# Assessing neoextirpations in the Adriatic Sea: an historical ecology approach

**Saša Raicevich and Tomaso Fortibuoni**

*ISPRA – Istituto Superiore per la Protezione e Ricerca Ambientale, Chioggia, Italy*

## 1. Background

### 1.1 The unknown of our present is our past

Historical ecology is a discipline that explicitly acknowledges the need of incorporating time as a fundamental variable into ecological analysis. Indeed "ecology IS an historical discipline" but, quite often, ecologists focus on current bio-ecological systems, with the dangerous assumption that they represent and behave as pristine systems.
What an historical ecologist does is try to reconstruct historical baselines and to investigate changes in ecological patterns and processes over time, aiming at identifying the role played by different driving forces. This applies in particular to those studying biodiversity and its changes over historical times to better understand present ecosystems.

To this end, historical ecologists rely on a range of disciplines that are inherently scientific (in the sense of the so-called "hard science"), including paleoecology, zooarcheology, genetics, etc. To reconstruct baselines and trends in driving forces, it is usually necessary to consider other sources of information (Lotze and Worm, 2009) and establish a dialogue with scholars belonging to disciplines that have different epistemological backgrounds like archaeology, history, and anthropology.

Historical ecology in marine ecosystems rapidly developed in the last two decades, due to the recognition that the understanding of the present status of marine species and ecosystem functioning could be biased by the lack of information on their historical status. As Pauly (1995) highlighted new generations of scientists might have a different perception of marine biodiversity compared to older generations, who had the opportunity to investigate the sea few decades earlier. By posing the issue of the so-called "shifting the baseline syndrome", Pauly clearly showed that it is necessary to define past baselines to understand the present status of biodiversity and the role of different processes that affected it. Another major input of historical ecology in the marine domain the global overview by Jackson *et al.* (2001) on the historical role of driving forces that affected the marine environment, demonstrating that fishery historically preceded all other sources of ecological disturbance.

The historical ecology approach was incorporated into global research actions like the Census of Marine Life that, inter alia investigated biodiversity historical changes in the framework of the History of Marine Animal Populations project (www.hmapcoml.org). This project fostered the collaboration between humanities and science scholars, that put their attention to the recovery of historical records to describe changes in biodiversity and the driving forces that affected it, in particular fisheries. Although some researchers raised concerns on the balance between scientific and historical disciplines in the HMAP project, this initiative had the merit to show the need to reconstruct the impact of humans under the lens of marine environmental history (Bolster, 2003).

### 1.2 (Neo)extinctions *vs.* (neo)extirpations

Historical ecology can facilitate the understanding of current biodiversity, in particular by tracing historical changes in marine fauna. While the long history of life on our planet has been characterised by five major global processes of extinction commonly named "Mass Extinctions"[1], scientists and the general public are now concerned that the speed of disappearance of species has sharply increased during the current "Anthropocene", with prospects of a "6th Mass Extinction". The current biodiversity crisis is induced by anthropogenic driving forces (Carlton, this volume) but the consequences of this human-induced loss of species are not fully understood.

Thus there is an urgent need of quantifying this process, identifying those species which are at risk of extinction and the role played by humans, in order to prevent or at least alleviate any further negative impact of our species on nature.

There are obviously some practical difficulties in assessing the extinction of a species, particularly in the sea (Roberts and Hawkins, 1999; Purvis *et al.*, 2000; Dulvy *et al.*, 2004). Furthermore, notwithstanding the long history of exploitation of marine biological resources, there are really few known extinctions of marine fishes on a global scale (see Carlton, this volume). Conversely 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. Extirpation represents an early warning of species' vulnerability as it is a step towards global scale extinction (Pitcher, 2001).

For consistency with the terminology proposed by Carlton (this volume), we will use the term "neoextirpation" to refer to local or regional disappearance of species in historical time (since 1500). A growing number of marine species have been reported to have declined or even disappeared from discrete areas of their overall historical geographic range (Dulvy *et al.*, 2003) in almost all the seas, including the Mediterranean. The main cause has been identified as fishery exploitation (55%), followed by habitat loss or degradation (37%), introduction of invasive species (2%) and other factors such as climate change, pollution and disease (6% in total). Fishing and habitat loss in particular have caused severe declines at regional and local scales in several Mediterranean Sea taxa (Coll *et al.*, 2010). It is worth noting that neoextirpation is not a peculiarity of mechanized/industrial fishery, since it has been reported even in subsistence and artisanal fisheries (Pinnegar and Engelhard, 2007). Moreover overfishing came much earlier in the historical sequence of events (Bradbury, 2001).

### 1.3 Extinction risk in the Mediterranean Sea fauna

The Red List of the International Union for Conservation of Nature (IUCN) is a global initiative that aims to assess the conservation status of species/populations worldwide. The selection of species to be included in the assessment is made by regional experts that routinely review the status of species according to different quantitative criteria (IUCN, 2001) that include: reduction in population size, geographic range, absolute population size estimates; probability of extinction.

According to the application of different quantitative thresholds, species are ascribed to different levels of extinction risk, from higher to lower. In particular, "Critically Endangered", "Endangered" and "Vulnerable" species are categories referred to threatened species, while "Near Threatened" and "Least Concern" are used for those species whose extinction risk is limited or negligible. Most often, species may fall into the "Data Deficient" category, since quantitative data may not be available for assessing their status according the Red List criteria.

The analysis of the latest assessments available for Mediterranean Sea species carried out by exploring the IUCN database shows that a total number of 268 Mediterranean species (Kingdom:

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[1] 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. For instance, the 5th mass extinction, which was probably caused by a giant meteor collision, occurred 65 million years ago, at the end of the Cretaceous period, and ended the reptilian dominance of the Earth leading to the current mammalian domination.

Animalia) have been assessed so far, with an increase in the evaluation effort in the last 4 years (Fig. 1). The main taxa considered include fish and elasmobranchs, reptiles, mammals, cephalopods, crustaceans, cnidarians and gastropods. The large majority of species falls in the "Data Deficient" and "Least Concern" categories; however, 50 species are considered to be "Threatened", 14 are "Critically Endangered", 12 are "Endangered" and 22 are "Vulnerable" to extinction.

