ECOLOGY AT THE INTERFACE
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Biodiversity and Ecosystems

NON-NATIVE SPECIES IN ITALIAN FRESHWATER HABITATS: A MACROECOLOGICAL ASSESSMENT OF INVASION DRIVERS

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A macroecological approach to invasion biology

- Invasion biology research often focus on single alien taxon or group of related species (i.e. genera, family, orders)
- The availability of large database (i.e. Lifewatch database) allow to test generalized invasion patters in a macroecological framework:
  – Multiple taxa
  – Multiple habitat
  – Multiple sites

The LifeWatch database

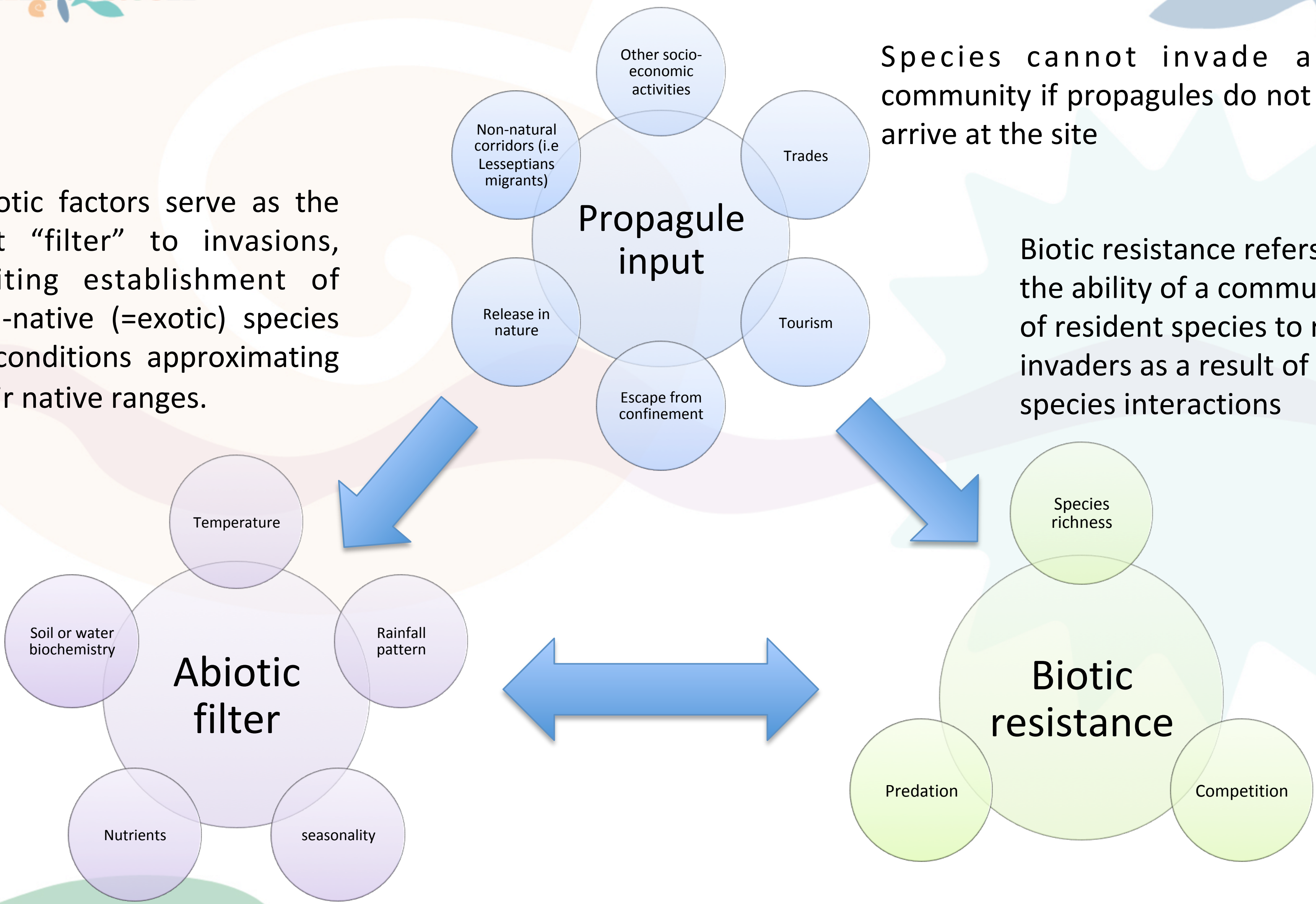
- 34386 OBSERVATIONS
- 12406 SPECIES
- 378 ALIEN SPECIES
- 563 SITES
- 42 TAXONOMIC (PHYLA) GROUPS
- 26 HABITATS (EUNIS LEVEL 2)

The Propagule, Abiotic, Biotic framework

Species cannot invade a community if propagules do not arrive at the site

Abiotic factors serve as the first "filter" to invasions, limiting establishment of non-native (=exotic) species to conditions approximating their native ranges.

