30 YEARS

1985- 2015

CENTRE D’ESTUDIS AVANÇATS DE BLANES

The goal of the project MetaBarPark is to develop and validate a tool (techniques and protocols) to characterize the biodiversity of representative communities of the Marine National Parks using environmental DNA.

The Contents of the Bulletin

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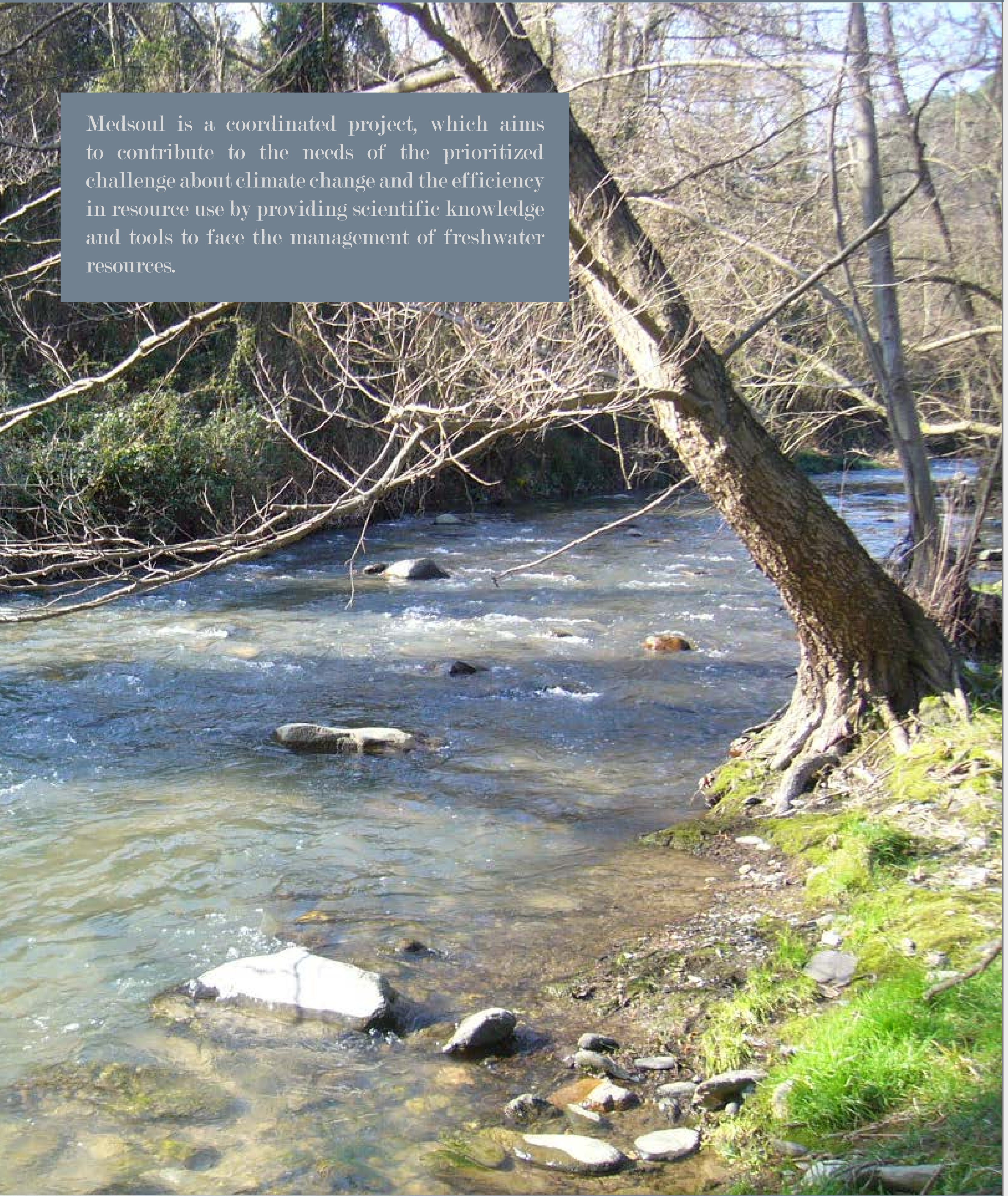


Medsoul is a coordinated project, which aims to contribute to the needs of the prioritized challenge about climate change and the efficiency in resource use by providing scientific knowledge and tools to face the management of freshwater resources.

More than 50 years of scientific research in Blanes

FROM THE "AQUARIUM" TO THE CENTRE D'ESTUDIS AVANÇATS DE BLANES (CEAB)

By María Jesús Uriz

Blanes, "the Costa Brava Portal", as its touristic trademark announces, is geographically located on a privileged rocky littoral with spectacular steep cliffs. The beauty of the Costa Brava landscape has conferred to the village an international touristic reputation. However, the touristic prestige of Blanes did not hamper its parallel trajectory on investigation.

Indeed, Blanes has had a long tradition in scientific research on Natural Systems, likely triggered by Carlos Faust, who founded the Botanical Garden Mar i Murtra with its associated International Station of Mediterranean Biology in 1920. At the beginning of the forties, a young Ramon Margalef, who would become one of the best ecologists worldwide, started his research on freshwater protists in the dependencies of the Botanical Garden. In 1949, the Consejo Superior de Investigaciones Científicas (CSIC) set up in Blanes one of its four coastal Institutes of Fishery Research (IIP) with its provisional headquarters in the fishermen huts at the Blanes harbor. When in 1957, the IIP moved to a new building in Barcelona, it did leave a coastal marine laboratory harboring a small public aquarium, which would persist in place for 30 years.

The Blanes laboratory, commonly known as " the Aquarium" closed in 1987, after retirement of its latest director Manuel Rubió. The inauguration of the Centre d'Estudis Avançats de Blanes (CEAB), also belonging to the CSIC, took place in

The Aquarium & Laboratory at the Blanes harbor in the seventies.

First computers. 1985.

First sponge meeting. 1986.

1985, almost concurrently with the Aquarium pre-closure. This is maybe because the CEAB has been commonly regarded as a continuation of the Aquarium of Blanes. However, the initial scientific objectives of the CEAB had little to do with the research that had been conducted at the old Laboratory-Aquarium.

The Blanes laboratory had all the requisites of a Coastal Marine Station: easy access to various Mediterranean marine ecosystems, fluent collaboration with local fishermen, who facilitated sampling far from the coast, and an open water system of aquaria, which allowed the maintenance of living organisms for experimentation. Despite its small size, this laboratory-aquarium, took benefit of its privileged situation and received scientists from marine research Institutions around the world, as well as students from the Spanish Universities for summer stays and PhD researchers on benthic fishes and invertebrates.

The CEAB team in 1990.

Conversely, the CEAB was not initially planned to perform research on marine sciences but to gather scientists from everywhere during their sabbatical stays. Federico Mayor Zaragoza, Minister of Educación y Ciencia in 1981-1982 (UCD), supported by scientists such as Joan Oro, at that time retired from his research activities at the NASA, lead this project. However, the replacement of UDC by the Socialist party at the Spanish Government in 1982, altered the CEAB exciting formula, which stimulated the creativity of those scientists working "apart together" at the CEAB. Joint seminars where the speaker lowed down the difficult terms and concepts of his own field of research to facilitate general understanding were organized weekly. The "marine" learned about solar winds, Red Giants, White Dwarfs, and fuzzy logics, while the mathematics, physicists, and informatics were fascinated because of the shapes, functioning, and names of marine organisms. This unique "experiment" bred unexpected results, such as some formal collaboration between "the Intelligent" (as we, the biologists, used to name the people of the Artificial Intelligence Department) and "the biologists". Co-surpervision of one master and one doctoral thesis, besides several coauthored papers on expert systems for sponge identification emerged from ideas that have grown up during the joint seminaries and the daily talks at the CEAB canteen.

But the CEAB, like any living being does, evolved with time. As originally planned, the group of Artificial Intelligence leaved the CEAB to form its own Institute in Bellaterra in 1994. Few years later (1999), the Astrophysicists moved to Barcelona to take part of the Institut de Ciències de L'Espai (ICE). The CEAB seemed to have found its definite research career on marine sciences, but a team of Freshwater Ecology from the University of Barcelona joined the marine in 2001 and both groups were the germ of the current Departments of Continental Ecology and Marine Ecology.

Comings and goings did not impede the CEAB to find its long-term scientific way: the study of aquatic systems and their responses to environmental, natural and man-induced changes. The circle was closed and the early research on fresh-water organisms initiated by Margalef at the Blanes Botanical Garden in the forties followed by the investigation on the marine benthos at the old aquarium (IIP) regained prominence to become the only current research lines of the CEAB.

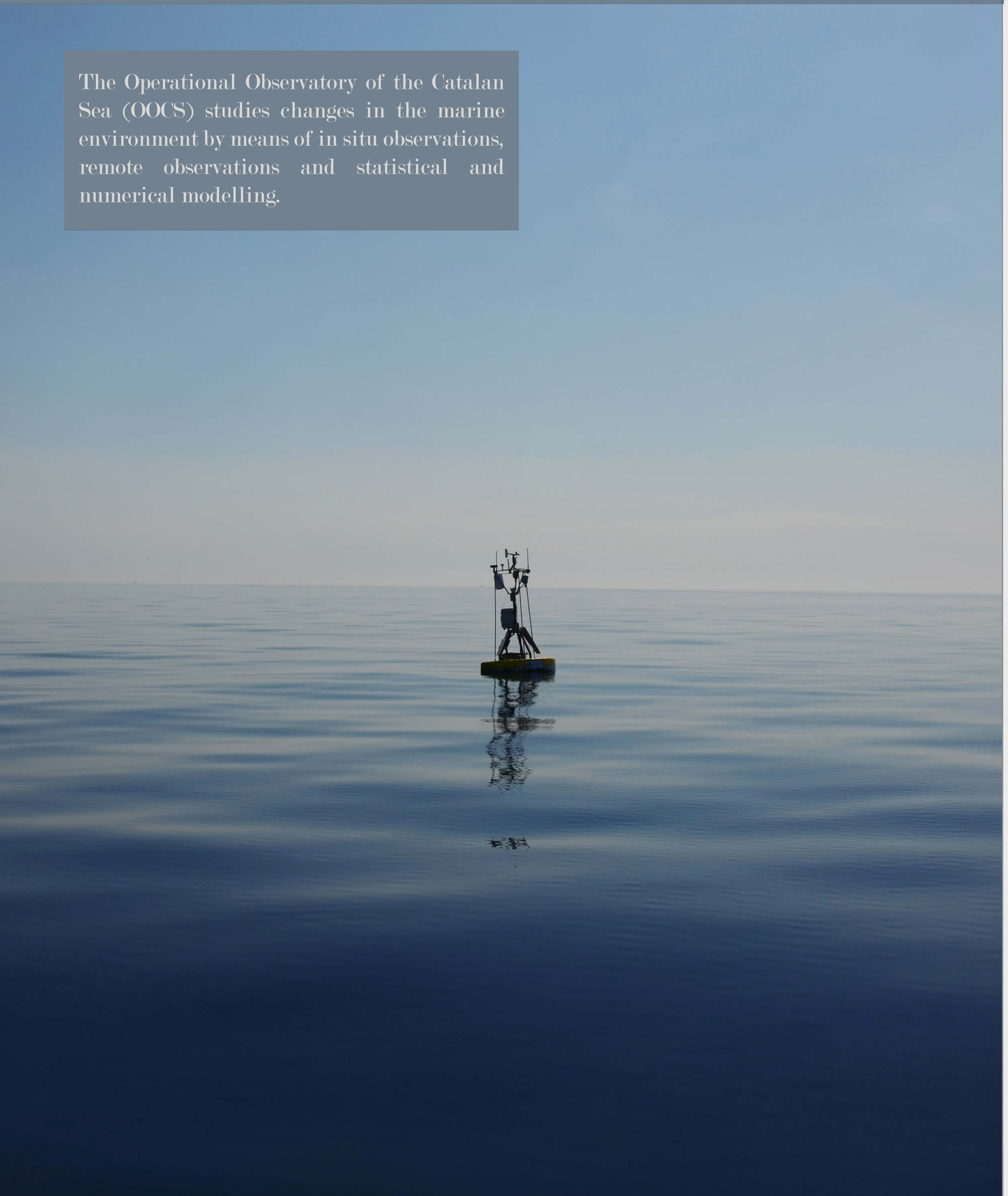
Second sponge meeting. 1988.

Natural Products meeting. 1989.

The CEAB team in1991.

The CEAB team in 2001.

The Operational Observatory of the Catalan Sea (OOCS) studies changes in the marine environment by means of in situ observations, remote observations and statistical and numerical modelling.



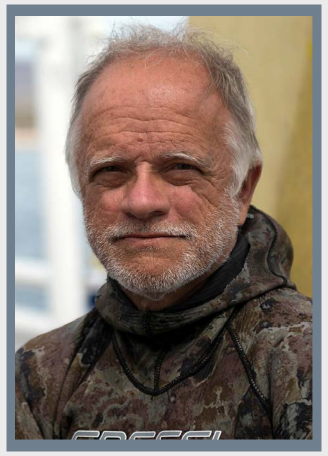
The directors of the CEAB ▸

THE DIRECTORS OF THE CENTRE FOR ADVANCED STUDIES OF BLANES

Antonio Cruzado
1985 - 1987

Francesc Esteva
1987 - 1994

Maria Jesus Uriz
1994 - 1998

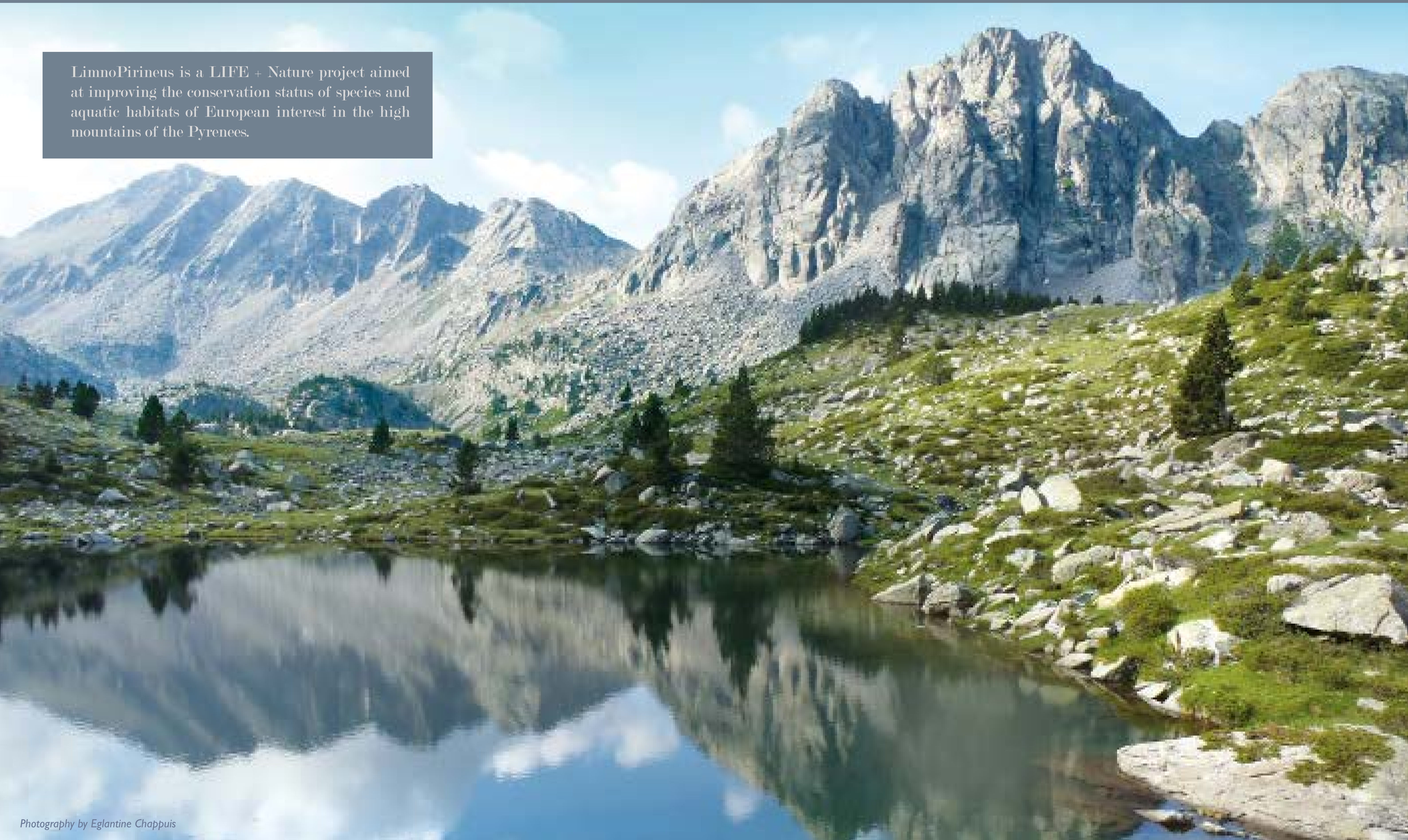


Enrique Ballesteros
1998 - 2002

Daniel Martin
2002 - 2014

Emilio Ortega Casamayor
2014 - Present

LimnoPirineus is a LIFE + Nature project aimed at improving the conservation status of species and aquatic habitats of European interest in the high mountains of the Pyrenees.



Photography by Eglantine Chappuis

Our researchers take the floor ▶

ALCOVERRO, TERESA

Head of Marine Ecology Department
Since 2015

Researcher
1996 - Present

CHANGING PARADIGMS: THREE DECADES OF STUDYING SEAGRASS ECOSYSTEMS

Ecosystems are badly behaved things. More often than not, they do not comply with our most basic expectations of them. As eager students of marine biology, we leap into the water, filled with a text-book understanding of how our ecosystems should behave, confident that they will confirm our deeply-held convictions of them. Yet the ecosystems that we love have a perverse way of challenging these convictions, leaving us profoundly frustrated. It is a hard-fought lesson to acknowledge that science is built not so much from an accumulation of quantifications-of-the-obvious but from trying to understand the pieces that don't quite fit the accepted paradigms. These misfit pieces are as fascinating as they are frustrating, and, if we study them long enough, could even be the basis of a whole new paradigm – a whole new way of looking at an ecosystem we thought we knew so well.

Posidonia oceanica *seagrass meadow.*

There are probably few systems as ripe for these voyages of surprising discovery as benthic ecosystem. It has been less than half a century since SCUBA diving opened these systems up to detailed investigation, and the last few decades have seen breath-taking progress in our understanding of how these systems work. As marine benthic ecologists we have been privileged to witness first hand, and even make a few modest contributions to the way we look at the marine benthos, not merely in the Mediterranean, but across the world. The changing paradigm of seagrass meadow functioning is a clear example of how much research has changed the way we think about these systems in the last three decades.

Around 30 years ago these were ecosystems we thought we knew well. They were clearly limited and regulated by resources – light and nutrients – seagrass leaves senesced and died, making decomposition the most important pathway of nutrient recycling. Herbivores and other higher trophic groups played minor roles, if they were important at all. During this decade, most research focussed on documenting how seagrasses solved the problem of resource acquisition in different conditions of nutrient limitation, clonal integration and nutrient recycling, and the effects of eutrophication and organic matter on seagrass meadows. In effect, seagrass meadows were merely underwater grasslands – just without the herbivores.

The fact was, that as we studiously measured nutrient uptake and decomposition rates in meadow after meadow, we were being constantly followed by groups of curious onlooking herbivores, and we eventually had to take notice of them. The more we looked at the plants themselves, the more we found that had invested heavily in resisting herbivory. If herbivores were not important today, they certainly played an important role in shaping seagrass adaptations in their long co-evolutionary history. The acknowledgement that herbivores were a vital part of this system was slow to take hold, but around two decades ago, we saw data being gathered on herbivores and herbivory in seagrass meadows. The research was patchy and limited to a few regions in the tropics and in the Mediterranean, but from these studies it was becoming clear that herbivores were much more important than previously thought. From contributing less than 5% of the fate of primary production, herbivores began to be seen as real ecosystem engineers. And increasingly, it became evident, that it was not merely the large megaherbivores that were responsible for this offtake. Herbivorous fish and sea urchins could be equally important functional species, vital in shaping the character of seagrass meadows. Where they have not succumbed to overfishing, fish herbivores could consume more than 50% of primary production – a consumption that the plants appear to tolerate without any problems thanks to their fantastic systems of adaptation including compensatory growth and clonal extension. Increasingly, our underwater grasslands were beginning to resemble terrestrial savannahs, sculpted by the forces of repeated grazing pressure.

Beyond a certain density though, herbivores clearly test the adaptive capacity of seagrass. Under these conditions, plants show reduced fitness, sexual reproduction virtually disappears, and habitats can undergo major species shifts, leading even to complete meadow extinction. This is particularly true when high densities of megaherbivores are involved. How 'natural' is this excessive herbivory? On the one hand, it could be perfectly normal for seagrass meadows to

Sampling ecosystems of Posidonia oceanica *for the monitoring program of "L'Agència Catalana de l'Aigua".*

Manipulative experiments with Posidonia oceanica.

appear and disappear, existing in a patchy dynamic equilibrium as herbivores rotate between fragments, sequentially driving each to extinction before moving on. Most short-lived seagrasses appear well adapted to this by investing in dormant seeds that remain viable in the sand for a long time. On the other hand, it is possible that the increasing population trends we see in megaherbivores are far from normal – they are only possible because the large predators that controlled them in the past are now absent.

Green turtles for instance are making an encouraging recovery all over the world while their main predators – several species of large sharks – are becoming functionally extinct. These 'unnaturally' high numbers of green turtles could grow way beyond the capacity of seagrass meadows to support them, driving the ecosystem to extinction. The jury is still out on which of these views is 'true'.

Space is the final frontier. The last decade has seen a burgeoning of research on how trophic processes play themselves out within the seascape of the meadow. Seagrass meadows are ideal systems to study these landscape-level processes because they are relatively simple compared to most terrestrial systems, and have only few key species of herbivores.

How these few herbivores behave becomes critical and very elegantly links seascape ecology to ecosystem function through animal movement and behavioural ecology. There have been a series of studies emerging that explore notions of connectivity and fragmentation from the point of view of long-ranging species, and the direct and indirect consequence of herbivore choices on higher trophic interactions. This is leading to an increasing interest in seascapes of fear – showing that animal behaviour in the presence of their predators can have significant functional consequences for the ecosystems they inhabit.

Where we stand today, we realise that we are only at the beginning of a very long road towards understanding an ecosystem we thought we had completely understood a few decades ago. As researchers our group in CEAB has had the good fortune to have been part of this entire intellectual journey – from the initial studies on resource ecology to the study of trophic interactions and seascape ecology and, more recently, to behavioural ecology. Far from being planned and strategic, these transitions have been organic, as we have adapted our studies to each turn in our understanding of the system. From this changing paradigm, we have learnt clear lessons about what we need to do if we want to manage and conserve these precious ecosystems. For one, it is critical to keep nutrients in check. We also need to think hard about what a 'pristine' seagrass meadow represents – with its full complement of herbivores and their dominant predators. Meadows have co-evolved with this community of species and can remain healthy and functioning only when they are conserved together.

The last few decades have been an exciting time to be doing research on benthic marine systems and we cannot wait to see where the next few decades will take us on our continuing journey of discovery of these endlessly fascinating ecosystems.

ALONSO, DAVID

Ramon y Cajal Researcher
2011- Present

OUR BIOSPHERE: COMPUTATION AND THEORY FOR A WORLD IN CRISIS

My history here is still short. Almost five years ago, the Summer of 2011, I landed at the Center for Advanced Studies (CEAB-CSIC) in Blanes, a sunny locality on the Northern Catalan Coast. I came right away from the University of Groningen, the Netherlands, where I had been holding a VENI postdoc position for three years and enjoying —sometimes enduring— windy, cold winters, and variable, and too often, rainy Summers. Ever since I have been living and working here in Blanes under a "Ramon y Cajal" fellowship. As it is well-known, the consequences of the deep financial crisis all over the world resulted in Spain in tremendous budgetary cuts.

As for research, whether in terms of the GDP percentage devoted to research, quantity of money invested or number of researchers, the figures have been all declining since 2010. The crisis has been hard for every citizen in Southern Europe. Researchers desperately compete for resources to keep their research agendas up and running. In particular, I would love to obtain more money and projects to hire more students and postdocs in order to enlarge my group and work on those research questions I am interested in, but current economic context is harsh and poses serious difficulties for every Spanish research group to grow. In spite of all these severe problems, I have received funding from the Spanish Ministry of Economy and Competitiveness for a research project that let me hire a great postdoc, José Angel Capitán, who just recently started a lecturer position at the Polytechnic University of Madrid, and a motivated PhD student, Vicente Jiménez Ontiveros, who is scheduled to defend his PhD thesis by the end of 2017.

CEAB history is 30 years long, but in just the last 5, I have already witnessed important changes that should improve the ability of our center to cope with current research and societal challenges. Let me just highlight two of them.

First, I have participated with enthusiam in an ambitious project to buy and set up a high performance computer cluster, a computational facility for the center, the "computational biology laboratory". Second, I have seen how a small number of people committed to work on outreach and dissemination of scientific culture has grown now into a well-established group in our center. Several researchers from the staff have been deeply involved in the consolidation of this group, who is in charge of organizing the CEAB open doors week every year, seminars, and other events all year around. Myself I strongly support the group and most of its current outreach activities. Recently, the group has obtained funding for an original project that works with School teachers to expand their capabilities of teaching science and technology in the classroom.

Ecology studies interactions between organisms within their dynamic environments. In particular, most of my research focuses on the study of the main factors controling biodiversity and community composition across spatio-temporal scales. Ecological systems are tremendously complex. The realization that they are just another example of a complex adaptive system [11] pervades all my research since my PhD early years. In general, complex systems can be regarded as ever-adapting, large networks of individual agents interacting through a fluid network structure in a finite number of ways. In the attempt to understand systems as complicated as our brains, global eco-

nomy, or coral reef fish communities, interdisciplinary scientists use techniques, models, hypothesis and methods essentially developed by physicists working on statistical mechanics. In Ecology this approach was initially put forward by James Brown and Brian Maurer [6,13]. Broadly speaking, this is the branch of physics devoted to understand the link between the parts and the whole, between the constituents of a system, whether molecules of a gas or electrons in a semiconductor, and the macroscopic properties of the system as a whole.

How do macroscopic properties we observe emerge from the microscopic interactions between the elements integrating the whole system? The key concept here is "emergence". To what extent do properties at a given level of organization result from processes occurring at lower levels of or- ganization? In which sense is the whole much more than the sum of the parts? In particular, to mention two relevant questions from different fields, how do consumer beliefs and behaviors end up determining market prices and market crashes? How do species compositional changes along gradients emerge from individual interactions and specific adaptations to the environment?

