Chapter 23
Ecology and Education in Marine Protected Areas: Insights from Brazil and South America

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Abstract South American coastal habitats include a wide range of benthic ecosystems, many of which are unique and constitute hotspots of biodiversity. Marine protected areas (MPAs), instituted mostly during the second half of the twentieth Century, are considered a key management tool to conserve regional biodiversity, prevent overexploitation, and generate economic benefits. Educational actions to promote changes in basic values, principles, and attitudes – although considered also as a main objective – frequently have a poor conceptual basis. In conjunction

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with the evaluation of their effectiveness by long-term, site-based ecological and socio-economic research, in Brazil MPAs are aiming to implement a holistic approach. This will allow the development and testing of environmental practices that integrate ecology, economy, ethics, and conflict resolution in the different uses of marine space. However, ecological long-term studies, socio-economic long-term evaluation, and the integration of education and ethics are still incipient. With the recent creation of some independent networks in different South American countries related to the assessment of biological communities, marine biologists of this continent are now focusing more on: (1) sharing methodologies and data to allow comparative and integrated continental analyses, and (2) integrating social components, including not only economic but also ethical values and participatory approaches. Toward this aim, the Chilean Long Term Socio- Ecological Research network (LTSER-Chile) has developed a Field Environmental Philosophy program that could be adapted to MPAs educational programs, and also contribute to the integration of ecology and ethics in theory and praxis for an Earth Stewardship initiative.

Keywords Benthic ecosystems • Environmental education • Long term research • Marine protected areas • Monitoring

23.1 Marine Protected Areas (MPAs) in South America

South American coastal habitats include a wide range of benthic ecosystems, many of which are unique and constitute hotspots of biodiversity (Miloslavich et al. 2011), such as the kelp forests on the Cape Horn Biosphere Reserve and the coral reefs of the Tropical Atlantic. These ecosystems can occupy extensive areas, such as the rhodolith beds and mangrove forests along the Tropical Southwestern Atlantic. In addition to global threats imposed by Global Environmental Change (GEC), these ecosystems are endangered by local and regional stressors, thereby risking a series of ecosystem services provided by them (Turra et al. 2013; see Orenstein and Groner 2015 in this volume [Chap. 18]).

The time for mitigating GEC is over, and the application of adaptation measures has come to the forefront (Heffernan 2012). The past decade presented an exceptional number of unprecedented extreme weather events (Coumou and Rahmstorf 2012); some of them, such as hurricanes and heat waves, directly impacting marine communities. *Marine protected areas (MPAs) are considered a key management* tool to buffer GEC by conserving biodiversity, preventing overexploitation of marine communities, and presenting potential economic benefits such as enhancement of local fisheries, sustainable tourism opportunities, and maintenance of other ecosystem services (Sala et al. 2013; Lubchenco et al. 2003; Kearney et al. 2013; Huntington et al. 2010). MPAs strengthen ecological resilience to climate variability, by offering habitat for range-shifting species, a key element for biotic community responses to long-term climate change (Bates et al. 2013). However, to effectively confront GEC, MPAs should undertake a more holistic role, including the development and assessment of environmental management and education practices that integrate ecology and economy, as well as ethics and conflict resolution in the uses of marine space.

Figure 23.1 shows the current distribution of MPAs in Latin America, and the world context. It is notorious the scarcity of MPAs in most of the South American Pacific coast. In addition, South American MPAs are very recent, most of them created after the 1980s (Schiavetti et al. 2013). Today there are 404 coastal and marine protected areas: 336 in Brazil (Schiavetti et al. 2013), 8 in Chile, 14 in Uruguay (Gambarotta 2006) and 46 in Argentina. Outside these MPAs, there are some vast marine-terrestrial protected areas, such as the Cape Horn Biosphere Reserve or the Namuncurá – Burdwood Bank, in southern Chile and Argentina, respectively. The Burdwood Bank was created in July 2013, and represents the first entirely oceanic MPA of Argentina. It has a total surface of 17,000 km^2 with 1,800 km^2 permanently closed to fishing. With this new MPA, the total surface of marine and coastal protected areas in Argentina is still less than 5 %. So, in this and other South American countries, the goal of protection of 10 % of the ocean established by the Convention of Biological Diversity (http://www.cbd.int/sp), is far from being reached.

