www.cat-science.cat

Margalef Prize Lecture 2011

Conservation and social-ecological systems in the 21st century of the Anthropocene era*

Juan Carlos Castilla

Departamento de Ecología, Centro Interdisciplinario de Cambio Global y Núcleo Milenio de Conservación Marina, Facultad de Ciencias Biológicas, Pontificia Universidad Católica de Chile, Santiago

Resum. La conservació és un concepte «esmunyedís» que es pot interpretar de moltes maneres. Aquest assaig revisa alguns enfocaments històrics de la conservació i les seves romàntiques (fins i tot, patriòtiques) connotacions equitatives inicials equitables amb la preservació, segons proposaren els filòsofs i els naturalistes nord-americans del segle XVIII. També presenta la perspectiva oposada, defensada en la mateixa època pels filòsofs europeus, consistent a reconèixer que el món real no és el mateix per a tota l'eternitat, sinó que és dinàmic i producte de la societat, la indústria i l'Estat. En el context del segle XXI, es tracten els fonaments científics, socials i ètics de l'era antropocènica i els objectius i els nivells espacials de la conservació, com també les connexions entre la conservació, la sostenibilitat i l'equitat econòmica. L'assaig explora dues opcions per a fer front a la conservació de la natura a l'Antropocè. En primer lloc, el punt de vista sostingut pel moviment de l'«ecologia profunda», i en segon, el representat pel Projecte Millennium d'Avaluació dels Ecosistemes. Hi ha una visió personal de prioritats sobre què cal conservar, i on i com fer-ho. Es tracten aspectes com la sostenibilitat ecològica i social i la conservació dels recursos marins a llarg termini a Xile considerant-los com a exemple d'un enfocament modern i comprensiu de conservació. Finalment, l'assaig se centra en la manera com el professor Ramon Margalef (1993) va visualitzar la complexa interacció entre els éssers humans i la natura i com els elements centrals d'aquest assaig continuen estant en consonància amb els seus punts de vista.

Paraules clau: conservació · era antropocènica · sistemes socioecològics · ètica ambiental · sostenibilitat · governança · gestió · Xile · pesca · Margalef

Summary. Conservation is a 'slippery' concept that can be interpreted in many different ways. This essay reviews historical approaches to conservation and its romantic (even patriotic), initially equitable connotation of preservation, as proposed by 18th century North American philosophers and naturalists. The opposing view is presented as well, i.e., that the real world is not the same for eternity but dynamic, and the product of the interaction of society, industry and the state, as proposed by European philosophers around the same time. In the context of the Anthropocene era of the 21st century and based on scientific, societal and ethical grounds, the aims and spatial scales of conservation are discussed, as are the connections between conservation, sustainability, and economic equity. Two options to deal with the conservation of nature in the Anthropocene are explored herein. First, the view held by the 'deep ecology' movement, and second, that represented by the Millennium Ecosystem Assessment project. A personal view on the priorities of what, where, and how to conserve is presented. The long-term social-ecological sustainability and conservation of coastal marine resources in Chile is discussed as an example of a modern and comprehensive approach to conservation. Finally, this essay calls attention to Professor Ramon Margalef (1993), specifically, his visualization of the complex interplay among humans and nature, which is very much in line with the views of the author.

Keywords: conservation · Anthropocene era · social-ecological systems · environmental ethics · sustainability · governance · management · Chile · fishery · Margalef

* Based on the lecture given by the author at the Faculty of Biology of the University of Barcelona, on 26 October 2011. Juan Carlos Castilla was the recipient of the Ramon Margalef Prize in Ecology 2011.

Correspondence: J.C. Castilla, Departamento de Ecología y Centro Interdisciplinario de Cambio Global, P. Universidad Católica de Chile, Casilla 114-D, Santiago, Chile. Tel. +56-23542651. Fax+56-23542621. E-mail: jcastilla@bio.puc.cl

Introduction

Over the course of two centuries, 'conservation' has been interpreted in so many different ways that nowadays it can even represent opposing views. For example, in the 1800s and early 1900s, environmental thinkers in North America understood conservation to mean 'preservation.' Thus, to conserve 'wilderness' was seen as the most important mechanism to preserve the world. Wilderness was the final refuge to escape from modern life, and a natural cathedral in which to experience God. Wilderness was viewed as a moral, spiritual, inspirational, and even patriotic reservoir [30,48,61,76,93]. In the 19th century, the world's wilderness faced serious threats: accelerated human development, advanced urbanization at a pace previously unknown, and new and aggressive technologies. Human societies underwent revolutionary and rapid changes, particularly in the northern hemisphere. To confront the human invasion of wilderness, the preservationist movement developed the flagship idea of creating 'parks devoid of people' or 'parks away from people' as means to protect it (see comments on the impacts of this conservation strategy and the displacement of indigenous populations in [48]). At that time, ecology had not really developed as a science; hence, the implementation of protected areas was not scientifically based. Aldo Leopold [52] was one of the first to incorporate the 19th and early 20th century preservationist movement into an ethical approach, by seeking to strengthen the relationship between humans and nature and by preaching the value of nature in itself.

Although seldom mentioned (but see Riechmann [76]), in Europe, Marx and Engels [58] held ideas totally opposite to the prevailing ones about nature and society: "the sensible world… is not for eternity and always the same, but is the product of industry, the state and society. Today the nature that proceeded human history does not exist anywhere". This analytical and pragmatic view was completely unethical to the more religious/romantic view of nature and human society held by North American romantics such as Emerson, Thoreau, Muir, and Leopold. Marx and Engels did not seek to provide a recipe of how to solve socio-environmental problems, but rather delineated a framework for and a diagnosis of the challenges human activity can impose on the environment. In their view, the challenge was to motivate society, government, and industry (markets) to confront the ever-changing socio-ecological realms.

The European industrial revolution of the 19th century, followed by the intense economic activity after World War II, a period of accelerated industrial developments, and the discovery and use of powerful ways to manipulate (directly or indirectly) the environment substantially changed Planet Earth, with marked impacts on its biophysical systems. Thus, it has been argued that the Holocene era (characterized by a warmer and more stable climate than that of the Pleistocene era) thereby ended and a new era emerged: the Anthopocene [88,89], the beginning of which coincided with the initial phases of the industrial revolution (ca. 1800) [25,91,97]. In the Anthropocene, the human footprint and the signs of socio-environmental fatigue are vividly obvious. Indeed, concern has been raised that we have already surpassed several socio-ecological thresholds, and about the speed at which we are reaching numerous 'points of no return' [74]. Clearly, the last 200 years of economic development, technical, and social discoveries, and previously unimaginable innovations have vastly improved human health and well-being. Nonetheless, one billion people (1/7 of the total population) continues to live under extreme poverty, defined as earnings of less than 2.5 USD per day. In this context, we must to ask ourselves: What does 'conservation' mean in the Anthropocene era?