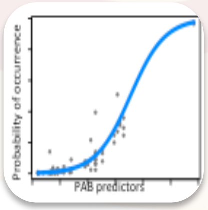
Biotic resistance refers to the ability of a community of resident species to repel invaders as a result of species interactions



Identify emergent patterns regarding the potential drivers of occurrence and richness of alien species in freshwater organisms within a PAB framework

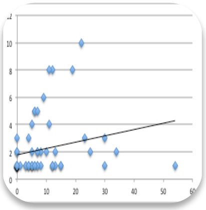
Habitat vulnerability

Are different freshwater systems (lotic vs lentic) more susceptible to invasion?



Invasion drivers

Which abiotic, biotic and pressure attributes of the recipient site affect invasion probabilities (presence/absence)?

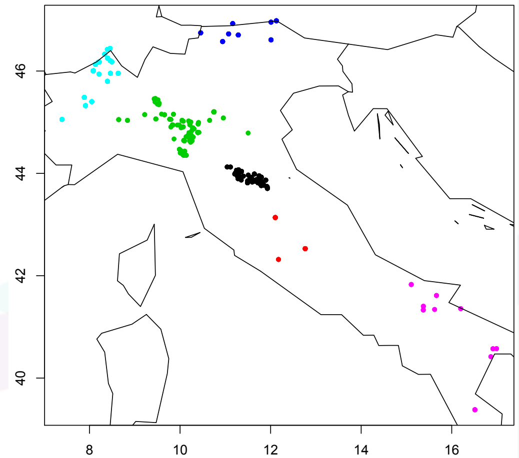


Determinants of AS richness

What are the determinants of high or low AS richness in the invaded sites?

Focus on ecosystems and sites

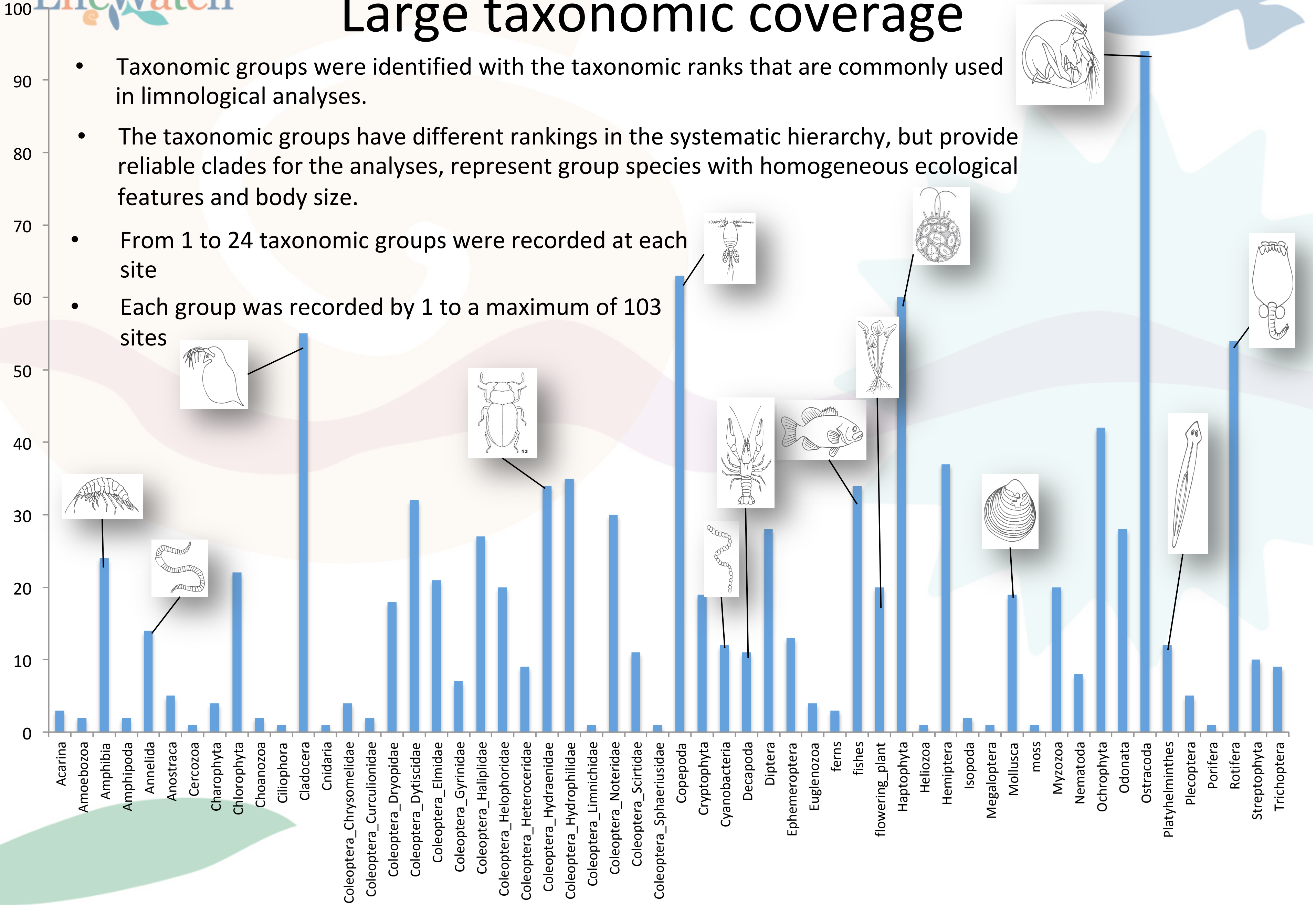
- We explicitly chose to focus on natural environments only.
- Sites were classified according to the European Nature Information System hierarchical classification of habitats and includes
  - Four level-2 EUNIS lentic habitats
    - C1.1: Oligotrophic lakes
    - C1.2: Mesotrophic lakes
    - C1.3: Eutrophic lakes
    - C1.6: Temporary lakes
  - Three level-2 EUNIS lotic habitats
    - C2.1: Springs
    - C2.2: Turbulent watercourses
    - C2.3: Smooth-flowing watercourses