In addition to the limitations in area, South American MPAs present other basic deficiencies, such as the absence and/or low efficiency of management plans, monitoring programs, the lack of adequate infrastructure, personnel, and enforcement (Gerhardinger et al. 2011). Furthermore, the integration between federal, state, municipal and, private protected areas is very low. This leads to superposition, conflicts, and a poor understanding of the missions and responsibilities of each instance. In this context, although environmental education formally is included within the Conservation Units Systems of most countries, educational actions are frequently absent, deficient, or inadequate to the context of each protected area (Berchez et al. 2007).

MPAs are regulated by national laws or other means and should be created in order to provide ecological, social, and economic benefits to the reserved areas and its borders. They were initially proposed as a means to preserve marine biodiversity and unique habitats, and as an opportunity for recreation, education, and research (Sala et al. 2013). However, the focus frequently has been placed on the implementation of rules and restrictions. For example, the Brazilian legislation (Brasil 2000) considers as core goals of these areas "to discipline the occupation processes, protect the biological diversity, and to secure the sustainability of natural resources, observing the natural attribute quality." In Argentina, the main goal for the creation of MPAs is to protect the reproductive sites of marine birds and mammals (Campagna et al. 2007). During the last decade this restrictive vision has moved toward a more holistic ecosystem–conservation approach (SAyDS 2007).

Despite the limitations and lack of clear and specific guiding elements to planning, management, and monitoring of South American MPAs, positive outcomes regarding biodiversity conservation and fisheries management have been achieved (Floeter et al. 2006; Francini-Filho and Moura 2008a, b; Edgar et al. 2014; Sala et al. 2013). These achievements gradually have been incorporated into the