This essay addresses this question from different angles. First, it explores the definition and meaning of conservation and its relation to environmental sustainability and equity. Second, it examines some of the main options that have been proposed to tackle modern conservation problems. Third, the autor presents his own view on the what, where, and how of conservation, highlighting the need for better governance approaches. Finally, a practical approach to conservation and sustainability is offered, including a description of the Chilean experience in the management and conservation of common-pool coastal marine resources.

Conservation

A matter of definition. In line with the 19th century North American view of nature, in specialized dictionaries such as that of Allaby [1], the aim of preservationist approaches is defined as to "maintain the environment and resources quality and balances among the species in a particular area." According to other preservationist definitions the aim of conservation is to maintain natural systems in 'natural equilibrium' [6,52], in 'natural homeostasis' [79], or under an adequate 'health condition.'

Nevertheless, as argued by many authors [85–87], we do not have a holistic ecological theory supporting the idea that natural biological systems tend towards homeostasis, single equilibrium points, fixed predicted balances, or stable environmental health states. On the contrary, nowadays there is substantial experimental ecological evidence showing that the Earth's diverse terrestrial, freshwater, and marine communities/systems show highly varied spatial and temporal dynamics and tend to move among multiple stable points ([83] and references therein). Moreover, 'resilience' [32,39,83,89] has emerged as a key concept in the analysis of the spatial and temporal dynamics of socio-ecological systems. In essence, resilience can be understood as the capacity of a system (individual, community, city, economy) to deal with change and to continue to develop. Thus, in my view, in the Anthropocene era, and particularly in the 21st century, the definition of conservation has to include: (a) the rational management of biophysical systems in the biosphere, within given social and economical constrains; (b) the production of ecosystem services for human well-being, without the depletion of the natural diversity of those ecosystems; and (c) an acknowledgement of the naturally dynamic character of these systems within resilience thresholds. Even though this definition still raises the critical question of what is meant by 'rational management,' it contrasts with the preservationist definition of conservation, in which no references are explicitly made to the natural dynamics and resilience of socio-ecological systems, nor to human requirements or socio-economic constraints.

The scale and aims of conservation, the roles of NGOs, sustainability, and equity. The scale at which conservation is pursued and its specific aims are critical issues in research programs and prioritization schemes. At a national level, there is always room for society to influence local legislation, scales, and mechanisms to be used in the implementation of conservation measures, and, above all, in conservation adaptive strategies. Generally speaking, national legislation determines how a particular society defines conservation, selects conservation objectives, and identifies the tools to be used to fulfill them. There are also international agreements establishing certain conservation objectives (e.g., the Ramsar Wetland Convention, the Convention on Biological Diversity). From this point of view, the definition of conservation (or the context in which the word is used) is critical. For instance, it would be substantially different if a country's legislation defined conservation exclusively in the terms set out in the Convention on Biological Diversity vs. the rational management of socio-ecological systems centered on ecosystem services for human well-being.

At a regional or global scale, private actors also influence conservation schemes in accordance with their own definitions of conservation. Non-governmental organizations (NGOs) in particular have specific aims and strategies and diverse conservation targets. For example, the declared mission of the Wildlife Conservation Society (WCS, one of the oldest of such organizations, 1895) is to save wildlife and wild places across the globe using science-based approaches. The WCS is committed to protect 25 % of the world's diversity. Education is seen as an important tool in this endeavor, as is the establishment of urban wildlife parks. The goals of the Nature Conservancy (1951) include conservation of the lands and waters on which all life depends. Its approaches include the acquisition of lands, partnerships with corporations, and community-based management. The World Wildlife Foundation (1961) seeks to build a future in which people live in harmony with nature. It specifies three main objectives: saving endangered species, protecting endangered habitats, and addressing global threats such as toxic pollution, overfishing, and climate change.

In these three examples, endangered species and habitats, wilderness, and biodiversity protection/conservation and education are the main aims of conservation. Typically, such organizations adopt the conservation and protection of an endangered flagship species (panda, Sumatran tigers, Asian elephants, orangutan, whales, sharks, corals, etc., and habitats they inhabit) as a central, but not exclusive, objective.

Moreover, other international, intergovernmental organizations, such as the World Bank [47] and the International Union for the Conservation of Nature (IUCN), focus, in one way or another, on conservation and development. The IUCN is one of the oldest of these organizations (established in 1948) and it offers a network of international forums for governments, NGOs, scientists, and local communities aimed at finding 'pragmatic solutions' for conservation and development. The conservation of biodiversity is central to the IUCN's mission; that is, conservation and sustainability at both the local and the global level. The IUCN builds on its own strengths in the sciences, which form the basis of actions intended to influence those of governments.

This is a short summary of the many angles from which conservation can be seen, interpreted, and prioritized. There are private, governmental, intergovernmental regional, international, as well as country- and local-level forms of conservation. Certainly, over the past two centuries there has been an evolution in the meaning, interpretation, and use of the concept of conservation; although the preservation of wildlife has been retained throughout, largely based on its public appeal. However, Raup [75] advised caution in the glorification of the 'wilder is better' paradigm [46].

Undoubtedly, during the Anthropocene era radical changes have affected Planet Earth: urbanization and mega-cities, the serious problem of global climatic change, an increase in the size of the human population, etc. These problems and their consequences will be with us for centuries to come. The Earth's population is past 7 billion inhabitants, poverty remains an enormous problem, the gap between 'rich and poor' has dramatically increased, and most of the Planet's ecosystem services have seriously deteriorated [59]. Latin America is case in point. It is one of the faster-growing developing regions of the world, where poverty has been substantially reduced in the past 20 years; nevertheless, in 2010, 32 % of the Latin American population still lived in conditions of poverty and 13 % in extreme poverty with almost 250 million people currently living around or below the poverty line. In today's world, this is inexcusable. Clearly, in Latin America efforts to relieve poverty assume priority as there is little hope for land and water conservation unless it is linked to human well-being. The challenge in Latin America, as elsewhere, is how to soundly combine development with the sustainable conservation of socio-ecological systems.

