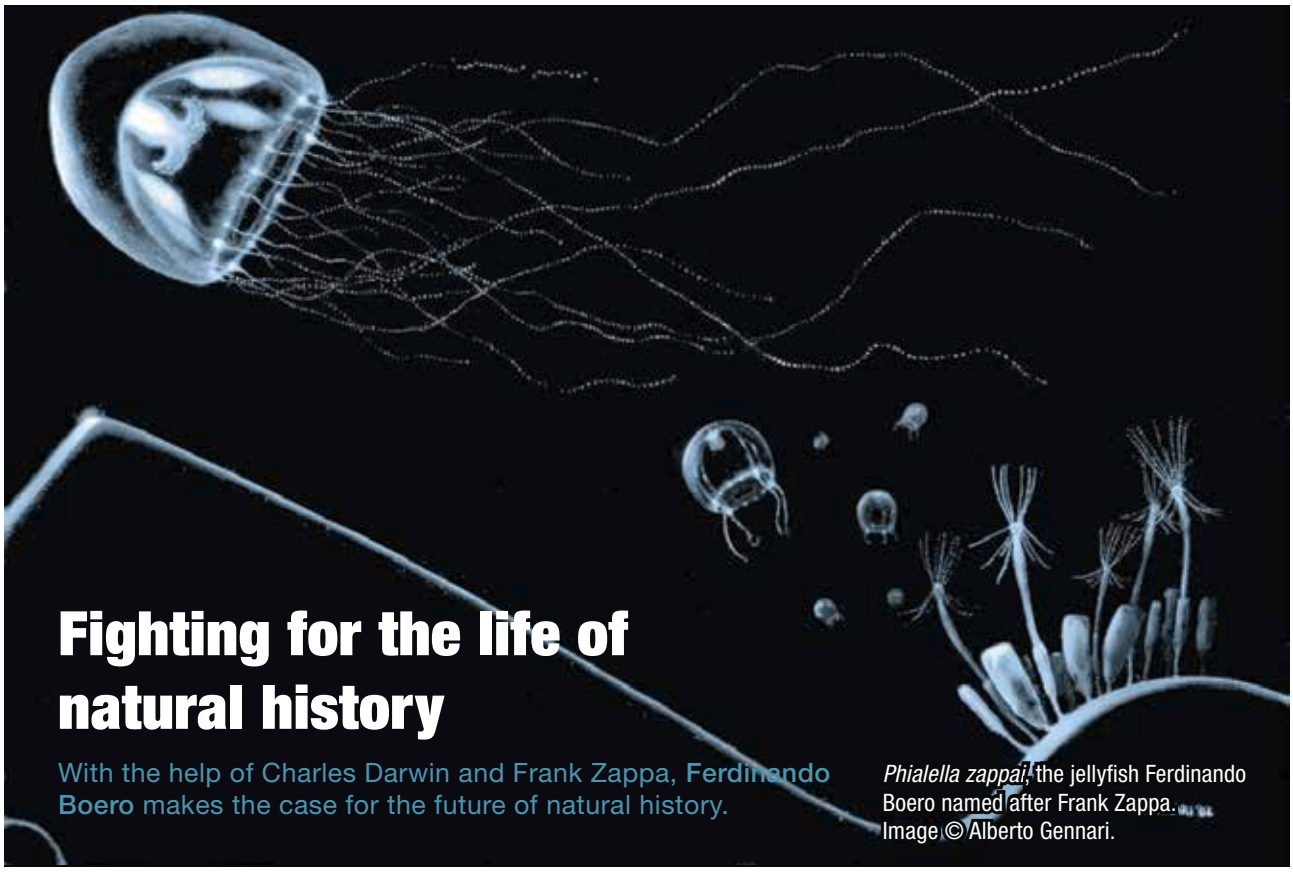


Fighting for the life of natural history

With the help of Charles Darwin and Frank Zappa, **Ferdinando Boero** makes the case for the future of natural history.

Phialella zappai, the jellyfish Ferdinando Boero named after Frank Zappa. Image © Alberto Gennari.

