SCI. MAR., 65 (Suppl. 2): 199-206 SCIENTIA MARINA 2001

A MARINE SCIENCE ODYSSEY INTO THE 21st CENTURY. *J.M. GILI, J.L. PRETUS and T.T. PACKARD (eds.)*

Natural History: the sense of wonder, creativity and progress in ecology*

PAUL K. DAYTON and ENRIC SALA

Scripps Institution of Oceanography, La Jolla, California 92093, USA.

SUMMARY: This essay addresses the question of blending natural history and ecological wisdom into the genuine creativity exemplified by Prof. Ramon Margalef. Many have observed that modern biology is a triumph of precision over accuracy, and that ecology has sought maturity by striving toward this model in which the precision value of the tools has supplanted important questions. In pursuing a model of hard science, ecology has struggled with Popperian approaches designed to create a thin patina of "real science" over the vast seas of uncertainty so admired by the naturalists. We start with a discussion of the importance of natural history in ecology and conservation, and the present state of natural history in academic ecology. We then discuss the respect for natural history in human cultures, and conclude that an infatuation with authority has obfuscated the important truths to be found in nature. We consider some general processes associated with creativity, and finally we ask how natural history influences creativity in ecology. We conclude that the soaring creativity exemplified by Ramon Margalef is based on a joyful almost spiritual understanding of natural history and the courage to avoid authority.

Key words: natural history, ecology, scientific progress, traditional knowledge, authority, understanding of nature.

INTRODUCTION

"A nine-story terrace rises up from a basket of dirt"
Lao-Tzu, *Te-Tao Ching*

People have impacted essentially all the habitats in the biosphere. There are growing societal needs for an ecological science that can correct the environmental insults and contribute to management of sustainable ecosystems. Questions regarding ecological management are ubiquitous and difficult. For example, all habitats suffer cumulative impacts; how can one evaluate the ecological damage of particular small impacts without a baseline of what is natural? That is, since the system is already perturbed, how can one generalize ecological limits to additional perturbations? One needs to understand stabilizing processes such as persistence, resilience and recoverability or successional processes that can simplify or make communities more complex. Natural systems are characterized by variation at all scales: how do ecologists determine thresholds across the scales? Worse, *a priori*, can we predict a threshold? Considering the highly perturbed condition of so much of our environment, restoration is another management issue of growing importance. Realistically it almost never can be natural in the sense of restoring ecological conditions characteristic of pre-human contact (Pitcher, 2001). So what arbitrary goals does restoration require? How does one restore a habitat even assuming a desired goal? Which species traits are useful in restoration? How

*Received May 29, 2001. Accepted July 27, 2001.

do human caused extinctions shape future diversity and evolution? Such insights must come from a very solid understanding of ecological processes in such a way that future trends can be deduced from past and present processes. These issues involve knowledge of minimum population size, genetic connectivity, positive and negative relationships such as symbiosis or diseases. Important insights into the resolution of almost all these questions can be found in the natural history of the ecosystems, and traditional and local ecological knowledge very likely offer some of the most perceptive ideas and hypotheses. But where does natural history fit? Is it a science?

Natural history provides the foundation of ecology. Consider Wallace who probably deduced natural selection before Darwin and observed patterns in nature wherever he went. Consider Bates and Muller with their appreciation of mimicry, a subject now considered of fundamental evolutionary importance (for example, perhaps up to 35-50% of all non-venomous snakes are mimics, Harry Greene, pers. comm.). Natural history is therefore the underpinning of ecology and evolution science. There is no ecology, no understanding of the functioning of ecosystems and communities, no restoration, or in fact, little useful environmental science without an understanding of the basic relationships between species and their environment.

THE STATE OF NATURAL HISTORY IN ECOLOGY TODAY

Despite its fundamental role, natural history recently has been ignored and dismissed. It has been displaced, expelled from the ivory tower, and it is presently seen as less prestigious than other disciplines. More than ever, ecologists study problems caused by human activity, but they study these problems in the absence of an understanding of natural patterns**.** Usually ecologists have not sufficiently considered human culture as an integral part of the equation**,** or unequal power between cultures and how that leads to destruction. Because of funding realities, many scientists pursue funding opportunities themselves rather than asking what are the most appropriate questions and at what scale should they be studied. Finally they continue the tradition of testing hypotheses, often at inappropriate scales, rather than seriously attempting to solve problems. Often they ignore other science traditions, long-term common sense observations, and their own scientific foundation of natural history.

