iso INVA

IMPACTS OF INVASIVE SPECIES ON FOOD WEB STRUCTURE

11-13 JULY 2022

LISBON (GMT+1)

BOOK OF ABSTRACTS

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CONFERENCE PROGRAM

11/07/22

WELCOME

14:15 — BY **CHRISTOS GKENAS**

KEYNOTE TALK

14:30 — BY **CHRIS HARROD** CL

The power of **STABLE ISOTOPES** to reveal otherwise hidden ecological information in a changing world: from individual consumers to whole landscapes

REGULAR SESSION — MARINE FOOD WEBS

15:30 — TALK BY **HELENA PIRES** PT

Benthic source dominance in temperate rocky reefs revealed by stable isotopes

15:45 — TALK BY **MARIA MERCADO** MX

Determination of stable isotopes d13C and d15N of the genus *Neoporphyra* (Bangiales: Rhodophyta) in the Gulf of California

BREAK

16:30 — TALK BY **LARISSA MARQUES** BR

The effect of two invasive azooxanthellate corals *Tubastraea coccinea* and *Tubastraea tagusensis* on trophic interactions with native species

16:45 — TALK BY **CHLOE VAN GROOTHEEST** US

Using diet and stable isotopes to understand the effects of habitat fragmentation on the ecology of a native and nonnative goby within a California wetland

17:00 — TALK BY **LARISSA MARQUES** BR

Diversity analysis and trophic structure of a recently invaded tropical rocky shore

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KEYNOTE TALK

14:00 BY **JULIEN CUCHEROUSSET** FR

STABLE ISOTOPE insights into the effects of invasive predatory fish on food webs: a global perspective

REGULAR SESSION FRESHWATER FOOD WEBS

14:45 TALK BY **JOANA MARTELO** PT

Trophic niches of native and nonnative fishes along a gradient of invasion

15:00 TALK BY **ABDUL QADEER** CN

Influence of habitats and physicochemical factors on trophic transfer processes of antibiotics in a freshwater ecosystem: application of stable isotopes

15:15 TALK BY **ZHENG ZHOU** DE

Tropical land use alters functional diversity of soil food webs and leads to monopolization of the detrital energy channel

BREAK

KEYNOTE TALK

16:00 BY **ROBERT BRITTON** EN

Insights into the trophic ecology of invaded freshwater fisheries from **STABLE ISOTOPE** analysis

REGULAR SESSION FRESHWATER FOOD WEBS

16:45 TALK BY **VANESSA DE SANTIS** IT

Stable isotopes revealed non-native fish assemblages' potential competitive advantages in two protected small and shallow lakes of northern Italy

17:00 TALK BY **MELANIE POLLIERER** DE

Tropical land-use conversion in Indonesia alters energy fluxes and functions in canopy arthropod food webs

17:15 TALK BY **VINICIUS URBANO** BR

Energy source to *Schizodon borellii* accordingly to the land use

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SPECIAL SESSION — Uncovering HISTORICAL RECORDS locked inside MUSEUM COLLECTIONS

14:00 — TALK BY **JUDITE ALVES** PT

NATURAL HISTORY COLLECTIONS as research infrastructures for the study of biodiversity

14:45 — TALK BY **THOMAS TURNER** EN

LONG-TERM ECOLOGICAL RESEARCH enabled by biodiversity collections, stable isotope analysis, and environmental informatics

BREAK

16:00 — TALK BY **IVAN GONZALEZ BERGONZONI** UY

Historical **FOOD-WEB CHANGES**: ecological niche shifts in omnivorous fish of the lower Uruguay river following the invasion of the Golden mussel (*Limnoperna fortunei*)

16:45 — TALK BY **NATHALIE GONTIER** PT

Causation in the food web: a historical-philosophical analysis

17:00 — TALK BY **CHRISTOS GKENAS** PT

Historical food-web changes in invaded fish communities in the Lower Guadiana Basin

CLOSING SESSION

17:15 — BY **CHRISTOS GKENAS**

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KEYNOTE TALK

CHRIS HARROD
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THE POWER OF STABLE ISOTOPES TO REVEAL OTHERWISE HIDDEN ECOLOGICAL INFORMATION IN A CHANGING WORLD: FROM INDIVIDUAL CONSUMERS TO WHOLE LANDSCAPES

