Integrating Ecology and Environmental Ethics: Earth Stewardship in the Southern End of the Americas

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The South American temperate and sub-Antarctic forests cover the longest latitudinal range in the Southern Hemisphere and include the world's southernmost forests. However, until now, this unique biome has been absent from global ecosystem research and monitoring networks. Moreover, the latitudinal range of between 40 degrees (°) south (S) and 60° S constitutes a conspicuous gap in the International Long-Term Ecological Research (ILTER) and other international networks. We first identify 10 globally salient attributes of biological and cultural diversity in southwestern South America. We then present the nascent Chilean Long-Term Socio-Ecological Research (LTSER) network, which will incorporate a new biome into ILTER. Finally, we introduce the field environmental philosophy methodology, developed by the Chilean LTSER network to integrate ecological sciences and environmental ethics into graduate education and biocultural conservation. This approach broadens the prevailing economic spectrum of social dimensions considered by LTSER programs and helps foster bioculturally diverse forms of Earth stewardship.

Keywords: conservation, temperate forests, sub-Antarctic ecoregion, long-term ecological research, field stations

At the beginning of the second decade of the twenty-first century, the Ecological Society of America has proposed a framework for Earth stewardship as a means of engaging science and society in rapidly reducing the rates of anthropogenic damage to the biosphere (Power and Chapin 2009, Chapin et al. 2011). This call for action presents two major challenges for ecologists.

First, linking global phenomena with regional biocultural heterogeneity requires that researchers adopt interdisciplinary and international approaches and that they make use of ecological observatories and field stations to conduct long-term research in diverse regions of the planet (Palmer et al. 2005, Porter JH et al. 2009). However, such global monitoring efforts are still constrained by major geographical gaps: Ecological studies and environmental observatories have until now 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), and that are inhabited by cultures with unique forms of ecological knowledge and sustainable lifestyles (Callicott 1994).

Second, according to Power and Chapin (2009), in order to be stewards, "ecologists are obliged to be among the leaders who will define society's path to planetary stewardship" (p. 399). This calls for scientists to integrate social and cultural dimensions into their research. However, to achieve such integration, ecologists must bridge a major conceptual gap: Long-term socioecological research programs have mostly emphasized economic values while the broader dimensions of ethics have been overlooked (Rozzi et al. 2010a).

In this article, we address the geographical and conceptual gaps by (a) introducing the recently created Long-Term Socio-Ecological Research (LTSER) network in Chile and linking it to the International Long-Term Ecological Research (ILTER) network, thus adding a new biome to this planetary network—the South American temperate forests; (b) introducing the methodology of *field environmental philosophy* (FEP), which integrates ecological sciences and environmental ethics into biocultural conservation, thus offering an innovative methodology that contributes to the implementation of Earth stewardship.

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The South American temperate forest biome: A globally significant gap in ILTER

High latitudes harbor the world's largest expanses of remote biomes that remain the least altered by direct modern human impact (Sanderson et al. 2002, Ellis and Ramankutty 2008). More than 50% of the 76 million square kilometers (km^2) of terrestrial wilderness areas identified by Mittermeier and colleagues (2003) is found above 45 degrees (°) latitude in both hemispheres. Moreover, of the 13.5 million km^2 of old-growth forests classified as *frontier forests* by Bryant and colleagues (1997), an estimated 54% occurs in Russia, Canada, Alaska, and southwestern South America, at latitudes greater than 45°. Consequently, high-latitude forest ecosystems and their associated wetlands offer an unparalleled opportunity for global society to undertake proactive international collaboration aimed at conserving these regions and conducting long-term ecological research (LTER) (Chapin et al. 2006, Rozzi et al. 2006, 2008a). In addressing this challenge, however, the scientific community is strongly constrained by a regional bias in the intensity of current long-term research efforts, which are numerous in the temperate latitudes of North America and Europe but largely absent from southern latitudes (Lawler et al. 2006).

