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Food for Thought

Obstinate nature

Philippe Cury*

IRD (Institut de Recherche pour le Développement) MARBEC, UMR 248, Avenue des Arts 8, 1210 Ville de Bruxelles, Belgium

Corresponding author: tel: 33 (0) 6 75 65 46 34; e-mail: philippe.cury@ird.fr.

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Resolving ecological patterns is challenging but fascinating as it generates new ways of looking at nature. I recapitulate here four independent scientific ideas that I developed throughout my career and that have contributed to a better understanding of the functioning of marine ecosystems. The optimal environmental window relating wind intensity and fish recruitment, the extended homing strategy developing an ecology of individuals, the wasp-waist control of marine ecosystems, and the bird-forage fish interaction are the four patterns that are presented. Communicating results to a large audience is not simply an added value of a scientific career but a responsibility for scientists when considering global emerging challenges. I encourage young scientists to communicate in an open and organized manner, as it will contribute to changing stakeholder's views and fisheries management. Love of science and ground-breaking ideas are key to scientific careers and creativity can be sustained in many ways throughout a scientist's career. I provide several tricks inspired by my personal experience that can help young scientists to stay innovative in the long run. Finally, I combine ecology and music, my two favourite topics, illustrating that an obstinate nature and an unexpected combination of unrelated ideas are key when dealing with research.

Keywords: early career scientists, ecosystem approach, marine ecology, patterns, research strategy.

Fish and music

During my childhood, I would spend most of my time either rearing fish in tanks—my parents were very patient as I had up to 20 tanks full of fish in the garage!—and playing classical music on my piano. (I learnt piano at 9 years old and discovered Ludwig van Beethoven—may be the most fabulous genius of all times—when I was 12 years old. It was a shock (and still is) to read his music—with always many difficulties, as many pieces of his work are impossible to play as an amateur. Fascinated by pianos, I developed the cumbersome habit of collecting them.) I always wanted to study fish as I found them fascinating, beautiful, diverse, and mysterious—they do not talk. In 1979, while studying to be an engineer in agronomy with a specialty in fisheries science, I decided to get an additional statistical and modelling background by doing a Masters and a Ph.D. in biomathematics in Paris as I realized that ecology was becoming more and more quantitative in the 1980s. In 1983, I was employed by the French Research Institute IRD—Institut Français de Recherche pour le Développement—working in the tropics. I must say that I was lucky as I had the chance to pursue my passion all my life: thanks to IRD which gave me the opportunity to study fisheries in several countries (Senegal, South Africa, Côte d'Ivoire, and Ghana) as this is one of the very few Institutes that sends its scientists to Africa, Asia, or Latin America for long periods of time to collaborate with local researchers. At a later stage, I also had the opportunity to combine my two passions, ecology and music, and I will explain here how this was possible.

Ernst Mayr, who had a long—one century—and a fruitful life, told scientists about the fact that a life dedicated to science is not linear, and that scientific activities change with time and age.

Food for Thought articles are essays in which the author provides their perspective on a research area, topic, or issue. They are intended to provide contributors with a forum through which to air their own views and experiences, with few of the constraints that govern standard research articles. This Food for Thought article is one in a series solicited from leading figures in the fisheries and aquatic sciences community. The objective is to offer lessons and insights from their careers in an accessible and pedagogical form from which the community, and particularly early career scientists, will benefit.

From his farm in Wilton, New Hampshire, Ernst hand wrote a letter to the famous geneticist W. Provine:

> In your work. . ..please always remember that a scientist's achievement may lie in many different areas: as an innovator (new discoveries, new theories, new concepts), as a synthesiser (bringing together scattered information, sharing relationships and interactions, particularly between different disciplines, like genetics and taxonomy), as a disseminator (presenting specialized information and theory in such a way that it becomes accessible to nonspecialists [popularizer is a misleading term]), as a compiler or cataloguer, as an analyst (dissecting complex issues, clarifying matters by suggesting new terminologies, etc.), and in other ways. (Provine, 2005).

A scientific career is not uniform. I developed several of these paths proposed by Mayr in my scientific career by trying to be an innovator, a synthesizer, and a disseminator as I found that those activities are useful and have very different impacts.

