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PRIMARY RESEARCH PAPER

Common, rare or extirpated? Shifting baselines for common angelshark, *Squatina squatina* (Elasmobranchii: Squatinidae), in the Northern Adriatic Sea (Mediterranean Sea)

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Abstract Historical baselines are needed to reconstruct long-term changes in marine animal populations and enhance our ability to articulate management recommendations. We reconstructed common angelshark (*Squatina squatina*) abundance in the Northern Adriatic Sea over the last two centuries by integrating different sources of formal and informal information. The wide amount of information collected helped assessing if the species is actually extirpated from the area, as stated in previous studies. According to naturalists' accounts and historical documents, in the nineteenth and early twenty-first centuries the species was so abundant to sustain targeted fisheries, and large quantities of *S. squatina* were sold in the main fish markets. In the 1960s, the species collapsed and got economically extinct. Even if it was never caught in the area through scientific surveys during the period 1948–2014, from fishermen interviews emerged that the species is not extirpated. However, only 50% of interviewees caught *S. squatina* at least once and they were significantly older than the fishermen that never caught it (shifting baseline syndrome). Moreover, the size of the fish caught significantly decreased through time, indicating the depletion of larger individuals. Our integrated approach can be applied to any poorly assessed species so that appropriate international conservation measures can be prioritized.

Keywords Endangered species · Naturalists' accounts · Landings · Scientific survey · Historical ecology · Fishers' ecological knowledge

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Introduction

The long history of life on our planet has been characterized by five major global processes of extinction commonly named Mass Extinctions. These were abrupt changes in the number and composition of species which shaped, along with the evolutionary process of speciation, the composition and diversity of life as we currently know it. There are evidences that in the so-called Anthropocene the speed of disappearance of species has sharply increased (Grady et al., 2004), allowing defining the current global process of extinction as the Sixth Mass Extinction (Barnosky et al., 2011). The alert arises from the fact that, in contrast to the previous Mass Extinctions, the current biodiversity crisis is induced by anthropogenic-driving forces (Carlton et al., 1999).

Thus, there is an urgent need to quantify this process and identify species at risk of extinction (Grady et al., 2004), in order to minimize further negative impacts of humans on nature (Harnik et al., 2012). For this purpose, it is fundamental to reconstruct species' historical abundance in order to prevent the so-called "shifting baseline syndrome" (Pauly, 1995) by considering "natural" the actual rarity of a previously abundant species. However, there are some practical difficulties in assessing the extinction of a species, particularly at sea (Callum & Hawkins, 1999; Dulvy et al., 2004), and extinction is a relatively uncommon phenomenon in the marine environment (Harnik et al., 2012). Indeed, only three mammals, five birds, four gastropods and another 18 low taxonomic level *taxa* have been reported to be extinct in the last three centuries on a worldwide scale in the marine domain, while there is no known extinction of marine fishes on a global scale (Dulvy et al., 2003; McCauley et al., 2015).

On the contrary extirpation, which occurs when a species ceases to exist at local or regional scales, is more frequent and has been described for several marine species (Harnik et al., 2012). Extirpation may represent an early warning of species' threat as it may be a step towards global-scale extinction (Pitcher, 2001).

The validation of an extirpation is fundamental and can be instrumental in promoting legal protection to prevent further losses (Luiz Osmar & Edwards, 2011). Conversely, considering a species as extinct prematurely could undermine potential conservation measures and contribute to its demise (Collar, 1998). It could also reduce public confidence in the accuracy of extinction designation, and be used to distrust conservation practices (Monte-Luna et al., 2007). On the other hand, the failure to detect real extinctions can hinder our understanding of factors that lead to them and hamper the prevention of further losses (Luiz Osmar & Edwards, 2011).

Actually, a growing number of previously abundant marine species are reported to have declined or even disappeared from discrete areas of their overall historical geographic range (Dulvy et al., 2003). The main cause has been identified as overexploitation, followed by habitat loss or degradation, introduction of invasive species and other factors such as climate change, pollution and disease (Jackson et al., 2001). In particular, fishing has caused severe declines at regional and local scales on fish, molluscs or crustaceans, both on target and non-target species. Compared to other sources of impacts on marine ecosystems, overfishing has come much earlier in the historical sequence of events (Jackson et al., 2001). Moreover, extirpation is not a peculiarity of mechanized/industrial fishery, since even in subsistence and artisanal fisheries local-scale extinctions have been reported (Pinnegar & Engelhard, 2008).

The increasing concern for the negative impacts of exploitation on marine species and ecosystem functioning made conservation issues and the identification of species at risk of extinction a priority in fisheries science (Agardy, 2000). Within this framework, the International Union for Conservation of Nature (IUCN) has compiled the Red List of Threatened Species. In the Mediterranean Sea, a recent assessment has identified 62 marine species (Kingdom: Animalia) at risk, i.e. 35 Chondrichthyes, 12 Actinopterygii, 11 Mammalia and 4 Reptilia (IUCN, 2013). Among these, selachians (skates, rays and sharks) and mammals are described to be the most vulnerable groups due to their intrinsic ecological features that make them highly vulnerable to exploitation (Reynolds et al., 2005).

