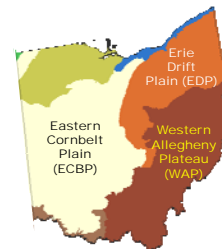


# Predicting the effects of toxic substances upon functional diversity of North-American fish species.

Leslie Faggiano<sup>1</sup>, Dick de Zwart<sup>2</sup>, Arie Vonk<sup>2</sup>, Scott Dyer<sup>3</sup> and Muriel Gevrey<sup>4</sup>



<sup>1</sup> University of Girona, Spain  
<sup>2</sup> RIVM, Bilthoven, The Netherlands  
<sup>3</sup> Procter & Gamble, Cincinnati, Ohio, USA  
<sup>4</sup> University of Toulouse, France

Email contact: leslie.faggiano@udg.edu

## Introduction:

Currently, we face a major challenge in determining the impact of the widespread presence of toxic substances in freshwater ecosystems. The establishment of a causal relationship between a stressor and his effect can be hampered by natural variability (as every sampling site exhibit a unique combination of environmental variables and species) and by the presence of confounding factors (other anthropogenic or natural stressors can mask the effect of a particular stressor).

The use of species traits represents a promising approach towards encompassing both natural variability and confounding factors [1]. The functional diversity approach holds more potential for making quantitative prediction of the representation organismal groups along gradients of environmental alteration caused by humans than the typical taxonomical approach. Moreover, in this study the use in this study of a comprehensive spatial database of biological (fish), chemical, habitat, land-use, and toxicity variables for hydrologic catchments throughout the state of Ohio (USA) provided an opportunity to take into account the myriad of potential factors that might affect biological community status.

## Materials:

- A list of two 'biological' traits, i.e trophic ecology and reproductive strategy, for each fish species was obtained from the literature [2]. Moreover, the mean body mass of 60 fish species collected in Ohio was used to split them in three categories: Small (n= 24; mean body mass: 3.20g), Medium (n=17; mean body mass: 18.03g) and Big (n= 19; mean body mass: 407.81g). Fish assemblage data collected in three different ecoregions (Eastern Corn Belt Plains: 537 sampling sites; Erie Drift Plain: 289 sampling sites and Western Allegheny Plateau: 288 sampling sites) were used to weight the occurrence of these three traits.
- Four different sets of environmental descriptors were spatially related to monitored biological sites:
  - Habitat characteristic (quality of: substrate, cover, channel, riparian, pool and riffle)
  - general Chemistry (Nitrate, Total Phosphorus, TDS, Hardness, Ca, Mg, Na, BOD, COD, pH, TSS, Ammonia, Nitrite, TKN, K, Cl, SO4 and Conductivity)
  - Landcover (percentage of land use by: agriculture, forest, urban and water)
  - Estimated Toxicity effects (multi-substances Potentially Affected Fraction) from in stream exposure to pesticides, pharmaceuticals, estrogens, household product chemicals and industrial chemicals.

## Methods:

- A between Principal Component Analysis (PCA) was used in order to obtain a percentage of variance explained in each dataset (Chemistry, Habitat, Landcover, Toxicity and traits) by the differences between ecoregions. A Linear Discriminant Analysis (LDA) was performed on the environmental parameters to highlight the most important variables explaining the main differences between ecoregions.
- Several multilayer perceptron with backpropagation learning algorithms (MLP BP) were applied in order to make quantitative predictions of the relative frequencies of the traits categories (Size, Reproduction and Trophic) and of two biodiversity indices (Index of Biotic Integrity and fish richness) according to the four sets of environmental descriptors. The BP algorithm is a supervised learning algorithm designed to minimize the mean square error between the results or predictions computed by the network and the observations. Model performance was determined using the correlation coefficient (*r*) between observed and estimated values of all the output variables.

## Results:

Table 1 shows percentage of variance (Between PCA ratio) explained by differences between ecoregion for the biological database (Traits) and for the 4 sets of environmental descriptors.

Traits	Chemistry	Habitat	Landcover	Toxicity
1.8	12.51	3.2	45.23	13.73

Figure 1 gives the results of the LDA performed on the environmental variables (Habitat related variables have been discarded for this analysis) in response to ecoregions. The differences between ecoregion were best explained by the two Landcover variables (forest and agriculture) as well as Hardness, Mg and Ca. The WAP ecoregion was characterized by high values of percentage of forest as oppose to ECBP and EDP ecoregions.

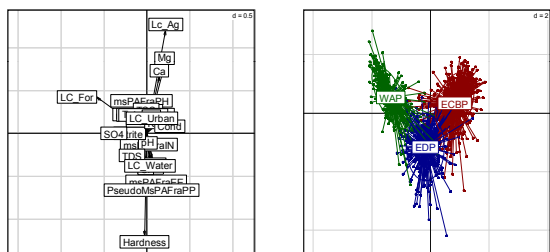


Figure 2 shows the distribution values of biological variables: a) IBI and richness; b) body Size; c) Reproductive strategies and d) Trophic group. There is a clear decrease in frequency form Small to Big fish species as well as a low proportion of Carnivorous and Planktivorous compare to the other trophic groups.