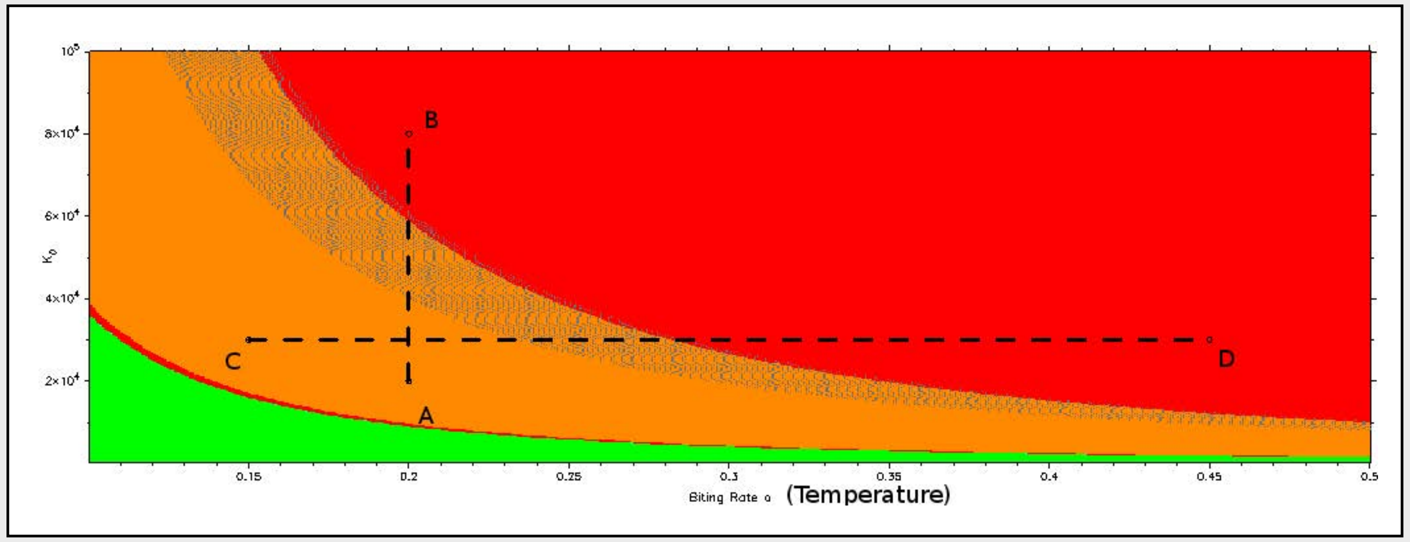


Figure 1. Colors represent dierent model outputs for each parameter pair, mosquito biting rate, on the horizontal axis, which increases with increasing temperature, and mosquito carrying capacity, on the vertical axis. For instace, increasing temperature can take the system from point C, a malaria-low-incidence state (in orange), to point D, a malaria-high-incidence state (in red). Shaded regions represent bi-stability, this is, situations when high and low-incidence states can be both reached for the same parameter values depending on the history of the system.

The neural network in my brain producing now this text is radically different from other types of complex networks controling, for instance, global economy. In fact, some scientists think that radical different systems should necessarily require different methodologies, underlying hyphothesis, descriptions and interpretations.

Why should their descriptions have anything in common at all? I believe this criticism is only true to a certain extend. Highly specialized scientists working on the particularities of a certain group of insects only living on a limited number of host plants are, of course, essential, but, broadly speaking, modern science is highly quantitative, and mathematics provide general concepts, models, and frameworks that apply across disciplinary boundaries [8]. We live in the "big data" age. The comparative analysis of big amounts of data from different fields may pave the way to new theories [3]. Universal principles should govern our ability to predict plausible future states of a given system if we have a fair description of its current state. Determination of prediction horizons use methods that apply across fields [17, 14]. Such general principles will have the character of "law of nature" and, therefore, elegantly, apply across disciplines. They will not have the form of deterministic Newtonian principles, but rather have formulations in terms of inequalities similar to the second law of thermodynamics.

As you see, in essence, I am very interested in exploring to what extent natural systems in their tremendous complexity can be described by and understood in terms of simple — perhaps universal— low dimensional abstractions and useful approximations. Fruitful, cutting- edge examples of this kind of research are those related to regime shifts and phase transitions [12,18].

These phenomena occur when systems shift abruptly from one state to another when they are forced across critical thresholds. A macroscopic system property undergoes an abrupt state shift as a result of a slight change in another variable across a critical threshold. This involves that, close to these critical points, system response can be highly non-linear. In Physics, a slight increase in temperature close enough to the boiling point induces a water-to-gas phase transition. Surprisingly, these types of critical transitions occur in seemingly non-related systems such as marine systems [15], fisheries [16], deserts [9] or societies [7]. Even more astonishing is the fact that the underlying mathematics across all these different systems is essentially the same.

Although we all like major scientific advances, science makes also progress through incremental improvements. Scientific literature is sometimes boring because it is full of tiny improvements that are sometimes difficult to appreciate. Throughout my research, I always like to keep in mind the big picture because tiny advances, actually, pave the way to truly breakthroughs. Anyway, most of our publications are probably tiny contributions to science, but, in one way or another, here at CEAB, we all share the proud of contributing to the progress of science.

Just to give an idea, let me highlight here only two of my favorite contributions. The big picture of the first one is related to the origins of population variability. A well-accepted reason why populations change in time is environmental temporal variability, such as rainfall and temperature. How does environmental forcing influence population dynamics? It is often said that populations integrate environmental variability, but much less is known about how environmental fluctuatons are actually transduced into population fluctuations. In 2011 we published a paper to demonstrate that human-induced climate change through increasing temperatures plays a central role in malaria transmission in the highlands of Kenya, East Africa [1]. The human-mosquito-malaria dynamic model I developed, interestingly, shows a critical transition from low to high malaria incidence as temperature increases over a critical threshold (see Fig 1).

The second contribution I would like to mention was done in collaboration with Teresa Alcoverro and Rohan Arthur from CEAB and Aleix Pinyol-Gallemí who was at that time an undergraduate student from the University of Barcelona [2]. This contribution is related to my efforts to disentangle the main drivers of community assembly. How

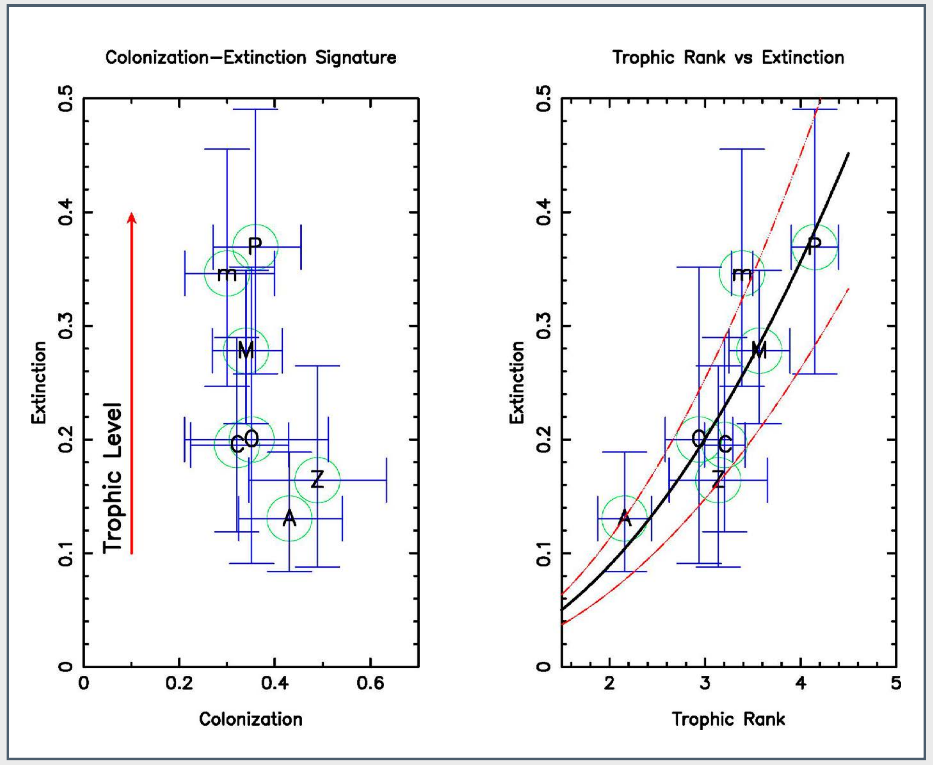


Figure 3. Extinction probabilities show a clear signal of average trophic level across seven guilds of coral reef fishes including algal feeders (A), zooplanctivores (Z), omnivores (0), coralivores (C), macroinvertivores (M), microinvertivores (m), and piscivores (P). As shown on the right panel, as trophic levels increases from 2 (herbivors) to 4 (piscivores), the extinction probability per year goes up quadratically, from about 0.1 to 0.4 [redraw from ref 2].

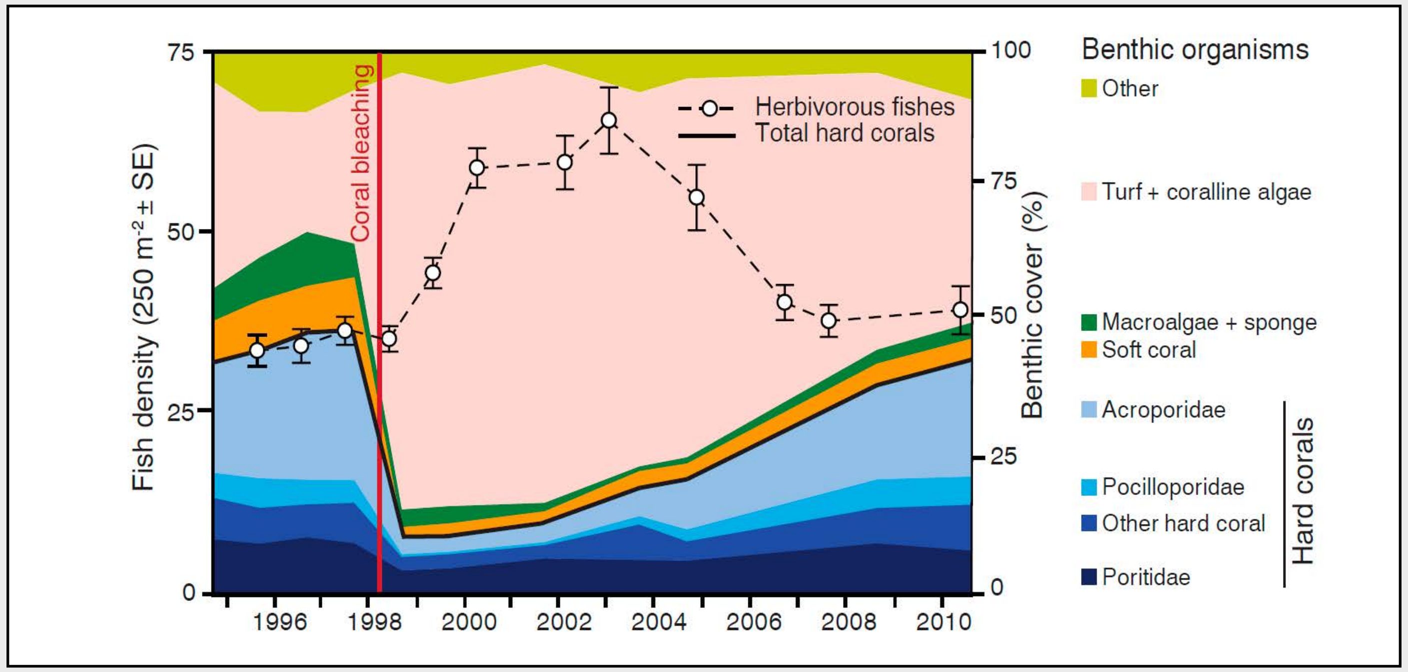


Figure 2. Recovering of a coral reef ecosystem after a coral mass mortality induced by a severe "El Niño" event. [5]

predictable is ecological succession? How predictable is community re-assembly after a big perturbation? These are central questions in community ecology. In that paper, we analyzed data from coral reef fish communities aftera El Niño-related bleaching event and revisited Island Biogeography Theory to show that extinction rates increase with trophic position, which means that higher trophic guilds, such as top predators, are inherently more susceptible to natural perturbations even in the absence of targeted fishing (fig. 3)

Human society faces big challenges, is highly technified, and generates knowledge and new possibilities at incredible pace. As said, we are in the big data age, but also in the age of the sixth extinction [10], and in the age of ever increasing social inequalities. A huge amount of energy and resources now is routed through our social organization worldwide. For instance, 20 to 40% of global net primary productivity is sequestered by humans [4]. Animal agriculture is responsible for about one third of global fresh water consumption in the world today and for up to 91% of Amazon destruction. Agricultural production, processing, transportation and consumption of food are all activities of planetary scale with global impacts on our biosphere.

They conform the so-called food system. These activities use three strategic resources —water, energy and land— which are at the center of most wars and conflicts today. In the near future, I am very interested in analyzing in detail the role of food systems in determining critical regime shifts across scales.

How plausible is a planetary-scale critical transition? Inherent complexities to human-dominated systems make future very hard to predict. If forecasting the future is almost impossible, what we urgently need is to start creating now the future we want to live in. Challenges are global and urgent. I envision a future where science and technology, an economy for the common good, and real democracy are the central pillars of a new global order.

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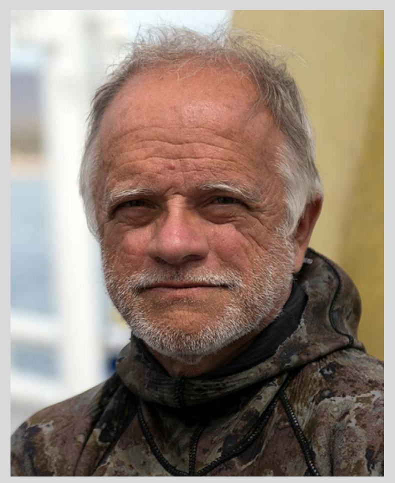


BALLESTEROS ENRIC,

Researcher
1986 - Present

SHIFTING FUNDS IN MARINE BENTHIC ECOSYSTEMS: FROM SURVIVAL TO PLENTY AND BACK

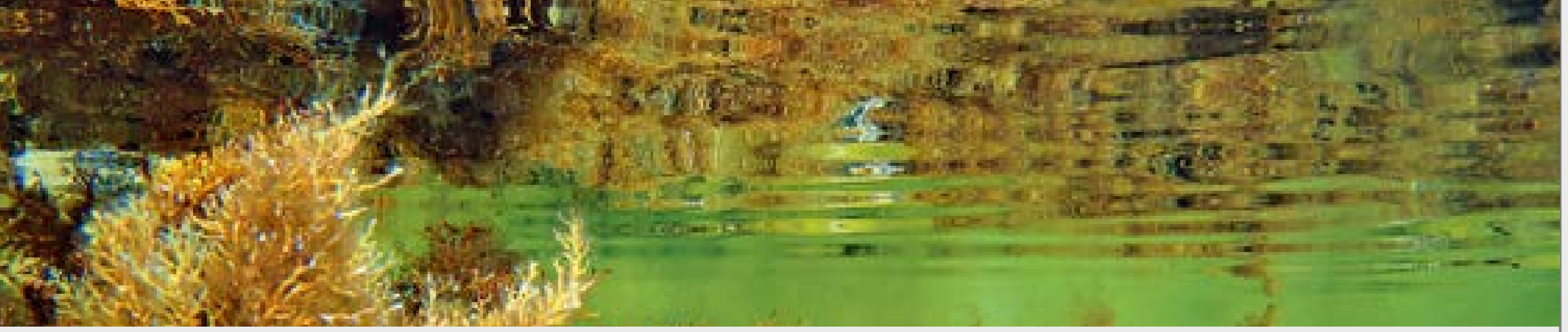
11 February 1986. My first day at work in a brand new research institute devoted to Marine Ecology and Artificial Intelligence close to the city of Barcelona, but far away enough from Barcelona to be in close contact with nature. Its name, Centre d'Estudis Avançats de Blanes (CEAB; Center of Advanced Studies from Blanes), is vague enough to accommodate almost any kind of scientific discipline that can be branded as "advanced". I suppose that it was not an easy task to find a name for a scientific institute whose research areas were marine ecology, artificial intelligence and -later on- astrophysics.

The building is surrounded by luxurious Mediterranean pine forests, has amazing views over the Montseny, a beautiful mountain whose cap is occasionally covered by snow in winter, and is located at a 5 minutes drive from granitic rocky shores with interspersed small coves. I am here to develop my scientific career as a marine ecologist. The best job and place I could ever imagine. A dream.

I come from the Department of Ecology at the University of Barcelona, where I had been working in my PhD thesis between 1981 and 1984 and was appointed as teaching assistant from 1985 until yesterday. There, I did not have an office, but a place in a room plenty of other assistants, technicians and students. This place was like an ant's nest, where I could hardly concentrate on my work and prepare my teaching lessons. But I was feeling great. Friendship atmosphere, youth, plenty of interaction with rookie ecologists like me, and with a big boss, Ramon Margalef, idolized by everybody.

First field work expedition carried out by CEAB scientists together with researchers from the Marine Science Institute of Barcelona (ICM). From left to rigth: Andrés Maldonado (ICM), Kike Ballesteros, Iosune Uriz (CEAB) and Jordi Camp (ICM). October 1986, Cabrera, on-board of "Garcia del Cid".

I park my beat-up Citroën in front of the building and I am welcomed by the oceanographer Dr. Antonio Cruzado, earlier director of the institute.



After a brief walk inside the almost empty building, he asks me to choose a room. All the rooms are completely empty. Four walls, that's it. I choose a big one; it will become my office. The warehouse assistant brings me a table without drawers, a chair, and a telephone that he plugs into the phone connection and places it over the floor. "This is everything", he tells me. I am shocked. I leave the room (it does not deserve the name "office") to ask Antonio Cruzado if this is a joke. Where I am supposed to put all my books? The laboratory I have in front of my room is also completely empty: not even a single test tube. And microscopes? What is this? He replies me that this is everything the institute will provide me as a new researcher. He kindly offers me a second chair, in case somebody is coming to visit me. "The first thing you have to do is asking for projects (=money)" he asserts. I come back to my room, sit down, look around at the echoing walls, and question myself if coming here has been a smart choice. Probably not, but I have to succeed. I am not a person easy to be defeated. Dreams cannot turn into smoke so quickly!

Fortunately, there is another marine biologist at the institute, María Jesús (Iosune) Uriz. We join our two single-member teams to apply for the project "Towards a model of organization of Mediterranean littoral rocky benthic assemblages", which receives funding from the Spanish Government. Iosune also gets the project "Ecological foundations for searching new pharmacological drugs in Mediterranean benthic ecosystems" funded by the company Pharma-Mar. These two projects allow us to furnish our offices and buy the basic materials for performing our research (microscopes and other lab material, inflatable boat, tanks, diving compressor, van), but most importantly to engage other young people in these two research lines, whether scholarship assistants and researchers or emerging professors at the University of Barcelona. These very first years we were able not only to survive but we started the basis for the current Department of Marine Ecology of the CEAB. These projects and energy were key for obtaining new research positions in the CEAB and for not being absorbed by the powerful Institute of Marine Sciences based in Barcelona.

The collaboration between Iosune and me, essential during these first years, progressively decreased as she increasingly focused her research in

Cover image of the Handbook of Coastal Habitats of Catalonia, a study carried out to help policy makers and stakeholders to improve the management of natural resources of the Catalan coast.

Carcharhinus albimarginatus, *a very common shark species inhabiting the tropical reefs studied by the Pristine Seas project.*

processes occurring at the level of cells, individuals and populations and I gained interest at processes taking place whether at the community or ecosystem level. A critical year for my research was 1992, when the invasive seaweed *Caulerpa taxifolia,* the killer alga, became renowned. In order to control the progression and to study the biology and ecology of this alga in the Mediterranean I got European, national and regional funding together with other labs in Marseilles and Nice (France). Easy money. I became a specialist in marine bioinvasions in a place and time where and when almost nobody worked on this issue. Bioinvasions also allowed me to start a collaboration with the Departments of Environment and/or Fisheries of regional governments (Generalitat de Catalunya, Govern de les Illes Balears) that lasted for 21 years and progressively broadened to the implementation of the Water Framework Directive, the Habitats Directive and the creation and management of Marine Reserves. Thanks to the plenty of money I was able to build up a team of specialists that excelled in the knowledge of different taxonomical groups and methodologies. Monitoring projects were put in place and carried on during several years. In this period of time we also obtained some of the so-called "competitive" grants or projects. We also focused in other questions that deserved a more specific, different, or accurate approach, like the populations and communities made up by species of the algal genus *Cystoseira*, the Mediterranean underwater ecological relatives of oaks *(Quercus)* from the terrestrial environment, or the highly biodiverse and vulnerable coralligenous outcrops, Mediterranean biogenic reefs that only grow at dim light conditions.

However, nothing lasts forever. The current economic crisis that so sharply stroked Spain from 2009 onwards suddenly cut off most financial revenues. Still, in 2010 we obtained a project to make a description and cartography of all the littoral habitats from Catalonia, where we developed a completely new methodology to map littoral habitats, which are restricted to very small areas following steep gradients of environmental factors. This project finished in 2013 (http://mediambient.gencat.cat/ca/05_ambits_dactuacio/patrimoni_natural/sistemes_dinformacio/habitats/habitats-litorals-/) and the extension to be done in the sublittoral zone down to 135 meters depth (the continental shelf) was stopped due to funding restrictions. The awarding of a CSIC project with internal funds (2013-2016) has allowed the continuation and finishing of the loose ends of the last and previous projects but has not guaranteed the long-term surveys that were in some cases initiated as far away as in 1992. We find ourselves again in the path of survival but with the conviction that most of the investment in money, time and energy of two decades has been thrown away and with the almost certainty that time for long-term surveys is over. Moreover, the eagerness has turned up into confusion and frustration. Bad feelings if we want to keep moving onto science.

But survivors as we are, we will keep trying. Crisis, also, will not last forever and some initiatives are emerging. We will try to continue monitoring the abundances and effects of invasive species, try to better understand the dynamics of *Cystoseira,* the "Mediterranean underwater trees", and will continue surveying the littoral and sublittoral assemblages for temporal changes in relation to anthropogenic disturbances. Moreover, our engagement in the Pristine Seas project of National Geographic (http://ocean.nationalgeographic.com/ocean/explore/pristine-seas/) is exciting, as this project is becoming the most relevant contribution to marine conservation ever. Surrender is not a word in our dictionary.

BARTUMEUS, FREDERIC

Head of Continental of Ecology Department
Since 2015

Research Professor
2003 - Present

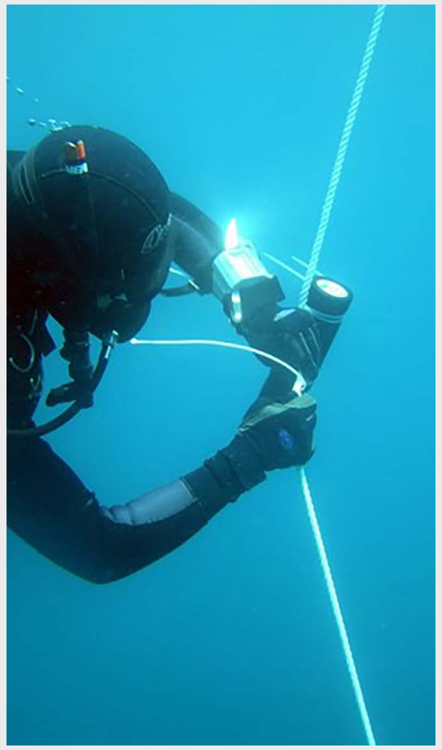
MOVEMENT ECOLOGY

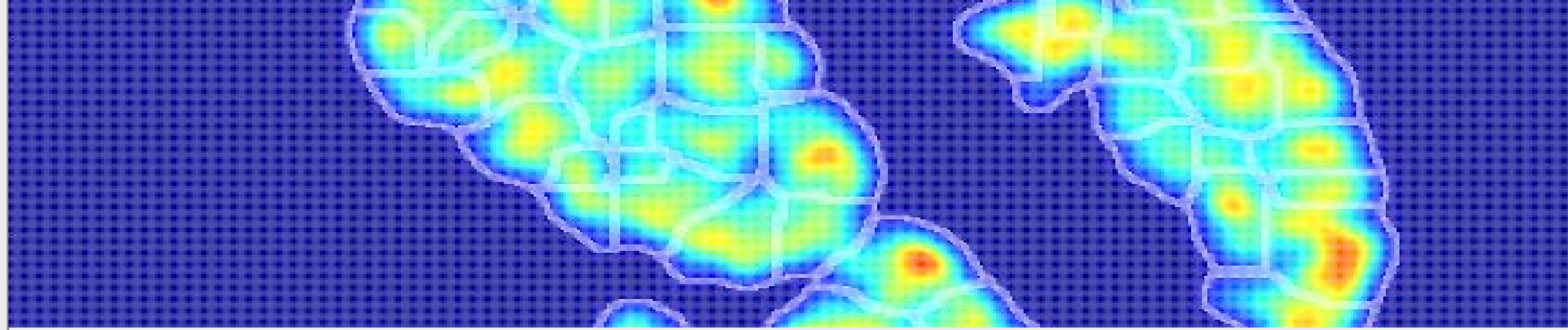
Movement is one of the most fundamental features of life on Earth. The change of location by organisms across multiple spatial and temporal scales quilts our planet in a rich tapestry of phenomena with diverse implications for ecosystems and humans [1]. Movement plays a major role in determining the fate of individuals, the structure and dynamics of populations, communities and ecosystems; and the evolution and diversity of life. It is a crucial component of almost any ecological and evolutionary process, including major issues associated with habitat fragmentation, climate change, biological invasions, and the spread of pests and diseases [2].

Recent developments in GPS tracking and remote sensing are enabling detailed tracking of animal locations (including humans) concurrently with acquisition of landscape data and information on individual physiology and behavioural status. The availability of better tracking and bio-logging technologies [3, 4] is challenging researchers' ability to make sense of the resulting data, but also creating exciting opportunities to test and develop core theory in contexts as different as migration, foraging, invasion biology, or epidemics [5].

The Movement Ecology paradigm [1, 2] has emerged as a framework that places animal motion as the central theme in order to stimulate the development of new methods and to promote understanding of the causes, consequences, underlying mechanisms, and emergent spatiotemporal patterns of all movement phenomena. The development of world-wide movement databases such as Movebank (www.movebank.org) is facilitating the storage and exchange of data and requires revolutionary improvements in data management, processing, and analytical techniques, at least as challenging as the bioinformatic revolution of genomics and proteogenomics [6]. This exciting context is attracting renewed interest to the study of animal movement and dispersal processes, bringing together specialists from a wide range of disciplines [7, 8].

Traditional modeling and quantification of animal movement is based on the solid grounds of random walk and diffusion theory [9, 11] but because of the lack of adequate empirical data, the mechanistic links between movement patterns and animal behaviour have remained poorly understood [1,12,13]. **The main challenge in modern movement research is to use a new generation of highly-resolved, massive, movement data to improve our understanding on the mechanistic links between behavioral processes and movement patterns** [12-14]. Our research at CEAB-CSIC strongly contributes in this direction, focusing on the following questions: (A) how to **integrate scales** from (microscopic) behaviour to (macroscopic) movement patterns, specifically **to link individual behaviour with the generalized concept of diffusion,** (B) how **internal states** and **information use** (organism-environment interactions) modulate **movement, specifically in search/foraging processes,** and (C) which **evolutionary mechanisms** link individual motor behaviour, movement patterns, and survival/fitness.





Fish tracking with acoustic telemetry in the Medes Islands.