Species to be assessed in the Red List are identified by regional experts on the basis of the availability of quantitative, semi-quantitative or qualitative data. Therefore, any attempt in collecting historical data and information, especially on most vulnerable but at the same time "data poor" species, could contribute to improve substantially our knowledge of the current status of marine species.

Overall, insufficient data exist to quantify the historical level of elasmobranchs in the Mediterranean and, in particular, few information is available on commercial elasmobranchs exploited by Italian fisheries (Dell'Apa et al., 2012). Thus, sources other than scientific time series (the so-called informal knowledge), such as traditional ecological knowledge retrieved from fishermen (Neis et al., 1999; Maynou et al., 2011) and naturalists' observations (Sáez-Arroyo et al., 2005; Fortibuoni et al., 2010; Brito & Sousa, 2011), could be useful in providing information to marine scientists.

In the present work we collected, integrated and compared different sources of information covering more than 2 centuries, in order to set an historical baseline for common angelshark (*Squatina squatina*, Linnaeus 1758) in the Northern Adriatic Sea. In particular, we combined data from naturalists' diaries, local archives, fish market statistics, old scientific explorations, modern scientific surveys and anecdotal information obtained from fishermen. Since the species was classified as "Critically Endangered" at a global scale by the IUCN (Morey et al., 2006), we further verified if the species is now locally extinct in the area, as stated by previous authors (Dulvy et al., 2003).

Materials and methods

The species

The common angelshark is a temperate-water bottom-dwelling shark occurring on sand or muddy bottoms from close inshore areas to the outer shelf, from 5 m to at least 150 m depth. The species may also enter into estuaries and brackish waters (Ebert & Stehmann, 2013), and may be found in areas with macroalgae, kelp or rocks (Morey et al., 2006). Shallow waters are generally more frequented by juveniles and pregnant females (Lipej et al., 2004).

Maximum length and weight are 250 cm and 80 kg, respectively (Serena, 2005), females reach sexual maturity at lengths from 128 to 169 cm, while males at 80 to 132 cm (Capapé et al., 1990). According to Morey et al. (2006), the biggest individual recorded in the Mediterranean was 130 cm long.

The common angelshark has been utilized by humans as source of food for thousands of years. Its meat, considered light and easily digestible, was sold fresh or dried and salted, while its skin was used for polishing wood and ivory. The use of this species as food has continued into modern times and it represents also as a source for shark liver oil and fishmeal (Compagno, 1984).

Squatina squatina originally ranged from Scandinavia to northwest Africa, including the Mediterranean and Black Seas (Ferretti et al., 2015). It was historically common over large areas of the coastal, continental and insular shelf of the North-East Atlantic (Başusta et al., 2006). This species was relatively frequent in coastal artisanal fisheries (trammel nets, gillnets, lobster tangle nets), trawls and bottom longlines (Morey et al., 2006). It was still being caught regularly and considered common in the United Kingdom at the beginning of the twentieth century (Garstang, 1903). However, since the mid-twentieth century intense commercial fishing has seriously reduced its populations to the level of local extinction or nearly so (Fowler, 2010). Steep population declines have been reported also from the North Sea and the French coast. Actually, almost all of the residual population is found around the Canary Islands, where the implementation of conservation measures is urgent (Ferretti et al., 2015).

In the Mediterranean Sea, there are few current or historic population estimates for this species. It was mostly caught by trawling and set nets on sandy and muddy detritic bottoms, at depths from 5 to 30 m (Bini, 1967). The shark was reported as frequent during the first half of the twentieth century, but steep population declines were recorded during the second half of the century (Ferretti et al., 2015). For instance, *S. squatina* is considered as a severely declined shark in Turkey's seas (Fricke et al., 2007), and the species may now be absent off the Balearic Islands, where it was frequent (Ferretti et al., 2015). Its past and present status in the Adriatic is poorly described.

In the Adriatic Sea, another species of the genus *Squatina* was known (Faber, 1883), *S. oculata* Bonaparte, 1840, which however has been considered more rare since the end of the nineteenth century (Brusina, 1888). For further information about *S. squatina* see Online Resources Table A1.

Area of study

The Northern Adriatic Sea is the northern-most area of the Mediterranean Sea. It receives the greatest river run-off of the Mediterranean Sea (excluding the Black Sea), mainly from the Po River (Sangiorgi & Donders, 2004), it is shallow, semi-enclosed and the seabed is characterized by muddy and sandy bottoms, as well as few rocky outcrops (Brambati et al., 1983). The upper Adriatic is a highly productive area characterized by a great abundance of benthic invertebrates and pelagic plankton consumers, which attract elasmobranchs (Ferretti et al., 2013). In its northern part a wide continental shelf and easy accessible "soft" grounds allowed early development of trawling fisheries (Botter et al., 2006; Fortibuoni, 2010). The ecosystem has been intensively exploited for centuries (Botter et al., 2006; Fortibuoni, 2010), and large marine predators have declined dramatically (Lotze et al., 2011).