Being an innovator

Scientific research is really enjoyable and delivers a lot of pleasure. I realize that it is one of the most challenging and wonderful of human activities. I actually never use the term "work" to describe my job, since research is for me a daily-life pleasure. Creativity, that is to say innovative and disruptive ideas, is at the heart of scientific research. It must not be an objective in itself—i.e. I want to be an innovator!—but the result of being fascinated and obstinate about solving ecological patterns.

One never builds a career on criticizing colleague's ideas—unfortunately many peers spend their time doing that—you have to develop your own ideas. Ideas come in many ways. An idea that has stuck with you since you were young, an idea that emerges during a discussion with colleagues, or an idea that surfaces from being under the pressure of speaking at a plenary conference.

All of the ecological patterns that I wanted to tackle throughout my career were quite straightforward as they can be formulated into simple questions: why is the recruitment of fish sometimes positively and sometimes negatively correlated with wind intensity? Why are all individuals different and what does intraspecific diversity imply for population dynamics? What is the impact of forage fish on the other components of marine ecosystems? How many forage fish should we leave in the ocean to maintain bird populations? These are all independent scientific questions that were generated out of different unplanned observations or improbable discussions with colleagues and that I detail below.

Optimal environmental window (OEW)

In 1985 I met with Dr Claude Roy, in Senegal, an oceanographer working in IRD interested in multidisciplinary approaches. We both were excited about the quantification of the relationships between climate and fisheries for pelagics following a stay at the Pacific Fisheries Environmental Group, California (PFEG) directed by Andy Bakun.

Fish recruitment is erratic from one year to another and we thought that comparing existing recruitment time series worldwide using newly developed non-linear statistical techniques would help to solve ecological patterns observed in many fisheries and particularly in Africa where we were working.

The instability of pelagic stocks has long been recognized and related to environmental fluctuations. The best evidence being that there exist outbursts or collapses of pelagic fish without any fisheries. We always look at population stability as an objective but it may actually be a natural and good thing for marine prey to experience sudden collapses and recoveries from a predator–prey perspective. My own conviction is that forage fish resources are particularly unstable, as they need to escape marine predators, in other words to disappear from an ecosystem for a certain number of years constitutes the best strategy to avoid predators (Cury, 1988). Ever since Johan Hjort (1914), the great pioneer in recruitment studies, there has been a continuing scientific debate to explain this instability and the relative importance of the density-dependent vs. density independent factors in the renewal and resilience of marine fish populations (Cury *et al.*, 2008, 2014). Some authors have insisted on trophic aspects, others on the importance of turbulence for larval survival, while others were convinced that the variability of recruitment was due to the transport of larvae out of the retention areas. Each partly has defended the validity of a particular mechanism from a chosen case study and concluded on a positive or a negative relationship between recruitment and upwelling intensity or wind stress, thereby fuelling heated controversy on a sensitive subject. The tension between two eminent scientists, David Cushing (Cushing, 1982) who developed the match/mismatch hypothesis focusing on the timing, as a function of climate, of the blooms of primary producers (i.e. phytoplankton) and Mike Sinclair (Sinclair, 1988), defender of spatial structures for the retention and survival of larvae (i.e. member-vagrant hypothesis) remains well known. Claude and I knew both of these eminent scientists and told ourselves that they cannot totally be wrong but both right! In reality, a comparative approach made it possible to reconcile those seemingly contradictory views. Having worked with Roy Mendelssohn at PFEG to develop empirical non-linear statistical approach (GAM, generalized additive models), we built a model with Claude Roy that was based on the existence of two limiting factors for recruitment, one of trophic order, the other of hydrodynamic order and that these are a function of the intensity of the wind. We developed a theoretical scheme where a dome-shaped relationship links the success of recruitment and the intensity of upwelling or wind stress. This model, which defines an optimal environmental window (OEW), was validated and calibrated in the main upwelling areas (i.e. Peru, California, Morocco, Senegal, and Côte d'Ivoire) where time series of recruitment indices and upwelling indices over several decades were available. Fish recruitment was found to be at its maximum level for a moderate value of wind intensity of 5–6 m/s (Cury and Roy, 1989; Cury *et al.*, 1995). In fact, this value, well known to physicists, is a threshold beyond which the wind begins to exert a significant effect on the mixing of the superficial layer of the oceans; and in planktonology, it is recognized as essential in defining the key factors that influence plankton dynamics.

