No place to hide:

How large-scale protection zones could benefit sharks and rays in the Mediterranean

Lauren Daly and Francesco Ferretti
Hopkins Marine Station, Stanford University, USA

Croatian port of Maslinica. © Joadl.

Around the world many elasmobranch (shark, skate and ray) populations are in decline, due primarily to overfishing. Similarly, the community composition of many marine ecosystems has changed dramatically in the last few decades as a result of the direct and indirect effects of commercial fishing. Is there anything we can do to help preserve diversity and encourage the rebound of an already highly depleted elasmobranch community? A recent study published in *Scientific Reports*[1] found that large-scale fisheries protection zones might be one solution.

People have fished in the Mediterranean Sea for thousands of years, typically for commercially valuable species such as tuna and Swordfish. Sharks and rays were usually caught accidentally during this process and considered 'by-catch'. Since they were not considered important or commercially valuable, extraction of species such as Spurdogs, smoothhounds and rays occurred in huge volume, largely without remark. Here, we examine changes in the relative abundance of sharks and rays in the Adriatic Sea [see Fig. 1, bottom right], highlighting the role of commercial fishing – bottom trawl fisheries in particular – as a major driver in depleting elasmobranch abundance and diversity over the last six decades.

Understanding changes in marine ecosystems

Marine communities change in structure and composition as a result of fishing, with species displaying differing vulnerabilities to exploitation. Some species have a faster reproductive rate, or can escape more efficiently from fishing gears, while others benefit from the decline of their direct competitors. However, understanding and explaining community changes in large marine ecosystems is challenging, particularly when it requires experiments. These experiments are often impractical due to scale and cost, as well as incorporating large, mobile animals.

One solution is to focus on particular areas characterised by differences in the intensity of impact (such as fishing pressure) or environmental variables (temperature, depth, seabed topography). Observing and comparing changes in abundance and distribution of animals within these distinct areas is an efficient, cost-effective alternative, helping scientists understand to what degree the changes are an effect of natural environmental variables or the result of human impact.

Trawl surveys

Our study analysed scientific trawl surveys in the Adriatic Sea over six decades, examining a total of 2575 tows carried out between 1948 and 2005 [see Fig. 1].. A trawl survey is a scientific sampling method in which a large net is deployed behind a boat, and dragged for 30-60 minutes over the seafloor. Everything caught is counted and identified to give scientists an idea of the diversity and abundance of species occurring in a particular time and location. By comparing catches of elasmobranchs across surveys performed during different time periods, our study was able to explain and estimate long-term changes in the diversity, abundance and distribution of populations.

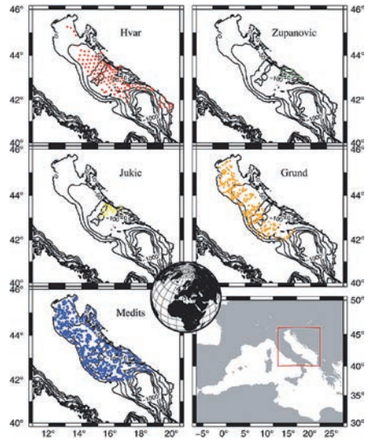

Figure 1 Positions of tows performed during the surveys analysed in the Adriatic Sea. © Ferretti *et al*. 2013.

The Adriatic Sea

The Adriatic has broad accessible fishing grounds, in which large fisheries for shellfish and groundfish have developed. At the same time, this area also provides an interesting case study as commercial fishing developed unevenly on either side. Along the western (Italian) coast, fishing methods were historically more industrialised, with correspondingly high catch volumes. While on the eastern (Croatian) coast, fisheries developed more slowly, in a less industrialised fashion. In terms of fleet size and power, Italy lists twice the number of otter trawlers (1541) as Croatia (855), with an average trawler having some 2.25 times the horse-power of an average Croatian vessel. By comparing two sides of the same sea, affected by contrasting regimes of fishing intensity, our study revealed the response of a complex elasmobranch community under different scenarios of impact.