Biology undergraduates at many universities in the US are not taught the "classic" Botany or Zoology. Many first-year graduate students do not know major phyla or the life history biology of their study organisms. Without grounding in the fundamentals of natural history, students will have difficulties in understanding ecology. Yet, some of them have been taught ecology using textbooks based almost entirely on molecular biology and theoretical population biology. This prevailing attitude denies students the sense of wonder and sense of the place fundamental to the discipline. Worse, there are ecologists who have never seen the communities or populations they model or speculate about, and who could not identify the species composing these communities. This is like having the illusion of conducting heart surgery without knowing what a real heart looks like.

WHY THE DEMISE OF NATURAL HISTORY?

Why is natural history so dismissed? Natural history and systematics often are disparaged as stamp collecting, the implication being that the practitioners mindlessly collect facts. This elitist attitude is based on ignorance of the old naturalists and systematists who were deeply observant: they saw much in nature and carefully wrote it down, sometimes in beautiful poetic prose that rings through the ages, or sometimes they struggled under the enormity of the truth they were communicating, and one can sense their commitment to understanding nature. It is a terrible disservice to imply that they were collectors of trivial facts. This was never true; nobody collects facts or describes species in a vacuum. Furthermore, no generalizations can be made without repeated observation.

Moreover, we have heard from several prestigious ecologists that natural history is a discipline that does not require a great intellect. Ironically, such opinions are formulated by specialists, masters of techniques rather than true detectives of the natural world. Real progress in understanding nature tends to be made by generalists, but the selection for individual success lies at the extreme – the specialist. Fretwell (1972) described this process in terms of divergent fitness of ecologists attempting to integrate general theory and natural history. In this context, ecologists are judged by specialists, and in order to be successful in the eyes of specialists, one

must specialize also. The selection to specialize is based not on the real understanding of nature, but on social influences from colleagues usually acting as competitors and judges. The irony is that ecological progress depends upon a synthesis of theory and sophisticated analysis, modern technology, and especially natural history.

As ecology moved from descriptive to mechanistic phases, our sociology moved toward T.S. Kuhn's paradigmatic behavior in which we are most comfortable within a larger framework where the questions and rules are clear and there are strong social pressures to conform. This is formalized by the flow of support from individualized small science to very large integrated research programs where the players have small roles well defined by the group. They also have large budgets that reward group mentalities more than individual creativity. What does this imply for scientific creativity? The recent past in the United States has seen a great deal of support for coordinated programs (e.g. IPB, LTER, JGOFS, GLOBEC) as opposed to small individual programs. This general model would tend to preclude proposals by young investigators who have not been accepted into the invisible colleges that control the large programs. It is important to emphasize that large scale programs tend to address important questions, and they must be based on cooperation and integration. But at the same time they are sufficiently expensive that risk absolutely must be minimized, and such risk-averse philosophies select bookkeepers rather than the high-risk poets such as Ramon Margalef. Ironically, while low risk and productive, the large-scale programs have not produced as many great innovative leaps as individual efforts of naturalists.

It is clear that respect for natural history is social and is recoverable, but the respect has to be at the ground level. Sadly, the loss of nature itself due to human abuse of the biosphere is much more permanent and central. This leads to a vicious circle in that the loss of our natural heritage inevitably results in the loss of the human experiences in nature where the expectations and love of natural relationships are learned. Thus we are missing our appreciation of what has been lost, and these reduced expectations of nature result in the loss of respect for it. How do we break this circle? This is a serious problem because the beauty of and the empathy with nature represent the soul of ecology. This soul has been eroded as the loss of nature continues with less and less passion exerted in her defense. It seems as though our self-esteem somehow has been misplaced, and we now focus on the importance of our specialization without much regard for the evolutionary wisdom of the ages that is lost.