In 1978, Rupert Riedl, a prominent marine biologist, told me this story: 'In the Fifties I visited the Zoological Station of Naples, proposing to study marine biology by scuba diving. Peter Dohrn, the head of the Stazione, told me that they needed scientists, and not sportsmen. So I dove in submerged marine caves, collected specimens, took pictures, measured physical variables *in situ*. The main thing I did, though, was … looking. You can understand a lot by looking at things! The results of the "expedition" were so outstanding that the Station published them in a volume of their journal.'

Since then, marine biologists have been seen as tanned persons who dive in wonderful parts of planet ocean, taking samples that are brought to a laboratory for further analysis.

Hard-core marine biologists jump into the ocean and look around. They do not look for the usual stuff, though. I, for one, dove in shark-infested waters from Papua New Guinea to California, but I seldom looked at the sharks: I was interested in hydroids. My eyes were tuned to hydroids and I could stay underwater for hours inspecting every substrate, looking for them. Then I brought them to the laboratory and reared them in jars, let them liberate their tiny jellyfish and nursed them until they became mature, reconstructing the life cycle of these minute creatures.

Description

The first concern of naturalists, then, is to document what they see, and they are excited when they find things that are still unknown to science. When I started to study hydrozoans, there were two classifications for these animals: one for the polyps and one for the medusae. So, my job was to link the two stages, and reconstruct their life cycle. I named my first new species after the modern music composer Frank Zappa: *Phialella zappai* Boero, 1987. Frank, in exchange, wrote a song on the jellyfish and myself: 'Lonesome Cowboy Nando'.

Conceptual continuity

Zappa's musical opus explores many directions, but all his music is linked by a thread that he called 'conceptual continuity' and plays a single 'big note'. The same applies to natural history. Think about the work of the greatest naturalist of all time: Charles Darwin. Charles (let's call him that, he is one of us) was a taxonomist who authored a monograph on barnacles. Then he founded evolutionary biology and ecology with his book *On the Origin of Species*. Later, he founded anthropology with *The Descent of Man*, where he introduced sexual selection. He also founded psychology by writing on the expression of emotions in humans and other animals, and soil biology, digging deep into the life of earthworms. He tackled the fertilization of orchids, vegetable moulds, cross- and self-fertilization in the vegetable kingdom, climbing plants, the geology of South America, and the origin of atolls. A naturalist works on all aspects of nature, especially in its living expressions.

Experiments and models

Description is not enough, though, and Darwin also carried out experiments. For instance, he dug and cleared plots in which he planted single species, or a variety of species, to discover that the higher the biodiversity, the greater the yield of the plot. The words biodiversity and ecosystem function had not been coined yet, but Charlie had already carried out experiments showing that the two are inextricably linked. He also kept the seeds of several plants in seawater, to see how long they resisted while still being able to germinate. Then he used knowledge of marine currents to calculate the paths seeds could travel to reach distant islands, producing models of dispersal!

Mere theoretical calculations

However, Charles trusted experience more than theoretical models and, in the *Origin*, he wrote: 'I have taken some pains to estimate the probable minimum rate of [the elephant's] natural increase … But we have better evidence on this subject than mere theoretical calculations, namely, the numerous recorded cases of the astonishingly rapid increase of various animals in a state of nature, when circumstances have been favourable to them for two or three following seasons'. He made calculations, but they cannot replace the real job of naturalists: observation.

Ferdinando Boero (right) in 1984, with (seated), one of the giants of marine biology Sir Frederick Russell, former Director of the MBA, the discoverer of vertical migrations of plankton, and author of *The Medusae of the British Isles*. Standing is hydrozoan specialist Paul Cornelius. Image © Ferdinando Boero.