A. Integration of Scales: from behavioural Modes to Anomalous Diffusion.

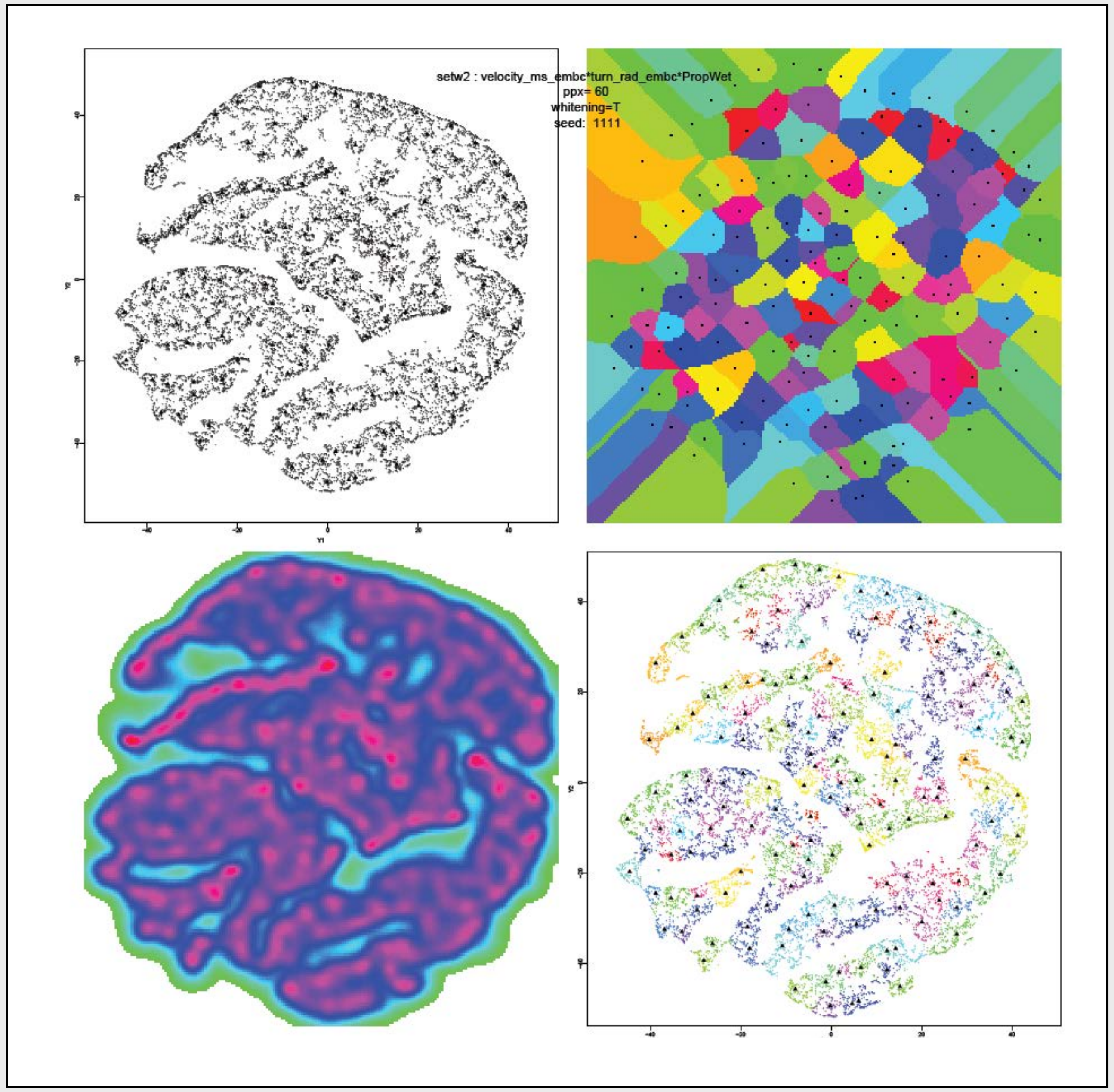
Behavioural modes are movement sequences of steps, turns, and stops associated with the fulfillment of a particular goal. The segmentation of trajectories into such **basic functional units** has been acknowledged as one of the 'core' problems in movement ecology and the 'essential link' to make inferences between animal movement and population dynamics [1, 12, 15, 16]. As physiological and other information becomes available through bio-logging devices, we may improve our understanding of how animals allocate time to different tasks (behavioural modes) and how this allocation changes depending on the interaction between animal internal motivations and different

Behavioural Annotation in Migration of Pandion haliaetus.
Data from: Raymond Klassen. Migration Ecology Group. Dep. Animal Ecology. Lund, Sweden.

environments, thus providing a mechanistic way to model movement patterns conditional on individual state [13]. One may expect that the mixture of behavioural modes viewed over a sufficiently long time period can be described as a simple (normal) diffusion. However, recent empirical results show that animals [17-19], including humans [20], can spread faster (superdiffusion) or slower (subdiffusion) than what would be expected from classic diffusion theory (normal diffusion). This fact raises **the need to extend the classic theory of diffusion towards new mathematical frameworks capable to accommodate the so-called anomalous diffusion.** The new generation of movement data, together with new statistical analyses targeting behavioural modes (dynamic brownian bridges, behavioural change point analysis) and the development of generalized-diffusion mathematical frameworks (continuous time random walks, generalized diffusion equations) provide the adequate template to develop powerful mechanistic and predictive tools for large-scale movement and spreading patterns, from large-scale foraging to invasive processes.

B. Search Behaviour: Information Use and Organism-Environment Interactions.

Our understanding of how individuals integrate different sources of information in order to make foraging/navigation movement decisions is still poor. Detailed **biotelemetry data** analysis of free-ranging animals will definitively bring light to the problem of **information use and memory** [13, 16] and will clarify the distinction between pure search (non-informed movement) and taxis (informed movement) in foraging processes [21, 22]. A new and promising research line consists on **studying foraging/search ecology in high-throughput, large-scale, experimental setups with the use of model organisms**. The goal is to link different levels of biological organization (genetic, neurological, physiological, and ecological) with large-scale properties of movement (type of diffusion, front wave propagation, search efficiency, waiting times).

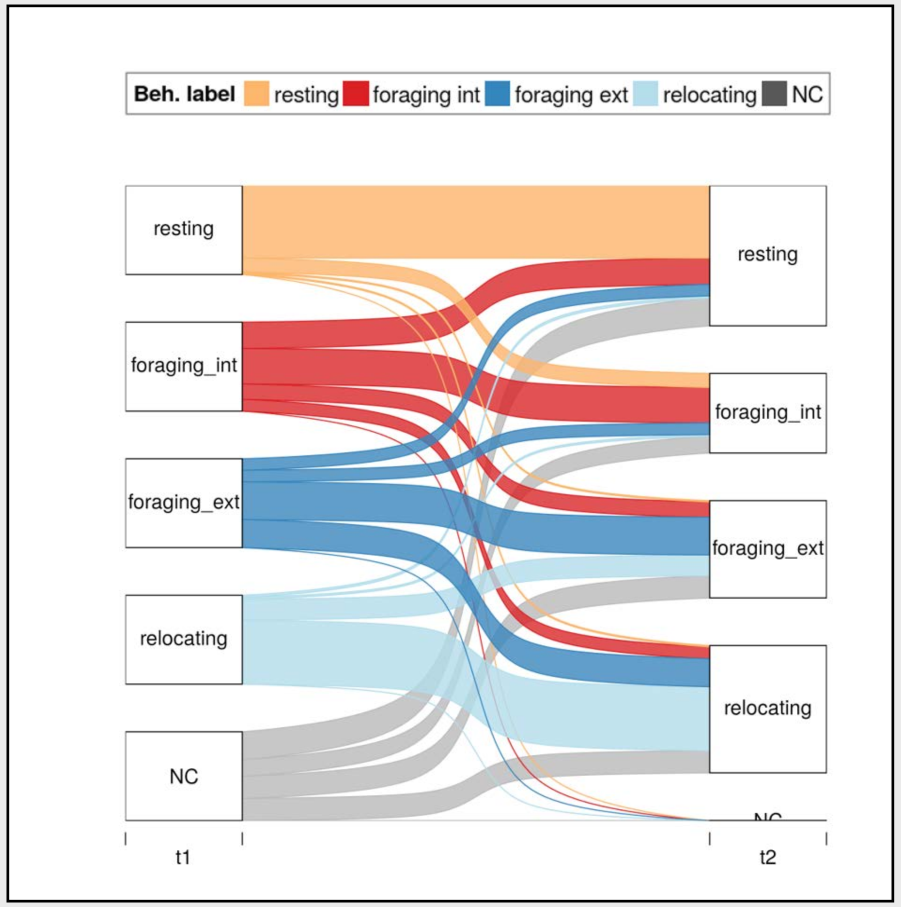


Movement behavioural landscapes using seabird trajectory variables and a mutivariate unsupervised classification algorithm (t-SNE algorithm).

C. Evolution of Movement: Comparative Movement Ecology and Model Organisms' Experimentation.

The lack of adequate empirical data and mechanistic approaches has constrained evolutionary thinking on large-scale properties of movement up to recently. The massive and new generation of data available will allow to **perform comparative analyses across species to in order look for phylogenetic signatures** [23, 24] **or detect the historical signature of key innovations** [25] related to movement traits and/or properties. We are particularly interested on the evolution of **behavioural intermittence** and its role in governing random motor output. Evidence of randomly generated action (action that is distinct from reaction because it does not depend upon external stimuli) can be found in 'simple' organisms [26-28]. Hence, behavioural output can be independent of sensory input. This is in line with the fact that in early development of individual organisms the motor system slightly precedes the sensory system. Merely being actively dispersed in space should have favoured the evolution of simple motor systems [29]. Even complex animals have to find an effective way to explore the environment when insufficiently equipped or insufficiently informed. The physiology of how this happens has been little investigated. Based on international collaborations at CEAB we are working with **model organisms (such as *C. elegans*) to explore behavioural intermittence as an evolutionary template, and to unveil the main sources and fundamental structure of random animal motility**[12, 22, 30, 31].

The study of Movement Ecology at CEAB should promote the development of a comprehensive and integrative view of organism movement and a better understanding of the causes, mechanisms, patterns, and consequences of all movement phenomena. The ultimate goal is to provide a comprehensive understanding of animal movement from and ecological and evolutionary standpoint of view based on field and lab experimental data, and to be on the lead of such a new and exciting research field.



Movement modes classification and flow of a foraging seabird.

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RIPARIAN AND STREAM ECOSYSTEMS: HOT SPOTS OF NUTRIENT RETENTION WITHIN CATCHMENTS

BERNAL, SUSANA

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Water quality is a major Societal Challenge within the EU Research and Innovation Programme Horizon 2020. Despite decades of economic investment and technological improvement, half of the freshwater bodies in Europe are still affected by high nutrient loads from diffuse and point sources. Chronic nutrient fertilization causes eutrophication problems and threatens ecosystem's and human's welfare. In the Mediterranean basin, increasing aridity and water demand from urban areas turns water quality in a tremendous economic and technological challenge for Society. Future climate scenarios stress smaller groundwater reservoirs and lower stream discharges and consequently freshwater bodies will become extremely vulnerable to nutrient excesses. Within this context, ecosystems that can naturally contribute to improve stream water quality in Mediterranean regions are thus, essential from an ecologic, environmental, and social perspective.

In the last years, the Integrative Freshwater Ecology Group has focused an important part of its research on identifying landscape units with a disproportionally high capacity to transform and retain nutrients. We seek to understand by which mechanisms these biogeochemical hot spots can improve water quality, quantify their contribution to nutrient retention at relevant ecosystems scales, and investigate under which conditions water quality-related ecosystem services are maximized. The results obtained have important implications not only for ecosystem conservation purposes but also provide scientific-based knowledge for ecosystem restoration actions and integrated management of catchment water resources.

Riparian zones are well-known for being natural filters of nutrients arriving from adjacent landscapes, nitrogen (N) in particular. Since the 1980s, the number of studies showing the N buffering capacity of riparian ecosystems has continuously increased. The acquired knowledge has had important implications on environmental protection protocols, such as keeping riparian buffer strips in agricultural landscapes. Most of these studies, however, have been conducted in temperate regions where the N buffering capacity of riparian ecosystems relays mostly on microbial denitrification, that is the release of N to the atmosphere by transforming nitrate to N_2 gas. Denitrification is an anaerobic process which requires water-logged soils. In Mediterranean zones, anaerobic conditions are rarely met because riparian soils are not water saturated and thus riparian denitrification is minimal. Conversely, we have shown that Mediterranean riparian soils are hot spots of N supply because intermediate soil moisture conditions stimulate organic matter mineralization and nitrification (the microbial transformation of ammonium to nitrate). Our model predictions suggest that this pattern will be accentuated in the future because warming will burst nitrification in Mediterranean riparian soils. Moreover, the proliferation of N_2-fixing species such as the invasive black locust (Robinea pseudoacacia) could further enhance the role of riparian forests as N sources by adding N into the riparian soil and providing N-rich leaf litter to stream biota.

High supply of N by riparian soils could severely diminish the N buffering capacity of Mediterranean riparian ecosystems and increase the amount of N entering to the stream via groundwater and/or surface flow. Nonetheless, Mediterranean riparian zones can still act as N buffers, though their potential for N retention may be more related to geomorphology and hydrology than to soil biogeochemistry. For instance, we have recently showed that hydrological retention of stream water within the alluvial aquifer could increase catchment N retention by 30-50% on an annual basis. These findings highlight that the mechanisms responsible for N retention in riparian zones can differ greatly between climatic regions. Thus, a good understanding of both soil processes and hydrological linkages between stream and riparian systems is crucial for evaluating the potential of these ecosystems to reduce catchment N loads in Mediterranean regions.

Detail of a streambed with cobbles and gravels. These substrates are colonized with microbial biofilms capable to transform and retain nutrients from the water column.

In addition to riparian zones, streams can further contribute to improve water quality because they are highly reactive ecosystems. Headwater streams have a large capacity to transform and retain nutrients within relatively short distances. Yet, the influence of in-stream processes on annual catchment budgets is still poorly understood because nutrient uptake is typically assessed at small scales (< 300 m reach lengths) and during particular periods. By combining synoptic approaches and hydrological models, we have shown that net uptake can decrease nutrient fluxes by 4-40% within few kilometres in headwater streams. Further, we have found that gross primary production by stream algae can control day-night variations of stream nutrient concentration, and that this fine-scale dynamics can resonate at larger scales and ultimately decrease stream N loads.

These results support the idea that streams can contribute to improve water quality at the catchment scale and thus, these ecosystems could ameliorate the risks associated to nutrient excesses. However, the capacity of urban streams to retain N is still under debate. There is little evidence of the ability to store N of stream biota and/or to remove N perpetually via denitrification.

Are urban streams N saturated? Or else, are we missing the relevant time scales at which crucial steps of the N cycle occur? Can restoration actions help to enhance the retention of nutrients, pathogens and other contaminants in urban streams? These questions will be the focus of our research in the upcoming years and hopefully we may be able to provide some answers to water stakeholders and Society sooner than later.

Mediterranean headwater stream flanked by a riparian forest of Alnus glutinosa *and* Sycamore sp. *Fuirosos, Montnegre-Corredor Natural Park, Vallés Oriental (NE Spain). (Fig. 1).*

Tree roots submerged in the stream boulders covered with algal biofilms. These two types of primary producers contribute to decrease stream nutrient concentrations, especially during the vegetative period.

Stream-riparian interface at Font del Regàs, a subhumid headwater stream within the Montseny Natural Park (La Selva, NE Spain).

BUCHACA, TERESA

At CEAB
2003 - Present

Ph.D. Associate

MARKER PIGMENTS IN PALAEOLIMNOLOGY

Lakes are excellent 'sentinels of change' because they can provide insight into the effects and mechanisms of global change through their sediments natural archives. Broadly defined, palaeolimnology is the study of the physical, chemical, and biological information stored in lake deposits using different indirect indicators, the so-called proxies. The study of lake sediments, and specifically the biotic and abiotic components that integrate information from the water column, catchment area, and atmosphere, can help asses baseline conditions for different physical, chemical, and biological systems (e.g., climate, nutrients, ecosystem functioning), as well as the impacts of and recovery times after disturbances of ecosystems.

Some of the most widely used biological proxies in palaeolimnological studies include pollen, diatoms, chrysophyte scales and cysts, plant macrofossils, cladocera, chironomids and organic geochemical proxies. Organic geochemical proxies are contained on the amount and composition of organic matter in lacustrine sediments and include among others, concentration and accumulation rate of organic carbon, $C_{organic}/N_{total}$ ratio, composition of $\delta^{13}C_{organic}$ and $\delta^{15}N_{total}$ and pigments of photosynthetic organisms. Higher plants, algae and microbes synthesize a variety of pigmented organic compounds for use in photosynthesis. Chlorophyll a is the most common, but aquatic plants have evolved carotenoid compounds that enable photosynthesis in the absence of the red wavelengths absorbed by chlorophyll a. Photosynthetic organisms have a characteristic composition of pigments depending on the Division or Class where they belong which allows the utilization of pigments as taxonomical markers that may allow to infer the algal assemblages growing in the lake in the past.

Sediment record retrieved from Lake Redon (Central Pyrenees) covering the Holocene period.

In that context, the research we have been conducting was initially focused in the study of high mountain lakes in the Pyrenees and started with the development of new pigment-based methods to reconstruct long-term changes in lake primary production. At long time scales (i.e. from a few decades to millennia) the key element controlling primary production in mountain lakes is the coupling of lake dynamics with the catchment biogeochemistry. Phosphorus is a scarce element at those altitudes; therefore, it is efficiently retained by vegetation. The research conducted showed how sensitive those ultraoligotrophic lakes are to a small increase in phosphorus loading and, on the other hand, how efficient in retaining phosphorus is the vegetation-soil complex, when it is not mechanically affected (e.g. catchment

anthropogenic perturbations).
The wider knowledge of taxonomic specificity and about diagenetic processes involved made possible to extend the application of pigment-based methods to study trophic interactions in lakes that had been receiving an anthropogenic impact along the last decades and then we focused attention on lakes from the Azores Archipelago. With these studies we found that the composition of zooplankton, and microbial and algal assemblages changed rapidly after the perturbation, and the covariance between fish stocking, nutrient loading and enhanced temperatures captured most of the variability in algae accumulation, and thus likely in lake primary production as well. Our study demonstrated the sensitivity of these remote species-poor lakes to increased nutrient loading, introduction of non-native species, such as fish, and climate change as shown earlier for the likewise species-poor alpine lake ecosystems.
All these studies rose up the issue of the

Field work in the island of Sao Miguel (Azores Archipelago).

Lake Furnas (Azores Archipelago).

Sampling fish populations in Azorean lakes.

relative importance of climate change and nutrient inputs. Whereas the cumulative impact of climate change on freshwater ecosystems has been relatively gradual, the onset of modern agricultural practices and human-mediated changes to atmospheric and hydraulic loads has certainly resulted in an accentuated nutrient signal in recent decades. Such evidences suggested that the relative contribution of climate change and nutrient inputs to lake ecosystems is a scale-dependent process. Therefore, by considering data at spatio-temporal scales we examined larger gradients of climate and anthropogenic change, which allow for a broader generalization of the response of temperate to subarctic lakes to multiple stressors. This study provided the first quantitative evidence across north temperate to subarctic latitudes that cyanobacterial expansion has been non-linear over time, disproportionate relative to other algae and induced mainly by nutrient fertilization. The increase in cyanobacteria in areas most impacted by anthropogenic change (lowland regions with agriculturally developed watersheds) followed our hypothesis, however, we were surprised to see that cyanobacteria also increased in numerous remote, alpine lakes. In these relatively remote sites, the temperature signal and atmospheric nutrient loading is likely to have played a more important role than run-off from agriculture or point source nutrient enrichment.

Future directions in our research interests point to enlarge knowledge on ecosystem responses to climate variability by looking for relationships between Late Glacial and Holocene climate variability in Western Europe and changes in lake primary producer assemblages using marker pigments as proxies in the sediment record.

In situ sediment core subsampling.

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CASAMAYOR, EMILIO O.

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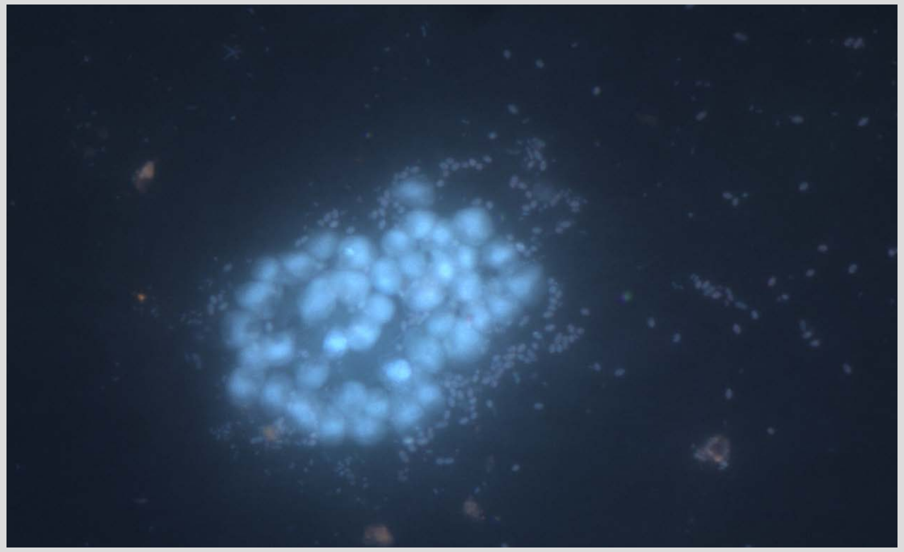
Since 2014

Researcher

THE MICROBIAL BIODIVERSITY OF NATURAL ECOSYSTEMS

Conservation biology is the scientific study of biodiversity oriented to protect species, habitats, and ecosystems from unsustainable exploitation, uncontrolled extinctions and the increasing weakening of biological interactions. Conservation biology involves the interaction among apparently unrelated disciplines such as social and natural sciences, economics, and computational and political sciences, among others, promoting integrative and transdisciplinary views on ecosystem health and aiming to formulate scientific basis for the best practices in natural resource management. Unlike with plants and animals, microscopic organisms have been mostly excluded in conservation studies and microbiology has developed as a scientific discipline lacking of a natural history background. Microorganisms are however fundamental components to maintain the ecological integrity of any ecosystem. Apparently, the study of microorganisms lacks of naturalistic attractive and of conservation-orientated perspectives because of cells inconspicuousness, low probabilities of extinction, and potential widespread distribution. Therefore, environmental managers and lawyers, citizens, and stakeholders in general have obviated the fate of natural microbial communities among their daily worries and strategic planning, beyond the concerns for pathogens. Threats on microorganisms have been not considered as part of the natural resources management policies or in the estimation of the influence of human activities in nature. Microscopic organisms have been therefore mostly excluded in conservation studies.

In the early 90s of the past century, the International Programme of Biodiversity Science DIVERSITAS, a program promoted among others by the International Council of Scientific Unions (ICSU) and now migrated to both Future Earth (http://www.futureearth.org/) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), tried to reverse this view highlighting the crucial role that microbial biodiversity plays in the maintenance of many ecosystem services. The term 'ecosystem services' describes ecosystem resources and processes that benefit human society, and its identification and value quantification can provide additional arguments for the protection of species and ecosystems that could easily reach public opinion and policy decisions. DIVERSITAS emphasized the immense genetic diversity of microorganisms and their crucial and unique roles as



Unknown extremophile microbes inhabiting a salt lake (salada) in Monegros.

basic components of food webs and biogeochemical cycles and ecosystem services, and included "microbial biodiversity" within the nine fundamental cross-cutting research themes of critical importance for biodiversity science. The Microbial Biodiversity programme urged to develop innovative methods and techniques to accelerate the discovery and characterization of microbial diversity, and to establish reliable databases to collect and exchange information on the biological characteristics of microorganisms. It was particularly encouraged to improve the knowledge in freshwater microbial diversity to increase the available understanding of the effects of microbial diversity on aquatic ecosystem functioning, suppression of diseases organisms, provision of clean water through the respiration of organic carbon, denitrification, and other metabolic processes, and to gain insights into the functioning and microbial regulation of biogeochemical cycles. The programme also urged to explore major issues concerning the conservation, origin, and maintenance of microbial biodiversity.

In 2007, I was appointed as a member of the Spanish committee of DIVERSITAS to help to achieve some of the ambitious aims of the international programme. For the last 20 years, and mainly over the past decade, microbial ecologists have developed, optimized and standardized powerful methods to capture microbial taxonomic and functional diversity. They have successfully combined multidisciplinary approaches from different scientific disciplines such as microbiology, ecology, biogeochemistry, molecular biology, bioinformatics and computational science and have efficiently linked available information on microbial diversity within a worldwide network.

This sustained effort circumvented some of the methodological and conceptual concerns that had strongly limited the general perception of how important microbes are for Earth biodiversity and initiated the effective transplantation of concepts and basic knowledge from the general ecology grounded on plants and animals to microbial ecology.

Sampling high-altitude Lake Redon in the Pyrenees in winter.

Sampling a deep karstic lake in Central Spain.

Sampling an inland salt lake in Monegros.

Sampling coastal salt ponds in the Mediterranean area.

Artemia salina (0.5 cm length), one of the main microbial predators in the saladas of Monegros.

In 2003, thanks to the Ramon y Cajal initiative of the Spanish Government and the support of the Limnology group headed by Professor Jordi Catalan, I joined the Center for Advanced Studies in Blanes and launched the current Microbial Ecology team, pionnering some of the above mentioned issues for more than 12 years already. The team has carried out research activities under different research topics for instance (i) Microbial Ecology, General Ecology, and Global Change Ecology, (ii) Microbial processes and Biogeochemical cycling (mostly C, N, and S cycles), (iii) Microbial biogeography and Global bacterial dispersal, (iv) Life in Extreme Environments, (v) Molecular Ecology and Evolution, and (vi) Data mining, Metagenomics and Ecoinformatics.

We used a wide array of environments and natural model systems such as (i) Sulfurous and Karstic lakes, (ii) Alpine and Polar areas, (iii) Saline lakes and Ponds, (iv) reactive biofilms in streams, (v) the Aerial plankton, (vi) Coastal and Marine Systems, and lately (vii) the Gut microbiome, to develop, improve and test methodologies and theories and to unveil the composition and functioning of the microbial component. Because of the high specific activity, abundance and versatility, microorganisms are primarily responsible for the main biogeochemical cycles, controlling rates of the chemical transformations. They also have a key role in the remineralization and the conversion of dissolved organic carbon in particles, and are also the main primary producers in much of continental aquatic ecosystems both by photosynthetic and chemosynthetic metabolisms. In fact, microorganisms are most abundant and most genetically and physiologically diverse living beings. They constitute a large part of the global biomass with an evolutionary history present for more than 3/4 of the Earth history. The long interaction with the geological component has certainly promoted a highly sophisticated microbial biochemical machinery.