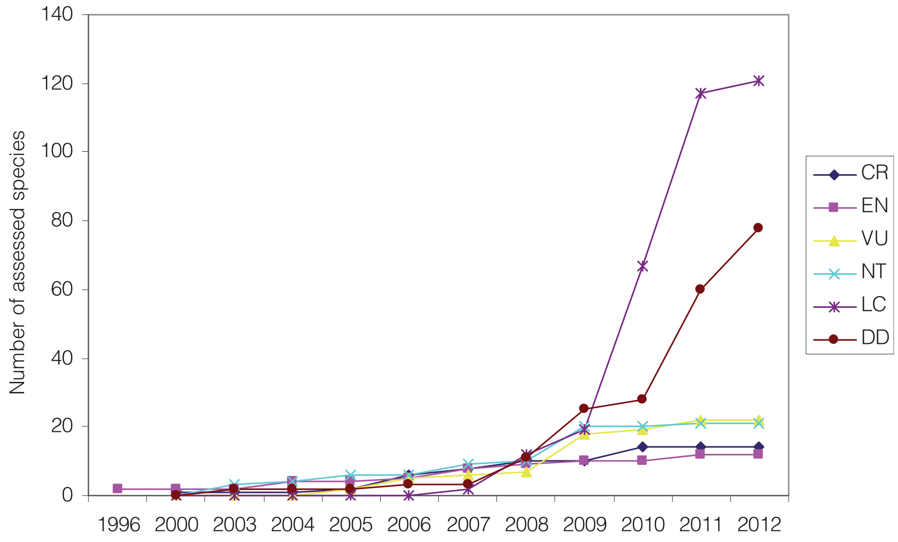


Fig. 1. Cumulative number of Mediterranean marine species (Animalia) assessed in the IUCN Red List since 1996. CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient (Source: http://www.iucnredlist.org/; October 2012).

These data show that, overall, elasmobranchs comprise the highest number of "Threatened" species (29), followed by bony fish (12), reptiles (4) and mammals (3) (Fig. 2). The same pattern applies to the number of "Critically Endangered" species, where 7 species of cartilaginous fishes, 4 bony fish, 2 reptiles and 1 marine mammal make the highest category risk.

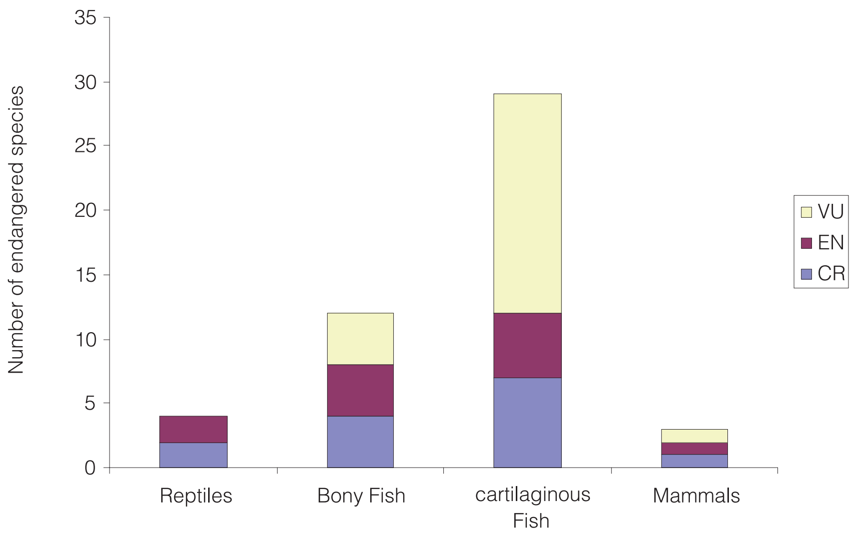


Fig. 2. Cumulative number of threatened Mediterranean marine species referred to different taxa currently assessed in the IUCN Red List (2012). CR = Critically Endangered; EN = Endangered; VU = Vulnerable (Source: http://www.iucnredlist.org/; October 2012).

It is worth noting that the IUCN assessment of the extinction risk of species does not evaluate most Mediterranean species due to a lack of quantitative data (i.e., "Data Deficient" category). The retrieval and analysis of historical data, might contribute to increase the number of assessed species, ascertain their historical range of distribution and, possibly, abundance and biomass.

## 2. Assessing cartilaginous fishes neoextirpation in the Adriatic Sea: an historical ecology approach

This paper focuses on the neoextirpation of elasmobranchs, since they show a high vulnerability to fishery exploitations (Stevens *et al.*, 2000) and are generally considered to be under threat in the Adriatic Sea (see Soldo, this volume).

In a recent study (Fortibuoni *et al.*, 2010) we assessed historical changes in the fish community of the Northern Adriatic Sea considering a long-term timescale, namely the last two centuries. Our aim was to describe long-term changes in fish community by reconstructing time series integrating landing statistics and naturalists' observations by means of an intercalibration process. The study showed relevant changes in fish community structure, with a relative decrease in cartilaginous fishes, as well as a reduction in large-sized, late-maturing and long living species.

On the basis of the dataset acquired in this way we will now infer information on the local neoextinction (i.e., neoextirpation) of species, that deserve a different computational and research approach (i.e., singles species vs. community-based). Our starting point will be, thus, the historical reconstruction of a baseline for elasmobranch occurrence in the Adriatic Sea by using naturalists' accounts.

### 2.1 Linneus' legacy: Adriatic Sea naturalists' accounts

The introduction of the binomial classification of species, according to a hierarchical approach introduced by Linneus in his *Systema Naturae* (1735), stimulated European naturalists and zoologists to engage in a sort of "race" to describe and name all species. This process was fairly developed even in the Adriatic Sea, where many naturalists visited the region in order to describe marine and coastal species. Among others, we recall Vitaliano Donati, with his "Della storia naturale marina dell'Adriatico (1750)" (On the natural history of the Adriatic Sea), or Alberto Forti, who carried out surveys in the Northern Adriatic Sea in the 1770-1773 and studied the migration of sardines and bluefin tuna. The famous Lazzaro Spallanzani also conducted surveys in the Adriatic, were he studied the production of electricity of the torpedo, as well as the fauna of the lagoon of Chioggia. Other important naturalists who studied the Adriatic Sea fauna include Stefano Chiereghin (1745-1820), Giuseppe Olivi (1764-1795), Stefano Andrea Renier (1759-1830), Fortunato Luigi Naccari (1793-1860), Giovanni Domenico Nardo (1802-1877) and Alessandro Pericle Ninni (1837-1892).