At that time there was one computer and one printer for the whole fishery centre in Senegal. Nonetheless, we developed the paper in only two months as Claude and I were enthusiastic about this hypothesis and the results straightforward (Cury and

Roy, 1989). The OEW concept has been applied to many fish species, even tuna, and this has allowed the research community to better understand the different temporal and spatial reproductive strategies of pelagic fish species (Roy *et al.*, 1992). It also represents a simple relationship between stock recruitment and climate that is useful when developing complex ecosystem models (Cury *et al.*, 2014).

Obstinate nature and the "extended homing strategy"

To reveal ecological patterns, such as the OEW, is most often a matter of posing simple and basic questions that result from observing nature. I was fascinated when watching schools of sardines in the Monterey Bay aquarium that every single individual is different from the others. In ecology, individuals of the same species are supposed to respond in a similar way to environment factors. The fact that nature created individuals that are all different is a fascinating topic in ecology. I found that it was time to link intraspecific diversity to population dynamics and to develop thoughts to formulate an ecology of individuals. With Andy Bakun we were about to prepare an international conference in Monterey California in 1993 on upwelling systems and I had to write a paper for this occasion. I decided to start working on this idea that is still a subject of fascination and great interest 30 years later.

Reading the literature on reproductive behaviour of animals, I was intrigued by marine turtles, salmon, sharks, birds, butterflies, and many others that exhibit similar reproductive strategies where the adults return to the site of their birth (i.e. "natal homing"). Using this obstinate strategy, they reproduce at the exact same place as their parents did using fascinating imprinting mechanism memorized at an early stage in their lives. A simple and efficient reproductive strategy for animals such as turtles that survived the dinosaurs! To do what your parents did is a guarantee to avoid problems and to improve your survival. If evolution is about "what to do as you do not know the future", nature found a good recipe "doing the same" at the individual level. Keeping the imprinted environmental cues that have been acquired at an early stage and to transmit them to the next generation appear to be a safe and conservative long-term reproductive strategy.

This can be generalized to terrestrial and marine animals in general as the same strategy applies for successive generations reproducing at the same geographic location (philopatry) but also for species that are tracking moving environmental targets (i.e. "apparent" dispersal) (Cury, 1994). Using different case studies and different perspectives developed in ethology, ecology, and evolution, I proposed a generalization of the concept of "natal homing" named the "extended homing strategy" by postulating that a newborn individual imprint environmental conditions that determines the choice of its future reproductive environment (Cury, 1994). As a consequence, the adaptability of a population to its environment is ensured because of the diversity and multitude of "imprinted" individuals and not because of individual adaptability. It questions the classical postulate that an individual reproduces when environmental conditions are "favourable" to the species. All individuals have different early environmental imprints; they are not interchangeable from a demographic point of view.

Darwin recognized the importance of "natal homing", but lacking time to develop a full chapter on this topic in his seminal book on the "Origin of species", he asked G. J. Romanes to pursue this field of investigation. Romanes never properly developed the idea that was in fact revisited much later in ethology by Konrad Lorenz (Cury and Pauly, 2013, 2019). Ecology and pattern resolution have to consider individual dynamics and determism in order to really link ecology and evolution. This is a vast field of research that is still fascinating, as it will have to cross many fields of research including genetics, behaviour, ecology, and population dynamics. The "extended homing strategy" has stimulated research in population dynamics by proposing an ecology of individuals and by acknowledging that the recipe of life lies in inertia and a bit of innovation, at the individual level (i.e. the existence of strays that are never numerous within a population but sufficient to ensure adaptability). The extended homing strategy led to several theoretical or applied developments (e.g. Le Page and Cury, 1997, Mullon *et al.*, 2002). Ecology and evolution work together and the extended homing strategy constitutes one of the main powerful mechanism to create diversity, the obsession of life. Today, this line of research is strong in ecology with the development of individual-based modelling approaches that allow heterogeneity between individuals or different groups of individuals to be considered. However, many implications of the extended homing strategy have not been fully captured as it calls into question strong paradigms in ecology.

