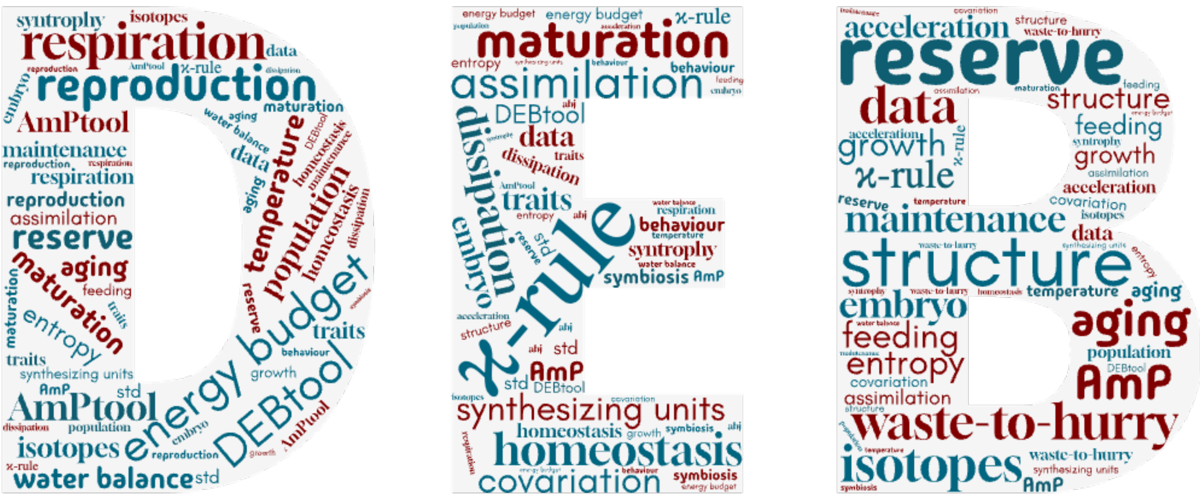
DEB 2025 9th International Symposium
& Thematic School on DEB theory for metabolic organization

26 May - 6 June 2025, Heraklion (Greece)

Book of Abstracts



Hosted by:

ΠΑΝΕΠΙΣΤΗΜΙΟ ΚΡΗΤΗΣ
UNIVERSITY OF CRETE

About DEB2025

Welcome to DEB2025, the ninth in a distinguished series of tele-courses, schools, and symposia dedicated to the Dynamic Energy Budget (DEB) theory for metabolic organization.

The theme of the DEB2025 Symposium is "Stress ecology and biodiversity under climate change". As we enter the anthropocene and are now crossing critical planetary boundaries, numerical modelling is an indispensable tool for scientists, managers, and stakeholders. DEB theory provides a framework for constructing families of related models, rooted in a mechanistic description of the individual metabolic processes. This mechanistic approach is essential for linking functional traits to predictive variables, ensuring that models remain adaptable to shifting environmental conditions. A key challenge in model applications is the assessment of parameter values. Many applications of DEB theory have demonstrated the capacity to extract meaningful parameters from data, enabling models to inform effective decision-making. This symposium will showcase the latest advancements in DEB theory and its applications, fostering cutting-edge, cross-disciplinary developments to address the pressing ecological challenges of our time.

With more than 1,250 publications incorporating DEB theory and nine special issues dedicated to its development and applications, it has become a cornerstone in an era defined by data abundance and interdisciplinary collaboration. In conjunction with this 2025 course and symposium, we are now organizing the https://deb2025.sciencesconf.org/resource/page/id/34 10th special issue, a testament to the continued growth and vitality of the DEB research community. DEB provides a common quantitative language that connects scientists across fields and ecosystems. The thematic school held in advance of this symposium reflects this spirit: offering early career researchers training, mentorship, and tools, while also serving as a platform for experienced scientists to refine techniques, explore new directions, and shape their research questions.

This year's event includes 75 participants from 22 different countries (Argentina, Australia, Brazil, Canada, China, Croatia, Denmark, France, Germany, Greece, Italy, Israel, Netherlands, Poland, Portugal, Saudi Arabia, Slovenia, Spain, South Africa, Sweden, UK, USA). The programme includes four keynotes speakers, 31 contributed talks and 21 posters.

We hope this symposium offers valuable insights, collaborations, and fresh inspiration for your work with DEB theory.

The DEB2025 Organizers

Organization

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CEA

Contents

Navigating the puzzle: Dynamic energy budget models for assessing environmental risks and efficacy of pesticides

André Gergs * [1]

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The registration of plant protection products requires comprehensive assessments of both efficacy and environmental risk, necessitating a careful balance between optimal performance and minimizing ecological impact. A mechanistic understanding of chemical behavior is vital for making accurate predictions in untested scenarios, such as extrapolating results from laboratory settings to field conditions and accounting for varying exposure situations. This complexity involves multiple levels of biological organization and the distribution and degradation of active ingredients in the environment as well as their uptake and metabolism in target and non-target organisms. Additionally, understanding life history traits and population dynamics of both pests and non-target species is crucial for effective assessments and management. In this context, toxicokinetic-toxicodynamic (TKTD) modeling, particularly Dynamic Energy Budget (DEB) modeling, plays a key role in enhancing our understanding of these interactions. (1) This presentation will first elucidate how DEB-based TKTD and population models can optimize application timing for insecticides. By integrating formulated product interactions with environmental factors, these models provide insights that enhance sustainable pest management strategies. (2) Secondly, I will illustrate the utility of DEB-TKTD models in environmental risk assessments. Through several examples, I will demonstrate how these models can be applied to address the uncertainties typically associated with those assessments.

*Keynote speaker

Keynote Session 2: Theoretical and methodological developments and new applications

The Evolution of how life harnesses energy and elements, from the big bang to biodiversity

Gonçalo Marques * [1]

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Life emerged on our planet, which remains the only known place where its existence is confirmed. The integration of Dynamic Energy Budget (DEB) theory and Big History offers a comprehensive framework for exploring the evolution of energy use and the role of key atomic elements in shaping life on Earth. DEB theory is based on strong first principles, providing quantitative models of how organisms acquire, allocate, and utilize energy. These models can be used to link individual metabolic processes to broader ecological and evolutionary dynamics. In contrast, Big History contextualizes these biological developments within the grand narrative of cosmic, planetary, and life evolution. Here I will examine how life's energy strategies have evolved in response to shifting environmental and biochemical constraints. Starting from the origins of essential elements in stellar nucleosynthesis to the metabolic innovations that transformed Earth's biosphere. Key milestones such as the emergence of photosynthesis and the rise of multicellularity, will be explored through the lens of the same first principles that sustain DEB theory, providing insights into the adaptive mechanisms that have shaped biological complexity. By synthesizing these perspectives, I will highlight the deep interconnections between energy flow, elemental cycles, and evolutionary processes.

*Keynote speaker

Keynote Session 3: Metabolism across levels of biological organization

Decoupling the dynamic duo: Examining whether and how symbiosis regulates metabolic resilience in an era of global change

Randi Rothan * [1]

[1] Boston University, USA

By definition, DEB Theory is inherently dynamic, embracing the flux and flow of energy acquisition and exchange between organisms and their environment. Symbiotic organisms pose additional challenges because their energetic exchange is governed by the metabolic demands and constraints of both themselves and their partners. Corals are a classic mutualism between an animal host and a photosynthetic symbiont, with reciprocal nutrient and energy flow between partners. However, this energy flow is increasingly disrupted (dysbiosis) due to drastic and extreme environmental perturbations, resulting in coral bleaching and often, mortality. In these unprecedented times, a relatively diminutive Northwest Atlantic coral is fast-becoming an important experimental system to probe the fundamentals of basic coral metabolism. This temperate coral has a facultative association with photosynthetic symbionts where the coral host can live with - and functionally without - symbionts in multiple energetic states. After a decade of study, we have found that this coral challenges long-held assumptions about coral biology, compelling us to ask (and answer) fundamental questions about symbiosis, metabolism, physiology, and evolutionary ecology with lab, field, and modeling studies. We are using the quantitative and empirical values from these studies in application of DEB theory, which has the potential to transform our holistic understanding of facultative symbioses. This talk will explore the potential of DEB theory to help understand and predict trophic flexibility of symbiotic partners under environmental stress, and how symbiosis does (or does not) contribute to metabolic resilience.

*Keynote speaker

Marine ecosystems in the Anthropocene: functional aspects and ecological challenge

Ioannis (Yannis) Karakassis * [1]

[1] University of Crete, Greece

Life emerged in the sea and for more than 85% of the evolutionary time it had remained an exclusively marine issue. However, there are more species in the terrestrial environment than in the oceans mainly due to the spectacular speciation of insects. On the other hand, there are more marine phyla (i.e. major differentiation life plans) in the sea, almost half of them endemic to the marine realm. Differences between terrestrial and marine ecosystems involve differences between the ambient fluids but also differences in variability and predictability of marine and terrestrial ecosystems. Marine biodiversity comprises organisms with numerous functional traits resulting in multidimensional matrices showing patterns similar to those of species by samples. Furthermore, the use of traits, as opposed to species, allows comparisons among different biogeographic provinces which harbour different faunal elements. A large-scale study comparing response of benthic taxa to disturbance across ocean provinces is discussed.

*Keynote speaker

Abstracts for oral presentations alphabetically

Modeling the Spatiotemporal Impacts of Ocean Warming and Acidification on the U.S. Atlantic Sea Scallop to Guide Adaptive Fisheries Management

Halle Berger*[1], Samantha Siedlecki[1], Shannon Meseck[2], Emilien Pousse[3], Dvora Hart[4], Felipe Soares[1], Antonie Chute[5], and Catherine Matassa[1]

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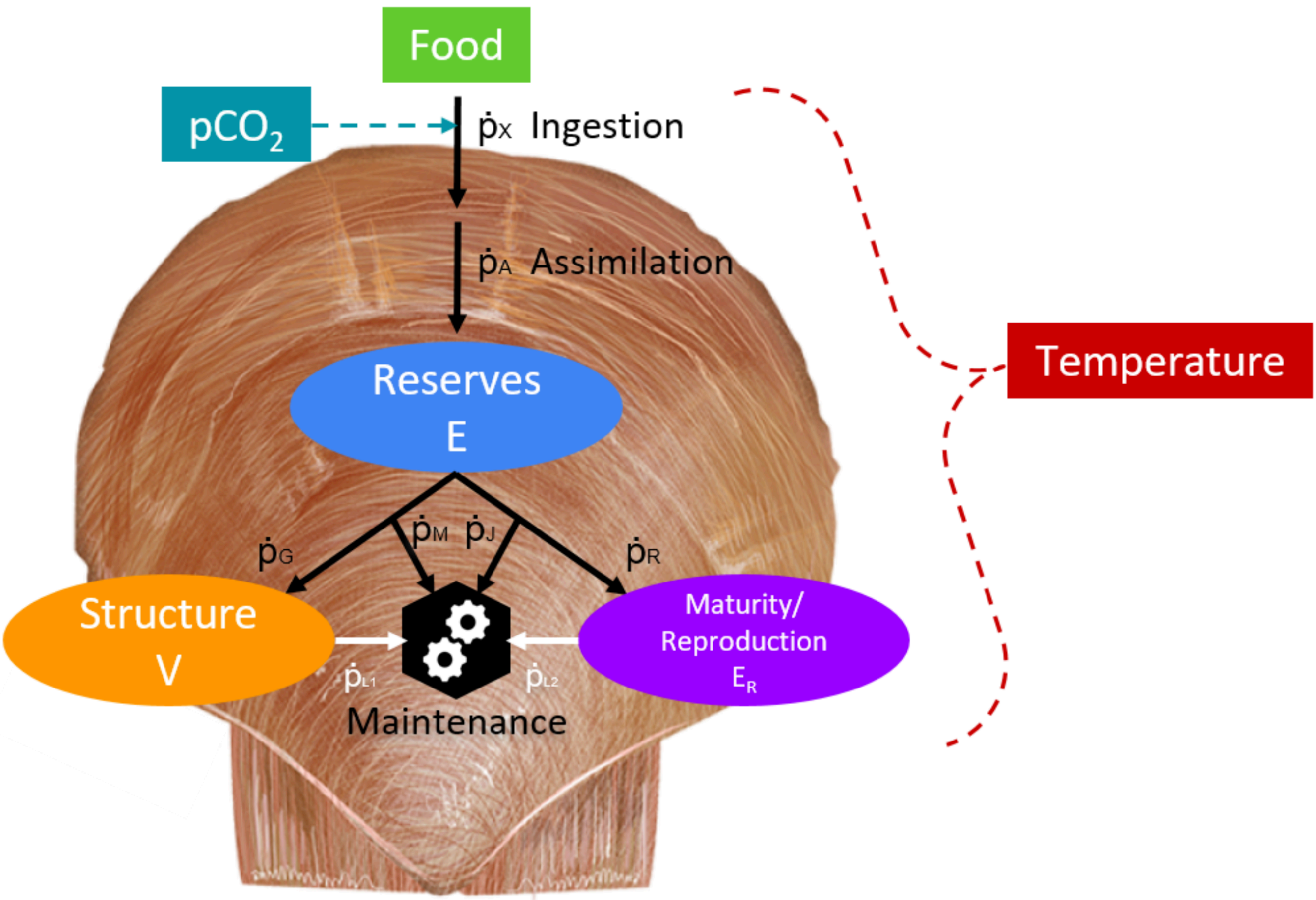
Abstract

The Atlantic sea scallop (Placopecten magellanicus) fishery is one of the most valuable fisheries in the U.S. However, changing ocean conditions driven by climate change and ocean acidification (OA) may cause declines in scallop availability, harvest, and revenue. Scallop habitats in the Northeast and Mid-Atlantic already experience suboptimal temperature and carbonate chemistry conditions episodically. Regional oceanographic models predict that these conditions will continue and worsen in the future under the most severe emissions scenario, projecting that most scallop habitats will experience chronic stressful conditions by 2100. Here, we project the effects of OA and warming on sea scallop growth historically and over the next century using a dynamic energy budget (DEB) model coupled to a regional ocean model. The model was able to simulate observed patterns in scallop growth based solely on temperature, food, and pCO2 conditions. Under combined end-of-century OA and warming, scallops grew slightly faster but reached smaller maximum shell heights in most areas, with mortality largely confined to the southern Mid-Atlantic. While OA contributed to sublethal impacts on growth uniformly across the region, warming had a more variable effect, ranging from positive in the north to lethal in the south. Notably, the cold pool area and deep Gulf of Maine emerged as thermal refugia and simulated scallops there did not experience net negative impacts on growth despite OA, making these areas potential candidates for rotational management. Altogether, our findings demonstrate the utility of the spatially coupled DEB model as a tool to inform adaptive fisheries management.

Keywords: Bivalve, climate change, multiple stressors, future projections, fisheries management

*Speaker



Food
pCO2
ṗX Ingestion
ṗA Assimilation
Reserves
E
ṗG
ṗM
ṗJ
ṗR
Structure
V
Maturity/
Reproduction
ER
ṗL1
ṗL2
Maintenance
Temperature

High Throughput Adaptation of Standardized Ecotoxicological Exposure Tests in Daphnia magna and Other Invertebrates

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Abstract

Modern mechanistic modelling can create extrapolations of chemical toxicity across multiple organisms; however, it tends to require large amounts of measurements. New technology and equipment have introduced the opportunity of using high-throughput testing techniques to facilitate the collection and automated processing of high volumes of experimental data. This study demonstrates the adaptation of *Daphnia magna* chronic OECD standard procedures to a High Throughput setting using a Cell imager and well plates. The method was extended to other invertebrates used in similar ecotoxicological tests, such as *Moina macrocopa and Heterocypris incongruens*. In the experiment, *D. magna* was cultured closely following OECD guidelines, adapting them to culturing in well plates. The experiment comprised ten individuals per replicate for each of five concentrations for eight chemicals. A further 80 individuals were established in the medium without any chemical addition to serve as controls. This required twenty-four 24-well plates with 480 wells used in total in the experiment.

D. magna lengths ranged between 1.8 and 3.0 cm after 14 days, with little mortality ($< 20\%$). A dose-response effect for sublethal endpoints (growth and reproduction) was found for all eight chemicals tested.
We aimed to standardize high throughput methods by exposing the organisms to a range of different chemicals, measure chronic toxicity responses and use Dynamic Energy Budget Theory (DEB) Toxicokinetic – Toxicodynamic (TKTD) modelling to test fits and derive relevant parameters. Results indicate that this technique can greatly improve cost efficiency of ecotoxicological tests to complement mechanistic modelling needs.

Keywords: Standardized, Ecotoxicology, Daphnia, OECD, High, Throughput

*Speaker

From mechanistic population dynamics models to functional traits projections : the case of sand reworking by lugworms in the context of climate change

Lola De Cubber*[1]

[1]MARBEC, IRD, Univ Montpellier, Ifremer, CNRS – MARBEC, Univ Montpellier, IRD, IFREMER, CNRS, Sète, France. – Sète, France

Abstract

A major challenge in marine ecology is understanding population and ecosystem dynamics under environmental change. The integration of bioenergetic dynamic budget (DEB) models with individual-based models (IBMs) has significantly advanced our understanding of population responses. However, scaling these approaches to community and ecosystem dynamics remains challenging in coastal and benthic systems, where ecosystem engineers disproportionately influence ecosystem function and structure through their effect traits on ecosystems.
In this study, an IBM was developed to analyze the sand reworking activity of two benthic engineers (*Arenicola marina* and *A. defodiens*) under climate change scenarios. The model integrates a DEB-IBM framework with a sand reworking module based on the DEB model's ingestion flux and individual structural volume. Calibrated with data from the literature, the model generates robust predictions of bioturbation activity. Climate projections, including changes in sea surface temperature under RCP8.5 scenarios, and ad-hoc changes in chlorophyll-a levels (±10% from 2010-2020 satellite observations), were incorporated to assess population dynamics and associated sand reworking across species' distribution ranges by 2100.
The results reveal significant spatial variations in sand reworking patterns, with a general decline observed in regions where populations are currently most abundant. This decline in bioturbation activity could drive substantial changes in community structure and ecosystem functioning. To fully grasp the impacts of climate change on sandy ecosystems inhabited by these species, further studies should explore the links between sand reworking activity and sediment oxygenation.

Keywords: ecosystem engineers, functional traits, sand reworking, climate change

*Speaker

Refuges lost? Searching for refuges from disease and climate change for the critically endangered golden frog, Atelopus zeteki/varius

Luisa Maria Diele-Viegas*[1], Jakub Zegar[1], Jamie Voyles[2], Corinne Richards-Zawacki[3], and Michel Ohmer[1]

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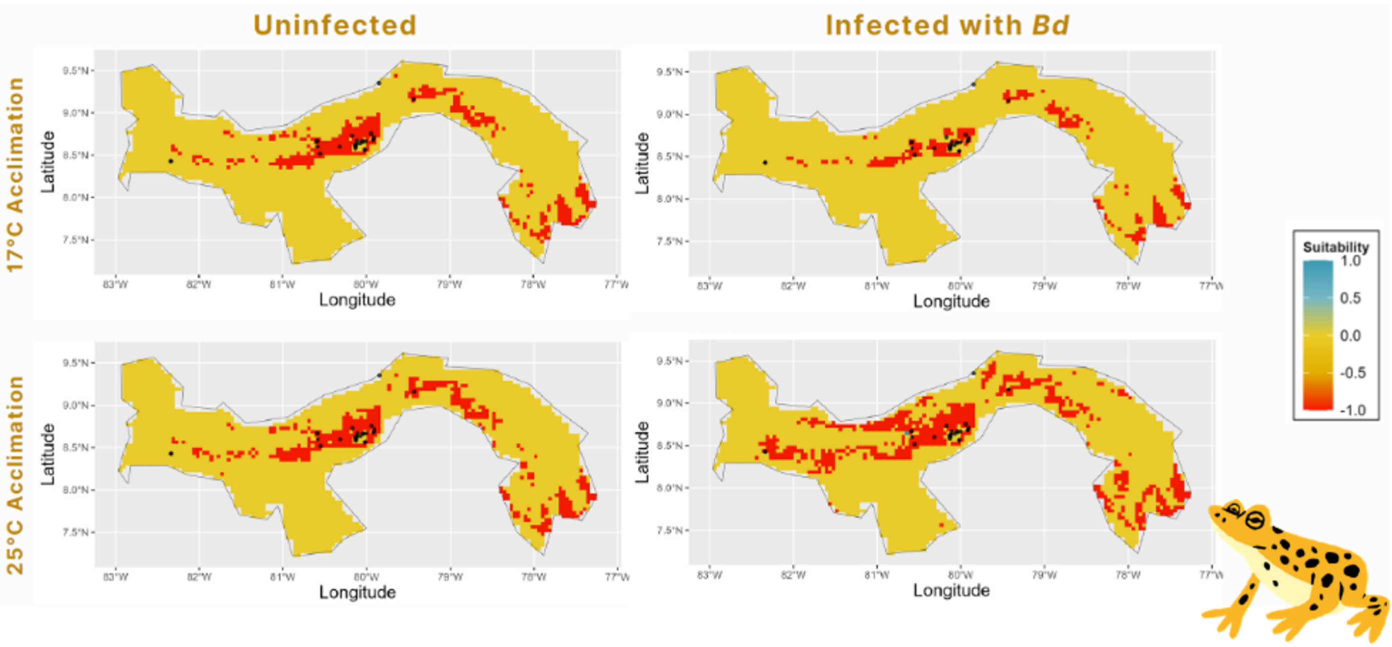
[2]University of Nevada – United States
[3]University of Pittsburgh – United States

Abstract

Harlequin toads have experienced dramatic population declines, primarily driven by infections caused by the fungal pathogen *Batrachochytrium dendrobatidis* (Bd). The fungus has led to near extinction in the wild of the Panamanian golden frog, *Atelopus zeteki/varius.* Climate change exacerbates these threats by altering environmental conditions that influence host susceptibility and pathogen dynamics, further jeopardizing the survival of remaining populations. In this study, we integrate the Dynamic Energy Budget (DEB) theory to assess how Bd infection interacts with climate to shape the thermal ecology and potential spatial distribution of *Atelopus spp.* We combine previously collected data on how Bd infection affects thermal preferences with experimentally obtained measures of critical thermal limits (CTmin, CTmax) and locomotor performance in infected and uninfected frogs to determine activity restriction across space using field-collected body temperature (Tb) data, Bd infection status, and environmental temperature data from HOBO loggers. By coupling these physiological responses with DEB-based and ecological niche models (ENMs), we explore how infection-induced energetic constraints alter individual survival and environmental suitability under future climate scenarios. Our findings highlight the importance of DEB modeling in understanding the bioenergetic consequences of disease in amphibians, offering a mechanistic approach to predicting species responses to multiple stressors. This study contributes to advancing DEB applications in conservation physiology and provides insights into the persistence of one of the most imperiled amphibian groups in the Neotropics.