Data sources

An extensive survey was carried out in libraries, archives and museums in Venice, Padua, Rome, Trieste, Chioggia (Italy) and Split (Croatia) in order to collect reports, books, journals and scientific publications dealing with fisheries and fish fauna in the Adriatic Sea. We examined approximately 500 documents and acquired and digitalized around 300. Such documents include naturalists' lists of species and descriptions of fish fauna, grey literature dealing with fishing activities, landing statistics and official governmental reports on fisheries and fishing fleets in the area of study.

Fisher-based information was gathered by means of questionnaire-based interviews following a standardized sampling protocol (Bergmann et al., 2004; Sáez-Arroyo et al., 2005).

Naturalists' accounts

The main sources of information on fish fauna in the Adriatic Sea between the nineteenth century and the second half of the twentieth century were the historical records of Italian and Austro-Hungarian naturalists (Fortibuoni et al., 2010).

Thirty-three naturalists' books were examined, covering a period of 120 years (1818–1938) (Online Resources Table A2). Naturalists' knowledge of fish fauna was primarily based on direct observations at fish markets and at ports, on interviews with fishermen, on literature and on the analysis of natural history museum collections (Fortibuoni et al., 2010). Even if it was not possible to fully assess to what extent naturalists were copying each other, we checked in each book cross references and included in this study only documents primarily based on new information gathered directly by the author. The work conducted by these naturalists provides the earlier available systematic description of species that can be used to set an historical baseline of marine biodiversity in the area, more than two centuries ago (Raicevich & Fortibuoni, 2013).

Historical fisheries and fish markets data

Information and data on fisheries targeting *S. squatina* were collected from naturalists' accounts and fisheries statistics/reports. Information spans from the early nineteenth to the early twenty-first centuries (Online Resources Tables A2 and A3).

According to the historical sources consulted, main fishing gears used to fish the species were firstly the gill net called "squaenera" in Italian (or "sklatara" in Croatian), and secondly bottom trawls. The name of this net derives from the local name of common angelshark (Italian = "squaena"; Croatian = "sklat"), indicating that *S. squatina* was the main target species for this gear. According to Faber (1883), "The Squaenera is a ground-net of coarse twine for angel sharks (Squaene), and rays, also for sea-spiders, and lobsters. Mesh, 20 cm in the diagonal; length, 20 m; depth, 1.5 m; price, 15 fl".

According to Lorini (1903), the net had a mesh size of 16 cm, from knot to knot, and was high 4 knots. From 150 to 200 nets were generally used at the same time and they were set on flat soft bottoms, independently on the distance from the coast. The nets were set following a winding trajectory to increase the entangling effect and were retrieved after 2–3 days. Aside from angelsharks, other species frequently caught were rays, torpedoes, stingrays, eagle rays, turbots, lobsters, spiny lobsters, spiny spider crabs, but also sturgeons (Lorini, 1903).

The landing statistics, covering the period between 1905 and 2013 (with some gaps), used for the purpose of this research were from major fish markets for which landing logbooks were established, i.e. Venice and Trieste (Online Resources Table A3). Annual landings were given for *S. squatina* in terms of wet weight (kg/years), and for some years also the mean price for kg was reported.

Scientific survey data

Presence of *S. squatina* records were also searched in scientific surveys carried out in the area of study between 1948 and 2014 (Table 1; Online Resources Fig. A1). These surveys used different sampling gears, such as otter trawl, beam trawl, gill net and trammel net.

Fishers' interviews

52 fishers from 12 harbours distributed in 6 regions and 3 countries (Italy, Slovenia and Croatia) were interviewed between December 2013 and September 2014 to retrieve information on *S. squatina* current and past fishery and abundance in the Northern Adriatic Sea. Fishers' observations covered the period 1934–2014. All interviews were carried out in person at the ports by experienced interviewers. The interviews included a page with the objectives of the research and contact information, which was read out to the participants before starting the interview. All participants were adult and provided written consent to participate in the study by reading the questions in advance and consequently agreeing to participate in the interview. Participants could decide either to have their names, age and contacts (phone number, e-mail, address) written down in the first page of the interview or to leave it anonymous. Interviews' information was analysed and results are reported anonymously.

Individual interviews were executed with the aim of getting information on different aspects of their fishing activity, i.e. role onboard (e.g. skipper, fisher); year of start/stop commercial fishery; fishing gear used; main fishing grounds. Fishing gears were successively classified according to EU Fleet Register's segment code system.

