any future work, e.g. angel shark research or designing conservation measures in this area. Both methods would also highlight the importance of sharing angel shark records with the scientific community.

RECOMMENDATION 4: Develop a sub-regional action plan for the Adriatic Sea.

The Mediterranean Regional Action Plan for Angel Sharks (MedRAP) was developed and published in 2019 to focus angel shark conservation efforts (Gordon *et al*. 2019). The MedRAP sets out a road map for the development of sub-regional action plans (SubRAPs) to better facilitate action in each subregion of the Mediterranean, and allow effective delivery of aims set out within the MedRAP (Gordon *et al*. 2019). The SubRAP for the Aegean Sea was the first to be published in August 2020 (Gordon *et al*. 2020).

The objective of the SubRAPs are to gather data and evidence, share information, standardise approaches and allow better cooperation and communication across subregions in the Mediterranean (Gordon *et al*. 2019). The results of this study can be used as a baseline to help develop the Adriatic SubRAP with partners across the Adriatic Sea and should be considered a priority.

RECOMMENDATION 5: Develop angel shark LEK case study template to replicate research in other countries.

The LEK case study conducted in Croatia revealed many new angel shark records, not reported to the ASSM, demonstrating that establishing positive relationships with local coastal communities are vital to better understand distribution. The LEK study used in this analysis was focused on Croatia, therefore it is difficult to make recommendations at a Mediterranean Sea or Adriatic Sea scale until similar studies are conducted in other localities to allow for comparison. Replication of the LEK study across other countries in the Mediterranean Sea, in particular those bordering the Adriatic Sea would significantly improve our understanding of angel shark distribution. Areas identified within the analysis where sightings overlap MPAs could also be used to guide where to implement LEK studies, for example in Corsica, where sightings overlapped the Pelagos Sanctuary. To enable consistent and comparable data to be collected, an angel shark LEK Study template should be created and shared with colleagues across the Mediterranean Sea.

RECOMMENDATION 6: If Angelshark hotspots are confirmed with further study, identify mechanisms to develop MPAs to protect these habitats (see Recommendation 2 & 3).

The Nature Protection Strategy and Action Plan of the Republic of Croatia (2017–2025) will derive strategic goals from the Aichi Biodiversity targets (listed in the Strategic Plan for Biodiversity 2011-2020 of the Convention of Biological Diversity) and the EU 2020 Biodiversity Strategy targets. This includes potential for development of new MPAs in Croatian waters. As a first step, results of this project should be discussed with the Ministry of Economy and Sustainable Development whilst further research is being carried out to confirm presence and use of angel shark hotspots (See Recommendation 2 and 3).

Any future MPAs developed for angel sharks in Croatia should consider:

- Areas where sightings have been reported and further research confirms the importance of this site for angel shark life history.
- Involve local communities in identification, development of management protocols and designation of possible future MPAs.

- Evaluate different management tools that may be necessary to enable best benefit for angel sharks, e.g. consideration of specific fishing restrictions or seasonal protection of specific habitat.
- Ensure the management plan includes angel shark monitoring programmes and evaluation of impact measures.

References

Abdulla, A., Gomei, M., Hyrenbach, D., Notarbartolo-di-Sciara, G. and Agardy, T. (2009). Challenges facing a network of representative marine protected areas in the Mediterranean: prioritizing the protection of underrepresented habitats. *ICES Journal of Marine Science*, 66(1), 22–28.

Akyol, O., Ünal, V., Capapé, C. (2015). Occurrence and Biological Observations on Angel Shark S*quatina squatina* (Chondrichthyes: Squatinidae) from the Turkish Waters (Eastern Mediterranean). *Turkish Journal of Fisheries and Aquatic Sciences*, 15, 925–929.

Barker, J., Bartoli, A., Clark, M., Dulvy, N. K., Gordon, C., Hood, A., … Meyers, E. (2016). Angelshark action plan for the Canary Islands. Zoological Society of London (ZSL).