Keywords: Atelopus zetekii, DEB model, ecophysiology, Bd, conservation

*Speaker


Uninfected
Infected with Bd
17°C Acclimation
25°C Acclimation
Latitude
Longitude
9.5°N
9.0°N
8.5°N
8.0°N
7.5°N
83°W
82°W
81°W
80°W
79°W
78°W
77°W
Suitability
1.0
0.5
0.0
-0.5
-1.0

"Agent-based population models of small pelagic fishes explain changes in life-history traits through Dynamic Energy Budget Theory"

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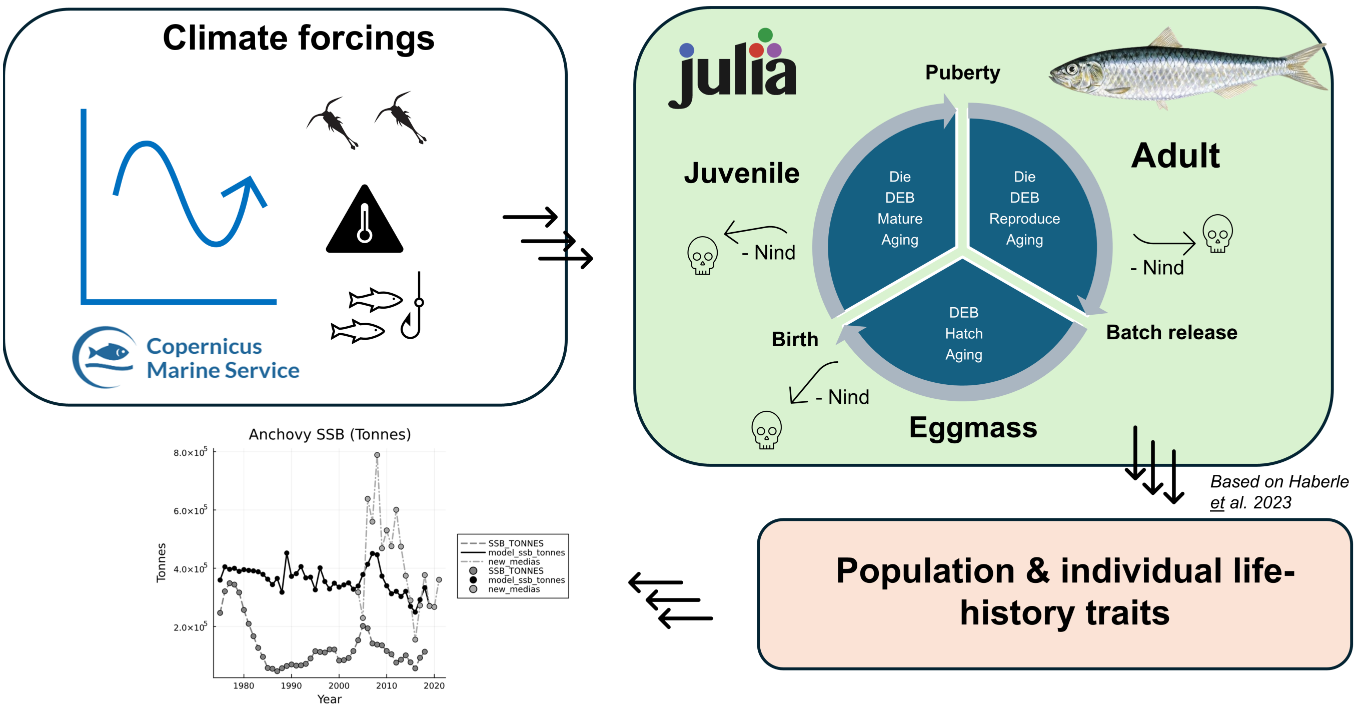
Abstract

Sardines and anchovies are vital components of marine food webs and fisheries, yet the causes behind their shrinking sizes at all life stages remain unclear. Improving our ability to predict sardine and anchovy population dynamics is crucial for sustainable management and understanding their responses to climate change, including changes in life-history traits. To address these challenges, we developed an agent-based population model using the high performance programming language Julia. This model simulates the bioenergetics of sardines and anchovies across all life stages based on the Dynamic Energy Budget Theory, accounting for temperature, food availability, and age-specific natural and fishery-induced mortality. The model account for stochastic variability and transmission of key parameters influencing growth and reproduction through generations. In this way, the model provides a platform to test various hypotheses for the observed size reduction: are the fish maturing earlier and remaining smaller due to rising temperatures, increased fishing pressure, or shifts in the plankton community? Using climate and evolutionary simulations, we demonstrate that environmental and anthropogenic forcings alone cannot account for the observed reduction in body size and the concomitant shift toward earlier reproduction in sardines and anchovies. Our analyses indicate that selection for fast-growing, small-bodied individuals is the most plausible mechanism driving these trends.

Keywords: Demography, Life history traits, Small pelagic fishes, Agent based model, Natural Selection.

*Speaker



Climate forcings
Copernicus
Marine Service
julia
Puberty
Juvenile
Adult
Die
DEB
Mature
Aging
Die
DEB
Reproduce
Aging
DEB
Hatch
Aging
- Nind
- Nind
Birth
Batch release
- Nind
Eggmass
Based on Haberle et al. 2023
Population & individual life-history traits
Anchovy SSB (Tonnes)
Tonnes
Year
SSB_TONNES
model_ssb_tonnes
new_medias
SSB_TONNES
model_ssb_tonnes
new_medias

Modeling Microbial Activity To Improve Sustainability Of Sub-Surface Flow Treatment Wetlands

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[1]Universitat Politecnica de Catalunya – Spain

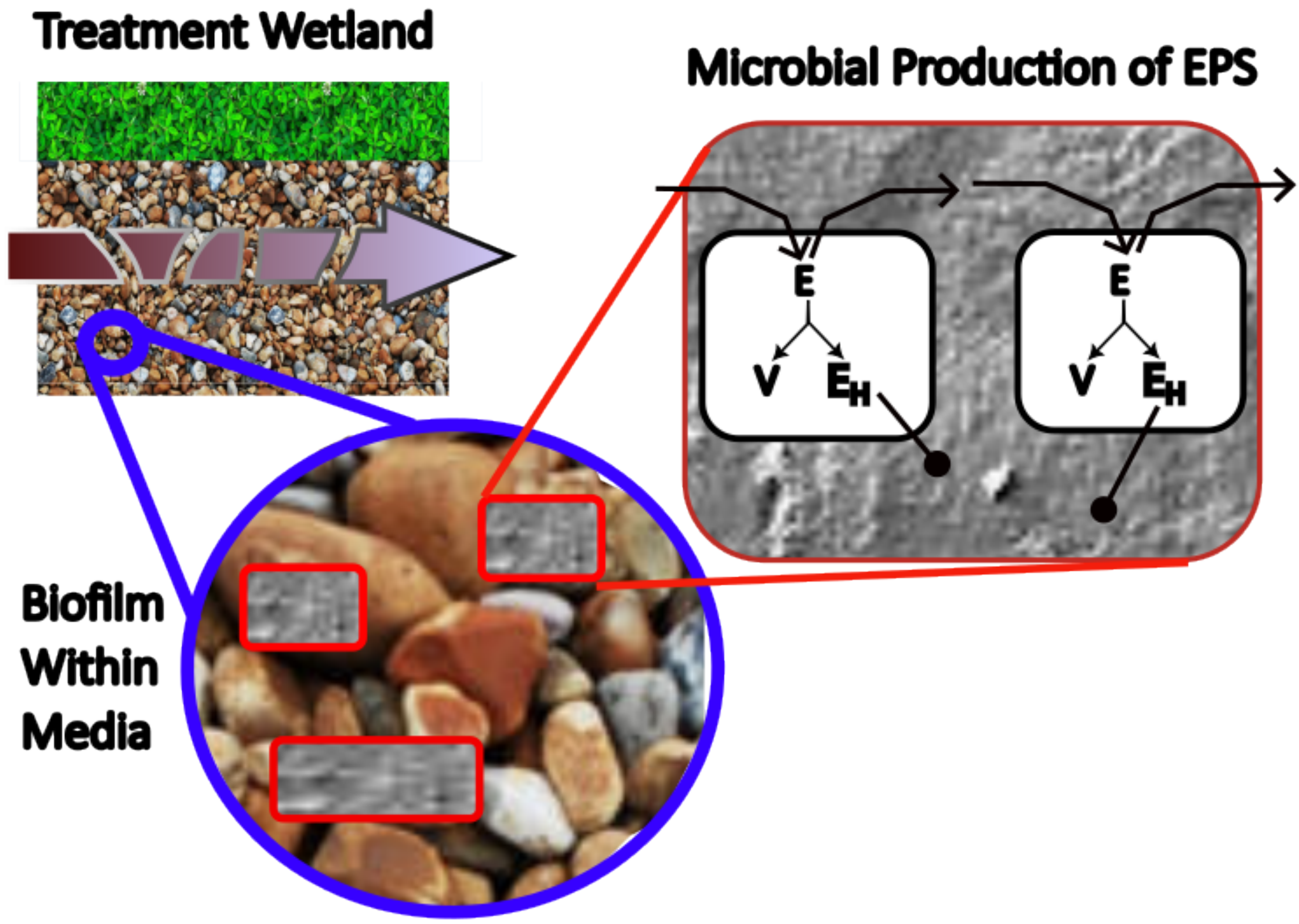
Abstract

Sub-surface flow treatment wetlands (SSF TW) are wastewater treatment systems designed to emphasize specific processes found in natural wetland ecosystems. SSF TWs can contribute to United Nations Sustainable Development Goal 6, "Clean Water and Sanitation." among others.
Microbes play a central role in SSF TW, where transformations of organic matter and nutrients take place as wastewater flows through a matrix of porous media and extracellular polymeric substance (EPS) produced by microbes. Biofilm – the total mass of microbes and EPS - is a critical component as well as a challenge to SSF TW system operation because microbes produce EPS in response to local environmental conditions. Biofilm contributes to clogging of pore spaces within TW media, can cause premature declines in pollutant removal efficiency, and ultimately leads to the end of system service life.

While a number of mechanistic numerical models are available to study internal SSF TW processes, none separates estimates of microbial biomass and production from EPS mass and production. This represents a broad gap in our understanding of how microbial dynamics actually contribute to TW system efficiency, clogging, and service life.
The objective of this study is to improve sustainability of SSF TW by developing a DEB model of microbial activity and EPS production. Departures from the Standard DEB model include: multiple taxa, multiple substrates, multiple reserves, and assignment of EPS production to DEB model maturity and reproduction. The model will quantify EPS production, as well as microbial biomass, growth, and pollutant reduction capacity (e.g. denitrification) observed in SSF TWs.

Keywords: Sustainability, wastewater treatment, bacteria, EPS

*Speaker


Treatment Wetland
Microbial Production of EPS
E
V
E_H
E
V
E_H
Biofilm Within Media

Energy restrictions cancel the effect of temperature on the common sole (Solea solea) in the Gironde estuary

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Abstract

Estuarine and coastal ecosystems are key nursery habitats for the development and growth of many juveniles of marine fish species. Human-induced environmental changes, to which coastal and estuarine areas are particularly sensitive, will largely impact juveniles' life history traits and consequently, the whole population at sea. Increase of water temperature is the best described and predicted environmental change related to climate change, and will certainly affect the nursery function of estuarine areas. Yet, our capacity to estimate consequences are limited and lack mechanistic models applied at the population level. As a major estuary of Western Europe, the Gironde estuary is a relevant case study to evaluate the effects of rising temperature on fish populations.

To study the specific impact of temperature on life history traits of juvenile common soles (*Solea solea*) in the Gironde estuary, we used a bioenergetic model based on DEB theory. Since the estuary is supposed to have reached its maximum carrying capacity, effects were also estimated in a context of limited energy availability, with forecast scenario based on IPCC previsions.

As soles in the Gironde estuary are below their thermal optimum, growth and development are expected to accelerate with increased temperature when food is not a limiting factor. Consequently, soles reach maturity sooner and grow larger. However, when we consider a restriction in available energy, linked to limited carrying capacity of the estuary, the effect of temperature is cancelled and changes in life history traits are negligible. However, a reduced energy in the reserve is estimated, which might alter the response to other environmental changes.

Keywords: Estuary, temperature, stress, energy restriction, juvenile fish

*Speaker


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Predicting Coral Bleaching in the Red Sea Using a Dynamic Energy Budget Model

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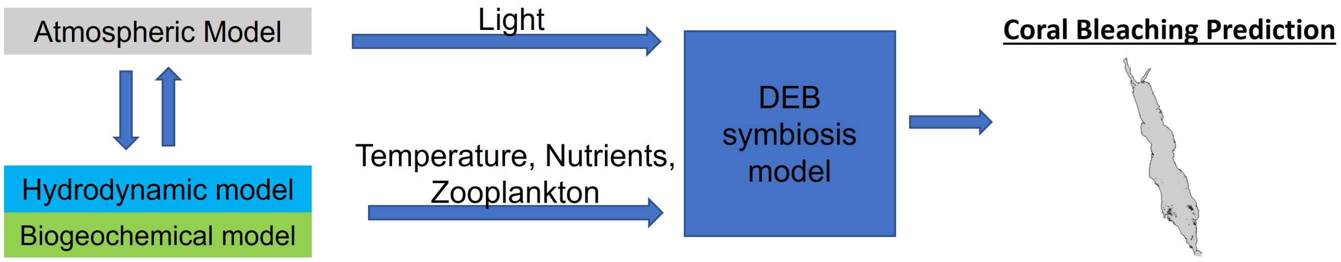
Abstract

The Red Sea's coral reefs are among the most biologically diverse ecosystems globally, providing essential food and income for coastal communities. However, they are increasingly threatened by climate change-induced coral bleaching, which has led to significant coral cover loss during recent mass bleaching events. Given the ecological and socio-economic importance of reef-building corals, advanced predictive models for coral bleaching are essential. Most existing models primarily focus on thermal stress, often overlooking essential factors such as water quality, heterotrophic feeding, and physiological processes. The Dynamic Energy Budget (DEB) theory provides a biologically coherent framework for multi-stressor analysis, allowing the integration of physiological traits with various environmental variables. In this study, we applied a pre-existing DEB symbiosis model to simulate coral bleaching in the Red Sea. The model was driven by outputs from an operational 3D hydrodynamic-biogeochemical model (MITgcm-NBLING) and satellite-derived Photosynthetically Active Radiation (PAR) data. Simulations were performed at the basin scale, and model performance was assessed against historical field observations of coral bleaching. The DEB symbiosis model effectively replicated observed spatiotemporal bleaching patterns, underscoring its potential as a valuable tool for investigating coral bleaching dynamics and enhancing predictive capabilities.

Keywords: symbiosis, corals, bleaching, Red Sea

*Speaker



Atmospheric Model
Hydrodynamic model
Biogeochemical model
Light
Temperature, Nutrients, Zooplankton
DEB symbiosis model
Coral Bleaching Prediction

Theory and ecological trait data standards can improve the utility of functional trait databases

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Abstract

Trait databases have an important role to play in the future of ecology and evolution. Yet there are challenges in how to structure them, how to prioritise content, and how to limit bias towards traits based on ease of measure or taxonomic peculiarities. Theory can guide which traits (and metadata) to measure, but it is less prescriptive about how to best structure and store data. Ecological trait data standards aim to address this question and to facilitate efficient re-use of trait data. Here we explore how both theory and trait data standards can be used to inform the design of a functional trait database of life history observations required quantify the processes of energy and mass exchange and allocation during individual ontogeny. We specifically use Dynamic Energy Budget (DEB) theory and its associated parameter database, which has > 5500 species across the tree of animal life, and the traits.build framework for trait database construction. We present a database of over nearly 33,000 'zerovariate' life history trait measurements that have passed through the filter of the DEB parameter estimation process.

Keywords: Life history, Bioinformatics, traits.build, Metabolic theory, Functional traits

*Speaker

The use of Artificial Intelligence to facilitate the estimation of DEB parameters using the AmP procedure

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Abstract

Dynamic Energy Budget (DEB) theory provides a rigorous mathematical framework for modeling the processes of energy acquisition, allocation and utilisation in living organisms. The Add-my-Pet (AmP) portal provides estimates of DEB parameters for nearly 6,000 entries together with the data and the Matlab codes used for the estimation procedure. However, the manual generation of the species-specific files (mydata, predict, pars_init, run) remains time-consuming and limits the expansion of DEB models to new species.

Artificial intelligence (AI) is being considered as a solution to partially automate this process. It is planned to use machine learning and natural language processing (NLP) to automatically extract and structure the data needed to generate the mydata file for new species. Additionally, by leveraging the nearly 6,000 entries in the AmP database, AI could:

Automatically generate the complementary files (run, predict, pars_init).

Identify which parameters could be fixed and which could be estimated based on the available data.

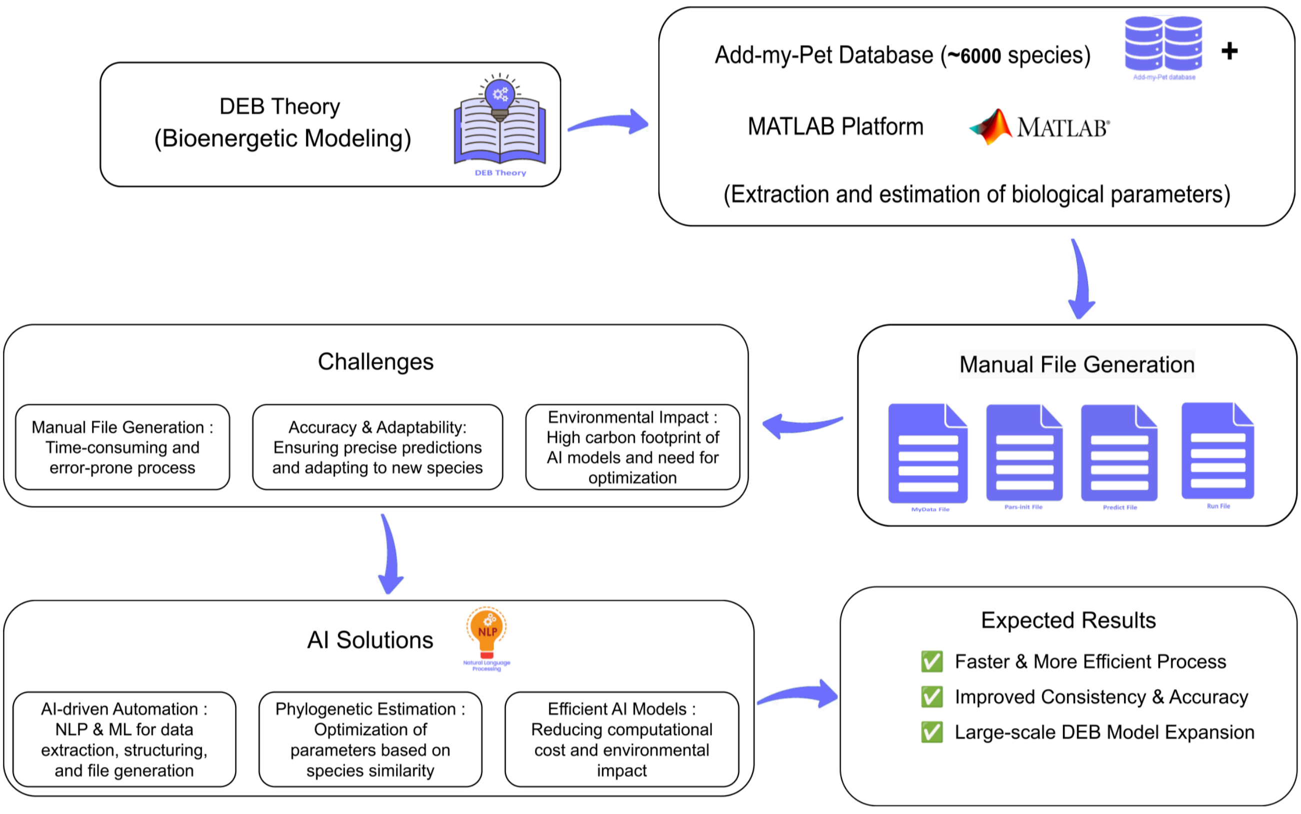
Suggest initial parameter values based on phylogeny and the AmP database.