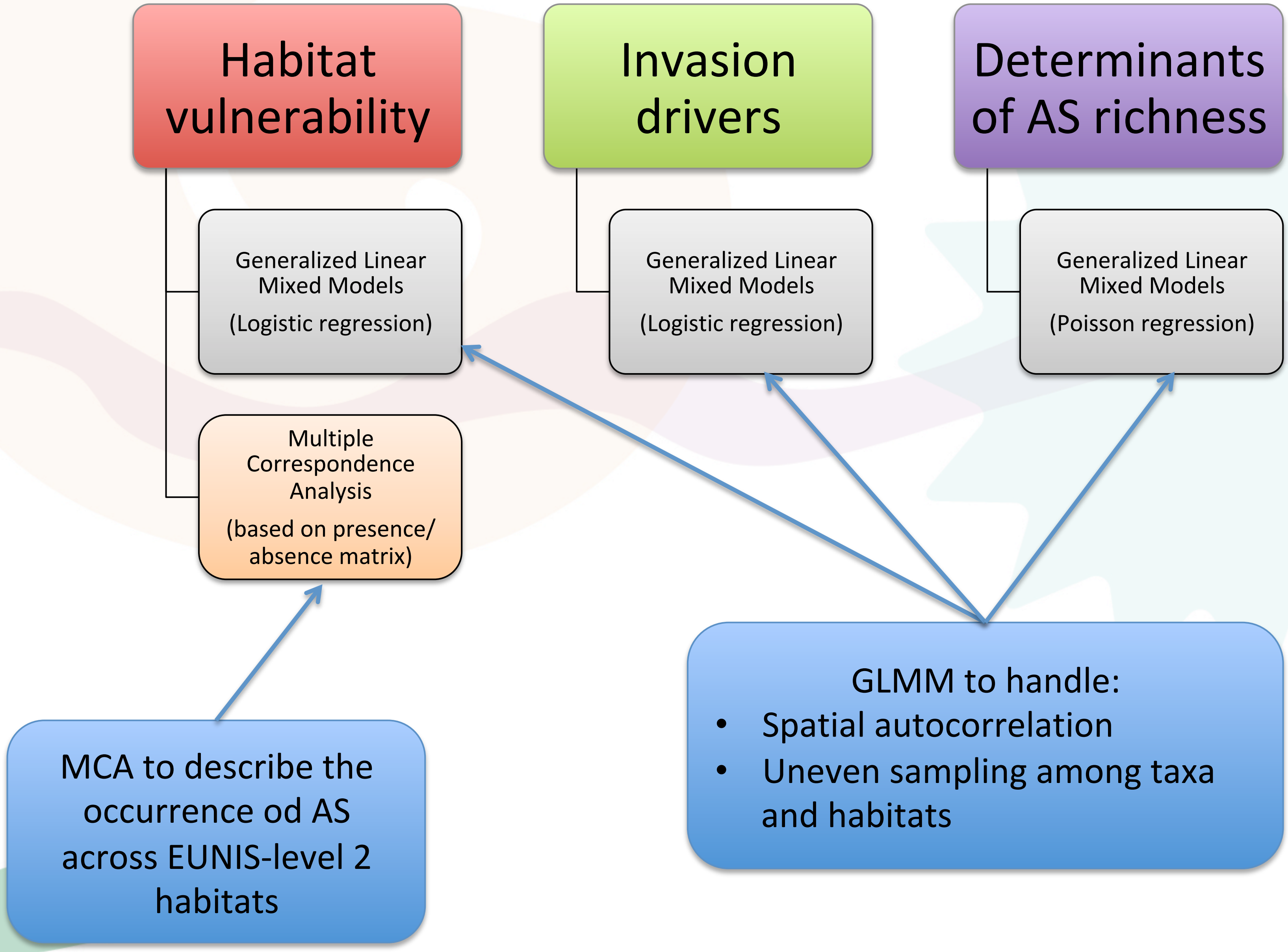


- A total of 5778 occurrence data were collected.
- Occurrence records refers to 1729 species from 236 sites
- A total of 46 species were considered to be non-native (< 3% of the total diversity in the dataset)

Large taxonomic coverage

- Taxonomic groups were identified with the taxonomic ranks that are commonly used in limnological analyses.
- The taxonomic groups have different rankings in the systematic hierarchy, but provide reliable clades for the analyses, represent group species with homogeneous ecological features and body size.
- From 1 to 24 taxonomic groups were recorded at each site
- Each group was recorded by 1 to a maximum of 103 sites




Habitat vulnerability
Invasion drivers
Determinants of AS richness