Wasp–waist ecosystems

Sometimes ideas come under strong pressures and not by just watching sardines in a tank! In 1999 Mike Sinclair asked me to co-organize with him an ICES/SCOR symposium in Montpellier on the "Ecosystem effects of fishing". I became nervous about the synthesis on pelagics I was supposed to provide. I had good scientific friends worldwide and together we discussed how to synthesize the role of pelagics in marine ecosystems. Their importance as prey for marine predators was a hot topic in California, Chile, West Africa, and South Africa. We decided to compare the role of forage fish in those ecosystems.

In upwelling systems there is often a crucial, intermediate level occupied by small pelagic fish that develop huge biomasses, which are zooplanktonophagous, and represented by only a few species that exhibit large fluctuations in abundance. Using several decades of data, colleagues and I explored patterns of interactions between fish, their prey and predators to characterize the functional role of small pelagic fish in ecosystems (Cury *et al.*, 2000). Fish abundance controls to some extent their prey (top-down control) in South Africa, Ghana, Japan, and the Black Sea. Conversely, the abundance of pelagic fish controls their predators (bottom-up control) such as seabirds and predatory fish in the Benguela, the Gulf of Guinea, and the Humboldt. Pelagic fish would, therefore, exert an essential trophic control in the dynamics of the ecosystems and constitute an intermediate level likely to regulate the functioning of the ecosystems. The term "Wasp waist", first introduced by Jake Rice (1995), was therefore used to characterize the functioning of upwelling ecosystems as forage fish play a critical role in shaping ecosystems (Cury *et al.*, 2000). The results show the importance, too often neglected, of trophic control by one or the other components of the ecosystem and not only a bottom-up control. Certain scientists initially perceived this work as too simplistic and I remember making an oral presentation of the different controls in marine ecosystems at a conference (bottom-up, top-down, and wasp-waist controls). I received strong criticism from two professors during a conference; their main complaint was that ecosystems do not "work like this". However, at the end of the presentation many participants came to me and asked for my presentation saying that this approach is useful for training students and introducing control concepts when analysing patterns in marine ecosystems. This trophic simplification has finally proved unifying in defining controls in marine ecosystems. Today many studies have focused on revealing trophic cascades in open marine environments (e.g. in the Black Sea or in the North Atlantic-West, Travis *et al*., 2014). Never give up on your ideas if you think that they are useful and correct. Lynne Shannon, a scientist working in South Africa, told me to ignore the negative comments that I received. In fact, that advice helped me a lot, as I realized that there will always be people complaining about what you are doing. Just ignore them!

One-third for the birds

In South Africa I met with two great bird specialists, Robert Crawford and Lynne Shannon, and with them I learnt a lot about the interaction between forage fish and Cape Gannets or penguins in the Benguela. Robert was upset because birds were not considered in fisheries management despite the fact that the ecosystem approach to fisheries was regarded as a priority in South Africa. From 1998 to 2004, I worked in South Africa, but it was only in 2009—while I was participating in a panel of experts funded by the Lenfest Ocean Program of the Pew Charitable Trusts—that I realized the full contribution of forage fish to marine predators (Pikitch *et al*., 2014). To strengthen the ecosystem approach for birds I came to the conclusion that only a world comparative approach would lead to recognition of the importance of forage fish for bird survival and might serve to change conservative fisheries management. A global comparative approach is always stronger than a local study. In 2010, I contacted the bird specialists and explained to them the project. In less than 12 months, 14 enthusiastic world bird and forage fish experts performed the comparative approach. Sharing precious data that had been collected during decades of field work is always a sensitive issue. When I contacted the bird experts, I made extremely clear that it was their data and that we would put together an incredible dataset to quantify a key predator–prey relationship. The objectives and the management of the work were clearly defined. We agreed that, if it worked, we would publish a paper in a high rank journal. If it did not work, I guaranteed that this dataset would not be used anymore. Trust is key to collaborative work and rules need to be fixed at the beginning of the work (not after!). I had to find a budget to support a meeting between all of the experts. I asked IRD for a budget of 20 000 euros to organize two meetings: In fact, I used my position as Director to make that happen quickly! We met two times in nice locations: in Cape Town in South Africa and Sète in France. We analysed one of the most complete datasets on predator–prey relationships in marine ecology in just about a year (Cury *et al*., 2011).