In 1992, the Earth Summit in Rio de Janeiro focused on conservation, sustainability, and poverty alleviation as the main targets for the next 20 years. Subsequent evaluations have shown that despite large increases in private, governmental, intergovernmental investments, and the implementation of numerous conservation/development strategies and conservation efforts in the past 20 years, conservation is failing ([84] and references therein). However, in the next Rio+20 Earth Summit 2012, the sustainability of the Earth, conservation targets, and poverty alleviation will be stressed once again, with no reason to believe that there will be any more success in the next than in the preceding 20 years. One of the mistakes is to continue overwhelmingly focusing on poverty alleviation, while failing to deal with the ever increasing wealth gaps in our societies. As Wilkinson and Pickett [95] pointed out: social problems, health, happiness, violence, illiteracy, well-being, a fairer future, and most probably also environmental sustainability, are determined not by how wealthy a society is, but how equal it is. Accordingly, the concept of conservation must be intrinsically linked to sustainable development and human well-being and applied within the triad of scientific, societal, and ethical grounds. This is the real challenge for the Anthropocene era; however, world leaders able to meet it are nowhere to be found.

Exploring the options during the later phases of the Anthropocene era

A way out: Deep ecology. Arne Naess [64], in 1973, at a conference in Romania, introduced the concept of 'deep ecology.' His central argument was that the main reaction of environmental sciences to the problems following World War II was, at best, remedial, aimed only at controlling the symptoms through the use of technology, especially with respect to the control of pollution and the efficient exploitation of natural resources. He characterized this scientific approach as 'shallow ecology.' According to Naess, efforts to address the social and cultural aspects underlying environmental problems had failed, and hence the profound causes of environmental degradation were not being tackled. To overcome this failure, he proposed a deep ecology approach, i.e., one not limited to focusing on the symptoms of environmental problems but which also examined the underlying socio-cultural causes of the environmental crisis. His solution was not a simple proposition, since its framework criticized the environmental/scientific and philosophical/metaphysical values underlying political systems, as well as the life styles and, above all, the ethical values of post World War II industrial society. Deep ecology was based on seven central principles: rejected anthropocentric thought, called on biospherical egalitarianism and environmental symbiosis, presented an anti-class posture, included fighting against pollution and resource depletion, and promoted local autonomy and decentralization. In Naess' view, these principles should guide a new life style. While the principles are rather general they have, nevertheless, inspired the deep ecology movements and the actions of some governments [80]. However, the Anthropocene era norms of life as set out by Naess are much easier to implement and more accessible in socioeconomically developed societies than in developing ones; including those with substantial portions of the population living close to or below the poverty line. The poor are undoubtedly more dependent on ecosystems services (and biodiversity), have less freedom with respect to their ability to adopt a deep ecology life style, and are more vulnerable to the consequences of environmental degradation.

Yet, many of Naess' principles were fully practiced in pre-Anthropocene traditional cultures, in which, for instance, the satisfaction, pleasure, and joy of being, as humans, an integral part of nature formed part of the vision of the cosmos expressed by these cultures and was essential in their local ecological knowledge. By contrast, particularly in the Occident, the Anthropocene era has been largely marked by a loss of our primordial vision. But, does this mean that we have to go far back in our histories to sustain, protect, and conserve socio-ecological systems, for ourselves and for future generations?

Another way out: The Millennium Ecosystem Assessment Project and the Program on Ecosystem Change and Society. In the Millennium Ecosystem Assessment (MA) project [59], alternative or complementary ways to approach conservation and sustainability on Earth were suggested. This project [60] is an outgrowth of a program that was implemented following the 2000+5 World Summit on Sustainable Development (WSSD, Geneva) in order to fulfill the terms of the United Nations Millennium Development Plan. The project was launched by then UN Secretary-General Kofi Annan in June 2001. More than 1200 scientists, from numerous branches of knowledge and 100 different nations, participated in the 4-year project.

The WSSD called for "... improve[d] policy and decision-making at all levels through, inter alia, improved collaboration between natural and social scientists, and between scientists and policy makers, including through urgent actions at all levels to: (a) increase the use of scientific knowledge and technology, and increase the beneficial use or local and indigenous knowledge in a manner respectful of the holders of that knowledge and consistent with national law; (b) make greater use of (environmental) integrated scientific assessment, risk assessments and interdisciplinary and intersected approaches…". In the final analysis, societies need to be enabled to rationally manage their biological resources and their ecosystems, using the resources at hand. In summary, the objectives were to elucidate ways and mechanisms by which sustainability, conservation, and the management of socio-ecological systems could be improved throughout the world.

MA 2003 [59] provided a framework for decision-makers that had as its central, driving concept the achievement of human well-being. Interestingly, the goal of the MA was to amalgamate two extreme ethical environmental positions: anthropocentrism (nature for people) and biocentrism (nature for nature's sake). Although in the philosophical approach of the MA human well-being is at the center of the model, the intrinsic value of nature is also recognized as is the awareness in the conservation and sustainability of socio-ecological systems, and efforts that need to be be made to balance the two, since nature and human well-being can be seen to be in a permanent state of interaction.

In spite of the lack of robust models and a theoretical basis to link diversity, ecosystem dynamics, ecosystem services, resilience, and above all the underlying connections with human well-being, the MA used the concept of 'ecosystem services and human well-being' to carry out a multi-disciplinary analysis of environmental and sustainability assessments. An ecosystem is a biophysical dynamic complex of plant, animal, and microbial communities that interact with the nonliving environment as a functional unit. Ecosystems provide numerous services to people: *provisioning services* (fish, water, fuel, resources), *regulating services* (air quality, erosion control, water purification), *cultural services* (spiritual enrichment, reflection recreation, aesthetic experiences), and *supporting services* (soil formation, primary production, oxygen production) [60]. Ecosystem services can be used as proxies to understand and support practical conservation measures as well as sustainability and economic development [92]. They provide practical tools to approach the natural capital assets connected with life-supporting services and human well-being [16,26,34,40].