Surprising data

We encountered expected results, as well as some surprising discoveries, while analysing the trawl data [see Tab. 1]. As expected, we found a structurally depleted elasmobranch community exhibiting a general decline in abundance of >94% since 1948, with most of the 33 species detected by the surveys strongly declining over time. Furthermore, eleven species disappeared throughout the period of the surveys (they did not occur in the observational record after the year 2000), updating the list of possible extinctions in the Adriatic to twenty-two. Catch per Unit Effort and species richness was greater on the eastern side of the Adriatic [see Fig. 2] – reflecting the less intense fishing pressure on the Croatian side, both historically and more recently.

Yet, the Adriatic was not in good shape even sixty years ago. Many species targeted in dedicated fisheries between the 19th and the 20th centuries (for example larger, less resilient species such as Angelsharks, Common Skate and Tope) were sporadic, or already gone, prior to the commencement of the surveys in 1948.

Interestingly, rates of population decline and species occurrence were not uniform – the result of differences in biology among species, as well as the effects of concurrent changes in predator and competitor (for food or space) populations.

This was most clearly illustrated in the least exploited areas, in which some elasmobranch species demonstrated population increases. This implies the presence of complex ecological interactions as seen in other heavily exploited marine regions of the world – such as the Gulf of Maine and the Gulf of Mexico – where populations of small sharks and rays increased as a result of reduced predation and competition from larger elasmobranch species[2]. Similarly, some of the more mobile species such as Spurdog, Eagle Rays and smoothhounds were found in relatively high abundance in areas biologically suitable for the species, but considered by the authors to be amongst the most heavily exploited by commercial fisheries. In contrast, in more heavily exploited Italian waters these compensatory changes where absent, possibly already having occurred prior to the survey period.

Species	Tows	Individuals	First	Last
Heptranchias perlo **Sharpnose Sevengill Shark**	2	2	1948	1948
Leucoraja circularis **Sandy Skate**	2	2	1948	1948
Pteromylaeus bovinus **Bull Ray**	1	44	1948	1948
Galeorhinus galeus **Tope Shark**	15	18	1948	1957
Squatina squatina **Angelshark**	11	16	1948	1958
Dipturus batis **Common Skate**	14	17	1948	1968
Raja radula **Rough Skate**	8	8	1968	1994
Rhinoptera marginata **Lusitanian Cownose**	2	2	1994	1994
Dasyatis centroura **Roughtail Stingray**	4	4	1957	1996
Dalatias licha **Kitefin Shark**	3	7	1995	1997
Raja polystigma **Speckled Skate**	2	2	1999	2000
Dipturus oxyrinchus **Longnosed Skate**	30	60	1948	2001
Torpedo nobiliana **Back Torpedo**	1	1	2001	2001
Oxynotus centrina **Angular Roughshark**	17	48	1948	2003
Torpedo torpedo **Common Torpedo**	2	2	1996	2003
Chimaera monstrosa **Rabbit Fish**	11	71	1994	2004
Etmopterus spinax **Velvet Belly**	11	57	1994	2004
Rostroraja alba **White Skate**	16	18	1948	2004
Squalus blainville **Longnose Spurdog**	79	348	1948	2004
Dasyatis pastinaca **Common Stingray**	45	94	1948	2005
Galeus melastomus **Blackmouth Shark**	41	1147	1948	2005
Leucoraja melitensis **Maltese Skate**	1	1	2005	2005
Mustelus asterias **Starry Smoothhound**	63	94	1948	2005
Mustelus mustelus **Smoothhound**	186	1302	1948	2005
Myliobatis aquila **Common Eagle Ray**	133	539	1948	2005
Raja asterias **Starry Skate**	55	129	1948	2005
Raja clavata **Thornback Skate**	536	3612	1948	2005
Raja miraletus **Brown Skate**	327	1780	1948	2005
Raja montagui **Spotted Skate**	9	9	1948	2005
Scyliorhinus canicula **Smallspotted Catshark**	812	24401	1948	2005
Scyliorhinus stellaris **Nursehound**	139	396	1948	2005
Squalus acanthias **Spurdog**	425	3632	1948	2005
Torpedo marmorata **Marbled Torpedo**	68	92	1948	2005

