

Large marine predators in the Mediterranean Sea. A losing game or there is still room for their recovery?

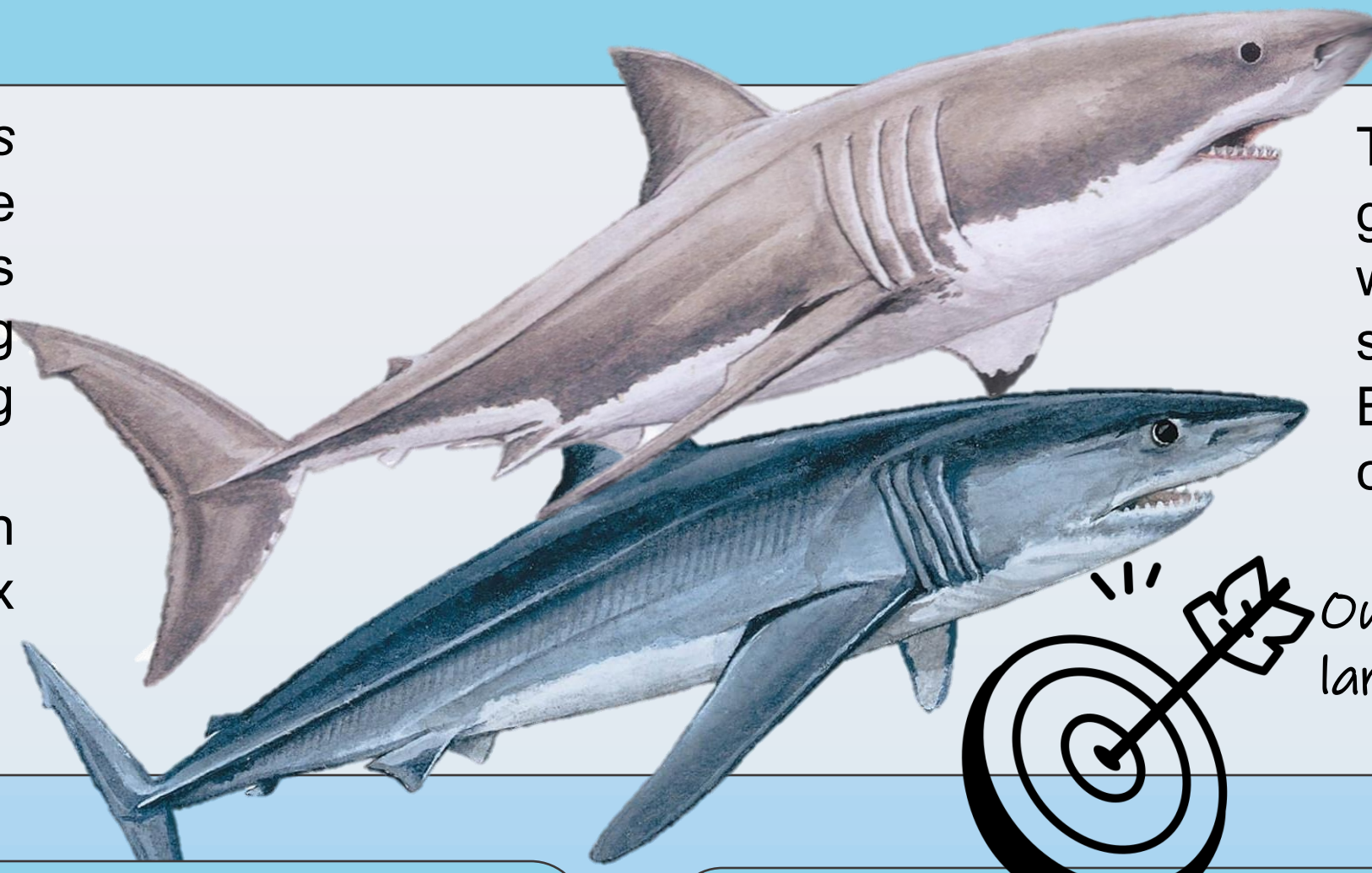
PhD Student: Chiara Gambardella

DiSVA, Laboratorio Zoologia Marina

*Tutor: Prof. Carlo Cerrano, Teresa Romeo,
Francesco Colloca, Francesco Ferretti*