NATURAL HISTORY IN TRADITIONAL CULTURES

"Out of the ground the Lord God formed every beast of the field and every bird of the air, and brought them to the man to see what he would call them; and whatever the man called every living creature, that was its name."

Genesis 2.19.

It would appear that natural history has a long tradition in Judeo-Christian cultures, as Adam's first task was to establish the natural history of his ecosystem (Farber, 2000). This respect for natural history can be seen far earlier in the ice age caves of southern Europe where artists with remarkably perceptive sensitivity to nature as seen in animal behavior was rendered in the magnificent work reaching back over 30,000 years. Elsewhere, at least that long ago, Australian people were also creating wonderful art that eventually showed a fine understanding of anatomical details, and the Pleistocene history of the manipulation of their habitats shows sophisticated understanding of the natural history (Flannery, 1994). The dreamtime mythology of Australia, so extremely sensitive to the local natural history, is matched by the mythology of most cultures around the world. It is obvious that people have always had a love-fear relationship with nature, and that from the very beginning human beings have been extremely sensitive naturalists. And indeed, while we are fast losing these human cultures (Nettle and Romaine, 2000), many were based on sophisticated understanding of the patterns and processes of the natural world around them (Johannes, 1981). Are there any fundamental differences between such traditional understanding of nature and the type of understanding to which ecologists aspire? Were these early naturalists also ecological scientists? Does modern ecology exclude such sophisticated understanding of nature? Indeed, the urgency to succeed forces young scientists to get along with their elders and to write many papers with rather limited focus, so, to follow the above examples, we do have some short-lived oral history, but where are the artists who paint the cave paintings with such brilliant renditions of nature?

ECOLOGICAL VALUES (AND THEOLOGICAL PARALLELS)

To better understand what we are losing by dismissing natural history, we need to explore the evolution of ecology and of science in general. We believe that human value systems strongly influence science. E.O. Wilson (1998) has written, "Science…is the sword in the stone that humanity finally pulled. The question it poses, of ultimately lawful materialism, is the most important that can be asked in philosophy and religion. Its procedures are not easy to master, even to conceptualize; that is why it took so long to get started, and then mostly in one place, which happened to be Western Europe." He continued, "Science is the organized systematic enterprise that gathers knowledge about the world and condenses the knowledge into testable laws and principles. The diagnostic features of science that distinguish it from pseudoscience are first, repeatability: the same phenomenon is sought again, preferably by independent investigation, and the interpretation given to it is confirmed or discarded by means of novel analysis and experimentation. Second, economy: scientists attempt to abstract the information into the form that is both simplest and aesthetically most pleasing – the combination called elegance – while yielding the largest amount of information with the least amount of effort. Third, mensuration: if something can be properly measured, using universally accepted scales, generalizations about it are rendered unambiguous. Fourth, heuristics: the best science stimulates further discovery, often in unpredictable new directions. Fifth, consilience: the explanations of different phenomena are most likely to survive are that that can be connected and proved consistent with one another."

What are the scientific values in ecology? How do they evolve? How can one learn the values of an academic discipline? For the most part the academic values are learned from examples and teachings of practitioners. Obviously the values are broad enough to cover almost any type of research, but while it is rarely explicitly stated, the practice of ecology is laden with rules and authorities that interpret these rules. These rules tend to ignore the importance of history at all scales. It is very rare to see an appreciation of the fact that all marine populations evolve in a total environment (abiotic and biotic) that includes geological time as well as oceanographic processes, and that many of these factors are important if not experimentally testable. None of them are approachable with single tools.