Table 1 Species detected in the Adriatic trawl surveys (1948–2005). Tows are the number of trawl tows that caught the species. Individuals refer to the cumulative number of specimens detected in all tows. First and Last are the years of the first and last catch, respectively. Table adapted from Ferretti *et al*. 2013.

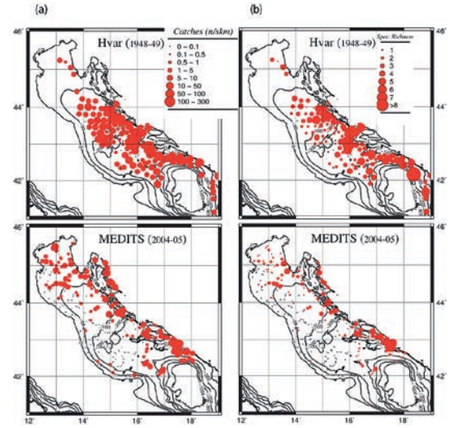

Figure 2 Spatial comparisons of catches between Hvar and MEDITS surveys. (a) unstandardised Catch Per Unit Effort, and (b) species richness. For MEDITS we selected only the last two years of the series (2004–05) for a balanced temporal comparison. Crosses are tows with no elasmobranchs. © Ferretti *et al*. 2013.

A large-scale experiment

Interestingly, the Adriatic has functioned as an unintentional long-term, two-treatment experiment on the effectiveness of large marine reserves for the conservation and recovery of large mobile animals. In this case the different jurisdictions (Croatian and Italian) functioned as the treatment levels. Since the Croatian coast had a smaller fishing fleet, it acted much like a marine refuge. Faced with less fishing pressure, some species could sustain exploitation, while other more mobile and widely distributed species such as Spurdog, Eagle Rays and smoothhounds could even spillover into more heavily fished areas.

From our perspective, this was suggestive of a significant benefit in creating marine protected areas on a large scale (similar in size to the territorial waters of Croatia) in heavily exploited areas such as the Adriatic. Existing marine protected areas in the Mediterranean are too small for effective protection and rehabilitation of populations of highly mobile species, with animals able to be fished once they leave the protected area.

Hope for the future

So what is to be done? Is there any hope for the sharks and rays of the Mediterranean? We think so. With the establishment of adequately-sized marine protected areas, shark and ray populations have the opportunity to rebound. Effective management and conservation of less-depleted elasmobranch communities in Croatian waters could promote recovery of these animals throughout the Adriatic Sea.

The Adriatic Sea is an area of international jurisdiction, with diverse economic and political interests. However, highly mobile animals, including sharks and rays, do not stay within arbitrary lines and areas. Hence international management and cooperation is needed to protect these rapidly diminishing communities. Croatia will now join the European Union (EU) in July of 2013. This means its territorial waters will gradually become more accessible to EU fishing fleets, in particular the Italian fleet, whose vessels already operate in the more productive marine areas close to the Croatian border. An Adriatic Sea Fishery Protection Zone planned and managed at an international level, with a focus on reducing fishing pressure in western areas and controlling the development of fisheries in the east, could act as a buffer to enable the less-depleted elasmobranch community in the eastern Adriatic avoid the fate of its western counterpart.

References

1. Ferretti, F. *et al*. 2013. Long-term change in a meso-predator community in response to prolonged and heterogeneous human impact. *Sci. Rep.*, 3: 1057
2. Ferretti, F. *et al*. 2010. Patterns and ecosystem consequences of shark declines in the ocean. *Ecol. Lett.*,13, 1055-1071