A major planetary LTER initiative, the ILTER network (*www.ilternet.edu*) encompasses 543 sites in 44 countries. However, 509 of these sites (93.7%) are located in the Northern Hemisphere, whereas only 34 sites (6.3%) are in the Southern Hemisphere (figure 1). In the Northern Hemisphere, ILTER sites are predominantly found at high latitudes. More than 60% of the ILTER sites (n = 348) are concentrated in temperate and boreal latitudes over 40° north (N), and less than 30% of ILTER sites (n = 161) occur at subtropical and tropical latitudes (0°–40° N). In addition, less than 10% (n = 34) of the world's ILTER sites have been established within the tropical latitudinal range between 20° N and 20° south (S) (figure 1), where most of the world's biodiversity is found (Myers et al. 2000).

Less noticed but also critical for global coverage of ILTER is the absence of sites at temperate and sub-Antarctic latitudes in the southern continents. There are currently no ILTER sites at latitudes between 40° S and 60° S. Beyond sub-Antarctic latitudes, at polar latitudes (greater than 60° S), we find a few ILTER sites in Antarctica. Therefore, the latitudinal range between 40° S and 60° S currently represents the only absolute gap for ILTER coverage (figure 1). This blind spot neglects an entire temperate biome and precludes long-term comparative research on high-latitude ecosystems in both hemispheres. The South American temperate and sub-Antarctic forests cover a vast area that harbors the world's southernmost forest ecosystems and has remained relatively free of direct human impact in modern times (Armesto et al. 1998). New ILTER sites established at the austral sub-Antarctic (40°–60° S) latitudes would foster comparisons with data sets from equivalent sites in the Northern Hemisphere, which are essential to complete global climate and land-use models (see Lawford et al. 1996).

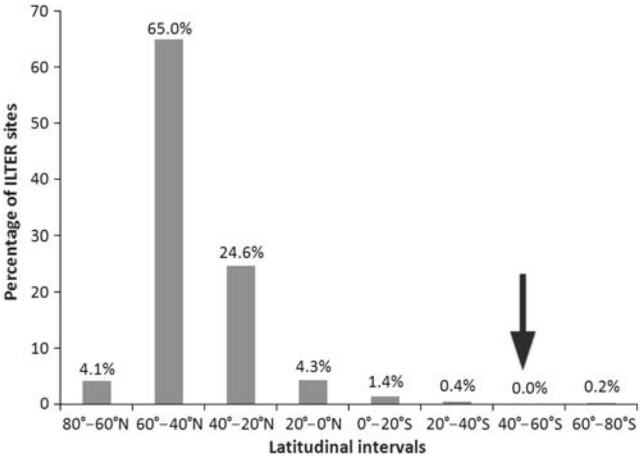


*Figure 1. Relative percentage of study sites in the International Long-Term Ecological Research (ILTER) network at different latitudinal intervals. In addition to the lack of sites in the Southern Hemisphere in general, there is a notorious gap in the temperate and sub-Antarctic regions of South America, between 40 degrees (°) south (S) and 60° S. In contrast, a large number of Northern Hemisphere ILTER sites concentrate between 40° N and 60° N. The data for the 543 ILTER sites were obtained from the Web site (*www. ilternet.edu/member-networks*) on 1 April 2011.*

Other long-term international global monitoring and ecological research networks also neglect the South American temperate forest biome. FluxNet has more than 500 meteorological tower sites that operate on a continuous basis in five continents to record carbon dioxide flux in terrestrial ecosystems, but these sites are presently restricted to a latitudinal range of 70° N through 30° S (Sundareshwar et al. 2007). The Global Lake Ecological Observatory Network includes 27 observatories on five continents, but these sites are also restricted to between 69° N and 38° S, notwithstanding one lake observatory in Antarctica at 77° S (*www.gleon.org*). The terrestrial transects established by the International Geosphere–Biosphere Programme (IGBP) are at high latitudes only in the Northern Hemisphere. In the Southern Hemisphere, the IGBP includes humid tropical, semiarid tropical, and midlatitude grasslands (Koch et al. 1995, Steffen et al. 1999), but no temperate or sub-Antarctic forests.