The work conducted by these naturalists represents, to our view, the most valuable legacy of Linneus in the Adriatic Sea, since they provided the earlier available systematic description of species that can be used to set a baseline of marine biodiversity in the area, more than two centuries ago. Moreover, their work was not limited to the description of species according to their morphology (that allows to check the consistency of the species' identification according to modern classification), as they provided additional, (and fundamental) information on species' perceived abundance, seasonality, size, spawning period, behaviour, as well as information on their economic use, especially if they had a commercial value and whether or not they were targeted by fishery and which fishing gears were used to this purpose. Naturalists' knowledge of fish fauna was mainly based on direct observations at fish markets and ports, on interviews of fishermen, on literature and on the analysis of Natural Museums' Collections. For instance, the abbot Stefano Chiereghin's family owned a group of 10 fishing boats in the port of Chioggia, which allowed him to describe the fauna and flora of the Adriatic Sea in the early 19th century in his masterpiece "Descrizione de' Pesci, de' Crostacei e de' Testacei che abitano le lagune ed il Golfo Veneto"[2].

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[2] Interestingly, only one original copy of his study was printed at the time and it is preserved in the "Biblioteca Marciana" in Venice. The large number of volumes, including many hand drawings from Chiereghin, prevented the printing of the book which was too expensive. A reprint of the book is now available thanks to the effort of Cinzio Gibin, and is printed by Editrice Canova.

To the purpose of establishing a historical baseline of elasmobranch species in the Adriatic Sea, we collected and surveyed historical documents from the major archives, libraries and natural museums of the Adriatic area (Venice, Padua, Trieste, Chioggia, Split). We collected 36 naturalists' descriptions of the Adriatic Sea fauna over the period 1818-1956. Species whose identification was unclear, or that were quoted by less than five authors, were excluded from the analysis.

Naturalists' accounts allowed to reconstruct the historical perceived abundance of fish species according to a semi-quantitative scale, including four classes (very rare, rare, common to very common)[3], over a period of approximately one century and a half (1818-1956; for more details, see Fortibuoni *et al.*, 2010). Forty three species of cartilaginous fishes were described, 17 were considered common (10 rays and skates and seven sharks), showing that a rich assemblage of cartilaginous fishes was present in the nineteenth century in the Adriatic Sea (Table 1). We defined as our "historical baseline" the most common class (modal score) of perceived abundance observed in the period 1818-1956, and compared it with the current status and trend of species in the Mediterranean as defined by IUCN (Table 1). It is evident that many species that were formerly considered as common in the Adriatic Sea are now considered under threat in the Mediterranean. For instance, the blue skate (*Dipturus batis*) and the bottlenosed skate (*Rostroraja alba*), once common in the Adriatic, are now assessed as "Critically Endangered" and they show a decreasing trend. The same applies to angelsharks (*Squatina* spp.). We remark that for eight species the IUCN risk status is not defined due to the lack of quantitative data ("Data Deficient" category).

[3] It is worth noting that this semi-quantitative scale does not represent absolute abundance values, but a hierarchy of abundance that follows a logarithmic scale (see Fortibuoni *et al.*, 2010). Thus, the shift from common to rare category, for instance, implies a logarithmic reduction in perceived abundance.

Table 1. Comparison of the historical baseline (1818-1956) of elasmobranch presence in the Adriatic Sea, defined on the basis of naturalists' descriptions, and their current status and trend in the Mediterranean Sea, as assessed by IUCN. CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient (Source: http://www.iucnredlist.org/; October 2012).

| Group | Scientific name | Common name | ADRIATIC SEA HISTORICAL BASELINE | MEDITERRANEAN CURRENT STATUS (IUCN) | TREND (IUCN) |
|---|---|---|---|---|---|
| Rajiformes | *Dasyatis pastinaca* | Common stingray | Common | DD | unknown |
| | *Myliobatis aquila* | Common eagle ray | Common | DD | unknown |
| | *Pteromylaeus bovinus* | Bull ray | Common | DD | unknown |
| | *Dipturus oxyrinchus* | Longnosed skate | Common | NT | unknown |
| | *Dipturus batis* | Blue skate | Common | CR | decreasing |
| | *Raja asterias* | Starry ray | Common | LC | Stable |
| | *Raja clavata* | Thornback ray | Common | NT | decreasing |
| | *Raja miraletus* | Brown ray | Common | LC | Stable |
| | *Rostroraja alba* | Bottlenosed skate | Common | EN | decreasing |
| | *Torpedo marmorata* | Spotted torpedo | Common | DD | unknown |
| | *Dasyatis centroura* | Roughtail stingray | Rare | LC | unknown |
| | *Leucoraja fullonica* | Shagreen ray | Rare | NT | decreasing |
| | *Torpedo nobiliana* | Atlantic torpedo | Rare | DD | unknown |
| | *Torpedo torpedo* | Common torpedo | Rare | DD | Stable |
| | *Gymnura altavela* | Spiny butterfly ray | Very Rare | VU | decreasing |
| | *Rhinoptera marginata* | Lusitanian cownose ray | Very Rare | NT | unknown |
| | *Mobula mobular* | Devil fish | Very Rare | EN | decreasing |
| | *Raja radula* | Rough ray | Very Rare | DD | unknown |
| Squaliformes | *Scyliorhinus canicula* | Small-spotted catshark | Common | LC | Stable |
| | *Scyliorhinus stellaris* | Nursehound | Common | NT | Unknown |
| | *Squalus acanthias* | Piked dogfish | Common | VU | Decreasing |
| | *Squatina oculata* | Smoothback angelshark | Common | CR | Decreasing |
| | *Squatina squatina* | Angelshark | Common | CR | Decreasing |
| | *Galeorhinus galeus* | Tope shark | Common | VU | Decreasing |
| | *Mustelus asterias* | Starry smooth-hound | Common | LC | Unknown |
| | *Mustelus mustelus* | Smooth-hound | Common | VU | Decreasing |
| | *Alopias vulpinus* | Thintail thresher | Rare | VU | Decreasing |
| | *Prionace glauca* | Blue shark | Rare | NT | Unknown |
| | *Carcharhinus plumbeus* | Sandbar shark | Rare | VU | Decreasing |
| | *Oxynotus centrina* | Angular roughshark | Rare | VU | Unknown |
| | *Heptranchias perlo* | Sharpnose sevengill shark | Rare | NT | Unknown |
| | *Hexanchus griseus* | Bluntnose sixgill shark | Rare | NT | Unknown |
| | *Carcharodon carcharias* | Great white shark | Rare | VU | Unknown |
| | *Isurus oxyrinchus* | Shortfin mako | Rare | VU | Decreasing |
| | *Sphyrna zygaena* | Smooth hammerhead | Rare | VU | decreasing |
| | *Squalus blainville* | Longnose spurdog | Rare | DD | unknown |
| | *Cetorhinus maximus* | Basking shark | Very Rare | VU | decreasing |
| | *Etmopterus spinax* | Velvet belly lantern shark | Very Rare | LC | unknown |
| | *Echinorhinus brucus* | Bramble shark | Very Rare | DD | unknown |
| | *Lamna nasus* | Porbeagle | Very Rare | VU | Decreasing |
| | *Carcharias taurus* | Sand tiger shark | Very Rare | VU | Unknown |
| | *Galeus melastomus* | Blackmouth catshark | Very Rare | LC | Stable |
| | *Sphyrna tudes* | Smalleye hammerhead | Very Rare | VU | Decreasing |