Most of the ideas discussed above were synthesized and further developed, in a wider sustainability dimension, by the MA project [9,65]. Recently the Program on Ecosystem Change and Society (PECS) [10] launched an initiative designed to build on the goals of the MA, with the guiding vision of "a world where human actions have been transformed towards stewardship of social-ecological systems for global sustainability." Once again, the critical concept here is that ecosystem services are not generated by natural (human-less) ecosystems in themselves but instead by socio-ecological systems functioning at local to global scales [24]. Interestingly, a comprehensive exercise (2009–2011) was carried out by the UK regarding the state of its natural environments and ways to estimate national wealth, in terms of the benefits nature provides to society and to continuing prosperity, based on an ecosystem services approximation [94] .

Therefore, following the leadership of the MA and PECS, the 21st century definition of conservation should be linked with the utilitarian tool of ecosystem services (see objections to this view in Odling-Smee [66]) and used for the identification and evaluation of the dynamics of socio-ecological systems and the interactions, feedback, and trends therein. This will allow conservation and environmental sustainability objectives to be jointly approached via the characterization, determination, and evaluation of ecosystems services, for the long-term sustainability and improvement of human well-being in a particular area of the environment and considering the resilience of socio-ecological systems [54]. Indeed, the sustainability of these systems must go hand in hand with development, and conservation.

Under the umbrella of an Anthropocene era, Earth conservation approaches will need to be based more than ever on the triad of ecological, societal, and ethical variables. In this setting, the private sector must assume a key role, as new visions and approaches are needed. Sanderson [82] proposed new conservation approaches based on global alliances, the use of novel political strategies, and economic development. As a case in point, the new, privately owned preserve Karukinka (680,000 acres) in Tierra del Fuego, Chile, provides an example of the comprehensive implementation of this approach, in which the WCS has discretion (in accordance with the Chilean government) to manage Karukinka accordingly [2].

Several papers and reviews have been written since the MA ended [8,10,46,67,70,73]. These have stressed the need to apply some of the tools developed in the MA initiative, such as accounting and market approaches [35,81], but above all highlighted the need for progress by focusing on a comprehensive trans- and interdisciplinary understanding of complex socio-ecological systems and the critical role of resilience [7,83,89].

Conservation priorities and a personal view of the priorities of conservation: What, where and how?

In the conservation arena, the questions of what, where, and how are critical, but their possible answers often turn out to be highly polarizing and controversial. Once again, this is due to the fact that 'conservation' is an operational concept rooted in multiple (environmental ethical, scientific, and societal) approaches [85]. For instance, at global scales, biodiversity conservation priority templates have been identified within the framework of irreplaceability, prioritizing either low or high species vulnerability (reactive or pro-active approaches, respectively) [4)]. In addition, biodiversity conservation strategies and priorities based on the idea of biodiversity 'hotspots' [62] or on biogeographic spatial units ('ecoregions') have been proposed. The two approaches have had only limited successes and have generated many controversies [4,5,36,53,66]. Furthermore, it must be pointed out that global conservation approaches refer mostly to terrestrial systems, while aquatic systems figure very poorly [68,78]. There is also a complementary need to identify conservation targets at site-specific scales [77] and to include, both at the land and seascape scale, elements of conservation connectivity targeting the spatial structure of ecosystems.

In the following, I explore two extreme views for conservation priorities and what, where, and how to conserve. At one extreme is the popular view that the main answer to these questions must focus on highly charismatic and culturally important species in danger of extinction (and their respective habitats), or on species whose populations have been dramatically reduced due to direct or indirect human interventions (panda, elephants, sharks, corals, birds, tigers, great apes, whales, etc.; in many cases the lists suspiciously contain mammals that are very appealing to humans). In this view, the priorities and objectives of conservation are to recuperate or to stop the deterioration of these populations and to preserve them for present and future generations. It recognizes that the substitution of these species is not possible and in several countries legislation has acknowledged their intrinsic value. In these cases, a recurrently used conservation tool is the establishment of parks or reserves. Many NGOs have adopted these approaches and progress has been made, particularly in cases in which conservation has been scientifically based. Nonetheless, the need for the injection of large amounts of money cannot be ignored [66]. Certainly, this is a necessary aspect of nature conservation, but the conservation of flagship species only partially answers the original questions. In fact, it is unlikely that the conservation of charismatic species is the most urgent and critical conservation challenge to be tackled nowadays.

At the other extreme, the view is that the aim of conservation is the conservation of complete ecosystems as well as ecological services for human well-being. This view is subject to different interpretations, most typically 'nature–human-less' ecosystems, which simply do not exist, and socio-ecological systems, which have been widely explored in the past 10 years [59,94]. Followers of this approach argue that natural ecosystems provide a variety of goods and important services to humanity that are of social and economic value to its well-being, but many of these services are being degraded. According to MA 2005 [60], 60 % of ecological services on the Planet are already degraded. Therefore, it is a matter of urgency and priority to focus on these services and the whole systems that deliver them. This is a very challenging conservation road map for the future.

Conservation and social-ecological systems. Governance, sustainability, and the management of socio-ecological systems

Environmental sustainability and/or the conservation of socio-ecological systems needs to be framed, locally or globally within societal schemes of governance [49]; that is, at the local or international scale, where the established arrangements take on a prominent role in the governability scheme. This applies not only to state, government, regional, international, and global organizations but also to markets, education, civil society, institutions, and media [41,50]. There are a handful of successful examples in connection with the protection of resources and environments, based on agreed global/international governance schemes; for instance, in the regulation of the use of chlorine and the protection of the ozone layer as stated in the Montreal Protocol. But not all global/international governance is effective. As an example, global governance schemes for the sustainability, conservation, and rational exploitation of the oceans' renewable resources have been impossible to implement at a global scale [3,63,69,71,72,96].

In effect, the world fishery crisis has shown that in most places of the world governance schemes for local and global fishery have either failed or are highly inadequate [27,28]. Nevertheless, in coastal fishery there are a handful of success examples in which the sound governance of socio-ecological systems has led to the sustainability and conservation of coastal marine resources in indigenous/local communities in which there is still a 'sea-going-culture,' including a deeply rooted sea tenure and self-governing ethical values in the respective societies [17,21,22,27,31,42–44].

Can governance schemes, conservation, and the rational use of resources and ecosystem services be approached not only at local scale, for example in small-traditional sea-going societies, but also at a larger scale, for instance at country scale? Are there examples of the right combination of science, local knowledge, and political will that together result in more rational governance ecosystem schemes and lead to adequate socio-ecological fishery management, resource sustainability, and conservation outcomes?