Barker, J., Meyers, E.K.M., Caro, B., Sealey, M. and Jiménez Alvarado, D. (2019). Guidance Document: Identification and Protection of Juvenile Angelshark Habitat in the Canary Islands. Angel Shark Project: Canary Islands.

Bianchi, C.N. and Morri, C. (2000). Marine Biodiversity of the Mediterranean Sea: Situation, Problems and Prospects for Future Research. *Marine Pollution Bulletin*, 40, (5), 367–376.

Claudet, J. and Fraschetti, S. (2010). Human-driven impacts on marine habitats: A regional meta-analysis in the Mediterranean Sea. Biological Conservation, 143(9), 2195–2206.

CMS (Convention on Migratory Species) (2017). Concerted Action for the Angelshark (*Squatina squatina*). UNEP/CMS/Concerted Action 12.5. Available at: https://www.cms.int/sites/default/files/document/cms_cop12_ca.12.5_angelshark_e.pdf

Coll, M., Piroddi, C., Albouy, C., Ben Rais Lasram, F., Cheung, W.W.L., Christensen, V., Karpouzi, V.S., Guilhaumon, F., Mouillot, D., Paleczny, M., Palomares, M.L., Steenbeek, J., Trujillo, P., Watson, R. and Pauly, D. (2012). The Mediterranean Sea under siege: spatial overlap between marine biodiversity, cumulative threats and marine reserves. *Global Ecology and Biogeography*, 21, 465–480.

Coll, M., Piroddi, C., Steenbeek, J., Kaschner, K., Lasram, F.B.R.,6, Aguzzi, J., Ballesteros, E., Bianchi, C.N., *et al*. (2010). The biodiversity of the Mediterranean Sea: estimates, patterns and threats. *PLoS ONE*, 5, e11842.

Coll, M., Santojanni, A., Palomera, I., Tudela, S. and Arneri, E. (2007). An ecological model of the Northern and Central Adriatic Sea: Analysis of ecosystem structure and fishing impacts. *Journal of Marine Systems*, 67(1–2), 119–154.

Compagno, L.J.V. 1984. FAO species catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. FAO Fisheries Synopsis No. 125, Volume 4, Part 1.

Danovaro, R. and Boero, F. (2019). Italian Seas. C. Sheppard (eds.) World Seas: An environmental evaluation, Volume 1: Europe, the Americas and West Africa, 2nd Edition. Academic Press. 283–306.

Dulvy, N. K., Fowler, S. L., Musick, J. A., Cavanagh, R. D., Kyne, P. M., Harrison, L. R., Carlson, J. K., *et al*. (2014). Extinction risk and conservation of the world's sharks and rays. *eLife*, 3, e00590.

EMODnet. (2020). EMODnet broad-scale seabed habitat map for Europe (v2019) – licenced under CC-BY 4.0 from the European Marine Observation and Data Network (EMODnet) Seabed Habitats initiative (www.emodnet-seabedhabitats.eu), funded by the European Commission.

http://gis.ices.dk/geonetwork/srv/eng/catalog.search#/metadata/f7d5a168-0097-4437-944e-cc63111d15c6 [Accessed 11.06.2020].

European Commission (2020). Natura 2000. [Accessed: 14 August 2020] https://ec.europa.eu/environment/nature/natura2000/index_en.htm#:~:text=Natura%202000%20is%20a%20network,on%20land%20and%20at%20sea.

Ferretti, F., Myers, R. A., Serena, F. and Lotze, H. K. (2008). Loss of large predatory sharks from the Mediterranean Sea. *Conserv. Biol*. 22, 952–964.

Ferretti, F., Osio, G.C., Jenkins, C.J., Rosenberg, A.A. and Lotze, H.K. (2013). Long-term change in a meso-predator community in response to prolonged and heterogeneous human impact. *Scientific Reports*, 3, 1057, 1–11.

Fortibuoni, T., Borme, D., Franceschini, G., Giovanardi, O. and Raicevich, S. (2016). Common, rare or extirpated? Shifting baselines for common angelshark, *Squatina squatina* (Elasmobranchii: Squatinidae), in the Northern Adriatic Sea (Mediterranean Sea). *Hydrobiologia*, 772, 247–259.