Authority

By what authority have these important rules evolved? Ecologists surely are not the only ones who love authority. The wonderful Aristotelian natural history of the classic era was largely lost or grotesquely corrupted by Christian authorities that based their concept of reality in their interpretation of the Bible. Much of the interpretation is based on the writings of Augustine of Hippo (Aurelius Augustinus 354-430 AD), who, as an early Christian, developed a fixation on the importance of authority. He searched for truth and dabbled with many religions that based their concepts of truth on assertions and untested authority. He developed an obvious and strong attraction to Plato's ideal model of truth perceived only as dim shadows in the back of a cave. Augustine struggled through this: "We feast on sewage while dimly remembering the nectar and ambrosia of high heaven." He persuaded himself that Plato's ascent to truth equated knowledge with virtue. Augustine compared Babylon, the city of man (necessarily corrupt and evil) with his City of God, which flourishes eternally, beyond all strife. Note the Platonic parallels between perceived and ideal. Augustine saw the sacraments of the church as absolutely necessary. Without their aid, all men would inevitably succumb to evil. He wrote the first Catholic justification for state persecution of those in error of not accepting the authority of the church; to Augustine, error has no right. To disbelieve in forced conversions is to deny the power of God; and God must whip the son He receives *per molestias erudito*. Interestingly, to Augustine, true education begins with physical abuse. His mind shut down all that opposed his established authority, and Augustine became the father of the Inquisition.

This fixation on authority was challenged by the Irish Johannes Scotus Erigena, (810-877) who was anti-Platonic, and whose fundamental principle was reason based on nature. His *De Divisione Naturae* (the Division of Nature – written in 870) based all authority on reality that he defined as nature. His main theme was that reason (and nature) was a much more powerful means of ascertaining truth than authority or faith. He argued that real authority could only be derived from nature. To Scotus, nature is a synonym for reality, and he considered reality as found in nature to supplant the Platonic thinking codified by ecclesiastical authority of the Church. He emphasized reason and logic over platonic authority. He used this to oppose all authority – every authority not confirmed by true reason

(nature) seems to be weak, whereas true reason (nature) does not need to be supported by any authority.

In 1225 Pope Honorius III ordered all copies of *De Divisione Naturae* burned. But there is an irony: When Honorius died, the new Pope, Clement IV, commissioned Roger Bacon to write his opus in 1266. Roger Bacon was the first renaissance inductionist and advocate of the experimental method that he explicitly developed. He set forth a system of natural knowledge that must have been influenced by the recently burned works of Scotus. He was explicitly anti-authoritarian and defined the following stumbling blocks to comprehending the truth:

1. Beware the example of frail and unworthy authority
2. Beware long established custom
3. Beware the sense of the ignorant crowd
4. Beware the hiding of one's own ignorance under the pretense of wisdom.

Some of this old wisdom must ring true to many ecologists who sat politely though lectures on various theoretical constructs, and thought to themselves: "but in the real world…." Or wondered what has really been learned from exercises designed for the statistical elegance of the analysis rather than interesting general questions about nature. Or have struggled with other statistical rules based on Augustinian authority rather than Scotus' sense of reality. Or why, when we know the natural history, must we ignore the reality and create null models based on ignorance of this knowledge? It seems that the value of natural history and experimental analysis have been with us for hundreds of years, but our culture easily acquiesces to the Augustinian authority within the infrastructure of our science.

Ecologists ought to challenge these self-proclaimed authorities and return to the values of Johannes Scotus and recognize nature as the ultimate authority. Surely this is not to reject the great value to the theoretical work that 1) is based on appropriate natural history, 2) provides answers that can not be determined empirically, or often 3) in conservation where there is great urgency. Nor is this to reject the importance of the established format of developing and testing theory; rather it addresses our questions and allegiance to unworthy authority. Are we looking for significance or truth? It is easy to falsify stupid null hypotheses and obfuscate the truth. Einstein dreamt himself traveling on a light beam and solved one of the most intractable questions of modern physics. His quantum leap was doubtlessly facilitated by the fact that he was not in academia and hence not limited by any authority.

The objective of this essay is to return our focus to nature. The testing of theory remains the cornerstone of science, but if ecologists embed this process in excellent natural history such that the tests are based in reality, we might recover the joy and spirit of natural history from the trivia imposed by some authorities while at the same time developing a better understanding of ecology.

ARE NATURALISTS POETS OR BOOKKEEPERS?