Generalized Linear Mixed Models
(Logistic regression)
Multiple Correspondence Analysis
(based on presence/ absence matrix)
Generalized Linear Mixed Models
(Logistic regression)
Generalized Linear Mixed Models
(Poisson regression)
MCA to describe the occurrence od AS across EUNIS-level 2 habitats
GLMM to handle:
• Spatial autocorrelation
• Uneven sampling among taxa and habitats

Habitat vulnerability

We could not reject the null model (LRT: p=0.110) of no differences of aliens species occurrence between lentic (level-1 EUNIS: C1) and lotic habitats (level-1 EUNIS: C2).

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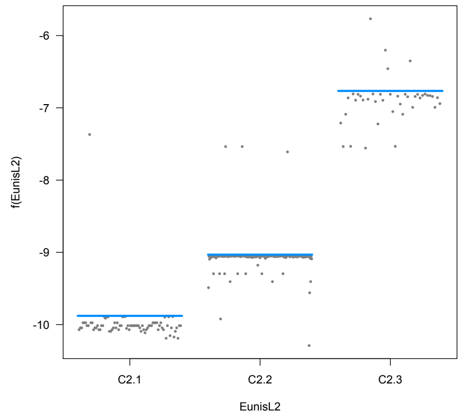
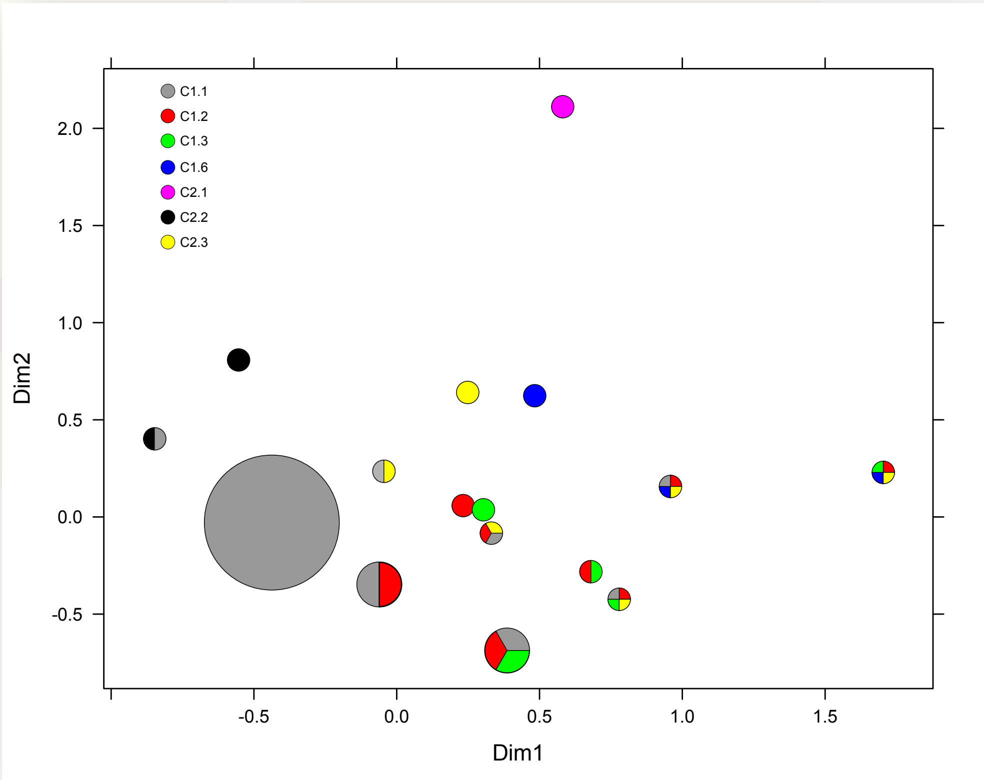
The four categories of Level-2 EUNIS lentic habitat were not significantly different