**2.2 Historical accounts of commercial fishing activities**

Using naturalists' accounts may provide very useful information on historical perceived abundance of species. However, further data are possibly needed to support such evidences. In particular, fisheries-related historical accounts will be useful to this end. The Adriatic Sea is rich in such information (Raicevich *et al.*, 2008; Fortibuoni *et al.*, 2009; Fortibuoni *et al.*, 2010), that can be traced and collected in publications and research journals that were published, in the area in the late 19th and early 20th century.

The description of historical fishing activities can provide important information on several issues including target species, fishing gear and boat technology, fishing seasons and fish markets. All such information can help establish historical presence of a species in a definite area, as well as the capability of fishermen to catch it (and indirectly, the possibility of naturalists to describe them), even allowing to know whether the species was imported from other areas and sold at the local market. The presence of fisheries targeting certain species may support the hypothesis that the species itself was relatively abundant in the area. Most often, unfortunately, detailed data on fishing grounds and target species are lacking.

An extensive search and analysis of historical documents allowed us to reconstruct the fishing activities in the Adriatic Sea and in particular the Chioggia fishing fleet (for details see Botter *et al.*, 2006; Fortibuoni *et al.*, 2009). This picture is rather relevant since the *Chioggiotti* were used to migrate across the whole Adriatic Sea to follow the migration pattern of main target species. Moreover, they were skilled fishermen adopting a range of fishing gears that allowed them to catch both demersal and pelagic species, including cartilaginous fishes (Botter *et al.*, 2006).

A relevant publication of Levi Morenos (1916) was devoted to economic issues related to the context of Austro-Hungarian empire waters in the early 20th century (at that time, from Trieste down to Dalmatia), claiming that the *Chioggiotti* had the right to continue fishing in such areas. In this document the author supports such a request based on a detailed description of the fishing fleets and their activities. It also included maps of the distribution of fishing grounds and reference to the main target species and the fish markets where catches were sold. Levi Morenos maps allow to identify an historical baseline refered to winter and spring, 1910 (Figs. 3 and 4, respectively) for nine elasmobranch species: *Raja clavata*, *R. miraletus*, *Dipturus oxyrhincus*, *Torpedo torpedo*, *Squatina squatina*, *Scyliorhinus canicula*, *S. stellaris*, *Squalus acanthias*, and *S. blainville*.

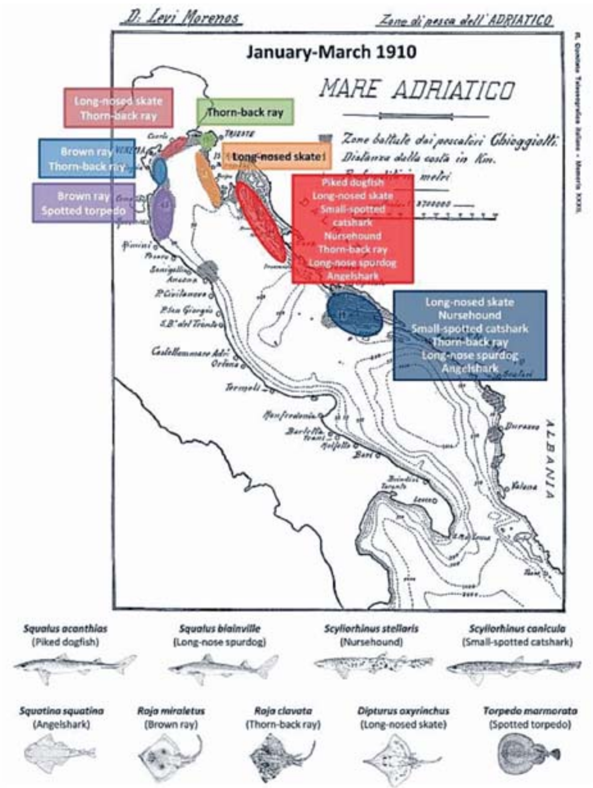


Fig.3. Historical distribution (January-March 1910) of cartilaginous fishes caught as main target species by Chioggia fishing fleet (from Levi Morenos, 1916).

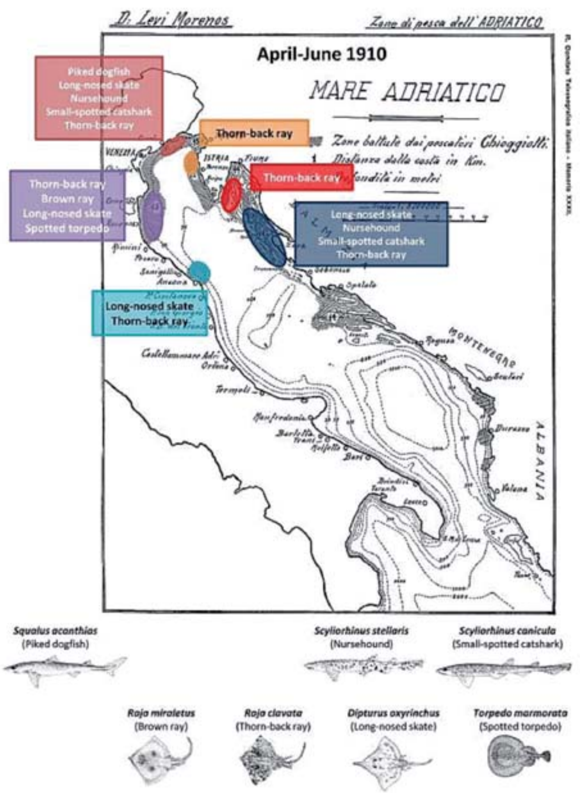


Fig. 4. Historical distribution (April-June 1910) of cartilaginous fishes caught as main target species by Chioggia fishing fleet (from Levi Morenos, 1916).