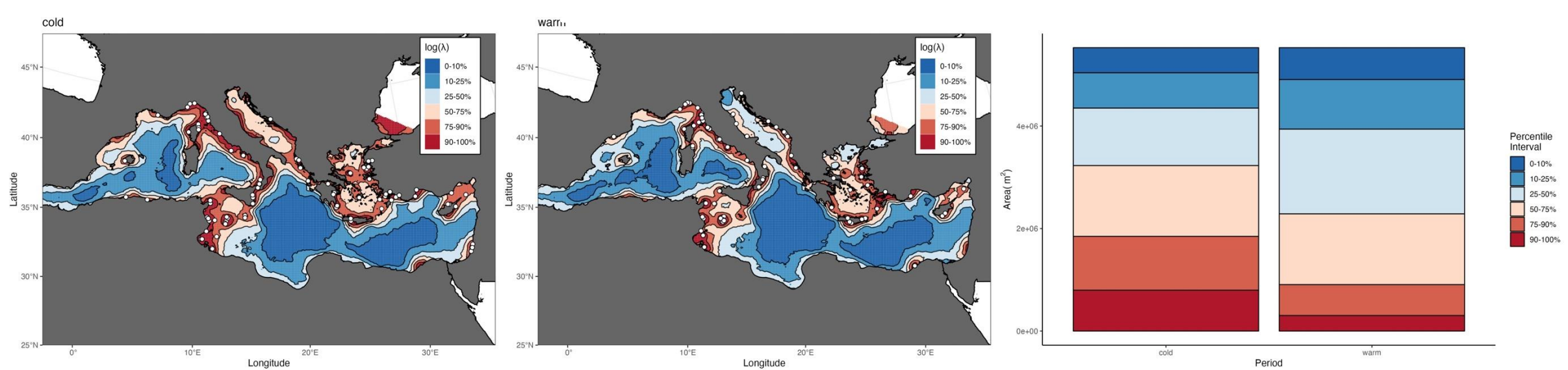
Introduction & Aims

Large marine predators like the **shortfin mako** (*Isurus oxyrinchus*) and **white shark** (*Carcharodon carcharias*) are Critically Endangered¹ in the Mediterranean Sea, yet little is known about their ecology and population structure. Studying them is challenging due to their elusiveness, wide-ranging movements, and the lack of coordinated regional monitoring ². This knowledge gap hampers conservation efforts in a basin heavily impacted by centuries of overfishing and complex management.



This **PhD project** investigates the distribution, population genetics, and trophic ecology of the shortfin mako and white shark in the Mediterranean Sea. By integrating spatial modeling, molecular tools, and field data (eDNA, BRUVs, tagging), we aim to uncover patterns critical for conservation.