A case study. Socio-ecological conservation and the sustainability of coastal marine resources in Chile: the tragedy of the commons and positive externalities

In 1968, Hardin [38] published a seminal paper titled "The tragedy of the commons," highlighting two major human factors driving environmental changes and altering ecosystem resilience. The first was the constantly increasing demand for natural resources and environmental services, linked with the exponential growth of the human population. The second was the risk of overexploitation of natural resources under common pool property. Hardin's article described the situation that arises when common pool resources must be shared for which property rights do not exist or are very limited; for example, sea resources, air, biodiversity, and, in some countries, fresh water. Hardin [38] suggested that human societies were doomed to eventually overexploit common pool resources unless two coercive alternatives for management and sustainability were imposed: (a) the institutionalization of private property on common pool resources, (b) control on these resources via top-down centralization by the government. Hardin's article has been widely criticized due to the oversimplification represented by his claims that only two state-established institutional arrangements can solve the commons dilemma: centralized government tools and private property ([29] and see also the series of articles on common pool resources in Science 2003, 302:1906-1929), while obviously, others are likely to be available.

Chile, at the end of 1980, faced serious socio-ecological problems regarding its fisheries derived from the tragedy of the commons. Common pool coastal marine resources (the first 5 miles offshore) had been exploited for more than four decades under an open access fishery regime. This, in conjunction with the adoption of neoliberal policies, trade liberalization, privatization, and incentives for exporting renewable resources, under a dictatorial regime [11,34], resulted in the severe overexploitation of coastal marine resources [12–15,18). Furthermore, conflicts had arisen regarding spatial coastal interferences occurring among and between small-scale artisan and industrial fleets.

The sustainability and conservation of coastal marine resources in Chile was tackled using new legislation, and scientific and local knowledge. The Fishery and Aquaculture Law (FAL Nº. 18.892, 1991) included the implementation of previously unthinkable fishery management and conservation tools, many of which were designed to solve the tragedy of the commons. Of major importance to coastal marine resources was the implementation of sea zoning and the allocation to fishery fleets and/or to local communities exclusive-access fishing rights. For instance, the FAL decreed three major sea-zoning schemes along Chilean maritime territories: (a) artisan exclusive zones (AEZ), comprising zones of 5 nautical miles and extending along ~2500 km of the coast line and around oceanic islands, covering approximately 30,000 km^2, for the exclusive use of the artisan small-scale fleet. Exclusive rights to fish were allocated for all species (pelagic, benthic [18]); (b) inside the AEZ, in inshore shallow waters, the FAL decreed exclusive territorial use rights for fisheries (TURFs) for benthic resources, accessible exclusively by organized small-scale fisher communities. These management and exploitation areas for benthic resources (MEABRs) function under a co-management scheme [12,17–20,23,27,34]; (c) finally, the FAL also mandated the creation of restricted fishery zones to protect reproductive stocks (genetic reserves), areas for re-stocking, and marine parks to preserve ecological units of scientific interest.

Recently, two papers [18,34] analyzed the results of this fishery governance, administration, and conservation polices implemented in Chile over the past 20 years. Both found that the 1991 Chilean fishery governance reforms stabilized many fishery landings (mainly those of benthic resources), with a major reduction of the industrial fleet, a possible slow-down in the 'olympic race for fish,' and above all improved bottom-up governance structures, such as those related to resource tenure systems and exclusive fishery rights. While Chile had abused critical social-ecological fishery thresholds during the open access fishery regime, a partial recovery was achieved after the implementation of the 1991 fishery legislation, particularly in coastal socio-ecological systems. Nevertheless, especially in the industrial Chilean fishery sector, governance and management problems remain to be solved [51].

However, when the present socio-ecological status of coastal fisheries in Chile is contrasted with that previous to the 1991 legislation, the results are encouraging. Further, in the case of coastal small-scale fisheries at least three positive external benefits have derived from the implementation of the new governance and the co-management policies: (a) positive influences on environmental/conservation perceptions by local fishers [33]; (b) add-on conservation (biodiversity) benefits linked to fishery areas managed by artisan communities as TURFs [33]; (c) consolidation of bottom-up governance and co-management, such that fishers' organizations have been fostered as well as the development of diverse and complex co-management social networks. The engagement of fishers in the MEABR system has been associated with horizontal and vertical linkages that enable the exchange of assets and information, both of which are critical for the functioning of co-management [56]. Recent research found positive and strong correlations between the collaborative and trustworthy relations between fisher organizations and the various stake-holders, on the one hand, and co-management of social and ecological performance, on the other. The MEABR policy stopped the tragedy of ungovernable resource users and developed a platform allowing social capital and other organizational skills to become important aspects of resource exploitation and conservation [37,57]. More and better connected organizations now improved the chances of obtaining sustainable outcomes. This is a practical example of how sustainability and conservation of a social-ecological system can be approached. Fishery is typically a provisioning ecosystem service and the case study of Chilean coastal fisheries has shown how, via the implementation of novel top-down and bottom-up governance structures, progress can be made regarding resource sustainability and conservation: basically by engaging and empowering stake-holders directly in the management and governance systems. This is another example of how Hardin's tragedy of the commons can be resolved using novel governance structures and non-coercive scenarios.

Conservation/sustainability is the playing field where natural systems (humans included) and human well-being are in constant action, with humans determining rational or non-rational approaches to the game to ensure its continuation. In fact, there is a multiplicity of human-constrained socio-ecological systems, and not just ecological (human-less) systems, in need of adequate governance.

Last but not least, in this Anthropocene era one of the most appropriate ways to approach and solve socio-ecological conservation, environmental, and sustainability problems is, as discussed to above, to incorporate resilience theory [83] and engage people (users, stake-holders) in the design, operation, and implementation of solutions. It is difficult to imagine how top-down conservation procedures (at local, national or international levels) can succeed under scenarios in which a very large number of the Earth's inhabitants live in domesticated urban environments [46]: at present about 50 % of the world population, and in 2050 as high as 60 %. Rather, the alleviation of poverty will continue to be an ethical challenge, particularly for developing nations. In the future, environmental education would play a larger role in conservation, since in the Antropocene era we are becoming increasingly dependent on younger generations 'assuming the Anthropocene' and on the use of technological advances to solve socio-ecological problems. Previous, romantic notions of conservation are no longer valid, as conservation is now more appropriately viewed as a challenge of the Anthropocene era [45,90] (this essay). Most fortunately, the impressive and astonishing ways in which communication technology in the Anthropocene era has developed over the past two decades may lead to a shift that favors humanity.