Oligotrophic = Mesotrophic = Eutrophic

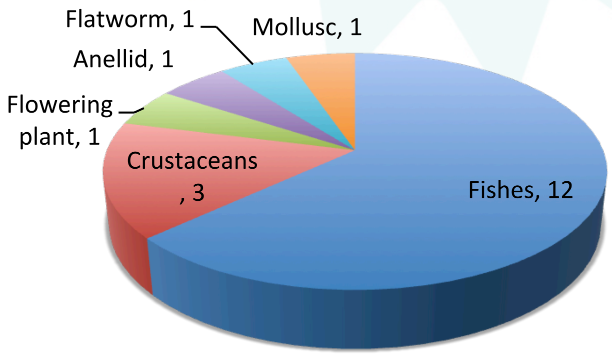
Among level-2 EUNIS lotic habitats we found significant differences (LRT: p=0.002), due to a higher probability to find alien species habitat C2.3 (smooth-flowing watercourses)



The invasion of freshwater habitat from a qualitative point of view



- 27 AS found only in one habitat type. 18 of these were found in oligotrophic lakes
- 19 AS found in 2 up to 4 different habitat types: 9 are shared between lentic and lotic habitat types; 10 AS were shared across 2 or 3 different lentic habitat



Invasion drivers and determinants of AS richness

- Proportion of AS species
- As richness in invaded sites

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Pressure
- Accessibility

Abiotic
- Mean annual temperature
- Mean temperature diurnal range
- Temperature seasonality
- Annual precipitation
- Precipitation seasonality

Biotic
- Species richness
- Body Size

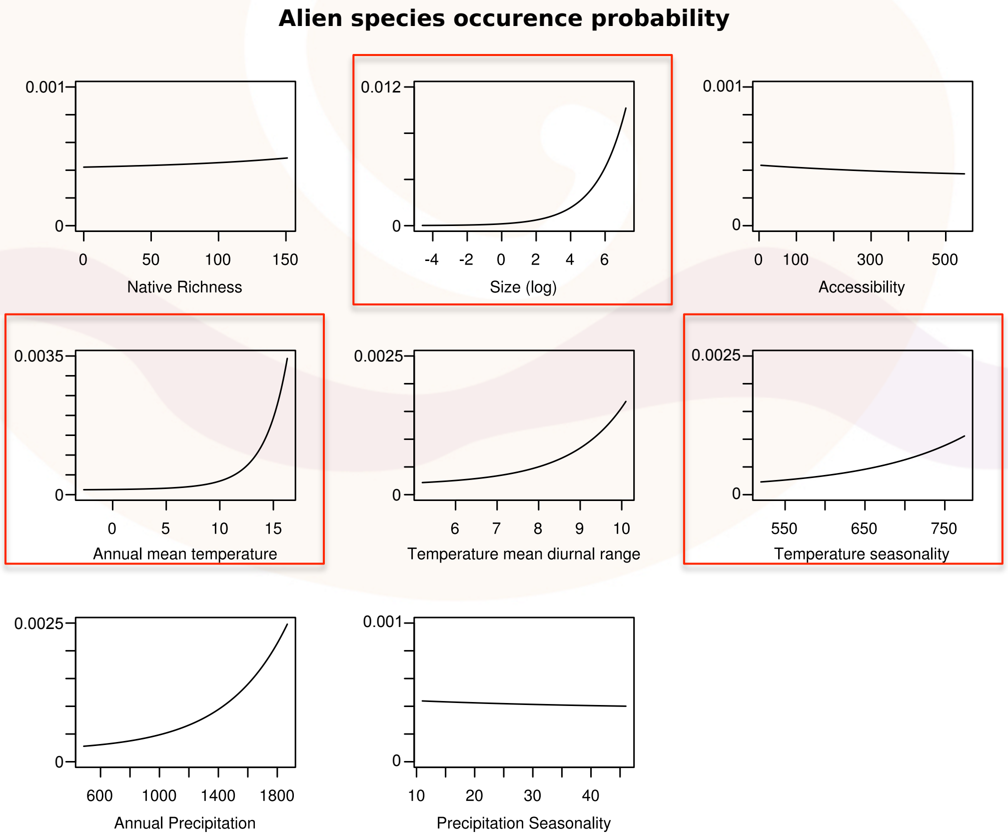
GLMM model averaging (based on 95% CI Δaic)