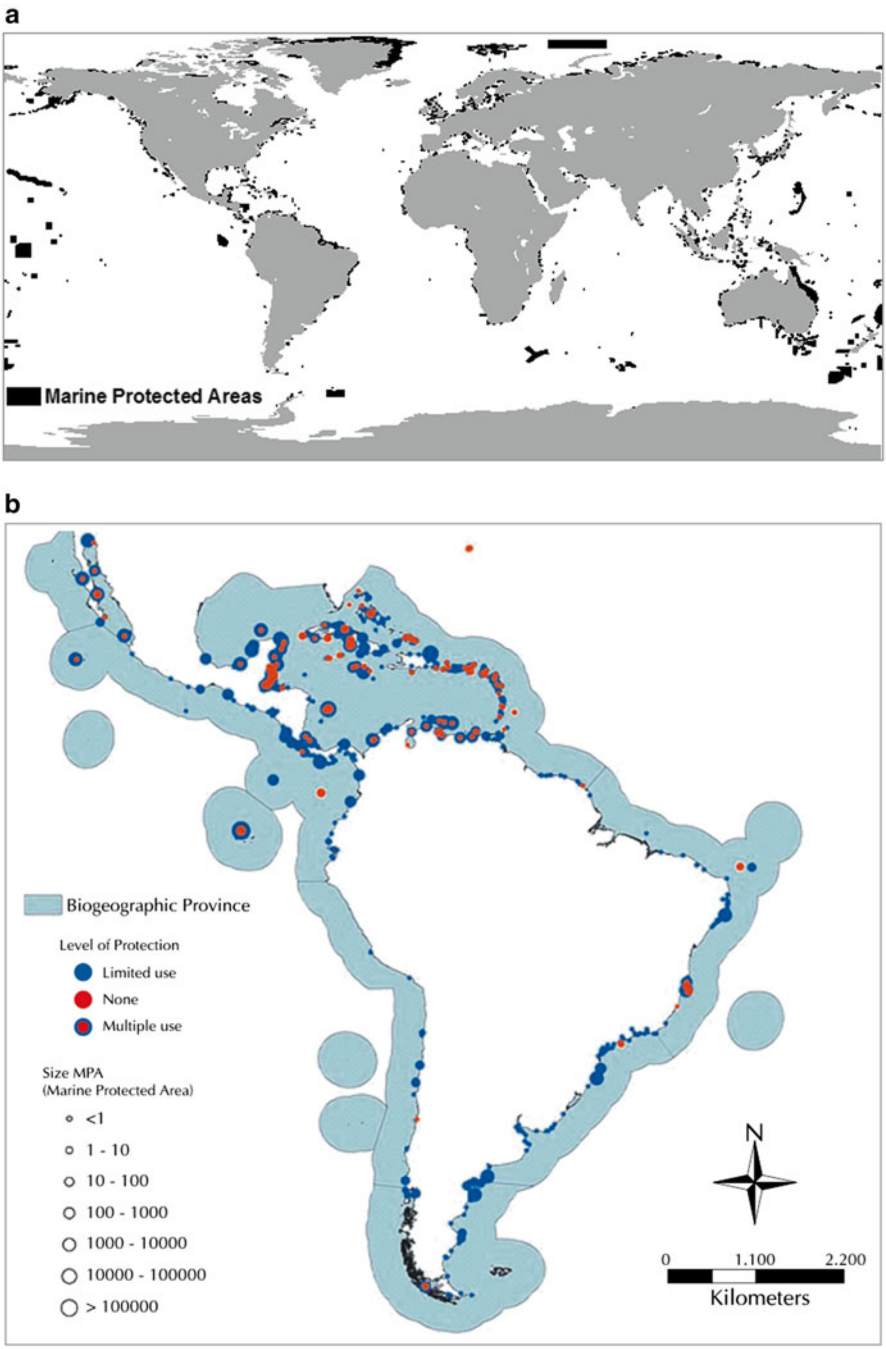

Fig. 23.1 (**a**) Marine protected areas in the world (IUCN and UNEP-WCMC 2010) and (**b**) Latin America (Modified from Guarderas 2007). Distribution of marine protected areas in Latin America and the Caribbean classified by degree of protection against extractive activity

toolbox for marine and coastal management. Yet, socio-economic and ecological benefits generated by MPAs still remain difficult to predict and are debated around the world (Edgar et al. 2014).

MPAs streamlining requires a precise diagnosis of its current status, to better identify outcomes and deficiencies, allowing for due corrections. Actions should be continuously followed by long-term assessments programs of both environmental and social dimensions. For South American MPAs, these evaluations are rare, and most of the available data includes only traditional taxonomic surveys, which are insufficient even for appropriate biodiversity assessments.

In the following sections we present an overview of the ongoing long-term research at South American MPAs, with focus on Brazil and Chile. We provide some successful examples of holistic programs that could lead towards the implementation of an Earth stewardship.

23.2 Some Ecological Long-Term Studies at Brazilian and Chilean MPAs

The establishment of continuous long term monitoring ecological sites is essential to facilitate the early detection of ecological changes, and to apply correct management measures. Populations and communities of marine species often respond quite differently to human pressures within well-designed MPAs (Edgar et al. 2014; Fraschetti et al. 2012). Continuous evaluations in MPAs are especially important in order to assess the impacts related to GECs (Turra et al. 2013). However, global monitoring efforts still are constrained by major geographical gaps. Ecological studies and environmental observatories have overlooked some regions of the Earth that have ecological attributes that are essential to the functioning of the biosphere as a whole (Lawler et al. 2006; Rozzi et al. 2012).

Even basic ecological information regarding the marine community structure in South America countries is extremely scarce, as documented for Brazil (Ghilardi et al. 2008) and Chile (Navarrete et al. 2010). For example, the structure of a vast ecosystem such as the Rhodolith Beds of the Tropical South-western Atlantic Realm remain almost unknown (Spalding et al. 2007). They were described only during the last decade by a few studies restricted to the Eastern Brazilian Ecoregion (Amado-Filho et al. 2010; Pereira-Filho et al. 2011; Berchez et al. 2009).

In relation to long-term marine monitoring and research programs, Chile has relied on the work of a few study sites and research teams. Two paradigmatic sites in Central Chile (33°S, 71°W) are: (i) the marine protected area of Las Cruces Biological Station created in 1982 by the Pontifical Catholic University of Chile (Navarrete et al. 2010), and (ii) the Montemar Institute of Marine Biology built in 1941 as a field station of the University of Chile, to work in partnership with local fishermen. When the University of Valparaíso was formed in the 1980s, its Faculty of Ocean Sciences undertook its administration. With similar goals, in southern Chile the marine stations of Dichato and Mehuin (39°S, 73°W) were inaugurated by the University of Concepcion and the Austral University of Chile, respectively.

Unfortunately, the first of this stations was damaged severely by a Tsunami in 2010 (Harris 2010), and the second one experienced many administrative difficulties. At the end of the 1990s, in the sub-Antarctic region of Western Patagonia, the coastal stations of Huinay (39°S, 73°W) in Aysen, and the Omora Ethnobotanical Park (55°S, 67°W) in Cape Horn, were created in association with the Pontifical Catholic University of Valparaiso and the University of Magallanes, respectively.

