PREDICTING THE IMPACT OF MULTIPLE CONTAMINATIONS AT THE POPULATION LEVEL USING BIOMARKER MEASUREMENTS IN STICKLEBACK.

SUMMARY

Currently, the Water Framework Directive is based on measuring the unit concentrations of around fifty chemical substances to assess the state of the aquatic environment. However, although these measurements are compared to threshold values derived from laboratory bioassays, chemical analyses alone do not allow for an evaluation of the toxic complexity of the mixtures present at the studied sites. To better understand the effects of pollutant cocktails in the environment, the use of biomarker batteries in biomonitoring is a relevant approach. Indeed, biomarkers serve as early indicators of the impact of contaminants on populations and communities and are widely used in research. However, the lack of a standardized methodology (such as the choice of species or the type of biomarker of interest) and the challenges in interpreting results make their integration into regulatory monitoring programs difficult.

Ineris has participated in various projects aimed at standardizing the use of biomarkers in monitoring programs (SASHIMI, Biosurveillance, DIADeM projects, etc.) and defining ranges of natural variation. In parallel, efforts have been made to model the links between biomarker responses, the effects measured on individuals, and their consequences at the population level, particularly for biomarkers related to reproduction.

In this context, the proposed doctoral research aims to improve the operational use of biomarkers by linking early biological responses (biomarkers) observed in the field to their effects on organism traits and performance, and subsequently assessing the impact of these effects on the sustainability of population dynamics. This research builds upon previous work on biomarkers related to reproduction and energy management and will extend the approaches to include genotoxicity parameters.

More specifically, this doctoral project will seek to establish relationships between biomarker responses obtained during a field campaign (as part of the Interreg Orion project) and individual and population-level responses using scaling models. This work will leverage mathematical scaling models developed at Ineris for the three-spined stickleback. In particular, recently developed models that have linked two reproductive biomarkers to population-level effects will be used (e.g., the relationship between spiggin levels and male nesting behavior, as well as the relationship between circulating vitellogenin levels and female fertility).

Three key objectives are identified:

- Evaluating biomarker responses following in situ exposure (adult fish caging).
- Confirming and modeling the link between selected biomarkers and associated life-history traits (based on field and laboratory data).

- Predicting the impact of multiple contaminations at the population level based on biomarker measurements obtained from stickleback caging along the Meuse River (using field data).
- The student will participate in field campaigns scheduled as part of the Interreg Orion project and contribute to improving knowledge on the link between biomarkers and life-history traits through controlled laboratory tests.

METHODOLOGY AND KEY STAGES

October 2025 – April 2026:

- Literature review on the topic and development of a methodological proposal (October 2025 – March 2026).
- Study the relationship between biomarkers and life-history traits based on energetic data (from a previous project) and reproductive markers (initial data from a previous project).
- Field caging experiment (March 2026) and in vitro exposure of spermatozoa before fertilization (April 2026).

April 2026 – December 2026:

- Biomarker – life-history trait relationship analysis (April – May 2026): comet assay, SCSA, egg quality, egg/larvae/juvenile survival, sperm quality.
- Participation in the second sampling campaign (October 2026).
- Analysis of key biomarkers (energetic, reprotoxic, genotoxic – October 2026).
- Application and refinement of scaling models using field analysis data (Interreg ORION project – May 2026 – March 2027).

January 2027 – April 2028: Integration of all results into a DEB-IBM model (developed in previous research).

April 2028 – September 2028: Scientific dissemination and manuscript writing (5 months).

DESIRED PROFILE

Master's degree (MSc) in: (i) Ecotoxicology, Toxicology, and/or Environmental Health, or (ii) Biostatistics/Biomathematics with solid knowledge in Ecology/Toxicology. The candidate should have a strong interest in computer programming.

HOST LABORATORY

The PhD research will take place within the ESMI unit of INERIS (located in Verneuil-en-Halatte, 60 km north of Paris) in collaboration with the TEAM unit. INERIS has all the necessary technical platforms to conduct this PhD project.

The PhD position will be fully funded (100%) by INERIS, and the doctoral candidate will be employed on a fixed-term contract (CDD) for the entire duration of the PhD.

Application Process

To apply, candidates must send the following documents by email to **remy.beaudouin@ineris.fr** and **Anne.Bado-Nilles@ineris.fr** before **May 5, 2025**:

- CV
- Cover letter
- At least one recommendation letter from an academic supervisor or previous mentor
- Master's (or equivalent) transcript of records