Finally, already in 1993 Professor Ramon Margalef, in the second edition of his book *Teoría de los Sistemas Ecológicos* [55], page 152, visualized and described the complex interplay among humans and nature. Almost 20 years years later, some of the central elements of this essay are very much in line with Margalef's views.

"Population builds up in the cities and people, goods, assets and information flow in between populations and over rural areas. Exploited rural areas have a tendency to be large and disconnected between them. The same as rich phytoplankton patches that provide food to vast oceanic regions. At cultivated areas, as exploitation pressure increases, the original matrix of nature is eroded and reduced to tinny fragments and shrubs hedges, and its disappearance is a crucial blow to nature and species conservation. Cities and communication infrastructure between them are transportation systems comparable both to lumber, roots and fungus of forests and also to the rich matrices of pelagic zooplankton. The energy and information transport capacity of these matrices are substantially different, due to the greater dynamism shown by mature natural matrices. The coordination between both kinds of matrices can be as difficult as matching terrestrial and river fractals. Civilization development is linked to the deterioration of mature natural matrices, of a rather static characteristic, and to the development of human communication matrices. Nevertheless, the aspiration of conservation may plausibly combine both trends; making use, for instance, of abandoned fragments of landscape and communication routes so to maintain a minimum reserve of no excessively exploited natural systems" (free translation by the author of the essay).

Acknowledgements. This paper is dedicated to the memory of Professor Ramon Margalef, whose work and life inspired young scientists in Latin America. I most sincerely thank the *Generalitat de Catalunya* (Autonomous Government of Catalonia) for awarding me the *Premi Ramon Margalef d'Ecologia 2011*. This paper has served several purposes, but one of them has been to reinforce friendships with my colleagues Peter Kareiva, Andres Marín, Stefan Gelcich, and Omar Defeo. Once again, I have learned much from them. Financial support received from the Arauco Chair in Ecology and Environmental Ethics and the Marine Conservation Millennium Nucleus–Pontifical Catholic University of Chile are gratefully acknowledged.

Professor Juan Carlos Castilla, recipient of the Ramon Margalef Prize in Ecology 2011, pronounced the lecture entitled "Conservation and social-ecological systems in the 21st century of the Anthropocene era," on 26 October 2011 in Barcelona.

Premi RAMON MARGALEF d'ecologia

The Autonomous Government of Catalonia created the Ramon Margalef Prize in Ecology to honor the memory of the Catalan scientist Ramon Margalef (1919–2004), one of the main thinkers and scholars of ecology as a holistic science, and whose contribution was decisive to the creation of modern ecology. This international award recognizes those people around the world who have also made outstanding contributions to the development of ecology science. More information can be obtained at: www.gencat.cat/premiramonmargalef.

References

1. Allaby M (2005) Dictionary of Ecology. Oxford University Press, Oxford
2. Amrock J (2006) Challenges for private sector conservation: the future of conservation in Tierra del Fuego. Indiana Journal of Global Legal Studies 13:595-615
3. Botsford L, Castilla JC, Peterson CH (1997) The management of fisheries and marine ecosystems. Science 277:509-515
4. Brooks TM, Mittermeier RA, da Fonseca GAB, Gerlach J, et al. (2006) Global biodiversity conservation priorities. Science 313:58-61
5. Brummitt N, Lughadha EN (2003) Biodiversity: where's hot and where's not. Conservation Biology 17:1442-1448
6. Callicott JB (1989) In defense of the land ethics. Essays in environmental philosophy. State University of New York Press, Albany
7. Carpenter SR, Walker BH, Anderies JM, Abel N (2001) From metaphor to measurement: resilience of what to what? Ecosystems 4:765-78
8. Carpenter SR, DeFries R, Dietz T, Mooney HA, et al. (2006) Millennium ecosystem assessment: research needs. Science 314:257-258
9. Carpenter SR, Mooney HA, Agard J, Capistrano D, et al. (2009) Science for managing ecosystem services: beyond the Millennium ecosystem assessment. PNAS 106:1305-1312
10. Carpenter SR, Folke C, Norström A, Olsson O, et al. (2012) Program of ecosystem change and society: an international research strategy for integrated social ecological systems. Current Opinion in Environmental Sustainability 4:134-138
11. Castilla JC (1990) Clase Magistral: importancia y proyección de la investigación en ciencias del mar en Chile. Revista de Biologia Marina 25:1-18
12. Castilla JC (1994) The Chilean small scale benthic shellfisheries and the institutionalization of new management practices. Ecology International Bulletin 21:47-63
13. Castilla JC (1995) The sustainability of natural renewable resources as viewed by an ecologist and exemplified by the fishery of the mollusc *Concholepas concholepas* in Chile. In: Munasinghe M, Shearer W (eds) Defining and measuring sustainability. United Nations University and The World Bank, Washington DC, pp. 155-160
14. Castilla JC (1996) The Chilean dived-invertebrate resources: fishery, collapses, stock rebuilding and the role of coastal management areas and national parks. In: Hancock DA, Smith DC, Grant A, Beumer JP (eds) Developing and sustaining world fisheries resources: the state of science and management. Proceedings of the Second World Fisheries Congress, Brisbane, Australia. CSIRO Publishing, Melbourne, pp. 130-135
15. Castilla JC (1997). The sustainable use of marine coastal resources in Chile: co-management and the artisanal fishing community scale. Proceedings of the Third World Academy of Sciences, USA, 6th General Conference, Rio de Janeiro
16. Castilla JC (2005) Un ensayo sobre ecosistemas, servicios, biodiversidad y bienestar humano en el ámbito marino y aproximaciones hacia valorizaciones económicas. In: Figueroa E (ed) Biodiversidad Marina: valoración, usos y perspectivas ¿Hacia dónde va Chile? Editorial Universitaria SA, Santiago, pp. 571-581
17. Castilla JC, Defeo O (2001) Latin American benthic shellfisheries: emphasis in co-management and sustainable use of benthic invertebrates. Review Fish Biology and Fisheries 11:1-30
18. Castilla JC (2010) Fisheries in Chile: small pelagics, management, rights, and sea zoning. Bulletin of Marine Science 86:221-234
19. Castilla JC, Defeo O (2005) Paradigm shifts needed for world fisheries. Science 209:1324-1325
20. Castilla JC, Fernández M (1998) Small-scale benthic fisheries in Chile: on co-management and sustainable use of benthic invertebrates. Ecological Applications 8:S124-S132
21. Castilla JC, Gelcich S (2006) Chile: experience with management and exploitation areas for coastal fisheries as building blocks for large-scale marine management. In: Hatziolos M, Cordell J, Chrietie P, Castilla JC, Gelcich S