Currently, most of our field research is carried out in three freshwater inland si-tes:

(i) the Limnological Observatory of the Pyrenees (Spanish version here) (LOOP)

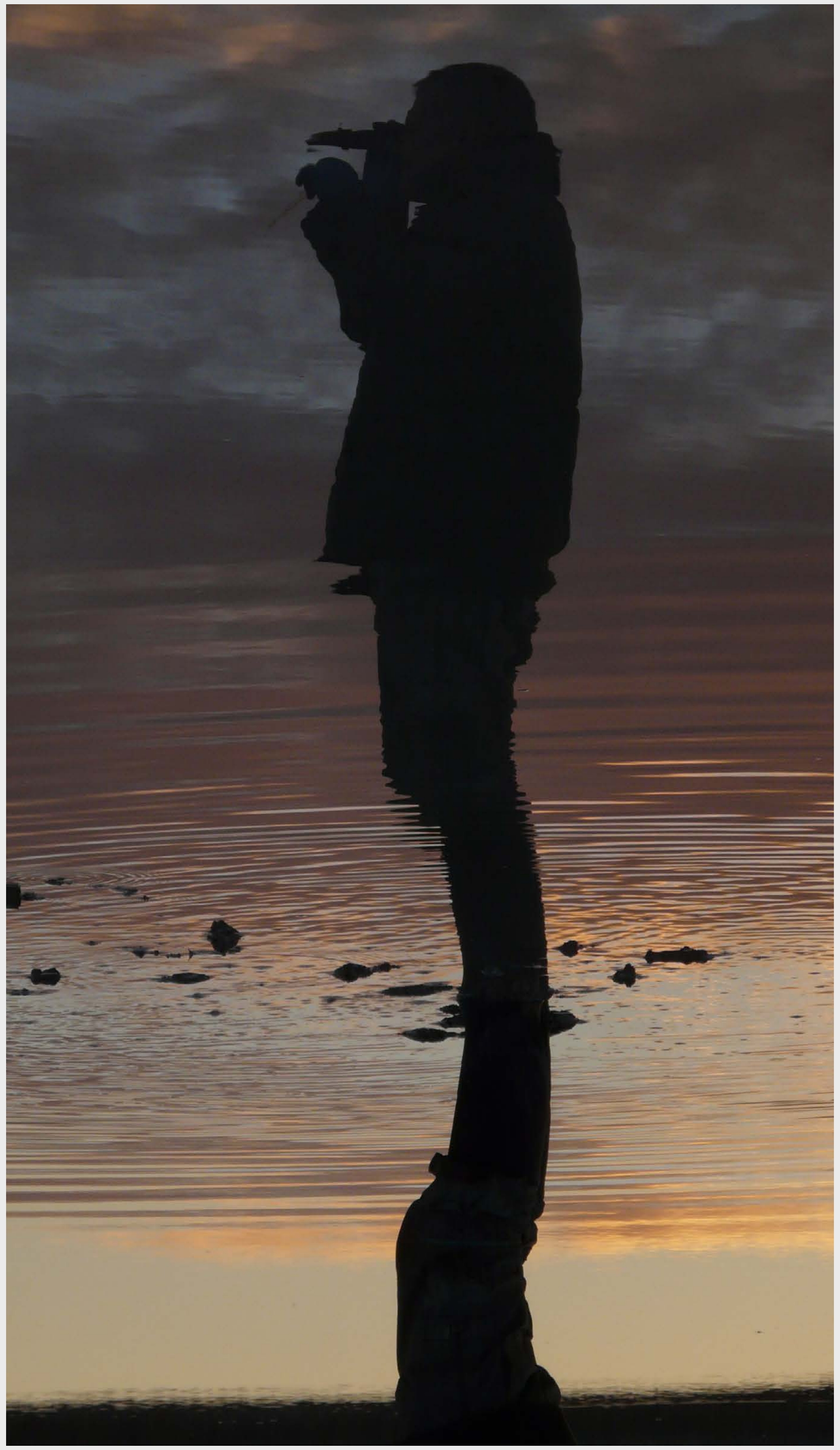
Cold, wet and misty in the winters of Monegros.

a LTER site within the National Park of Aiguestortes i Estany de Sant Maurici focusing on the microbial ecology of an alpine lacustrine district and intercontinental airborne bacterial dispersal

(ii) the protected area of Monegros Desert looking at the microbial ecology of shallow saline lakes (RAMSAR site “Saladas de Sástago-Bujaraloz”) and the dynamics and adaptations of microbial communities to frequent environmental stress and highly dynamic ecosystems

(iii) the karstic area of Lake Banyoles (RAMSAR site) studying the microbial ecology of anoxic and sulfurous (euxinic) environments as a proxy to infer past Earth conditions

We use powerful molecular biology tools on microbial physiology and ecosystem processes to link microbial biodiversity and biogeochemical cycling studies, especially for chemoautotrophic prokaryotes, archaea and the nitrogen and sulfur cycles. Our approach ranges from gene to ecosystem and from single cell physiology to emerging ecological patterns. We are also looking for ecological thresholds for microbial diversity distribution along environmental gradients and for the bridges between the ecology of macroorganisms and microorganisms, addressing questions regarding spatial and temporal patterns of microbial diversity, community ecology, functional diversity, microbial dispersal, and community assembly. We are also interested in examining the response of aquatic bacterial communities to global ecosystems change especially in highly sensitive high mountain lakes areas as early warning systems of global processes and in the exacerbated interactions of microbes with the nitrogen cycle. Finally, we look at the microbial metagenomics data using statistical and theoretical approaches of General Ecology within an evolutionary framework.



Looking forward to unveil new microbial secrets.

Despite this successful research period, microbial ecology is still in its infancy predicting microbial species distributions across landscapes, understanding why some areas have high or low species richness, or highlighting whether or not vulnerable groups of microbial species or microbial processes exist, missing useful information for land and ecosystems management. There is considerable biodiversity to be explored yet and although microbes can currently be reasonably well identified and classified in relation to each other enabling the fast and proper universal communication among microbial ecologists, a high-quality census needs still of methodological improvements. Genomes and metagenomes currently available are growing exponentially and single cell genomics and in silico genome reconstruction permits to reach the genetic potential of a microorganism without culturing. The inadequacy of methods and conceptual separation of microbiology from natural sciences with strong ecological and evolutionary background such as zoology and botany, should not be an unbeatable barrier anymore. In fact, microbial systems may push forward traditional disciplines and theoretical ecology to new unexplored frontiers. The Center for Advanced Studies of Blanes has the potential to successfully achieve this goal.

CEBRIAN, EMMA

Ph.D. Associate
1997 - 2015

INVASIVE SPECIES IN A CHANGING SEA

The Mediterranean Sea can be considered one of the hottest hotspots of marine bioinvasions on earth (Rilov and Galil 2009). It probably hosts the greatest pressure of introduction vectors in the oceans: Suez Canal, intense maritime traffic and aquaculture. High anthropogenic pressures besides a high variability of environmental conditions makes the Mediterranean a region particularly prone to marine bioinvasions and a special site for studying the main process involved in biological invasions.

However, invasive species are by no means the only problem threatening marine diversity. Climate change is also impacting on marine environments worldwide and the Mediterranean Sea does not escape from this global trend. Moreover, climate change can cause impacts both directly, as well as synergistically with invasive species understanding of the spatiotemporal range and magnitude of these impacts remains critically poor.

It is accepted that main processes derived from climate warming and invasive species interact simultaneously in a complex manner. The success of an introduced species in getting established and behaving invasive often depends on how suitable climatic parameters are in the region of introduction. For example, global warming is claimed to promote the spreading of alien species (Walther et al. 2009); however, this would not apply for cold-affinity species (e.g. Womersleyella setacea; Cebrian & Rodriguez Prieto 2012).

Likewise, some studies suggest that habitats degraded by global warming are more likely invaded than nearly-pristine habitats, envisaging explicitly or not, a cause and effect link between climate

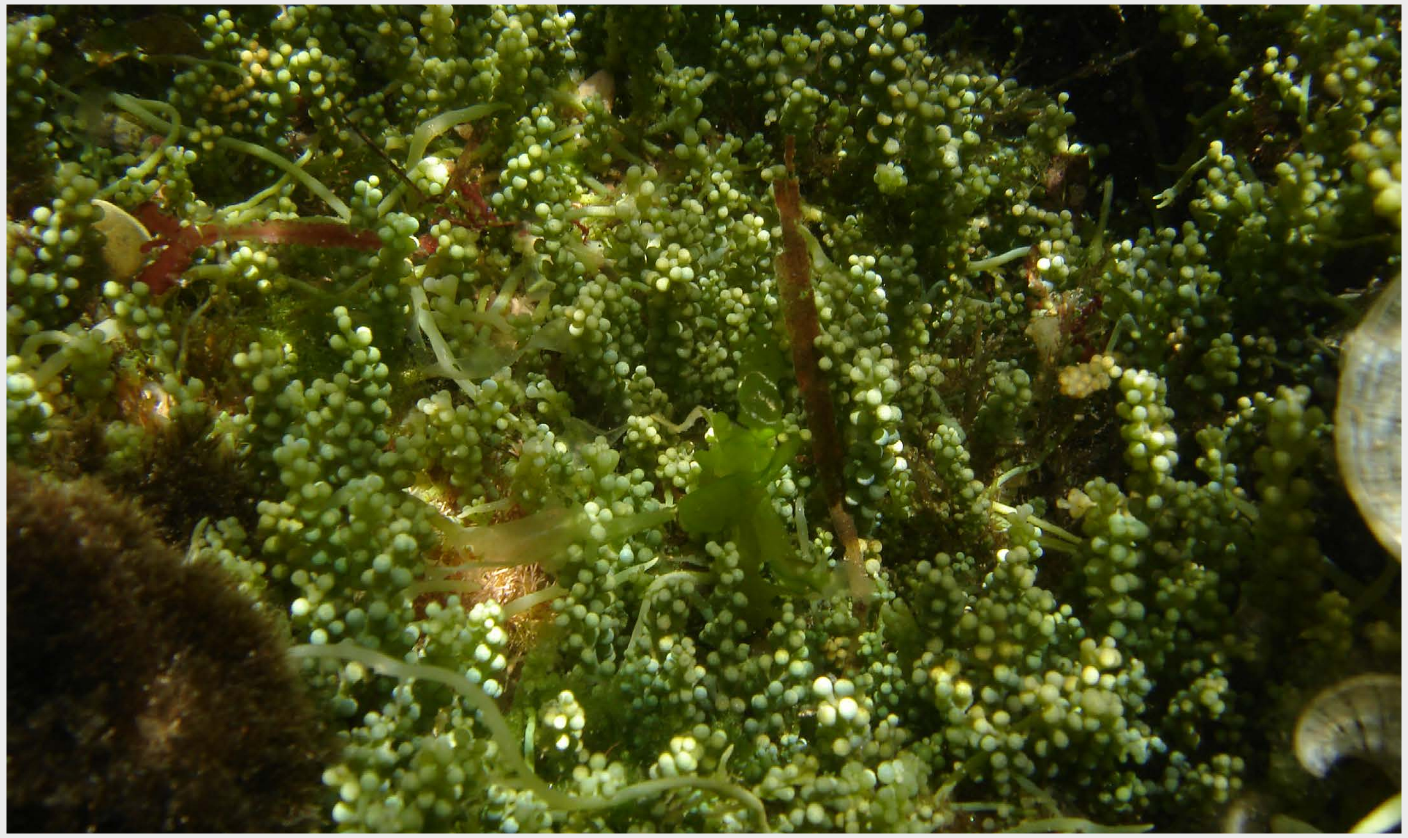
Lophocladia lallemandii, *invasive filamentous red algae in the Mediterranean Sea, the Red Sea and the Indo-pacific zone.*

(Cebrian et al. 2012). Given the spread of invasive species throughout the Mediterranean and the projected trajectory for climate change in this region, the likelihood of further negative impacts on native biological diversity is high. Despite this looming disaster, our warming and the success of biological invasions (e.g., Bianchi 2007, Galil et al. 2007, Occhipinti-Ambrogi, 2007, Stachowicz et al. 2002). However, results arising of some empirical systems do not support this idea (Verdura et al. 2015), but reveal instead conflicting re-

sults that have provoked intense debate. We've shown that the synergy of both perturbations may lead to further indirect but dramatic consequences on the persistence of populations that have already been affected by global warming (Cebrian et al. 2012; Linares et al. 2012; De Caralt & Cebrian 2013). We've also been aware of the dramatic decline of many key species in shallow water Mediterranean habitats (Ballesteros 2009; Cebrian et al. 2011), which could facilitate the spread of invasive algae thriving in the same habitats (Cebrian and Ballesteros, 2009, 2010; Cebrian & Rodríguez-Prieto 2012; Linares et al. 2012; Cebrian et al. 2012) and provided an striking example of climate-mediated range shifts of invasive species into temperate seas (Vergés et al. 2014).

However, one challenge that arises for managing marine environments in the face of climate change and biological invasions is to study why some habitats are more likely to be invaded than others (habitat invasibility) and how global warming may promote, or in contrast limit, habitat invasibility. Once an exotic has been introduced, resistance to invasion greatly varies among recipient assemblages (Levine & D'Antonio 1999; Lonsdale 1999; Kennedy et al. 2002). Some studies have investigated native ecosystems features (biodiversity, or direct competitors of invasives) determining the susceptibility to be invaded. We have reported the limited role of the native herbivorous sea urchin *Paracentrotus lividus* to resist *Caulerpa cylindracea* invasion (Cebrian et al. 2010), and the uncertain role of *Salpa salpa* (Tomas et al. 2011), but further experimental studies are needed to elucidate which factors provide resistance to macroalgal invasions to the native assemblages. Theory suggest that healthy and diverse ecosystems, as those attaining Good Environmental Status, improve both the resistance and the resilience of native ecosystems to climate change and bioinvasions, but no MPAs, for instance, where healthy benthic ecosystems are thriving, can stop the blooms of the invasive algae once they are introduced (Cebrian & Ballesteros 2009, 2010). Consequently, one aspect that deserves further investigation is whether more diverse communities should be less susceptible to invasion or not. The contrasting patterns found between studies may be partially driven because almost all manipulative diversity-invasibility experiments carried out so far in marine environments have used small, simple model systems, mostly early successional aquatic microcosms (e.g. Stackovicz et al. 1999; Stackowicz & Byrnes 2006; Marrafini & Geller 2015). There is increasing concern if the results from these experiments can be generalized in mature systems with complex community structure such as forests.

To know how diversity in marine complex communities may prevent alien invasion, or in contrast, if habitats less diverse (as those probably already affected by climate change) are more vulnerable to invasions is for us a priority.



Caulerpa cylindracea, *a very aggressive invasive algae very extended across the Mediterranean sea, originally coming from Australia.*

COMA, RAFEL

Scientist
1996 - Present

BENTHIC SUSPENSION FEEDERS AS INDICATORS OF THE EFFECTS OF GLOBAL CHANGE ON LITTORAL ECOSYSTEMS

In a world rapidly affected by global change, many organisms and communities are responding through changes in abundance and distribution. In the marine realm, habitat alteration and climate change are among the main factors affecting the functioning of the organisms. In this context, species invasion are recognized as a major problem causing large modifications on ecosystem structure and function. The main concern is how these changes are going to affect the services that marine ecosystems provide to us (food, climate and natural hazards regulation, nutrient cycling, nursery, commercial and recreational activities...).

Several definitions of invasive species can be considered if a geographic (introduced-native) and an impact criteria (harm-no harm) are used. From a narrow to a very broad definition, invasive species can be defined as those introduced species that affect an habitat or region, as those introduced or native species that affect an habitat or, as those widespread introduced species currently harmless to native habitats. All these definition are of interest within the context of understanding the effects that the dynamics of an species can have on an habitat, especially if the factors that affect an species dynamics become substantially modified by environmental climate change. The first one because it includes the species most usually considered when addressing the effects of invasive species. The second one because some native species exhibit a behaviour of rapid population growth that can be defined as invasive (native outbreaks). The third one because the widespread occurrence of these species represents a potential for a behavioural change from harmless to harmful in the habitat.

Attenuation of climate change requires the involvement of all major countries, an issue that takes time due to political and economic implications. Meanwhile, there is an urgent need for clear indicators of the rate of change related to warming and other human activities. To contribute understanding of the rate of change of the marine ecosystem, the factors, the processes and the mechanisms involved. We fo-

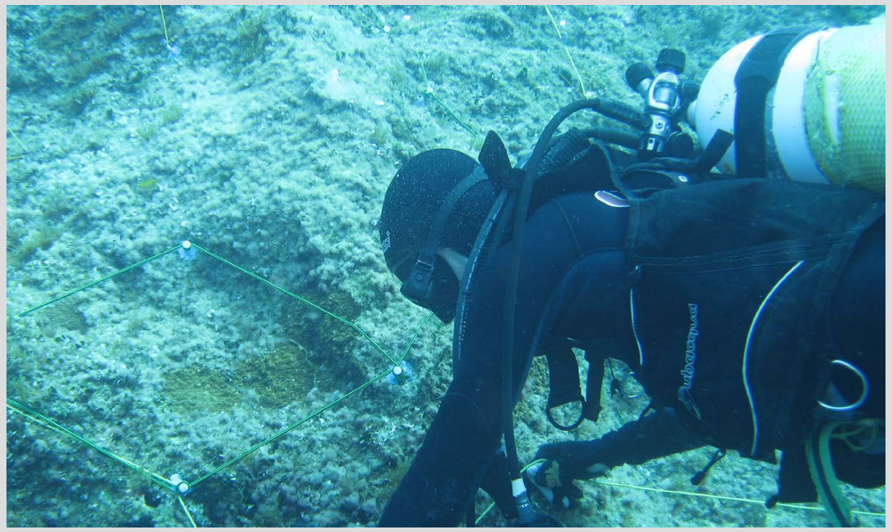


Figure 1. In situ long-term examination of demographic parametres of a coral species.

Figure 2. Field trip on SCUBA along the Mediterranean coast to assess population status of indicator species.

cus on the study of indicator species that can be considered as representative of the main dynamic of the community. The demographic parameters are the main determinants of the fluctuations of a population. The study of their variability and of the main factors that drive them is fundamental to distinguish natural fluctuations from those induced by anthropogenic stressors. Then, the long term study of the population dynamics of indicators species is crucial to distinguish change from natural oscillations.

Our research concentrates on the study of suspension feeder indicator species that are important contributors to the structure, functioning and/or biomass of different sublittoral benthic communities such as gorgonians, sponges and corals.

At present, the coral species *Oculina patagonica* appears as among the dominant species most clearly responding to the main global change alterations. The species has recently been exhibiting an invasive behavior with a drastic increase in abundance and distribution that affects the most productive Mediterranean benthic community, the shallow photophillous infralittoral. Our current investigation focus on the study of this coral species in order to determine its rate of change, the main factors that are affecting this rate, the processes that are been affected from this dominant species and the involved mechanisms. To this end: a) field examination of labeled colonies and areas on multiple sites and conditions is been conducted in order to determine recruitment, survival and growth (Fig.1); b) field surveys are been regularly perfomed along the Mediterranean littoral of the Iberian peninsula to examine changes in abundance and size structure of the populations (Fig. 2); c) field experiments are been conducted; and d) experimental studies of different hypothesis are been tested on aquaria to determine cause-effect relationships (Fig. 3).

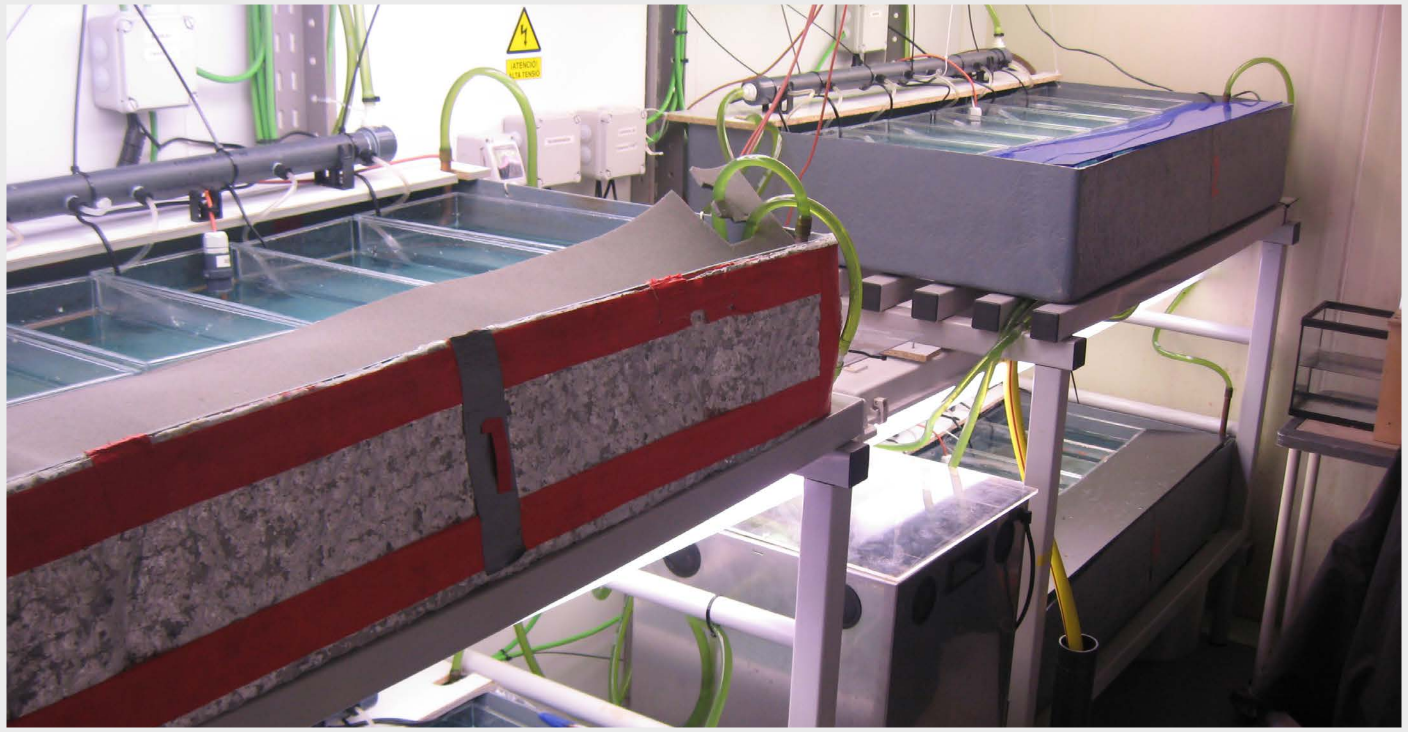


Figure. 3. Experimental hypothesis testing on aquaria of cause-effect relationships.

GACIA, ESPERANÇA

Scientist
1993 - Present

AQUATIC PLANTS AND WETLAND ECOLOGY

Aquatic plants are organisms secondarily adapted to living in aquatic environments. They can be ferns or flowering plants and require special adaptations for living submerged in water, or at the water's surface. They are often referred to as macrophytes when including macroalgae. Ecologically, they are key elements of water bodies such as estuaries, wetlands, stream riparian zones, ponds, shallow lakes and also marine coastlines, where they can cover huge areas. By having aquatic plants as model organisms our research group uses disciplines such as community ecology, functional ecology, ecophysiology, biogeochemistry, genetics and modelling to answer target environmental questions for aquatic ecosystems in front of global change. We base most of our research in fieldwork that we approach both observationally and experimentally.

MAIN FIELDS OF EXPERTISE:

Aquatic plant community ecology in shallow lakes

Most of our research is being conducted in the littoral of shallow lakes and ponds with particular attention to Pyrenean flora. We have gathered a large (> 200 water bodies) data base on macrophyte species presence and physico-chemical variables that we use both for management and conservation studies as well as for niche modelling. Our group is pioneer in detailed mapping of plant communities in lakes which allows upscaling any lake function mediated by macrophytes (e.g. nitrogen emissions, carbon balance) at the ecosystem level. Long term monitoring of this flora has allowed unique studies of resilience and recovery of endangered species in front of perturbations. Current research focus is on conservation of species and ecosystems threatened by climate change, habitat loss and introduced fish species. Our large biodiversity and environmental data set is being used for meta-ecology studies at regional and global scale in collaboration with scientists from abroad.

Ecological functions of seagrass meadows

The functioning of seagrass ecosystems is also a focus of research. Seagrass meadows are pivotal structural and functional elements in coastal waters and we have developed tools to assess the capacity of seagrasses (mainly Mediterranean *Posidonia oceanica*) to attenuate erosion, retain sediment and control biogeochemical

Figure 1. Isoetes lacustris L. at 5 m in Estany de Cabanes, National Park of Aiguestortes, Pyrenees (©EBallesteros).

cycles in the littoral. We have also contributed to gain knowledge on the role of seagrass ecosystems in the carbon balance in tropical and temperate meadows. We currently work on the role of seagrass meadows as biodiversity hot-spots as well as on the use of associated mesograzer communities to assess ecosystem quality.

Macrophytes as indicators of anthropogenic stressors

Species community composition has long been used as an indicator of water quality in continental stagnant water bodies. In Catalonia we have conducted extensive macrophyte and water quality surveys and have found that some ponds, temporary pools and the less abundant karstic lakes are the systems most affected by human pressures. We also confirmed that this area is a hotspot for macrophyte biodiversity because of the diversity of water body typologies (i.e. karstic lakes, reservoirs, alpine lakes, ponds, temporary ponds, meanders) and the Mediterranean weather. We also confirmed that biodiversity of aquatic plants is threatened mainly because of water scarcity and habitat loss (mostly temporary pools). Our group also explores water quality (i.e. eutrophication) in riverine macrophytes by using other indicators, such as the nitrogen stable isotopic signal of the plants themselves. The same tool has proven useful for studying physiological aspects of nitrogen use in aquatic plants such as nitrogen uptake and retention. We are also expanding the potential of aquatic plants as indicators of human perturbations to wetland species exposed to metal pollution. We have worked in paddy fields, heavily impacted water bodies, and recently at the Urban River Laboratory, an open air flume system working at the outflow of a wastewater treatment plant. In this facility we aim at improving the quality of grey water (outfall of the treatment plants) before entering streams in order to improve water and ecosystem quality in our heavily perturbed streams.

Figure 2. Reeds in the Natural Reserve at Flix reservoir, Ebro river.

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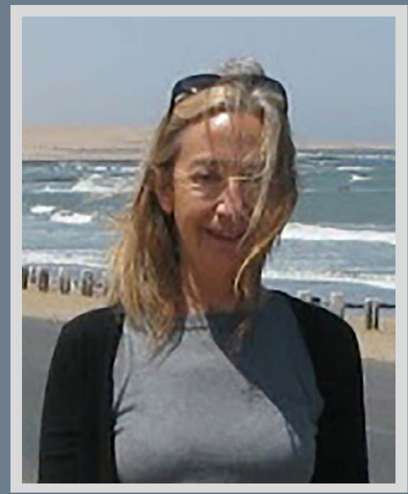

GORDOA, ANA

Scientist
1992 - Present

ADVANCES IN KNOWLEDGE ABOUT THE ATLANTIC BLUEFIN TUNA'S SPAWNING BEHAVIOUR

The Atlantic Bluefin Tuna is a singular and emblematic species given its physiology, its migratory behaviour and its high economic value, which is why it has been investigated by many research groups. Nevertheless, until seven years ago absolutely nothing was known about its spawning behaviour. This is where the CEAB reached a milestone worldwide as it was the first centre to determine this species' reproduction.

The triggering factor behind this research line was casual as result of listening stories and checking their truthfulness. Was all of that happened while chatting with the master of a tuna purse seiner, he told us: "whon full moon nights, tuna suddenly stop, and they do to spawn because I´ve seen a huge milky stain covering the surface of the sea". That's how it all started, we wanted to verify what he said, and then set up the experimental design machinery: Where? When? How?

Bluefin tuna (Thunnus thynnus) in the Mediterranean Sea, an emblematic species fished for centuries.

The setting up on where and when was opportunistic, based on existing fishing facilities. The L'Ametlla de Mar tuna purse seiners catch tuna in the Balearics exploiting the tuna spawning aggregations which occur in late spring and early summer. This is a live-capture fishery and the tuna caught in the Balearics are transferred to tuna transport cages which are transported and transferred to the fish farm facilities in L'Ametlla de Mar. So the "where" was the tuna transport cage and the "when" was while travelling to the farm.

We designed a fishing mechanism to collect plankton from the front and rear of the tuna transport cage, and samples were collected day and night during the 8-day voyage. It worked: the result was the mass collection of eggs at night from the rear of the cage. This was how the spawning of the Atlantic Bluefin Tuna was determining for the first time, and was later filmed in the ULTIMATUN documentary.

Since then, tuna transport cages have become experimental platforms which have allowed us to study in depth the spawning behavior of bluefin tuna. Since 2009, in the framework of a research and contract with the Balfegó Group, around 600 tuna spawners are transported to waters south off Ibiza, which is a round trip from l'Ametlla de Mar. The spawning behavior of this group is monitored nightly for 2 months.

This monitoring has allowed us to learn different reproductive aspects: when the spawnning peak takes place (around St. John; 23rd June); the timing pattern (between 02:00 a.m. and 05:00 a.m.); the consequences of such behaviour; the

Ana Gordoa is interviewed by a Spanish TV channel on her work on bluefin tuna.

individual spawning duration (some 30 days); the effect of atmospheric instability on spawning (it can inhibited for a few days); the hatching and its acceleration with temperature (from 45h. to 23h.). Moreover, the implemented fishing mechanism is currently used to collect eggs for culture.