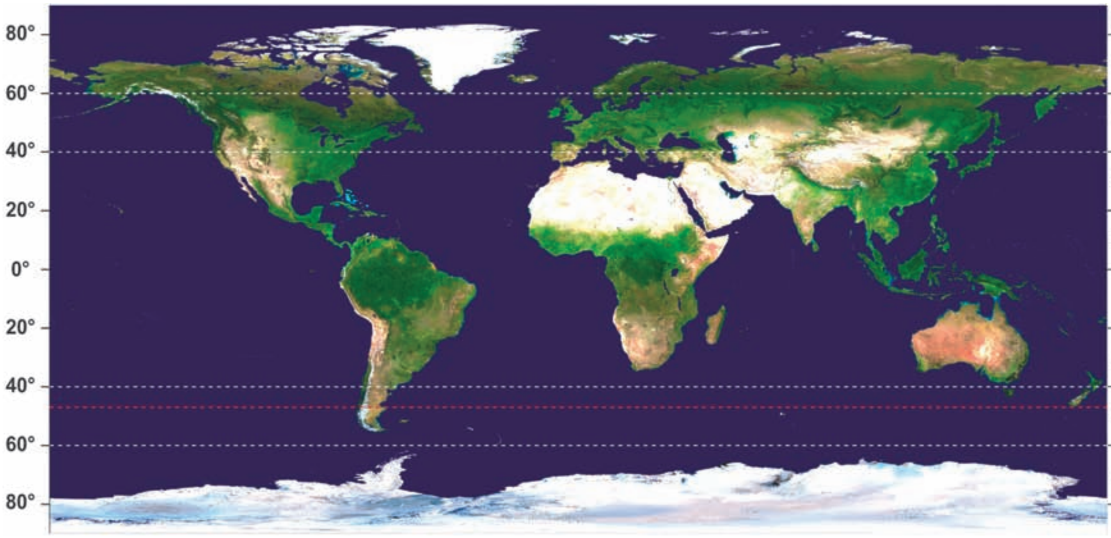
The recently established Chilean network of LTSER sites will contribute to rectifying this glaring omission in global networking. Below, we summarize the exceptional biological and cultural attributes of the South American temperate forest biome, which is now being integrated into ILTER.

Major biocultural attributes of the South American temperate forest biome

The Northern and Southern Hemispheres contrast markedly in their land:ocean ratios, generating sharp interhemispheric climatic and biotic differences in temperate and subpolar latitudes. The land:ocean ratios reach a maximum interhemispheric contrast at the 40°–60° latitudinal bands: In the Northern Hemisphere, terrestrial surface prevails with a 54% over a 46% of oceanic surface, whereas in the Southern Hemisphere, 98% of the surface is oceanic and only 2% is terrestrial (figure 2). Northern Hemisphere high-latitude ecosystems are characterized by a strongly continental climate (freezing winters and contrastingly warm summers), whereas the Southern Hemisphere temperate and subpolar ecosystems are modulated by a largely oceanic climate (mild winters and rather cool summers) (Arroyo et al. 1996, Lawford et al. 1996). In addition, the vast area of boreal and temperate forests in North America generate patterns of distribution and endemism for terrestrial organisms that differ greatly from the more insular patterns of distribution of terrestrial organisms in the Southern Hemisphere. The South American temperate forest biome extends over a narrowing strip of land from 35° S to 56° S at Cape Horn (figure 2). This South American biome is noteworthy with respect to global conservation priorities and intensified LTER programs because of the following 10 attributes.

(1) The absence of latitudinal equivalents in the Southern Hemisphere. Temperate forests occur along the southwestern margin of South America, ending in the sub-Antarctic Magellanic ecoregion. The latter spans a myriad of archipelagoes from 47° S to 56° S over a latitudinal range that stretches almost 10° of latitude beyond the southernmost forests in New Zealand and Australia, on Stewart Island (47° S) and in Tasmania (44° S), respectively. As a consequence, the South American temperate forest biome—specifically, its sub-Antarctic Magellanic ecoregion, which includes forest, wetland, freshwater, and marine ecosystems—has no latitudinal replicate on the planet and is therefore irreplaceable at the biome level.