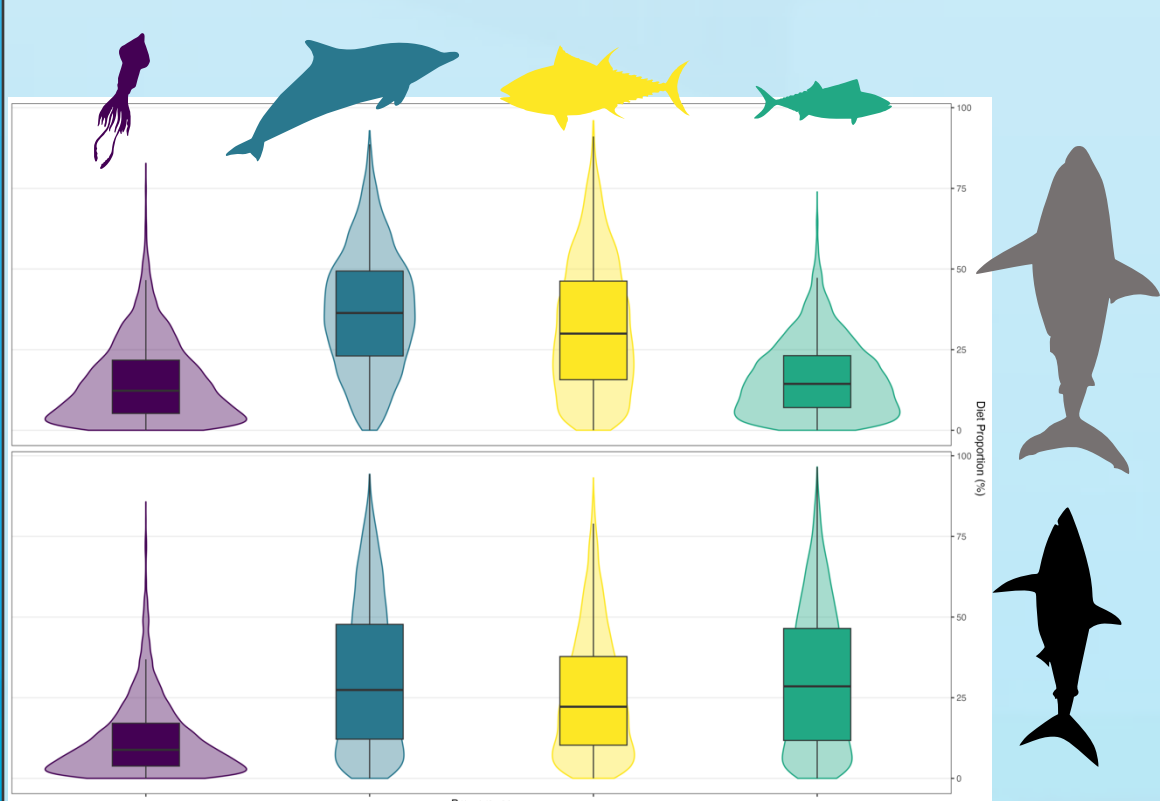
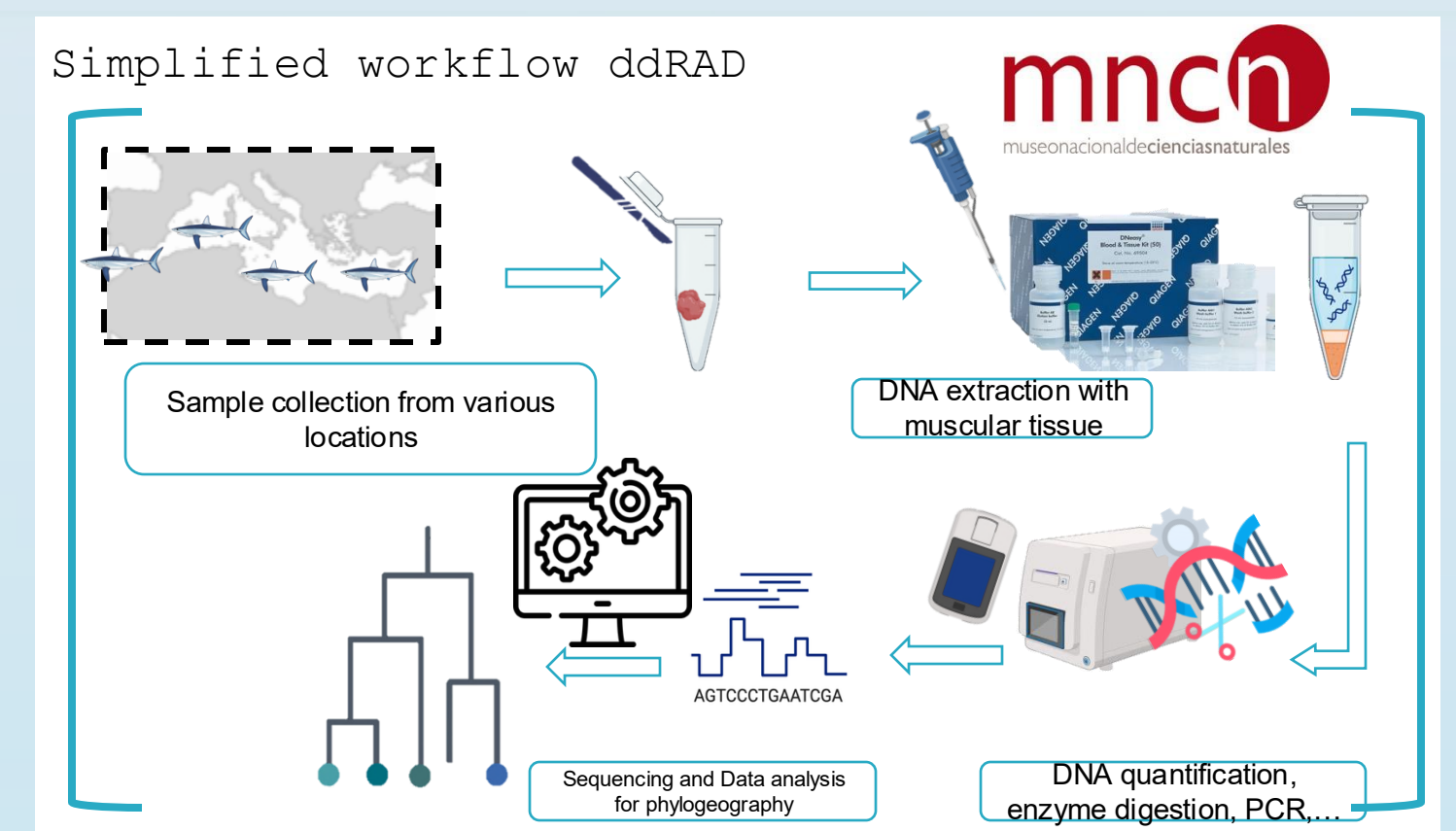
Our goal is to inform science-based management strategies for large pelagic predators in a rapidly changing marine ecosystem.