Beyond this species biology, we have also investigated its fishery from the eco-efficiency perspective to annual variations in fishing efficiency. These results, along with the spawning behavior results, have enable to provide advice about the optimum fishing period for fishing sustainability purposes, which acts as the basis for some modifications made to its regulation.

In the next phase: from the fishery to the farm, with research carried out in the growth and fattening of tuna in captivity. Until 2013, the fattening factor was basic to estimate the weight of tuna fish on the date they were caught. Nowadays, the size of caught specimens can be known thanks to the stereo cameras, which measure tuna when transfered from transport cages to fixed cages. The CEAB presents annually at the International Commission for the Conservation of Atlantic Tunas (ICCAT) the catch rates of the purse seiners fleet in the Balearics grounds, along with the size and ages structure.

We encountered different problems while investigating on transport cages, problems which have actually become study elements. Mass presence of *Pelagia noctiluca* jelly fish juveniles proved an inconvenience for spawning sampling as they clogged sampling nets. Did they also impact on tuna offspring? Were they able to ingest tuna eggs despite their small size?

We are currently attempting to answer these questions. The experimental results showed their voracity, and gave the highest ever rates observed for juvenile jellyfish stages (0.3 – 1.3 cm). We continue with this research line in order to estimate its impact on the Atlantic Bluefin Tuna's offspring success.

This research requires an infrastructure (transporting fleet, tuna, ships, feeding at high sea, etc.) that is only available in the tuna purse seiner fishing and farming sector, without their active collaboration this work would not be possible.

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MALDONADO, MANUEL

Researcher
1989 - Present

SPONGES: UNCONVENTIONAL ARCHAIC ANIMALS UNDER MODERN EVOLUTIONARY AND BIOTECHNOLOGICAL PROSPECTS

Sponges make the phylum *Porifera*, regarded to be —not without controversy— the oldest lineage among the living animals. They are unconventional animals. In exhibition halls and aquaria, sponges often disappoint to non-specialist audiences anger for excitement, because they are sessile organisms that do not display noticeable body behaviours. They lack muscles, sensory organs, nerves, and any coordinating neural centre, performing slow body movements that can only be perceived through time-lapsed systems or alike approaches. They also lack mouth and anus, and even a digestive tube. There are neither respiratory nor digestive systems for oxygen and food processing, and excretory organs for elimination of metabolic wastes and detoxification are lacking as well. Cells have to deal individually with oxygen, food, and wastes, sometimes by mechanisms that are unique in the animal kingdom.

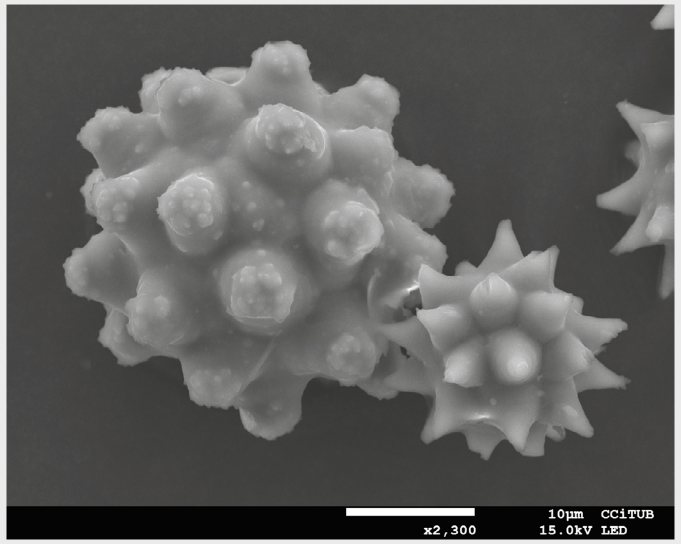
Certainly, the extreme anatomical simplicity of sponges has troubled biologists of all epochs at the time of establishing homology and equivalence to tissues and organs of other animals.

The structural and functional uniqueness of the sponge body favoured these organisms to be initially considered multicellular protists related to choanoflagellates, rather than animals. Only at the very end of the 19th century were sponges re-interpreted as animals, because spermatozoa and oocytes —the cells that all animals use for sexual reproduction— were discovered in some species of the group. Even after the gametes clearly pointed sponges to be animals, zoologists were not prone to thinking of these weird organisms as "real" animals and erected the subkingdom *"Parazoa"* to segregate sponges from the rest of "real" animals (i.e., subkingdom *"Eumetazoa"*). This condition of "para-animals" lasted virtually for the entire 20th century. The advent of molecular techniques in the 21st century has doubtlessly proved that sponges have animal genomes and, surprisingly, less unconventional than expected. For instance, sponges posses the

Monospecific sponge ground made by a dense population of the hexactinellid Sericolophus hawaiicus *at 400 m deep on the continental slope of Kona Island (Hawaii, USA).*

same repertory of neural genes than ctenophores, a group of predatory swimming animals that comparatively display plenty of coordinated movements and behaviours. Why sponges do not express those neural genes and persist as inert-like, behaviour-less animals remains both a mystery and a stimulating scientific challenge. The good news are that sponge genomes are now becoming a hot subject. They are thought to treasure pivotal information to understanding the evolutionary transition from the putative unicellular protist ancestor to the multicellular level and organ systems characterizing animals. In just a few decades sponges have therefore gone from being an almost ignored animal group that received little scientific attention to be radiant stars at the vortex of an international multi-laboratory battle to crack the secret of the origin of animals.

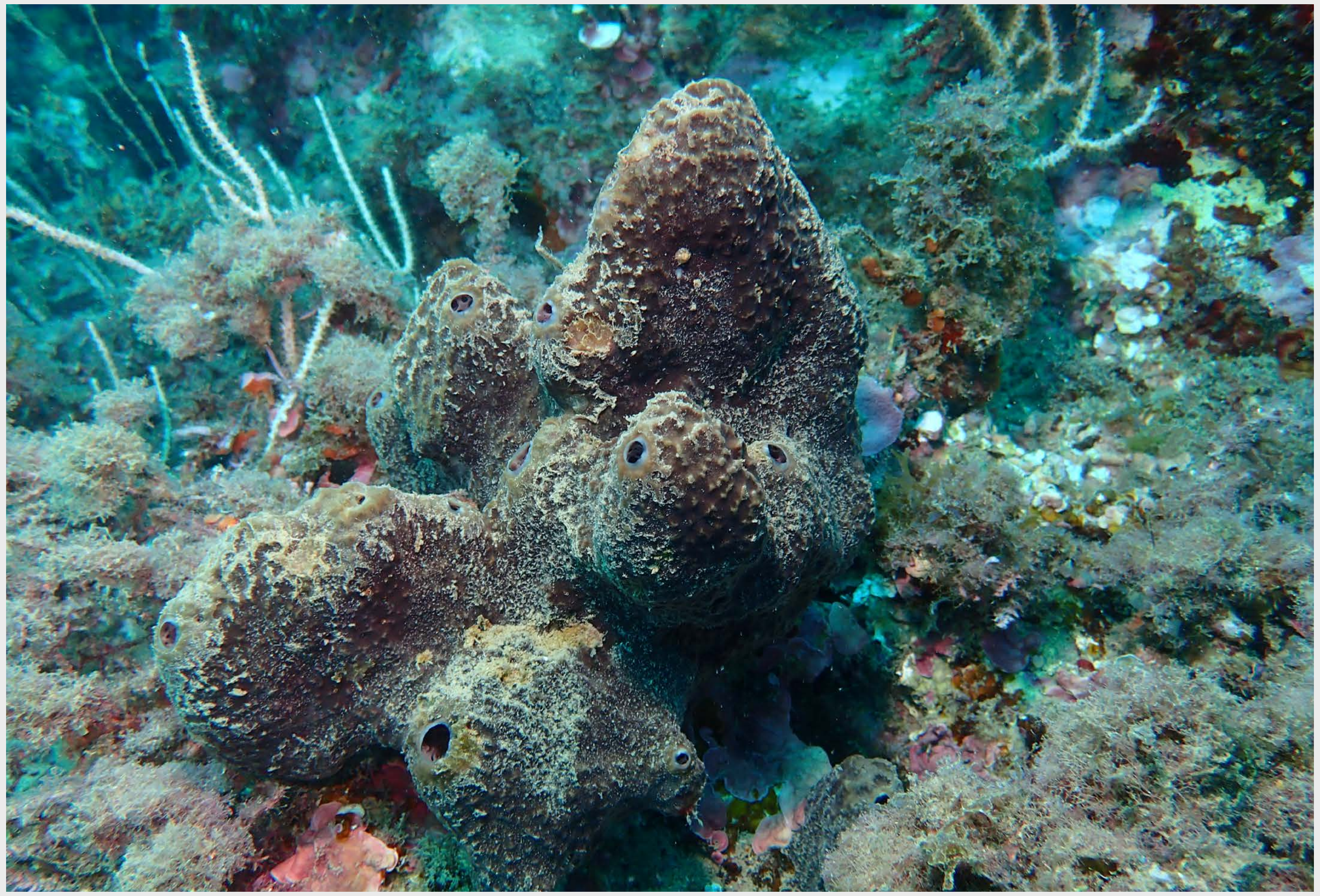
Yet sponges posses more singularities and additional mystery, some of which provide them with biotechnological appeal. Because lacking organ systems, their physiology must run by "alternative" pathways.



Picture taken by high field emission scanning electron microscopy, showing two of the millions of aster-like spicules that constitute the siliceous skeleton of the demosponge Chondrilla caribensis, *collected from Lee Stocking Island (The Bahamas).*

It is believed that it results in an intricate and not yet well-understood network of metabolic and cellular steps, often assisted by the activity of a complex universe of microbes, including archaea, bacteria, cyanobacteria, dinoflagellates, diatoms, and fungi, among others. After three decades of chemical trials, sponges rank at the top among the organisms producing chemical compounds with potential biological and pharmaceutical interest. To date thousands of singular bioactive molecules have been isolated from sponges, being still unclear which of them are produced by the sponge cells themselves, the microbes hosted by the sponges, or a combined action of both. After the initial thrill of discovering a promising therapeutic drug, the problem shifts to how obtaining it in large amounts for further developing the assays and trials and, if needed, commercialization. Man-made chemical synthesis is often either unachievable or unaffordable. Massive collection of sponges from the field is neither sustainable nor possible. For

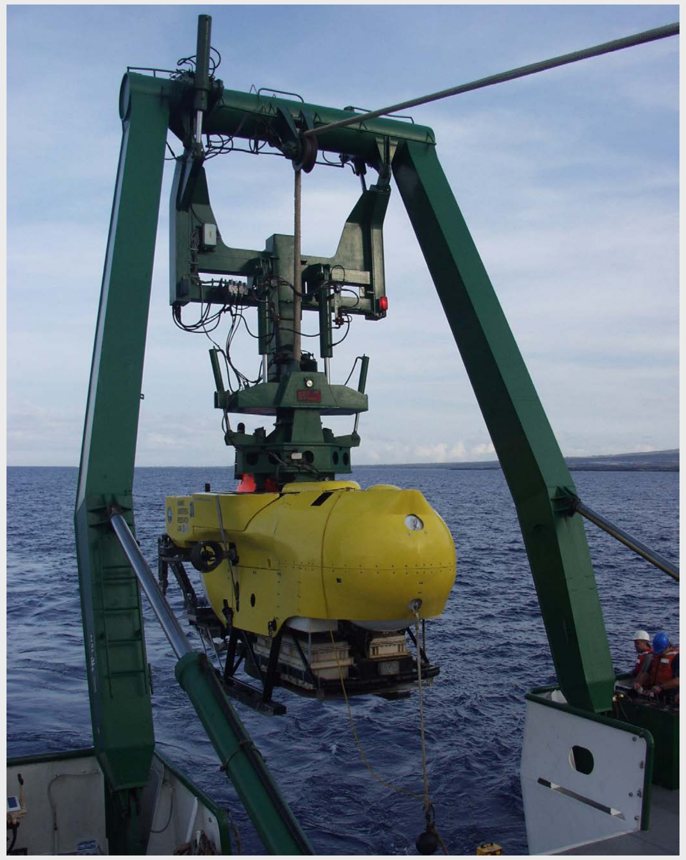
Diver taking pictures of sponges at the sublittoral of the Chafarinas Islands (Spain).



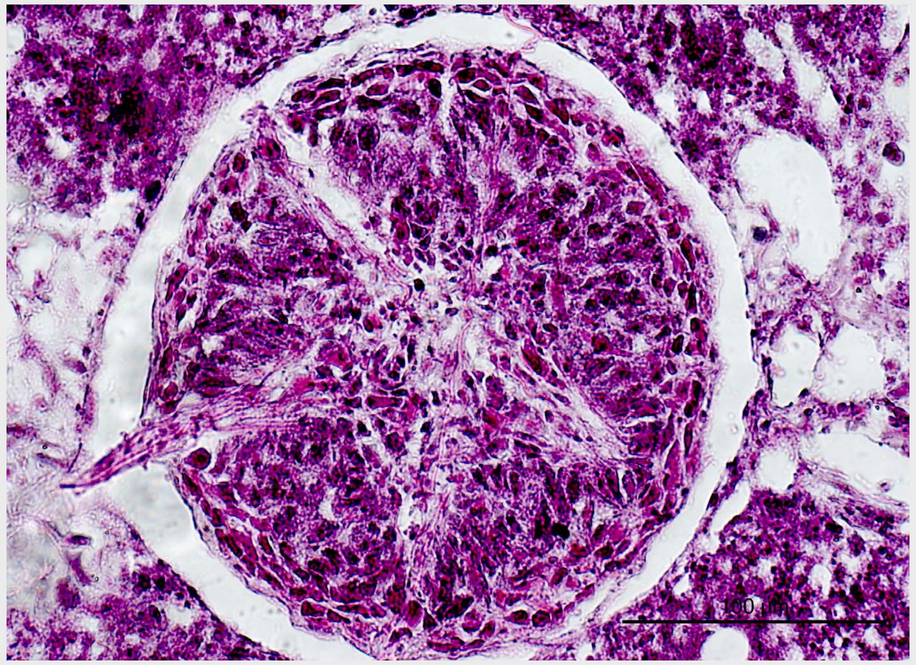
Individual of the keratose demosponge Ircinia fasciculata, *monitored as part of a study investigating events of massive mortality in this species apparently triggered by a unresolved combination of pathogens and global warming.*

instance, it has been calculated for a compound of interest that by collecting to extinction the entire world population of its source sponge, the obtained amount of compound would not be enough to complete the tests for the pre-clinical trial of the drug and, consequently, there would be nothing left for commercialization. For the past 20 years, research grants aimed to find a solution to this "supply problem" have economically sustained a myriad of laboratories worldwide, pursuing to produce large amounts of sponge compounds by culturing sponges, sponges cells, and sponge microbes. So far, none has been successful. The "supply problem" remains as a major factor preventing rapid development of new marine drugs, as well as a major scientific and biotech challenge.

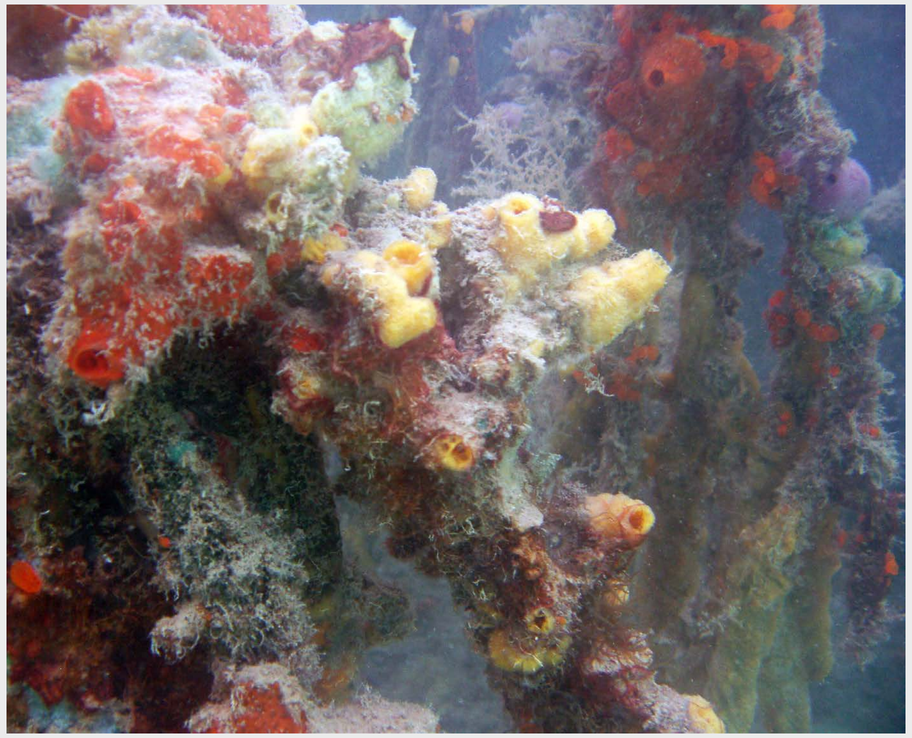
More recently, other elements of the sponge body have attracted biotechnological interest: their bones! Again, unlike in most other animal groups, the bones of most sponges, called spicules, are not based in the metabolism of calcium. In contrast, they have transparent, glass bones, made of silica (SiO_2), which is virtually the same material used in windows and mirrors. To form their skeleton, the silica is polycondensed (silicification) within the sponge body using the dissolved silicic acid available in seawater. The process is controlled by an enzyme called silicatein, which, as far as it is known, is exclusive to sponges. It was long known that mammals' bones experience slight silicification during its early growth, particularly long bones, such as the femur, the head and neck of which require trace deposits of silica for a regular development. Recent biomedical research has demonstrated that mammal bone fractures heal comparatively faster if sponge silica dust is injected in the bone injure. The results



View of the manned submersible "Piscis V" from the University of Hawaii ready to be launched (with Dr. Craig Young and Dr. Manuel Maldonado inside) to investigate a bathyal population of hexactinellid sponges at Kona Island (Hawaii, USA).



Histological section of an embryo brooded by the coral excavating sponge Thoosa mismalolli *as part of a study on coral destruction in reefs of the Mexican Pacific.*



Community of tropical marine sponges dominated by Tedania ignis *(fire sponge) and* Halicondria bowerbanki *growing on the roots of red mangrove tree at Twin Cays (Belize).*

even improve when the bone wound is treated directly with the silicatein enzyme. The use of sponge silicatein is therefore sparking a new generation of therapies for regeneration of bone fractures.

The sponge silica is also in the spotlight of optical research. During the biological process of silicification, the sponge cells select against the heavier isotopes of silicon, yielding an isotopically light silica. This high-purity material behaves as an efficient optic fibre during light transmission. Besides the purity of the material, the micro-arrangement of nanometre-thick concentric silica layers that conform the spicules appears to be very suitable for efficient multimodal light transmission with insignificant losses of intensity and wavelength. Both the cytological process of silica production and the internal ultrastructure of spicules are now under close scientific scrutiny, becoming inspirational sources for the formulation of a new generation of materials for led, optic fibre, and semiconductor elaboration.

Sponges have also potential applicability in environmental sciences. Although some sponge species are seasonal, most sponges are long living, with life spans that range from decades, to centuries and even millennia. Their bodies are therefore living archives that can potentially testify about major changes in the concentration of heavy metals, organo chlorine pesticides, and other sublethal pollutants in aquatic systems. Although a comprehensive protocol for a routine universal use of sponges as bioindicators is still to be developed, the few available studies indicate that sponges are great accumulators of a wide variety of compounds associated to the rising of industrialization of human societies. A calibration system to quantitatively translate the message of their accumulating activity is the only missing piece for their application as reliable bioindicators.

Sponges have also attracted interest for their potential to deal with organic pollution. A sponge is able to filter thousands of litres of water through its body daily, retaining virtually 100% of the bacteria, cyanobacteria, and the phytoplankton smaller than 10μM, which makes the base of the sponge diet. Such an amazing filter-feeding capacity can be used to alleviate the charge of bacteria and toxic microphytoplankton from waters where sewage pollution or red tides can be a problem (aquaculture farms, closed bays, etc).

The above handful of examples illustrates the interest that the primitive and simple sponges can have for biotechnology, material science, and engineering. It happens that during the past 30 years, the Centre for Advanced Studies of Blanes (CEAB-CSIC) has seeded a slowly growing group of sponge experts. In its origin, the pioneering bet on sponges - at that time a group of organisms with neither much "scientific glamour" nor biotech interest - was risky, with mistrust that it could lead to a high competitive scientific carrier. At the CEAB's 30th anniversary, it is to celebrate that, in the long run, with much hard work and some good luck, the "sponge bet" has brought back to the CEAB a good deal of national and international recognition. The CEAB's sponge research has renowned international reputation, being their sponge experts consulted and supported by major funding agencies and research institutions worldwide. Happy anniversary to the CEAB and its long standing commitment to the sponges.

MARTÍ, EUGÈNIA

Scientist
1999 - Present

GLOBAL CHANGE EFFECTS ON STREAM BIOGEOCHEMISTRY

During more than two decades, research in our team, included in the Integrative Freshwater Ecology Group at the CEAB, has focused on understanding how in-stream biogeochemical processes contribute to regulate the nutrient inputs from adjacent catchments and what are the controlling factors and mechanisms involved on nutrient cycling along the river networks. In particular, we have focused on the study of biogeochemical processes associated with the cycling and transport of bioreactive elements (i.e., carbon, nitrogen and phosphorous). Availability of these elements can be a limiting factor for the ecosystem's productivity, but at the same time, an excess of them can cause pollution and eutrophication problems. Ultimately, our research contributes to assess factors controlling the water quality of streams and rivers, which it is an important issue since human activity depends on the quantity and quality of this freshwater resource

Our research in relatively pristine headwater streams has shown that they can contribute to retain 50% of nitrogen inputs from their adjacent catchments; and thus, they are considered as nutrient retention hotspots within the fluvial networks. We have also been able to quantify particular processes associated with nitrogen cycling (assimilatory uptake, nitrification and denitrification) at whole-reach scale and how nitrogen from stream water is transferred into stream food webs. These studies highlight the high bioreactive capacity of streams. Nevertheless, this capacity is highly variable among streams and over time within a stream. This variability is influenced by environmental factors, such as nutrient availability, discharge and water residence time, as well as by the stream metabolism (gross primary production and respiration), which dictates the nutrient demand by in-stream biota.

Global change encompasses changes in climatic conditions (temperature and water availability) and in land uses within the catchments derived from human activity. The consequences of these changes on the ecosystems; and in particular, on the quantity and quality of freshwater resources, are of current social concern. Most of the streams draining catchments in the Mediterranean region are highly modified by land use transformations, which affect the hydrology, channel

Permanent stream in Santa Fe del Montseny (c. 1000 m.a.s.l), in winter.

morphology and chemistry of the streams, and in turn, alter their metabolism and nutrient retention capacity. For instance, nutrient retention efficiency is lower in streams receiving high nutrient loads derived from human activity. In addition, we have found that land use changes not only increase stream water nutrient concentration, but, in the case of nitrogen, they can also modify the relative proportion of nitrate and ammonium.

Intermittent stream in Arbucies (c. 200 m.a.s.l.), under summer drought conditions.

While diffuse inputs from agricultural activity increase stream water nitrate concentration, point source inputs from urban activity tend to increase ammonium concentration. These two dissolved inorganic nitrogen forms can undergo different biogeochemical process; and thus, changes in their relative proportion affect the in-stream cycling and downstream transport of this element. Overall, results indicate that ammonium is more biogeochemically reactive within the stream, while nitrate is more subjected to downstream transport.

Urban areas are dominant landscape components of catchments in the Mediterranean region; and forecasts for global population dynamics point at a higher concentration of humans in urban areas. Within this context, we have examined the effects of urban activity; in particular, the effects associated with point sources from wastewater treatment plant (WWTP) effluents on streams. Despite technological advances in WWTP operation, effluents constitute a source of nutrients, emergent pollutants and microbes to streams, which generate abrupt physical, chemical and biological discontinuities along the stream continuum. These discontinuities reduce the efficiency of nutrient retention and increase ecosystem respiration in receiving streams. However, remarkable inputs of ammonium from WWTP effluents are effectively reduced within relatively short stream distances (i.e., few hundreds of meters). These longitudinal changes are coupled with increases in nitrate, suggesting a dominance of ammonium transformation rather than uptake. In addition, we have observed that abundance of ammonia oxidizers (both bacteria and archaea) is higher in receiving streams; probably because inputs of these microbes from WWTP effluent are able to colonize the substrata of receiving streams.

Together these results indicate that streams receiving inputs from WWTP effluents are hotspots of nitrification, which can decrease the potential lethal effect of this nitrogen form on stream biota. In contrast, lack of nitrate removal along the receiving streams suggests that the denitrification capacity is limited, despite conditions for this process (i.e., low oxygen concentration and high availability of dissolved organic carbon) seem to be optimal. This results in a net export of nitrate from these streams with further implications for downstream ecosystems. In this sense, our current research focuses on understanding factors that may control denitrification in WWTP-influenced streams. The working hypothesis is that, despite inputs from effluents are rich in dissolved organic carbon; the quality of this carbon source may limit its use for denitrification in receiving streams.

Considering that WWTP effluents are also sources of microbes, among them pathogens, another question we are currently addressing is to estimate how pathogens persist along the receiving streams and how this is related to the biogeochemical reactivity of these ecosystems. Results from this research have implications not only for ecosystem health, but also for human health. To experimentally address these questions, over the past year, our research team, in collaboration with UB and Naturalea members, has built the Urban River Laboratory (http://www.urbanriverlab.com). This is an open-air research platform consisting of 18 flumes (12 m long and 60 cm wide), which receive inputs from a WWTP effluent. This research platform is fully supported by a local water management agency (Consorci per a la Defensa del Conca del Riu Besòs), which manages water resources (quantity and quality) in the Besòs catchment.

Ultimately, we expect that research from this platform will contribute not only to generate basic research knowledge, but also to provide insights that may help stakeholders to develop management strategies to both preserve stream ecosystem's integrity and improve the quality of freshwater water resources for humans.

MARTIN, DANIEL

Researcher
1993 - Present

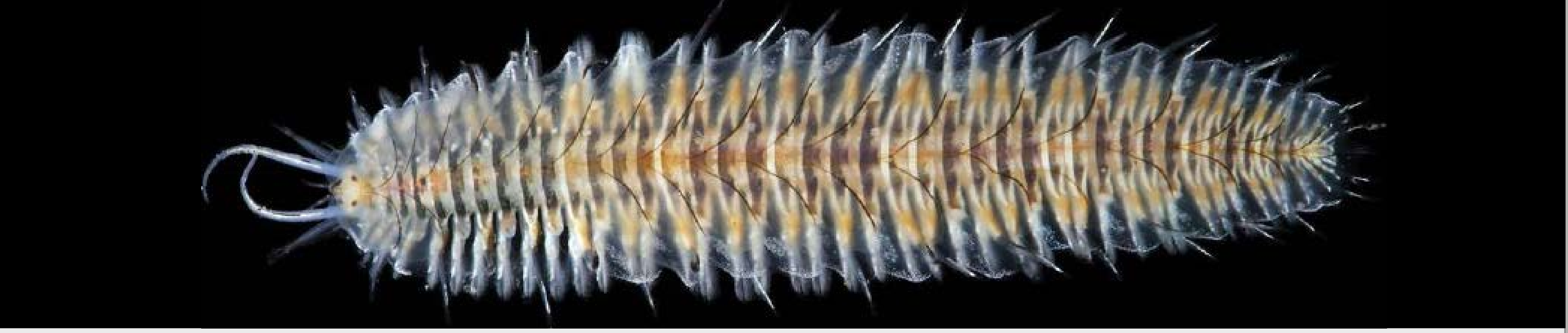
1998 – 2015: THE WORLD SYMBIOTIC POLYCHAETES REVISITED

The information on symbiotic polychaetes was scattered among different types of literature and it was not until Martin and Britayev (1998) that an exhaustive analysis was done. This review included more than 400 references and discuss on the characteristics of all symbionts known to date. As a result, a total of 375 species (292 commensals, 81 parasites) and 969 relationships (713 commensals, 253 parasites) were compiled. The authors, however, considered their contribution as a warning on the interest of this topic more than a closing publication, thus stating "The aim of the review is, therefore, to attract the attention of scientists to - and to encourage further studies on - the ecology of this particular and diverse group of symbionts". Coinciding with the celebration of the CEAB 30th anniversary, I decided to check whether this objective has (or not) been achieved nowadays.

