Mesohabitat suitability criteria for the spawning of Twaite shad (*Alosa fallax*, Lacépède 1803)

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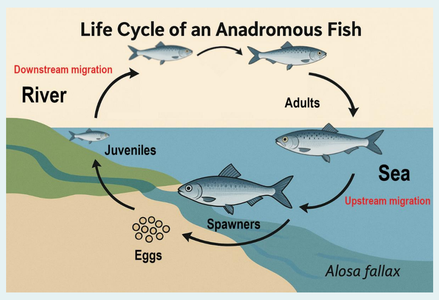
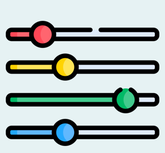
1 Introduction

Anadromous fish (e.g., *Alosa fallax*) are a particular group of **migratory species** that exemplify the interlinking of freshwater and marine ecosystems, **utilizing both environments to complete their life cycle.**



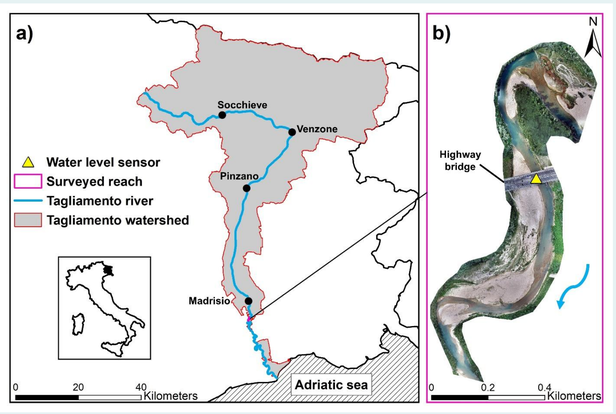
A. fallax is facing a **multitude of challenges and threats** that are undermining its existence[1] (e.g., altered hydrological regimes, barriers to migration, habitat degradation, and climate change).



There is still a **limited knowledge** of *A. fallax* **autecological and spawning habitat requirements**, especially in Italian rivers[2].

2 Methods

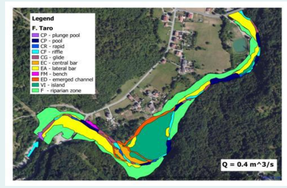
The study area



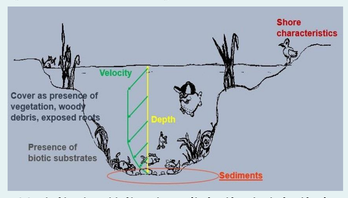
a) The Tagliamento River (NE Italy); b) the surveyed reach, 32 km upstream from the river mouth.

Habitat description

Meso-HABitat SImulation Model (MesoHABSIM[3])



Geomorphic Units (GUs[4]) or mesohabitats



Habitat attributes (biotic/abiotic)

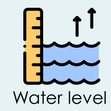
Data collection

Uncrewed Aerial Systems (UAS)

Acustic Doppler Current Profiler

GNSS receiver

- → RGB Orthomosaic
- → DTM
- → GUs mapping
- → Substrates
- → Covers
- → Depth and velocity
- → Flow
- → Water temperature
- → Spawning grounds

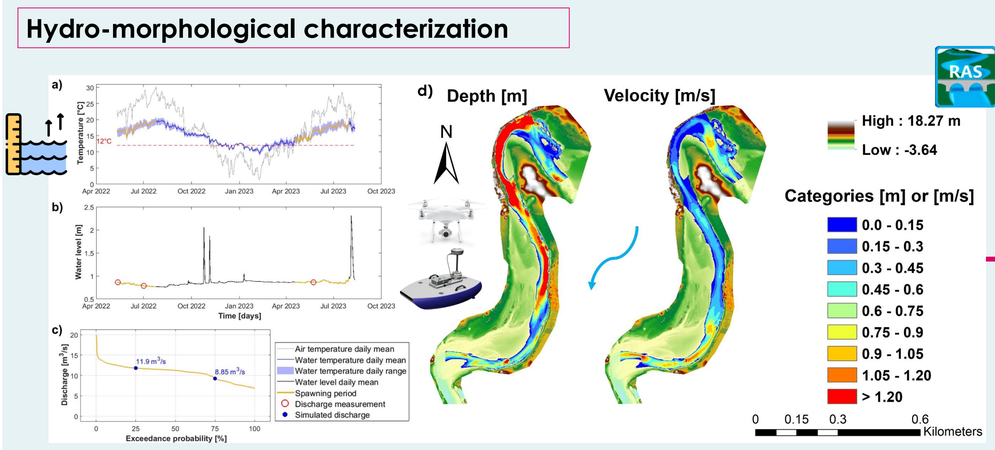


Water level sensor (WLS)