Giovos, I., Stoilas, V.-O., Al-Mabruk, S.AA., Doumpas, N., Marakis, P., Maximiadi, M., Moutopoulos, D., Kleitou, P., Keramidas, I., Tiralongo, F. and de Maddalena, A. (2019). Integrating local ecological knowledge, citizen science and long-term historical data for endangered species conservation: Additional records of angel sharks (Chondrichthyes: Squatinidae) in the Mediterranean Sea. *Aquatic Conservation*, 29(6), 881–890.

Gomei, M., Abdulla, A., Schröder, C., Yadav, S., Sánchez, A., Rodríguez, D. and Abdul Malak, D. (2019). Towards 2020: how Mediterranean countries are performing to protect their sea. 38 pages.

Gordon, C.A., Hood, A.R., Al Mabruk, S.A.A., Barker, J., Bartolí, A., Ben Abdelhamid, S., Bradai, M.N., Dulvy, N.K., Fortibuoni, T., Giovos, I., Jimenez Alvarado, D., Meyers, E.K.M., Morey, G., Niedermuller, S., Pauly, A., Serena, F. and Vacchi, M. (2019). Mediterranean Angel Sharks: Regional Action Plan. The Shark Trust, United Kingdom. 36 pp.

Gordon, C.A., Hood, A.R., Barker, J., Bartolí, À., Dulvy, N.K., Jiménez Alvarado, D., Lawson, J.M. and Meyers, E.K.M. (2017) Eastern Atlantic and Mediterranean Angel Shark Conservation Strategy. The Shark Trust, UK.

Gordon, C.A., Hood, A.R., Giovos, I., Aga – Spyridopoulou, R.N., Ozturk, A.A., Yigin, C.C., Fakioğlu, E., Ibrahim, D., Oruc, A., Niedermüller, S. (2020). Mediterranean Angel Sharks: SubRegional Action Plan (SubRAP) GSAs 22/23 (Aegean Sea and Crete). *The Shark Trust*, United Kingdom. 12pp

Holcer, D. and Lazar, B. (2017). New data on the occurrence of the critically endangered common angelshark, *Squatina squatina*, in the Croatian Adriatic Sea. *Natura Croatica*, 26(2), 313–320.

Jiménez-Alvarado, D., Meyers, E.K.M, Caro, M.B., Sealey, M.J. and Barker, J. (2020). Investigation of juvenile angelshark (*Squatina squatina*) habitat in the Canary Islands with recommended measures for protection and management. *Aquatic Conserv: Mar Freshw Ecosyst*., 1–7.

Kyne, P.M., Jabado, R.W., Rigby, C.L., Dharmadi, Gore, M.A., Pollock, C.M., Herman, K.B., Cheok, J., Ebert, D.A., Simpfendorfer, C.A. & Dulvy, N.K. (2020). The thin edge of the wedge: extremely high extinction risk in wedgefishes and giant guitarfishes. *Aquatic Conservation: Marine and Freshwater Ecosystems,* 30, 1337-1361. https://doi.org/10.1002/aqc.3331.

Lapinski, M. and Giovos, I. (2019). New records of the critically endangered *Squatina squatina* (Linnaeus, 1758) from Corsica, France. *Acta Adriat*., 60(2), 205–210.

Lawson, J.M., Pollom, R.A., Gordon, C.A., Barker, J., Meyers, E.K.M., Zidowitz, H., Ellis, J.R., Bartolí, A., Morey, G., Fowler, S.L., Jiménez Alvarado, D., Fordham, S.V., Sharp, R., Hood, A.R. and Dulvy, N.K. (2020). Extinction risk and conservation of critically endangered angel sharks in the Eastern Atlantic and Mediterranean Sea. *ICES Journal of Marine Science*, 77(1), 12–29.

Lotze, H. K., Coll, M. and Dunne, J.A. (2011). Historical changes in marine resources, food-web structure and ecosystem functioning in the Adriatic Sea, Mediterranean. *Ecosystems*, 14(2), 198–222.