Stable isotope analysis (SIA) is now a standard instrument in the aquatic and invasion ecologist's toolbox. Stable isotope data are now routinely used to characterise food webs and the impacts of environmental change such as the introduction of non-native species. Like all tools, SIA can be used correctly or inappropriately, and the utility of the information gained will obviously vary according to how the approach is used. For example, some researchers follow a relatively standard approach to the analysis of stable isotope data. Although this provides key information, it can fail to identify interesting ecological information that permits a greater understanding of consumer diet and movement and how ecosystems function. Here, using examples from 2 decades of using SIA with collaborators across the world, I review some of the most useful characteristics of SIA to rapidly identify otherwise hidden ecological variation. The data generated have proved relevant to the ecology, evolution, function and conservation of consumers and systems across the freshwater-marine gradient. They have also stimulated new thinking, projects, student theses and successful research careers. In several cases, it is apparent that the information generated using SIA is often impossible to produce using other techniques, at least for a similar cost. I will discuss how invasion ecologists can use stable isotopes to maximise the amount of ecological information gathered from their field-based studies.

REGULAR SESSION — MARINE FOOD WEBS

HELENA PIRES
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BENTHIC SOURCE DOMINANCE IN TEMPERATE ROCKY REEFS REVEALED BY STABLE ISOTOPES

Rocky reefs, like other coastal marine habitats are heavily impacted by anthropogenic activity. Given their importance as breeding, nursery and feeding grounds for several marine species, is imperative to protect them. To improve conservation methods, it is necessary to understand the complex network of interactions within rocky reef communities. Trophic relationships are one of the ways in which species are connected, with food webs representing the flow of matter and energy in an ecosystem. Stable isotope analysis (δ13C and δ15N) was used to characterize the food web of Arrábida MPA's rocky reef. The results showed a relatively short food web, most likely due to high abundances of juveniles, with consumers with diverse diets and feeding strategies, exploiting different sources of organic matter, of both benthic and pelagic origin. The benthic pathway was exceptionally important, suggesting a bottom-up control, and hinting at the importance held by macroalgae and benthic production in this ecosystem. There was also a high incidence of omnivores in all trophic groups, which could contribute to the similar trophic redundancy and trophic evenness found between

groups. This study is an important tool to better predict the responses of the Arrábida MPA ecosystem to human threats and environmental changes.

MARIA MERCADO
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DETERMINATION OF STABLE ISOTOPES D13C AND D15N OF THE GENUS *NEOPORPHYRA* (BANGIALES: RHODOPHYTA) IN THE GULF OF CALIFORNIA

Stable isotope analysis in macroalgae allowing to determine the nutrients exchanged between trophic levels and the oceanography dynamics in ecosystems with diverse mesoscale phenomena, like the Gulf of California (GC;Mexico). This study aims to establish baseline values in *Neoporphyra* species in the GC and determine the effect of environmental variables on isotopic values. Ten specimens were analyzed at each locality: 10 localities in 2006, and seven localities in 2008, all samples were obtained from the Phycological Herbarium of Baja California Sur (UABCS). d13C values ranged from –21.2 to –17.1‰, whereas d15N values ranged from 10.3 to 14.7‰. Significant difference exists in d15N values between the eastern and western coasts of the GC, indicating there were mixing and stratification processes. Isoscapes showing high d13C values in the middle and south of the Gulf, while high d15N values can be found throughout the coastal zone and in large islands, suggesting biogeochemical processes (upwelling, coastal discharges). Generalized additive models (GAMs), determined that temperature, chlorophyll, location (longitude and latitude), and year have a significant effect on the d13C values, while location and chlorophyll have a significant effect on d15N values. The present study provides the first isotopic baseline of the genus *Neoporphyra* in GC.