Future work will include the development of a DEB chatbot based on a Large Language Model, capable of assisting users in refining species-specific AmP files, which could be particularly useful in a learning context. However, some challenges remain, particularly regarding data curation and the carbon footprint of AI models. Solutions such as using optimized AI models with lower environmental impact are being considered to ensure efficient automation while maintaining the scientific rigor of the AmP procedure.

*Speaker

Keywords: Dynamic Energy Budget (DEB) theory, AmP Procedure, Natural Language Programming, Large Language Model

The use of Artificial Intelligence to facilitate the estimation of DEB parameters using the AmP procedure



Stylized facts or fiction?

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Abstract

Stylized facts - generalized descriptions of observed patterns in nature - are indispensable tools in model development, validation, and analysis. They stipulate empirical benchmarks that a robust model must satisfy. Though valuable, stylized facts are inherently simplified, acting as 'useful fictions' with varying degrees of accuracy and literary support. Dynamic Energy Budget (DEB) theory, a cornerstone of ecological modeling, presents a set of core stylized facts to which the prevailing kappa-rule DEB models adhere. However, the strength of support for these foundational facts remains unquantified, and a comprehensive review of potential alternatives is lacking. For example, data on fish growth and toxicokinetics suggest there could be additional or alternative stylized facts that may be inconsistent with current kappa-rule DEB model assumptions, or require a conversation on the domain of applicability. We aim to stimulate the discussion on stylized facts in DEB by presenting our effort to score the empirical support for currently accepted facts, and explore potential alternative formulations and their implications.

Keywords: stylized facts, model development, domain of applicability, consistency

*Speaker

Modelling the Bioenergetics and Life History Traits of Chironomus riparius – Consequences of Food Limitation and Toxicant Exposure

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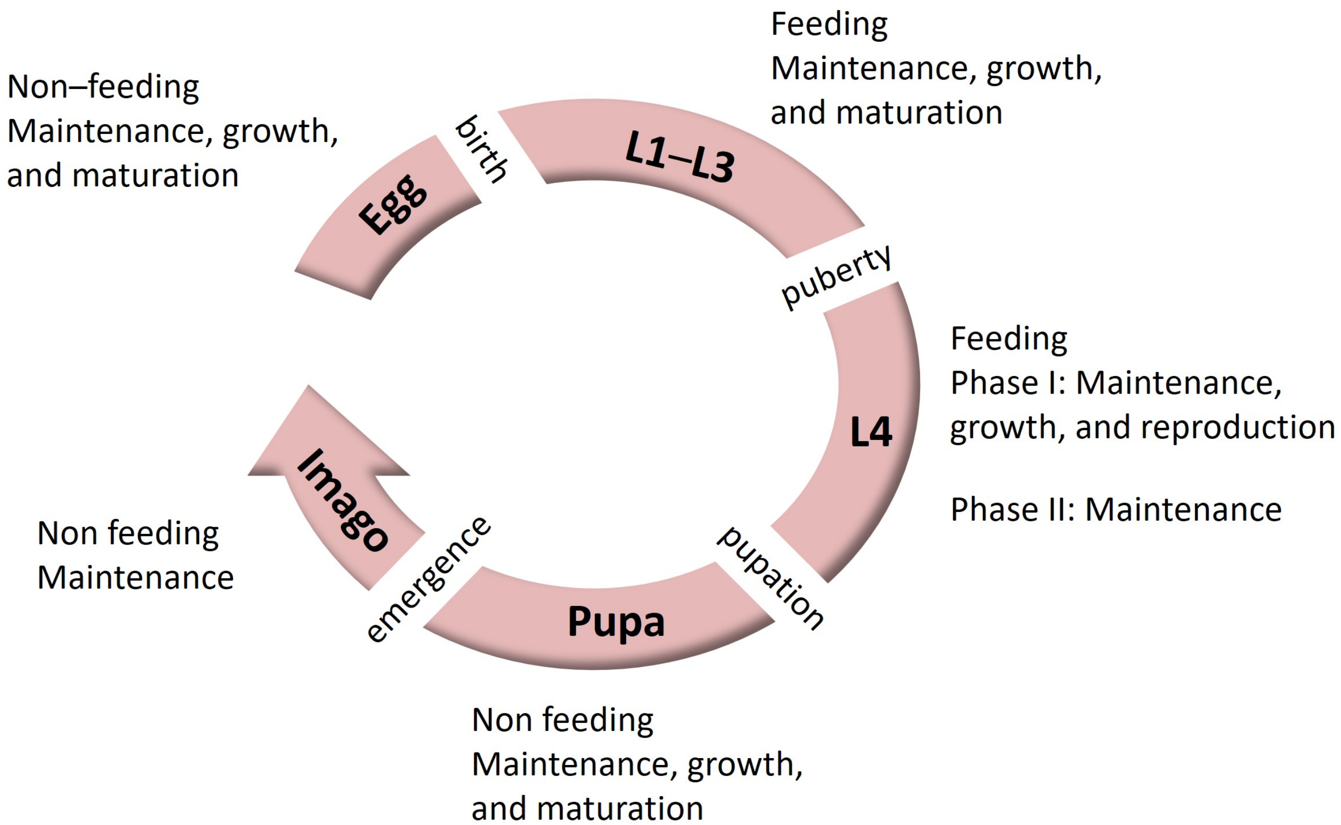
Abstract

Chironomids have a number of characteristics that make them a useful group for investigating the impact of environmental and chemical stressors on their life cycle stages. It is crucial to first understand sensitivities to environmental factors, as this provides a foundation for interpreting toxicity test results. Moreover, the interactions of chemical stressors with environmental stressors (e.g., temperature increases and food reduction) are underexplored. We focused on *Chironomus riparius* – one of the most extensively studied species in aquatic toxicity tests – to examine larval-stage changes conditions of both food abundance and limitation. We developed a model based on Dynamic Energy Budget (DEB) theory, a framework to capture the entire life cycle of an individual under varying food and temperature conditions. Information from this study and the literature indicate that the first three larval instars are immature, while the fourth larval instar is mature, during which the organism stores energy in two phases to support essential processes occurring in the subsequent non-feeding stages. The model successfully predicts the observed prolonged duration of the fourth instar under food limitation, the timing of life history events (e.g., pupation and emergence), as well as growth and egg production. To enhance our understanding of the impact of insecticides and of their interactions with environmental stressors on chironomids, we further developed a DEB-based toxicokinetic-toxicodynamic (DEB-TKTD) model. The DEB-TKTD model was subsequently used to explore the combined effects of multiple stressors – specifically, imidacloprid exposure, temperature and food availability – under both constant and time-variable exposure scenarios.

Keywords: Dynamic Energy Budget theory, holometabolous insects, aquatic insects, Chironomus riparius, biphasic larval growth, DEB, TKTD

*Speaker


Non–feeding
Maintenance, growth,
and maturation
Feeding
Maintenance, growth,
and maturation
Egg
birth
L1–L3
puberty
L4
Feeding
Phase I: Maintenance,
growth, and reproduction
Phase II: Maintenance
Imago
Non feeding
Maintenance
emergence
pupation
Pupa
Non feeding
Maintenance, growth,
and maturation

Closing lecture, with remarkable AmP entries and a short outlook

Bas Kooijman*[1,2]

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Abstract

My lecture has 3 chapters. I start with some evaluation remarks about what I heard during the symposium, underscoring some highlights.

Then, we now have 6000 entries in the AmP collection, 2000 more than in 2023, with a median Mean Relative Error of 0.04 for some 90000 data sets. I will discuss some problems, propose partial solutions and explain for a small selection of entries why they are remarkable from a biological or methodological point of view. This will be not that easy to detect when one skims rapidly through the collection. Examples are

a) ovoviviparous sharks incubate 1 or 2 yrs longer than data suggest, based on postnatal development.

Illustrating to need of theory to interpret data

b) why quite a few abj-entries have E_Hj very close to E_Hb as estimates, but this is not realistic and the result of absence of data on early growth.

Illustrating the need to detailed data to estimate parameters

c) slow growth can only be captured with a low somatic maintenance, with the need to make sure that the maintenance ratio remains smaller than one.

Finaly I make some remarks on possible future developments in DEB theory, linking levels of organisation and linking parameter values to eco-physiological properties.
Coral reefs, for instance, vary little in conditions over the seasons, which makes it likely that the inhabiting species have a low growth rate and so a low somatic maintenance.
By contrast, the growing season shortens towards the poles, which might relate to high maintenance on the basis of the waste-to-hurry principle.
A kind of inter-species variant of the Bergmann rule, where the intra-species variant is based on food density.
I expect new developments in the eco-evolutionary controls of the position of species in the altricial-precocial spectrum to supplements our earlier findings that
the cumulated total weight of neonates more or less equals the ultimate mother weight.
Altricial neonates tend to be relatively small and many with links to population dynamics

*Speaker

and trophic position, so to MacArthur's r/K-selection.
The aim is to build on the structure of meta-theory, by not only finding patterns in parameter values, but also patterns in these patterns
to improve our understanding of underlying evolutionary processes..

Keywords: AmP, meta theory, patterns in parameter values

How can a multi-reserves DEB model help us design experiments to better understand brown holopelagic algae Sargassum spp. growth and survival.

Maria José Lagunes*[1,2], Laure Pecquerie[2], Evelyn Raquel Salas-Acosta[3,4], Román Vásquez-Elizondo[4], Gonçalo Marques[5], Thierry Thibaut[3], Daniel Robledo[4], Solène Connan[2], Valérie Stiger-Pouvreau[2], Leo Berline[3], and Christophe Lett[1]

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[4]Cinvestav Unidad Merida, Applied Phycology Lab, Department of Marine Resources – Mexico

[5]MARETEC - Marine, Environment Technology Center, LARSyS, Instituto Superior Técnico – Universidade de Lisboa, Portugal

Abstract

Unprecedented quantities of brown floating macroalgae Sargassum have been recorded in the tropical North Atlantic Ocean; however, the factors affecting their growth and survival remain poorly understood. To study how environmental conditions influence Sargassum physiology, we use a multi reserves DEB model to quantitatively assess their growth and survival to current temperature, nutrient and light conditions. In the context of DEB theory, estimating a multi-reserves model parameters can be particularly challenging as the accurate calibration in a complex model heavily relies on the quantity and quality of datasets. In the case of holopelagic Sargassum, experimental data is scarce, which hinders our understanding of the effect of temperature, irradiance and nutrient concentrations on the growth and survival of this species.

To address these challenges first we evaluate the sensitivity of the parameter values to the

*Speaker

available data on holopelagic Sargassum. Then, we explore how different types of experimental data can reduce the incertitude on parameter estimates, thus increasing their identifiability and the prediction power of the algae multi-reserves model. This analysis allows us to determine which types of datasets contain the most information and guides the design of experiences to improve our understanding of Sargassum spp physiology. As a part of the BIOMAS project, (BIOenergetic Modeling Approach for Sargassum dynamics), experimental data from the different Sargassum morphotypes will be integrated to compare model predictions with experimental observations.

Keywords: Multi reserves model, Macroalgae, Data gaps, Parameter identifiability

Modelling domoic acid retention in Argopecten purpuratus and Pecten maximus: comparison of dynamics in fast and slow depurators.

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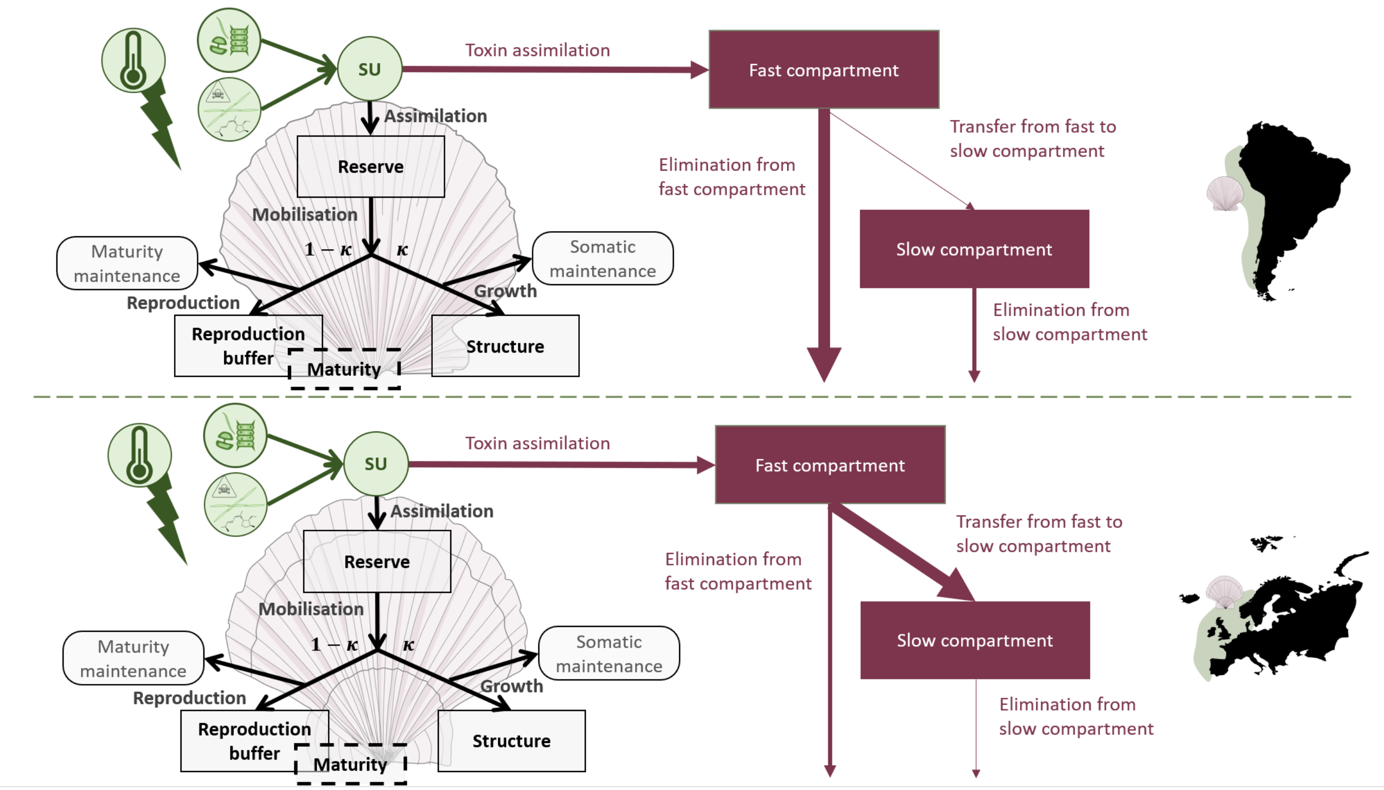
[2]Departamento de Acuicultura, Facultad de Ciencias del Mar, Universidad Católica del Norte – Chile

Abstract

As filter feeders, bivalves of the Pectinidae family are exposed to domoic acid (DA), the Amnesic Shellfish Toxin (AST) produced by species of the genus *Pseudo-nitzschia*. Pectinids can accumulate the toxin and transfer it to higher trophic levels, representing a significant socio-economic concern due to their high economic value. The DA retention is species-specific, some species, such as king scallops, retain the toxin for extended periods, while others, such as Chilean scallops, exhibit faster depuration rates. The physiological mechanisms explaining these differences are not fully understood yet. This study aims to develop a bioenergetic model based on Dynamic Energy Budget (DEB) theory integrated with a toxin kinetic module to describe DA retention. The model assumes that DA does not impact individual physiology and integrates two compartments: (1) a rapidly depurating compartment where the assimilated toxin is initially stored, and (2) a secondary compartment where a fraction of the toxin is transferred and eliminated more slowly. Initially, the DEB-DA model was calibrated and validated on the Chilean scallop using data from laboratory and field experiments following natural bloom of toxic *Pseudo-nitzschia* sp. Secondly, the model was applied to the king scallops based on data from field monitoring and experimental decontamination monitoring also following a natural bloom of *Pseudo-nitzschia*. The parameters of the toxin kinetic module were calibrated for each species and correspond to the hypotheses of physiological structures that trap DA in tissues present in king scallops, called autophagosome-like vesicles. This study provides new insights into species specific DA retention dynamics.

Keywords: Amnesic Shellfish Poisoning, toxin kinetics, pectinids, species comparison, DEB model

*Speaker



SU
Toxin assimilation
Fast compartment
Assimilation
Reserve
Transfer from fast to slow compartment
Elimination from fast compartment
Mobilisation
Slow compartment
$1-\kappa$
κ
Maturity maintenance
Somatic maintenance
Growth
Reproduction
Reproduction buffer
Maturity
Structure
Elimination from slow compartment
SU
Toxin assimilation
Fast compartment
Assimilation
Reserve
Transfer from fast to slow compartment
Elimination from fast compartment
Mobilisation
Slow compartment
$1-\kappa$
κ
Maturity maintenance
Somatic maintenance
Growth
Reproduction
Reproduction buffer
Maturity
Structure
Elimination from slow compartment

Inter-species comparison of life traits related to amnesic shellfish toxin kinetic in five scallop species

Eline Le Moan*[1], Laure Pecquerie[1], Laure Régnier-Brisson[2], Hélène Hégaret[1], Paulo Felipe Lagos[1], Léo Heyer[1], Salvador Emilio Lluch Cota[3], Fred Jean[1], and Jonathan Flye Sainte-Marie[1]

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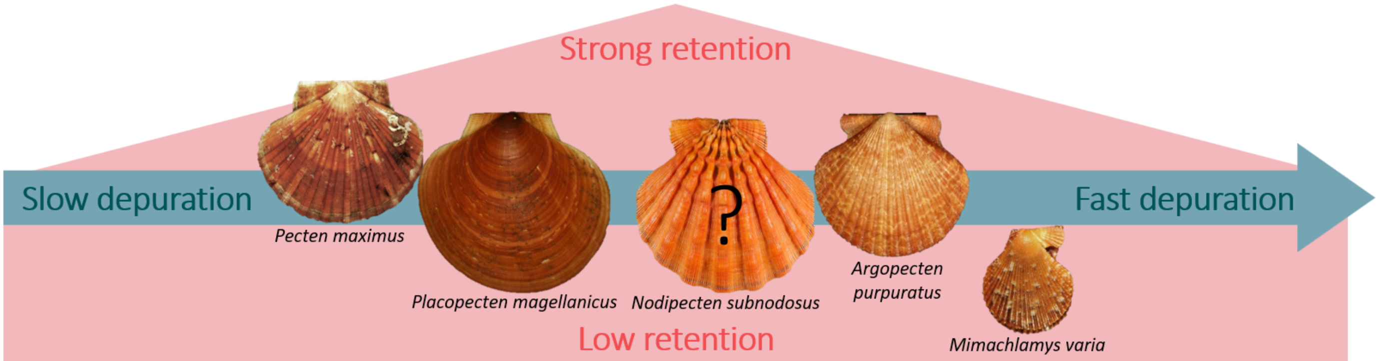
Abstract

Pectinid species (scallops) hold significant economic value, but their filtration activity makes them vulnerable to harmful algal blooms, particularly *Pseudo-nitzschia* species producing domoic acid (DA). This neurotoxin, responsible for Amnesic Shellfish Poisonings (ASPs) in birds and mammals, leads to prolonged sales bans when concentrations exceed the regulatory threshold. However, DA retention is species-specific, and the underlying mechanisms remain poorly understood. This study aims to compare pectinid species to assess whether interspecific differences in energetic traits influence DA retention. Using Dynamic Energy Budget (DEB) theory and the AmP multi-species estimation procedure as a common conceptual framework, we compared five pectinid species: two slow depurators (*Pecten maximus* and *Placopecten magellanicus*), two fast depurators (*Argopecten purpuratus*, *Mimachlamys varia*) and *Nodipecten subnodosus*, hypothesised fast depurator. We collected and compared life-history traits, focusing on life cycle transitions and reproductive effort, to establish the multi-species DEB parameter estimation. Three key parameters were then examined to explain differences in DA retention: specific assimilation, somatic maintenance costs and energy conductance. Our results, in addition to refined individual parameter estimations for the five species, revealed differences among species in these three parameters. However, only energy conductance consistently increased along the "slow-to-fast'" depuration gradient. Furthermore, we identified a limitation in describing the bivalve life cycle due to inconsistencies between larval and adult growth data. This study lays the groundwork for DA kinetics modelling and highlights the potential of multispecies parameter estimation for species comparisons. The presentation will cover key hypotheses, challenges and insights from this multispecies parameter estimation approach.