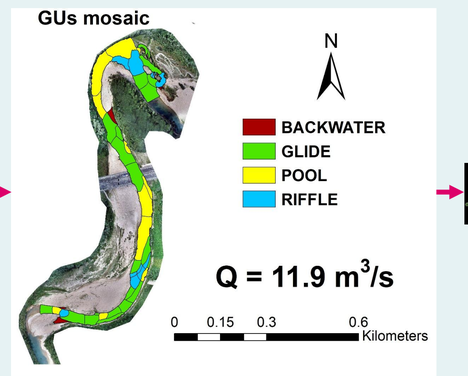
Infrared cameras

3 Results

Hydro-morphological characterization

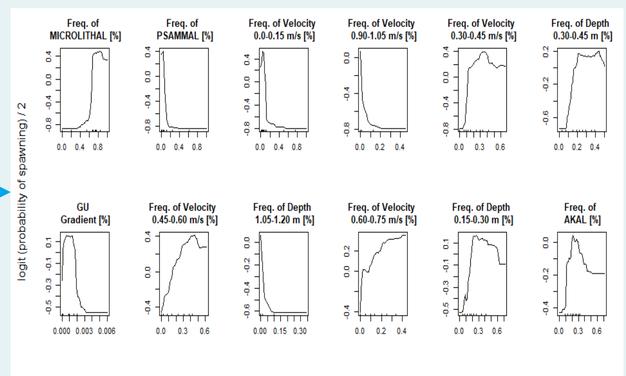


a) Water temperature and b) water levels recorded by the WLS (May 2022 – August 2023). Spawning activity was assumed to begin when temperatures exceeded 12 °C[5]. c) Flow duration curve for the spawning period. d) 2D hydrodynamic simulation results at Q = 11.9 m³/s, obtained using HEC-RAS software.



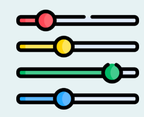
GUs mosaic at Q = 11.9 m³/s. A total of 104 GUs were identified for the two considered flow conditions (8.85 and 11.9 m³/s).

Mesohabitat suitability criteria



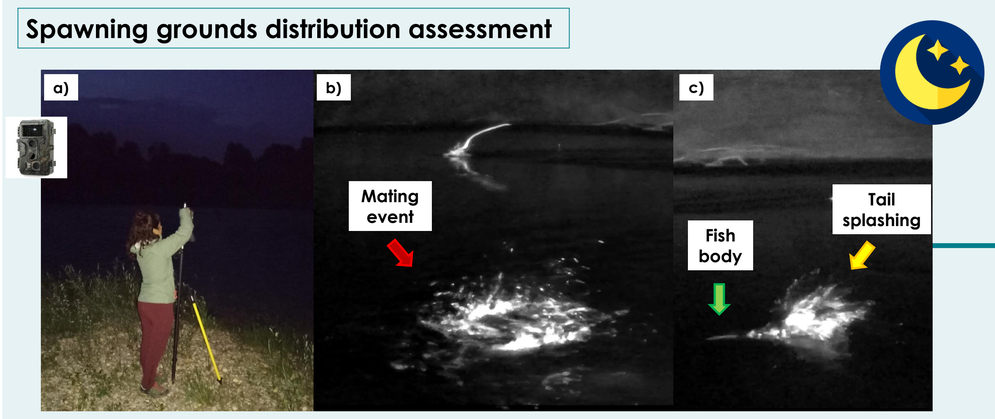
The parsimonious random forest (RF[6]) model for the spawning period of *A. fallax*. The selected habitat attributes are presented in order of importance through partial dependence plots.