Wilson (1998) argues that in science, original discovery is everything: scientists do not discover in order to know, but rather they know in order to discover. He sees a distinction with the social scientists: when attempting to sort out knowledge in order to sift for meaning, and especially when carrying out that knowledge outside the circle of discoverers, he is classified as a scholar in the humanities, but without original discoveries, one is not a scientist. A fundamental distinction thus exists in the natural sciences between process and product. The difference explains "why so many accomplished scientists are narrow, foolish people, and why so many wise scholars in the field are considered weak scientists. Scientific research is an art form; it does not matter how you make a discovery, only if your claim is true and convincingly validated." To Wilson, the ideal scientist thinks like a poet and works like a bookkeeper. Likewise, Margalef (1997) stated that a naturalist is more a poet than an engineer. A social scientist's perspective is different: "The closer historians of science look at the great achievements of science, the more difficulty they find in distinguishing science from pseudoscience and from the political, economic, and ideological contexts (Nader, 2000)." She observes that social scientists often fail to perceive scientific progress in the same self-serving Pollyannaish perspective as do the "hard" scientist.

"Wisdom is better than strength; Nevertheless the poor man's wisdom is despised, and his words are not heard." (*Ecclesiastes* 9:14-16). There is an age-old dichotomy: realism vs. relativism, scientific novelty vs. permanent wisdom, science vs. religion and all the history summarized as two cultures by C.P. Snow. Social scientists recognize cultural bias in all claims of universal factuality – science is but one system of belief among many as the very concept of scientific truth is a social construction invented by scientists.

While well known and discussed, like most dichotomies, this is misleading and is hurtful to both sides because it emphasizes the extremes and minimizes the "golden mean" of Aristotle. Obviously both extremes occur: there is a continuing social construction and growing empirical knowledge. Real progress occurs when science can be built on social wisdom in such a way that it is relevant to society as a whole. In this sense we see further when we stand on the shoulders of both giants.

Where do ecologists fit into this concept of science? Is ecological science opposed to humanities? What are our original discoveries? Are we poets if we follow these rules? Can we be both wise scholars and good scientists? Where is our creativity in ecology? Is academic ecological knowledge superior to traditional or local ecological knowledge? Our thoughts about the importance of these rules come from experiences with peer review and editorial judgments, professional interactions with colleagues, etc. Are these rules inimical to creativity? Are the distinctions between science and pseudoscience outlined by Wilson and enforced by our reviewing system compatible with ecological poetry?

What if we go farther back and look at the ice age hunters' understanding of natural history? Can anyone imagine that people so sensitive to the behavior of these animals did not understand a great deal about their ecology? Or consider the understanding exemplified by native fishing cultures: "When it comes to understanding fish behavior so as to manage its exploitation efficiently, full-time fishermen may know more than marine biologists…the native fisherman searches with his eyes and ears and he is…more in touch with his prey and their surroundings than his modern mechanized counterpart (Johannes 1981)." In order to avoid false or misleading comparisons between a model of science identified with reason and the domination of nature, and native uses of knowledge, it is imperative to document the process of knowledge formation and its use (Johannes, 1981, 1998). Certainly the same is true now as those who live and work in nature understand it the best.

ECOLOGICAL WISDOM

Where is the life we have lost living?
Where is the knowledge we have lost in information?
Where is the wisdom we have lost in knowledge?
T.S. Elliot

What is ecological wisdom? With the institution of specialists, wisdom has been lost, and our culture seems much poorer for this. It is interesting to juxtapose the wisdom of the ages that can be found in art and compare it to the progress in ecological research now often divorced from natural history. Certainly this is a matter of scale, perspective, and attitude. Ancient people have always had great respect for scholarship, and our greatest advances have come from very diverse minds. This is true in the arts as well as in science and one only has to look for example to the huge intellectual breadth of artists such as Samuel Coleridge or scientists such as Niels Bohr or especially Leonardo DaVinci. In all cases, wisdom involves the big picture, the entire spectrum of relationships. It is also a matter of keeping your eyes and soul open to the beauty around you. Or, as Confucius said: "Everything has its beauty but not everybody sees it."

Ecological wisdom involves the ability to see the beauty in nature and to integrate it into the patterns and processes studied by ecologists. Interestingly, this puts the values right back to Johannes Scotus. How do we perceive nature? Where is the beauty? Does nature intrinsically foster an attitude of love, empathy and a source of wonder and joy (the biophilia of Wilson)? Throughout human history we have been selected to conquer nature; it is a source of fear and threat, something that can feed us or kill us. Yet primitive people exalt nature. If not a love of nature, most cultures are built around a respect for nature. An empathy and appreciation of nature is solidly built into most human mythology. Certainly it induces a sense of awe and wonder in those who have enjoyed it.