Keywords: Multispecies parameter estimation, Dynamic Energy Budget, scallops, amnesic shellfish toxin

*Speaker


Strong retention
Slow depuration
Fast depuration
Pecten maximus
Placopecten magellanicus
Nodipecten subnodosus
?
Argopecten
purpuratus
Mimachlamys varia
Low retention

Advancing DEB Model Accuracy for New Zealand Green-lipped Mussel: A Lab-Centric Approach

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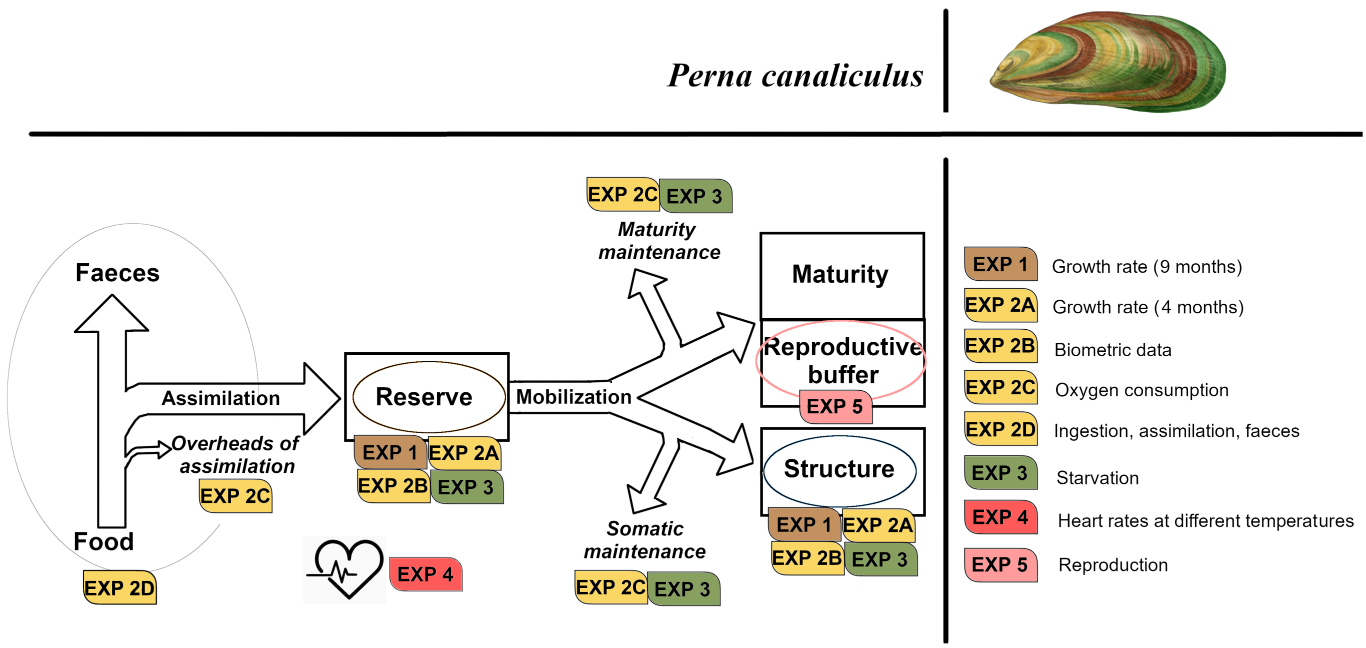
[7]National Biodiversity Future Center – Italy

Abstract

We present an enhanced DEB model for the New Zealand green-lipped mussel *Perna canaliculus* (GreenshellTM), calibrated using an extensive new suite of laboratory data (growth, reproduction, oxygen consumption, biometry, ingestion/assimilation, defaecation, starvation, and temperature response) alongside previously published values. This expanded dataset advances the DEB model's completeness score from 2.5 to 5.5, making *P. canaliculus* one of the most comprehensively parameterized organisms in the *Add-my-Pet* database. Our goal was to assess how much additional knowledge and predictive power could be gained by incorporating data from targeted laboratory experiments - specifically designed to meet DEB model requirements - into the calibration process.
Key findings include:
(i) Reliable temperature-response data are essential for accurately defining the thermal response curve; the presence or absence of such data should be considered when assessing DEB model completeness and its capacity to predict species' thermal responses;
(ii) Species-specific parameters, such as tissue organics and water content, improve accuracy compared to taxonomically generalized values;
(iii) Data from targeted laboratory trials as well as from diverse literature sources (spanning different environmental conditions, life stages, and populations) are essential for calibrating a robust species-level mechanistic model; and
(iv) Estimating energy requirements of bivalves would benefit from measuring routinely byproducts (pseudofaeces) and checking the experimental setup for potential feed residue.
These insights are highly relevant for predicting outcomes in commercial mussel aquaculture, particularly in the context of climate change adaptation, and emphasize the importance of robust parameterization in DEB-based analyses

Keywords: Targeted Experiments, Model Completeness, Thermal Response, Shellfish Aquaculture

*Speaker



Perna canaliculus
Faeces
Assimilation
Overheads of assimilation
EXP 2C
Food
EXP 2D
Reserve
EXP 1
EXP 2A
EXP 2B
EXP 3
EXP 4
Mobilization
EXP 2C
EXP 3
Maturity maintenance
Somatic maintenance
EXP 2C
EXP 3
Maturity
Reproductive buffer
EXP 5
Structure
EXP 1
EXP 2A
EXP 2B
EXP 3
EXP 1 Growth rate (9 months)
EXP 2A Growth rate (4 months)
EXP 2B Biometric data
EXP 2C Oxygen consumption
EXP 2D Ingestion, assimilation, faeces
EXP 3 Starvation
EXP 4 Heart rates at different temperatures
EXP 5 Reproduction

Filling in the data gaps for critically endangered leatherback turtles through mechanistic modelling

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[3]University of Western Australia – Australia
[4]Upwell turtles, Monterey CA – United States

Abstract

Leatherback turtles (*Dermochelys coriacea*) are highly migratory and long-lived, making these sea turtles vulnerable to numerous threats throughout their lives. All seven leatherback turtle populations are in various stages of population decline according to the IUCN Red List, despite global conservation efforts. The longevity of a population hinges on the ability of sufficient individuals to acquire enough energy to grow and produce a sufficient number of offspring within their lifetime. Growth and reproduction are constrained by the environment, generally with warmer and energy abundant environment resulting in faster growth, larger sizes, and more produced offspring. Quantifying the relationship between the environment and these life-history traits is complicated by the fact that leatherback turtles spend the majority of their life at open sea, and that rearing leatherbacks in captivity is extremely difficult. Here, we complement an existing Dynamic Energy Budget (DEB) leathearback model with newly acquired data on captive-reared juveniles and literature data on reproduction, and explore to what extent a well parameterized DEB model of a leatherback turtle can: (i) predict functional and life-history traits, including reproductive potential, of leatherback turtles; (ii) elucidate the effects of environmental conditions (food availability and temperature) on those traits; and (iii) predict the traits for two distinct (North-West Atlantic and East Pacific) leatherback turtle populations.

Keywords: dynamic energy budget model, environmental simulations, reproductive potential

*Speaker

The control of Escherichia coli mass and energy budgets by specific biochemical pathways inhibition

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Abstract

Many industrial, agricultural, and medical products are currently obtained in biotechnological processes. Host organisms, often genetically modified, are used to produce amino acids, biopolymers, biosurfactants, and organic acids. One of the key and most widely used microorganisms is *Escherichia coli*. The optimization of metabolic pathways leading to bioproduct overexpression was achieved mainly through genetic engineering techniques like gene 'knock out', which has led to an increase in the number of genetically modified organisms (GMO) used in bioprocesses. However, unlike non-modified strains, genetically modified organisms require specialized cultivation, storage, and disposal conditions. Wild-type strain metabolism control and optimization have to be achieved by adjusting the physical and chemical conditions of the culture including temperature, pH, media composition, and inhibitors occurrence. Inhibition of specific enzymes and biochemical pathways can lead to mass-energy imbalance and shifts towards other pathways. Therefore in this study, we discuss metabolism regulation of naturally occurring *E. coli* by chemical inhibition of specific biochemical pathways. We ask the question of how the mass and energy fluxes described by the Dynamic Energy Budget (DEB) theory will be affected by particular inhibitors of biochemical pathways involved in cell growth and development, and how can we use this knowledge to prepare simulations, predictions, and optimization of industrial bioprocesses conducted by *E. coli*. To answer this question, the influence of four antibiotics with specific known modes of biochemical action on *E.coli* growth and metabolism was tested: ciprofloxacin, azithromycin, rifaximin, and trimethoprim. *E. coli* was cultivated in batch reactors in a controlled environment. DEB model parameters identifiability was analyzed and their values were estimated. The changes in specific parameter values were used to explain the influence of inhibitors on the energy budget and to show possibilities of controlling and optimizing the potential bioprocess.

Keywords: optimization, bioprocess, biotechnology, antibiotics, inhibition

*Speaker

Exploring heritability of DEB parameters as phenotypical traits

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Abstract

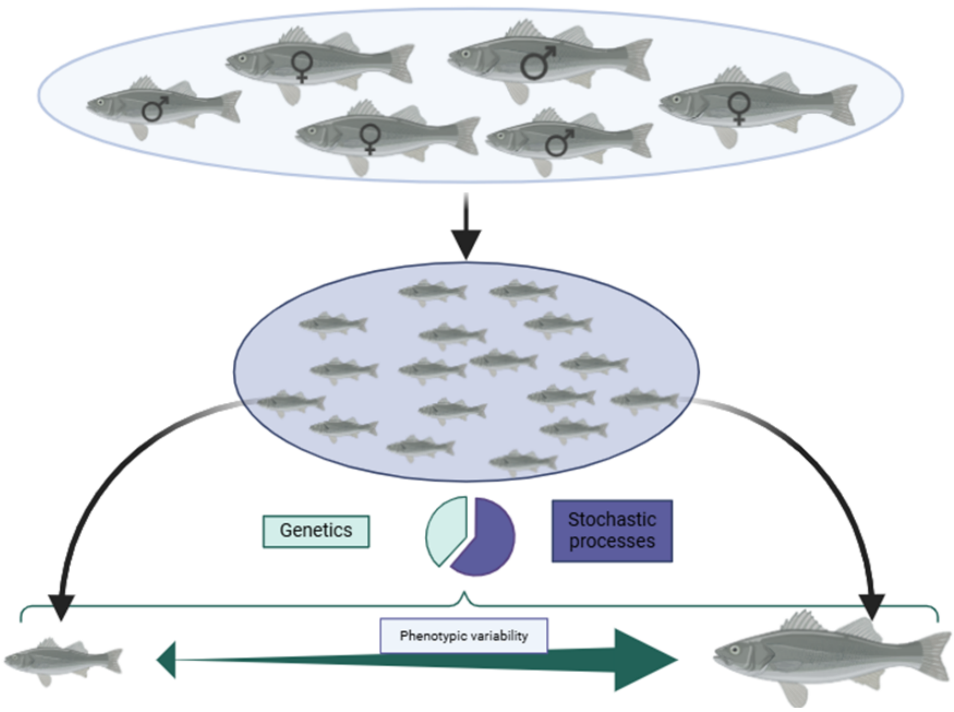
It has been suggested that genetically related fish living together can develop substantial differences in size over time. This variation may arise due to initial random differences in assimilation rates, which are then amplified by unbalanced social interactions (Kooijman, 2009). In this study, we propose that even minor genetic differences may contribute to the significant variation in growth trajectories consistently observed among kinship fish.

To test this hypothesis, we assessed the heritability (proportion of phenotypic variation in a given trait that is attributable to genetic relatedness) of growth-related traits. Considering that Dynamic Energy Budget (DEB) parameters at the individual level can be regarded as phenotypic traits, we examined the heritability of two DEB parameters directly linked to energy assimilation and energy mobilization: specific maximum assimilation rate and energy conductance.

We quantified the heritability of these parameters in two aquaculture-reared fish species: 2,515 European seabass (*Dicentrarchus labrax*) and 600 Gilthead seabream (*Sparus aurata*). Genetic relatedness between individuals was determined using genome-wide single-nucleotide polymorphism data. Individual-specific DEB parameters were estimated based on repeated measurements of length, weight, and muscle fat density (Palmer *et al.,* 2024). Finally, phenotypic variance was partitioned into genetic and unexplained variance using linear mixed modelling. The heritability of the specific maximum assimilation rate was found to be 0.48 in seabream and 0.42 in seabass, while the heritability of energy conductance was 0.42 in seabream and 0.39 in seabass. These findings indicate that nearly half of the observed variation in these DEB parameters can be explained by genetic relatedness.

Keywords: DEB parameters as traits, Between individual variability, Genetic relatedness, Heritability

*Speaker



Genetics
Stochastic processes
Phenotypic variability

MODELING OF ANURAN METAMORPHOSIS IN THE DYNAMIC ENERGY BUDGET FRAMEWORK

Erik Muller*[1,2], Carlo Romoli , Benoît Goussen , Lennart Weltje , Pernille Thorbek , Douglas Fort , Brittanie Peake , and Joachim Kleinmann

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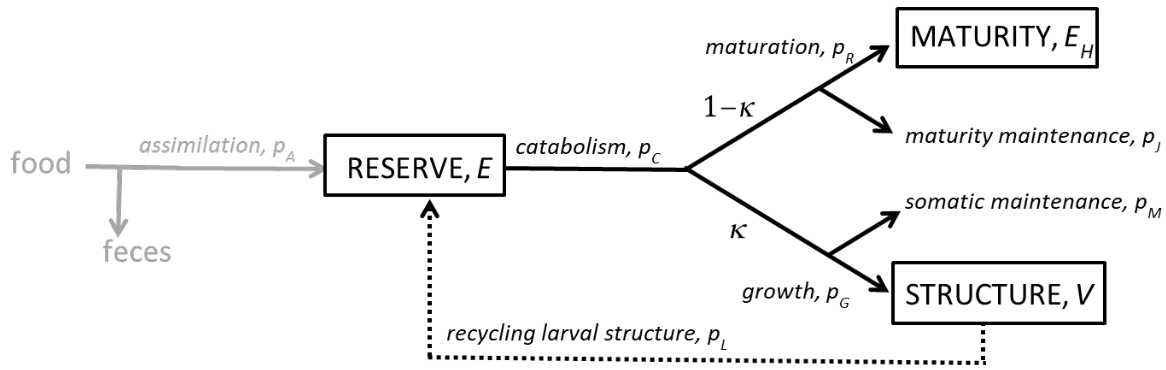
[2]ibacon GmbH – Germany

Abstract

The metamorphosis of anuran tadpoles into tetrapods is sensitive to natural and anthropogenic stressors, making it a key process in environmental risk assessment. Existing Dynamic Energy Budget (DEB) models lack a focus on the plasticity of the metamorphic climax, limiting their ability to evaluate such impacts. To address this, we developed two independent modeling modules that describe anuran metamorphosis and its plasticity, and integrated them into the standard DEB model.
Our model meets three essential criteria. First, adequately fed tadpoles emerge as viable froglets or toadlets. Second, it allows for the partial repurposing of structural mass, such as resources from the tail and gills. Third, it predicts that moderate temperature increases lead to earlier emergence at a smaller body size. The model effectively describes critical endpoints, including the onset and completion of metamorphosis, as well as the weight and length of tadpoles from hatching through metamorphosis as functions of food availability and temperature.

We validated the model using anuran species from four families: the common frog (*Rana temporaria*), the common toad (*Bufo bufo*), the African clawed frog (*Xenopus laevis*), and the gray tree frog (*Dryophytes versicolor*). The modules are expected to be applicable to other amphibians.
Outline of the energy flows in the standard DEB model for juveniles (solid arrows) with additional flow active only for tadpoles during metamorphosis (dotted arrow). During the climax of metamorphosis tadpoles do not feed (grey scale), while structure is recycled at a rate such that the reserve density remains constant.

*Speaker



Outline of the energy flows in the standard DEB model for juveniles (solid arrows) with additional flow active only for tadpoles during metamorphosis (dotted arrow). During the climax of metamorphosis tadpoles do not feed (grey scale), while structure is recycled at a rate such that the reserve density remains constant.

Determining the population implications of the sublethal impacts of sea lamprey parasitism on two coexisting lake trout morphotypes using a DEB-IBM

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Abstract

Lake trout (*Salvelinus namaycush*) are a vital ecological and economic species in the Great Lakes, but their populations were severely depleted in the early 20th century due to overfishing and parasitism by invasive sea lamprey (*Petromyzon marinus*). Management efforts have focused on suppressing sea lamprey, primarily considering lethal impacts, while overlooking sublethal effects that may influence lake trout dynamics. Additionally, lake trout exhibit morphotypic variation, with leans prioritizing reproduction over survival following sea lamprey attacks, whereas siscowets sacrifice reproduction to recover.

To evaluate how sublethal effects and morphotype differences influence lake trout populations, we developed a Dynamic Energy Budget–Individual-Based Model (DEB-IBM). This model simulates pools of young lake trout, sea lamprey, and individual juvenile and adult lake trout of both morphotypes. Daily growth, starvation, maturation, and reproduction are determined using DEB dynamics, while fishing mortality and attack probabilities are externally defined. DEB parameters were derived from laboratory and literature-based data, with sublethal effects of parasitism incorporated as stressors on volume-specific maintenance and maturity maintenance parameters using data from a common environment experiment documenting changes in reproduction and lipid storage as a result of parasitism.

Our DEB-IBM framework allows us to assess: (1) the impact of sublethal sea lamprey effects on lake trout abundance and (2) whether morphotypic differences facilitate sea lamprey persistence when one morphotype is suppressed. By integrating physiological responses to parasitism, this model provides a more comprehensive understanding of lake trout–sea lamprey dynamics in Lake Superior, offering insights for more effective conservation and management strategies.

Keywords: Parasitic stress, IBM, ABM, lake trout, sea lamprey

*Speaker

Sea lamprey wounding and mortality

Challenges for DEB modeling of organismal responses of organisms exposed to "forever chemicals"

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Abstract

Per- and polyfluoroalkyl substances (PFAS), - "forever chemicals" - pose risks to human and environmental health. We report progress in the DEB component of a study on toxicity of complex PFAS mixtures. The goal is to develop a testing framework that will evaluate mixture toxicity by connecting macromolecular and sub-organismal response to impacts on whole animals. We follow an approach advocated by Murphy et al. (2018: DOI: 10.1002/ieam.4063) that was previously implemented in experiments on *Daphnia magna* (DM) exposed to coalash, a mixture of approximately 30 metals (poster in this symposium). Our data set includes experiments measuring the lethal and sublethal impacts of a single compound (PFOS) and a PFAS mixture across the full DM life cycle. Individuals were sacrificed throughout at important developmental time points to measure gene expression. Parallel bioaccumulation studies are in progress. The presentation focuses on the challenges faced by DEB modelers. "DEBtox" modeling involves linked modules describing: (i) energy and material flows within an organism (DEB): (ii) uptake, transformation and excretion of toxicant (TK); (iii) a characterization of the toxicant action (TD). For PFOS, we first fit a DEB model to our control data plus literature data. When data become available, we will choose a TK module and estimate its parameters. The TD module will initially use a single "damage" variable that potentially affects all DEB processes. The biggest challenge for the DEB modeling is determining the level of detail to include, an issue highlighted recently by Romoli et al (2024: DOI: 10.1002/etc.5795) who concluded that ecological risk assessment cannot be based solely on goodness-of-fit or on the precision of model predictions. This finding has immediate implications beyond ecotoxicity and supports our emphasis on the value of molecular data.

*Speaker

Keywords: DEBtox, PFAS, Daphnia, gene expression

Machine-learning initialization methods for the calibration of DEB models

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Abstract

The selection of initial parameters for the calibration of a DEB model is not trivial. The parameter set must be feasible so the estimation procedure can begin. Ideally, it should also be close to the true species parameters to ensure fast convergence. A poor initial choice may even lead to numerical instabilities that halt the estimation procedure.

Currently, the only automated initialization method is the bijection method, an exact algorithm that predicts core parameters from zero-variate data. Here, we propose using machine learning techniques to provide initial parameters for DEB model calibration, introducing two approaches: a nearest-neighbor model and a neural network.