Table 1 Summary of the basic information on the scientific surveys considered in the paper

Survey	Institution	Period	Frequency	Fishing gear	Sampling approach	N. cruises	N. stations
HVAR	IOF	1948	Yearly	Otter trawl	Trawl-survey	1	5
GIANNETTO	LMBF and IOF	1975	Yearly	Otter trawl	Trawl-survey	1	3
GRUND	LMBF	1982–1988; 1991–1998; 2000–2007	Until 1995 biennial, afterwards annual	Otter trawl	Trawl-survey	31	1,185
MEDITS	LMBF and IOF	1994–2011	Yearly	Otter trawl	Trawl-survey	18	665
ICRAM	ICRAM	1995–1996	Yearly	Otter and beam trawl	Trawl-survey	2	49
SOLEMON	CNR-ISMAR; ISPRA; IOF; FRIS	2005–2013	Yearly	Beam trawl	Trawl-survey	9	404
GAP2 trawl-survey	ISPRA	2012–2014	Yearly	Otter trawl	Trawl-survey	3	63
GAP2 fishery-dependent	ISPRA	2012–2014	Daily	Otter trawl	Scientific observers	89	483
GAP2 logbooks	ISPRA	2012–2014	Daily	Otter and beam trawl	Fishers' self-sampling	660	4,347
CAMPBIOL	CNR-ISMAR	2011–2013	Daily	Otter trawl and gill net	Scientific observers	140	799
ISPRA	ISPRA	2006; 2008–2013	Daily	Gill net	Experimental set nets	37	349
ECOMADR	OGS	2006–2007	Seasonal	Otter trawl	Trawl-survey	7	29
TREZZE	OGS	2009	Seasonal	Trammel net	Experimental set nets	8	24
TRECORALA	OGS	2013–2014	Seasonal	Gill net and trammel net	Experimental set nets	20	71

IOF Institute of Oceanography and Fisheries of Split (Croatia), *LMBF* Laboratory of Marine Biology and Fisheries (Italy), *ICRAM* Central Institute for Scientific and Technological Research Applied to the Sea (Italy), *CNR-ISMAR* Italian National Research Council—Institute of Marine Sciences (Italy), *ISPRA* Italian National Institute for Environmental Protection and Research (Italy), *OGS* National Institute of Oceanography and Experimental Geophysics (Italy), *FRIS* Fisheries Research Institute of Slovenia (Slovenia)

Almost all fisher were professional skippers and crew of the fishing fleet, with the only exception represented by a worker of an important wholesale fish market of the area, a recreational fisher and the head of an aquarium (and also a recreational fisher). The interviews included a series of open or fixed questions, some of them using multiple-choice and with quantitative or qualitative (yes–no) answers. Faunistic guides and pictures were used to confirm the identification of the species investigated.

The following questions were posed: (1) Have you ever caught at least a specimen of *S. squatina*? (2) Does the species have a commercial value? (3–4) When (year/decade) and where did you catch it the first time in your career? (5) How large (length or weight) was it? (6–7) When (year/decade) and where did you catch it the last time in your career? (8) How large (length or weight) was it? (9) Can you define species abundance (very rare, rare, common, very common) at the beginning of your career? (10) Can you define species abundance (very rare, rare, common, very common) now? (11) In your opinion the species abundance has: decreased, increased, remained constant, disappeared.

Statistical analysis

We used non-parametric tests due to the asymmetrical distribution of the data. The non-parametric Mann–Whitney U test was used to compare the age of fishermen that have caught the species at least once during their career and the age of fishermen that have never caught it. The non-parametric Spearman rank's correlation was used to detect correlation between quantitative data, such as landings and year and the weight of fish and the year when it was caught. When fishermen referred fish size in terms of total length (L), the value was converted to biomass (W) using a length–weight relationship ($W = 0.03460 * L ^\wedge 2.708$) for *S. squatina* published in FishBase.

Results

Naturalists' accounts

In 28 out of 33 naturalists' books analysed, information on *S. squatina* was reported specifically referred to the Northern Adriatic Sea (Online Resources Table A2). In 13 books species' abundance was also described, and all of them classified the species as common/frequent in the area. Species' maximum total length was described in the range 150–200 cm, while its weight ranged between 13 and 80 kg. Some naturalists also described species' commercial interest, specifying that its skin was particularly appreciated for polishing and as shagreen leather, while its flesh was not much appraised, thus obtaining low–medium price as compared to highly valuable species such as European seabass (*Dicentrarchus labrax*) (Online Resources Table A4).

Historical fisheries and fish markets data

Historical accounts report that fishermen from Rovinj were used to undertake fishing trips with "squaenere" up to Unije island (48 miles away from their harbour) to catch angelsharks, other cartilaginous fish and spider crabs (Basioli, 1957a). In 1860, in this harbour there were 475 m of net per fisherman. At the end of the nineteenth century, along the Adriatic coast of the Austro-Hungarian empire, the fishing gear targeting *S. squatina* was mostly used in Trieste ($n = 7{,}025$, representing the 64% of the "squaenere" used in the area) and Rovinj ($n = 3{,}790$, representing the 34% of the "squaenere" used in the area) fishing districts, where highest catches were also recorded (21% Trieste and 51% Rovinj of total angelshark catches). It is worth noting that in the same period along the Austrian littoral (Hungarian-Croatian Littoral excluded) the "squaenera" was the second most widespread fishing set net ($n = 11{,}016$), following the so-called "sardellera" ($n = 13{,}006$), used to fish European pilchard (*Sardina pilchardus*) (Faber, 1883). In 1911 the main fishing harbour for this kind of fishery was Rovinj (272 m of net per fisherman), while in 1956 the main harbour became Poreć (123 m of net per fisherman). Between 1911 and 1956 the number of "squaenere" was reduced to 20% of the original number (Basioli, 1957a, b, c; Basioli, 1958a, b). Coming to the Italian western side of the Northern Adriatic Sea, few historical data are available. In 1950 there were 80 "squaenere" out of 649 fishing gears registered at the Venice harbour, representing the third most widespread fishing gear in the area.