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THE EFFECT OF TWO INVASIVE AZOOXANTHELLATE CORALS *TUBASTRAEA COCCINEA* AND *TUBASTRAEA TAGUSENSIS* ON TROPHIC INTERACTIONS WITH NATIVE SPECIES

When a species is introduced in a new location it is common for it to establish itself when it finds favorable conditions in the receptor community. The azooxanthellate corals *Tubastraea coccinea* and *Tubastraea tagusensis* are invasive species introduced in the Caribbean Sea, the Gulf of Mexico and in the Brazilian Southwest Atlantic. They are successful competitors for space, excellent in sexual and asexual reproduction, larval dispersion and recruitment, however, studies of feeding ecology and trophic relationships of species of the genus *Tubastraea* are scarce. In the present study, we used isotopic values of δ13C and δ15N to investigate trophic relationships in invaded rocky shore communities in different oceanographic and anthropogenic conditions. The metrics derived from the isotopic values demonstrated that at least one of the three invaded communities had a lower degree of trophic diversity, with species characterized by similar trophic ecologies and abiotic factors seemed to contribute to the biotic resistance of communities exposed to invasion events. *Tubastraea* spp. occupy a niche space similar to that occupied by the native community of suspension filters, sharing resources already consumed by the receptor community, which typifies theinvasive corals as successful competitors for food resources.

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USING DIET AND STABLE ISOTOPES TO UNDERSTAND THE EFFECTS OF HABITAT FRAGMENTATION ON THE ECOLOGY OF A NATIVE AND NONNATIVE GOBY WITHIN A CALIFORNIA WETLAND

Habitat fragmentation and persistence of nonnative species can negatively impact native flora and fauna within a sensitive wetland ecosystem such as the Seal Beach National Wildlife Refuge (SBNWR). This study evaluates the effect of fragmentation due

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to culverts on the ecology and potential interaction of the nonnative yellowfin goby (Acanthogobius flavimanus) and the native longjaw mudsucker (Gillichthys mirabilis) through use of dietary studies and stable isotopes. Within the SBNWR, the native goby dominates the natural creek habitat during spring, and overlaps with the nonnative goby in other habitats during other seasons. While stomach content and stable isotopes showed some similarity in diet between species, evidence suggests habitat partitioning may be occurring between the two species in times when they co-occur in the same areas. In addition, isotopic patterns were also driven by habitat characteristics, such as surrounding percent marsh, that aligned with the level of fragmentation present across sampling regions. Overall, this study demonstrates that stomach content analysis can be effectively used in conjunction with stable isotope analysis to gain accurate insight on the impact that fragmentation and persistence of nonnative species have on a wetland ecosystem.

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DIVERSITY ANALYSIS AND TROPHIC STRUCTURE OF A RECENTLY INVADED TROPICAL ROCKY SHORE

When a nonnative species remains in an invaded community for some time long-term effects on community diversity and ecosystem functioning are expected, as are changes in trophic interactions between the species. The blue soft coral *Sansibia* sp., presumably of Indo-Pacific origin, was first detected in Brazil in 2017. This study provides the first information on the trophic relationship that has developed between *Sansibia* sp. and 29 other benthic marine species in a food web on shallow tropical rocky reefs which have been invaded in the tropical southeast Atlantic. The difference in species composition of invaded and control areas was also assessed. *Sansibia* sp. showed δ15N values close to those of macroalgae, suggesting that its symbiosis with zooxanthellae represents an essential source of energy in addition to suspension feeding. A possible opportunist-generalist consumer, the arrow crab *Stenorhynchus seticornis* had values of δ13C and δ15N consistent with it being a possible consumer of *Sansibia* sp. The difference in species composition between areas and increase in the abundance of *Sansibia* sp. in shallow areas suggested there will be further expansion into more even more favorable locations, which leads us to recommend management (monitoring and eradication) of the invaded area.

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KEYNOTE TALK

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STABLE ISOTOPE INSIGHTS INTO THE EFFECTS OF INVASIVE PREDATORY FISH ON FOOD WEBS: A GLOBAL PERSPECTIVE

Human activities are impacting non-randomly the trophic structure of animal communities, notably by causing the loss of top predators. However, the introduction of non-native species by humans that often favour large-bodied species might replace, at least numerically, lost predators. These species, acting as novel components of recipient food webs, consume new resources and interact with other global change effects. This is particularly true for fish that are among the most widely introduced organisms in fresh waters and non-native fish species have larger body size and higher trophic position than native species. Understanding how they act on recipient communities and food webs is therefore of utmost importance. The use of stable isotope analyses in trophic ecology has flourished during the last two decades. Stable isotope analyses are based on the predictable relationship between a consumer and its diet and they provide a unique opportunity to assess the structural and functional impacts of non-native predators at different spatial scales. Here, I will illustrate how the compilation of stable isotope data at the global scale can be used to quantify the food-web consequences of non-native predatory fish.