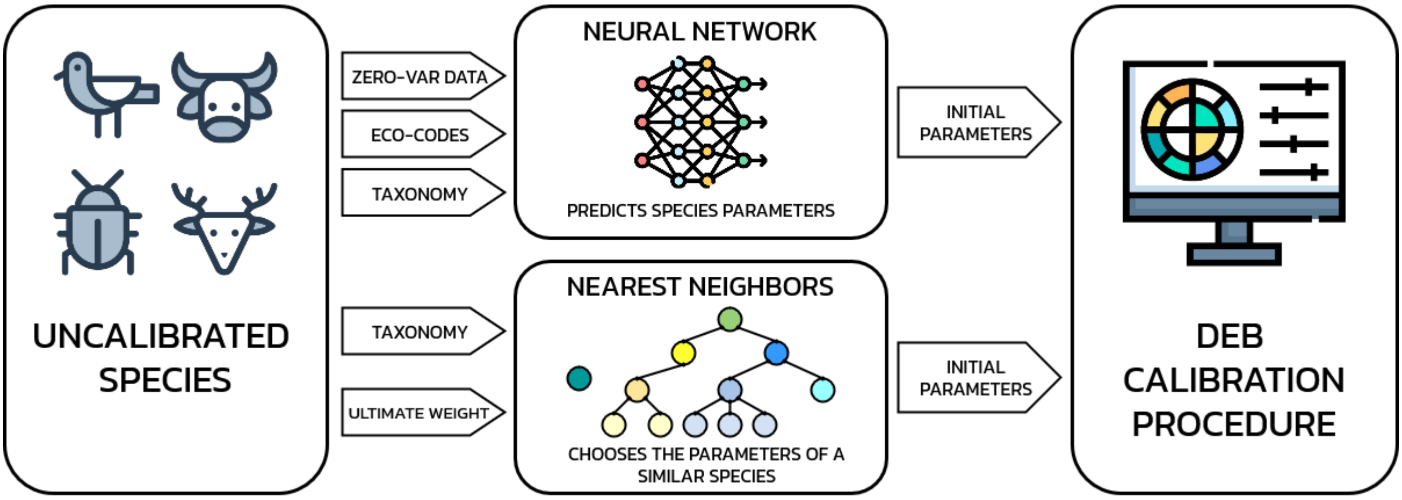
The nearest-neighbor model automates the ad hoc practice of selecting parameters from a similar species. It chooses initial parameter values from a taxonomically close species with similar ultimate weight and then adjusts them with covariation scaling relationships.

The neural network is inspired by the structure of the bijection method. The model predicts parameters using ages and weights at multiple life stages complemented by taxonomic and eco-code information. By restricting the outputs of the model, the predicted parameter set is guaranteed to respect all constraints except reaching birth.

The models were trained and evaluated on 2363 species . Both proposed approaches produce feasible solutions for 99% of species, while the bijection method had a success rate of only 40%. In a paired comparison, the nearest-neighbor initialization achieved lower final loss values for 50% of species, whereas the neural network approach performed better in 34% of cases (with 16% ties).

*Speaker

Keywords: parameter estimation, machine learning, initialization


UNCALIBRATED SPECIES
ZERO-VAR DATA
ECO-CODES
TAXONOMY
NEURAL NETWORK
PREDICTS SPECIES PARAMETERS
INITIAL PARAMETERS
TAXONOMY
ULTIMATE WEIGHT
NEAREST NEIGHBORS
CHOOSES THE PARAMETERS OF A SIMILAR SPECIES
INITIAL PARAMETERS
DEB CALIBRATION PROCEDURE

The use of Artificial Intelligence to facilitate the estimation of DEB parameters using the AmP procedure

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Abstract

Dynamic Energy Budget (DEB) theory provides a rigorous mathematical framework for modeling the processes of energy acquisition, allocation and utilisation in living organisms. The Add-my-Pet (AmP) portal provides estimates of DEB parameters for nearly 6,000 entries together with the data and the Matlab codes used for the estimation procedure. However, the manual generation of the species-specific files (mydata, predict, pars_init, run) remains time-consuming and limits the expansion of DEB models to new species.
Artificial intelligence (AI) is being considered as a solution to partially automate this process. It is planned to use machine learning and natural language processing (NLP) to automatically extract and structure the data needed to generate the mydata file for new species. Additionally, by leveraging the nearly 6,000 entries in the AmP database, AI could:

Automatically generate the complementary files (run, predict, pars_init).

Identify which parameters could be fixed and which could be estimated based on the available data.

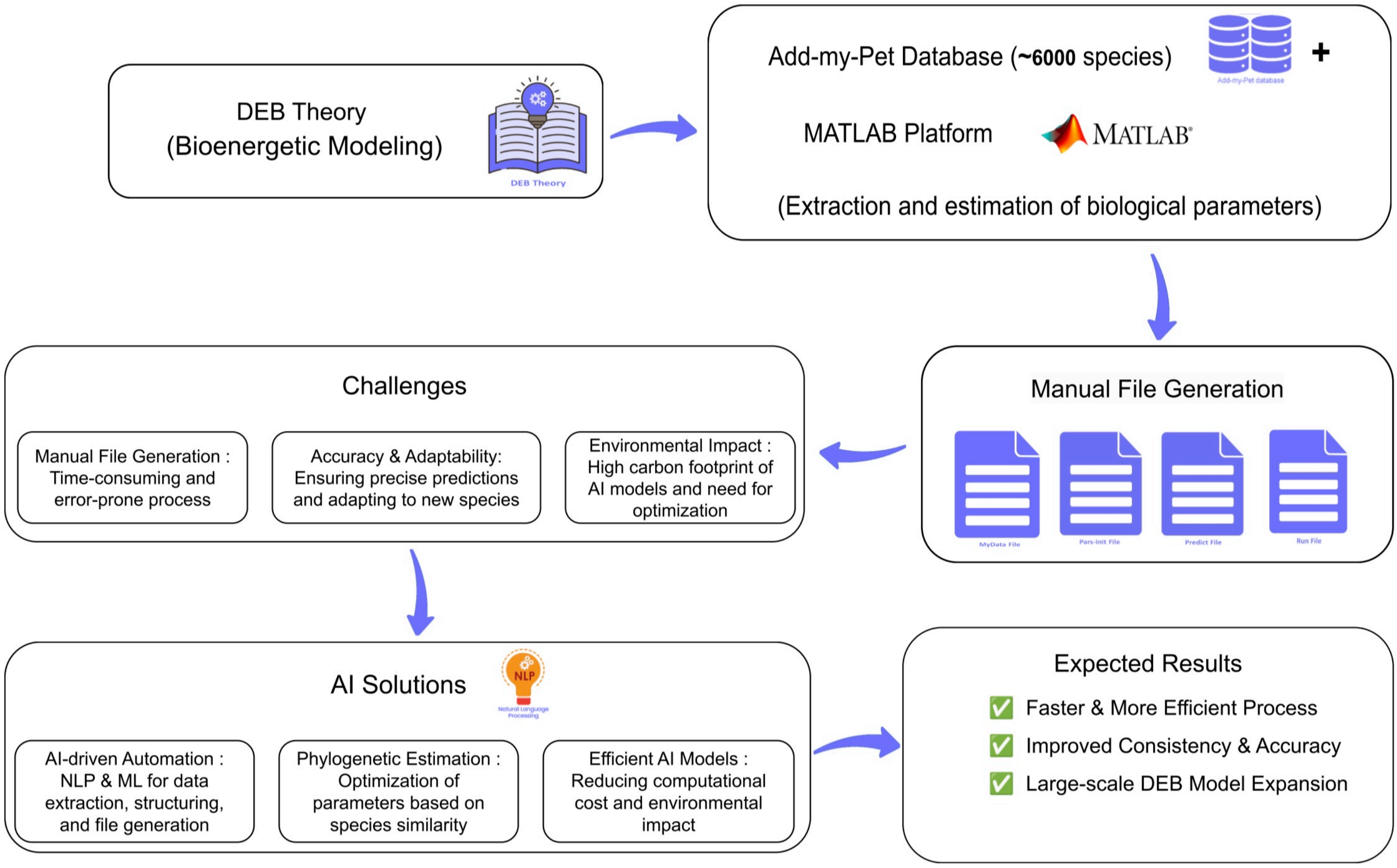
Suggest initial parameter values based on phylogeny and the AmP database.

Future work will include the development of a DEB chatbot based on a Large Language Model, capable of assisting users in refining species-specific AmP files, which could be particularly useful in a learning context. However, some challenges remain, particularly regarding data curation and the carbon footprint of AI models. Solutions such as using optimized AI models with lower environmental impact are being considered to ensure efficient automation while maintaining the scientific rigor of the AmP procedure.

*Speaker

Keywords: Dynamic Energy Budget (DEB) theory, AmP Procedure, Natural Language Programming, Large Language Model

The use of Artificial Intelligence to facilitate the estimation of DEB parameters using the AmP procedure



Modelling the Impact of Climate Change on Mountain Pine Beetle (*Dendroctonus ponderosae*) Cryoprotection Energy Allocation

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Abstract

Ectothermic insects depend on external temperatures to regulate their metabolism and energy use. Historically in temperate ecosystems, cold winters have naturally kept insect pest populations in check by causing increased mortality rates. However, with temperatures predicted to increase on average, climate change causes winters to warm faster than summers, thus increasing pest overwinter survival. Climate change has significantly contributed to the spread of the Mountain Pine Beetle (MPB) (*Dendroctonus ponderosae*), a native-invasive forest pest from Western North America. Warmer temperatures have facilitated its expansion eastwards into the boreal forest and across Canada. Recent outbreaks in the 2000s have killed approximately 54% of the merchantable pine in British Columbia. The cold-intolerant MPB successfully overwinters by accumulating cryoprotectants, such as glycerol, which lower its freezing point as temperature decreases in winter. This cryoprotectant synthesis is assumed to be an extra energetic cost for the beetle included in somatic maintenance. As winter temperatures increase and thus cold-related mortality decreases, we hypothesize that the cost of cryoprotection diminishes, and the beetle allocates previous cryoprotection energy allocation to growth, with impacts in other fluxes such as reproduction. To test this hypothesis, we formulated the first hex Dynamic Energy Budget model to estimate the MPB metabolic costs of maintenance, growth, and reproduction. This approach aims to enhance our understanding of how energy allocation strategies may evolve in response to climate change and their potential impact on MPB populations and future outbreaks.

Keywords: Cryoprotection, Cold tolerance, Climate change, Mountain Pine Beetle, Dynamic Energy Budget theory

*Speaker

Does DEB theory predict optimal values for the metabolic scaling exponent?

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Abstract

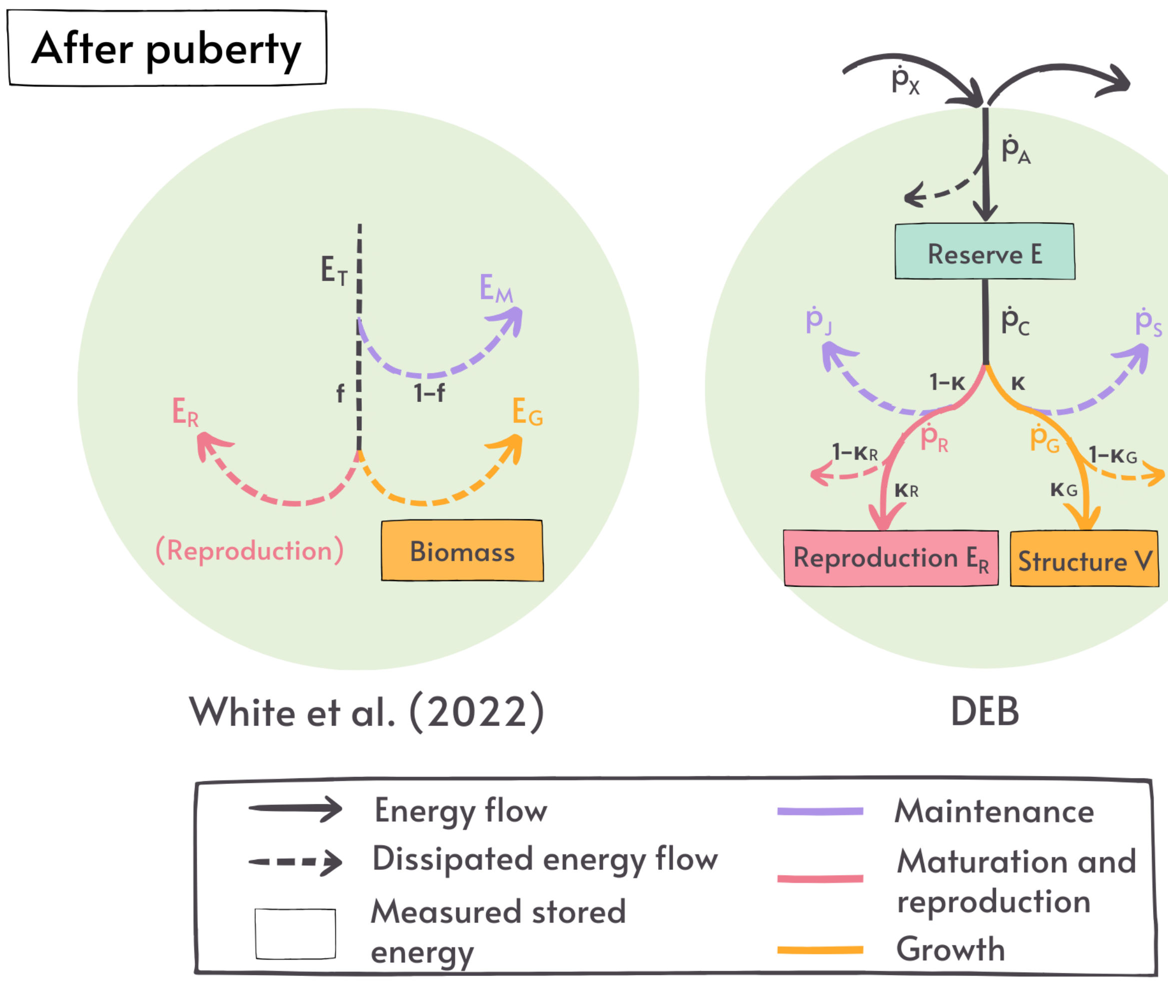
The metabolic scaling exponent describes the relationship between body mass and metabolic rate. It was often postulated to be fixed, at least at any given biological scale, with different values depending on the main mechanistic constraints considered. However, empirical studies have shown that the scaling exponent varies across different taxonomic groups and life stages. A recent evolutionary study used an energy balance model to investigate the relationship between the scaling exponent and dissipated energy. However, this model required strong assumptions.

We aimed to investigate the relationship between the ontogenetic scaling exponent and fitness while accounting for the whole energy balance of organisms and realistic mechanistic constraints. We simulated potential organisms by varying four DEB parameters and estimated two measures of fitness and two measures of the scaling exponent. The DEB parameters were constrained so that the mass at birth, mass at puberty, and ultimate mass were equal between all simulated organisms.

Preliminary results show that the relationships between fitness estimates and allometric scaling exponents were mainly mediated by variation in two parameters: the allocation coefficient and the costs of structure. The highest fitness values were obtained in organisms with a high scaling exponent before puberty (higher than 1) but a low scaling exponent after puberty (between 0.3 and 0.9), hence for low values and low costs of structure. The results suggest that "optimal" values for scaling exponents do emerge from a mechanistic model, but they do not converge with the values often postulated based on more simple mechanisms.

Keywords: intrinsic rate of increase, lifetime reproductive success, optimality theory, evolutionary constraints

*Speaker



After puberty
E_T
E_M
f
1–f
E_R
E_G
(Reproduction)
Biomass
White et al. (2022)
ṗ_X
ṗ_A
Reserve E
ṗ_C
ṗ_J
ṗ_S
1–κ
κ
ṗ_R
ṗ_G
1–κ_R
1–κ_G
κ_R
κ_G
Reproduction E_R
Structure V
DEB
Energy flow
Dissipated energy flow
Measured stored energy
Maintenance
Maturation and reproduction
Growth

Towards a Dynamic Theory of Societal Metabolism: Insights from DEB Theory

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[2]MARETEC - Marine, Environment Technology Center, LARSyS, Instituto Superior Técnico – Universidade de Lisboa, Portugal

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Abstract

Societies, like organisms, function as autopoietic systems, sustaining themselves through resource use, knowledge accumulation, and environmental interactions. This metabolic process is central to societal metabolism (SEM), studied through frameworks such as Societal Exergy Analysis (SEA), Economy-wide Material Flow Accounting (Ew-MFA), and Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM). However, these approaches rely on static accounting and lack a dynamic representation of metabolic processes and transitions.

In contrast, Dynamic Energy Budget (DEB) Theory provides a thermodynamically consistent framework for modeling biological metabolism, incorporating endogenous state variables and dynamic metabolic processes. To develop a comprehensive dynamic SEM theory, several improvements are necessary: (1) explicit distinction of metabolic processes such as assimilation, growth, and dissipation, (2) inclusion of endogenous state variables for material stocks, active and passive systems, and embodied information, (3) recognition of embodied information as a key driver of societal metabolism, influencing technological evolution and decision-making, and (4) ensuring that the model is consistent with empirical data.

This work serves as a basis for a dynamic SEM model that integrates these elements, enabling better assessments of sustainability, resource efficiency, and the impacts of environmental change on societies.

Keywords: societal metabolism, information, modeling

*Speaker

Exploring food composition effects on fish metabolism and growth

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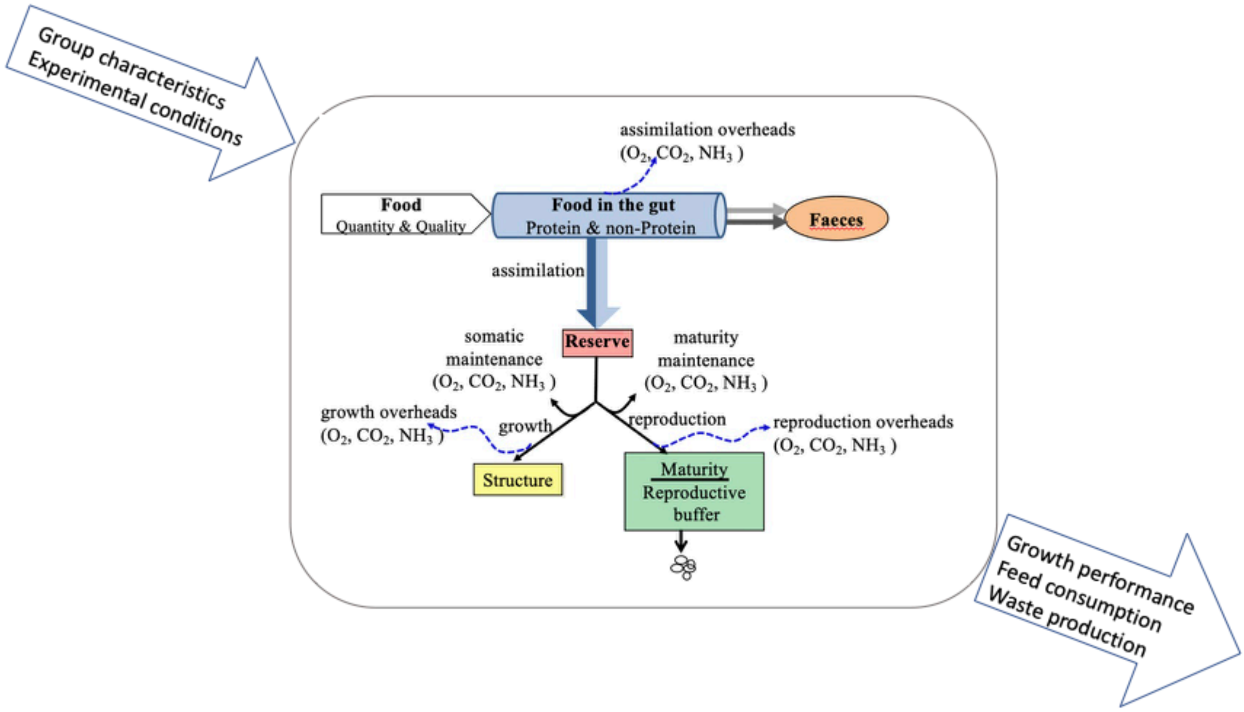
Abstract

The description of flow and transformation of energy and nutrients within a fish is key for fish research as it allows to optimize growth and reduce production costs of farmed animals, ensure animal welfare, and minimize environmental impact. In this work, we developed a nutritional bioenergetics model for fish based on Dynamic Energy Budget (DEB) theory, explicitly incorporating the digestion process. The model applies the concept of synthesizing units to distinguish between protein and non-protein food components regarding their contribution to the formation of reserves. This approach allows predictions of measurable quantities of interest to fish researchers, technicians and aquaculture operators, including feeding rate, oxygen consumption, carbon dioxide, ammonia and solid waste production, under different temperatures and various feeding conditions, both in terms of quantity and macronutrient composition. Without additional assumptions, the model also quantifies the effects of the dietary protein-to energy ratio on food intake and assimilation. For instance, lower food intake is prediced for fish fed high-energy diets (rich in fats) compared to diets with low energy content (poor in fats); a pattern that aligns with experimental observations in fish. The model has been parametrized and validated for rainbow trout (*Oncorhynchus mykiss*), Atlantic salmon (*Salmo salar*), European sea bass (*Dicentrarchus labrax*), and gilthead seabream (*Sparus aurata*), performing well under a variety of diverse datasets across different culture systems and experimental protocols.