From the Arctic to the Antarctic and from the Atlantic to the Pacific, when the abundance of forage fish (anchovies, sardines, krill…) declines, the breeding success of seabirds undergoes a sharp fall. If previous work had established this link between food availability and bird reproduction rate, the international study that I coordinated and that was published in *Science*, reveals the existence of a critical threshold of fish stocks, below which the success rate of seabirds is weakened (Cury *et al*., 2011). Seven marine ecosystems, 14 bird species, and the abundance of their prey in the marine environment were assembled. This dataset of incredible quality (438 years of field observation and fisheries statistics) allowed us to determine the form of the relationship between the breeding success of seabirds and the abundance of their prey. A threshold in prey abundance below which seabirds experience consistently reduced and more variable productivity was identified (Cury *et al*., 2011). This threshold turned out to be the mean long-term abundance of forage fish. In other words, it demonstrates that marine birds require at least the mean long-term abundance of their prey to maximize their breeding success; this constitutes an evolutionarily stable strategy. The long-term abundance of forage fish also represents one-third of the maximum level of the forage fish abundance observed in the studied time series, a convenient reference point to be used as an indicator to implement the ecosystem approach to pelagic fisheries. Several countries (e.g. Australia, South Africa, New Zealand, etc.) as well as the Marine Stewardship Council (MSC) are considering or using this indicator for the ecosystem approach or certification. Things went perfectly well during the work, except for some tension around a possible title for the paper, as one of the co-authors wanted an academic title. However, I remained strong on that as I thought that 'one-third for the birds' is a lovely and explicit title! I have to acknowledge that we are all good friends today as everyone was pleased with the outcome and the way that it was managed. All of the experts were so pleased that we later met several times (in Alaska and in Denmark) to continue this collaboration.

Being a synthesizer

The Ecosystem Approach to Fisheries (EAF) is fascinating as it brings together conservation and exploitation for the first time in the history of fisheries management. Those two fields of research have been working independently and this is the time to move away from managing single fisheries and toward managing fish species within an ecosystem. I tried during my career to assemble different approaches and disciplines around this change of paradigm in renewable resources. Early in my career in Senegal I had the chance to work with oceanographers, fisheries economists, and anthropologists and since then I am convinced that fisheries scientists must confront their views with those of other disciplines. I engaged myself in several consortia or networks, such as the European Network of Excellence Eur-Oceans, to develop ecosystem modelling, the SCOR-IOC WG119, the Euromarine consortium (www.euromarinenetwork.eu) to promote more integrative scientific approaches, Indiseas (www.indiseas.org) to evaluate the health status of marine ecosystems, and IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) to develop a global strategy for biodiversity using scenario building. I also co-organized several international symposia (e.g. FAO—Coping with global change in social ecological systems, Rome, SCOR-IOC-UNESCO WG 119 on indicators for EAF, ICES "Ecosystem effects of fishing", Montpellier, 1999). In 2004, I was co-organizer with Villy Christensen (University of British Columbia) of the international symposium on "Quantitative ecosystem indicators for fisheries management" in Paris, which attracted more than 350 participants from 54 countries (Cury and Christensen 2005).

To get involved in such consortia, organization of symposia or networks is incredibly time consuming but young scientists should be aware that a scientific career is not only writing articles but also connecting people and creating networks, a rewarding task when considering challenging topics. This creates opportunities for new collaborations and scientific perspectives in an organized manner in order to be able to tackle the global challenges that the marine environment is facing today. Do not stay alone in your laboratory with only a few colleagues; the scientific world is vast and enjoyable and the present challenges are pressing and require integrative views and actions.

Being a disseminator

Books can change your life and definitely change your way of thinking. When I was young I read the book by Paul Colinvaux entitled "why big fierce animal are rare" (1979), an amazing essay on life and patterns in nature. I then realized that ecology was about exploring patterns by asking naive and simple questions. I also discovered Darwin (in France nobody ever told me to read Darwin despite my extended training in biology and ecology!). Darwin is fascinating by his rigor, his exploration in depth of nature and by making coherent all sort of disparate observations into a comprehensive framework. The great authors always teach you many things, their profound knowledge, enthusiasm but also how to conduct your research. Reading books (and not only the latest published papers in highly cited journals!) is crucial to our understanding of the evolution of scientific ideas and their genesis.

