LATE MIOCENE NEOSELACHIANS FROM KEFALONIA, GREECE: RECONSTRUCTING BIODIVERSITY AND A PALEOENVIRONMENT IN THE EASTERN MEDITERRANEAN



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ABSTRACT

The Miocene epoch (23.03–5.333 Ma) represents a key interval that led to the formation of Earth's modern continental and oceanic configurations and biodiversity. This study reconstructs the Late Miocene (Tortonian) marine paleoenvironment of Kefalonia, Greece, through analysis of a historically collected neoselachian (shark and ray) fossil assemblage. Using comparative anatomy and actualistic paleontology, fossil teeth were identified and extant ecological affinities were used to infer past conditions. The assemblage yielded 12 taxa across 8 genera, including apex predators *Otodus megalodon* and *Cosmopolitodus hastalis*, and a notable occurrence of Myliobatiformes. Results indicate a shallow, subtropical marine ecosystem with heterogeneous habitats and a diverse neoselachian fauna. This study contributes to Greece's fossil record and establishes a regional biodiversity baseline for the Tortonian Eastern Mediterranean.

FROM THE TETHYS TO THE MEDITERRANEAN

Originally the Tethys Ocean (connected to Indian and Atlantic Oceans)

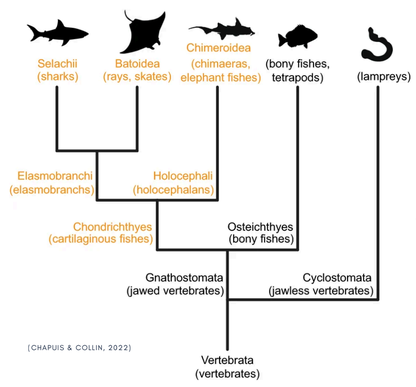
- **Early Miocene:** Still connected to both oceans (open-oceanic, tropical conditions with coral reefs & diverse marine fauna)
- **Middle Miocene Climatic Optimum:** Warmer temperatures, expansion of tropical biota, high neoselachian biodiversity
- **Late Burdigalian:** Indian Gateway closes (proto-Mediterranean forms)
- **Tortonian:** Small sub-basins with restricted exchange
- **Messinian** (end of Miocene): Complete isolation → Messinian Salinity Crisis
- **Pliocene:** Gibraltar strait reopens → modern Mediterranean (northward shift, exit from tropical belt)

WHAT ARE NEOSELACHIANS?

Class: Chondrichthyes (emerged over 400 mya)
Subclass: Elasmobranchi (greatly diversified from the Jurassic onwards)
Neoselachians: = modern sharks and rays + closest fossil relatives

SIGNIFICANCE OF NEOSELACHIANS

- One of the most highly endangered groups.
- Ecological significance maintaining balance in ecosystems.
- Optimal group for gaining insight into past marine environments (fossil proxies).

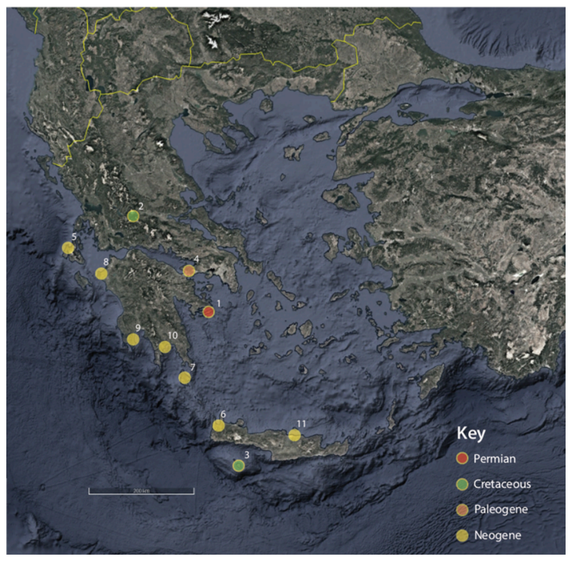


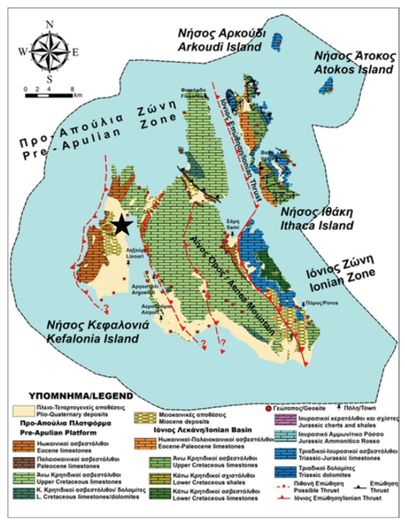
1 **POLYPHYODONTY → ABUNDANT FOSSIL RECORD**