Keywords: DEB theory, nutritional bioenergetics, finfish farming, protein, to, energy ratio

*Speaker


Group characteristics
Experimental conditions
assimilation overheads
(O_2, CO_2, NH_3)
Food
Quantity & Quality
Food in the gut
Protein & non-Protein
Faeces
assimilation
somatic
maintenance
(O_2, CO_2, NH_3)
Reserve
maturity
maintenance
(O_2, CO_2, NH_3)
growth overheads
(O_2, CO_2, NH_3)
growth
reproduction
reproduction overheads
(O_2, CO_2, NH_3)
Structure
Maturity
Reproductive
buffer
Growth performance
Feed consumption
Waste production

Long-term dynamics of a simplified DEB-based ecosystem model

Jaap Van Der Meer*[1]

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Abstract

Recently we presented a stoichiometric carbon and nitrogen model of an entire ecosystem based on Dynamic Energy Budget (DEB) theory (van der Meer et al. 2022 Ecol. Model.). The living matter of the ecosystem was represented by producers, consumers, and decomposers, each with either one (consumers and decomposers) or two (producers) reserve compartments. Additionally four types of detritus were considered, resulting in a model with 11 state variables. The dynamics of the nutrients carbon dioxide and ammonium followed automatically from the dynamics of the other state variables, because of the law of mass conservation. The model contained 33 parameters and 27 conversion constants.

Although the model is relatively simple compared to many ecosystem models that are generally used by applied ecologists, analyzing the system dynamics of this model in response to, for example, the forcing functions light and nutrient availability, or to parameter variability is still a daunting task. Here we therefore present a simplified version of the model that only considers producers and consumers, both with no more than one reserve compartment. By leaving out detritus and decomposers, we implicitly assume that decomposition is an infinitely fast process. Hence, losses during consumer feeding and death are supposed to be immediately transferred into inorganic nutrients. We further assume that carbon dioxide is not limiting any process rate. The simplified model has four state variables and only 12 parameters and 8 conversion constants.

This simplification allows for a detailed analysis of the long-term model dynamics by means of bifurcation analysis. We show that the dynamical behavior of the model resembles that of the Rosenzweig-MacArthur model, but since the DEB model is based on first principles such as area-volume relationships and rules of mass conservation, we are able to provide a more mechanistic interpretation of the link between environmental forcing and parameter values and dynamical model behavior.

Keywords: Canonical community model, bifurcation analysis, Rosenzweig, MacArthur model, paradox of enrichment

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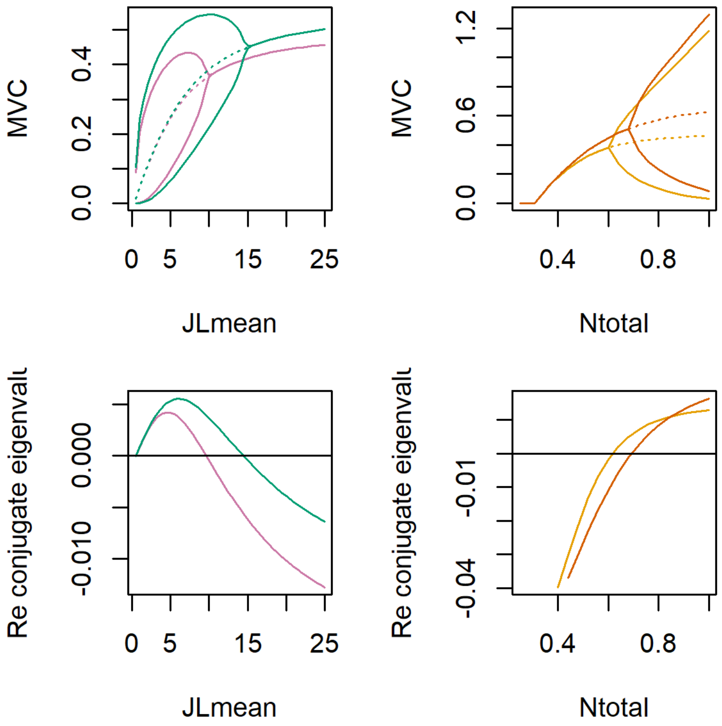
MVC
0.0
0.2
0.4
0
5
15
25
JLmean
MVC
0.0
0.6
1.2
0.4
0.8
Ntotal
Re conjugate eigenvalu
-0.010
0.000
0
5
15
25
JLmean
Re conjugate eigenvalu
-0.04
-0.01
0.4
0.8
Ntotal

A new-modeling framework to estimate environmental determinants and intra-specific variability in life history traits: an application to fish

Matthieu Veron*[1], Stéphane Chantepie[2], Bruno Ernande[3], Olivier Maury[4], Baptiste Alglave[5], and Bastien Sadoul[6]

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[2]Biologie intégrée pour la valorisation de la diversité des Arbres et de la Forêt – Office National des Forêts, Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement, DECOD (Ecosystem Dynamics and Sustainability), Ifremer, INRAE, Institut Agro – France

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Abstract

Understanding and predicting rapid phenotypic changes critically rely on identifying the sources of variability among and within populations as well as their consequences on life-history traits. While the Dynamic Energy Budget (DEB) theory stands out as a powerful tool to describe life-history traits of various aquatic species in an environment where food and temperature fluctuate, it traditionally assumes homogeneous populations, where all individuals share the life history traits and DEB parameters of an "average" individual. This approach overlooks the inherent, partly genetic, variability between and within populations, often attributing it solely to environmental differences. Yet, accurately predicting dynamic environmental effects on life history traits requires accounting for inter-individual variability to better disentangle both effects. We introduce *OptMyDEB,* a new flexible modeling tool that addresses these shortcomings. This generic modeling platform implements an integrated DEB model that is sufficiently flexible to incorporate many types of data and to capture parameter variability across populations, sexes and individuals. *OptMyDEB* is an R package that has been designed to fit DEB models through maximum likelihood estimation using

*Speaker

Template Model Builder (TMB). TMB is a statistical framework that combines automatic differentiation for efficient gradients computation and Laplace approximation for integrating random effects. This allows the optimization of high-dimensional parameter spaces, making TMB well-suited for fitting complex nonlinear dynamic systems. The ability of the framework to reliably estimate DEB parameters and their variability is first demonstrated using a simulation-estimation approach. Then, experimental data are used to infer individual variability in DEB parameters for two fish populations.

Keywords: Dynamic Energy Budget, life history traits, interindividual variability, Template Model Builder, R package

FishNess

FISH ROBUSTNESS

Global patterns of climate change impacts on desert lizard communities

Zihan Zhou*[1]

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Abstract

Desert faunas are highly vulnerable to ongoing climate change due to their proximity to physiological limits. However, interspecific variation in functional traits complicates species-specific vulnerability assessments at a global scale. Leveraging recently published comprehensive trait databases and phylogenetic trees, we compiled a complete parameter dataset for constructing biophysical models for 235 desert lizard species. Using species-specific model parameterization, we projected the impacts of climate change on desert lizards worldwide. Our analysis revealed significant variations in thermal tolerance and field body temperature across taxonomic groups and desert realms. Furthermore, we identified heterogeneity in climate change impacts among different taxa, particularly concerning hydration risk, hyperthermia, and shifts in feeding demand, both across and within desert realms. Climate change refugia-defined as warm desert regions with high lizard diversity and low predicted physiological stress-are projected to persist to varying degrees across different desert regions. However, few of these refugia fall within existing protected areas. Our findings underscore the critical role of interspecific variation in functional traits in assessing species' vulnerability to climate change and highlight the urgent need to enhance the protection of refugial areas within the world's warm deserts to safeguard lizard biodiversity.

Keywords: Climate changeDesert lizardsBiophysical modelingFunctional traitsClimate refugia

*Speaker

Abstracts for poster presentations alphabetically

Salinity impact on the life history traits of the bloody cockle (Senilia senilis) in the Sine Saloum inverse estuary: a bioenergetic modelling approach

Jocelyn Coïc*[1], Yoann Thomas[1], and Jonathan Flye Sainte-Marie[1]

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Abstract

The impact of extreme salinity on bivalve physiology and phenology has the potential to influence a wide range of biological processes, including food acquisition, growth, reproduction, respiration, endocrine and immune systems, and behaviour, which can ultimately result in increased mortality. The Dynamic Energy Budget (DEB) theory provides a mechanistic framework for studying the effects of stressors at the individual level and across all life stages. The present study aims to implement a DEB model on the West African bloody cockle (*Senilia senilis*). This bivalve is exposed to spatio-temporal variations of extreme salinity conditions in the Sine Saloum inverse estuary (Senegal). Its millennial artisanal fishing, which is part of the culture and traditions of local populations, is crucial for their food security and economic autonomy. The combination of extreme salinity levels and overfishing has potentially led to a decline in both stock and size of catches. Following the implementation of the Add my Pet procedure to estimate the species' DEB parameters, stylised facts were established in order to conceptualise the modes of action of salinity variations in the framework of the DEB theory. The effects of salinity are parametrized on the basis of experimental results and validated on the basis of growth measurements carried out in contrasting sites in the estuary. This model provides a powerful tool to understand population dynamics under salinity stress and will sustain the management of *S. senilis* artisanal fishery.

Keywords: Salinity, Bivalve, Stylized facts, DEB theory, West Africa

*Speaker

How acclimation to thermal variability shapes behaviour and associated energetic costs in a temperate dung beetle

Alex Coverley*[1], Kimberley Sheldon[2], and Katie Marshall[1]

[1]University of British Columbia – Canada
[2]University of Tennessee, Knoxville – United States

Abstract

Fluctuations in daily temperature can range beyond 20 ◦C and are projected to increase under anthropogenic climate change. Body temperature affects ectotherm performance across a range of physiological processes. The rate of reaction for physiological and biochemical processes are temperature dependent, affecting species success and spatial range. Generally, at higher temperatures more energy is needed, and terrestrial ectotherms vary in behavioural and physiological responses. We hypothesised that O. taurus beetles adjust their behaviour under thermal variability to reduce energy consumption through shifts in their locomotive strategies and activity window. We tested associated energetic trade-offs under variability for a temperate dung beetle (*Onthophagus taurus*). *O.* taurus' foraging behaviour consists of both crawling and flying. Flying is energetically demanding and only possible at higher temperatures but increases foraging speed and area. We acclimated beetles to 20 ◦C ± 12 ◦C with a 12:12 L:D cycle and maintained the control at 20 ◦C ± 2 ◦C. We recorded behaviour across a 24-hour period for all three groups following six days of acclimation. We then measured CO2 production across a range of temperatures to determine flight initiation temperature and its energetic cost. Acclimation to a higher amplitude of thermal variability increased the likelihood *O.* taurus would fly at lower temperatures and increased the level of activity at all temperatures. Preliminary DEB models suggest far greater energetic costs when incorporating differences in locomotive choices as a result of acclimation.

Keywords: Acclimation, Thermal variability, Locomotion, Energetics, Flight

*Speaker

Energy Dynamics and Life History Traits of the freshwater Three-Spined Stickleback: A DEB Approach

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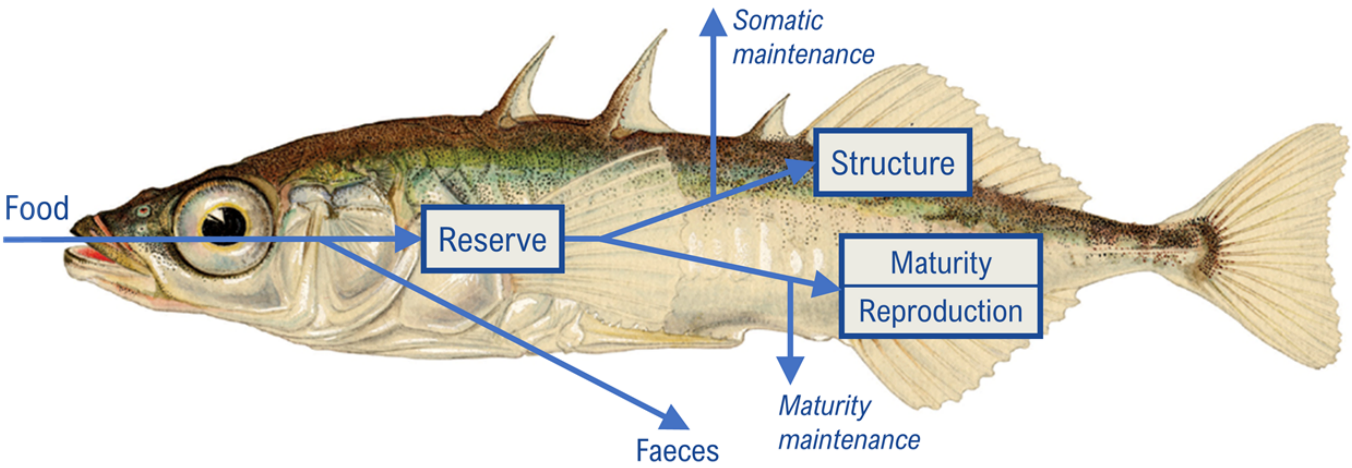
Abstract

The three-spined stickleback (*Gasterosteus aculeatus*) is a small teleost fish species widely distributed across northern hemisphere ecosystems. It can play a significant ecological role by dominating fish communities and influencing ecosystem functions. Due to its extensive distribution and ecological importance, the three-spined stickleback has become a model organism in evolutionary ecology, behavior, and evolutionary genetics studies. Additionally, it is considered an important sentinel species in aquatic ecotoxicology. The primary aim of this work is to develop a complete life-cycle model for the freshwater three-spined stickleback using the principles of Dynamic Energy Budget (DEB) theory. To achieve this, a systematic review of experimental data on growth, larval development, maturity, and reproduction from freshwater populations of the species was conducted. The model was calibrated using the method of covariation for parameter estimation from DEBtools for MATLAB. The calibrated DEB model will be used to explore the effects of multiple stressor interactions on the stickleback, as well as to simulate population dynamics in Central European streams.

Keywords: three, spined stickleback, freshwater, ecotoxicology

*Speaker


Somatic maintenance
Food
Structure
Reserve
Maturity
Reproduction
Maturity maintenance
Faeces

Empirically Parameterizing a Dynamic Energy Budget Model for the Facultatively Symbiotic Coral Astrangia poculata

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[5]College of the Holy Cross – United States
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Abstract

As changes in the global environment strain existing energy limits, organisms are forced to respond to stressors more frequently and to a greater degree. Corals have become an emblematic example of environmental sensitivity in the Anthropocene– with massive die-offs resulting from the breakdown of the coral-algal symbiosis. Dynamic energy budget (DEB) models have been used to assess and predict the impacts of global change and evaluate the resilience of tropical corals. Assessing the independent energy dynamics of host and symbiont in these models is challenging, however, due to the obligate nature of the tropical coral-algal symbiosis. The temperate coral *Astrangia poculata* exhibits a facultative symbiosis; existing with (symbiotic) or relatively without (aposymbiotic) endosymbionts. This provides a tractable opportunity to disentangle the contributions of auto and heterotrophy to coral growth and metabolism. The overarching aim of this research was to leverage a laboratory experiment to parameterize a DEB model for both symbiotic and asymbiotic *A. poculata* in the Add My Pet (AmP) framework. In a 90-day experiment, we exposed host (aposymbiotic) and holobiont (symbiotic) *A. poculata* to different light and food levels. At regular intervals, we collected physiological metrics including polyp growth, grazing rate, biomass, lipid, protein, and chlorophyll content. Experimental results show that *A. poculata* biomass is more sensitive to changes in light versus food level; higher light levels correspond to higher biomass and lipid levels, especially in symbiotic corals. Comparisons of AmP parameter estimates for aposymbiotic vs. symbiotic *A. poculata* will provide critical insights into the energetics of symbiosis.

Keywords: coral, symbiosis, physiology

*Speaker

From Native Waters to Invasive Frontiers: Modeling Atlantic Blue Crab (Callinectes sapidus) Performance Under Changing Environmental Conditions

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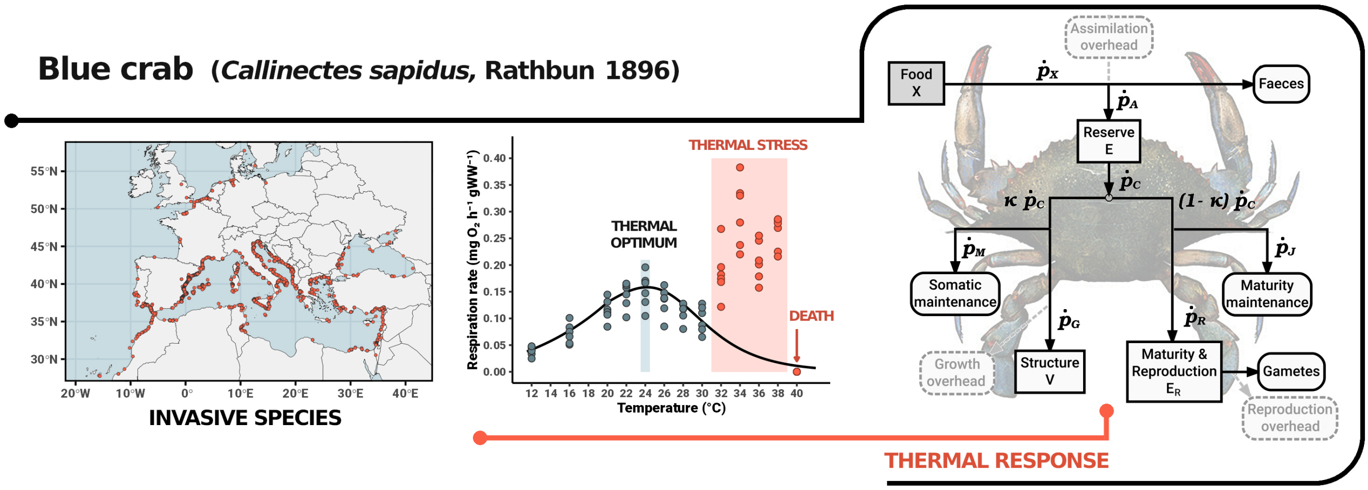
Abstract

The Atlantic blue crab, *Callinectes sapidus*, is an iconic resource in its native range (e.g., Chesapeake Bay, western Atlantic from Nova Scotia to Argentina), but has recently become invasive in the Mediterranean and Black Sea, leading to significant ecological and socio-economic impacts. Given that temperature strongly influences crustacean metabolic rates and growth, while salinity plays an important role in blue crab development and reproductive success, understanding the performance of *C. sapidus* across diverse environmental conditions is critical. Yet, no comprehensive modeling framework currently exists to predict the species' performance across varied environments. This gap hampers both the conservation and management of native stocks (e.g., Chesapeake Bay) and the containment or exploitation of invasive populations (Mediterranean). Here, we present a mechanistic model based on Dynamic Energy Budget (DEB) theory, incorporating newly measured laboratory data on thermal tolerance and oxygen consumption, biometric field measurements, and an extensive historical dataset documented in the literature, dating back to the 1920s. The model captures sex-specific differences in energy acquisition and quantifies how temperature influences growth and reproduction. Preliminary simulations indicate that *C. sapidus* exhibits a broad thermal tolerance with an optimal range near 24 ◦C, closely matching conditions in Mediterranean habitats already experiencing warming trends. Projected future temperature increases are expected to facilitate further expansion of *C. sapidus*, potentially causing cascading effects on native biodiversity. The model provides a valuable tool to evaluate suitable habitats for invasive expansion and inform context-specific adaptive management strategies-for instance, offering guidance on conservation measures in native populations or targeted harvest of males or females in newly invaded regions.