All these species were described as common in naturalists' accounts (Table 1) and were caught in nearshore areas from the Po river mouth northward and, southward, from Trieste to Dalmatia. Such information the "presence" of relatively high "amount" of a species in the considered fishing grounds, where the cartilaginous fishes were caught (among others) as main target species. On the opposite, we cannot assume that species were "absent" in the other fishing grounds where they were not reported as main target species.

The fish caught relatively close to the fishing ports of Chioggia and Venice was 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; Fortibuoni *et al.*, 2010). All this holds true as well for the landings in Trieste market, and thus the landings data should represent the catches in the surrounding area.

### 2.3 Historical and modern landings data

Quantitative historical data are usually scarce, and the only data available before the second half of the twentieth century in the Adriatic Sea are landing statistics. Before World War II, Trieste and Venice probably represented the most important wholesale fish-markets of the Adriatic area, where most of Adriatic fish caught in the surrounding fishing grounds were sold (Fortibuoni *et al.*, 2010). In 1945, the Chioggia fish market was also established, since the city hosted (and still hosts) the largest fishing fleet of the Adriatic region.

Thus, we scoured libraries and archives searching for landing statistics referred to the Trieste, Venice and Chioggia fish-markets. Being biased toward commercial species and not standardized in terms of fishing effort or fishing gear, landings have the intrinsic limitations of fishery-dependent data. However, quantities sold at fish-markets are correlated to biomass at sea, and thus landings may represent a useful proxy to reconstruct massive changes in fish abundance (Pauly *et al.*, 1998).

Our search allowed collecting landings for the period between 1900 and 2000 of some commercially important groups of cartilaginous fishes at the Trieste and Venice fish-markets (Fig. 5). Data from Chioggia were merged with Venice since after World War II the fishing fleet supplying the fish-market of Venice began to sell fish also in Chioggia (the market will be called Venice-Chioggia hereafter). Here we present data referred to *Raja* spp. (mainly *Raja clavata* and *R. miraletus*), *Scyliorhinus* spp. (*Scyliorhinus canicula* and *S. stellaris*), *Squatina* spp. (mainly *Squatina squatina*) and *Mustelus* spp. (mainly *Mustelus mustelus*). Data are aggregated at genus level since, in most of the cases, landing statistics provide information that are coarse in terms of taxonomic resolution.

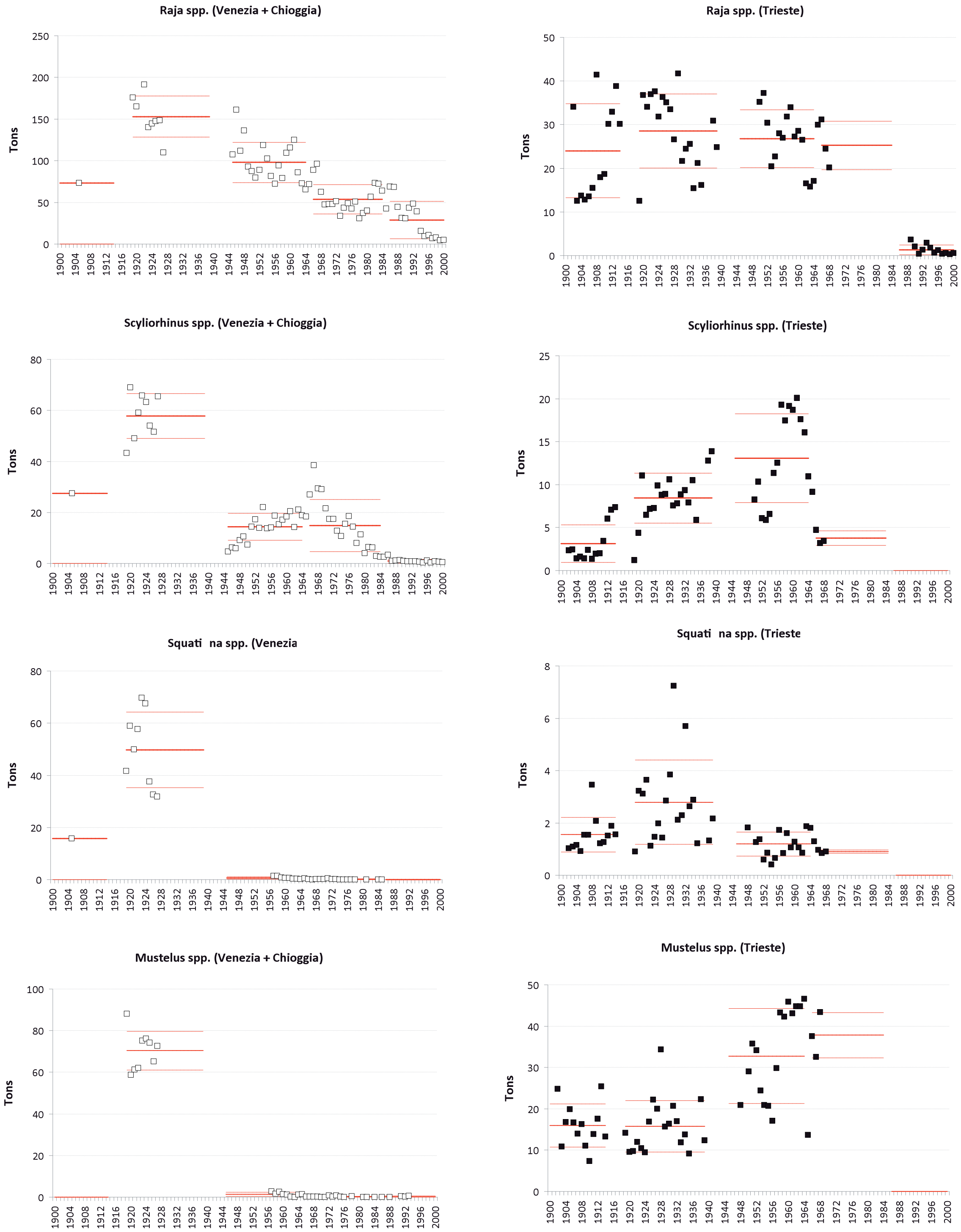


Fig. 5. Landing statistics (tonnes) of (from the top) *Raja* spp., *Scyliorhinus* spp., *Squatina* spp. and *Mustelus* spp. referred to the fish-markets of Venice-Chioggia (white-squares) and Trieste (black-squares) between 1900 and 2000. Mean (± st.dev.) have been estimated and over-imposed (red lines) for the following historical periods: 1900-1914; 1919-1939; 1945-1965; 1966-1985; 1986-2000.