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TROPHIC NICHES OF NATIVE AND NONNATIVE FISHES ALONG A GRADIENT OF INVASION

Rivers are exposed to multiple anthropogenic stressors that may interact in complex ways to affect species, communities and ecosystem functions. Species invasion and habitat change are particularly concerning, but while their individual impacts are fairly well understood, we know little about their interactions. This may be especially important in strongly modified Mediterranean harbouring unsaturated communities highly prone to invasion. Here, we used a stable isotopes approach to examine the effects of fish invaders and habitat change on food webs in the Lower Guadiana Basin (Portugal). We conducted our study in 34 dry-season pools along gradients of invasive fish richness and abundance, and habitat change. We quantified resource basis and trophic niches using stable isotope mixing models and analysed how basal resources, primary consumers and predators vary along the invasion and habitat gradients. We expect invasive species and habitat change to have interactive effects, altering trophic interactions and rewiring the flow of energy through food webs. Specifically, we expect the addition and removal of food web nodes in association with invasive species and habitat change, respectively. This would lead to reorganization of food web configurations through novel interspecific interactions, propagating via bottom-up or top-down processes. Finally, we expect lower trophic redundancy through fewer species occupying similar niche positions. Our findings will improve understanding of interactive effects of anthropogenic stressors on flow of energy through food webs and of ecosystem functioning in modified riverscapes.

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INFLUENCE OF HABITATS AND PHYSICOCHEMICAL FACTORS ON TROPHIC TRANSFER PROCESSES OF ANTIBIOTICS IN A FRESHWATER ECOSYSTEM: APPLICATION OF STABLE ISOTOPES

Habitats of species and physicochemical factors are of great importance in determining the trophic transfer of contaminants in freshwater ecosystems. There is little information on how multiple physicochemical factors and habitats influence the trophic transfer of antibiotics in freshwater food webs. This study investigated the concentrations of 7 sulfonamides (SAs), 4 fluoroquinolones (FQs), 4 tetracyclines (TCs) and 2 macrolides (MLs) in the Lake Dianshan food web. Stable isotope analysis (SIA), and mixing models were used to assign trophic levels and distinguish between the benthic food web (BFW) and pelagic food web (PFW). Values of stable nitrogen isotope (δ15N‰) and stable carbon isotope (δ13C‰) ranged from 10.2±0.11 to 19.72±0.05 and -33.67±0.18 to -20.79±0.50, respectively. Total concentrations of antibiotics ranged from 36.63±12.739 ng/g dry weight (dw) to 105.85±12.955 ng/g dw for all species. The relative abundance was in the following order: $\sum$FQs (36.49%) >$\sum$SAs (26.70%), >$\sum$MLs (12.63%) for all biota. TMFs values for individual antibiotics were ranged from 0.10 to 1.20 and 0.31 to 1.82 for PFW and BFW, respectively. Three classes of antibiotics $\sum$FQs ($p<0.05$), $\sum$TCs ($p<0.05$), and $\sum$MLs ($p<0.05$) showed significant trophic dilution in PFW, opposite to non-significant trophic dilution in BFW. The influence of various physicochemical factors was not strong over trophic transfer (e.g., octanol-water partition coefficient-LogKow (r =- 0.05 in PFW, r = -0.14 in BFW) and distribution coefficient-LogD (r = 0.06 in PWF, r = -0.28 in BFW)) except for aqueous solubility (LogS). Results indicated a significantly higher trophic dilution of antibiotics in the PFW than the BFW. Among the studied six physicochemical factors, only LogS has a significant influence ($p < 0.05$) on the trophic transfer of antibiotics in the freshwater food web. Health risk assessments indicated that currently, there were no serious risks present for urban and rural populations.