Writing books is crucial to a scientific career even if you have to write them on your own time, as I did. I was approached in 2007 by Ronald Blunden, the French editor working for Calmann-Levy, who told me that during his last scuba dive in the Mediterranean Sea, he saw very few fishes. He was disappointed and wanted to do something for the ocean. With a scientific journalist, Yves Miserey, I wrote "une mer sans poissons" in 2008 in a few months as editors are always in a rush. This book is based on scientific evidence and raised important issues related to the history of exploitation of marine resources. The book was successful and translated into Chinese, Japanese, in even Catalan. The impact was great. I was invited by four successive French Ministers, the Prince Albert 2 of Monaco (I am presently President of the Scientific Council of the Oceanographic Institute of Monaco), Yohei Sasakawa chairman of the Nippon foundation, and by many institutions and policy makers to discuss fisheries issues. Later, in 2013, I wrote with my friend Daniel Pauly a book entitled "Mange tes méduses! Réconcilier les cycles de la vie et la flèche du temps". This title was misleading and I was invited by radio shows to talk about how to cook jellyfish! Scientists should realize that writing articles in peer-reviewed journals is a must for their career but that policymakers and the rest of the world will never read scientific literature except when this is translated into popularized books. Writing such books teaches you a lot, for example how to express a scientific result to the public, not distorting its content and transmitting it in a lively manner. Writing books also incredibly enlarges your audience and constitutes the best way to disseminate and promote your own ideas, and to communicate to a large audience. Books are powerful as they can change the world with their content (e.g. Darwin). Social media has different targets and dynamics. Although YouTube and TED talks can expand your audience, I am not totally convinced that they will survive the test of time and influence people in the long run as some books do. I might be wrong, but I do believe in the magic of books. Scientists too often ignore that they know basic and incredible things that is of great interest to everyone. However too few scientists are involved in communicating to the public and I convey young scientists to communicate ecology, which is quite attractive and an urgent matter of interest for the public.

Advice to a young scientist

Creativity is precious and must be fed constantly as this is a fragile but indispensable gift. I list below some advice and tricks that might be helpful to early career scientists.

Be obstinate and never give-up

- "There is *no such thing as a Scientific Mind*. Scientists are people of very dissimilar temperaments doing different things in very different ways. Among scientists are collectors, classifiers, and compulsive tidiers-up; many are detectives by temperament and many are explorers; some are artists and others artisans. There are poet-scientists and philosopher-scientists and even a few mystics. What sort of mind or temperament can all these people be supposed to have in common? Obligative scientists must be very rare, and most people who are in fact scientists could easily have been something else instead" from Peter Medawar, "Hypothesis and Imagination" (Times Literary Supplement, 25 October 1963). Be confident in yourself, in your own ideas, but push them as far as you can and resist criticisms such as "this is worthless", "you are on the wrong path", "impossible to achieve, too ambitious", or 'this was already done or known'. . . There exist scientists that will complain about every idea that you might have. Go ahead! I realized in my career that there are two types of scientists: the creative one and the complaining ones! Just listen to the first and ignore the other.
- *Do not think that everything has already been found in the past* and that your contribution will be minor. Discoveries will come with your obstinacy in looking at new but also old problems in a fresh way. The worst review I received in my career was for what I consider my best paper (Cury, 1994), the reviewer said that I should look for a new job and leave ecology! Obstinacy is essential for survival in the scientific arena!
- *Science requires a long-term involvement:* work with long-term objectives (ambitious hypothesis, conceptual idea, "jardin secret") and try to be adaptive and pragmatic in the short term. Combining love of science, hypothesising and imagination are key to a scientist's activity. I know that long term is not really fashionable in the "modern" research environment but cherish your own ideas that are often acquired at an early stage of your career; they are precious even though you will have to adapt to new and pressing topics and perhaps put them aside for long periods, but never give up on them.
- *Science is the art of the soluble*: "If politics is the art of the possible, research is surely the art of the soluble. Both are immensely practical-minded affairs' (Medawar, 1969). Decompose any important question into soluble and tractable scientific issues that can be tackled in a scientific manner and in a reasonable time period (i.e. months or 1 or 2 years). Sometimes bright scientists never achieve their objective because they cannot build a strategy to define steps in their research, a career planning is something never taught but important.
- *Use your writings as the forefront product of your creativity* and as the currency for discussion, communication, and exchange.