In Brazil the programs running for more than a decade are confined to two stations on the Coral Reef Ecosystem of the northeast Brazilian Coast: one developed 14 years ago, based on the AGRRA Protocol (Leão et al. 2010), and the other 17 years ago, based on the Reef Check Program (Hodgson 1999). Fortunately, during the last 3 years new large initiatives have been developed, including the South American Research Group on Coastal Ecosystems (SARCE)[1] and ReBentos networks of continental and regional (Brazil) scopes, respectively. Discussion is also under way in the federal agency that controls the Brazilian Federal Reserves or protected areas (Chico Mendes Institute - ICMBio), as to the development of a protocol to be employed by stations in all MPAs. However the same is not true for most state or municipal protected areas. This scenario highlights the need for developing integrated monitoring programs.

Most methodologies employed in these projects are targeted towards detecting specific responses, and thus only give a limited comprehension of the community structure. This is a limiting factor not only for detecting variations, but also for interpreting their causes. These insufficiencies are the same that have been consistently criticized by most marine reserves assessments, such as limited sample replication, non-random reserve placement, or inadequate controls for temporal and spatial variability (Huntington et al. 2010; Huntington and Lirman 2012). With the development of these recent assessments, Brazilian and South American scientists and decision makers are concerned with the diversity of protocols and efforts. This challenges the possibilities of comparing and integrating data across sites. SARCE is the only program with an integrated continental scope, with sites in Chile, Peru, Venezuela, Colombia, Brazil, Uruguay, and Argentina. There is, therefore, the need for integration also from a regional political view.

Although programs directed towards the monitoring of physical components are increasing, the integration between biological and physical data, essential to the understanding of community dynamics and defining its main drivers, is still low. To improve the integration of biophysical studies, proposals such as the integration of the ReBentos and Coastal Zone Climate networks (http://www.rebentos.org; http://redeclima.ccst.inpe.br) are being developed.

Linking the planktonic, nektonic, and terrestrial compartments is essential. Furthermore, marine ecosystem functions are largely determined by matter and energy transformations mediated by microbial community interaction networks. It has been found recently that viruses are also a crucial components of marine ecosystems, and their abundance exceeds bacteria and phytoplankton by at least an

[1] The SARCE network was established in 2010 . Today, it includes more than 30 researchers from 9 South American coastal countries and has sampled with a standardized protocol in more than 50 sites around the continent.

order of magnitude (Bidle and Falkowski 2004; Hurwitz et al. 2013). None of the current programs consider the influence of these components, which strongly compromises the interpretation of the causes of changes.

23.3 MPAs and Socio-economic Long-Term Evaluation

The integration of socio-economic research into Ecological Long-Term Studies, followed by the integration of noneconomic ethical components to evaluations and consequent educational actions, represents a significant step forward due to the inclusion of the human component in these processes (Maass and Equihua 2015; Redman and Miller 2015 in this volume [Chaps. 14 and 17]). They complement ecological assessments facilitating both the comprehension of causes and consequences, and the undertaking of correct mitigation or adaptation measures when necessary. Furthermore, they provide a basis for "a dialogue about how humans value nature" (Rozzi et al. 2012; Pimm 1994) from the understanding of individual and social perceptions about ecological phenomena. The lack of success of many initiatives could be attributed to the absence of this information to support MPAs management.

Definition of sectors and services of MPAs usually is related to a formal, or informal, management plan. The definition of areas for conservation, economic use, or educational purposes, is frequently a controversial task. Economic benefits, such as traditional exploitation, fisheries, or ecotourism, are frequently the more important concern of the general public. Stakeholders' perceptions based in their cultural basis and beliefs, plays a fundamental role in decisions, and afterwards in the effectiveness of implementation. Thus, the evaluation of stakeholders' perception is essential and should precede educational action and correction measures. A significant increase of the knowledge on perception about marine conservation and MPAs arouse from studies related to GEC.