In 1905, at the Venice fish market 15,760 kg of *S. squatina* were sold. Data are also available for the years 1919–1924, where a mean of 57,540 (± 10,589) kg of the species were sold yearly. After World War II, data are available from 1957. Landings registered in the 1920s were never reached again, while starting from the 1960s a significant (Spearman-$r = -0.84$, $P < 0.05$) decline in landings occurred (Fig. 1). Official landings of common angelshark declined from more than 1,400 kg, to less than 20 kg from the 1950s to the 1980s. Between 1986 and 2002 no angelshark was sold, while the last record dates back to 2005, when a single specimen of 3.5 kg was sold.

As regards the Trieste fish market, data are available for the period 1904–1968 (with some gaps), since fish market records for the period 1969–1985 were destroyed and after 1986 species landings were recorded in the market category "skates and rays". This does not necessarily mean that they were not caught, but that the amount landed yearly may have decreased to the point where records may have been grouped with those of other species (Başusta et al., 2006). Quantities of *S. squatina* sold at Trieste market peaked in the late 1920s (7,240 kg landed in 1929), with values higher than those sold in Venice between late 1950s and late 1960s. Results showed a significant decline (Spearman-$r = -0.35$, $P < 0.05$) with time of landings (Fig. 2).

Scientific survey data

3,685 trawl tows were considered, plus 4,347 trawl tows were self-sampled by fishers through electronic logbooks. As regards gill nets, 444 stations were considered in the present work (Table 1; Online Resources Fig. A1). In none of the above-mentioned surveys *S. squatina* was caught.

Fishers' interviews

Most fishers interviewed were between 50 and 60 years old (Fig. 3A), and the mean fishing experience of all fishers was 36 years (min = 6; max = 61). Fishers usually use more than one fishing gear, changing it according to season and target species dynamics, and thus were classified as polyvalents (Fig. 3B). However, almost all fishermen classified as polyvalents who also use fishing gears were able to catch *S. squatina,* i.e. bottom trawls and gill nets. The second most represented segment was bottom trawlers. Interviewees' fishing grounds cover approximately the whole area of study.

50% of interviewed fishers never caught or even did not know the species. Among fishers that have at least caught it once, 69% affirmed that the species has disappeared from the Northern Adriatic Sea. Among the remaining fishers, one affirmed that it has declined while the others did not have an opinion about this issue.

However, it is worth noting that one specimen of 50 cm of total length, and another one of 60–70 cm of total length were caught in 2013 (most recent sightings). In addition to the individual sold at the Venice fish market in 2005 (see previous paragraph), a fisher reported that two specimens caught in the Northern Adriatic Sea were sold in 2013 at the Fano fish market (Fig. 4).

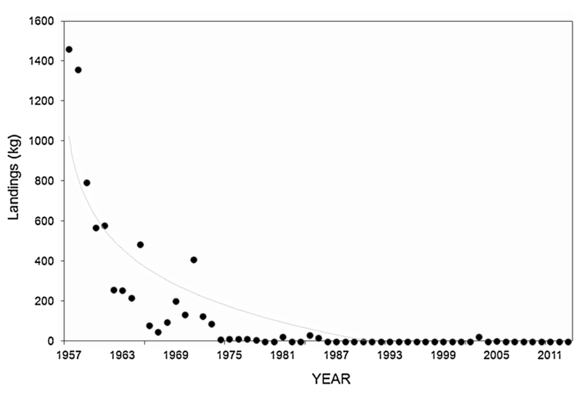

Fig. 1 Official commercial landings for *Squatina squatina* at the Venice fish market in the period 1957–2014 (with a *logarithmic regression line* shown). Spearman-$r = -0.84$; $P < 0.05$

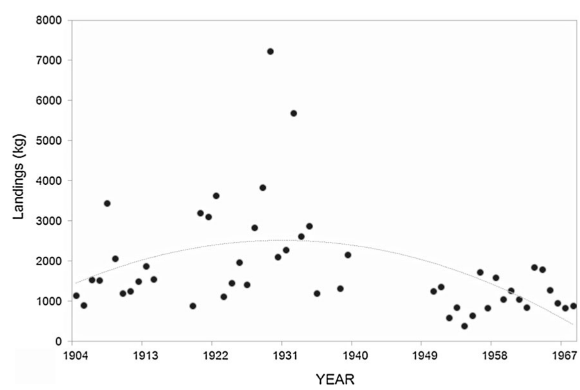

Fig. 2 Official commercial landings for *Squatina squatina* at the Trieste fish market in the period 1904–1968 (with a *second-order regression line* shown). Spearman-$r = -0.35$; $P < 0.05$

Fishers that have caught the species at least once were significantly ($U = 199$; $Z = 2.54$; $P = 0.01$) older than the ones that have never seen it (Fig. 5). The size of *S. squatina* individuals caught significantly declined (Spearman-$r = -0.52$; $P < 0.05$) with time (Fig. 6).