As a young scientist it seems always difficult to interact with experienced (old and impressive!) professors, publications to be discussed with them will make interaction easy. I interacted in my early career with great scientists (Margalef, Beverton, Thom, May, Lasker, Cushing, Aubin, etc.) by showing them what I wrote. This constitutes the most natural and fruitful way of interacting with colleagues in the scientific world. I was stupefied that great scientists always interact very easily with young scientists on scientific issues. All of them replied to my letters and they gave me advice and sometimes their intimate view of how they view nature. I remember Beverton telling me that models used in fisheries might be too optimistic when dealing with the resilience of fish populations, Margalef writing a long hand-written letter in French telling me that the habits of animals structure what we observe in nature, Reuben Lasker writing just 8 days before passing away to thank Claude Roy and myself for the OEW paper that synthesized many of his thoughts. I keep those letters preciously (I must confess that I do not do the same for the thousands of e-mails that I receive!).

- *Stimulate your imagination*: To be creative, scientists need libraries and frequent exchange with other scientists. However, there exist many ways to maintain creativity throughout a scientific career (e.g. by reading, listening to music, and the performing arts or doing nothing, just watching the ocean). And do not forget to read, read, and read. I must confess that Darwin, Cuvier, Mayr, Zweig, de Staël, Basquiat, Bach, Beethoven, and many other great thinkers and artists have changed the way I view the world.
- *Science is about novelties, high risk/high gain and ground-breaking ideas:* Avoid the "me too!" and be innovative. I had the chance to meet Mr. Packard from the HP Corporation when I was in California and he told me that he wanted to hire innovative scientists who are not copying the others but who are taking risks. Redundancy is more and more frequent in science but of low interest for the author and the reader; it always pays to take risks by developing new ideas, new concepts, and new methods. Recently I was an evaluator for the European Research Council (ERC) that is promoting high risk/high gain and ground-breaking projects and I think that more and more young scientists will have to build innovative projects at the beginning of their career.
Research is like Art, an activity where risks should be taken. When taking risks you will receive criticisms, a sign of scientific existence!

Be open minded and curious

- *Science is about surprise*: learn from the unexpected as scientific interest lies in what "does not work" or in "outliers" from what we already know. There is always a tendency to be fascinated by what other successful scientists are doing. Try to force yourself to find your own way and focus your attention on scientific questions derived from your own experience. Your own ideas are precious.
- *Promote multidisciplinary approach:* Science is becoming more integrated and is today conducted by interdisciplinary teams. Do not hesitate to propose collaborative work with colleagues within and beyond your own discipline, it always pays to be curious.
- *Promote the comparative approach in ecology* and never say "this does not work in *my* ecosystem"; think "big" and try to generalize your results. Daniel Pauly taught me that global challenges require global analyses.

Become an acknowledged scientist

- *Quantity and quality work together:* We tend to oppose quantity and quality, but that is a mistake. Great scientists have quantity and quality working together as they publish many papers (e.g. among the most famous Einstein, Darwin, etc.). If you write something that is not of interest, do not worry nobody will cite it and it will disappear quickly, this will not hurt anyone, except you (I was sometimes surprised that papers that I was proud of were not particularly well cited).
Passionate scientists are good and prolific writers (with few exceptions!) and writing remains the most powerful tool to stimulate ideas. Once I received an evaluation of my work saying that I was publishing too many scientific papers; this was not a constructive comment for a starting scientist!
- *Nice little things.* Start by writing nice little papers that you can accomplish in a reasonable time period and develop your expertise (Darwin started with cirripeds!). I started my career working on the selectivity of gillnets in Lake Chad in Africa!
- *Empowerment:* your results are going to (and should) be used by others. Make their life easier and think how your scientific production is going to be used and disseminated (raw data, synthetic figures or tables, critical reviews, new ideas, etc.). Always ask yourself if the figures that are in your publication can be of any interest to a class of students. I realized this quite late in my career, but I must confess that I put effort into accessible figures or tables that increased the number of citations of the paper dramatically (Cury *et al.*, 2011). When I was nominated as the Director of the marine research laboratory in Sète, the first position that I hired was a graphic artist. Everyone in the laboratory complained at the beginning but soon they all agreed that this was key for improving our publications. Thus, a creative graphist, Pierre Lopez, helped us to produce wonderful and intelligible figures (one Science editor even asked me who was drawing the nice figures that were in our submitted publication!).
- *Acknowledge your colleagues:* Science is becoming more and more collaborative. Most problems between scientists come from lack of acknowledgment and disagreements over authorship order on publication. Be transparent, fair, and discuss those key issues at the beginning of any collaborative work in an open way, not at the end as this will be too late. Problems in a laboratory or between scientists almost always arise from badly managed cooperation.