Having this in mind, I undertake an exhaustive revision of the literature on symbiotic polychaetes produced since 1998, and compared the results with those compiled this year. The result proves a significant increase in the number of known symbiotic polychaetes: almost 60% more species (582) and relationships (1530) are currently known. Among them, 459 species and 1164 relationships correspond to commensals, and 126 and 373 to parasites, respectively.

Considering commensal polychaetes, nine families have been newly reported as including symbiotic representatives. The aphroditids, chaetopterids, orbinids, pholoidids, scalibregmatids and sigalionids include only one new report each, while fabriciinid and sibogliniids include two and eighteen, respectively. However, most of them are involved in a single relationship. The polynoids are still the most diverse family and has experienced the highest increase in number of known species, together with syllids. Both families altogether represent almost a 50% of all newly reported commensal species and more than 50% of the newly reported relationships. They also include

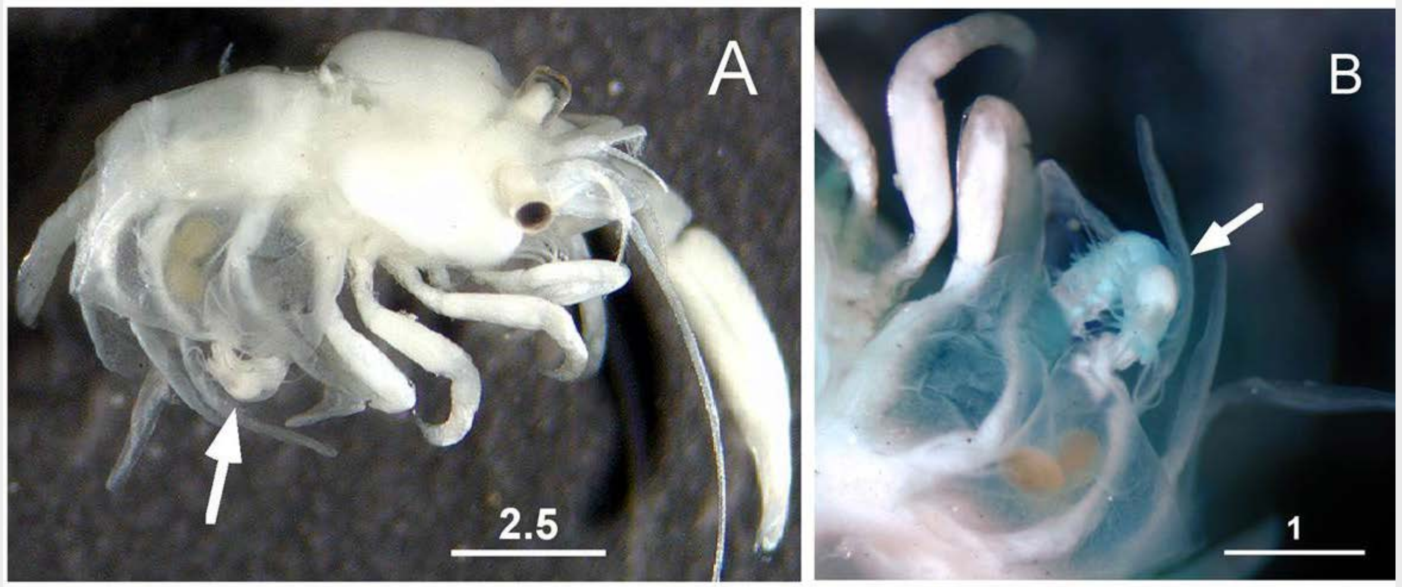
Medioantenna variopinta *on its host cnidarian* Solanderia secunda *from Sulawesi (Indonesia).*



some of the most spectacular species, like the bright coloured polynoid *Medionatenna variopinta* (Di Camillo et al., 2011). Commensal polychaetes have even been reported from the fossil records, with the host being a deep-sea sea urchin.

Concerning the hosts, polychaetes were already known to live commensalistically with many marine macroinvertebrates, so that only cephalopods and tunicates have been newly reported as host since 1998. Cnidarians are the group that increased more in number of newly reported species and relationships, including more than 30% of the total in both cases. Sponges include about 20% of the newly reported hosts and about 10% of the relationships, most of them in association with syllids of the so-called *"Haplosyllis spongicola"* sibling-species complex (Lattig and Martin, 2009, 2011a, b; Lattig et al., 2010a; Lattig et al., 2010b). On the other hand, numerous groups did not vary from 1998 to date (among them, the cirripeds, foraminifers, isopods, nudibranchs, polyplacophorans, and vestimentiferans).
Considering now the parasitic polychaetes, six families have been newly reported as including symbiotic species: hesionids, serpulids, polynoids, phyllodocids), typhloscolecids, and fabriciids, which range from one to eight newly reported species and one to thirty relationships. In turn, the spionids experienced the highest increase in newly reported species and relationships, with more than 70% and 90% of the total, respectively. As it occurred among commensals, some families (i.e. alciopids and lumbrinerids) did not vary from 1998 to date.

Overall, the number of newly reported parasitic species is much lower than the commensal ones, so that there are less groups newly reported as hosts (i.e. decapods, chaetognats, and brachiopods). In turn, decapods, gastropods, and cnidarians included the highest number of both newly reported species (61%, 27% and 20%, respectively) and relationships (83%, 16% and 10%, respectively). Curiously enough, cephalopods, ophiuroids, and sponges decrease both in number of newly reported host species and relationships. In most cases this was caused by a re-evaluation of the association as a commensalistic or mutualistic, with the most typical example being that of the sponge associated species of *Haplosyllis* (Lattig and Martin, 2011a). Finally, bryozoans, cirripeds, ctenophores, echiuroids, holothuroids, nemerteans, phanerogams and tunicates did not vary from 1998 to 2015.



Haplosyllides aberrans parasitizing the shrimp *Platycaris latirostris* which, in turn, lives symbiotically with the cnidarian *Galaxea astreata*.

The updated information of symbiotic polychaetes also allows me to infer some general trends. One of the most consistent concerns the degree of specificity of the associations. For instance, the number of symbionts living in association with a single host decreased a little bit, but still dominates and represents a bit more than 50% of the total. Conversely, some things have not changed and, for instance, the increasing amount of new knowledge does not allow me to assess whether some of these associations are really singular or, instead, they are qualified as so due to a lack of real information. In some cases, I suspect that the second possibility could be more feasible, and this seems to be confirmed by numerous recent studies. For instance, the hesionid *Oxydromus humesi*, previously known from a single record in Congo living in association with one species of tellinid bivalve, is now known to be associated to two more tellinid species in Iberian waters (Martin et al., 2012; Martin et al., 2015). The syllid *Haplosyllis chamaeleon*, considered a Mediterranean endemism living in association with *Paramuricea clavata*, is now known to live also in Cantabrian waters in association with *Paramurica grayii* (Lattig and Martin, 2009), and *Haplosyllides aberrans*, previously synonymized with *H. floridana* and living in association with sponges, is now a valid species reported as a parasite of coral-symbiotic shrimps (Martin et al., 2009). In turn, at the other extreme of the distribution, the number of polychaetes being involved in numerous relationships (i.e. more than 10) almost doubled from 1998 to date. Therefore, I may conclude that there seems to be trend in which symbiotic polychaetes are often involved in relationships being much more complex than expected. I am almost certain that this trend will be confirmed, as new knowledge will be further generated.

The information summarised above partially responds my initial question. However, I have not yet analysed the rhythm of production of new knowledge before and after 1998. A quick view on these rhythms certainly points on a marked difference. Effectively, since the first know symbiotic polychaete was described by Koch (1846), an average of three symbiotic species (two commensal and less than one parasitic) and about seven relationships (five commensal and two parasitic) were newly reported each year until 1998. From this year on these numbers have increased to thirteen (eleven commensals, two parasites) and thirty eight (twenty nine commensals, nine parasites), which overall represents a rhythm five times higher, both in terms of species and relationships.

Modestly, I would really like to think that part of this recent increasing interest on symbiotic polychaetes, as well as the fact that researchers pay more attention to the peculiarities of the symbiotic relationships (rather than simply reporting new species or relationships), was triggered by our 1998 paper. Thus, I am concluding this contribution to the CEAB's 30th anniversary by confirming that we were not wrong with our intended purpose for the 1998 review, as the particular mode of life of the symbiotic polychaetes are nowadays becoming more and more attractive to researchers.
Finally, in agreement with the objectives of the volume in which this contribution is integrated, and taking into account the modern perception of science, I would like to state that the next logical step in this filed should be to be able to transfer the interest on symbiotic polychaetes, which is currently almost fully restricted to the academic world, towards a non-specialised audience.

Oxydromus humesi from Cádiz Bay (Spain). Dorsal and ventral view of the anterior and posterior ends.

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MATEO, MIGUEL ÁNGEL

Scientist
2004 - Present

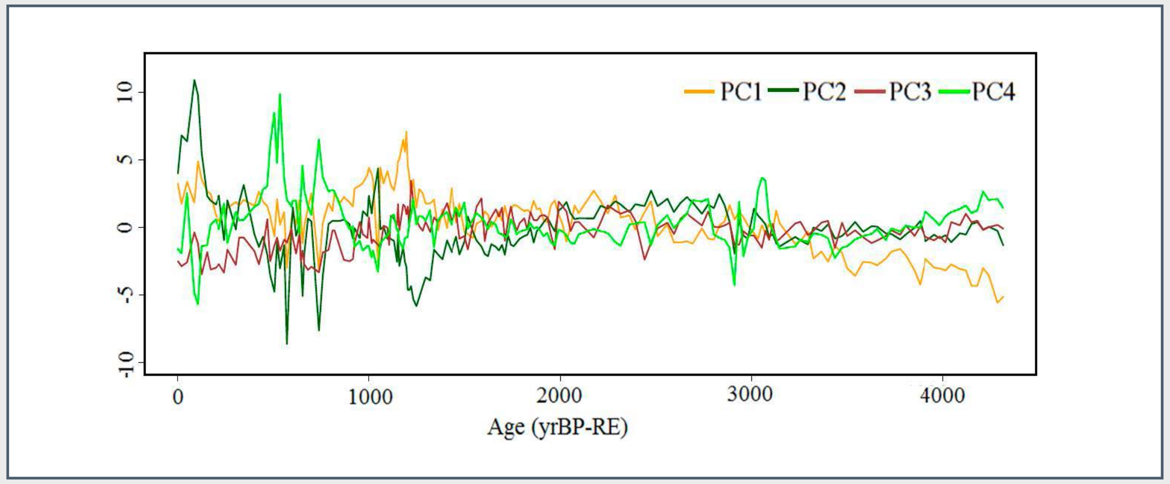
THE GROUP OF AQUATIC MACROPHYTE ECOLOGY (GAME)

The origins of the Group of Aquatic Macrophyte Ecology (GAME) go back to the year 2000. That year, using a rather artisanal but very effective field coring method, it was possible to sample a 5m-long core of the peaty sediments formed by the Mediterranean seagrass *Posidonia oceanica* in the small bay of Portlligat, located in the north of the Costa Brava, Spain. The 'Core 2000' has been since then the backbone of the Group giving birth to two pioneering research lines nowadays widely recognized and followed all over the world. Since inception of the Group, it has been directed by Dr. Miguel Ángel Mateo Mínguez, at that time a contracted researcher at the Plant Physiology Department of the University of Barcelona. When awarded with a Ramon y Cajal Fellowship in 2004, Dr. Mateo and his team moved to the Centre for Advanced Studies of the Spanish Council for Scientific Research (CEAB-CSIC). Four years later, he was appointed CSIC tenured researcher and, more recently, Adjunct Professor at the Edith Cowan University of Perth, Australia. Since then, GAME has found in CEAB-CSIC the ideal headquarters where to develop its scientific activities and is proud to be one of the active groups witnessing and celebrating its 30 years of existence!

The Core 2000 revealed two important facts: 1. the sediments underlying the seagrass *P. oceanica* were highly organic and contained a remarkable stock of organic and inorganic carbon and 2. the core represented a perfect chrono-sequence spanning over 4000 years of age. These two facts turned out to become the scientific foundations for two fertile research lines relevant for the global carbon cycle and for the use of marine paleo-archives for the study of change in the coastal ecosystem over the Holocene Period. During the last 15 years, in the framework of 15 competitive projects, GAME has been one of the leading groups on seagrass ecology, gaining an outstanding reputation in the area of carbon biogeochemistry in coastal marine ecosystems, and the leading group in paleo-ecology using the seagrass sedimentary archive. Apart form other important contributions in the field of seagrass ecology (1. use of stable isotopes as environmental, trophic, and physiological tracers, 2. population ecology, 3. environmental diagnosis using aquatic macrophytes), the work of the Group has focused on the cycling of carbon and other nutrients in benthic marine ecosystems and beach ecosystems. The Group has applied its knowledge to the development of ecosystem mass balances, the estimation of regional carbon storage (CO_2 sequestration) and the paleo-reconstruction of past environmental conditions. GAME is widely acknowledged as a leading Group on the study and estimation of carbon stocks and fluxes of Mediterranean seagrass ecosystems, a pre-requisite to understanding the role of seagrasses in carbon sequestration.

GAME's expertise in marine carbon storage has led to the Group playing a central role in the assessment of regional and global carbon storage in marine ecosystems (i.e. Blue-carbon) and, more recently, its incorporation into formal climate change mitigation policies. In 2012 the team was requested by the IUCN to prepare a report on the role of seagrass ecosystems in climate change mitigation, and has recently been granted by the EU LIFE program to coordinate the development of a Mediterranean-region research initiative on the storage of carbon in seagrass ecosystems and its incorporation into carbon trading schemes.

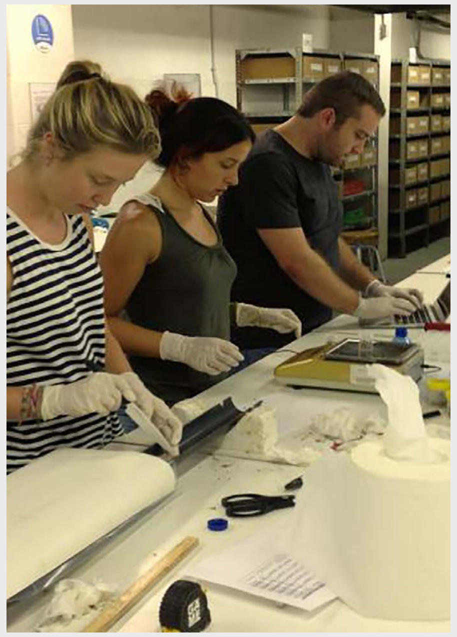
GAME has been publishing extensively on marine ecology, biogeochemistry and global change. Its publications are highly cited in the literature on marine carbon cycling and include significant works published in Nature, Global Biogeochemical Cycles and other leading marine ecology journals. These works include: a pioneering publication in 1997 setting the foundations of the study of the long-term refractory accumulation of organic carbon in seagrass sediments, another one in 2002 introducing these sediments as paleo-archives, one in 2006 reviewing the knowledge on carbon fluxes in seagrass ecosystems, two in 2009 and 2010 presenting the first environmental reconstructions using the seagrass paleo-archive, one in 2011 establishing the origins of metal pollution in the Mediterranean, a 2012 key publication in Nature which synthesised the global stocks of carbon captured in seagrass ecosystems, and a synopsis of the effects of climate change on Mediterranean seagrasses appeared in 2014.



Factor scores of a Principal Component Analysis using various proxies along the 'Core 2000' of Posidonia oceanica *sampled in Portlligat. This figure reveals a growing environmental instability towards recent times, initiated ca. 1300 years ago and probably reflecting the impact of the humanization in the Western Mediterranean. Source: Leiva, C. (2015)* Posidonia oceanica *(L. Delile) and carbon stable isotopes: a proxy for paleoenvironmental reconstructions and ecosystem management. Master Thesis, University of Barcelona.*

Some members of the GAME team celebrating the success of a mission in Cabrera Island (Balearic Archipelago, Spain), on board the R/V García del Cid. June 2015. From left to right, Prof. Dr. Paul Lavery (ECU, CEAB-CSIC), Oscar Serrano (ECU, CEAB-CSIC), Eduard Serrano (CEAB-CSIC), Dr. Ambra Milani (front, CEAB-CSIC), Anna Thoran (behind, CEAB-CSIC, UWA), Nerea Piñeiro (USC-CEAB), Carmen Leiva (CEAB-CSIC), and Prof. Dr. Miguel Angel Mateo (CEAB-CSIC, ECU). Photo by the Group of Aquatic Macrophyte Ecology (GAME).

A sediment core from a P. oceanica meadow in the Natural Park of the Cabrera archipelago. The shifts between more and less organic episodes are very evident.



Sampling a marine sediment core in the laboratory.

In addition to printed scientific papers, GAME is also very active in the dissemination of its activity in national and international conferences (around 200 oral presentations), as well as in the media, including printed press, radio, and television (around 100 participations). Furthermore, GAME organizes outreach activities regularly to help rising the awareness of the general public on the need to preserve our ecosystems (courses, talks, seminars, and round tables). Finally, through the participation of its leader in the Board of Directors and in the Publications and Awards Committee of the Association for the Sciences of Limnology and Oceanography (ASLO), GAME contributes to fostering the aquatic sciences worldwide. An important aspect of GAME is its experience in the coordination of multi-institutional and multinational research programs, incorporating both ecological and socio-economic studies. GAME has coordinated several major national and international studies of the Mediterranean region, including North Africa and Australia. GAME has no geographical barriers when it comes to collaborate and enjoys reuniting and participating in multinational and multidisciplinary consortia. GAME is not just an acronym; it is a declaration of intent, of belief for and commitment to making of science an enjoyable experience driven by passion and not by performance indicators. This approach has placed the Group in an excellent position to facilitate the involvement of researchers from different nationalities in National, Regional and International research initiatives. The countries of origin of the people collaborating or having collaborated with GAME amount 20 and include Australia, Brazil, Canada, Denmark, Egypt, England, France, Germany, Greece, Italy, Kenya, Malta, Mexico, Morocco, Portugal, Spain, Sweden, The Netherlands, Tunisia, and the USA.

The people that have contributed to GAME have been, beyond any doubt, the most important capital of the Group. Including Secondary and High school students, Degree and Master students, PhD and Post-doc fellows, contracted technicians and researchers, and adjunct doctors, GAME has hosted 32 people from 9 countries, including Australia, Brazil, Colombia, Denmark, Germany, Italy, Morocco, Spain, Tunisia, and the USA. In addition to its Group leader, GAME is currently integrated by a by 3 adjunct professors (Spain and Australia), 2 post-docs (Spain and USA), one contracted technician (Spain), 3 PhD students (Spain and France), 2 master students (Denmark, Perú) and 3 final degree students (Spain).

Between the elaboration of this note and 2020, GAME will be working on 1. the three active projects it is currently leading, funded by the National Research Program, the National Parks Funding Scheme, and the EU LIFE program, and 2. in an University-Industry collaboration project funded in Australia. In those projects we are addressing unedited problems of the phenomenon of refractory accumulation from an edaphological perspective, making the first attempts at modelling the carbon accumulation dynamics, exploring a wide range of new proxies for the paleo-reconstruction of environmental change from local to global scales, and elucidating the source of the dangerous ambient lead concentration in Port Pirie, Australia. The studies take place mostly in two Mediterranean regions with a high presence of seagrass meadows: The Mediterranean Sea, and Western and South Australia.

The reef-like, organic-rich structure formed by the Mediterranean endemic seagrass Posidonia oceanica*: the mat. Observed in Formentera, Balearic Islands, Spain. Photo by the Group of Aquatic Macrophyte Ecology (GAME).*

MACPHERSON, ENRIQUE

Research Professor
1994 - Present

THE IMPORTANCE OF THE TAXONOMY

Imagine a big dictionary, very big and very thick. With many pages, all of them white, without any word inside. The task of taxonomists is to search "words", define and include them into this dictionary. This dictionary is the Nature. Without words we can't write or speak languages, and we can't understand Nature. Any theory, any applied work, any conservation strategy can be biased by the wrong use of "words". Can you imagine a language that does not update its dictionaries? It will soon be considered a dead language. It seems that ecology is moving in this direction. Our "dictionaries" are becoming obsolete and this will ultimately bring us to an ecology with deficits, founded on a taxonomic basis obtained decades or centuries ago.

"The battle delivered against taxonomy has obtained a victory; nowadays the classification of an organism has become a difficulty." Ramón Margalef wrote this statement in 1968 in his book Principles of Ecological Theory. Since then, the status of taxonomy in the scientific world has fallen increasingly. However, it is surprising to observe that many scientific articles are published such as those published in emblematic magazines like Science or Nature-and TV documentaries warn us of the importance of biodiversity and how it is seriously threatened by insatiable human greed. And it is even more surprising to see that scientific community, totally aware of such threats, ignores or undervalues men of science who are trying to find out how many species live in ecosystems and how to identify and distinguish them correctly.

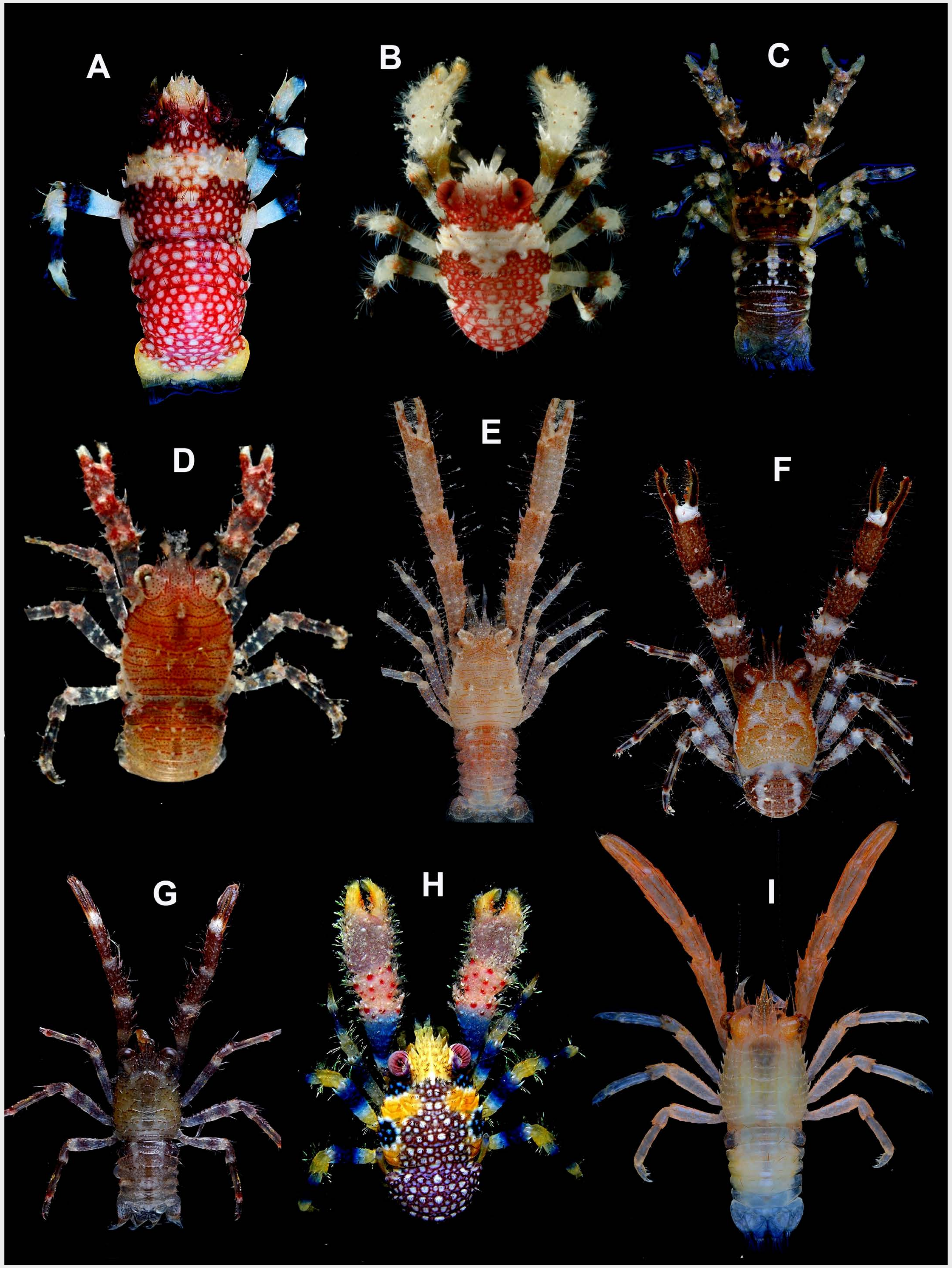
The biased used of the index of impact is leading the Natural Sciences towards a cul-de-sac: the number of taxonomists is decreasing at a dramatic rate and as a logical consequence so are the monographs on flora and fauna.

As the eminent ecologist Paul K. Dayton pointed out: "The last century has seen enormous environmental degradation: many populations are in drastic decline, and their ecosystems have been vastly altered. These environmental crises coincide with the virtual banishment of natural sciences in academe and research centres". There is an urgent need to understand the causes of the decline, how the species interact with other components of the environment, and how ecosystem integrity is determined. If we don't know which species are involved, we can't understand the problema and find the solutions. Whitout taxonomy this is not possible.

In this gloomy panorama the CEAB is producing a long list of taxonomic works.

For instance, the recent book of "*Guía de las macroalgas y fanerógamas marinas del Mediterráneo Occidental"* co-authored by E. Ballesteros is charmingly anachronistic in the best sense of the word. It is a splendid work that helps to palliate the ignorance about an important group due to the lack of works like this monograph.

Fortunately, there are other examples in our Institute. There is no doubt that these works fully accomplish the difficult mission of being the tiger shot for future studies on the biology, ecology and conservation of our ecosystems. May be the victory of the battle of taxonomy is not such a victory.



A, Galathea pilosa *De Man, 1888, Papua New Guinea, ovigerous female 4.5 mm.* **B,** Galathea pilosa *De Man, 1888, Maldives, male 3.6 mm.* **C,** Galathea platycheles *Miyake, 1953, Madagascar, female 2.2 mm.* **D,** Galathea platycheles *Miyake, 1953, Western Australia, ovigerous female 1.9 mm.* **E,** Galathea politula *n. sp., Vanuatu, holotype, M 3.5 mm.* **F,** Galathea polydora *n. sp., Vanuatu, male 3.3 mm.* **G,** Galathea polydora *n. sp., Vanuatu, ovigerous female 2.5 mm.* **H,** Galathea polyphemus *n. sp., French Polynesia, male 4.4 mm.* **I,** Galathea providentia *Laurie, 1926, Madagascar, female 3.0 mm.*

PUIG, MARIÀNGELS

Assistant Director
Since 2015

Scientist
1991 - Present

STREAM MACROINVERTEBRATES: SURVIVING TO GLOBAL CHANGE AND CYANOTOXINS

To say that global change in rivers is going to be studied is a redundancy because it is impossible to investigate in river ecology without consciously or unconsciously including the effects that global change induces on these ecosystems. The rivers are more or less chanalized, they have regulated flows, they receive diffuse and punctual contaminations from their drainage basin or from other watersheds distanced by atmospheric transport and precipitation, they are interconnected and invaded by many introduced species that in many cases are also invasive. The latter can be found even in high mountain headwaters, as in the Pyrenees where some species of predatory fish transform the pristine lakes into eutrophic ones, from which rivers with low quality waters leave[1].