Data show that at the beginning of the twentieth century high quantities of cartilaginous fishes were landed in Trieste and Venice-Chioggia; in most cases historical landings were higher than those recorded after the 1950s, even if fishing effort and capacity were significantly lower at that time (Fortibuoni *et al.*, 2009; Fig. 6). For instance, in the period 1919-1939 in Venice-Chioggia the yearly mean value of landings for rays (*Raja* spp.) was 153 (± 8) tons, while afterwards landed quantities severely declined (Fig. 5). A declining trend of rays in landings was also observed in recent years, both in Venice-Chioggia and in Trieste. The same can be said for angelsharks (*Squatina* spp.), where yearly mean landed quantities were about 50 (± 14) tons in the period 1919-1939, to be followed by a clear reduction in the landings and showing "commercial extinction" in the '60s in Trieste and in the '80s in Venice-Chioggia.

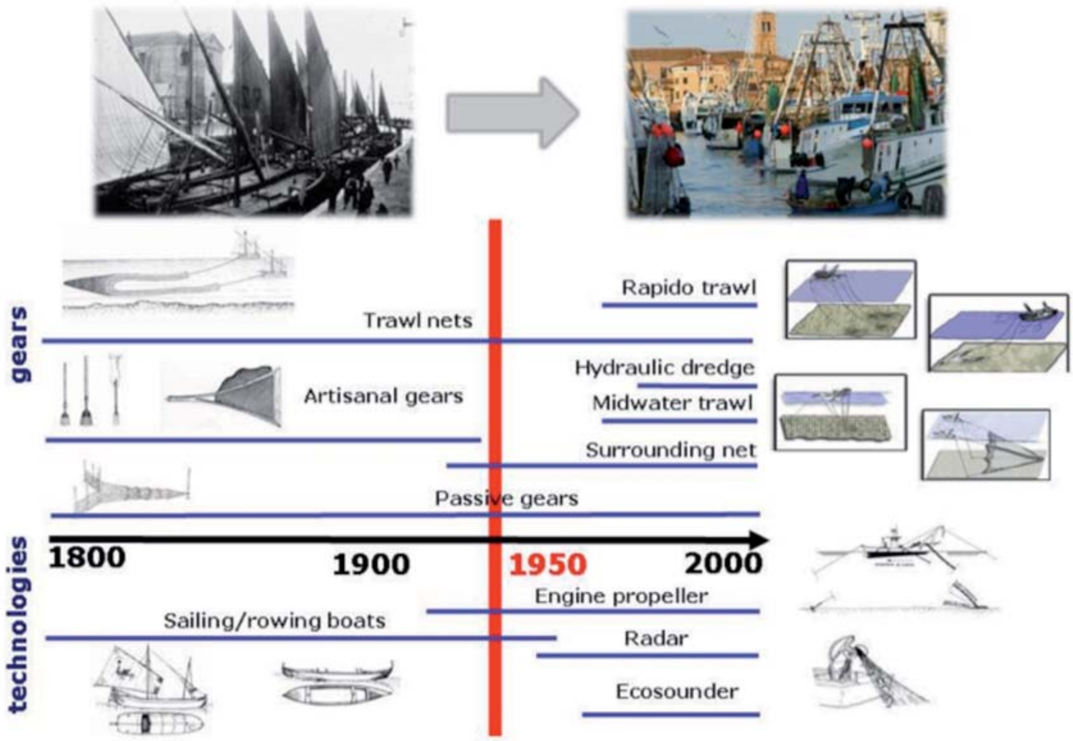


Fig. 6. A conceptual map of changes in fishing gears and technology in the Adriatic Sea (western coast fisheries) from 1850 up to 2000. After World War II, traditional sailings boats were abandoned due to the adoption of engine propeller. The use of new technological devices (e.g., radar, echosounder) and new fishing gears (i.e., mid-water pelagic trawl, rapido trawl, hydraulic dredges) increased the catchability of target species.

Data shown below (Fig. 5) point to a long-term decline in the landings in all considered taxa in the northernmost sector of the Adriatic Sea, in relation to species that were historically caught nearshore. The collateral information that there was an expansion of fishing grounds (in particular from the Chioggia fishing fleet) towards the Northern Adriatic open sea (based on Vessels Monitoring System, Fig. 7) since the '50s, further supports the possibility of a contraction of the species range since historical time.