Be a writer

- *Daily writing:* write every day during defined hours and always have at least three or four papers in the pipeline. This will help you to assemble material and ideas around objectives and this will make your writing much easier, even painless! Enjoying writing is a condition to producing a good paper. People enjoy reading articles that were written with pleasure. The reader should refer to Sand-Jensen (2007) if they really prefer to write consistently boring scientific literature! I try to write for two hours a day without any phone, e-mail connection, or other distracting devices!

- *Work in economical mode:* one paper = one idea and one idea = one paper. Concise and parsimonious papers are easier to write, to read, and to understand. I remember spending months and months working on a paper that contained two ideas: It was impossible to publish and the paper was constantly rejected, I had to cut the paper into two to publish it.
- *Avoid procrastination:* The best results are always obtained with economical means: write it now and avoid delaying with spurious arguments such as "I need more data, additional experiments, improved models, more time". . .. At the beginning this seems impossible but with obstinacy you realize that we can achieve a lot with minimum materials. Everyone is concerned by procrastination, as we are all somewhat lazy! The best way to fight laziness is to keep a strict daily routine.
- *Avoid plagiarism and misuse of the Internet:* There is a great danger to copy/paste from the web. You must use many new ways of collecting information and knowledge. However, do not forget that you have to synthesize and reformulate any input, and that you have to deliver your own views. Be cautious, software exists that can spot instantly a misuse of the internet (and misuse would be detrimental to your career). You can steal ideas from others but in a smart way: that is, by synthesizing and bringing an added value to what exists! Pablo Picasso once said: "good artists copy, great artists steal".

Love of science and music

What I really love is to catch ideas that are nomadic and that can be found in different fields**.** Exploring consistency with other theories, approaches, or disciplines is fascinating. I developed the idea that Obstinacy is the main process for an individual to survive (Cury, 1994). In fact, I found the same ideas developed in music. Music is about variations, just like nature. I spent many years writing a book entitled *33 transformations* (Cury, 2020) where I use a common theme, the "extended homing strategy" that I introduced before, to tell 33 stories on the transformation of our world. This book uses music as a guideline around the Beethoven project (i.e. Ludwig van Beethoven wrote 33 transformations on a basic musical theme produced by the composer Anton Diabelli in 1823, this constitutes one of the most incredible and ground-breaking music ever written). Those transformations are built on the recurrent theme: "can we live without our natal roots?" This book uses music, ecology, and human myths telling different stories related to Charles Darwin, Konrad Lorentz, Sigmund Freud, Stefan Zweig, Frederic Chopin, Bram Stoker, Richard Wagner, Voltaire, Dracula, Batman, and many others.

Conclusion

I hope that early career scientists will enjoy their scientific life as much as I have. In our scientific career, by developing our own ideas, we get something to be proud of that makes us happy. I hope that my love of science and the story that I told you was helpful. Finally I would like to quote my favourite author, Charles Darwin (1887) who, as usual, provides invaluable comments on our scientific life:

> Therefore my success as a man of science, whatever this may have amounted to, has been determined, as far as I can judge, by complex and diversified mental qualities and conditions. Of these, the most important have been—the love of science—unbounded patience in long reflecting over any subject—industry in observing and collecting facts—and a fair share of invention as well as of common sense. With such moderate abilities as I possess, it is truly surprising that I should have influenced to a considerable extent the belief of scientific men on some important points.

In today's research environment we might not always have the luxury to have long-term project but we have to resist—through our obstinacy—in achieving our own ideas throughout our life while addressing the global challenges marine environment actually face. To end, I wish you (including women of course!) to be as successful as Charles Darwin, a passionate, dedicated, and obstinate man.

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When I was asked to detail my life as a scientist I was reluctant, meanwhile I told myself that I should not be selfish and tell the young scientist what I learnt throughout my career and acknowledge the fantastic people that I met in my career.

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