Discussion

Identifying baselines for poorly assessed or non-target fishery species is usually difficult and implies an approach integrating multiple data sources (Lotze & Worm, 2009; Lotze & McClenachan, 2014). This is the case of *S. squatina* in the Northern Adriatic Sea.

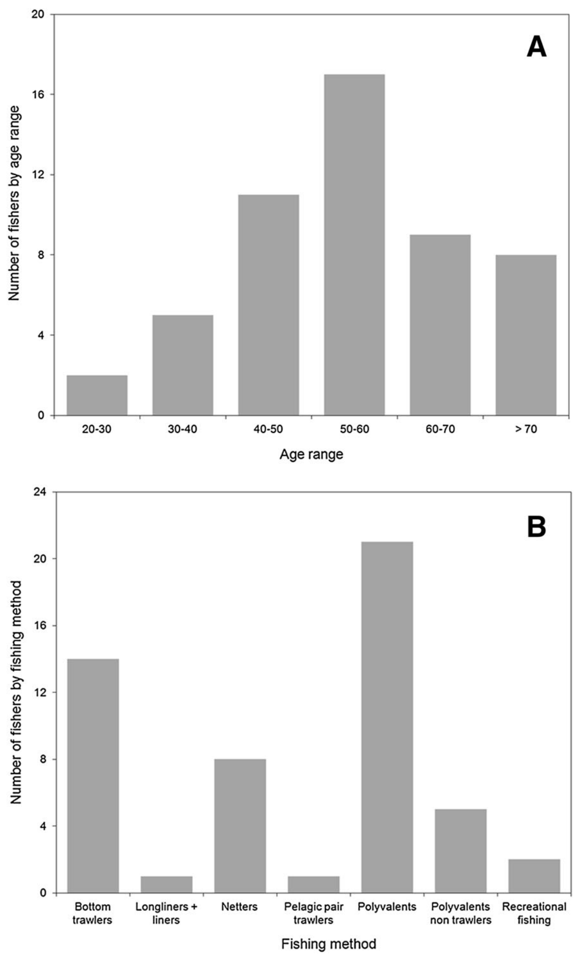

Fig. 3 Number of fishers interviewed by age range and fishing method. Number of **A** fishers interviewed by age range ($n = 52$), and **B** by fishing methods used by fishers

According to Dulvy et al. (2003) the species was extirpated from the area, while Monte-Luna et al. (2007) called its local extinction into question.

Eyewitness accounts, written by naturalists, provided us with valuable insights on the pre-industrialization status of *S. squatina* in the Northern Adriatic Sea. The species was common at least until mid-twentieth century, and large-sized individuals were widespread throughout the area (historical baselines). It is worth noting that the size range reported by naturalists for the Northern Adriatic Sea (150–200 cm) exceeds the maximum size of 130 cm reported in the literature to this day (Morey et al., 2006).

At the beginning of the twentieth century, high quantities of *S. squatina* were landed in Venice and Trieste, confirming that the species was abundant. Before and immediately after World War II, Trieste and Venice represented the most important wholesale fish markets of the Northern Adriatic area, where most of the fish caught in the surrounding fishing grounds were sold (Fortibuoni, 2010). Indeed, the fish caught relatively close to the fishing port of Venice were landed there due to the lack of technology to preserve fresh fish and the relatively low speed of the fishing vessels that, at that time, were mainly sailing boats (Botter et al., 2006; Lotze et al., 2011). All this holds true also for the landings of the Trieste fish market (Krisch, 1907), and thus landings data represent the catches in the surrounding areas (Istria county included). It is worth mentioning that in a few cases the taxonomic resolution of fish market data collected in the present study was not at species' level, mixing the two species *S. squatina* and *S. oculata*. However, naturalists' accounts support the inference that the large majority of the catches ascribed to the genus *Squatina* were constituted by *S. squatina*.

After the 1960s landings of the species dramatically declined, even if fishing effort and capacity (and thus the catching power) increased (Fortibuoni, 2010; Lotze et al., 2011), the species got economically extinct. Similar large declines were observed also in other areas (Morey et al., 2006). For instance, Vacchi et al. (2002) reported the dramatic decline of common angelshark in the Northern Tyrrhenian Sea between 1898 and 1922. For commercially exploited species with a mid-low commercial value, such as *S. squatina*, economic extinction usually occurs before biological extinction (Dulvy et al., 2003).