2 **TEETH ARE DECAY-RESISTANT (DENTINE + ENAMELOID)**

3 **TOOTH MORPHOLOGY = TAXONOMY + FEEDING ECOLOGY**

NEOSELACHIANS IN GREECE AND KEFALONIA





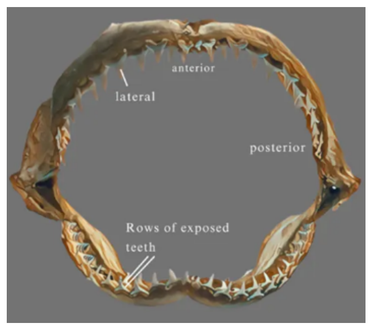
★ **Fossil locality (Skineas Quarry)**

- **Overall fossil record in Greece not extensively developed with limited localities.**
- **Kefalonia Location:** Westernmost part of the External Hellenides, near the Hellenic arc.
- **Skineas Quarry** in Kefalonia is the most studied neoselachian fossil locality in Greece.
- **Previous Study in Kefalonia → Symeonidis & Schultz (1968):** *Prionodon egertoni*, *Hemipristis serra*, *Odontaspis (Synodontaspis) acutissima*, *Odontaspis sp.*, *Carcharodon megalodon*, *Isurus desori*, *Isurus hastalis trigonodon*
- ***Additional Findings in Kefalonia:*** Iliopoulos et al. (2024)*: Otodus megalodon*, *Hemipristis serra*, *Carcharhiniformes*, *Isurus sp.*, *Sparidae* & Iliopoulos, Svana, & Roussakis (2022): *Sirenian fossils (dugong) - Metaxytherium sp.*
- **Age of deposits: Tortonian age (11.63-7.246 mya),** based on biostratigraphic evidence using Pectinidae and *Heterostegina* sp.

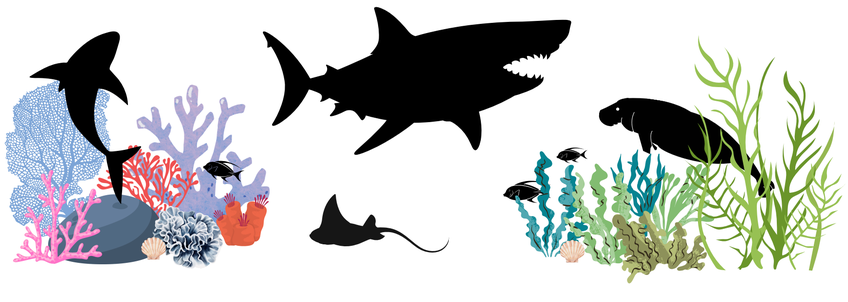
THEORETICAL BASIS AND METHODOLOGY

- ***Comparative anatomy, actualistic paleontology, & phylogenetic niche conservatism.***
- **Process:** Lab Processing (acetic acid dissolution & peeking method), categorization into morphotypes and identification, paleoenvironmental reconstruction using extant relative data and preferences.