Accuracy: 98.8%
Sensitivity: 100%
Specificity: 97.6%
TSS: 97.6%

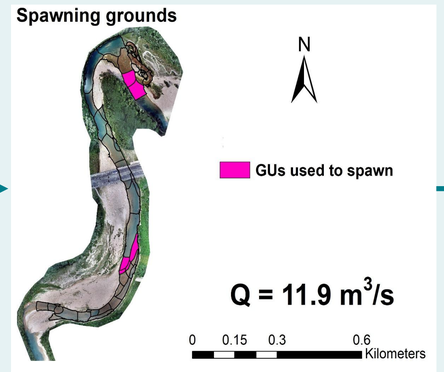


Shallow depths: 0.15-0.45 m
Moderate flow velocities: 0.30-0.75 m/s
Fine sediment: microlithal (2-6 cm) and akal (gravel)

Spawning grounds distribution assessment

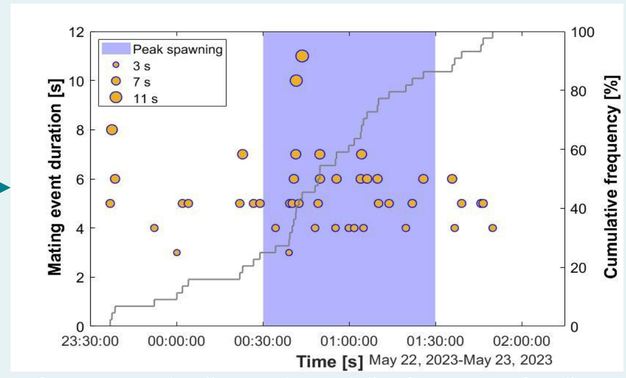


a) Infrared camera system (GardePro Trail A3S) installed on a river bar near identified spawning grounds. b) Mating event captured by the infrared camera. c) A premating activity (tail splashing). Frames extracted from videos recording.



Glides and riffles where spawning activities were observed

Mating events analysis



Occurrence, duration, and cumulative frequency of mating events recorded during the first night of observation (May 2023).

Mating events: 72
Mating attempts: 35
80% of events involved single mating pairs

Peak mating activity: 00:30 - 01:30 h
Mating event duration: 3–11 s (mean = 5.5 s)

55% of mating events involved clockwise rotation

2 nights of **videos recording**

4 Discussion

Specimen of *A. fallax* captured within the study site

- Anadromous fish in Italian rivers face growing threats, yet their spawning habitat preferences remain poorly understood. This study addresses this gap by investigating the meso-habitat spawning preferences and reproductive behavior of *A. fallax* in the Tagliamento River (NE Italy).
- Using the **RF algorithm within the MesoHABSIM** framework, **we identified key habitat attributes** associated with *A. fallax* spawning activity. The **model's high predictive performance** suggests its **effectiveness for assessing available riverine habitat**, though future validation in other river systems is needed to evaluate its transferability.
- ***A. fallax* showed a marked preference for spawning in** specific areas (i.e., **glides** and **riffles**) located upstream of notable increases in riverbed slope, while **nearby extensive and deep pools** likely serve as **daytime refuges.** These findings highlight the importance of geomorphic complexity in the selection of suitable spawning sites.
- Local water temperature recording were essential for inferring the spawning period. In the surveyed reach, **spawning was observed to occur at slightly lower temperatures** (14.6–17.8°C) **than typically reported in the literature**[5], likely due to the substantial contribution of groundwater to discharge.
- **Videos recording** using **infrared cameras** enabled the **identification and precise spatial localization of mating events within GUs**. Additionally, **key mating behaviors were clearly documented**, with potential for further enhancement through integration with UAS.
- **Observed mating behavior** was **consistent with previous studies on other European shad populations[7], confirming possible genetic connectivity across regions**[8]. Additionally, preliminary evidence indicates that **lunar phases may influence mating occurrence**, highlighting a promising area for future research.

5 Conclusions

- This study[9] showed that ***A. fallax* prefers to spawn in glides and riffles**, characterized by **shallow depths**, **moderate flow velocities**, and **fine substrates,** such as small pebbles and gravel.
- By **integrating high-resolution field data** with **machine learning** (i.e., Random Forest) within the MesoHABSIM framework, we **effectively predicted suitable spawning habitats** for *A. fallax*.
- I**nfrared camera systems** proved to be **a non-intrusive, cost-effective method for monitoring of *A. fallax* spawning behavior.**
- Currently, no dedicated monitoring framework exists in Italy for this species. Therefore, **further research and structured, long-term monitoring are urgently needed**.
- **Conservation strategies should:**
  1. **Adopt a multiscale approach** that addresses habitat quality, river connectivity, and flow/sediment regimes across the catchment;
  2. **Expand the monitoring network for discharge, water quality, and temperature** to support the identification and maintenance of suitable spawning conditions for *A. fallax*.

6 References

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