Health in Biology: Detecting Vulnerability in a Changing World

The inter-departmental *Health in Biology* meeting held at ISEM in April 2026 brought together researchers from the ISEM teams Bio2S and ORIGINS, as well as colleagues from the Centre d'Économie de l'Environnement de Montpellier (CEE-M). Across the presentations, a shared set of questions emerged around the detection of early changes in biological and socio-ecological systems, the unequal distribution of vulnerability, and the propagation of disturbances across levels of organisation. While being independent studies, the meeting highlighted a set of converging methodological and conceptual challenges across disciplines working on health, biodiversity, and environmental change.

Detecting early and latent changes in biological systems

A first transversal theme concerned the identification of biological changes that occur before they are directly observable.

At the organismal level, experimental work on human responses to early-stage immune activation showed that subtle changes in body odour, facial appearance, and movement can be detected within hours of inflammation onset and are sufficient to modify social perception and trigger avoidance behaviours (Arnaud Tognetti, CEE-M). This suggests that behavioural systems may be sensitive to states of infection earlier than previously assumed, i.e., before the emergence of overt symptoms.

Similar questions arise at the developmental level. Comparative analyses of vertebral morphogenesis across vertebrates suggest that conserved developmental constraints can be used to identify early markers of potential anomalies in human spinal development, with implications for prenatal screening strategies (Lionel Hauthier, ORIGINS). In both cases, the focus is not on pathology itself, but on upstream indicators that precede it.

At the genomic and ecological levels, hidden variation also plays a central role. Pangenomic analyses based on multiple globally distributed human genomes revealed that transposable elements contribute substantially to genetic diversity and gene regulation. Rare variants identified through this framework may be associated with disease susceptibility and population structure (Anna-Sophie Fiston-Lavier, ORIGINS). In parallel, environmental DNA approaches in aquatic systems and bat guano demonstrated that biodiversity and pathogen presence can be inferred from indirect molecular traces, enabling the detection of otherwise unobserved ecological complexity (Helena D'Cotta, Bio2S; Orianne Tournayre, ORIGINS).

Together, these studies converge on a common issue: relevant biological variation often exists before it becomes directly measurable at the level of symptoms, species counts, or phenotypes, requiring indirect or integrative detection strategies.

Vulnerability as an interaction between exposures and pre-existing states

A second theme concerned the conditions under which exposure to a disturbance translates into adverse outcomes.

Rather than acting uniformly, environmental exposures often interact with pre-existing vulnerabilities. In the case of air pollution and COVID-19 outcomes, increased mortality associated with fine particulate matter was observed primarily among individuals with comorbidities, while no significant effect was detected in otherwise healthy populations (Carla Morvan, CEE-M). A related dynamic was observed during the COVID-19 pandemic at the population level. Beyond direct infection effects, excess non-COVID mortality, identified using variation in epidemic timing across territories, increased following hospital system saturation, reflecting reduced access to care for other conditions (Emmanuelle Lavaine, CEE-M). Together, these results show how environmental and system-level constraints can amplify vulnerability beyond the disease itself.

In labour and health economics, similar interaction effects were observed. Job loss and workplace automation both had significant impacts on mental health, but these effects were heterogeneous, depending on re-employment prospects, age, and skill level, suggesting that vulnerability is unevenly distributed across socio-economic groups (Pauline Leveneur, CEE-M).

In ecological and food systems, comparable interaction structures were identified. In aquaculture systems exposed to multiple simultaneous stressors—chemical inputs, pathogens, and antimicrobial use—health outcomes in fish reflected the combination of exposures rather than single drivers (Mame Boucar Diouf, Bio2S). Similarly, in oral and cognitive health, interacting feedback loops between diet, metabolic inflammation, and oral microbiome composition suggest bidirectional pathways linking behavioural, biological, and neurological processes (Daisy Recchia, Bio2S).

Across these systems, vulnerability appears less as an intrinsic property than as an emergent outcome of interactions between exposures, internal states, and feedback mechanisms.

Cross-scale processes and interconnected systems

A third theme concerned the ways in which processes operating at different levels of organisation jointly shape outcomes.

At the interspecific level, infectious disease dynamics are strongly influenced by pathogen diversity. In white-nose disease in bats, the causative agent is not a single fungal species but two cryptic, host-specialised species with distinct spatial distributions, a finding reshaping the evolutionary history of this disease outbreak in North America (Sébastien Puechmaille, ORIGINS).

At the population and ecosystem levels, long-term genetic analyses of migratory fish in the Sanaga River revealed species-specific patterns of connectivity and demographic expansion, shaped by historical climatic changes and potentially affected by current anthropogenic pressures such as dam construction (Hervé Tjomb, Bio2S). In parallel, biodiversity monitoring in Lake Guiers showed how combining classical sampling with environmental DNA improves detection of fish diversity, while also revealing current limitations linked to incomplete reference databases (Helena D'Cotta, Bio2S).

At the interface between environment, health, and society, studies on zoonotic emergence highlighted how ecological change, aquaculture intensification, and socio-economic conditions jointly influence pathogen circulation and cross-species transmission dynamics (Marine Combe, Bio2S). These

processes illustrate how environmental and social drivers are embedded within shared transmission systems.

Taken together, these contributions emphasise that disturbances rarely remain confined to a single level of organisation or species. Instead, genetic, behavioural, ecological, and socio-economic processes interact across scales to shape system-level outcomes.

Research perspectives

Several directions for future research emerged from the discussions. First, integrating heterogeneous data sources (genomic, environmental, epidemiological, and socio-economic datasets) appears essential for capturing the multi-level structure of vulnerability. Second, methodological exchanges across disciplines could strengthen causal inference and interpretation. Approaches developed in economics for identifying causal effects may be useful for ecological and epidemiological studies, while evolutionary and ecological frameworks may inform the analysis of long-term health dynamics. Finally, a shared challenge concerns the modelling of cross-scale interactions. Disturbances such as pollution, infectious diseases, ecological degradation, or economic shocks rarely remain confined to a single level of organisation. Understanding how they propagate across molecular, individual, population, and ecosystem levels remains a key research objective.

Rather than providing definitive answers, the meeting highlighted the extent to which researchers working on different systems are addressing related problems, suggesting that further integration across disciplines may be as important as methodological or empirical advances within fields.

Host institute

Institut des Sciences de l'Évolution de Montpellier (ISEM-UMR5554)

Organizers

Marie Charpentier, Bio2S
Jonathan Romiguier, ORIGINS
Arnaud Tognetti, CEE-M

Contributors

Mame Boucar Diouf, Bio2S
Damien Bricard, MRE
Marine Combe, Bio2S
Helena D'Cotta, Bio2S
Anna-Sophie Fiston-Lavier, ORIGINS
Lionel Hauthier, ORIGINS
Emmanuelle Lavaine, CEE-M
Pauline Leveneur, CEE-M
Carla Morvan, CEE-M
Sébastien Puechmaille, ORIGINS
Daisy Recchia, Bio2S
Hervé Tjomb, Bio2S
Arnaud Tognetti, CEE-M
Orianne Tournayre, ORIGINS