(eds) Scaling up marine management: the role of marine protected areas. The World Bank Publication, Washington DC
22. Castilla JC, Gelcich S (2008) Management of the loco (*Concholepas concholepas*) as a driver for self-governance of small-scale benthic fisheries in Chile. In: Townsend R, Shotton R, Uchida H (eds) Case studies in fisheries self-governance. FAO Fisheries Technical Paper 504, Food and agriculture organization of the United Nations, Rome
23. Castilla JC, Manríquez P, Alvarado J, Rosson A, et al (1998) Artisanal "caletas" as units of production and co-managers of benthic invertebrates in Chile. In: Jamieson GS, Campbell A (eds) Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management, Canadian special publication, Fisheries and Aquatic Science 125:407-413
24. Chapin FS, Carpenter SR, Kofinas GP, Folke C, et al. (2010) Ecosystem stewardship: sustainability strategies for a rapidly changing planet. Trends in Ecology & Evolution 25:241-249
25. Crutzen PJ, Stoermer EF (2000) The Anthropocene. Global Change Newsletter 41:17-18
26. Daily GC, Matson PA (2008) Ecosystems services: from theory to implementation. PNAS 105:9455-9456
27. Defeo O, Castilla JC (2005) More than one bag for the world. Fishery crises and keys for co-management success in selected artisanal Latin American shell fisheries. Review Fish Biology and Fisheries 15:265-283
28. Defeo O, McClanahan TR, Castilla JC (2007) A brief history of fisheries management with emphasis on societal participatory roles. In: McClanahan TR, Castilla JC (eds) Fisheries management, progress towards sustainability. Blackwell Publishing, Oxford
29. Dietz T, Ostrom E, Stern PC (2003) The struggle to govern the commons. Science 302:1907-1912
30. Emerson RW (1836) Nature. James Munroe and Co., Penguin, Boston
31. Ernst B, Manríquez P, Orensanz JM, Roa R, Chamorro J, Parada C (2010) Strengthening of a traditional territorial tenure system through protagonism in monitoring activities by lobster fishermen from the Juan Fernández Islands, Chile. Bulletin of Marine Science 86:315-338
32. Folke C (2006) Resilience: the emergence of a perspective for social-ecological systems analyses. Global Environmental Change 16:253-267
33. Gelcich S, Kaiser MJ, Castilla JC, Edwards-Jones G (2008) Engagement in co-management of marine benthic resources influences environmental perceptions of artisanal fishers. Environmental Conservation 35:36-45
34. Gelcich S, Hughes TP, Olsson P, Folke C, et al. (2010) Navigating transformations in governance of Chilean marine coastal resources. PNAS 107:16794-16799
35. Gelcich S, Peralta, L, González C, Camaño A, Fernández M, Castilla JC (2011) Scaling-up marine coastal biodiversity conservation in Chile: a call to support and develop ancillary measures and innovative financing approaches. In: Figueroa E (ed) Biodiversity conservations in the Americas: lessons and policy recommendations, Editorial Fen-Universidad de Chile, Santiago
36. Grenyer R, Orme CDL, Jackson SF, et al. (2006) Global distribution and conservation of rare and threatened vertebrates. Nature 442:93-96
37. Gutiérrez NL, Hilborn R, Defeo O (2011) Leadership, social capital and incentives promote successful fisheries. Nature 470:386-389
38. Hardin G (1968) The tragedy of the commons. Science 13:1243-1248
39. Holling CS (1986) The resilience of terrestrial ecosystems: local surprise and global change. In: Clark WC, Munn RE (eds) Sustainable development of the biosphere. Cambridge University Press, England
40. Jack BK, Kousky C, Sims KRE (2008) Designing payments for ecosystem services: lessons from previous experience with incentive-based mechanisms. PNAS 105:9465-9470
41. Jentoft S, Chuenpagdee R (2009) Fisheries and coastal governance as a wicked problem. Marine Policy 33:553-560
42. Johannes RE (1978) Traditional marine conservation methods in Oceania and their demise. Annual Review Ecology and Systematics 9:349-364
43. Johannes RE (1998) Government-supported village-based management of marine resources in Vanuatu Ocean Coastal Mangemenet 40:165-186
44. Johannes RE (2002) The renaissance of community-based marine resource management in Oceania. Annual Review Ecology and Systematics 33:317-340
45. Kareiva P, Marvier M (2007) Conservation for the people. Scientific American 297:50-57
46. Kareiva P, Watts S, McDonald R, Boucher T (2007) Domesticated nature shaping landscapes and ecosystems for human welfare. Science 316:1866-1868
47. Kareiva P, Chang A, Marvier M (2008) Development and conservation goals in world bank projects. Science 321:1638-1639
48. Kareiva P, Lalasz R, Marvier M (2011) Conservation in the Anthropocene. In: Shellenberg M, Nordhaus T (eds) Love your monsters: Post-environmentalism and the Anthropocene. Breakthrough Institute, Oakland CA
49. Kersbergen K, Van Waarden F (2004) Governance as a bridge between disciplines: cross-disciplinary inspiration regarding shifts in governance and problems of governability, accountability and legitimacy. European Journal of Political Research 43:143-171
50. Kooiman J, Bavink M, Chuenpagdee R, Mahon R, et al. (2008) Interactive Governance and Governability: an Introduction. Journal Transdisciplinary Environmental Studies 7:1-10
51. Leal CP, Quiñones RA, Chávez C (2010) What factors affect the decision making process when setting TACs? The case of Chilean fisheries. Marine Policy 34:1183-1195
52. Leopold A (1949) A Sand county almanac, and sketches here and there. Oxford University Press, New York