Random effect:
- Taxonomic group
- Habitat
- Nodes/sites

Invasion drivers and determinants of AS richness

Pressure	Abiotic	Biotic
• Accessibility (time in minutes to reach the closest town with at least 50000 inhabitants)	• Mean annual temperature • Mean temperature diurnal range • Temperature seasonality • Annual precipitation • Precipitation seasonality	• Species richness • Body Size (maximum body size was estimated for each species and then averaged by taxon)

Invasion drivers



Significant variables:

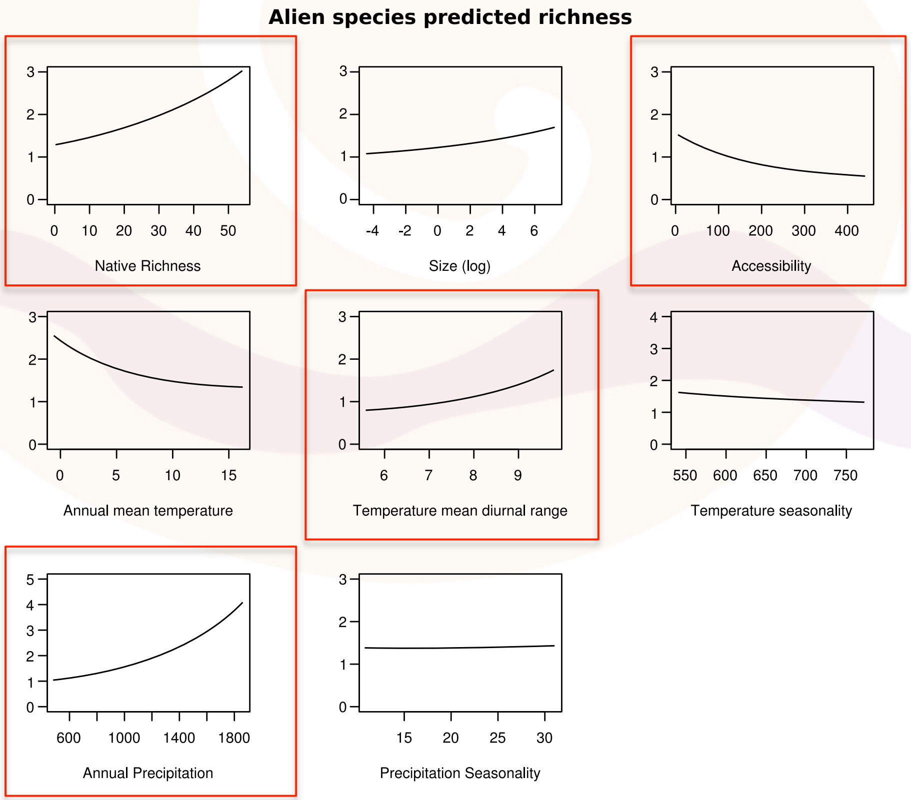
- Higher seasonality
- Annual mean temperature > 10°C
- Size > 20mm

Fixed Effect	Estimate ± se	Wald z	Pr(>|z|)	RI
(Intercept)	-19.69 ± 4.38	4.49	<0.001	
Mean annual temperature	0.391 ± 0.197	1.982	0.047	0.75
Annual precipitation	0.002 ± 0.001	1.63	0.103	0.61
Temperature seasonality	0.007 ± 0.003	2.257	0.024	0.81
Body size	0.591 ± 0.225	2.621	0.008	0.88
Temperature mean diurnal range	0.588 ± 0.346	1.696	0.089	0.66
Accessibility	-0.001 ± 0.003	0.36	0.718	0.28
Precipitation seasonality	-0.011 ± 0.053	0.207	0.836	0.26
Native richness	0.002 ± 0.013	0.165	0.869	0.25