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TROPICAL LAND USE ALTERS FUNCTIONAL DIVERSITY OF SOIL FOOD WEBS AND LEADS TO MONOPOLIZATION OF THE DETRITAL ENERGY CHANNEL

Agricultural expansion is among the main threats to biodiversity and functions of tropical ecosystems. It has been shown that conversion of rainforest into plantations erodes biodiversity, but further consequences for food-web structure and energetics of belowground communities remains little explored. We used a unique combination of stable isotope analysis and food-web energetics to analyze in a comprehensive way consequences of the conversion of rainforest into oil palm and rubber plantations on the structure of and channeling of energy through soil animal food webs in Sumatra, Indonesia. Across the animal groups studied, most of the taxa had lower litter-calibrated ∆13C values in plantations than in rainforests, suggesting that they switched to freshly-fixed plant carbon ('fast' energy channeling) in plantations from the detrital C pathway ('slow' energy channeling) in rainforests. These shifts led to changes in isotopic divergence, dispersion, evenness, and uniqueness. However, earthworms as major detritivores stayed unchanged in their trophic niche and monopolized the detrital pathway in plantations, resulting in similar energetic metrics across land-use systems. Functional diversity metrics of soil food webs were associated with reduced amount of litter, tree density, and species richness in plantations, providing guidelines on how to improve the complexity of the structure of and channeling of energy through soil food webs. Our results highlight the strong restructuring of soil food webs with the conversion of rainforest into plantations threatening soil functioning and ecosystem stability in the long term.

KEYNOTE TALK

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INSIGHTS INTO THE TROPHIC ECOLOGY OF INVADED FRESHWATER FISHERIES FROM STABLE ISOTOPE ANALYSIS

Alien fishes are frequently released into freshwater fisheries to increase the fish diversity and catch rates. Understanding how these alien fishes integrate into the fish community and the food web is important for determining the outcome of their introductions, such as their feeding interactions with native species and how their presence has impacted species at other trophic levels. Using a case study approach, I demonstrate that stable isotope analysis (SIA) can provide insights into the trophic ecology of these invaded fisheries that are unavailable from any other method. Firstly, I show that how alien European barbel *Barbus barbus* in the River Severn, western England, have strongly diverged trophic (isotopic) niches with other fishes at smaller sizes but with these niches converging as fish lengths increase. This niche convergence is driven by the increasing dietary contributions in all species of barbel angling baits based on marine fishmeal, with this trophic subsidy able to be traced through the food-web up to large Northern pike *Esox lucius*. I then demonstrate how SIA has revealed that invasions of the small Asian cyprinid fish topmouth gudgeon *Pseudorasbora parva* usually result in strong patterns of trophic niche divergence with functionally similar native fishes, with this apparent in experiments lasting 150 days through to ponds where the fishes have been in sympatry for 8 years. Finally, I reveal how ecological changes in Lake Naivasha, Kenya, driven by invasion meltdown processes, have impacted the population of the globally invasive largemouth bass *Micropterus salmoides* through dietary shifts and abundance declines. These case studies demonstrate that SIA provides a powerful tool for investigating how alien fish invasions alter the trophic ecology of freshwater fisheries.

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STABLE ISOTOPES REVEALED NON-NATIVE FISH ASSEMBLAGES' POTENTIAL COMPETITIVE ADVANTAGES IN TWO PROTECTED SMALL AND SHALLOW LAKES OF NORTHERN ITALY

Italian fresh waters host 57 established non-native fish species but ecological conditions of fish assemblages are seldom evaluated, particularly in small and shallow lakes. Here, traditional fish surveys (gillnetting and electrofishing) and stable isotopes analysis (SIA) of carbon and nitrogen were combined to assess fish assemblage composition and trophic structure, and to characterize the interspecific trophic interactions (as isotopic niches and their relative asymmetric overlap) of the native and non-native species (NS and NNS, respectively) found in two protected small and shallow lakes, San Michele and Campagna (northern Italy). Despite the two lakes had different fish assemblages, dominated both in biomass and number by NS (Campagna) and NNS (San Michele) respectively, SIA revealed that in both lakes NNS had greater trophic structure and were exploiting a wider range of resources with a higher asymmetric overlap than NS. In both lakes, the NNS *Ameiurus melas* had the broadest isotopic niche and the highest asymmetric overlap suggesting a potential competitive advantage over NS, in case of limiting resources. The results sustain the hypothesis that ecophysiological plasticity favors the successful invasion of NNS and highlight that SIA is a powerful tool for identifying potential conservation issues and priorities.

