UNIVERSITÀ POLITECNICA DELLE MARCHE
Department of Life and Environmental Sciences

PhD in Marine Biology and Ecology

Ecology and population connectivity of lamnid sharks in the Mediterranean Sea

PhD Candidate

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GENERAL SUMMARY OF THE THESIS

Large pelagic sharks are among the most threatened vertebrates worldwide, and the Mediterranean Sea represents a particularly concerning case, where fishing pressures, data paucity, and weak management all merge together in the same area.

Despite their ecological importance as apex predators, the status, distribution, and ecological role of large lamnid sharks such as the shortfin mako (*Isurus oxyrinchus*) and the white shark (*Carcharodon carcharias*) remain poorly understood in this basin. Among lamnids occurring in the Mediterranean, the porbeagle (*Lamna nasus*) is also present, although it is exceptionally rare in this basin. The current knowledge gap severely hampers the development of effective conservation and recovery strategies.

The general aim of this PhD thesis is to enhance understanding of spatial dynamics, population connectivity, and trophic roles of large lamnid sharks in the Mediterranean Sea, with a particular focus on the shortfin mako and white sharks, by combining opportunistic data, statistical modelling, genomic tools, trophic analyses, and innovative field approaches. Through this multidisciplinary framework, the thesis addresses three major gaps: (i) the lack of reliable information on spatio-temporal trends of shortfin mako shark occurrence in the Mediterranean Sea, (ii) the population connectivity between the Mediterranean and the adjacent Eastern Atlantic Ocean for shortfin mako sharks, and (iii) the limited knowledge of trophic interactions between co-occurring large lamnid sharks.

The first chapter addresses the gap in distributional knowledge of the shortfin mako. Reliable abundance trends and occurrence data for this species are almost absent in the Mediterranean, as fishery-independent and fishery-dependent surveys are scarce and bycatch is poorly documented. To overcome this limitation, a database with opportunistic records and citizen-science observations was compiled and analysed them through a Bayesian spatial modelling framework. This approach allowed to account for observation bias and heterogeneity in sampling effort, producing the first basin-scale, effort-corrected maps of shortfin mako occurrence in the Mediterranean Sea and identifying potential hotspots and annual patterns.

The second chapter concerns the lack of genetic and demographic information for Mediterranean shortfin mako population. The extent of connectivity between the Mediterranean and the eastern Atlantic remained unresolved, despite its central importance

for management under ICCAT regulations. By applying a genome-wide ddRADseq approach to samples from both sectors (Mediterranean Sea and Eastern Atlantic Ocean), the population structure, gene flow, and genetic diversity between the two sectors are investigated. This chapter contributes to clarifying whether Mediterranean makos should be managed as an independent unit or as part of a wider Atlantic stock.

The third chapter focuses on the trophic ecology role of large lamnid sharks in the Mediterranean, a topic for which empirical data are extremely scarce in the basin. In the Tunisian Plateau, where shortfin mako and white shark are known to overlap, it was applied stable isotope analysis to assess their trophic positions, prey use, and isotopic niche overlap. This study provides the first comparative trophic evaluation of these two species in the Mediterranean and helps to clarify whether they compete for similar resources or partition niches, with implications for understanding ecosystem functioning and predator–prey dynamics in the basin.

Finally, the fourth chapter highlights methodological innovations in the study of elusive pelagic sharks, drawing on the experience of the "White Shark Chase" project, a collaborative effort with an international team of scientists and conservation partners. Research on large pelagic sharks in the Mediterranean has been constrained by the rarity of encounters, misidentification, and logistical challenges. This chapter illustrates how integrative approaches combining citizen science, opportunistic data, eDNA detections, and field campaigns, can overcome these limitations. By presenting case studies such as the tagging of a juvenile mako and the first eDNA detection of white sharks in the Sicily Channel, and the multiple inter-annual records of juvenile shortfin mako sharks, this chapter demonstrates how collaborative approaches can generate critical data for endangered and elusive species.

Taken together, the chapters of this thesis aim to provide a more comprehensive understanding of the status, connectivity, and ecological role of two important large pelagic sharks in the Mediterranean Sea. By addressing fundamental gaps in distribution, genetics, and trophic ecology, and by testing innovative methodologies, this work contributes new insights and practical tools for the conservation of species that are regionally Critically Endangered and globally declining.

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