- **Area-based protection** is a cornerstone for halting the loss of biodiversity, identifying key sites or seascapes of importance for biodiversity or target species³.
- Most of the available information on **pelagic sharks** comes from opportunistic sightings in the Mediterranean Sea, because standardized monitoring programs for sharks are still lacking².
- We compiled **630 presence-only records** (422 from 2016–2023) and used point process models (INLA/inlabru)⁴ to estimate **makos** occurrence while accounting for sampling bias.
- The model revealed a latitudinal gradient in occurrence and identifies consistent hotspots, especially in the Sicily Channel.
- Seasonal models (warm vs. cold months) confirm that the Sicily Channel remains a key area year-round, supporting its relevance for area-based conservation.

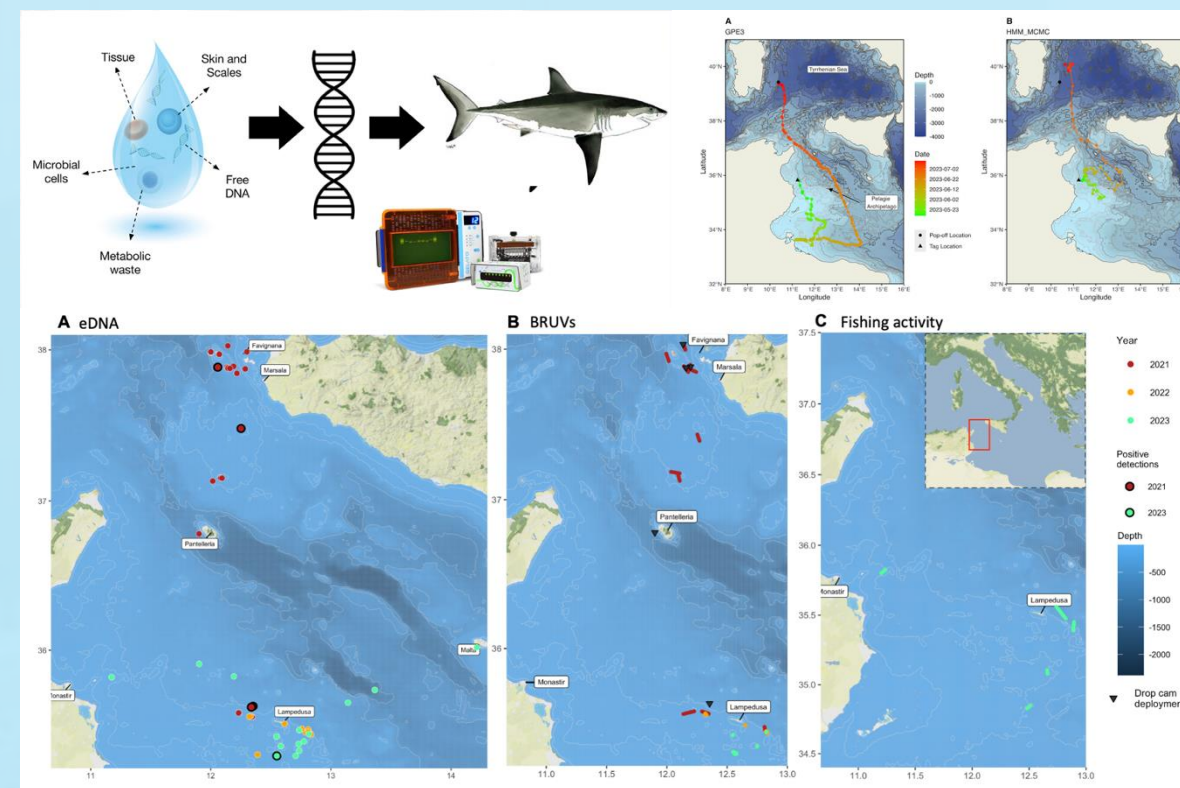
Chapter 2 Differences in Mediterranean and Atlantic shortfin mako populations