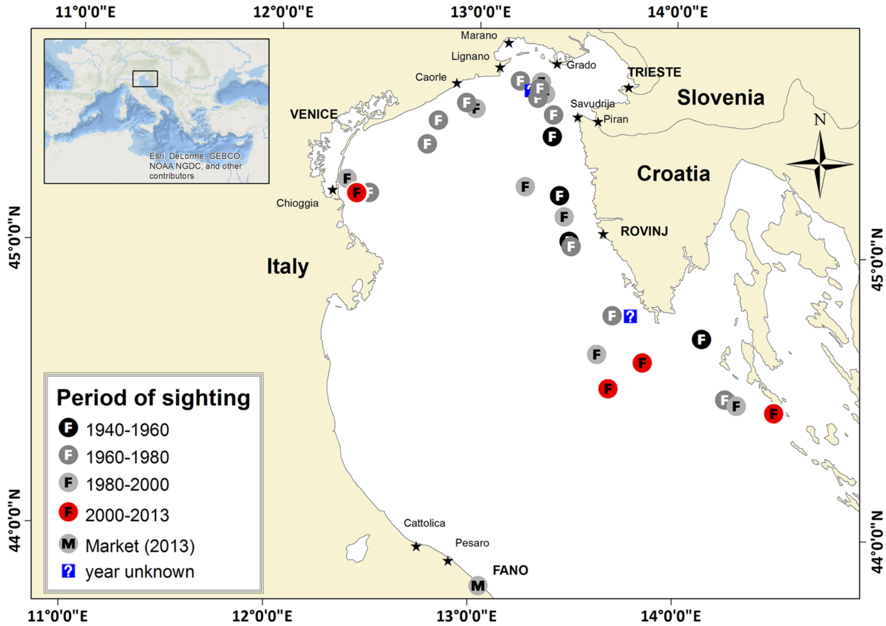

Fig. 4 Map of *Squatina squatina* sightings referred by fishers. *F* sighting at sea; *M* sighting at the fish market. *Black stars* indicate the harbours where the interviews were performed

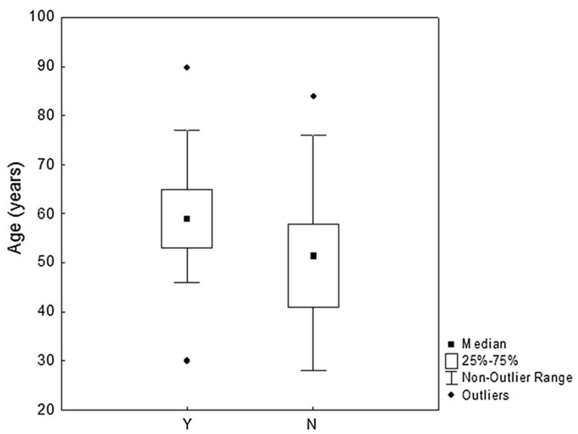

Fig. 5 Comparison between the age of fishers who caught *Squatina squatina* at least once during their career (Y) and those that have never seen it (N) in the Northern Adriatic Sea

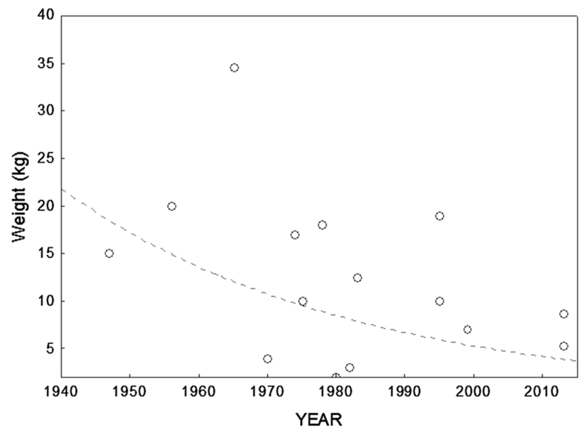

Fig. 6 Weight (kg) of the individuals of *Squatina squatina* caught by fishermen versus year in which they were caught (with an *exponential regression line* shown). Spearman-$r = -0.52$; $P < 0.05$

Although data from scientific surveys in the Northern Adriatic Sea have been available since 1948 (HVAR expedition), the low sampling intensity in this first campaign (Online Resources Fig. A1a) impedes a proper use of this information to determine the status of rare species with any accuracy (Dulvy et al., 2003). However, since 1982 the Northern Adriatic Sea was extensively sampled, with sampling intensity increasing with time (Table 1; Online Resources Fig. A1). No individuals of *S. squatina* were caught during the above-mentioned surveys, suggesting that the species is likely extirpated from the Northern Adriatic Sea at least since the 1980s. Also Maynou et al. (2011) indicated the early 1980s as the time period in which angelsharks disappeared on the western Italian Adriatic coasts, and Ferretti et al. (2013) hypothesized its extirpation from the Adriatic Sea since the species is not caught in scientific trawl surveys since 1958.

Table 2 Evaluation of the qualitative evidence for and against local extinction of *Squatina squatina* using the framework of Butchart et al. (2006)