But it is fair to ask whether natural history has relevance to the science of ecology. We argue that it does and we are concerned about the loss of respect for natural history and systematics. Do working ecologists build their science on natural history? The answer is not very often, and lost in normative fashionable ecology is respect for nature herself.

PROGRESS: NATURE, CREATIVITY, AND SCIENTIFIC METHODS

How does genuine **creativity** occur? Is there a connection with natural history? We might look for examples associated with creative people. One means of identifying creative insights in science is to evaluate premature ideas. Science is full of pre-

mature ideas. Some like Mendel's work was simply ignored. Other premature ideas were considered outrageous and not worthy of attention (e.g. Gondwanaland, catastrophic events). How are we to separate outrageous from ridiculous or silly ideas in ecology? It was Einstein who said that, if an idea did not look absurd the first time, it was hopeless. As the value of Bayesian statistics sinks into ecological thinking, the importance of a subjective source of creativity becomes much more obvious. What are the pathways to creativity? Do they relate to natural history or do they come via some other medium?

We can look to artists as well because scientists follow similar paths to creativity.

1. Almost all creative people are very curious about nature: they are inspired by nature.

2. Creative events do not happen *de novo*: they come from people well versed in their fields. In ecology they must be based on good natural history. Ecological science can be general or specific, but not to be real is fatal. This experience also provides a "feel for the system," which is nothing else than intuition. Intuition may not be considered "hard science," although it can be more valuable than other limited approaches to understanding nature. Ecologists ought to understand that intuition is another way to analyze data. The problem with accepting it is that we still do not understand how intuition works.

3. Orthogonal views are common. Creativity is often not so much original as it is simply a different approach, a new twist, the "deductive leap." It is not luck: it comes from constantly looking for alternative approaches. In ecology the orthogonal views usually come from an appreciation of the natural history of the system wedded to an understanding of various scales.

4. Creative thinking is often associated with social courage to dream and fantasize and be different. Kids do a great job. "Let's pretend." Adults are impressed with creativity but often fail to support this process. As Coleridge said, "Genius resides in a combination of a child's sense of magic and an adult's trained mentality."

5. For some reason peer pressure destroys imagination. But consider the observation of Jose Clemente Orozco: "Errors and exaggerations do not matter. What matters is boldness in thinking... in having the temerity to proclaim what one believes to be true without fear of consequences. If one were to await the possession of absolute truth, one must either be a fool or a mute." Creative ecologists must have the courage to put imagination at public risk without fear of making a mistake. Finally,

6. Creativity comes from passion. The human brain is the ultimate instrument, and it works best with joy, curiosity and enthusiasm. Yet modern scientists are trained to reject passion.

"The ignorant crowd" fails to recognize the importance of joyful enthusiasm. Scientists often push the importance of extreme skepticism. In fact skepticism and a sincere effort to negate hypotheses is critical to science. This is appropriate, it is our most effective tool, but the tool only can be applied to ideas that spring from creative human minds. In this sense it is important to realize that the essential negativism of science can suppress the value of a good hunch, the educated guess that comes from a sense of the place and the problem. The value of enthusiasm, of joy, blended into a real gut feel for the system, is part of the creative process. The enthusiasm, joy, and deep pleasure so often associated with the human passion for nature and natural history is the source of almost all the creative leaps in ecology. Nobody better exemplifies this soaring creativity than Ramon Margalef.

Are stimulating hypotheses science? When rigorous application of scientific methods to trivial hypothesis is mistaken for good science, precision triumphs over accuracy. How can ecological scientists move from the mystical artistic relationships to good science? In the 18th century meteorology focused on the beauty of the clouds; great effort went into creating a natural history of cloud forms, and the compilations were esthetically pleasing and much appreciated, but they contributed almost nothing to our understanding of weather and climate which awaited the development of atmospheric sciences based on rather ordinary laws of physics. In the same sense, naturalists such as Aristotle, Elton, Darwin, Wallace, etc. produced spectacular visions of patterns in the natural world – but have these patterns produced solid ecological understanding that can be generalized? Of course they can, but the generalizations depend upon the understanding of the processes that create the patterns.