Collecting evidence

Hence, Darwin acquired evidence by looking, collecting and analysing samples, and making experiments and simulations. Then he joined the dots that linked all the pieces of evidence and built the greatest theory of them all. This is what naturalists should do, and there is a lot to discover yet. Unfortunately, naturalists have fun in collecting and observing, and this is their weakness, because they are often happy just to look at nature, and do not organize their data so as to give them a meaning that applies to a significant portion of the natural world. As Elton put it, in *Animal Ecology*, natural history lost its reputation at the beginning of the last century when it mutated into ecology, a discipline that he labelled as 'scientific natural history', implying that naturalists are not scientists …

Nature is not black or white!

How can we tell a scientist from an amateur butterfly collector? Karl Popper asked scientists to produce predictive laws. He exemplified this approach with an ornithological 'law': all crows are black. We cannot check all crows, so we can only provisionally accept the law as true. However, if a white crow is found, the law is proven false and is to be rejected. And what if we find an albino crow? Popper does not like ad hoc explanations, but the existence of albino crows disallows a universal law on the colour of crows. Evidently, nature is more than black and white. The universal statement becomes a series of existential statements: the majority of existing crows are black, but there also exist white crows. And we can find percentages that weight the frequency of one characteristic against another. Naturalists produce existential statements because their science is too complex to be described and predicted with universal statements. When the punctuated equilibria were proposed, for instance, they falsified the universality of gradual evolution, not its existence! Both saltational and gradual evolution exist.

Predicting history

Those who practise natural history are natural historians. Are historians (those who study the Roman Empire and the wars that punctuate our history) asked to perform predictions about the future? Is it legitimate to ask them to produce equations and models that, once the values of some relevant variables are considered and run through some computer program, will predict what will happen? Economists do that, and they invariably fail. Contingencies are the drivers of history: a virus, subprime lending, the twin towers, the fall of the USSR, the election of one president instead of another, can change the course of history and the outcomes of economic systems. These things are inherently unpredictable. Historians do not produce predictions, but they do produce wisdom.

The laws of nature

Darwin detected two important laws of nature. One says that all species tend to increase in numbers by reproduction. The other one says that even if all species tend to increase in numbers, not all can do so, because there is not enough space for them all on this planet. The law of the limit buffers the law of growth. This wisdom, stemming from natural history, should be heeded by those who just want growth: infinite growth is impossible!

How many species?

Lord Bob May[5] was a physicist. He introduced chaos theory in ecology with a famous paper on 'Simple mathematical models with very complex dynamics', but then he saw the light and asked: 'How many species are there on Earth?' He was surprised to realize that we do not know. We can perform mere theoretical calculations about the number he asked for, but the

5 Robert McCredie May, Baron May of Oxford, OM, AC, FRS, FAA, FTSE, FRSN, HonFAIB

mission is to actually know them all. We invest more money to take pictures of distant galaxies than we do to explore the biodiversity that sustains us.