The climate change generated by global change, extends its impact on the whole Earth. And in our study areas it emphasizes the temporality of the Mediterranean streams and the Pyrenean headwaters, as well as the catastrophic effects of droughts and floods in all of them. It should be remembered that there are already data showing the increase in temperature in mountain lakes[2], which in the Pyrenees have temperatures with large daily fluctuations in summer, with maximums well above 20°C, because the effect of the change Is more evident above the forest boundary in mountain ranges with altitudes such as the Pyrenees.

Since the beginning of my research, aquatic macroinvertebrate communities have been the focus of my studies on the effects of global change [3], and on climate change in recent years [4]. Macroinvertebrates allow practical approaches for river quality assessment [5], accurate conservation studies of their biodiversity, comparative studies of biological traits and species strategies to assess the resistance and resilience of communities [6] before the advance of climate change or for management and restoration models.

In fact, the importance of macroinvertebrates lies in their role within the structure and function of river ecosystems as intermediate links between

Tordera river macroinvertebrates (A. García-Rubies).

the primary producers, algae and cyanobacteria that they control, and the high predators that consume them (fishes and amphibians) . This is a classic top-down control scheme, which can be reversed to down-top by toxin production by river benthic cyanobacteria [7,8] and benthic-planktonic lake cyanobacteria.

Nowadays my research focuses mainly on the effects of climate change on high mountain aquatic macroinvertebrate communities, including paleolimological reconstructions, to know what strategies will allow them to survive and which will not, as well as the role that cyanotoxins can play in these processes.

Sant Nicolau river from Aigüestortes National Park (Pyrenees) (M.A. Puig).

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SOCIO-ECOLOGY

SARDA, RAFAEL

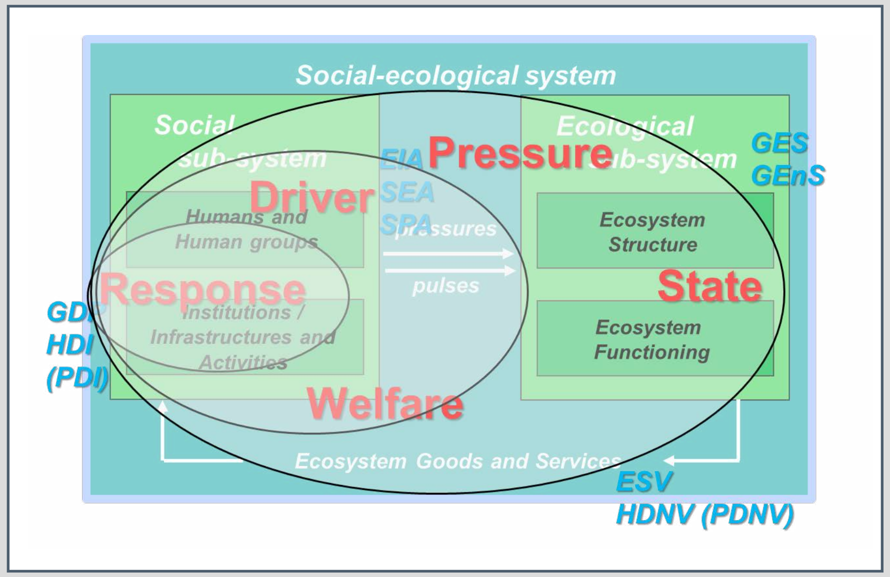
Researcher
1990 - Present

We live in an era of a rapid accelerated global change (planetary-scale changes in the Earth system) being human activity, predominantly the global economic system, the prime driver of this change. This global change pattern is driving us into a deep environmental crisis. This environmental crisis can be described by observing three main tendencies; human footprint is increasing, planet earth has a bounded carrying capacity for its natural resources and the natural capital is degrading. Altogether makes the old concept of Sustainable Development **"meets the needs of the present without compromising the ability of future generations to meet their own needs"** difficult to achieve. We are running an unsustainable machine in an unsustainable way. Our Natural Capital, the extension of the economic notion of capital to goods and services relating to the natural environment is in danger and this jeopardizes our ability to leave a safe environment for future generations.

In today's world, natural resources cannot be treated as discrete entities that need to be analyzed separately; they are dependent of the social and economic systems with which they interact. The concept of social-ecological systems has been gaining acceptance to analyze this complexity. Social-ecological systems (Figure 1) are **"complex adaptive systems in which humans are part of nature and the dynamics of both dimensions are strongly linked at equal weight".** When managed, these coupled co-evolving systems should focus on the ability to respond to feedbacks from the environment considering the tendencies of ecosystem goods and services that we obtain as benefits from the environment.

The social-ecological paradigm of our present days recognizes the mutual inter-associations between human societies and ecological processes that are necessary for the survival of both. This paradigm give much more importance to the Natural Capital as resource provider and put pressure to better define the sustainable development path that we need to construct for the future of humanity "enhancing social capital and economic prosperity while maintaining the integrity of natural systems and its potential for the provision of ecological good and services".

During the last two decades, a research line of the CEAB-CSIC uses this previous own new definition to



develop new research and applications in the frontier between social and natural systems, how they work and interact, how to cope with present and emerging, local and global environmental problems and the role, if any, that science and regulations might play on it. Different aspects become drivers of research: how to investigate and to promote a better care of ecosystem service provision, how these interacting systems of people and nature (social-ecological systems) can best be managed to ensure a sustainable and resilient supply of the essential ecosystem services on which humanity depends. All of this while developing tools and making recommendations to move from present focused impact-driven policies to more desirable state-driven policies.

Social-ecological systems can be analyzed through different information platforms. In our research, we use the proposed Driver-Pressure-State-Welfare-Response (DPSWR) framework to adequately organize information of the interrelation between the human and the natural sub-systems inside. As the above figure indicates, human systems (people's capabilities and their activities) become drivers of change (D). They pressure constantly or in pulses natural related systems (P). Those Natural systems (structural units and the functions they made) alter their status (S) that in turn can translate into the degradation of fundamental natural resources used by man (natural goods and ecosystem services) diminishing human welfare (W). The recognition of such degradation should allow man to made adequate policy responses (R) to solve the pattern of accelerated degradation. The information generated through the DPSWR framework expressed issues in a highly inter-related form which is something that we cannot observe if we use other sets of indicators that inform different pieces of the social-ecological system puzzle in isolation.

Using the social-ecological science and the framework outlined above, we have been working on the practical application of the United Nations Ecosystem Approach Strategy with the aim to reconcile the theory of Environmental Policy with the Practice of Environmental Management. We develop a standardized system, the so-called Ecosystem-Based Management System to bring these issues into real applications (www.msfd.eu). We are disseminating such system with the main goal to apply it into Integrated Coastal Zone and Beach Management structures (http://lagpweb.udg.edu/mevaplaya2/) as well in the adoption of this scheme into the Conservation of the Natural Capital and its use in Marine Protected Areas. Finally, to deal with our role of responsible civil servants, we are attending today different groups and commissions to bring recommendations into public norms such as the Interministerial Commission to transpose the Maritime Spatial Planning Directive, the **"Comissió Sectorial d'Investigació i Sostenibilitat"** and the **"Comitè de Seguiment de l'Estrategia Marina de la DM levantino-balear"**, both from the Genetalitat de Catalunya, or the **"Commissió de Sostenibilitat de les Comarques Gironines"**.

Suncheon Bay Wetland Protected Area (South Korea) a good example between conservation and development

TURON, XAVIER

Research Professor
2008 - Present

NEW TOOLS FOR BIODIVERSITY ASSESSMENT

We are witnessing the sixth big extinction of the history of life in our planet. Unlike the previous ones, this is caused by human activities and their impact on biodiversity. Recent updates of the Red List of Threatened Species by the International Union for Conservation of Nature show that ca. 33% of the assessed species are threatened in some way. Current estimates place the number of species that go extinct every year in the thousands, mostly as a result of multi-faceted anthropogenic impacts: over-exploitation, habitat destruction, climate change, introduced species, pollution, ocean acidification…The IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services, the biodiversity counterpart of the Climatic Change Panel) warns that oceans in particular are in imminent peril of an unprecedented marine extinction episode.

At the same time, taxonomy, the scientific discipline that deals with the description, identification, and classification of living beings, is suffering from underfunding, lack of prestige, and lack of career and employment perspectives. Taxonomy has failed to keep up with the development of other disciplines of biology, and the result is known as the "taxonomic impediment", in short, the insufficient taxonomic expertise to effectively describe the biodiversity on Earth. Taxonomic information is a pre-requisite for all research and management on biodiversity, yet for many groups of organisms there are between none and a few persons in the world that can reliably identify species. Even well-known taxa often lack specialists knowledgeable of important areas of the planet. Taxonomy is badly needed, yet taxonomists are considered as service-providers rather than true scientists.

Biodiversity crisis plus taxonomic impediment equals big trouble for assessment and conservation of the biota of the planet. Species become extinct at a faster pace than we can describe them. Urgent action is needed to alleviate this problem until taxonomy can regain its lost momentum. Hundreds of years of

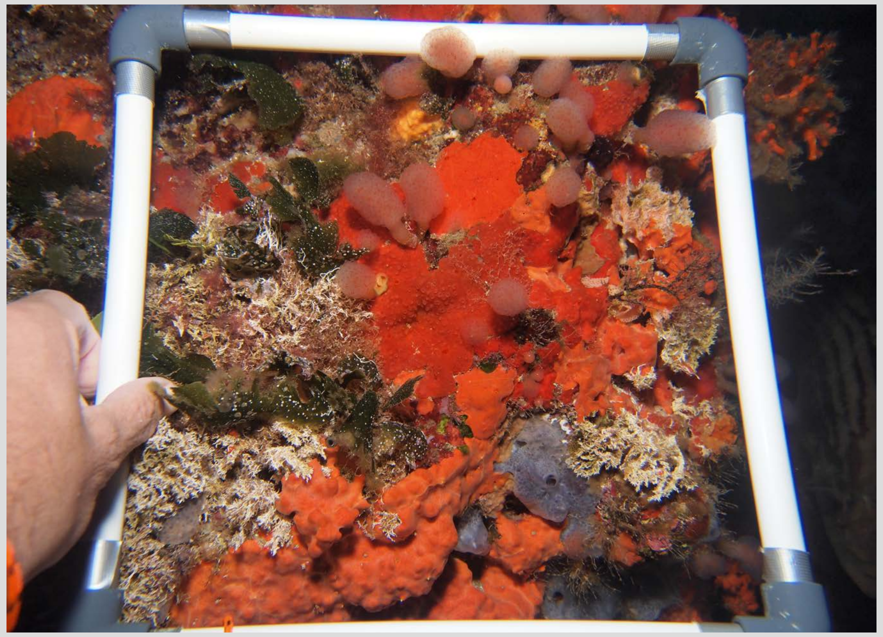


Figure 1. A square allows delimiting sampling units on rocky bottom communities in Cabrera Island.

taxonomic expertise are deposited in museum collections (often inaccessible or poorly curated) and taxonomic literature (often hard to obtain and plagued with incomplete descriptions). Intensive use of Internet can greatly contribute via cataloguing, archiving, and providing unrestricted access to taxonomic literature, and indeed there are many important initiatives in these fields, such as World Register of Marine Species, Encyclopaedia of Life, Biodiversity Heritage Library, to name only a few.

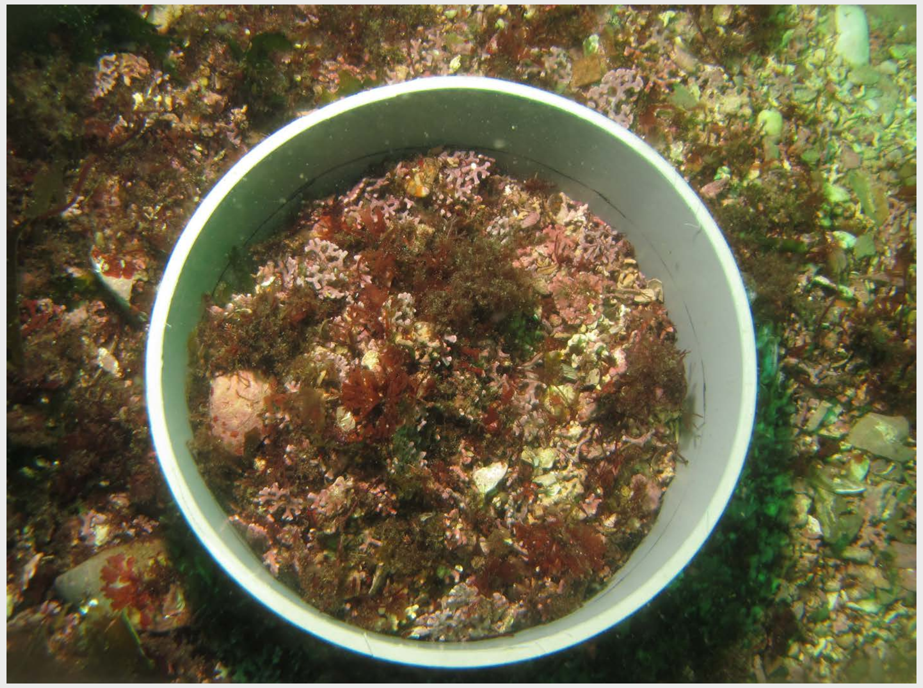


Figure 2. A corer is used to Sample the Maërl community in Cíes Islands.

In recent years we are starting to deposit and perpetuate the taxonomic expertise in genetic databases. This is done by generating sequences of organisms identified by taxonomists and making them public, so that non-specialist people can compare these with sequences obtained from target specimens to help in their identification. Genetics does not supplant taxonomy, rather, it is a way to preserve and to make amenable to others taxonomic knowledge using genetic features in addition to the traditional morphological characters. The Consortium for the Barcode of Life (BOLD) is an international initiative devoted to developing short DNA sequences as a global standard for the identification of biological species. It is the biggest initiative in genetic biodiversity ever undertaken. As of today, there are over 5,300,000 sequences deposited for over 250,000 species.

The method of generating short sequence tags as IDs for species has been labelled "barcoding", a catchy name reflecting the similitude of these sequence tags with the barcodes we see in so many shops today. Barcoding is not free from problems, among which the choice of the adequate marker, the curation of the databases and, above all, the need of a sound taxonomic expertise to correctly identify the specimens in the first place. Unfortunately, many of the least-known groups are also among the most difficult to barcode (f.i., small organisms), and a sustained (and well-funded) effort is necessary to populate the databases. However, barcoding has demonstrated now and again its utility and has revolutionized the way in which we identify species and assess biodiversity. In particular in the case of animals, where the first (5') half of the mitochondrial gene Cytochrome Oxidase I (COI) has shown an adequate resolving power at the species level in most groups. Even well-seasoned taxonomists now regularly use barcode sequences to identify problematic groups, and many faunistic/floristic works and descriptions of new species include the generation of the corresponding barcodes. Obtaining sequences is nowadays straightforward and cheap, and many biodiversity projects even in underdeveloped countries have benefitted from this new tool, indirectly accessing the taxonomic knowledge captured in the BOLD project. Barcoding studies have changed our view of extant biodiversity, the overwhelming message being that biodiversity at the species level has been grossly underestimated in many groups, with cryptic speciation phenomena being pervasive.

If barcoding changed the way to approach biodiversity studies in the last ten years, a further leap forward has been made possible by the advent of the new sequencing technologies (so-called Next Generation Sequencing, NGS). NGS methods can sequence in parallel heterogeneous mixtures of DNA (as opposed to the traditional Sanger method that generates one sequence at a time). This opened the door to analyse barcode sequences, not specimen by specimen, but using all DNA present in a community in a single run. This new method of biodiversity characterization has been termed metabarcoding, and refers to the sequencing of tags (barcodes) from DNA present in the community. DNA can come from bulk organismal samples if organisms have been isolated (from traps, decanted sediments, filtered water…), or from environmental DNA (eDNA), defined as the genetic material obtained directly from samples (soil, sediment, water…) without first isolating any target organism. eDNA includes DNA inside the organisms and extra-organismal DNA in cells, debris, exudates, or as free extracellular DNA.

Metabarcoding was invented by microbiologists (although the name is not commonly used in that field), as it was the logical (and perhaps only) way to deal with prokaryote communities, for which genetic tags based on the 16S rDNA were well known. The next step was to apply this technique to microbial eukaryotes and, only in recent years, metabarcoding has started to be assayed on fungi, plant, and metazoan communities using different regions of the 18S rDNA gene. In metabarcoding, the main steps are the extraction of DNA from samples, the amplification of the chosen barcode using universal primers, and the high throughput (NGS) sequencing of the amplicons. The sequences are then quality-filtered, artifacts and chimeras are removed, and MOTUs (Molecular Operational Taxonomic Units) are delineated by clustering similar sequences. The underlying idea is that MOTUs match diversity at the species level as closely as possible. Then MOTUs are assigned a taxonomic name by comparison with sequences from databases. All these steps have many alternatives and can introduce variability in the results. The field is young and new technical and bioinformatics developments are being made continuously. We are far from a standardized pipeline, but consensus is arising in several of the steps.

Metabarcoding has proven very useful in biodiversity assessment and monitoring, generating high-quality datasets with an order of magnitude more species (MOTUs) and in much shorter times than traditional methods. It has also been successfully applied to studies of ecological dynamics, interactions, symbioses, diets, identification of endangered or pest species without actually sampling them, and paleoecology, among others. The spectrum of potential applications of metabarcoding continues to widen. Current cutting-edge issues in metabarcoding include its value as a quantitative tool (with number of reads as a proxy for biomass of a given MOTU), the use of PCR-free approaches to avoid potential amplification bias, and the possibility of sequencing all genes present instead of a chosen barcode (metagenomics, so far only feasible with prokaryote communities).

We have been developing metabarcoding techniques in two different projects. In the CHALLENGEN project (MINECO) we have characterized α- and β-diversity of deep sea sediments from canyons in the NW Mediterranean. Micro- and meiofaunal organisms constitute a black box in biodiversity studies, and with the use of metabarcoding we have identified thousands of MOTUs, among which the dominant groups were Metazoa, Alveolata, Stramenopiles, and Rhizaria. We have detected strong heterogeneity at all levels studied, and have monitored seasonal differences in these communities. We have compared the information obtained with different extraction protocols, different genes, and different pipelines. Likewise, we studied the communities using DNA and RNA. While DNA persists in the sediments for some time and can correspond to organisms or remains transported in the water column, the RNA corresponds to the living organisms and represents the resident biota.

In another project (METABARPARK, OAPN) we sought to develop the technique for complex benthic communities (rocky substrates and Maërl). Metabarcoding has been traditionally used for homogeneous communities (sediments, soils, water) and its utility in more complex habitats remains unexplored. We have developed specific sampling protocols, including fractionation in size classes. While most metabarcoding studies have used the 18S rDNA gene, we have developed a pipeline for the use of COI in our samples, thus making the full BOLD database accessible for the taxonomic assignment of MOTUs. Thousands of MOTUs have been identified in four different sublittoral habitats in two National Parks (Cabrera Archipelago and Cíes Islands), and detailed community analyses have been made, including the temporal component. The possibility to assess species composition at an unprecedented level of detail is becoming a game-changer in the way we monitor biodiversity, often based on partial inventories which may not be adequate surrogates for the condition of the whole community.

Let me finish with the words of Wheeler and co-workers (Science, 2014): "Our generation is the first to fully comprehend the threat of the biodiversity crisis and the last with the opportunity to explore and document the species diversity of our planet. Time is rapidly running out". It's all in our hands!

Figure 3. Image of the diversity of crustaceans that can be found in the Maërl community.

URIZ, MARÍA JESÚS

Research Professor
1985 - Present

FROM TAXONOMY TO MOLECULAR ECOLOGY AND BIOTECHNOLOGY: THE SPONGES AS AN EXCUSE

Molecular Ecology of the Marine Benthos team

Sponges are sessile aquatic animals that remain in place for years, just filtering water. Indeed, they are not the best study pet for a biologist interested in animal behavior! This is what I thought when my PhD supervisor (M Rubió) suggested sponges as my thesis topic, after having demising my project proposal on tuna migration along the Mediterranean. "Almost every thing is known about fishes, while roughly nothing is known about sponges" he said. And he was completely right… but only for the second part of his assertion. In the seventies, no many world scientists were really working on sponges: none in Spain, one in Japan, Russia, The Nederland's, New Zealand, Australia, and the UK, and three in France, Italy, and USA. And most of them were busy at that time just with sponge taxonomy.

Thus, following Dr Rubió's advise, I conducted my thesis on taxonomy and ecology of sponges from Mediterranean fishery grounds, and I could appreciated soon that this specialization had not been a bad idea at all. Every small contribution to the field was new: discovering new species for science, finding free sponge larvae swimming at sea, associations of sponges with other animals…

Ecologists from several countries asked for my collaboration after understanding that sponges dominated many benthic assemblages. This was the beginning of a flourishing research line on sponges at the CEAB (and in Spain), concomitantly with the rise of sponge science in the world. More than 30 Spanish and European projects and a series of contracts with the PharmaMar Company have funded a large part of the CEAB research

Figure 1.1. Common Mediterranean sponge without skeleton (Oscarella) *(Foto: E.Ballesteros).*

Figure1.3. Tubular Sponge (Callyspongia) *from the Pacific (Foto: MJ Uriz).*

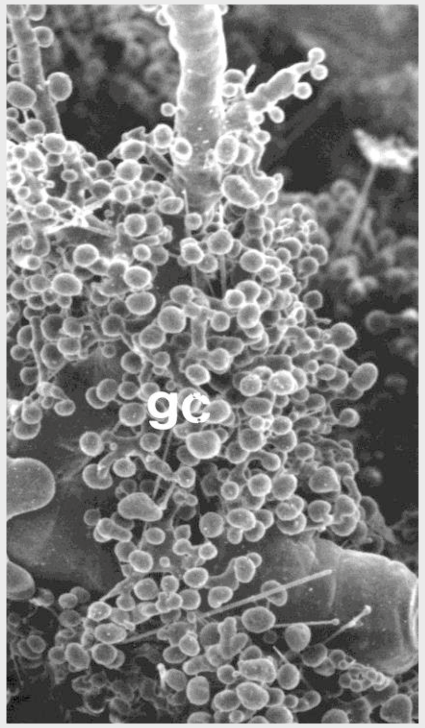


Figure 1.3. Aquiferous system of Cliona viridis*: choanocyte chambers (cc) connected through small conducts to the large exhaling conducts (arrows) (Foto: D. Rosell).*

on sponges during the last 30 years. Moreover, numerous publications in international journals, and the edition of several monographic books on sponges, have contributed to confer to the CEAB a worldwide reputation as a reference "Sponge Center".

Sponges concealed many relevant facets, the study of which have helped to resolve evolutionary, ecological, and biotechnological general issues. They are: i) The oldest extant animals on Earth -a perfect target for studying the origin of the pluri-cellularity-; ii) Key organisms in recycling dissolved organic matter

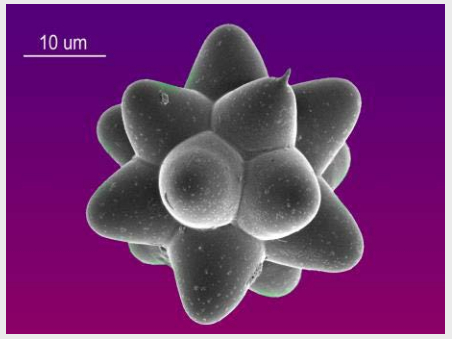


Figure 1.4. Siliceous spicule of an astrophorid sponge (SEM, Foto : MJ Uriz).

in the benthic systems through their abundant associated microbes; iii) Long-living filter feeders that accumulate contaminants from the water and result particularly suitable for assessing chronic marine pollution, and iv) The most prolific invertebrate Phylum in producing bioactive secondary metabolites with applications in pharmacology and cosmetics.

Certainly, along these years, we have described numerous new sponge species, as well as some new secondary metabolites from sponges, designed an expert system for sponge identification, and contributed to clarify the taxonomy and phylogeny of the Phylum. But more than this, we have used the sponges as a model to address general biological, ecological, environmental, and biotechnological questions. A dozen of students successfully defended their PhDs on biodiversity, pollution, chemical and general ecology, population genetics, and differential gene expression, and a few of them continued working on sponges (two at the CEAB) after obtaining a fix position.

Detailing the research conducted on sponges at the CEAB during the past 30 years would require as many pages as the more than 200 published sponge papers contain. Thus, I will take a quick look back through these years and only will mention a couple of studies that have represented breakthroughs in marine science.

We pioneered the Marine Ecology field in Europe by introducing the ecological principles and methods *(Mar Ecol Prog Ser 1991, 70)* in a discipline dominated by chemists of natural products. For the first time, the interactions among sponges and other invertebrates mediated by chemical substances were analyzed at a community level, evidencing that most benthic species allocated their available energy either to growth or to defense, according to the Optimal Defense Theory, developed for plants.

We identified for the first time the sponge cells where the bioactive metabolites accumulate, described how they are transported to the sponge periphery without causing damage to the sponge tissues and how they are released to the external medium and remain attached to the sponge surface to protect the sponge from predators *(Cell Tissue Res 1996, 285; Mar Biol 1996, 124)*. Posteriorly, we studied the biotechnological applications of sponge bioactive metabolites, focusing on overcoming the bottleneck for clinical assays of sponge-derived drugs, also known as "the supply problem". We proposed sponge embryos as a new source of material for cell culture, since embryos contain high amounts of stem cells, which are more versatile and resistant to infections under culture than adult cells *(Trends in Biotechnology 2007, 25, 10)*.

But, as it often occurs in research, some of our most impacting results rose from chance. We discovered mosaic multi-chimerism in sponges during a classical study of population genetics. We found a total of 36 genotypes in 13 sponge individuals, sampled at four points of their bodies. Interestingly, larvae produced by the colonies showed diverse genotypes so that no germ line dominance seems to occur *(Mol Biol Evol 2011, 28, 9)*. Chimeric individuals had never being found before in natural sponge populations. The hidden genetic diversity of chimeric individuals might explain why small isolated sponge populations survive for long without experiencing detrimental effects because of the genetic drift.

Chimerism is particularly important for sponges living in seasonal waters with dramatically changing conditions. One genotype could grow particularly quickly in some conditions, but lose out in others. If the going gets tough, the sponge may just expand the part that is best suited for the conditions at hand. This might contribute to explain why some encrusting sponges spend decades continuously shifting in shape and size without actually growing any bigger.

Finally, sponges are more than simple animals. They harbor from hundreds to thousands of symbiotic organisms, which

Figure 2. A one-week old explant of the sponge Corticium candelabrum *from an experimental culture to overcome the "supply problem" (see text) for pharmacological trials (Foto: S. De Caralt, MJ Uriz).*

include other invertebrates, but chiefly bacteria, archaea, and fungi *(Environmental Microbiology 2013, 15, 11; 2015, 17, 10)*. This symbiotic way of life is shared with other animals, but rarely the associated microbiome represents, such as in sponges, more than 50% of the holobiont biomass.
We are currently studying the bacterial communities of sponge assemblages from temperate and tropical seas, and their meta-transcriptomes and genomes, with the idea of finding the evolutionary causes and mechanisms that motivated these symbioses to persist since the Precambrian, and their implications in the acquisition of some characteristics of several extant invertebrates *(Evolution 2012, 66, 10)*.

The fast development of molecular tools has allowed us to address difficult questions in an affordable way by analyzing genes and controlling factors that determine their expression and function. The search of genes and metabolic pathways involved in the production of bioactive metabolites of interest for the development of new drugs against hardly curable diseases and their transfection to cultivable bacteria, are our next challenges in years to come.