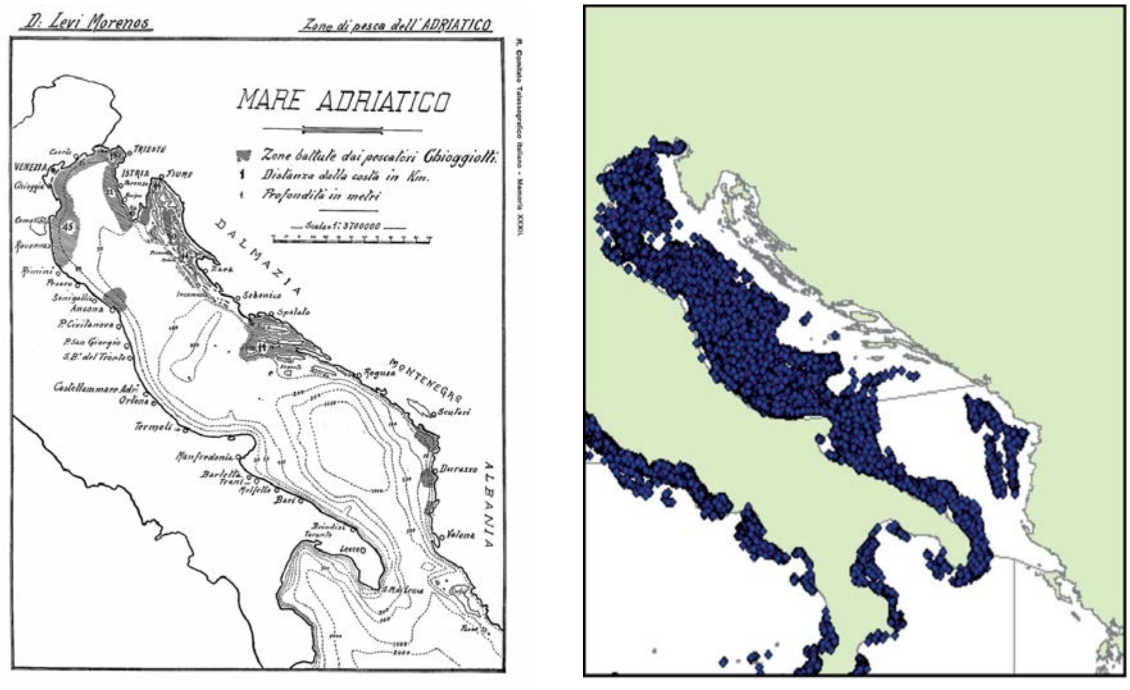


Fig. 7. An example of historical fishing grounds of Chioggia fleet (1910; grey areas) and current exploitation areas of the Italian fishing fleets in the Adriatic Sea (2008; blue dots). Pictures clearly show that the "open sea" is now exploited, while in the past only the coastal areas were impacted by fishing. Data for current fishing activities by Croatian fleets are not available.

## 2.4 Fishery independent data

In the absence of full accounts of changes in the fishing effort distribution over time and given the inherent difficulties related to the standardization of the landings data, it is difficult to quantify the extent of such changes in cartilaginous fishes.

To this end we examined the historical dataset of the HVAR expedition, the first trawl survey carried out in 1948 and 1949 by Yugoslavian scientists in the central and eastern Adriatic Sea (Karlovac, 1953). These data were compared to modern trawl survey data, i.e the GRUND data (2000-2002) (see Fig. 8), from a trawl survey that operated from 1982 to 2007 in the Adriatic Sea.

Our aim was to ascertain if the reduction in the landings, and the reduction in the range of distribution of cartilaginous fishes we inferred from the above reported information referred to the coastal northernmost part of the Adriatic Sea, were also detectable in the Central Adriatic Sea. More prominently, we were aiming in particular at identifying changes at species level, rather then genus, since neoextinction should be assessed at this taxonomic level, being the response of species to different sources of disturbance mediated by life-history traits. For consistency in the analysis, we selected those HVAR and GRUND stations that were sampled in the same area and in the same season. We considered four species, namely *Raja clavata*, *R. miraletus, Scyliorhinus canicula* and *S. stellaris*, since they show high catchability to otter-trawl (the sampling gear adopted in both trawl-surveys) and have contrasting life history traits.

As clearly seen in Fig. 8, there were no differences in the index of occurrence (i.e., % of positive hauls where the species was found) of *R. clavata*, while a significant decrease in the average weight of individuals can be clearly seen. This parameter varied from a modal value of nearly 1 kg in 1948 to a modal value of nearly 0.050 g in 2002. On the opposite, *R. miraletus* showed an increase in the range of distribution and a substantial stability in the modal weight.
A different picture emerges for the genus *Scyliorhinus*, where both *S. canicula* and *S. stellaris* show a clear reduction in the index of occupancy. In particular, the formerly widespread *S. canicula* showed a reduction from 50% to about 10% of the index of occupancy (although this was mirrored