53. Mace GM, Balmford A, Boitani L, Cowlishaw G, et al. (2000) It's time to work together and stop duplicating conservation efforts. Nature 405:393
54. Mäler K-G, Aniyar S, Jansson A (2008) Accounting for ecosystem services as a way to understand the requirements for sustainable development. PNAS 105:9501-9506
55. Margalef R (1993) Teoría de los sistemas ecológicos. Publicacions Universitat de Barcelona, Barcelona
56. Marín A, Berkes F (2010) Network approach for understanding small-scale fisheries governance: the case of the Chilean coastal co-management system. Marine Policy 34:851-858
57. Marín A, Gelcich S, Castilla JC, Berkes F (2012) Exploring social capital in Chile's coastal benthic co-management system using a network approach. Ecology and Society 17:13
58. Marx KH, Engels F (1846) Die Deutsche ideology (first published 1932) Progress Publishers, 1968 (Transcription by Delaney and Swartz, version online Marx/Engels, internet Archive (Marxist.org, 2000)
59. Millennium ecosystem assessment (2003) Ecosystem and human well-being: A framework for assessment. Island Press, Washington DC
60. Millennium ecosystem assessment (2005) Ecosystems and human well-being: synthesis. Island Press, Washington DC
61. Muir J (1912) The Yosemite. The Century Co., NewYork
62. Myers N (1988) Threatened biotas: "hot-spots" in tropical forests. The Environmentalist 8:187-208
63. Myers R, Worm B (2003) Rapid worldwide depletion of predatory fish communities. Nature 423:280-283
64. Naess A (1973) The shallow and the deep, long-range ecology movement. A summary. Inquiry 16:95-100
65. Naidoo R, Balmford A, Costanza R, Fisher B, et al. (2008) Global mapping of ecosystems services and conservation priorities. PNAS 105:9495-9500
66. Odling-Smee L (2005) Dollars and sense. Nature 437:614-616
67. Olsson E (2009) A general framework for the analyzing of sustainability of social ecological systems. Science 325:419-422
68. Olsson DM, Dinerstein E (1998) The Global 2000: a representation approach to conserving the Earth's most biologically valuable ecoregions. Conservation Biology 12:502-515
69. Pauly D, Christensen V, Guénette S, Pitcher TJ, et al. (2002) Towards sustainability in world fisheries. Nature 418:689-695
70. Ostrom E (2009) A general framework for analyzing sustainability of social ecological systems. Science 352:419-422
71. Pauly D, Christensen V, Dalsgaard J, Froese R, et al. (1998) Fishing down marine food webs. Science 279:860-863
72. Pauly D, Alder J, Bennett E, Christensen V, et al. (2003) The future of fisheries. Science 302:1359-1361
73. Proceedings of the National Academy of Science, USA (2008) Ecosystem Services. Special feature 105:9455-9506
74. Proceedings of the National Academy of Science, USA (2009) Tipping elements in earth systems. Special feature 106:20561-20621
75. Raup H (1979) Beware of conventional wisdom. Western Wildlands 5(3):2-9
76. Riechmann, J (2005) Introducción: Aldo Leopold, los orígenes del ecologismo estadounidense y la ética de la tierra. Introducción a "Una Ética de la Tierra", Colección Clásicos del Pensamiento Crítico. Libros de la Catarata, Madrid, pp. 7-35
77. Ricketts TH, Dinerstein E, Boucher T, Brooks TM, et al. (2005) Pinpointing and preventing imminent extinctions. PNAS 102(51):18497-18501
78. Roberts CM, McClean CJ, Veron JEN, Hawkins JP, et al. (2002) Marine biodiversity hotspots and conservation priorities for tropical reefs. Science 295:1280-1284
79. Rolston H (1988) Environmental ethics. Duties and values in the natural world. Temple University Press, Philadelphia
80. Rozzi R (2007) Ecología superficial y profunda: filosofía ecológica. Revista Ambiente y Desarrollo 23(1):102-105
81. Salzman J (2005) Creating markets for ecosystems services. Notes from the field. NYU Law Review 80:870-961
82. Sanderson S (2002) The future of conservation. Foreign Affairs 81:162-173
83. Scheffer M (2009) Critical transitions in nature and society. Princeton studies in complexity. Princeton University Press
84. Shellenberger M, Nordhaus T (eds) (2011) Love your monsters: post-environmentalism and the Anthropocene. Breakthrough Institute, Oakland CA
85. Shrader-Frechette K (2011) Ecología y ética ambiental. In: "Valores y ética para el siglo XXI". Edición BBVA, España, pp. 387-421
86. Shrader-Frechette K, McCoy E (1994). Applied ecology and the logic of case studies. Philosophy of Science LXI (1): 228-249
87. Sober E (2006) Evolution, population thinking and essentialism. In: Sober E (ed) Conceptual issues in evolutionary biology. MIT Press, Cambridge, MA, pp. 329-363
88. Steffen W, Grinevald J, Crutzen P, McNeill J (2011) The Anthropocene: conceptual and historical perspectives. Philosophical Transactions of the Royal Society A 369:842-867
89. Steffen W, Person A, Deutsch, L Zalasiewicz J, et al. (2011) The Anthropocene: from global change to planetary stewardship. Ambio 0044-7447. doi: 10.1007/s13280-011-0185-x
90. Syvitski J (2012) Anthropocene: An epoch of our making. Global Change Issue 78:12-15
91. Syvitski J, Kettner A (2011) Sediment flux and the Anthropocene. Philosophical Transactions of the Royal Society A 369:957-975
92. Tallis H, Kareiva P, Marvier M, Chang A (2008) An ecosystem services framework to support both practical conservation and economic development. PNAS 105:9457-9464

93. Thoreau HD (1854) Walden or Life in the Woods. Ticknor and Fields, Boston, MA
94. UK National Ecosystem Assessment (2011) The UK national ecosystem assessment synthesis of the key findings. UNEP-WCMC, Cambridge
95. Wilkinson R, Pickett K (2010) Why equality is better for everyone. Penguin Books, England
96. Worm B, Barbier EB, Beaumont N, Duffy JE, et al. (2006) Impacts of biodiversity loss on ocean ecosystems services. Science 314:787-790
97. Zalasiewicz J, Williams M, Steffen W, Crutzen P (2010) The new world of the Anthropocene. Environmental Science and Technology 44:2228-2231