Perceptions about the environment are influenced not only by its physical nature (Matos 2009), but also by cultural, social, and cognitive aspects (Saheb and Asinelli-Luz 2006). Both individual and social dimensions lead to behavior choices or political decisions, respectively (Whyte 1977). People with different values and interests draw different inferences from the same evidence about global climate changes (Kahan 2012). Experiences related to extreme climate events or local weather conditions, such as cold (Wallace et al. 2014) or hot weather (Zaval et al. 2014), wildfires (Moritz 2012), or hurricanes (Tollefson 2012), may influence global warming beliefs and are very important in changing perceptions about GEC (Howe et al. 2012; Myers et al. 2012). Frequently people overestimate their own knowledge and are unlikely to change their view (Leviston et al. 2013).

The media are fundamental instigators for shaping public opinion, even more importantly than scientific knowledge itself (Zaller 1992). Hence basic scientific consensus to communicate through the mass media (Lewandowsky et al. 2013; Kahan 2012), together with a basic political consensus (Brechin 2012; Brulle et al. 2012), is essential to changing public perceptions on GEC (Gore 2006). However, in spite of its importance, there is no comprehensive program with this aim specifically directed towards regional South American MPAs, where programs are restricted basically to ecological evaluations.

Confronted with pressing near-future challenges related to GECs, measures to implement long term socio-ecological research in South American MPAs are urgent. The recent establishment of new Long Term Socio- Ecological Research (LTSER) programs, such as LTSER-Chile, offers a holistic approach that offers an alternative to integrate into and complement with, the several MPA's efforts already in development.

23.4 Integrated Educational Experiences in South American MPAs

For most conservation unit categories, the development of educational actions is mandatory. For example, Brazilian legislation "SNUC" (Brasil 2000) defines as a main objective "to promote education, educational conditions, environmental interpretation and the recreation in contact with nature" (http://www.mma.gov.br/areas-protegidas/sistema-nacional-de-ucs-snuc). However, environmental education (EE) in Brazilian MPAs is still incipient. Activities for visitors are frequent at marine parks. However, most cases lack instructive activities. Hence, they offer only a superficial tourism, not a genuine ecotourism nor an educational experience. Structured EE activities are rare (Ghilardi and Berchez 2010), and most of them have a poor conceptual basis (Berchez et al. 2007).

Since the 1977 Tbilisi Conference Statement, evolving environmental educational concepts were synthesized during the Rio 92 Conference (Pedrini and Brito 2006). There is growing consensus that, for the betterment of living conditions as well as of those related to the environment, changes in basic values and attitudes are fundamental (La Trobe and Acott 2000). Toward that aim, the Field Environmental Philosophy (FEP) program developed at Omora Park in the Cape Horn Biosphere Reserve in Chile provides a valuable methodological approach that can be adapted to other MPAs (see Aguirre Sala 2015 in this volume [Chap. 15]). FEP's methodology integrates ecology and philosophy, and research results are communicated through metaphors and field activities guided by an ecological and ethical orientation and implemented through special trails or areas. FEP is based on a biocultural ethic that addresses not only human welfare but also the welfare of the whole community of life (Rozzi and Massardo 2011; Rozzi 2013).

EE requires holistic approaches that integrate the teaching of biology, ecology or other disciplines that focus on cognitive objectives with activities that target both emotional experiences and skills acquisition, to achieve enduring transformative processes (Ghilardi-Lopes 2014). Furthermore, EE actions should develop the capacity to contextualize these gains by applying new beliefs and behaviors to everyday life. Objectives related to social transformation, including the capacity to stimulate collective mobilizations and the evolution of social groups and forms of culture, or to promote political changes, are essential EE features (Berchez et al. 2007).

For Brazilian MPAs, only a few examples of attempts for more integrative work can be highlighted. One of them is the Reef Check Program which, for over a decade in the northeast Brazilian Region, in association with the Chico Mendes Institute for Biodiversity Conservation (ICMBio),[2] has developed long term monitoring of benthic communities, and also has included an educational component. Following a Citizen Science approach (Silvertown 2009; Osborn et al. 2005), local people are recruited to perform, after due training, periodic assessments on MPAs, using shared protocol and tables. Besides recruiting labor, the program provides practical comprehension and knowledge of the environment, and allows evaluation by the citizens themselves of environmental health conditions, stimulating the sense of belonging and thus leading to action and facilitating their action as disseminators of scientific knowledge within their groups of influence. Other positive points of the program include integrating the participation of non-local people, and continuing education. Outstanding results have been obtained, such as the professionalization of young collaborators who serve as MPA instructors for undergraduate education. Another example is the Underwater Trail Project that was begun in 2002 at the Anchieta Island State Park (Berchez et al. 2005, 2007). It initiated a training program for EE instructors, who promote the emergence of new well-based educational actions (Box 23.1). Among its distinctive characteristics, one is the association of the project actions with continuous education research, evaluating their success and deficiencies.