Logistic regression

AS occurrence ~ Pressure+Abiotic+Biotic + (taxonomic group+ Node/site + Eunis_L1)

Determinants of AS richness



Significant variables:

- Native richness
- Accessibility
- Temperature mean diurnal range
- Rainfall

Fixed Effect	Estimate ± se	Wald z	Pr(>|z|)	RI
(Intercept)	-2.1710 ± 3.7561	0.609	0.5423	
Accessibility	-0.0054 ± 0.0027	1.98	0.0477	0.66
Annual precipitation	0.0013 ± 0.0007	2.22	0.0264	0.63
Temperature mean diurnal range	0.4541 ± 0.2179	2.05	0.0404	0.57
Native richness	0.0231 ± 0.0104	2.185	0.0289	0.57
Size	0.1103 ± 0.0639	1.694	0.0903	0.4
Temperature seasonality	-0.0027 ± 0.0022	1.21	0.2265	0.29
Precipitation seasonality	0.0118 ± 0.0406	0.287	0.7741	0.21
Mean annual temperature	-0.0528 ± 0.1176	0.445	0.6562	0.3

Poisson regression

AS richness ~ Pressure+Abiotic+Biotic + (taxonomic group+ Node/site + Eunis_L1)

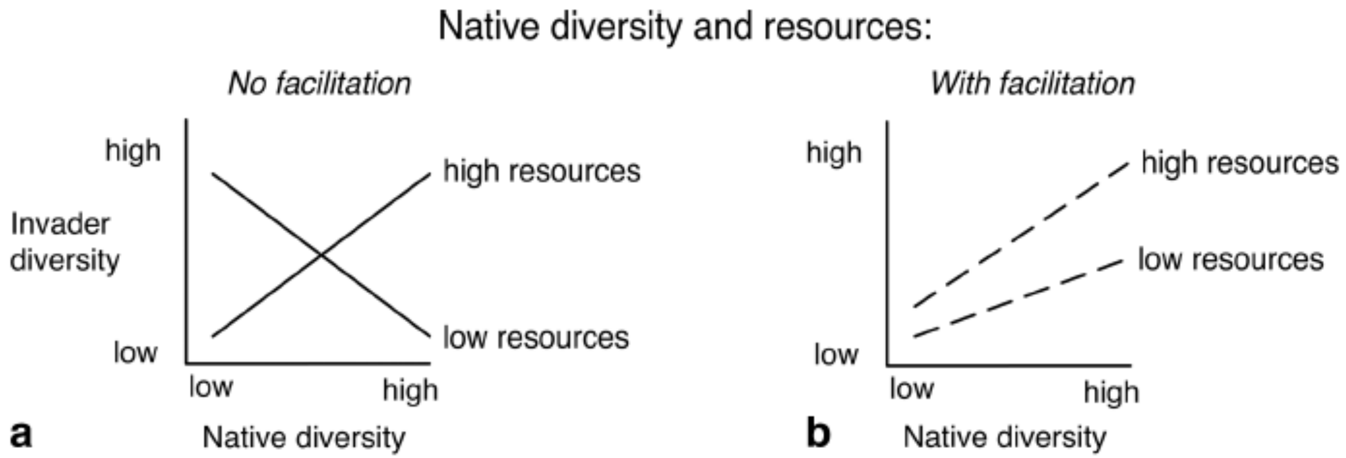
The role of size

Body size is important in many ways in both macroecology and eco-evolutionary dynamics, and may be a relevant trait in invasion biology

- Within our dataset, most of the alien species were fishes, flowering plants and other relatively large bodied taxa. The most common species shared among lentic and lotic sites were fishes, and this can be explained by their vagility. Yet, direct human activities are the main driver of the introduction of alien fishes.
- However, the occurrence probability increase when size reach only 2 cm! This can suggest that a very small size is a disadvantage in colonization process (i.e only passive transport and mostly accidental introduction)
- The effect of body size could be explained as well by the complexity to observe alien species in taxonomic groups with smaller size associated with taxonomic uncertainties, and by the larger biogeographical ranges in very small species , i.e. microbial species seems to be less prone to be (or to be considered) aliens

Native species diversity is an important determinant of invasion success?