(2) One of the last wilderness areas. Among the 12 largest remnants of old-growth forest in the planet, the South American temperate forest biome is the only one that is neither tropical nor boreal (Armesto et al. 2009). According to Bryant and colleagues (1997), 90% of the world's remaining frontier forests are found in only 12 countries, most of them in the tropical regions and in the Northern Hemisphere. The boreal and temperate forests of Russia, Canada, and the United States account for more than 59% of the remnant frontier forests (figure 3). Tropical forests in eight countries in turn (Brazil, Peru, Indonesia, Venezuela, Colombia, Zaire, Bolivia, Papua New Guinea) add up to almost 40% of the frontier forests. Only one nontropical country in the Southern Hemisphere (Chile) is included in the list, and it contributes only about 1% of the world's frontier forests. In addition, the sub-Antarctic Magellanic forest ecoregion has been identified as one of the 24 wilderness areas remaining on the planet (*sensu* Mittermeier et al. 2003) for the following three reasons: (1) more than 70% of its original vegetation cover is conserved, (2) it encompasses an area of more than 10,000 km^2 that lacks terrestrial connectivity and industrial and urban development, and (3) it harbors one of the lowest human population densities within temperate latitudes (0.14 inhabitants per km^2).



Latitude	Land	Ocean
80°–60°	52.8%	47.2%
60°–40°	**54.1%**	**45.9%**
40°–20°	40.0%	60.0%
20°–0°	24.5%	75.5%
0°–20°	22.8%	77.2%
20°–40°	17.3%	82.7%
40°–60°	**2.0%**	**98.0%**
60°–80°	33.4%	66.6%

Figure 2. World image showing that southern South America extends 9 degrees (°) beyond the latitude of Stewart Island, New Zealand (47° south [S], indicated by the dashed red line). Therefore, the world's southernmost forests in the sub-Antarctic Magellanic ecoregion have no replica in the Southern Hemisphere. In contrast to the vast cross-continental span of boreal forests in the Northern Hemisphere, the austral temperate forest biome narrows down to an identifiable point: Cape Horn Island (56° S). The white dashed lines enclose the latitudinal bands at 40°–60° in both hemispheres to illustrate the marked difference in land:ocean ratios at this latitudinal range (indicated in bold in the table).

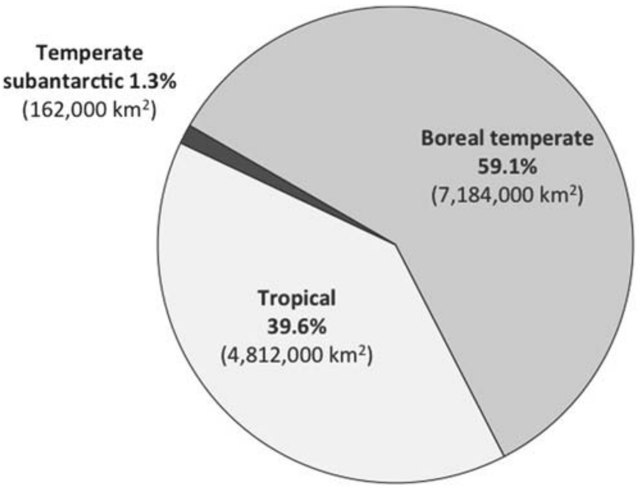


Figure 3. Areas of frontier forests (expanses of relatively undisturbed, predominantly old-growth forests that are large enough to maintain viable populations of most of their characteristic native species) as a function of the main biome type that remained at the end of the twentieth century. The data are based on the assessment by Bryant and colleagues (1997, p. 45). Abbreviation: km^2, square kilometers.

(3) Unique biodiversity and extremely high endemism. Topographic and climatic barriers isolate the austral South American forest biome from the nearest tropical forests by 1500–2000 kilometers (km) (Armesto et al. 1998). The high Andes along with the vast dry steppe of Argentina form the eastern boundary. To the north lies the hyperarid Atacama Desert. The southern Pacific Ocean bounds the region on the west and south. This geographic isolation has generated remarkably high levels of vascular plant endemism: Close to 90% of the woody species and 33% of the woody genera are endemic to this austral biome, including 24 monotypic genera (Arroyo et al. 1996). In addition, about 60% of the bryophyte species (mosses and liverworts) are endemic to the temperate forest biome (Villagrán et al. 2005), and the lush forests and moorlands of the sub-Antarctic Magellanic ecoregion are home to around 5% of the world's bryophyte species, on less than 0.01% of the Earth's land surface (Rozzi et al. 2008a). Among the vertebrate fauna, 50% of fish, 80% of amphibian, 36% of reptile, 30% of land-bird, and 33% of mammal species are endemic to the forest biome. Such levels of endemism are similar to those recorded for some oceanic islands (Armesto et al. 1996).