Box 23.1. Underwater Trail Project

The Underwater Trail project is a long-term experiment in marine environmental education developed by the University of São Paulo, beginning in 2002 (Berchez et al. 2005, 2007). Its objectives are to develop, apply, and test scientific research and education actions at the Anchieta Island State Park (23°S; 45°W – Fig. 23.2). This is an unpopulated, state insular protected area, located near (7 km) the coast. Due to its proximity to the city of São Paulo, this protected area receives up to 2,000 people a day during the summer periods. People arrive in boats, and stay confined basically along a beach 350 m long, and a trail with the same extension.

Educational models have been developed to stimulate transformative processes in the participants. These models integrate cognitive and emotional dimensions with skills acquisition. The visits include interpretation, direct contact with biodiversity, and the use of diving and trekking equipment. The sequence of activities consider the following 11 steps:

(continued)

[2] ICMBio is the Brazilian Ministry of the Environment's administrative arm.

Box 23.1. (continued)

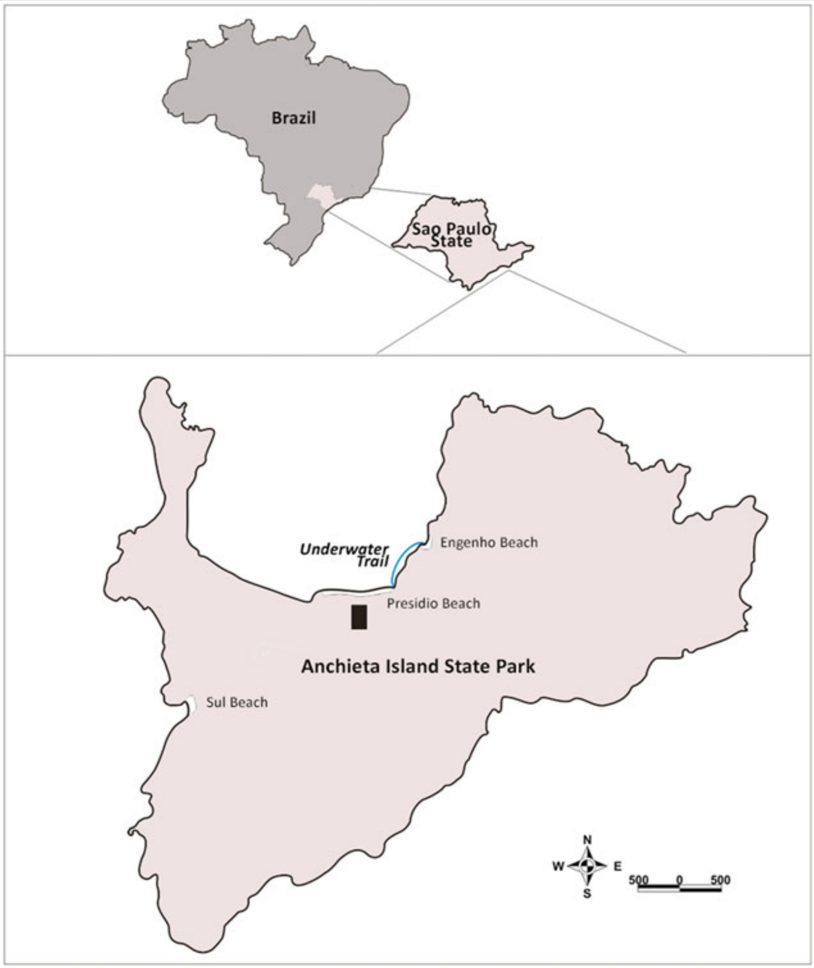

Fig. 23.2 Brazil, São Paulo State and Anchieta Island State Park (Robim et al. 2008). The *blue line* shows the area in which the models "Underwater Free Diving Trail," "Underwater Scuba Diving Trail," and "Ecosystems Trail" of the underwater trail project take place

1. Welcome and introduction,
2. stretching, relaxing, and sensitization,
3. MPA objectives, historical cultural and social background, nowadays conflicts and challenges,
4. nearby ecosystems and their sensitivities,
5. geological origin,
6. equipment characteristics, concepts and use,

(continued)

Box 23.1. (continued)

7. ecosystem functional interpretation,
8. organism functional interpretation,
9. economic relationships,
10. global environmental changes, and
11. closing.