Obviously, the research performed on sponges at the CEAB during the thirty last years could not have been possible without my pre-and postdoctoral students and technicians, but also without the inappreciable collaboration of colleagues who were appealed by the fascinating sponge world. Some of them merit particular mention for their prolonged partnership such as Xavier Turon, Kike Ballesteros, Daniel Martin, and Enrique Macpherson. Thanks to all of them from me and on behalf of sponges!

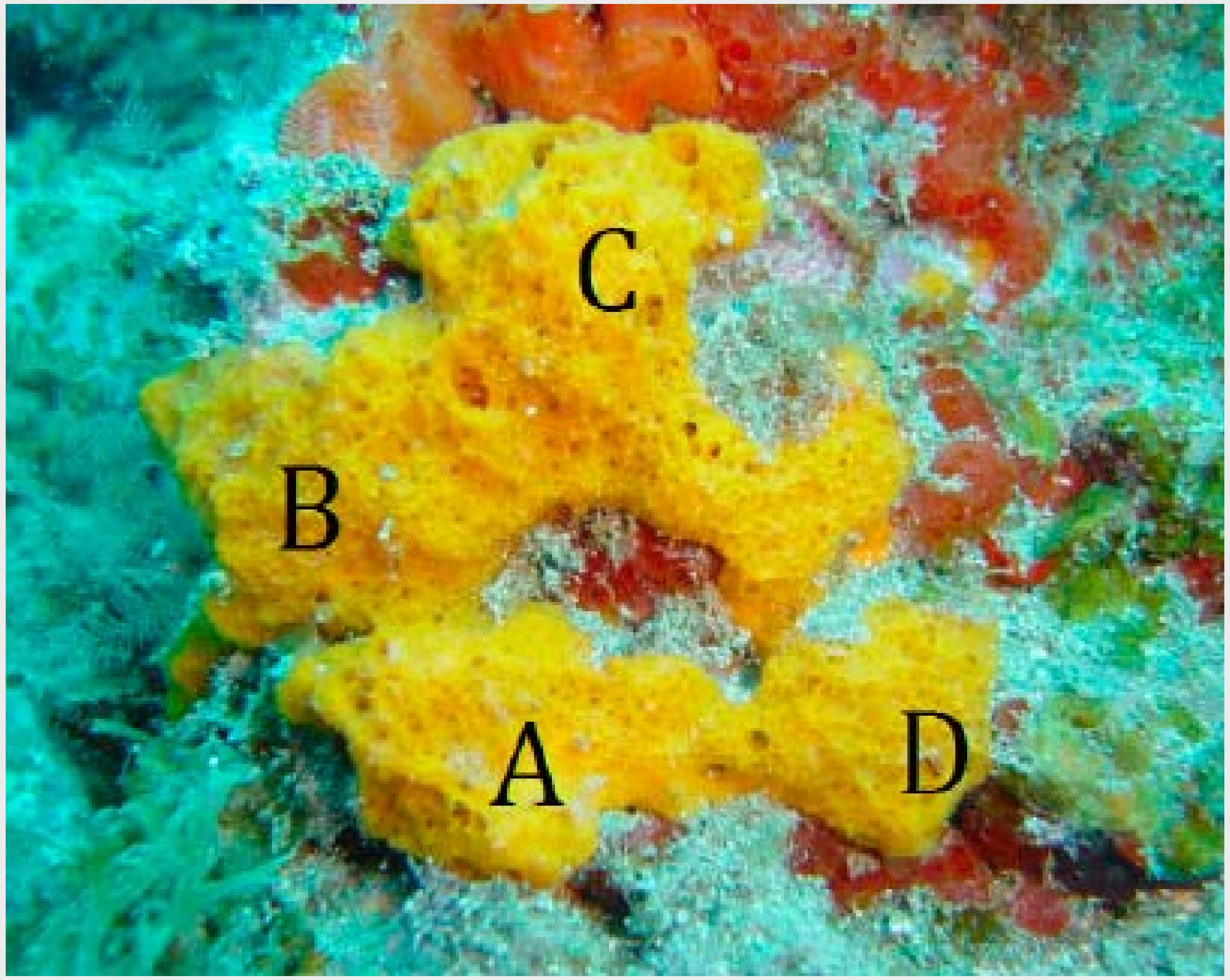


Figure 3. A chimeric individual of the sponge Scopalina. Letters indicate the presence of four genotypes.

VENTURA, MARC

Ramon y Cajal Researcher
2003 - Present

BIODIVERSITY, ECOLOGY AND CONSERVATION IN HIGH MOUNTAIN LAKES

The research we are performing aims at using high mountain lakes of the Pyrenees as a natural laboratory to study the generation of biodiversity, natural selection and how introduced species alter natural ecosystems. High mountain lakes are an excellent model for ecological studies due to their clearly defined external limits, their extreme ecological characteristics and to have a relatively low number of species. In addition, the Pyrenees are a separate biogeographic region within the European continent, and its 4500 lakes and ponds are a relatively recent (from a few to 15,000 years old). All these features give these ecosystems a special value for being used as models of ecological and contemporary evolutionary processes. The main objective of the research group is the study of local adaptations, eco-evolutionary interactions and their relationship with biodiversity using as ecosystems high mountain lakes in the Pyrenees. In particular we have two different lines of study:

1. Introduced species and biodiversity.
A line of research that has as main objective the description of the process of species invasions in high mountain lakes of the Pyrenees, and the study of the effects of these introductions and their ecological implications for the conservation of lake ecosystems. So far we have focused on the description of the effects of these invasions (conservation biology and ecology), but we have also started to study this phenomenon as a potential generator of local adaptations in species that have not been eradicated by the invaders (Evolutionary Ecology). This is possible because we were able to establish the date of introduction of fish in many lakes, and therefore we are able to study how some species' attributes are correlated with the time of invasion.

The first step in this line of study was to document the historical factors that have led to the introduction of fish in the Pyrenees (Miró and Ventura

Lake Closell, a fish removal site of LIFE LIMNOPIRINEUS in Alt Pirineu Natural Park.

2013, 2015). Secondly, we are describing the ecological consequences and the impact on biodiversity of the lakes of the introduction of these predators, focusing either on indicator groups of organisms, such as amphibians, benthic macroinvertebrates or planktonic crustaceans (Miró 2016), but also from the whole ecosystem perspective (Buchaca et al. 2016). The consequences of the introduction of fish in mountain lakes mainly derive from the fact that once introduced to the lakes they occupy the higher trophic level that previously did not exist. As a consequence, most of the most conspicuous taxa such as amphibians and some macroinvertebrates disappear from the lake, others decrease their abundance or adapt to scape predation. At present, we are coordinating a project aimed to improve the conservation of aquatic high mountain ecosystems of the Pyrenees (www.lifelimnopirineus.eu) including the restoration of some lakes to their fish free natural state, and the divulgation to schools and the general public of the biodiversity value of these ecosystems.

The feary shrimp Chirocephalus diaphanus *in a temporary pond of Aiguestortes i Estany de Sant maurici National Park.*

2. Species distributions and local adaptations, a basis to test the importance of eco-evolutionary feedbacks.

This is the research line that we have been developing for longer time and mainly uses crustacean zooplankton of high mountain lakes of the Pyrenees to study the relative importance of stochastic events with respect to the selective forces in determining the local genetic differentiation of natural populations, with the ultimate goal of finding cases of eco-evolutionary interactions. These interactions are more likely in species with shorter generations and simpler genetic composition such as crustaceans. Understanding the distribution of species and the importance of environmental factors in such distribution requires the understanding of how local factors affect population dynamics and structure of the metapopulation. The nature of island type of limnetic habitats creates opportunities for local genetic differentiation and adaptation to develop. We first studied the species ecology and changes in ecological characters, both morphological and biochemical, of some of the crustacean species (Ventura and Catalan 2005, 2008, 2010) and we are also developing new tools to study their trophic relationships (Larsen et al. 2013). At the whole biogeographic scale of the Pyrenees, we are studying the distribution of different groups of species, including amphibians, macroinvertebrates and crustaceans.

To understand the importance of local adaptation we focused first on the *cladoceran Daphnia longispina* Müller 1776, finding that its distribution is explained by a single colonization event and subsequent dispersion along the mountains (Ventura et al. 2014). We are also conducting similar studies with other species of crustaceans such as *Daphnia pulicaria* Forbes, 1893 (Dufresne et al. 2011, Vergilino et al. 2011). For some of the species we have had to solve their taxonomic status, such as for the cyclopoid copepods of the genus Cyclops (Krajicek et al. 2016) or for an *anostracean* of the genus *Phallocryptus* (Alonso and Ventura 2013).

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Sometimes the fieldwork has to be carried out in remote places and under extreme conditions, but these difficulties do not intimidate CEAB scientists.

CAPACITY BUILDING OF THE CENTRE FOR ADVANCED STUDIES OF BLANES (1990-2015)

92 DOCTORAL THESES

2015

D'Souza, Elrika (2015) Seagrass ecosystems of the Nicobar and Andaman Islands with emphasis on the *Dugong dugon* status and distribution. Madurai Kamaraj University (India). PhD Advisor: **Teresa Alcoverro**

Farina, Simone (2015) Scale-dependent factors modulate sea urchin predation in macrophyte ecosystems. Universitat de Barcelona. PhD Advisor: **Teresa Alcoverro**

Llorens, Tomás (2015) Connecting biodiversity and biogeochemical role by microbial metagenomics. Universitat de Barcelona. PhD Advisor: **Emilio O. Casamayor**

Lupon, Anna (2015) The influence of Mediterranean riparian zones on stream nitrogen dynamics. A catchment approach. Universitat de Barcelona. PhD Advisor: **Susana Bernal** **Best Spanish PhD Dissertation in Limnology Research (2014-2015)**

Merbt, Stephanie (2015) Microbial nitrification in urban streams: from single cell activity to ecosystems processes. Universitat de Barcelona. PhD Advisors: **Eugènia Martí & Emilio O. Casamayor** **EFFS Award for the best PhD Dissertation in Freshwater Sciences (2015-2016)**

Ribot, Miquel (2015) Effects of human activities on N cycling in Mediterranean streams: contrasts between nitrate and ammonium dynamics. Universitat de Barcelona. PhD Advisor: **Eugènia Martí**

Roca, Guillem (2015) Tracking environmental change in seagrass meadows: understanding indicator behaviour across space and time. Universitat de Barcelona. PhD Advisors: **Teresa Alcoverro & Javier Romero**

2014

Ahumada-Sempoa, Miguel A. (2014) The Northern Current and its interaction with the Blanes submarine canyon (NW Mediterranean Sea). Universitat Politècnica de Catalunya. PhD Advisor: **Antonio Cruzado**

Bacher, Kathrin (2014) Interactions between fish farming, wild fish populations, local fisheries and society: a case study in Catalonia, Spain. Universitat de Barcelona. PhD Advisor: **Ana Gordoa**

Peipoch, Marc (2014) The role of primary uptake compartments on stream N cycling, insights from 15N signatures. Universitat de Barcelona. PhD Advisors: **Eugènia Martí & Esperança Gacia**

Rivera Roldon, Carlos (2014) Diatom-based reconstruction of Late Glacial and Early Holocene environment in the Pyrenees. Universitat de Barcelona. PhD Advisor: **Jordi Catalan**

2013

Caraballo, Tatiana (2013) The ecology of colonial phytoplankton. Universitat de Barcelona. PhD Advisor: **Jordi Catalan**

Cardoso, G. (2013) Development of a model for the study of the dispersion of pollutants from a shrimp farm in the Estero de Urías lagoon complex: an urbanized coastal lagoon (Mexico). Universitat Politècnica de Catalunya. PhD Advisors: **Antonio Cruzado & Joan A. Sánchez**

De Mendoza, Guillermo (2013) Lake macroinvertebrates and the altitudinal gradient in the Pyrenees. Universitat de Barcelona. PhD Advisor: **Jordi Catalán**

Fernández-Guerra, Antoni (2013) Ecology and evolution of microbial nitrifiers. Universitat de Barcelona. PhD Advisor: **Emilio O. Casamayor**

Gera, Alessandro (2013) Landscape fragmentation and resilience in seagrass meadows. Universitat de Barcelona. PhD Advisor: **Teresa Alcoverro**

Ordoñez, Victor (2013) Ecology and genetics of invasive ascidians in the western Mediterranean. Universitat de Barcelona. PhD Advisor: **Xavier Turon**

Pagés, Jordi (2013) The role of herbivores as trophic connectors between marine ecosystems. Universitat de Barcelona. PhD Advisor: **Teresa Alcoverro**

Pérez-Porro, Alicia R. (2013) Differential gene expression along the sponge life cycle. Universitat de Barcelona. PhD Advisors: **Iosune Úriz & Gonzalo Giribet de Sebastán**

Sacristán, Oriol (2013) Chemical and microbial ecology of the demosponge *Aplysina aerophoba*. Universitat de Barcelona. PhD Advisor: **Mikel Becerro**

Schunter, Celia (2013) Challenges in marine ecology: genomic investigations of dispersal patterns and phenotypic plasticity in Mediterranean Fishes. Universitat de Barcelona. PhD Advisor: **Enrique Macpherson**

Wangensteen, Owen (2013) Biology and phylogeography of the black sea urchin *Arbacia lixula* (Echinoidea: Arbacioida). Universitat de Barcelona. PhD Advisor: **Xavier Turon**

2012

Ballen, Miguel Angel (2012) Study of the phagotrophic activity of phytoplankton by cellular analysis techniques. Universitat de Barcelona. PhD Advisors: **Jordi Catalan & Marisol Felip**

Barberán, Albert (2012) Microbial macroecology: understanding microbial community patterns using phylogenetic and multivariate statistical tools. Universitat de Barcelona. PhD Advisor: **Emilio O. Casamayor.** **UB Doctorate Extraordinary Award**

García Merchán, Victor H. (2012) Population genetic structure and oceanographic discontinuities in decapod crustaceans. Universitat de Barcelona. PhD Advisor: **Enrique Macpherson**

Lozoya, Juan Pablo (2012) Multi-risk assessment and users's perception: a further step towards Ecosystem-Based Beach Managament. Universitat de Barcelona. PhD Advisor: **Rafael Sardá**

Núñez, Laura (2012) Chemical ecology in the Antarctic marine benthos: natural products and chemical defense in hexactinelid sponges, soft corals and colonial ascidians. Universitat de Barcelona. PhD Advisor: **Manuel Maldonado**

Pineda, Mª Carmen (2012) A global wanderer: biology, phylogeography and resilience of the introduced ascidian *Styela plicata*. Universitat de Barcelona. PhD Advisors: **Xavier Turon & Susana López** **UB Doctorate Extraordinary Award**

Serrano, Letzi (2012) Distribution of soft-bottom Polychaete assembalges at different scales in shallow waters of the Northern

2011

Bacardi, Montserrat (2011) Trace element biogeochemistry in high mountain lake catchments: identifying anthropogenic versus natural components from the atmospheric contamination legacy in remote natural areas. Universitat de Girona. PhD Advisor: **Luis Camarero**

Chappuis, Eglantine (2011) The aquatic macrophytes of lakes, ponds and lagoons of Catalonia. Universitat de Barcelona. PhD Advisors: **Esperança Gacia & Enrique Ballesteros**

Gil, Joao (2011) The european fauna of Annelida Polychaeta. Universidade de Lisboa (Portugal). PhD Advisor: **Rafael Sardá**

Serrano, Oscar (2011) Insights in the mat of Posidonia oceanica: biogeochemical sink and paleoecological record. Universitat de Barcelona. PhD Advisor: **Miguel Ángel Mateo**

Soto, David Xavier (2011) Combining trace metal bioaccumulation and stable isotopes to reveal food web structure in freshwater ecosystems. Universitat de Barcelona. PhD Advisors: **Esperança Gacia & Jordi Catalán** **Best PhD Thesis for the Iberian Association of Limnology (biennium 2010-2012) and Finalist of the Best PhD Thesis for The European Federation for Freshwater Sciences (EFFS) Award (biennium 2011-2013)**

2010

Argerich, Alba (2010) Hydrological and geomorphological controls on stream nutrient retention. Universitat de Barcelona. PhD Advisors: **Eugènia Martí & Francesc Sabater**

Bernardello, Raffaele (2010) A 3D high resolution coupled hydrodynamic biogeochemical model for the Western Mediterranean Sea. Interannual variability of primary and export production. Universitat Politècnica de Catalunya. PhD Advisor: **Antonio Cruzado**

Bucci, Arianna (2010) Coastal microphytoplankton and microphytobenthos. Diversity, ecology and implications in silicon biogeochemical cycle. Universitat de Barcelona. PhD Advisors: **Manuel Maldonado & Zolia Velásquez**

Cabezas, Patricia (2010) Systematics and evolutionary history of the family Galatheidae (Crustacea: *Anomura*) in the South Pacific. Universidad Autónoma de Madrid. PhD Advisor: **Enrique Macpherson**

Llirós Dupré, Marc (2010) Diversity, dynamics and activity of mesophilic Archaea in stratified freshwater lakes. Implications in biogeochemical cycles. Universitat de Girona. PhD Advisors: **Emilio O. Casamayor & Carlos Borrego**

Noyer, Charlotte (2010) Relationship between genetic, bacterial, and chemical diversity of the Mediterranean sponge *Spongia agaric*. Universitat de Barcelona. PhD Advisor: **Mikel Becerro**

Salles, Marta (2010) Cystoseira-dominated assemblages from sheltered areas in the Mediterranean Sea; diversity, distribution and effects of pollution. Universitat de Girona. PhD Advisor: **Enrique Ballesteros**

Sánchez-Cámara, Jaime (2010) "Biology and Ecology of the weedy sea dragon *Phyllopteryx taeniolatus* (Pisces: Syngnathidae) and its implication in conservation management. Universitat de Barcelona. PhD Advisors: **Xavier Turon & David J. Booth**

Vassal'lo Saco, Jara (2010) Communities of benthic cyanobacteria, production and release of microcystins in the Muga River (NE Iberian Peninsula). Universitat de Girona. PhD Advisor: **María Ángeles Puig**

Villamor, Adriana (2010) Biology and Ecology of Mediterranean rocky bottoms asteroids. Universitat de Barcelona. PhD Advisor: **Mikel Becerro**

2009

Bartrons, Mireia (2009) Food web bioaccumulation of halogenated compounds in high mountain lake food webs. Universitat de Barcelona. PhD Advisors: **Jordi Catalan & Joan Grimalt**

Calderón, Isabel (2009) Spatio-temporal genetic structure and reproductive barriers in the genus *Paracentrotus* (Echinodermata: Echinoidea). Universitat de Barcelona. PhD Advisors: **Xavier Turon & Cruz Palacín**

García López, Juan Antonio (2009) Genomic patterns and phenotypic plasticity in prokaryotes analyzed within an ecological framework. Universitat Autònoma de Barcelona. PhD Advisor: **Emilio O. Casamayor**

Hervàs, Anna (2009) Bacterial dispersal on airborne Saharan particles. Survival and colonization in Alpine lakes of the limnological observatory of the Pyrenees. Universitat Autònoma de Barcelona. PhD Advisor: **Emilio O. Casamayor**

Latting, Patricia (2009) Review of species of the genus *Haplosyllis* (Annelida, Polychaeta, Syllidade): A morphological, morphometric, phylogenetic and ecological approach. Universitat Autónoma de Madrid. PhD Advisors: **Daniel Martin & Guillermo San Martín**

2008

Benito, Gervasio (2008) The role of benthic macroinvertebrates as a bioindicators in the control network of the ecologic quality of basins of Catalonia. Influence of water regime on the structure of the population. Universitat de Barcelona. PhD Advisor: **María Ángeles Puig & Miquel Selgot**

Martínez, Begoña (2008) Assessing the status of coastal waters: monitoring tools based on the ecosystems of Posidonia oceanic. Universitat de Barcelona. PhD Advisor: **Teresa Alcoverro**

2007

Ariza, Eduardo (2007) A set of indicators as a tool for beach management. Universitat Politècnica de Catalunya. PhD Advisor: **Rafael Sardá**

Blanquer, Andrea (2007) Molecular markers for phylogenetic and population studies of the genus *Scopalina* (Porifera: Demospongiae. Universitat de Barcelona. PhD Advisor: **María Jesús Úriz**

Brenner-Guillermo, Jorge (2007) Valuation of Ecosystem Services in the Catalan Coastal Zone. Universitat Politècnica de Catalunya. PhD Advisors: **Rafael Sardá & José Antonio Jiménez**

Cebrian, Emma (2007) Sublethal effects of metal contamination on marine sponges: responses at different biological levels. Universitat de Barcelona. PhD Advisor: **María Jesús Úriz**

De Caralt, Sonia (2007) Sponge culture: learning from biology and ecology. Wageningen University (Holland). PhD Advisor: **María Jesús Úriz**

Prado, Patricia (2007) Study of herbivores and their effects on the ecosystems of Posidonia oceánica. Universitat de Barcelona. PhD Advisors: **Teresa Alcoverro & Javier Romero**

Riesgo, Ana (2007) Gametogenesis, fertilization and embryonic development of coastal marine sponges: Ecological and evolutionary implications. Universitat de Barcelona. PhD Advisors: **Manuel Maldonado & Mercè Durfort**

Vergés, Adriana (2007) Defence strategies of marine macrophyte. Universitat de Barcelona. PhD Advisors: **Teresa Alcoverro & Javier Romero**

2006

Carreras, Josep (2006) Phylogeny, phylogeography and population structure in litoral fishes with different dispersal capabilities. Universitat de Barcelona. PhD Advisors: **Enrique Macpherson & Marta Pascual**

Linares, Cristina (2006) Population ecology and conservation of a long-lived species: the red gorgonian *Paramuricea clavata*. Universitat de Barcelona. PhD Advisors: **Rafael Coma & Joaquim Garrabou**

Meserburger, Gora (2006) Nutrient dynamics and metabolism in Mediterranean streams affected by nutrient inputs from human activities. Universitat de Barcelona. PhD Advisors: **Eugènia Martí & Francesc Sabater**

2005

Bartumeus, Frederic Lévy processes in animal movement and dispersal. Universitat de Barcelona. PhD Advisors: **Jordi Catalán & Ricard V. Solé** **UB Doctorate Extraordinary Award and Finalist of the UB Doctor's Cloister Award**

Buchaca, Teresa (2005) Pigments indicators: study of lakes in the Pyrenees signal and its application in Paleolimnology. Universitat de Barcelona. PhD Advisor: **Jordi Catalán** **Ramon Margalef of Ecology Award by the Institute of Catalan Studies**

Ortiz, Jesús (2005) Response of stream benthic communities to changes in discharge and nutrient availability. Universitat de Girona. PhD Advisors: **María Ángeles Puig & Manel Poch**

Pljuscheva, María V. (2005) The population structure and seasonal dynamics of *Lepidonotus squamatus* (Polychaeta, Polynoidae) in the White Sea. Institute of Animal Ecology (Moscow, Russia). PhD Advisors: **Daniel Martín & A.N. Severzov**

Tridu, Carlo (2005) Implications of Aquaculture Development in the Littoral Zone of the Western Mediterranean. Universitat de Barcelona. PhD Advisor: **Rafael Sardá**

Ventura, Marc (2005) Crustacean zooplankton dynamics in Lake Redon: A stoichiometric, biochemical and isotopic approach. Universitat de Barcelona. PhD Advisor: **Jordi Catalán**

2004

Mora Crespo, Joan (2004) Design of an environmental information system for use in integrated coastal zone management: application to the Costa Brava. Universitat de Girona. PhD Advisor: **Rafael Sardá**

Raventós, Nuria (2004) Reproduction patterns and early life stages ecology of the nesting fish *Symphodus roissali* (Risso). Universitat de Barcelona. PhD Advisor: **Enrique Macpherson**

2003

Grimaldo, N.S. (2003) Evolution of phytoplankton through river, coastal and pelagic systems in front of the Ebro River Delta, Mediterranean Sea NW. Universitat Politècnica de Catalunya. PhD Advisor: **Antonio Cruzado**

2002

Bahamon, Nixon (2002) Dynamics of Oligotrophic Pelagic Environments: NW Mediterranean Sea and Subtropical North Atlantic. Universitat Politècnica de Catalunya. PhD Advisor: **Antonio Cruzado**

Mariani, Simone (2002) Structure and chemical ecology of sponge larvae and newly recruits. Universitat de Barcelona. PhD Advisors: **María Jesús Úriz & Xavier Turon**

Martí Lluch, Ruth (2002) Spatial and temporal variation of the natural toxicity in benthic communities of Mediterranean caves. Universitat de Barcelona. PhD Advisors: **María Jesús Úriz & Xavier Turon** **UB Doctorate Extraordinary Award**

Vega, Cristina (2002) Chemical ecology and biological cycle of *Zigomycale parishi* (Porifera: Demospongiae). Universidad Nacional Autónoma de México (Mexico). PhD Advisors: **María Jesús Úriz & J.L. Carballo**

1999

Zika, Ulrike (1999) Factors affecting settlement and post- settlement processes in littoral marine fishes, focusing on *Aidablennius sphinx*. Swiss Federal Intitute of Technology Zurich (Switzerland). PhD Advisor: **Enrique Macpherson**

1998

Pinedo, Susana (1998) Structure and dynamics of Western Mediterranean soft-bottom communities along a disturbance gradient. Natural and man-induced viariability in the bay of Blanes. Universitat de Barcelona. PhD Advisors: **Rafael Sardá & Xavier Turon**

1997

Velasquez, Z. (1997) Phytoplankton in the North West Mediterranean. Universitat Politècnica de Catalunya. PhD Advisor: **Antonio Cruzado**

1996

Cardell, María José (1996) Structure and dynamics of the benthic macrofauna in marine sediments submitted to domestic and industrial discharges: effect of the waters and residual sludge of the treatment plant of Sant Adrià del Besòs (Barcelonès). Universitat de Barcelona. PhD Advisor: **Rafael Sardá**

Muniz Pereira da Costa, K. (1996) Distribution of nutrients in the western Mediterranean (Gulf of León and Catalan Sea). Influence of physical factors. Universitat Politècnica de Catalunya. PhD Advisor: **Antonio Cruzado**

Rosell, Dolors (1996) Systematics, biology and ecology of the Mediterranean excavating sponges. Universitat de Barcelona. PhD Advisor: **María Jesús Úriz** **UB Doctorate Extraordinary Award**

1995

Domingo Gou, Marta (1995) An expert system architecture for taxonomic domains. An application in Porifera: the development of spongia. Universitat de Barcelona. PhD Advisors: **María Jesús Úriz & C. Sierra**

1994

Becerro, Mikel (1994) Chemically mediated bioactivity of the encrusting sponge *Crambe crambe:* ecological implications. Universitat de Barcelona. PhD Advisors: **Maria Jesus Úriz & Xavier Turon**

1993

Alarcón, M. (1993) Simulation of long-range atmospheric transport on the northwestern Mediterranean: models of diffusion processes and career-deposition. Universitat de Barcleona. PhD Advisor: **Antonio Cruzado**

Maldonado, Manuel (1993) The coastal sponges of Alboran: systematics and biogeography. Universitat de Barcelona. PhD Advisor: **María Jesús Úriz**

1991

Martin, Daniel (1991) Macroinfauna of a Mediterranean Bay: Study of the levels of organization of the populations of Annelida Poliquetos. Universitat de Barcelona. PhD Advisor: **Rafael Sardá**

Varela, R.E. (1991) The deepest chlorophyll: Simulation of physical and biological processes. Universitat Politècnica de Catalunya. PhD Advisor: **Antonio Cruzado**

1990

Bibiloni, María Antonia (1990) Fauna of Baleares sponges: Qualitative and quantitative variations of the sponge population in a bathymetric gradient. Universitat de Barcelona. PhD Advisor: **María Jesús Úriz**

A CEAB scientists collecting samples and field data in a costal zone by direct sampling and in situ census.

30

YEARS

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