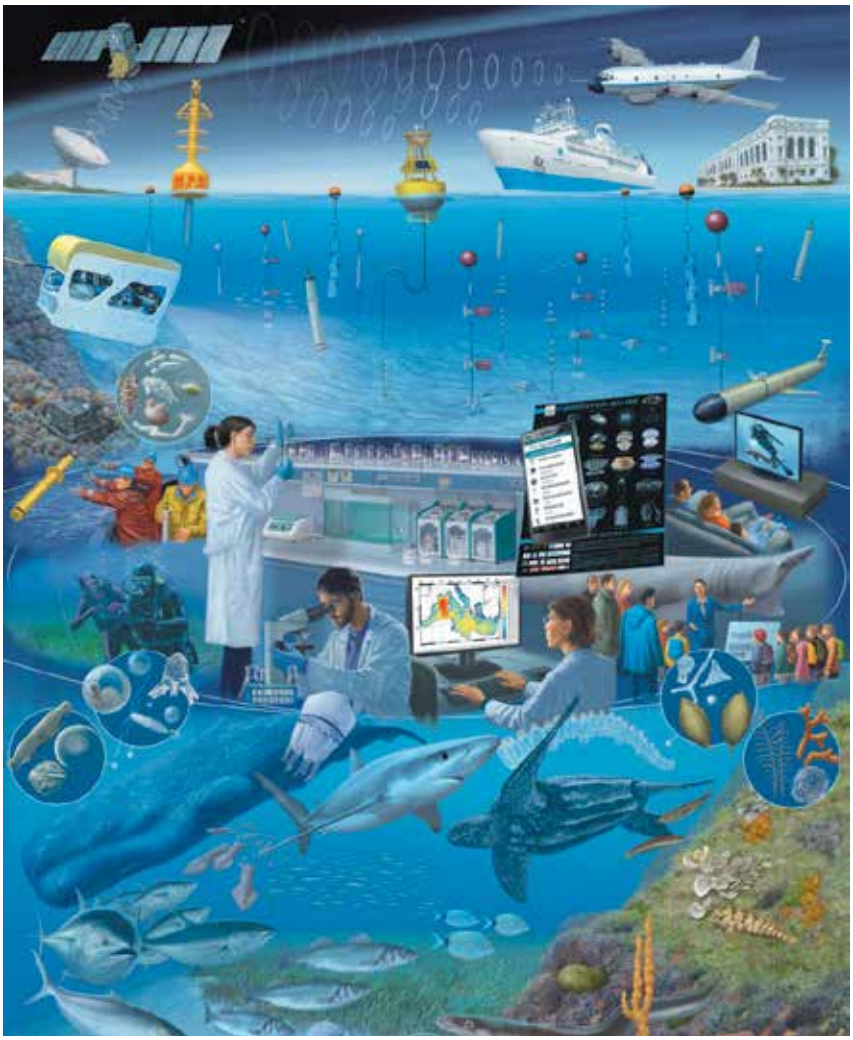
What are marine stations for?

Marine stations should be the bases from where naturalists explore marine biodiversity, making inventories of species, like those assembled at the European marine stations at Naples, Roscoff, and Plymouth, where every species was framed in its habitat(s), and its main traits were described. Some of these exercises date back to a century ago, and have not been repeated since: the expertise to perform this kind of work is almost gone. One might argue that these are old and obsolete approaches, and now we do better. The first descriptor of Good Environmental Status in the Marine Strategy Framework Directive (MSFD), however, prescribes that 'Biodiversity is maintained' in all EU waters. What is the state of biodiversity that we want? These marine stations produced the benchmark knowledge for present and future research. At most marine stations, however, the question: 'Do you have an updated all-species inventory for your surroundings, from bacteria to cetaceans?' usually produces a negative answer. Usually the lists are old. The available monographs are obsolete, written by the naturalists of the past. And if you ask: 'Ahem, the United Nations says that one million species are going to become extinct in the coming decades. What are the species that you do not find any more in the vicinity of your station? Can you provide a reliable list of putatively extinct species?' Again, in many cases the answer is vague.

Incomprehensible mismatches

The United Nations and the European Union, among others, highlight biodiversity, and express concern about species. It is not sufficient to know that species are there—as might be shown by metagenomics—we must also know how they make ecosystems function. The exploration of the links between biodiversity and ecosystem function is what modern natural history is all about: it requires scientists to go into the environment and look carefully, and take samples, and bring them back to the laboratory. To analyse them, to build models of the real world, so as to understand how to deal with it without compromising our chances for survival.

Decision-makers agree that this research is vital. Why, then, is it not supported as it deserves? The reason is that mainstream science is reductionist, whereas natural history is holistic, and many scientists do not like it because it requires skills that they consider obsolete. Natural history can provide answers to pressing and important questions, but it must fight for its life because it still has a bad reputation in the scientific community. Naturalists must not conform to mainstream science by performing reductionist natural history (an oxymoron). They can propose efficient ways to assess the state of biodiversity and ecosystems. The first Descriptor of Good Environmental Status in the MSFD prescribes that 'biodiversity is maintained'. Who but a natural historian can check that?



Observing the sea. Observation systems currently cover mainly physics, chemistry and biogeochemistry, providing a simplified vision of the marine environment. Observation systems must be upgraded so as to cover also biodiversity and ecosystem functioning. This will require a vast array of professionals, and naturalists will have a prominent role. Image © Alberto Gennari.

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