- Despite being **highly migratory**, the **shortfin mako** shows global population structure in mtDNA, but data are still lacking for the Mediterranean Sea⁵.
- Oceanographic barriers like the Strait of Gibraltar and Sicily Channel may restrict gene flow and contribute to genetic differentiation in the region⁶.
- We applied a genome-wide approach (**ddRAD-seq**)⁷ to samples from key areas (inside and outside the Mediterranean Sea) to investigate population structure
- Lab work for ddRAD library preparation whether the Mediterranean population



- **32 individuals collected**
 - **Moderate niche overlap:** A 17% overlap between juvenile white sharks and makos suggests partial resource sharing during early life stages in the Tunisian Plateau, supporting its role as a potential foraging area⁸.
 - **Ontogenetic shifts in isotopic niche:** Juvenile white sharks had a broader niche than YOYs, while the opposite was observed in shortfin makos reflecting different patterns of habitat use and dietary breadth
- mixing models revealed a notable contribution of dolphins (enging of neonatal or stillborn individuals rather than
- sence of pinnipeds, Mediterranean white sharks may rely (ing) compared to makos, which appear to retain active d.

White Shark Chase: a multi-annual (2021, 2022 and 2023) research program where an international team of researchers is tracking the last white sharks in the Mediterranean Sea⁹.



We focused on identifying the most suitable habitats for white sharks, but our multidisciplinary approach also provided insights into other pelagic species, thanks to the use of complementary methods such as:

- eDNA
- Pelagic Baited Remote Underwater Video
- Deep water Baited Remote Underwater Video
- Satellite tags

We detected white sharks at four sites from eDNA samples. Mid- and deep-water baited video detected 42 species of bony fishes, elasmobranchs, marine mammals (bottlenose dolphins), and reptiles (loggerhead turtles)

Conclusions and future perspectives

This project provides an integrated assessments to date of *Isurus oxyrinchus* and *Carcharodon carcharias* in the Mediterranean, combining spatial modelling, molecular ecology, and trophic analyses to fill key data gaps for two Critically Endangered species

Future goals...

- Expand spatial models by integrating covariates (e.g., salinity, slope, fishing effort) to better predict species distribution and refine conservation targets.
 - Increase sample size and geographic coverage for genomic analyses to confirm population boundaries and test for local adaptation within the Mediterranean.
 - Conduct long-term stable isotope and mixing model studies on adult individuals to fully characterize ontogenetic shifts and foraging ecology in both species.
 - Advocate for coordinated regional monitoring programs and standardized bycatch data collection to improve conservation planning for pelagic sharks in the Mediterranean basin.
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