Observational data	
Types of evidence for extinction	
For species with recent last records, the decline has been well documented	Yes. A dramatic decline in landings has been observed at least since the '60s, when the species got economically extinct
Severe threatening processes are known to have occurred	Yes. Since the early twentieth century intense commercial fishing targeting the species has seriously reduced its population, and nowadays fishing impact is mostly due to by-catch
The species possesses attributes known to predispose taxa to extinction	Yes. Angelshark is particularly vulnerable to overexploitation being characterized by life-history attributes like slow growth, late attainment of sexual maturity, long life spans and low fecundity
Recent surveys have been apparently adequate given the species' ease of detection, but have failed to detect the species	Yes. Since the '80 s scientific sampling effort in the Adriatic is high and increased through years, but no specimen of angelshark was caught
Types of evidence against extinction	
Recent field work has been inadequate	No. A series of expeditions whose primary objective was to study the demersal fish fauna were carried out during the last decades
The species is difficult to detect	No. The angelshark occurs on sand or muddy bottoms from close inshore areas to the outer shelf, from 5 m to at least 150 m depth. The species may also penetrate estuaries and brackish water
There have been reasonably convincing recent local reports or unconfirmed sightings	Yes. The specie was caught in the area by two fishers in 2013, one specimen of 50 cm of total length, and another one of 60–70 cm of total length. Moreover, an individual of *S. squatina* fished in the Northern Adriatic Sea was sold at the Venice fish market in 2005, while from an interview emerged that two specimens of the species caught in the Northern Adriatic Sea were sold in 2013 at the Fano fish market
Suitable habitat remains within the species' known range, and/or all species or congeners may survive despite similar threatening processes	Appropriate habitat remains for *S. squatina* but it is unlikely that individuals remain undetectable due to the small shallow water area of the Northern Adriatic Sea, which allowed it to be thoroughly surveyed during recent expeditions. In the area once lived also the congener *S. oculata* (smoothback angelshark), but the species was rarer than the common angelshark even in historical times

Considering fishers' ecological knowledge, only a half of interviewed fishers caught the species at least once, indicating that the species occurs in very low numbers since decades. Interestingly, they were significantly older than the ones that have never caught it. This generational amnesia recalls to the shifting baseline syndrome (Pauly, 1995), since younger fishers even do not know *S. squatina* or consider it "naturally" absent in the Northern Adriatic Sea, while the species was once common in the area. The same outcome was observed in the Catalan Sea, where only 14% of 106 fishers interviewed were able to recognize angelsharks, which suggests that they were practically extirpated before fishers started fishing (Maynou et al., 2011). Studies that compared the results obtained from scientific research with evidence based on fishers' knowledge reported that the last source is reliable for understanding fisheries resources dynamics (Neis et al., 1999; Rochet et al., 2008; Silvano & Valbo-Jørgensen, 2008).

Moreover, the size of *S. squatina* individuals reported by fishers significantly declined with time, indicating a gradual depletion of larger individuals that may have further hampered species resilience. *S. squatina* reaches maturity at a large size and late age, giving birth to a relatively small number of large pups after a long gestation and has a low intrinsic rate of population increase. The species is therefore slow to recover from depletion, while its large size and its morphology also makes it highly vulnerable to several fishing gears from birth (Fowler, 2010).

However, in contrast with what reported by Dulvy et al. (2003), according to fishers' ecological knowledge *S. squatina* is not extirpated from the Northern Adriatic Sea (Table 2), even if the population is highly fragmented and actual records are extremely infrequent (present baseline).

Although Monte-Luna et al. (2007) have questioned the extirpation of *S. squatina* in the Northern Adriatic Sea, no evidence was given on species' occurrence in recent years. The rare, but still registered, presence of *S. squatina* in our study recalls to revise the extirpation judgement of the species in the area and to adopt conservation actions useful to protect the individuals present. Indeed, premature declarations of extinction could reduce the confidence of the threatened species list (Monte-Luna et al., 2007) and undermine the public image of conservation science and management policies (Luiz Osmar & Edwards, 2011).

Conclusions

Though the reconstruction of the historical baselines, obtained integrating different sources of information, clearly showed the collapse of *S. squatina* in the Northern Adriatic Sea in the early 1970s, the species is still present in the area. The same applies to the south-eastern side of the Adriatic Sea (Soldo, 2013), confirming the unfavourable conservation status of this species in the whole Adriatic Sea, being mainly threatened by bottom trawling.

The common angelshark was not the object of specific management plan or conservation measure neither in the Mediterranean nor in the Adriatic Sea for many years. In 2009 the European Commission (Council Regulation (EC) 43/2009, Annex III Part B) published a not-binding statement that reported "Angel-shark in all EC waters may not be retained on board". At the same time, the Barcelona Convention listed the common angelshark in the Annex III and later on in the Annex II of the list of Endangered and threatened species, but without introducing any binding protection regime for the species. Indeed, in 2012 the species was still in the list of marketable species in Italy (Dell'Apa et al., 2012).

Only recently, the EU introduced the Council Reg. 43/2014, which under Article 12 prohibits to fish for, to retain on board, to tranship or to land, the common angelshark. The Regulation also imposes accidentally caught specimens to not be harmed and to be promptly released. Since the species has a relatively good survival to discarding, the mandatory return of by-catch would yield conservation benefits for the population. The adoption of best practice for handing discard could further contribute to increase survival of species, and standardized internationally accepted guidelines should be developed and enforced. The direct involvement of fishermen for the implementation of Article 12 of Council Reg. 43/2014 and species conservation would be fundamental.

However, since the current protection rules are valid only for EU waters (thus excluding non-EU partners, e.g., Montenegro and Albania), effective conservation measures should be adopted by all countries that are part of the General Commission for the Mediterranean. Otherwise, large portions of the Mediterranean will be left with no protection for the species.

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