CONCLUSIONS

Wilson (1998) described the structure of science correctly, but he did not define the objectives of science, especially in a way that can relate to ecology. A common problem in recent ecology is that the

generalizations are based on inappropriate assumptions rather than on good natural history. These generalizations masquerade as science because they are mensurate and precise, esthetically pleasing and appear heuristic and consilient, but they are not easily repeatable, and often are not relevant to reality.

We hold that the goal of useful science is to make **interesting accurate generalizations about nature based on as few relevant parameters as necessary**. Obviously the generalizations must be accurate and general. By accurate they must be based on Scotus' reality. While trivial generalizations abound, good science, to have value, must produce generalizations interesting to a wide audience. Finally, the relevant parameters are meant in an exclusive sense; good science must weed out the marginally relevant parameters because all of nature is trivially related. The generalizations must be based on those few parameters that can account for most of the uncertainty, following Ockam's parsimony principle. In this sense good natural history absolutely permeates ecological science because it defines every component of these objectives.

Creative ecology is based on a deep sensitivity to natural patterns and processes. Naturalists have the ability to synthesize perceptions of nature into reasonable hypotheses about the processes that cause the patterns, and then shift into the relatively simple scientific technology of testing hypotheses such that they contribute to a more general understanding of nature. In this sense, good natural history is fundamental to ecological science.

If we are to conserve what we love, we must imprint this love in our future ecologists. That is, building the house from the basement, teaching sound natural history in all universities having degrees in Biology or Ecology. This might sound evident to most European scientists, but it is not the case in many universities. Without a sound formation on natural history, we risk producing narrow-minded ecologists. Naturalists are closer to poets than to engineers (Margalef, 1997), and it is the intuition based on first-hand experience and common sense that produced the better leaps of thought. We should imprint on our students the importance of intuition, imagination, creativity, and iconoclasm, and prevent restricting them with the braincuffs of rigid assumption frames and techniques, if we are to revitalize an ecological science that is more than ever becoming a stronghold of fundamentalism.

ACKNOWLEDGEMENTS

First, it is a huge pleasure for us to acknowledge the career-long inspiration we have received from the example of Ramon Margalef. His thorough scholarship, his passion, love and understanding of nature, and his courage to be different and follow his own path have offered an example for all humanity. We thank Laura Nader and Reed Noss for sharing unpublished texts of lectures they gave to the Ecological Society of America meeting in August 2000, and S. Abbott, F. Coleman, H. Greene, R. Johannes, P. Levin, E. Parnell, and E. Scripps for comments.

REFERENCES

Farber, P.L. – 2000. *Finding order in nature; the naturalist tradition from Linnaeus to E.O. Wilson.* The Johns Hopkins University Press, Baltimore. 136 pp

Flannery, T. – 1994. *The future eaters*. Reed Books, Chatswood NSW, Australia. 423 pp

Fretwell, S.D. – 1972. *Populations in a Seasonal Environment.* Princeton University Press, Princeton, N.J. 217 pp.

Johannes, R. – 1981. *Words of the Lagoon; fishing and marine lore in the Palau District of Micronesia*. University of California Press.

Johannes, R. – 1998. The case for data-less marine resource management: examples from tropical nearshore finfisheries. *Trends Ecol. Evol.*, 13: 243-246.

Margalef, R. – 1997. *Our Biosphere.* Ecology Institute, Oldendorf/Luhe.

Nader, L. – 2000. Lecture before the Ecological Society of America (August, 2000)

Nettle, D. and S. Romaine. – 2000. *Vanishing voices; the extinction of the world's languages*. Oxford University Press. New York. 241 pp

Pitcher, T. – 2001. Fisheries managed to rebuild ecosystems? Reconstructing the past to salvage the future. *Ecol. Appl.* 11(2): 601-617.

Wilson, E.O. – 1998. Scientists, scholars, knaves and fools. *Am. Sci*., 86: 6-7.