Marba, N. and Duarte, C.M. (2010). Mediterranean warming triggers seagrass (*Posidonia oceanica*) shoot mortality. *Global Change Biology*, 16, 2366–2375.

Maynou, F., Sbrana, M., Sartor, P., Maravelias, C., Kavadas, S., *et al*. (2011). Estimating Trends of Population Decline in Long-Lived Marine Species in the Mediterranean Sea Based on Fishers' Perceptions. *PLoS ONE*, 6(7), e21818.

Meyers, E. K. M., Tuya, F., Barker, J., Alvarado, D. J., Castro-Hernández, J. J., … Rödder, D. (2017). Population structure, distribution and habitat use of the Critically Endangered Angelshark, *Squatina squatina*, in the Canary Islands. *Aquatic Conservation Marine and Freshwater Ecosystems*, 27, 1133–1144.

Micheli, F., Halpern, B.S., Walbridge, S., Ciriaco, S., Ferretti, F., Fraschetti, S., Lewison, R., Nykjaer, L., and Rosenberg, A.A. (2013). Cumulative Human Impacts on Mediterranean and Black Sea Marine Ecosystems: Assessing Current Pressures and Opportunities. *PLoS ONE*, 8(12), e79889.

Morey, G., Barker, J., Bartolí, A., Gordon, C., Hood, A., Jimenez-Alvarado, D. and Meyers, E.K.M. (2019a). *Squatina aculeata*. The IUCN Red List of Threatened Species 2019: e.T61417A116768915. http://dx.doi.org/10.2305/IUCN. UK.2019-1.RLTS.T61417A116768915.en.

Morey, G., Barker, J., Bartolí, A., Gordon, C., Hood, A., Meyers, E.K.M. and Pollom, R. (2019b). *Squatina oculata*. The IUCN Red List of Threatened Species 2019: e.T61418A116782036. http://dx.doi.org/10.2305/IUCN.UK.2019-1. RLTS.T61418A116782036.en.

Morey, G., Barker, J., Hood, A., Gordon, C., Bartolí, A., Meyers, E.K.M., Ellis, J., Sharp, R., Jimenez-Alvarado, D. and Pollom, R. (2019c). *Squatina squatina*. The IUCN Red List of Threatened Species 2019: e.T39332A117498371. http:// dx.doi.org/10.2305/IUCN.UK.2019-1.RLTS.T39332A117498371.en.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. and Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, 403, 853–858.

Pinardi, N., Arneri, E., Crise, A., Ravaioli, M. and Zavatarelli, M. (2006). The physical, sedimentary and ecological structure and variability of shelf areas in the Mediterranean Sea. Robinson, A.R., Brink, K.H. (eds.) The Sea Vol. 14. Cambridge: Harvard University Press. 1243–1330.

QGIS.org (2020). QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.org

Raicevich, S. and Fortibuoni, T. (2013). Assessing neoextirpations in the Adriatic Sea: an historical ecology approach. In Briand, F. (ed.), Marine Extinctions - Patterns and Processes. CIESM Publisher, Monaco: 97–111.

Rigby, C.L., Simpfendorfer, C.A. and Cornish, A. (2019). A Practical Guide to Effective Design and Management of MPAs for Sharks and Rays. WWF, Gland, Switzerland.

Ruíz, J.M., Boudouresque, C.F. and Enríquez, S. (2009). Mediterranean seagrasses. *Botanica Marina*, 52, 369–381.

Soldo, A. (2013). Extinction vulnerability of chondrichthyans. In Briand, F. (ed.), Marine Extinctions - Patterns and Processes. CIESM Publisher, Monaco: 91–96.

Stevens, J.D., Bonfil, R., Dulvy, N.K. and Walker, P.A. (2000). The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. *ICES Journal of Marine Science*, 57(3), 476–494.

Tyberghein, L., Verbruggen, H., Pauly, K., Troupin, C., Mineur, F. and De Clerck, O. (2012). Bio-ORACLE: a global environmental dataset for marine species distribution modelling. *Global Ecol. Biogeogr*., 21, 272–281.