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TROPICAL LAND-USE CONVERSION IN INDONESIA ALTERS ENERGY FLUXES AND FUNCTIONS IN CANOPY ARTHROPOD FOOD WEBS

Land-use conversion of rainforest to oil palm and rubber plantation systems in Indonesia is causing vast decreases of arthropod biodiversity. However, little is known about changes in energy fluxes and functions of canopy arthropod food webs as influenced by land-use change. Here, we constructed realistic food webs of quantitatively sampled canopy arthropod communities based on bulk stable isotope analyses at order/family level in rainforests, rubber agroforests ('jungle rubber'), rubber and oil palm plantations. Using these food webs, we for the first time quantified energy fluxes and functions within entire canopy arthropod communities, documenting not only drastic decreases in energy fluxes, but also pronounced functional shifts if rainforest is converted to plantation systems.

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ENERGY SOURCE TO *SCHIZODON BORELLII* ACCORDINGLY TO THE LAND USE

The formation of the Itaipu Reservoir with the inundation of the Salto de Sete Quedas allowed fish species to invade the upper reaches of the upper Paraná river, as well as the herbivore *Schizodon borellii*. Thus, the present work has the objective to evaluate the feeding plasticity of *S. borellii* in three subsystems of the Paraná River Floodplain according to land use change. As well as, it was hypothesized that this species shows a modification in the energy sources according to predominant land use, around the rivers. Were collected fishes and their energy sources (aquatic macrophytes and riparian vegetation) and subsequently processed and measured their signature of δ13C and δ15N. The contribution of the baseline was measured in the software R and land use in ArcGIS. It was found that more areas of native vegetation non-arboric, pasture or pasture and agriculture mosaic occur together with more assimilation of the aquatic macrophytes to herbivore. On the other hand, the predominance of the forest showed more contribution from the riparian vegetation. Thus, concluded plasticity in the obtention of C is in accord with the available resources in the environment.

SPECIAL SESSION
UNCOVERING HISTORICAL RECORDS LOCKED INSIDE MUSEUM COLLECTIONS

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NATURAL HISTORY COLLECTIONS AS RESEARCH INFRASTRUCTURES FOR THE STUDY OF BIODIVERSITY

Natural history collections are essential to biodiversity research, as they are the fundamental underpinnings of all biological information. In a rapidly changing and increasingly resource-depleted world, the long-term datasets and specimens held in natural history museum collections have never been more important, as they are increasingly being used to address a variety of scientific questions and societal challenges. Scientific and technological advances create new uses for biological collections that were not anticipated at the time of their assembly, providing an endless resource for present and future research.

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LONG-TERM ECOLOGICAL RESEARCH ENABLED BY BIODIVERSITY COLLECTIONS, STABLE ISOTOPE ANALYSIS, AND ENVIRONMENTAL INFORMATICS

Biodiversity collections are experiencing a renaissance fueled by the intersection of informatics, emerging technologies, and the extended specimen. This talk explores the enormous potential for transformative research in ecology using biodiversity collections, stable isotope analysis (SIA), and environmental informatics. Like DNA, SIA provides a fundamental 'currency' interpreted in the context of biogeochemical and ecological principles. Integration and extension of specimens across regional biodiversity collections allows for evaluation of ecological change at decadal and continent-wide scales. There are important, but surmountable, challenges to SIA research in this context including analysis of sparse samples, lack of isotopic baselines, and preservative effects. Key to harnessing the power of SIA is a centralized, searchable repository for isotopic data that links to digitized biodiversity data. The IsoBank Database Project is developing this resource to capitalize on big data analytics that interfaces with long-term environmental databases. The general framework could be further developed and explored in a research program that interfaces ecological observatory networks like the NEON project sponsored by the US National Science Foundation. The time is right to marshal biodiversity collections to provide important historical context to fundamental questions in freshwater ecological research, baselines for ecosystem monitoring following disturbance, and a quantitative means for assessing effects of ecosystem restoration.

