

HOLISTIC APPROACH TO CALIBRATE THE STOCK ASSESSMENT OF EUROPEAN EEL IN THE MEDITERRANEAN

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BACKGROUND

A central task in fisheries management is the development of approaches to assess the status of fish stocks so that levels of sustainable harvest and appropriate conservation measures can be derived^{1, 2}. This task is particularly challenging for diadromous species whose fragmented populations suffer multiple environmental impacts that add to fishing pressure, and are subject to decentralized management scenarios³. Among these, the European eel (*Anguilla anguilla*) is the most representative case, and its sustainable management and conservation is a challenge that has been going on for over 25 years⁴.

The European eel is a semelparous catadromous fish that spawns in the Sargasso Sea, and whose larvae after hatching, passively drift with the ocean's currents across the Atlantic to the coasts of Europe and the Mediterranean Sea^{5, 6, 7}. Larvae after metamorphosing to glass eels colonize water basins across all European and Mediterranean countries, where they grow for several years until they reach the maturation phase (silver eel). At this stage, spawners move again to coastal areas, with a process called escapement, and undertake the reverse migration across the Atlantic^{8, 9}. Eel has been targeted for centuries by thousands of artisanal fisheries scattered across all Countries and all habitats. This, coupled with the species' dependence on different ecosystems already sensitive to human pressures, makes the European eel vulnerable to several drivers of global changes¹⁰. The cumulative effects of all pressures acting on the eel stock are considered the cause of the consistent decline of the eel stock, documented since the early '90s^{4, 11}.

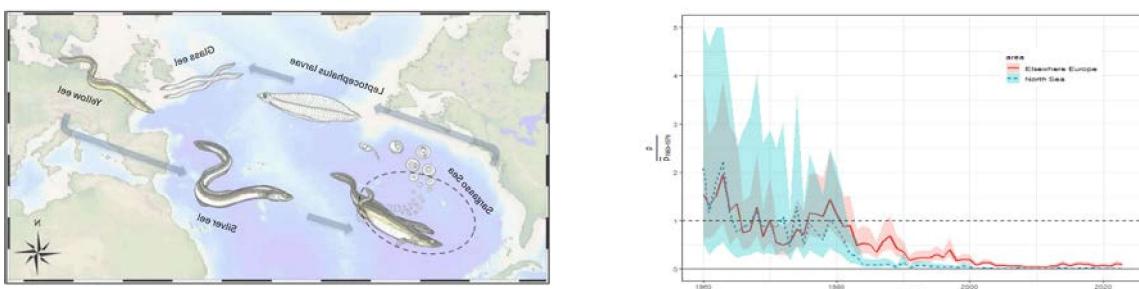


Figure 1 Left: Life-cycle of the European eel; **Right:** glass eel recruitment index for 2023

The stock status of the European eel was declared beyond biological limits by ICES in 1998^{11, 12}. A framework was established by the EU regulation EC 1100/2007¹³; the species has been listed as 'critically endangered' by the IUCN (International Union for the Conservation of Nature) Red List since 2008^{4, 14}, and FAO GFCM (General Fisheries Commission for the Mediterranean) has put in place since 2014 actions to coordinate assessment and management with Europe¹⁵.

AIMS OF THE PROJECT

The present project aims to contribute to the ongoing process of eel assessment towards its recovery, connecting activities on eel at national, Mediterranean and international levels by the Dipartimento di Biologia research group. The project focuses on evaluating silver eel escapement in the Mediterranean with interrelated activities, field and laboratory, for the absolute evaluation of silver eel escapement, coupled with model-based evaluations at different spatial scales. The comparison of predictions by models with *in-situ* observations will be crucial in demonstrating the reliability of model-based assessments or revealing bias tendencies of the model, from the general perspective to establish reliable targets for eel management that also address eel stock recovery.

METHODS AND ACTIVITIES

The project foresees the following tasks, articulated at three levels:

1) National level - Field work in two key sites in Italy (a lagoon in western Sardinia, and a lagoon in North Adriatic):

Based on the collaboration of fishermen cooperatives in the two sites (Project 1), direct monitoring techniques of silver eel escapement by side with innovative techniques will be carried out:

- **Direct counts** of silver eels at the lagoon fishing barriers → all catches of silver will be recorded by fishers to evaluate silver eel biomass across the seasons
- Quantification of **eel biomass by eDNA** (Project 2) → Environmental DNA will be extracted and used amplified for quantification by conventional PCR primers (followed by quantitative PCR (qPCR) ¹⁷).
- Experiments of **mark and recapture of silver eels** → individuals will be marked with T-Bar anchor tags and released. Counting recaptures of marked individuals in the total catch will allow to estimate population size, and especially to quantify silver eel escapement ^{18, 19, 20}.
- **Acoustic telemetry**, paired with the mark and recapture method → acoustic receivers (Vemco VR2Tx) with built-in tags (frequency of 69 kHz) will be installed in the study sites, and acoustic telemetry tags (Vemco V9) will be implanted in subsamples of the tagged animals. Signals will allow inference on migration activity, direction of movements, swimming speed, and other behavioral aspects.

2024	Field work	2025	Field work		2026	Field work	Lab work	2027	Modeling
	Sardinia/Orbetello		North Adriatic	Sardinia/Orbetello		North Adriatic	University of Tor Vergata		University of Tor Vergata
	Nov - Dec		Dec - Gen	Nov - Dec		Dec - Gen	Gen - Dec		Gen - Dec
	Direct Count		Direct Count	Direct Count		Direct Count	Data analysis		Data analysis
	Water Sampling for DNA		Water Sampling for DNA	Water Sampling for DNA		Water Sampling for DNA			
	Acoustic Telemetry		Acoustic Telemetry			Mark and Recapture	Demographic model		Demographic model
	Mark and Recapture		Mark and Recapture						

Figure 2: Workplan of activities

These activities will allow an absolute evaluation of silver eel escapement and continuous quantitative monitoring, a task rarely logically feasible and therefore implemented only sporadically, and never in Italy. Importantly, these activities will be carried out in synergy and collaboration with similar activities in other key sites in the Mediterranean GFCM FAO Project.