Keywords: Thermal tolerance, Environmental performance modeling, Dynamic Energy Budget (DEB) model, Conservation, Informed management

*Speaker


Blue crab (Callinectes sapidus, Rathbun 1896)
55°N
50°N
45°N
40°N
35°N
30°N
20°W 10°W 0° 10°E 20°E 30°E 40°E
INVASIVE SPECIES
THERMAL STRESS
THERMAL OPTIMUM
DEATH
Respiration rate (mg O2 h-1 gWW-1)
0.40 0.35 0.30 0.25 0.20 0.15 0.10 0.05 0.00
12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Temperature (°C)
Assimilation overhead
Food X
Faeces
Reserve E
κ ṗC
(1- κ) ṗC
Somatic maintenance
Maturity maintenance
Growth overhead
Structure V
Maturity & Reproduction ER
Gametes
Reproduction overhead
THERMAL RESPONSE

Integrating mixture toxicity in DEB-TKTD models: Understanding combined effects of pesticides on earthworm reproduction

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[3]Ecologie fonctionnelle et écotoxicologie des agroécosystèmes – Université Paris-Saclay, INRAE, AgroParisTech – France

Abstract

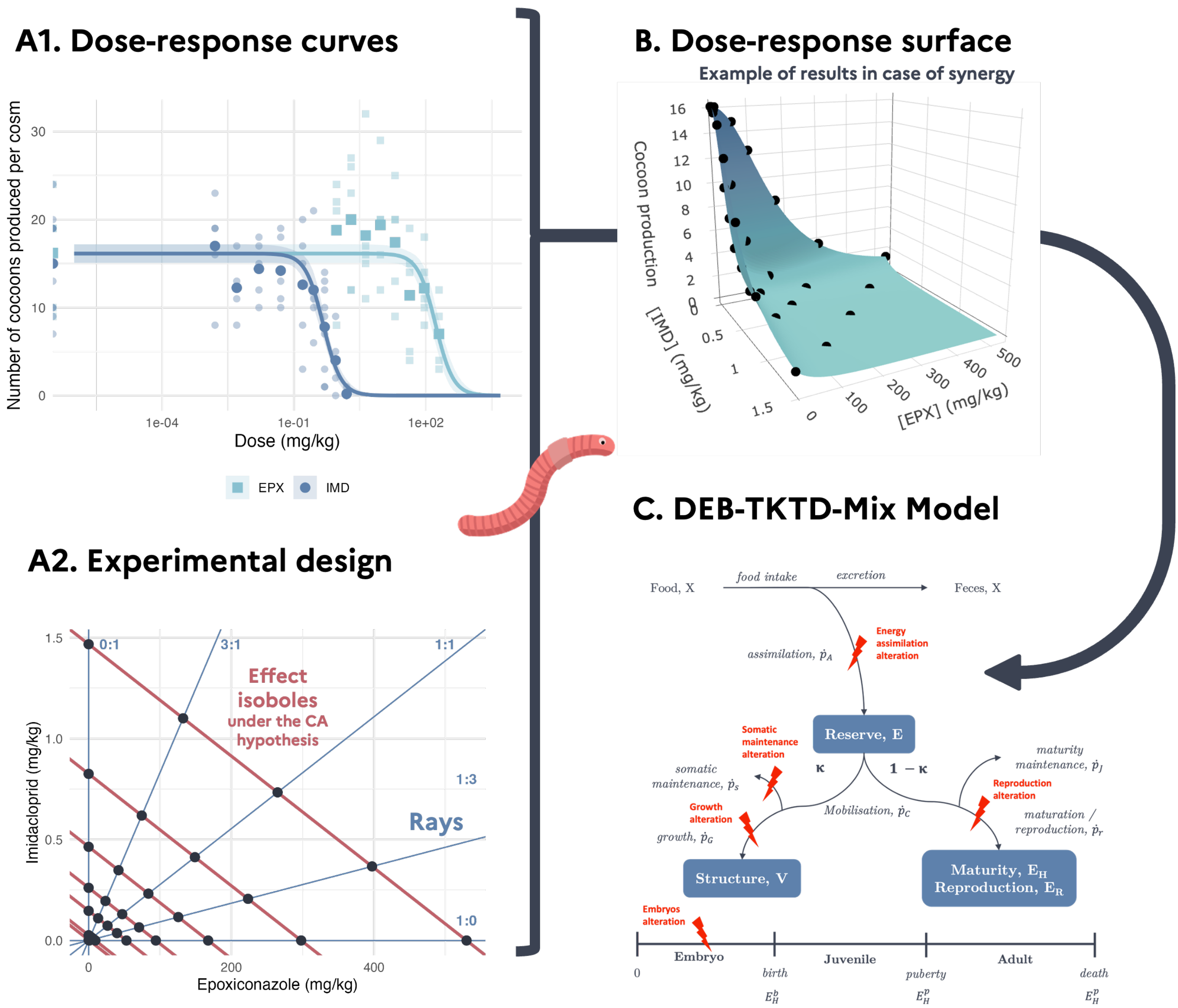
Soils play a critical role in ecosystem functioning, yet they are increasingly threatened by agricultural intensification leading to contamination with persistent mixtures of plant protection products (PPPs). While standard environmental risk assessment typically focuses on single compounds, soil organisms are exposed to complex mixtures of PPP residues, making it crucial to understand their combined effects.

Our study aims to develop a DEB-TKTD model to understand the physiological mode of action of a mixture of two prevalent PPPs in agricultural soils: epoxiconazole (fungicide) and imidacloprid (insecticide). Using the earthworm *Aporrectodea caliginosa* as a model organism, we first characterized the toxicokinetics of both compounds before examining their effects on reproduction through an adapted OECD guideline 222 experiment using a ray design (n = 7 mono-substance doses, n = 21 mixture doses, n = 3 replicates). By monitoring cocoon production, hatching success, and juvenile growth over 28 days, we will gather essential data to parameterize our DEB-TKTD model.

The integration of mixture toxicity data into the DEB framework will provide mechanistic insights into how these PPPs interact to affect earthworm life-history traits. This DEB-TKTD model will then be incorporated into an Individual-Based Model to predict long-term effects on population dynamics under realistic exposure scenarios. This multi-level modeling approach will help bridge the gap between individual and population responses to pesticide mixtures, contributing to more environmentally relevant risk assessment procedures.

Keywords: Earthworms, Pesticides, Mixture, DEB, TKTD

*Speaker


A1. Dose-response curves
Number of cocoons produced per cosm
Dose (mg/kg)
EPX
IMD
A2. Experimental design
Imidacloprid (mg/kg)
Epoxiconazole (mg/kg)
0:1
3:1
1:1
1:3
1:0
Effect isoboles under the CA hypothesis
Rays
B. Dose-response surface
Example of results in case of synergy
Cocoon production
[IMD] (mg/kg)
[EPX] (mg/kg)
C. DEB-TKTD-Mix Model
Food, X
food intake
excretion
Feces, X
assimilation, $\dot{p}_A$
Energy assimilation alteration
Reserve, E
Somatic maintenance alteration
somatic maintenance, $\dot{p}_S$
κ
1 − κ
maturity maintenance, $\dot{p}_J$
Reproduction alteration
Growth alteration
Mobilisation, $\dot{p}_C$
maturation / reproduction, $\dot{p}_r$
growth, $\dot{p}_G$
Structure, V
Maturity, E_H
Reproduction, E_R
Embryos alteration
Embryo
Juvenile
Adult
birth
puberty
death
E_H^b
E_H^p

Improving dynamic energy budget models of triploid oysters

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[2]School of Renewable Natural Resources, LSU AgCenter, Baton Rouge, LA, United States – United States

Abstract

Triploid organisms, bred to have three sets of homologous chromosomes rather than the typical two found in diploids, are common in agriculture and aquaculture. Triploid oysters have been widely adopted in aquaculture since their development roughly 40 years ago. Oyster farmers often prefer triploids primarily for their faster growth rates and reduced reproduction, which typically results in better meat condition during spawning season. Despite their commercial importance, significant gaps remain in understanding how the triploid condition affects oyster growth, physiology, and energy budgets in the face of climate change.
The enhanced growth of triploids, commonly called "triploid advantage," has been attributed to three main hypotheses: (1) reduced reproductive effort, (2) higher heterozygosity, and (3) larger cell sizes. While these pathways likely work in combination, dynamic energy budget (DEB) modeling efforts have primarily focused on adjusting the *kappa* parameter to reflect increased energy allocation to somatic growth. To further explore the other pathways and develop a more comprehensive model using the eastern oyster (*Crassostrea virginica*) as a case study, we conducted a starvation experiment to estimate structure-specific maintenance costs via respiration in diploid versus triploid oysters complemented with long-term growth studies and literature reviews to developed datasets for testing the alternative triploid DEB modeling approaches.
Preliminary results suggest that triploids starve at slower rates, but structure-specific maintenance needs are similar between ploidies despite significant differences in cell sizes. We use simulations with varied parameter sets to explore different modes of action for triploid growth focusing on allocation to structure (*kappa*), energy acquisition (ingestion and/or assimilation), and parameters beyond structure-specific maintenance costs that could be affected by cell size differences (energy conductance, costs for structural growth, and maturation thresholds).

Keywords: Oyster, aquaculture, triploid

*Speaker

Modelling the effects of multiple stressors on aquatic insects

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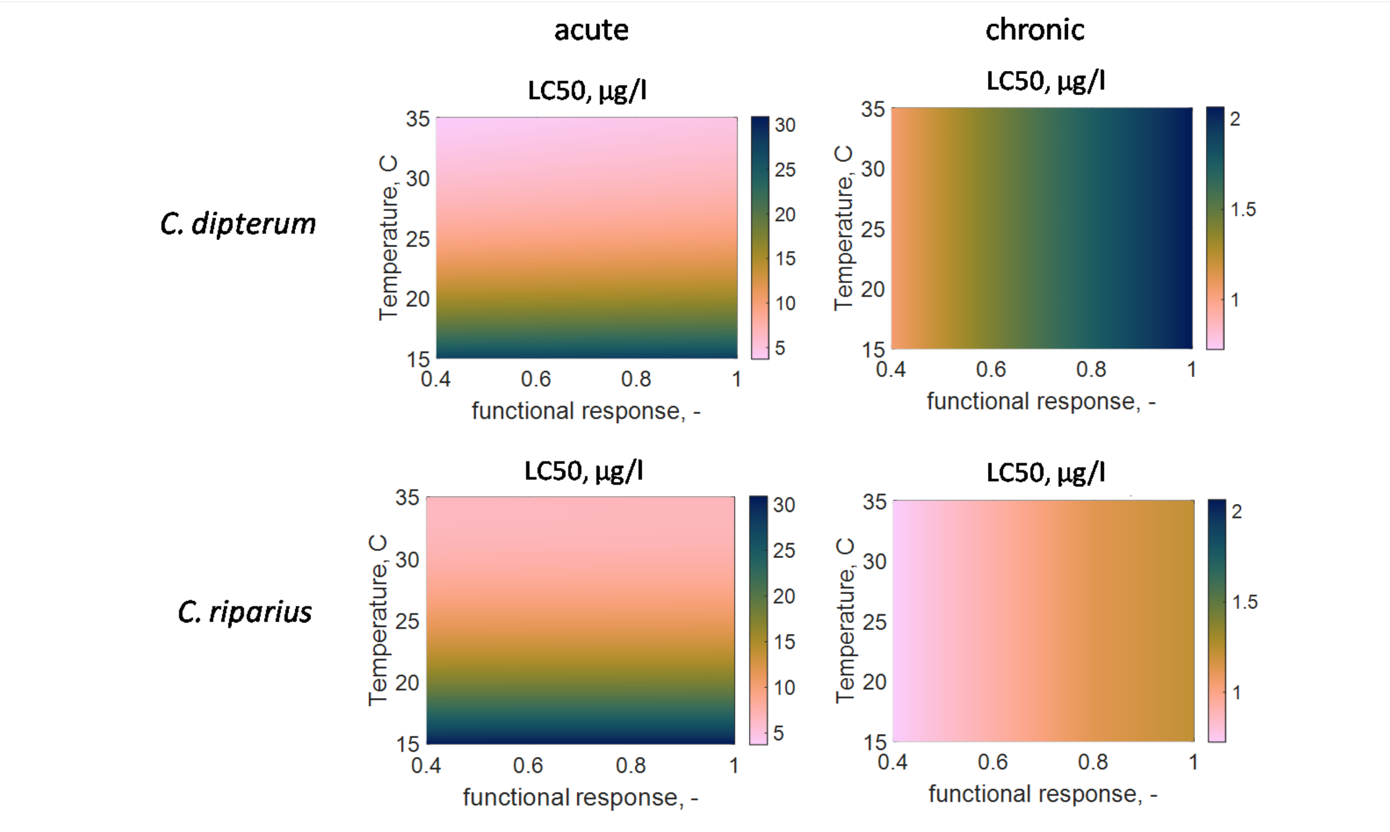
Abstract

Mayflies and other aquatic insects, known for their high sensitivity to neonicotinoid insecticides, serve as key non-target indicators in environmental risk assessments. While acute toxicity tests typically focus on lethality, it is important to evaluate sub-lethal effects, such as growth, to understand long-term toxicity. Additionally, the effects of chemical stressors in combination with environmental stressors (e.g., temperature increase and food scarcity) less well studied. To improve our understanding of how neonicotinoid insecticides and environmental stressors interact to impact aquatic insects, a Dynamic Energy Budget (DEB)-based toxicokinetic-toxicodynamic (TKTD) model was developed. The model was calibrated for two insect species, *Chironomus riparius* and *Cloeon dipterum*, using experimental data on feeding inhibition and immobility. These models were then used to assess the combined effects of multiple stressors, specifically imidacloprid exposure, temperature, and food availability, under both constant and variable exposure scenarios. Simulations from the model predicted LC50 and EC50 (50% effect concentration) values for mobility and sublethal effects, respectively. The timing and duration of exposure were found to be critical factors influencing sensitivity. In general, temperature had a greater effect in acute exposure scenarios, while food availability was more influential in chronic exposure situations. *C. riparius* showed rapid responses to changes in toxicant concentration, whereas *C. dipterum* displayed a more gradual reaction.

Keywords: Dynamic Energy Budget theory, toxicokinetic, toxicodynamic model, imidacloprid, Chironomus riparius, Cloeon dipterum

*Speaker


acute
chronic
LC50, μg/l
LC50, μg/l
C. dipterum
Temperature, C
35
30
25
20
15
0.4
0.6
0.8
1
functional response, -
30
25
20
15
10
5
2
1.5
1
LC50, μg/l
LC50, μg/l
C. riparius
functional response, -

Exploring the combined effects of pathogen-induced stress, temperature, and food scarcity on the bioenergetics of Pinna nobilis

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[2]Department of Fisheries Aquaculture, University of Patras, Mesolongi – Greece
[3]Department of Biology, University of Crete – Greece

Abstract

The endangered fan mussel (*Pinna nobilis*) has historically declined mostly due to extensive overfishing, habitat destruction from trawling and anchoring, as well as pollution, and seagrass meadows degradation. More recently, the species is facing severe population decline due to mass mortality events linked to pathogens such as *Haplosporidium pinnae, Mycobacterium* spp, and *Vibrio* spp. Climate change-induced temperature increases and food scarcity pose additional threats by affecting physiological responses, immune functions and survival. To prevent extinction, conservation efforts should focus on habitat protection and disease mitigation. Furthermore, a better understanding of *P. nobilis* bioenergetics in response to environmental factors could inform recruitment strategies. This study extends a DEB model for *P. nobilis* to assess the combined effects of pathogen infection and environmental stressors, such as temperature increase and food scarcity, on growth, maturation, and reproduction. The model successfully reproduces observed growth patterns in length and weight, clearance rate and oxygen consumption across a range of temperatures. Additionally, it accurately predicts ages and sizes at developmental transitions between life stages. The exact mechanism of the effect of pathogens on the energy flow is not yet fully comprehended. Results out of several experiments indicate that pathogens affect the mechanisms of cell homeostasis and immunity maintenance. We hypothesize that the pathogen mode of action is to increase rates of somatic and maturity maintenance through a stress parameter. By exploring how these stressors impact key biological processes, this study provides critical insights to support conservation efforts for this keystone species.

Keywords: DEB theory, Pinna nobilis, bioenergetics, stressors

*Speaker

TOWARDS A DYNAMIC ENERGY BUDGET MODEL FOR CHIRONOMIDS

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[2]ibacon GmbH – Germany

Abstract

Chironomids or nonbiting midges are holometabolous insects of the order Diptera. Typically, holometabolous insects feed, grow and build up large pools of somatic and reproductive reserve during the larval stage, then undergo a major metabolic and morphological transformation during metamorphosis to finally emerge as adults, which reproduce and often soon perish thereafter.
Due to their ecological significance and relative ease of cultivation, they are used in standard toxicity tests for the ecological risk assessment (ERA) of chemicals. This includes a lifecycle test in which larval growth, development times, reproductive output and survival are recorded. We wish to perform ERAs within the wider DEBtox/ DEB-TKTD framework, but are faced with experimental and theoretical problems. A DEB model that satisfactorily describes important stylized facts of the energetics and the life history of chironomids, among other holometabolous insects, is missing. In particular, it is challenging to concomitantly satisfy the following three stylized facts:

- The duration of larval length growth increases with decreasing food availability, while the time from the cessation of larval length growth to the emergence of adults appears to depend marginally on feeding conditions.
- Maximum larval length does not depend much on food availability (but differs between males and females). However, the weight of adults at emergence decreases with food availability during the larval stages.
- Food limitation in the larval stage reduces adult reproduction. We will illustrate and discuss these and other challenges to develop a DEB model for chironomids that is both realistic and practical for ERA.

*Speaker

New approaches improve ecological risk assessment by incorporating omics into bioenergetic models: A case study of Daphnia exposed to a coal ash mixture

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Abstract

The ecological risk of a chemical is traditionally measured by exposing a single organism to a single chemical in idealized lab conditions through standardized toxicity testing. These tests have many drawbacks that mostly stem from the inability to use this data to predict effects outside of the specific empirical parameters of the test, such as the impacts of other chemicals or mixtures or to extrapolate effects to an ecologically relevant outcome. At the other end of biological organization, novel molecular techniques yield increasing amounts of subcellular data. This information can potentially be used to better understand the individual-level impacts of a chemical by connecting exposure to an altered molecular pathway or mode of action, agnostic of any specific chemical or organism. Here we describe a case study looking at the effect of coal ash, a mixture of numerous metals known to exert toxicological effects, on a model freshwater organism, *Daphnia magna*. We exposed *D. magna* to coal ash through dietary algal exposure and measured impacts on survival, growth, and reproduction for 28 days. We measured the transcriptomic response at multiple time points, enabling us to analyze the suborganismal response of the *Daphnia* to coal ash exposure throughout their life cycle. We then modeled the response of *Daphnia* to coal ash using a Dynamic Energy Budget (DEB) model, testing various potentially impacted physiological modes of action (pMoAs). Instead of identifying the pMoA through traditional DEBtox methods which relies on only individual-level data, we correlated these model simulations with significantly differentially expressed genes to identify the best candidate pMoA based on the molecular coal ash signal. For each state variable in the DEB model, we applied a variable selection approach (using ARACNE) to identify a set of genes predictive of the state variable. We then sorted the genes associated with this variable selection approach and added them to the ARACNE model using machine learning. The model with the best fit to the DEB state

*Speaker

variables (as measured by R2) was selected. This process using transcriptomic data and DEB modeling identified the pMoA of "increased costs of reproduction" as the best description of the impact of coal ash on *Daphnia*. This case study represents an exciting development in using suborganismal data to quantitatively identify the bioenergetic mode of action of complex chemical exposure in a model freshwater organism.

Keywords: DEBtox, physiological mode of action, transcriptomics, Daphnia magna, predictive gene sets

Dynamic Energy budget and Non-Linear Averaging reveal variation in temperature effect on Homarus americanus in the Gulf of Saint Lawrence

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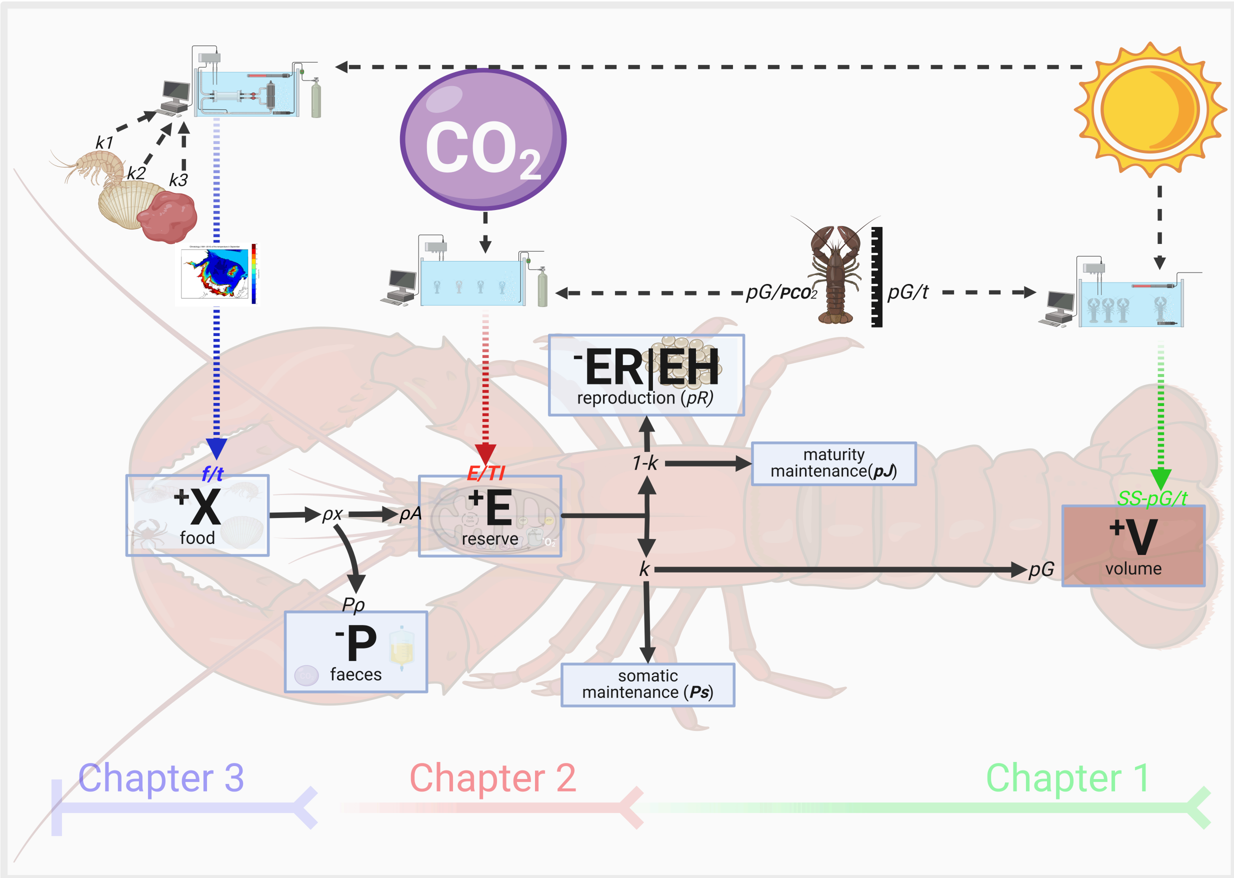
[2]Fisheries and Oceans Canada – Canada

Abstract

The application of experimental observations to predict physiological states in the field is critical and gaining momentum due to the ongoing impact of climate change. The American lobster, *Homarus americanus*, is an economically and ecologically important fishery resource for the Gulf of St. Lawrence (GSL), Canada. Their bentho-pelagic and eurythermal life-cycle facilitates their distribution despite exposure to current temperature gradients in the GSL. The warming-induced latitudinal shift in *H. americanus*' distribution was positive for the Gulf but may also harm the fisheries disproportionately. The goal of this research is to use temperature response experiments to discern variations in the physiology and behaviour of *H. americanus* so that uncertainties about the ongoing warming effect are minimized. To do so, the Scharpe-Schoolfield and Arrhenius temperature response equations were fitted to experimental data acquired from GSL-acclimated individuals and were separately incorporated into the DEB framework for a 30-year period using GSL temperatures. The Carapace Length for both models was compared with the parameterized DEB model without accounting for temperature effects, a standalone cumulative sum of growth rates from the Scharpe-Schoolfield growth rate estimation, and a tag-based mark and recapture data of *H. americanus* over the same area and time in the GSL to identify which methods best represent the physiological response to temperature in the GSL. These methods can be tailored to estimate area-specific temperature-based performance, to include other environmental effects, and, most importantly, to create Hovmöller-type figures that reveal variation in performance as environmental gradients evolve.