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HISTORICAL FOOD-WEB CHANGES: ECOLOGICAL NICHE SHIFTS IN OMNIVOROUS FISH OF THE LOWER URUGUAY RIVER FOLLOWING THE INVASION OF THE GOLDEN MUSSEL (*LIMNOPERNA FORTUNEI*)

Since the Asian golden mussel, *Limnoperna fortunei*, was first reported in the Río de la Plata in the 90', its invasion has continuously expanded thorough South America, promoting several negative ecosystem consequences. Several fish species consume and assimilate large fractions of *L. fortunei* in their biomass, partially controlling the abundances of this invader, but potential fish dietary and trophic niche modifications caused by the invasion have not been studied. Through gut content, stable isotopes and gut morphometry analysis in field-collected and historical museum samples, the potential dietary, trophic niche and physiological consequences of the invasion for predatory fish of the golden mussel were surveyed. The analysis of historical samples of

some of the most frequent *L. fortunei* consumers – i.e. *Megaleporinus obtusidens* and *Pimelodus maculatus*–revealed a reduction in direct terrestrial subsides and vegetal matter in diet as fish started to incorporate *L. fortunei*. This dietary shift provoked changes in isotopic niche towards an increased trophic position and a reduced trophic diversity in *M. obtusidens*. Furthermore, the digestive tract mass of *M. obtusidens* decreased after the invasion as its diet shifted from herbivory to carnivory, increasing by hence diet quality. This research set up several questions about the potential effect of *L. fortunei* on growth rates and abundances of *M. obtusidens* and *P. maculatus*, two of the most important species in commercial fisheries in the Uruguay river. Also, it may assist in predicting food web changes to be expected in newly invaded areas.

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CAUSATION IN THE FOOD WEB: A HISTORICAL-PHILOSOPHICAL ANALYSIS

It is important that scientific illustrations adequately convey the right messages. This is also the case for the food web which is a diagram that replaces the older food chain. Food chains used to be understood and depicted as linear chains, where organisms were ordered based upon their level of consumption or predation, while today, the same organismal relationships are depicted in a network-like fashion. Web diagrams are a means to reconceptualize organismal relationships as not only unilinear but as multilinear and reticulate, which in turn associates with reticulate evolution studies in general and symbiosis research in particular. I will detail how these images bring forth a new way to conceptualize causation. While causation used to be understood as running up or down the rungs of a linear hierarchy, networks and webs require the recognition of reticulate causation.

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HISTORICAL FOOD-WEB CHANGES IN INVADED FISH COMMUNITIES IN THE LOWER GUADIANA BASIN

Freshwater ecosystems are increasingly being reshaped by biological invasions, leading to biotic homogenization and biodiversity loss. However, the extent to which novel species may drive changes in food-web structure over time remains poorly understood. Clarifying changes in historical ecological processes is critical to inform conservation and restoration efforts in recipient ecosystems. Here, we address food-web changes associated with fish invasions in the Lower Guadiana Basin (LGB) over the past 40 years, by contrasting feeding relationships between museum-archived and contemporary specimens, using stable carbon (δ13C) and nitrogen (δ15N) ratios. Specifically, trophic niches of museum-archived fishes sampled throughout 1978–1987 and 1999–2004 corresponding to the initial establishment and spread of non-native fishes, respectively, were compared with those of fishes sampled in 2019, characterizing the integration of non-native species in the recipient ecosystem. We focused on five native species (*Anaecypris hispanica*, *Cobitis paludica*, *Iberochondrostoma lemmingii*, *Squalius pyrenaicus* and *Squalius alburnoides*) and four non-native species (*Lepomis gibbosus*, *Australoheros facetus*, *Micropterus salmoides* and *Gambusia holbrooki*) with potential to cover multiple trophic positions in the food-webs. We approached historical baseline resources using prey items in gut contents of the museum-archived fishes and characterized primary producers and macroinvertebrates in 2019. Prior to analysis, samples were normalized for high lipid content and corrected for preservation. We found considerable asymmetries in niche partitioning among species as invasion progressed. Over time, native species tended to be displaced to lower trophic levels, while non-native species showed significantly higher trophic niches, driven mainly by increases in trophic (δ15N) range. Our study highlights that stable isotopes may provide important insights on historical food-web structure and particularly on processes underpinning ecological changes associated with anthropogenetic pressures on freshwater ecosystems.