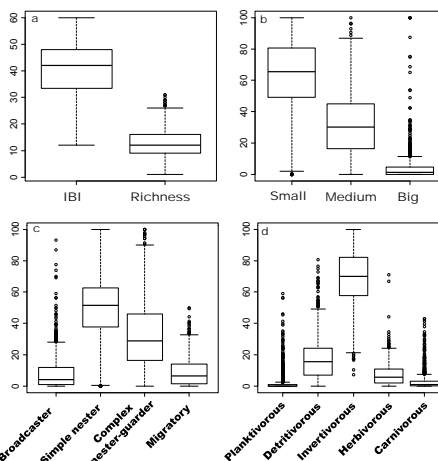


Figure 3 gives the mean and standard deviation of correlation coefficients values between observed and predicted values (MLP-BP) for each biological variable in function of the different sets of environmental predictors (Chemistry, Habitat, Landcover and Toxicity) for all the ecoregion (ECBP, EDP and WAP).

### IBI and Richness (a):

- ☐ Best prediction for IBI in general
- ☐ Comparable patterns within one ecoregion for IBI and Richness
- ☐ Best prediction with Toxicity found for Richness in the EDP ecoregion

### Size (b):

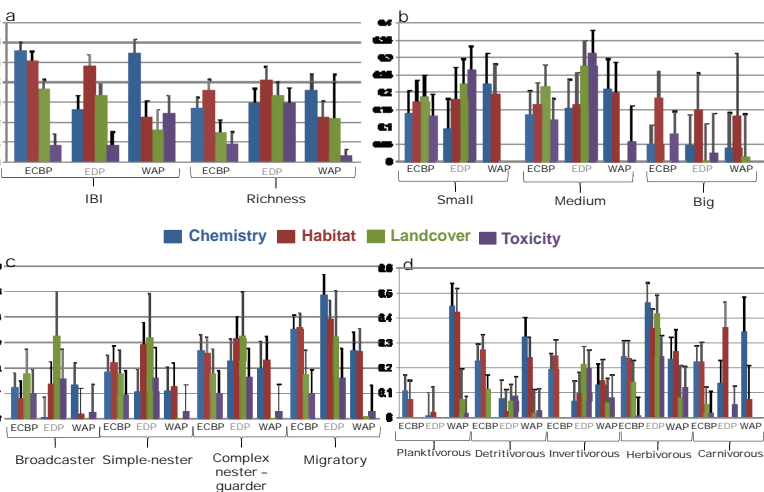
- ☐ Very poor prediction for Big fishes with a high variability compared to the 2 other modalities. Only Habitat variables seems to have an effect on the distribution of frequencies values of Big fishes.
- ☐ Similar patterns for Small and Medium Size fishes between ecoregions
- ☐ Best prediction in the EDP ecoregion for Small and Medium Size fishes for Toxicity and Landcover

### Reproduction (c):

- ☐ Worst prediction for Broadcaster: wide tolerance to environmental conditions
- ☐ Best prediction for Migratory: highly constrained by Habitat quality and general Chemistry
- ☐ Comparable patterns for Simple nester and Complex nester with an important effect of Landcover variables

### Trophic (d):

- ☐ For the WAP ecoregion; the 2 best sets of predictors are Habitat and Chemistry for all traits modalities.
- ☐ Poor prediction for Planktivorous except for the WAP ecoregion (dominated by forested area).
- ☐ Relatively high importance of Landcover and Toxicity for Invertivorous and Herbivorous fishes.



## Conclusions:

- ☐ Reproduction seems to be a suitable functional attribute to study the effects of land use on fish conditions.
- ☐ Important relationships between Toxicity and the traits modalities Size and Trophic group:
  - Size: different patterns between Small/medium and Big fishes
  - Trophic: only true for Invertivorous and Herbivorous fishes
- ☐ Our results suggest that different functional attributes of fish assemblages respond in different ways to environmental stress factors showing the suitability of this approach for a global biodiversity assessment.

### References:

- [1] Statzner B, Bady P, Doledec S, Scholl F. Invertebrate traits for the biomonitoring of large European rivers: an initial assessment of trait patterns in least impacted river reaches. *Freshwater Biology* 2005;50:2136-61.
- [2] Goldstein RM and Meador MR. Comparisons of fish species traits from small streams to large rivers. *Transactions of the American Fisheries Society* 2004; 133: 971-983.

### Acknowledgement:

The authors thank the expertise and cooperation of the Ohio EPA, whom without collecting biological data throughout the state would not make it possible to test the relationship of prognostics and diagnostics at diverse geographical scales. A PhD funding was provided by the EU project keybioeffects (MRTN-CT-2006-035695).