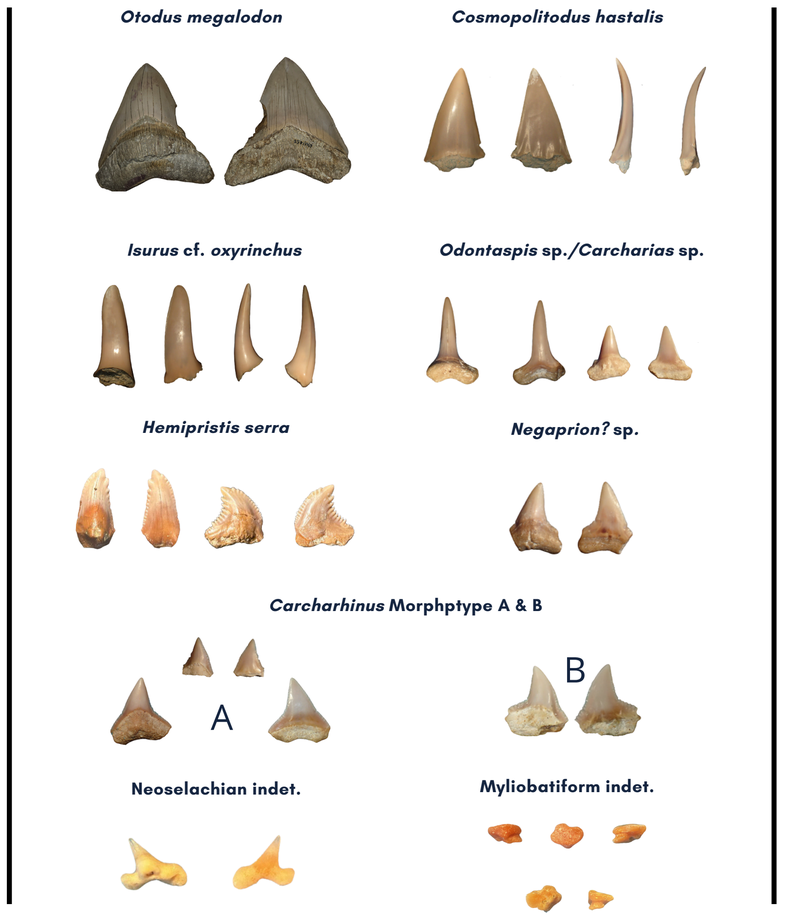








TAXONOMIC COMPOSITION OF SAMPLE



AFFINITIES OF EXTANT TAXA

BATHYMETRIC PREFERENCES OF KEFALONIA NEOSELACHIANS

Fossil Taxa	Extant Species	n Specimens	Lifestyle	Preferred Habitat	Bathymetric Range (m)			Inner Shelf	Mid-outer Shelf		Continental Slope			
					Min	Max	Common	50 m	100 m	150 m	200 m	250 m	300 m	500 m	1000 m	2000 m
Otodus megalodon	*Carcharodon carcharias*	10	PO	P	0	1280	0-250									
Cosmopolitodus hastalis	*Carcharodon carcharias*	17	PO	P	0	1280	0-250									
Isurus cf. *oxyrinchus*	*Isurus oxyrinchus*	1	PO	EP	0	888	0-150									
Odontaspis cf. *ferox**	*Odontaspis ferox*	2	BP	D/MP	10	2000	13-880									
Carcharias cf. *taurus**	*Carcharias taurus*	2	BP	N/EP	1	191	15-25									
Hemipristis serra	*Hemipristis elongata*	5	D	N/EP	1	130	1-30									
Negaprion sp.	*Negaprion* spp.	2	BP	N/BP	0	92	1-30									
Carcharhinus sp. A	*Carcharhinus* spp.	3	NP	N/P	~0	~200	~0-100									
Carcharhinus sp. B	*Carcharhinus* spp.	2	NP	N/P	~0	~200	~0-100									
Myliobatiform indet.	?	1	B	N	~0	~200	~0-100									

FOSSIL TAXA	EXTANT SPECIES	ENVIRONMENT	CLIMATE ZONE	SEA TEMPERATURE RANGE (C)
Otodus megalodon	*Carcharodon carcharias*	Marine, brackish	Subtropical	5-25
Cosmopolitodus hastalis	*Carcharodon carcharias*	Marine, brackish	Subtropical	5-25
Isurus cf. *oxyrinchus*	*Isurus oxyrinchus*	Marine	Temperate-tropical	16-?
Odontaspis cf. *ferox*	*Odontaspis ferox*	Marine	Warm temperate-tropical	6-20
Carcharias cf. *taurus*	*Carcharias taurus*	Marine, reef-associated	Subtropical	15.3-28.2
Hemipristis serra	*Hemipristis elongata*	Marine	Tropical	23.8-29
Negaprion sp.	*Negaprion* spp.	Marine, brackish, reef-associated	Subtropical-tropical	21 -29
Carcharhinus sp. A	*Carcharhinus* spp.	Marine	Temperate-subtropical	~18-30
Carcharhinus sp. B	*Carcharhinus* spp.	Marine	Warm temperate-subtropical	~18-30
Myliobatiform indet.	?	Marine, soft-bottom	Warm temperate-subtropical	~12-28

PALEOBATHYMETRY

- Does not account for sediment transfer & pelagic taxa adundance.
- Dominant neritic affinites & pelagic- oceanic apex predators.
- Extant taxa common depths → 0-250m.
- Overlapping depth preferences: 0-100m (likely depositional depth).

→ ***A shallow continental shelf habitat (0-200m depth), connectivity to open ocean waters***

PALEOENVIRONMENT AND ECOLOGICAL INTERACTIONS

= Regional context+affinities of extant taxa

Climate & Temperature:

- Extant relatives → warm-temperate to tropical climate zones.
- Overlap of sea temperature ranges: 21-25 C → SUBTROPICAL

Habitats:

- Coral reefs: Reef associated *C.taurus*, *Negaprion* sp.
- Soft-bottom: Myliobatiformes (rays)
- Sea grass meadows: *Metaxytherium* sp.

Apex Predators: *O. megalodon & C. hastalis* →sirenians (*Metaxytherium*)
Mesopredators: *I. oxyrinchus*, *Negaprion*, *Carcharhinus* →nektonic community
Shark-ray predation: *H. serra & C.taurus* diet
Durophagous Feeders: Myliobatiformes → benthic invertebrates (Pectinidae)

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