2) Regional level – Mediterranean: **Model-based assessment of silver eel escapement** at the same key sites, by using the demographic model (Project 3), *validating* indirect assessments of local stock status derived from population models, a practice called *ground-truthing*¹⁵.

By revising the model input parameters and validating assumptions, rarely fully available on a site-specific level, results will allow to perform the stock assessment of European eel for the whole Mediterranean in 2027¹⁹.

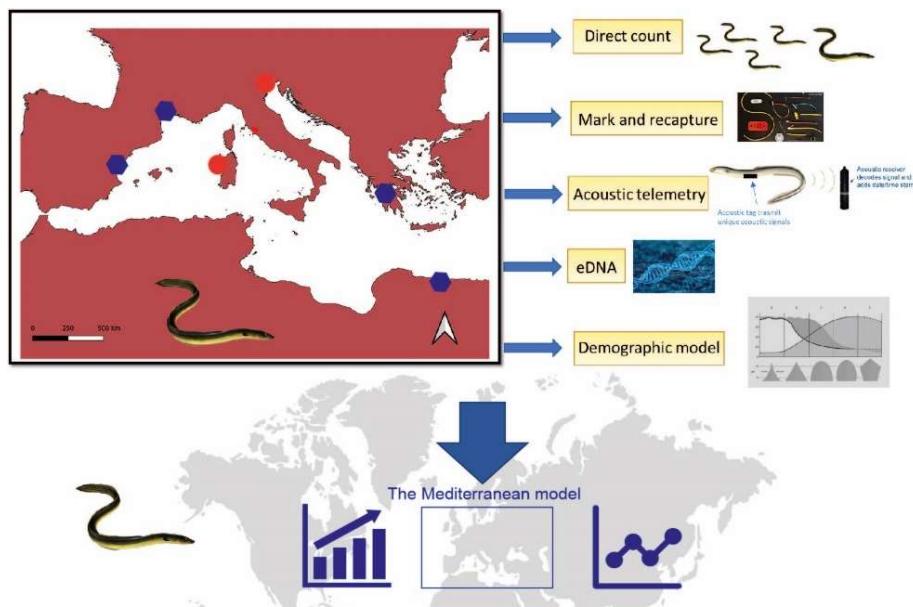


Figure 3: Conceptual scheme of the project

3) International – stock wide: As a final step, the above task of eel stock assessment for the Mediterranean will be coordinated with work ongoing within the DIASPARA project (Project 4), involving 13 Partners across Europe (INRAE coordinator), and whose aim is to align the collection of biological and anthropogenic impact data with models presently in use for eel assessment across Europe, to achieve the assessment of the eel global stock across its whole distribution range (Europe and Mediterranean).

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Ongoing projects:

Project 1: . Progetti PLNRDA - Raccolta, gestione ed elaborazione di dati nel settore della pesca, dell'acquacoltura e dell'industria di trasformazione dei prodotti ittici nell'ambito dell'articolo 23 del Regolamento (UE) n. 1139/2021 “Raccolta, gestione, uso e trattamento di dati nel settore della pesca e programmi di ricerca e innovazione”

- U.P.B.: CiccottiE.Conisma2019proroga22 -Contributo da CONISMA - Raccolta dati, settore pesca e acquacoltura - proroga 2022
- Accordo quadro (CIG 88556834CB e CUP J89J21009320007), concluso ai sensi dell'art. 54, comma 3, del D. Lgs. n. 50/2016 avente ad oggetto il servizio di raccolta, gestione ed elaborazione di dati nel settore della pesca, dell'acquacoltura e dell'industria di trasformazione dei prodotti ittici nell'ambito

dell'articolo 23 del Regolamento (UE) n. 1139/2021 "Raccolta, gestione, uso e trattamento di dati nel settore della pesca e programmi di ricerca e innovazione" – 2023-24

- WorkPlan 2025-2027 Anadromous and catadromous species data collection in fresh water – European eel Task 1 - Data collection of eel commercial and recreational fisheries, Task 2 – Biological variables of European eel

Project 2: Progetto PRIN FreshFish - eDNA: biomonitoring of inland water fish species richness through environmental DNA barcoding and metabarcoding - PRIN: PROGETTI DI RICERCA DI RILEVANTE INTERESSE NAZIONALE – Bando 2022 - Prot. 2022JJ7STN

Project 3: Progetto FAO GFCM (General Fisheries Commission for the Mediterranean) "Roadmap towards informing the future GFCM long-term management plan for European eel in the Mediterranean" – LoA between the Food and Agriculture Organization of the United Nations and Università degli Studi di Roma "Tor Vergata" Dipartimento di Biologia - U.P.B.: CiccottiE.FAO - Contributo dalla FAO 2024-2025

Project 4: EU DIASPARA "DIAdromous Species: moving towards new PARadigms to achieve holistic scientific Advice"

Coordinator: INSTITUT NATIONAL DE RECHERCHE POUR L'AGRICULTURE (FRANCE)

- EMFAF-2023-PIA-Fisheries Scientific Advice (Improving scientific knowledge to strengthen the science-basis of management decisions under the Common Fisheries Policy)

Topic: EMFAF-2023-PIA-Fisheries Scientific Advice Type of Action: EMFAF-PJG (EMFAF Project Grants)

Proposal number: SEP-210983107 Proposal acronym: DIASPARA