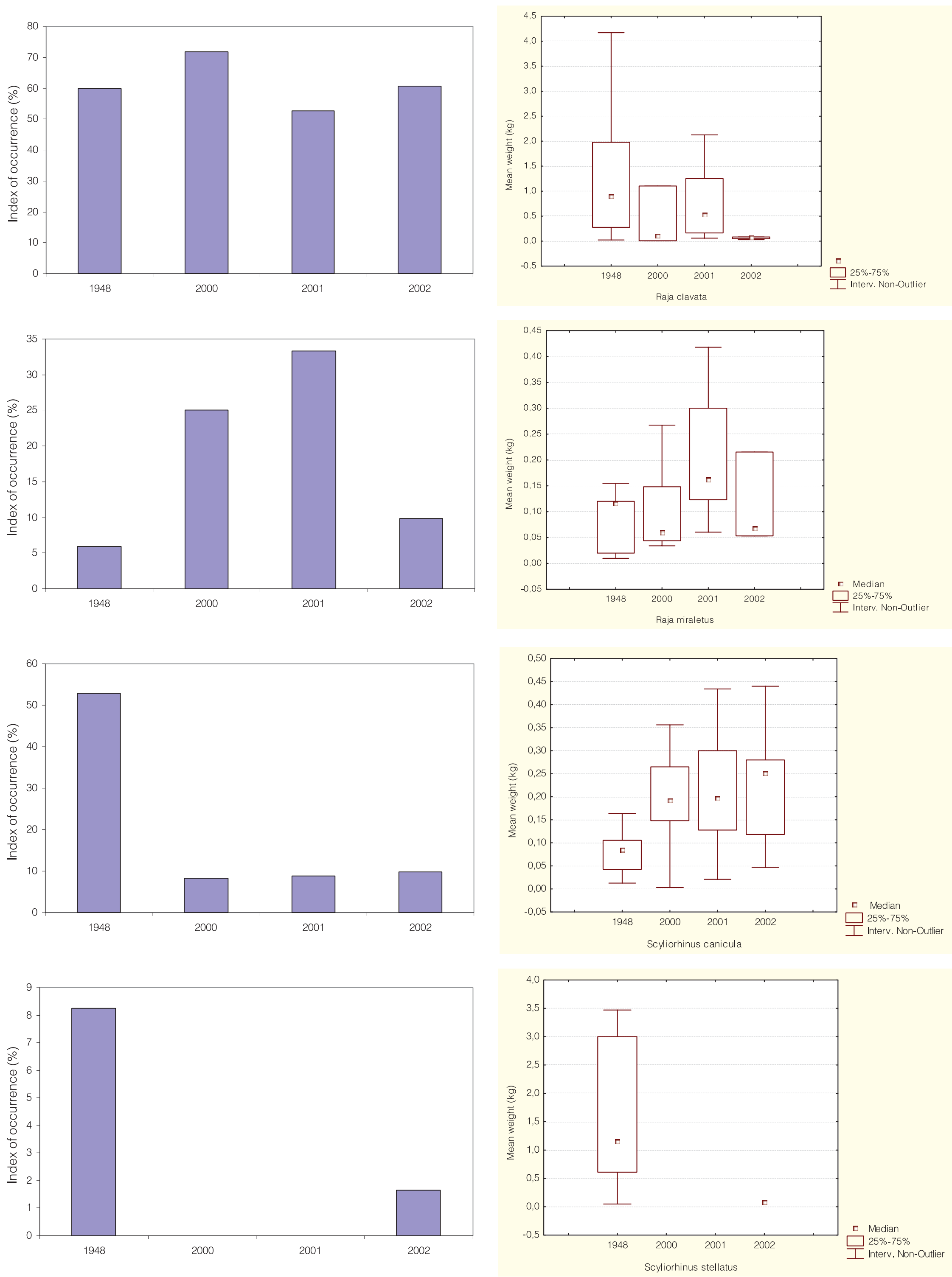


Fig. 8. A comparison of the index of occurrence (left panels) and average weights (right panels) of four selachians species (from top to bottom: *Raja clavata, Raja miraletus, Scyliorhinus canicula, Scyliorhinus stellaris)* in the Central Adriatic Sea in the HVAR expedition (1948) and GRUND trawl surveys (2000-2001-2002). Average weight (Median, interquartile range and max-min range) was estimated in each sampling station as ratio between total number of individuals and total weight.

by an increase in the average weight of individuals), while *S. stellaris* almost disappeared from the investigated area.

It is worth noting that, when taking into account the life-history traits of such species, the observed patterns can be rationalized, since *R. clavata* and *S. canicula* has lower $L_{max}$ (and related life-history traits like L at maturity) compared to *R. miraletus*, and *S. stellaris* which points to lower vulnerability to fishing pressure of the former two species (Dulvy *et al.*, 2003).

Our analysis is also confirmed by a study carried out by Jukic-Peladic *et al.* (2001) that compared HVAR data with another trawl survey (MEDITs) carried out in the 1998, and clearly showed a reduction in the number of cartilaginous fishes species, as well as in their relative importance in the catches in the Central and Eastern Adriatic Sea, also confirming the reduction in *R. clavata* and *S. canicula*. Moreover a recent publication of Piccinetti *et al.* (2012), that reports the average spatial persistence of species in the 1994-2010 period based on MEDITs trawl-survey, confirm that the four species considered are now present only in the eastern part of the basin.

### 2.5 A general overview: can multiple evidence be a proof?

In this work we showed the range of information that an historical ecology approach can use to trace neoextirpation, focusing on elasmobranchs in the Adriatic Sea as a case-study. Our activity allowed us to list a number of "evidence" that we can summarize as:

1) naturalists' accounts enabled us to reconstruct an early baseline for the Adriatic Sea cartilaginous fishes (since 1800), indicating that 43 different species were present in the area, many of which were common and are, nowadays, considered to be threatened;

2) historical accounts confirmed that, in the early twenty century, many of these species were exploited, and that fishery was carried out mainly in relatively coastal areas;

3) historical documents permitted also to describe the discrete areas where some cartilaginous fishes were abundant and thus exploited as target species;

4) landing statistics confirmed that in the past the yield of elasmobranchs was high in the Northern Adriatic Sea, but the low taxonomic resolution of landings partially prevented to assess changes in the relative abundance of species within a definite genus. However, clear signs of reduction in landings after World War II were recorded, especially in the last decades;

5) further historical accounts show that an expansion of fishing grounds from the coast to the open sea occurred in the meanwhile, fostered by sharp changes in fishing technology;

6) fishery-independent data confirmed that, for some species, a reduction in the index of occupancy or in the average weight happened in the last 60 years, showing the presence of a neoextirpation process;

7) the exploration of other published records based on trawl-surveys, also shows that most of the cartilaginous fishes once abundant in the western side Adriatic Sea can now be found only on the eastern side of the basin.

Our question, now, is whether the degree of coherence of such "evidence" collected from historical accounts, landings and trawl-survey data can be considered as final proof of a serious neoextirpation process occurring in the area. We believe that the overall data and sources presented indeed show that the current date status of Adriatic Sea elasmobranchs is a "shadow" of what the naturalists used to see few generations ago.

However, answering the same question at the species level is more complex. In our view, only by considering each single species, one by one, will be able to provide a final word on single species neoextirpation. For instance we can confirm that *Raja clavata*, *Scyliorhinus canicula* and *S. stellaris* are under threat, while for *R. miraletus* the answer is less certain.

Even less trivial is to assess the status of such species according to quantitative criteria such as those adopted by the IUCN Red List. The challenge is how to incorporate historical accounts into a formal process of species' risk evaluation.

In any case, we should recall that the pattern reconstructed has a deep ecological relevance since it allows us to say that the Adriatic ecosystem has changed, many top predators are gone, and therefore current day macroecological analysis should acknowledge the fact that we are now studying an "unnatural ocean". Our warning is that, most likely, the resilience of the Adriatic Sea elasmobranch group might have been hampered, and that the spectacular rise reported by Umberto D'Ancona (1926) after World War I fishing ban (that was studied by Vito Volterra to propose the so-called Lotka-Volterra equations, Volterra, 1926), might not occur nowadays, or take too long. A question that only time will be able to answer, if management best practices to protect cartilaginous fishes are introduced.

## 3. Moving forward

This contribution could only scratch the surface of a "gold mine" that needs to be exploited if we really intend to describe changes in biodiversity and understand the reality of the current 6$^{th}$ Mass Extinction. A further source of data that we did not take into account, but that is currently under assessment in the Adriatic Sea, is the fishermen's traditional knowledge whose value to describe changes in biodiversity is now widely recognised (Raicevich *et al.*, 2010). Other sources of data are Natural History Museums, that in turn may provide samples that could be used for genetic analysis, to determine historical trophic levels as well as population growth in the past, etc.

When dealing with marine species, and questioning their possible neoextinction, the issue of geographical scale is very relevant. The reduction in the number of species in a defined sector is the prerequisite to extirpation, while to infer information on possible neoextinctions we would need to widen our picture and move beyond the Adriatic Sea area. Therefore we consider that the development of a wider historical ecology approach in the Mediterranean Sea, that encompasses the several areas where naturalists' accounts and Natural History Museums were and are still active, as well as the retrieval of historical sources and the exploration of fishermen traditional knowledge, could allow reaching the geographical boundary where evidence became clear and neat proofs.

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