Keywords: DEB, Scharpe Schoolfield, Arrhenius, cumulative sum, H. americanus

*Speaker



k1
k2
k3
CO2
pG/PCO2
pG/t
-ER|EH
reproduction (pR)
1-k
maturity maintenance(pJ)
f/t
+X
food
px
pA
E/TI
+E
reserve
k
pG
SS-pG/t
+V
volume
Pp
-P
faeces
somatic maintenance (Ps)
Chapter 3
Chapter 2
Chapter 1

A full life cycle Dynamic Energy Budget (DEB) model for Peruvian anchovy Engraulis ringens in the northern Humboldt Current system (NHCS) with a focus on early-life history traits

Jorge Arturo Flores Valiente*[1], Laure Pecquerie*[2], Arturo Aguirre-Velarde[3], Fanny Rioual[4], Claudia Ofelio[5], Christophe Lett[6], François Colas[7], Jorge Tam[8], and Timothée Brochier[9]

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Abstract

The environmental conditions of the northern Humboldt Current system (NHCS) are highly variable and remain uncertain in the context of climate change. It is essential to understand how these environmental conditions affect the life history traits the Peruvian anchovy (Engraulis ringens), a keystone species, and the world's most valuable fish stock species. To do so, we have developed the first comprehensive dynamic energy budget (DEB) model for Peruvian anchovy, describing its development, growth and reproduction in response to temperature and food availability. Model parameters were estimated using larval length growth data from laboratory experiments at different temperatures, von Bertalanffy growth curves for juveniles and adults, and batch fecundity data. The model accurately reproduced observed growth patterns in length and weight of larvae, juveniles and adults, as well as

*Speaker

the ages and sizes at developmental transitions between life stages. We were particularly interested in early-life stages in terms of growth and survival under food deprivation and as a function of temperature, as the model was integrated into a Lagrangian drift model to simulate recruitment variability.

Keywords: DEB model, growth acceleration, larval shape correction function, Engraulis ringens

A Dynamic Energy Budget (DEB) model of anchovy (Engraulis ringens) growth and reproduction in the southern Humboldt ecosystem

Sebastián Vásquez*[1], Cristian Salas[1], Leonardo Castro , Jorge Flores-Valiente , Timothée Brochier , Christophe Lett , Nicolas Barrier , and Laure Pecquerie*

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Abstract

The Dynamic Energy Budget (DEB) model describes energy flow in individual organisms, integrating food assimilation, maintenance, growth, development, and reproduction as functions of environmental factors such as temperature and food availability. Recently, it has been successfully applied to the Peruvian anchovy *Engraulis ringens* in the northern Humboldt ecosystem, providing insights into biological processes across different life stages. In this study, we developed a DEB model for anchovy in the southern Humboldt, where this neritic species plays a crucial ecological and economic role. The model enhances understanding of how environmental variability influences development and survival during the embryo and larval stages, as well as growth and reproduction during the juvenile and adult stages, essential for assessing spatiotemporal population responses in a changing environment.

Additionally, this model enables the investigation of local adaptation in small pelagic fish. Given the species' wide latitudinal distribution, from a permanent tropical upwelling system in the north to a seasonal subantarctic river-influenced upwelling system in the south, populations are expected to differ in thermal ranges and reproductive timing. Comparing DEB parameters between these populations may reveal local adaptation in other physiological traits.
The model was calibrated using experimental and long-term biological monitoring data to estimate core parameters and examine the effects of environmental conditions on energy allocation for growth and reproduction. Finally, we demonstrate its integration with a Lagrangian larval drift model as a mechanistic approach to studying early-life survival and recruitment variability under changing food supply and temperature conditions.

Keywords: Anchovy, Engraulis ringens, southeastern Pacific, local adaptation, DEB model

*Speaker

Forecasting impacts of ocean acidification and warming (OAW) on Abalone growth and reproduction: A dynamic energy budget approach for contrasting climate scenarios.

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Abstract

In the face of ongoing global climate change, understanding the impacts of ocean warming (OW) and ocean acidification (OA) on marine biodiversity has become crucial. This study introduces a novel Dynamic Energy Budget (DEB) model for mollusks, focusing on the European abalone, to mechanistically predict the effects of OW and OA on their growth and reproduction under different Shared Socioeconomic Pathway (SSP) scenarios and varying food quality levels. The model incorporates high-frequency empirical data on sea surface temperature (SST), pH, four European coastal locations, in addition to food availability, with future projections extending to 2100. Algal biomass data were analyzed using Fourier transforms to capture seasonal food availability patterns, while SSP-based projections of SST and pCO2along with reduced food quality quantity levels were used to simulate daily environmental conditions over time. Key findings reveal that while abalone length remains relatively unchanged across different locations and climate scenarios when food quality is high, significant effects are observed on weight ($p < 0.05$) and reproductive performance under low food quality conditions. The gonadosomatic index ($p < 0.001$) shows marked declines, with fewer spawning events and a shorter spawning season projected by the end of the century under climate change scenarios. These results suggest that abalone might experience reduced body weight and reproductive output in future food quality deprived ocean conditions, underscoring their vulnerability to environmental stressors. The DEB model provides a robust framework for predicting biological responses and emphasizes the urgent need for adaptive strategies in marine conservation and aquaculture management as ocean conditions change.

*Speaker

Keywords: Ocean warming (OW), Ocean acidification (OA), Dynamic Energy Budget (DEB) model, European abalone, Shared Socioeconomic Pathways (SSP)

Integrating AI and DEB-otolith models for enhanced fish age and growth estimation

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Abstract

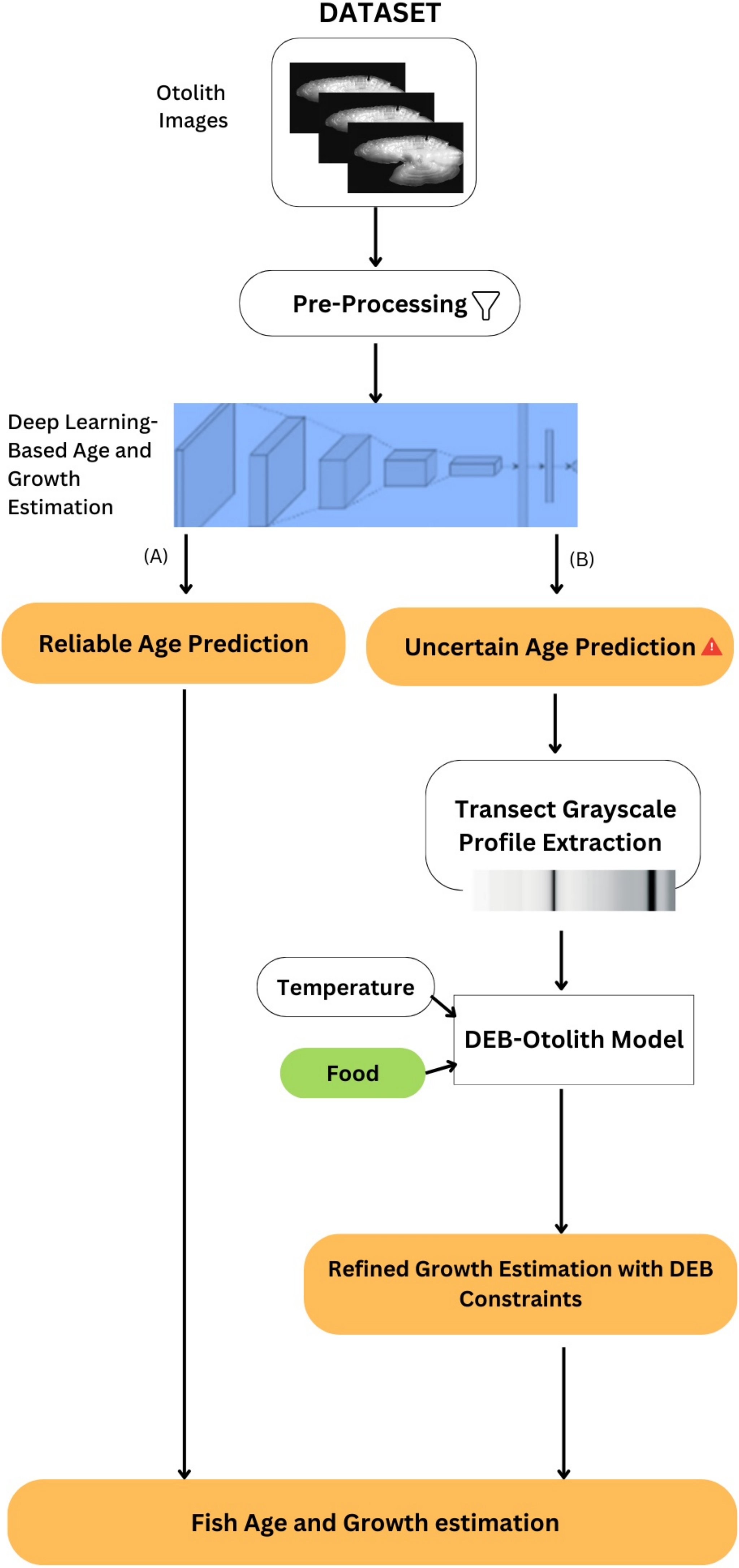
Accurate fish age and growth estimates are crucial for understanding population dynamics and ensuring sustainable fisheries management. Traditional methods involve manual interpretation of otolith structures, which is time-consuming and prone to inter-reader variability and misinterpretation. Artificial intelligence (AI), particularly deep learning, has emerged as a promising tool for automating otolith image analysis, improving efficiency, and reducing subjectivity. However, we foresee several limitations that may still lead to uncertainty in fish age and growth: (i) AI-based approaches primarily rely on statistical correlations and may overlook key physiological and environmental mechanisms underlying otolith growth and opacity; (ii) they are trained on datasets that may contain errors.

To address these limitations, we propose a hybrid approach that combines AI-driven otolith analysis with an existing DEB-otolith model, which integrates temperature- and metabolically dependent biomineralization processes. First, AI extracts growth parameters from otolith images and flag cases with high uncertainty. For uncertain cases, we extract grayscale variations along a transect of the otolith. The DEB-otolith model then reconstructs fish age and growth that best reproduce these grayscale variations, reducing AI prediction uncertainty.

As a first step, we will simulate synthetic otolith under controlled environmental conditions to assess how DEB modeling can improve AI-derived estimates. This methodological framework lays the foundation for a mechanistic integration of AI and DEB modeling, providing a biologically coherent approach to fish age and growth estimation. Future research will focus on validating this approach with real otolith datasets and assessing its applicability across different species and ecological contexts

Keywords: Fish Age and growth Estimation, Dynamic Energy Budget theory, Otolith Analysis, Artificial Intelligence, DEB, otolith model, Fisheries Management

*Speaker


DATASET
Otolith Images
Pre-Processing
Deep Learning-Based Age and Growth Estimation
(A)
(B)
Reliable Age Prediction
Uncertain Age Prediction
Transect Grayscale Profile Extraction
Temperature
Food
DEB-Otolith Model
Refined Growth Estimation with DEB Constraints
Fish Age and Growth estimation

Applying a DEBkiss Model to Acartia tonsa to Predict Physiological Responses to Environmental Stress

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Abstract

Acartia tonsa is a key marine copepod species, crucial in trophic dynamics and ecosystem functioning. It is also commercially significant as a live feed in aquaculture. While Dynamic Energy Budget (DEB) models have been applied to some copepod species, *A.tonsa* has not yet been explicitly modeled. Unlike some copepods, *A.tonsa* lacks lipid reserves but follows the typical molting sequence from nauplius to copepodite to adult, and a lack of growth after reaching adulthood. To investigate *A.tonsa*'s physiological responses to environmental stressors and assess the suitability of a DEB framework, we collected metabolic data from literature. We conducted experiments on respiration rates at temperatures exceeding the species' upper thermal limit. Results demonstrated that respiration rates increased with temperature up to an optimum, then declined, indicating thermal stress. Given the need for a simplified but effective modeling approach that takes into consideration the unique development of copepods, we applied the DEBkiss model, which has been previously used for copepods. Our findings indicate that DEBkiss captures the metabolic trends observed in *A.tonsa*, providing a valuable tool for predicting its responses to environmental change. This work enhances our understanding of copepod physiology under stress and supports the use of DEB models for future ecological and aquaculture applications.

Keywords: Acartia tonsa, DEB model, thermal stress, respiration, copepod ecology

*Speaker

Reconstructing environmental trajectories by combining growth and chemical information

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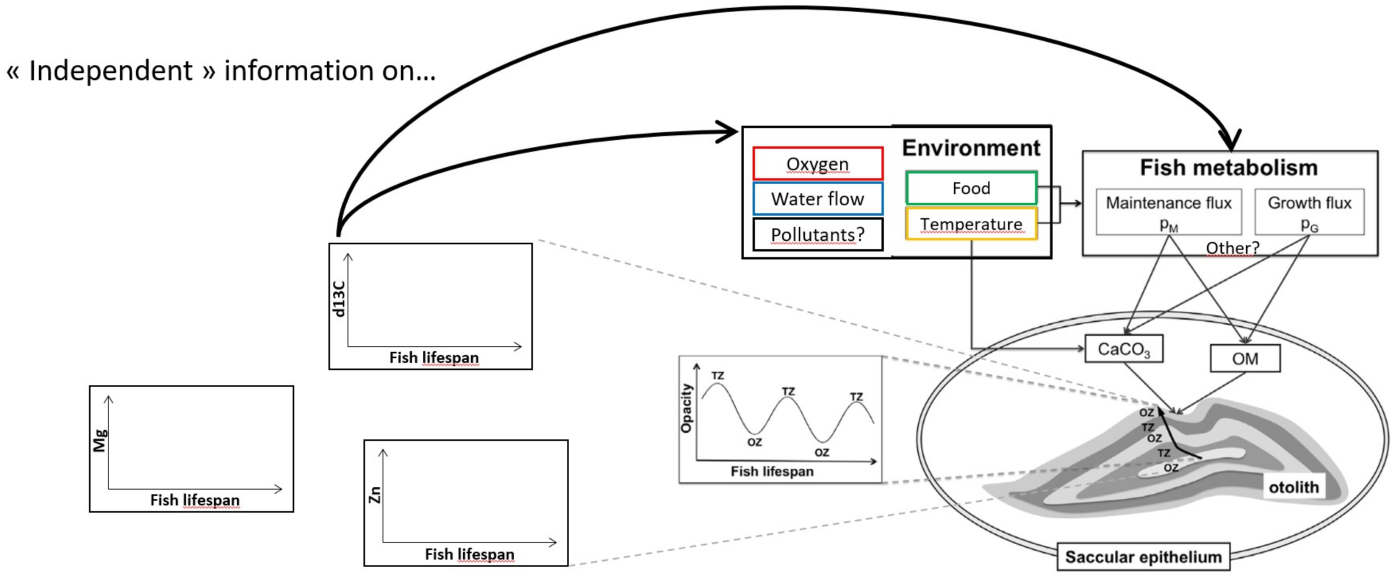
Abstract

In many fish species, and particularly in migratory species, monitoring the environmental conditions experienced by an individual during its life remains a challenge. However, it is essential to identify the causes of declines in population size and individual condition. Calcified pieces (vertebrae, otoliths, scales) constitute a valuable record, but they integrate the many sources of variation, particularly metabolic, which are often difficult to disentangle. Our aim is to use chemical and micro-chemical data to complement existing reconstruction approaches based on the growth of calcified pieces to improve our ability to distinguish the effects of different types of stress (thermal, hypoxic, metabolic) on these pieces. This requires a complementary model of elemental (such as Mg, Mn, P, Zn) and isotopic variations in otoliths. The main challenge comes from the fact that chemical and microchemical markers provide semi-quantitative information, reliable for tracing relative variations but more difficult to transpose into absolute values between different species or even populations. The performance of this model should be evaluated on the basis of chemical and environmental datasets. As a first step, we conducted preliminary analyses on samples of eels (*Anguilla anguilla*) from Mediterranean lagoons for which environmental conditions (temperature and oxygen concentration) are measured at high frequency and on salmon subjected to controlled emersion stress in experimental conditions. This will evaluate our capacity to detect acute environmental stresses (temporal resolution) as well as our capacity to distinguish intense acute stress from more moderate chronic stress (discrimination).

Keywords: environmental reconstruction, bones, acute stress

*Speaker



« Independent » information on…
Environment
Oxygen
Water flow
Pollutants?
Food
Temperature
Fish metabolism
Maintenance flux
p_M
Growth flux
p_G
Other?
$CaCO_3$
OM
d13C
Fish lifespan
Mg
Fish lifespan
Zn
Fish lifespan
Opacity
TZ
OZ
TZ
OZ
TZ
Fish lifespan
OZ
TZ
OZ
TZ
OZ
otolith
Saccular epithelium

Bioenergetic Modeling of native and invasive herbivorous fish in the Eastern Mediterranean Sea: Assessing Climate-Driven Performance Shifts

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Abstract

Global warming has facilitated the migration of several Red Sea species into the Mediterranean. Among the many that entered the Eastern Mediterranean following the opening of the Suez Canal, *Siganus rivulatus*, a tropical herbivorous fish, was one of the first non-indigenous species to establish itself in the region. This study aims to identify potential mechanisms that may give the invasive herbivore *S. rivulatus* a competitive advantage over its native counterpart *Sarpa salpa*. DEB models for both species were developed and used to simulate their performance across temperature and food gradients. Additionally, the models explored the effects of historical temperature changes between a past, cooler period (1982–1997) and a more recent, warmer period (1998–2022) in the northern and southern Eastern Mediterranean Sea. The findings suggest that rising temperatures have progressively favored the invasive *S. rivulatus*, enhancing its growth relative to *S. salpa* and providing a competitive edge that may explain its rapid expansion. Furthermore, the models offer insights into other ecological factors, such as food competition and reproductive differences, discussed in the context of existing knowledge. This study provides a mechanistic perspective on bioinvasions, helping to elucidate the metabolic and ecological responses of native and invasive species in the shifting Mediterranean ecosystem.

Keywords: Lessepsian migration, climate change, Sarpa salpa, Siganus rivulatus

*Speaker


Sarpa salpa
salema
Mediterranean
herbivorous
Temperature
native
Food
DEB
Climate change
Siganus rivulatus
marbled spinefoot
invasive
Bioinvasion
Suez

Dynamic Energy Budget model predicts physiological traits in polymorphic species

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Abstract

The prawn species *Macrobrachium amazonicum*, Heller 1862 (Decapoda: Caridea), exhibits polymorphism, resulting in different morphotypes with distinct physiological traits. This species has great importance in aquaculture and occurs in two major wild populations-continental and coastal-both exhibiting high individual diversity. Understanding the mechanisms driving this intraspecific growth variability is crucial. The Dynamic Energy Budget (DEB) theory is applied here to investigate the different physiological traits of *M. amazonicum*. Two DEB models were developed for each morphotype: one with varying assimilation rates and another with different somatic maintenance costs. These models were parameterized with weight and length data from the literature and used to simulate physiological characteristics such as mass gain, daily growth, ingestion, feces, excretion, and respiration rates. Both models exhibited similar patterns, though at different rates, when compared with experimental data. The morphotype-specific somatic maintenance model aligned more closely with experimental findings. We demonstrate that growth-based models can yield reasonable estimates for other physiological traits. This research aims to provide insights into intraspecific growth variability and physiological diversity in *M. amazonicum* using the DEB theory. Unraveling these underlying mechanisms improves our understanding of this species' polymorphism.

Keywords: Polymorphism, Calorimetry, Macrobrachium amazonicum

*Speaker