The sequence is planned to have a transdisciplinary character and to stimulate participants to later apply learning to their everyday life when they return home. Following this scheme, seven activities models have been developed to address the expectations of different public, and to expose visitors to a variety of ecosystems: (i) Underwater Free Diving Trail (Fig. 23.3), (ii) Underwater Scuba Diving Trail, (iii) Natural Aquarium Trail, (iv) Canoeing Trail, (v) Outside Water "Panels" Diving Trail (Fig. 23.4), (vi) Ecosystems Trail, and (vii) Vertical Trail. The activities at each of the interpretive trails last for approximately one hour. The activities, initially targeted to the general public visiting the MPA, were expanded to elementary and high school local students. Up to now, a total of 20,351 people have attended the activities, 1,405 of them belonging to public schools.

Fig. 23.3 People participating in Underwater Free Diving Trail

(continued)

Box 23.1. (continued)

Fig. 23.4 Outside Water "Panels" Diving Trail

Regarding the training of educators, most of them are undergraduate students at variety of disciplines at the University of São Paulo. These students serve educators who have a multiplying effect.

These students are very interested in environmental education (EE). Up to 300 students apply each year for the 50 annual vacancies in the teacher training course. Teachers from the public schools selected for the activities also are trained in the same way, and later are engaged as field monitors of their own students, under supervision of more experienced members of the group. Students receive credits for an elective course, and also receive a formal certificate documenting their training as EE monitor. A system of certification, with both horizontal and vertical steps, up to the category of examiner, is being tested. The training system is based in written protocols, explaining the models, including their educational contents, techniques, operational and safety procedures. Educators are urged to complement this basic content with their own experience. Books, chapters, articles, and web-pages have been developed in order to support and complement this training (e.g. Ghilardi-Lopes et al. 2012).

Up to now 733 educators have been trained, including 75 teachers from public schools. Part of this group, including one person from the first year (2002) and four from the second, are still participating as senior "non-profit" members. Since this work is completely volunteered, the high involvement indicates that they are motivated by ethical rather than purely economic values. At least 15 of these educators has been contracted as staff for Brazilian Protected Areas (BPA), a fact that shows the need that BPA have for people trained with this theory and practice integration in EE, having also multiplier capacity. Since the beginning, the EE actions have been annually evaluated by scientific research (Berchez et al. 2005), with results expressed in 22 papers or chapters. Studies have focused on the achievement of the educational objectives, the ecological impact of the activity, and more recently on the evaluation of visitors' perceptions about global environmental change.

23.5 MPAs Educational Agenda: Implications for Earth Stewardship

Involving decision-makers in the process is essential to transferring successful educational experiences to policy (Abecasis et al. 2013). The exchange of experiences among different stakeholders towards a common goal contributes to enlarging their vision along with that of managers. However, construction of the management plan and afterwards planning of educational activities should rely in science-based investigative data and previous experiences (Lubchenco et al. 2003).

Although the last decades have experienced a considerable increase in the number of MPAs, the improvement of their services still is a huge task. The integration of disperse experiences throughout South America is a primary task in order to improve efficiency, to save resources, and to allow the exchange of data and experiences. The sharing of successful local results identified by research programs, through frequent and intensive meetings, workshops, formal or informal courses, or distinct types of media, could be the way to accelerate development, in order to fulfill Earth Stewardship demands (see Chapin et al. 2015 in this volume [Chap. 12]).

MPAs represent areas of reduced human pressure, are expected to act as repositories of species and as habitat refuges (Costa et al. 2013). They are also marine regions where economic activities are controlled. For these reasons, protected areas are ideal to act as incubators of novel conservation experiences, integrating ecology, economy, and ethics, thereby acting as an educational instrument for spreading these concepts and abilities to society as a whole. Like LTSER sites, MPAs should integrate ecological sciences and ethical theories and values in educational programs (Rozzi et al. 2012). These basic concepts and practices also are required for an Earth Stewardship initiative, which demands an integration of theory and practice, overcoming disciplinary constraints and producing innovative responses to address environmental, economic, and social challenges.

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