- The relationship between native and alien richness is debated. The scale of the experiment and/or observation appear to be relevant in determining a positive or negative relationship.
- In our case the relationship is positive supporting a scenario where sites with high native richness can also host new non-native species.



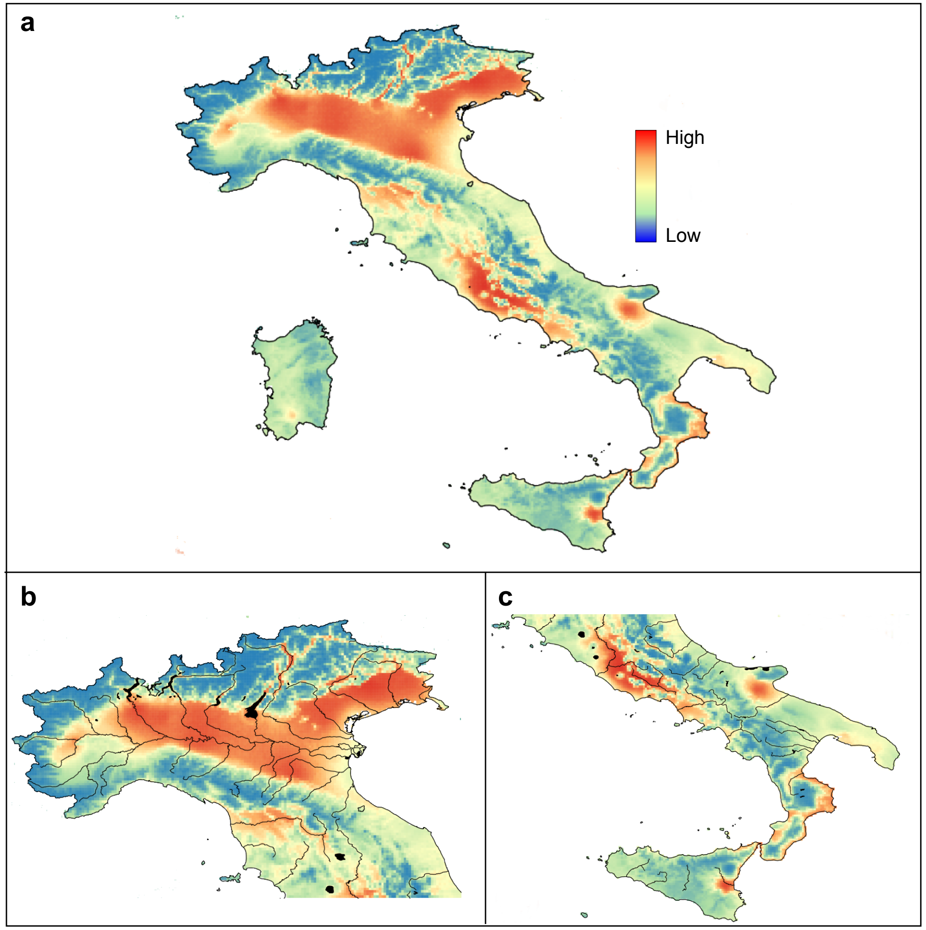
from Olyarnik et al., 2009

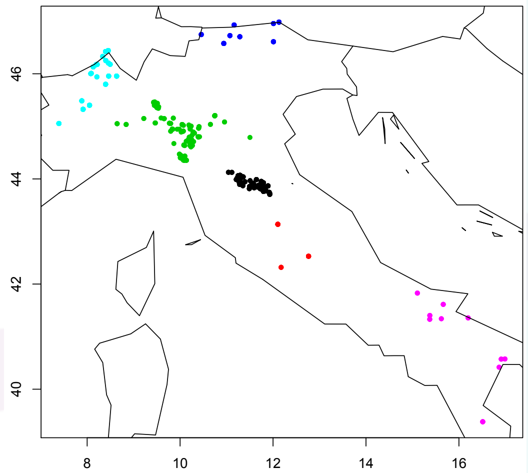
Abiotic filter and propagule pressure

We identified site-related features, showing that specific climatic conditions coupled with high accessibility produced a relative higher risk of invasion.

- AS occurrence probability and AS richness are both influenced by abiotic characteristic of sites. This support a primary role of climate as initial abiotic filter
- Proximity to large towns (propagule pressure) become relevant particularly to explain the number of alien species.

It is possible to predict high risk areas for AS invasion?





An important feature of our models is that it considers simultaneously different taxa and habitats, giving a picture of invasion dynamics not related to a single species.
In principle we can use this model to create an invasion risk map for the entire Italy.

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