(4) The largest area of temperate forests in the Southern Hemisphere. Extending over 26° of latitude (30°–56° S), South American temperate and sub-Antarctic forests cover an area of about 13.6 million hectares (ha) in Chile (Neira et al. 2002) and 2 million ha in southern Argentina (SADSA 2009). The total forest area of 15.6 million ha is the largest expanse of evergreen and deciduous temperate rain forest remaining in the Southern Hemisphere, more than twice as much as that in New Zealand and Tasmania combined. New Zealand temperate forests extend over 7° of latitude (40°–47° S) and cover an area of 4.5 million ha, whereas those of Tasmania growing between 41° S and 44° S cover an area of 1.4 million ha (Veblen et al. 1996).

(5) The largest temperate wetland area in the Southern Hemisphere. South American temperate forests at high latitudes are embedded in a matrix of peatlands, bogs, and cushion bogs, known as the *Magellanic moorland complex* (Godley 1960). Magellanic moorlands in the narrow tip of southern South America cover 4.4 million ha and represent the largest wetland area at high latitude in the Southern Hemisphere (Arroyo et al. 2005). The only other very large areas of wetlands in the Southern Hemisphere are tropical, including the Amazon River Basin, the Pantanal, and the Congo River Basin (Keddy et al. 2009). Under an oceanic climatic regime and embedded in archipelagic landscapes, the Magellanic moorlands offer an ideal system for comparative subpolar ecological research, particularly for assessing the drivers and trends of recent climate change. Austral peatlands also play a major and poorly understood role in the regulation of regional hydrologic cycles and, presumably, in determining the global carbon budget (Díaz et al. 2007).

(6) The world's cleanest rainwater and streams. Because southwestern South America is positioned outside of air streams carrying industrial pollutants and receives rainstorms that originated over the southern Pacific Ocean, the austral forests and associated ecosystems are to a large extent free of atmospheric pollution (Hedin et al. 1995). Precipitation chemistry in this region reveals one of the lowest concentrations of nitrate ever recorded (Likens 1991, Weathers et al. 2000). Therefore, the soils and streams in high-latitude South American ecosystems are uniquely suited for comparative biogeochemical studies, especially with chronically polluted temperate latitudes in Europe and North America (Galloway et al. 1994), and they provide a unique baseline to study the linkages between atmosphere and biosphere under conditions similar to those that prevailed prior to the industrial revolution (Hedin et al. 1995).

(7) Patagonian ice fields. Southwestern South America contains vast areas of continental ice: 4200 km^2 in the Northern Patagonian Icefield, 13,000 km^2 in the Southern Patagonian Icefield, and 2300 km^2 in the extensive glacier systems of the Darwin Cordillera on Tierra del Fuego and the neighboring archipelagoes (Porter C and Santana 2003). Together, these glaciers are (a) the largest ice masses in the Southern Hemisphere, aside from those in Antarctica; (b) immense reservoirs of freshwater; (c) unique depositories of records of past climate changes at high southern latitudes; and (d) more sensitive to global climate change than the Alaskan glaciers (Rignot et al. 2003).

(8) Past and present climate change history. The Quaternary history of glacial cycles in this region, at the southern margin of the westerlies wind belt, provides a unique setting for understanding the patterns of past and present climate change in the Southern Hemisphere lands and oceans, documented in sediment cores from austral peat bogs and lakes (Villa-Martínez and Moreno 2007). Comparative studies of the responses of the biota to past and present climate change in both hemispheres benefit from the fact that the Patagonian glacial ice was (and is) prevailingly oriented north to south, in close association with the Andean Cordillera, and not east to west as ice in the Northern Hemisphere is (Veblen et al. 1996, Patterson 2010). In addition, the high habitat heterogeneity and the marked temperature and rainfall gradients over a relatively small continental area offer an ideal scenario for assessing the responses of the biota to global climate change.

(9) The diversity of indigenous cultures and languages. A mosaic of indigenous cultures has historically lived in close association with the southern temperate forest biome (Hidalgo et al. 1996). Each Amerindian group has been closely associated with distinct ecosystems. For example, the close links to the land are compellingly expressed in the language of the Mapuche, who define themselves as the people (*che*) of the land (*mapu*). Indeed, the names of the three main Mapuche groups refer directly to the particular habitats they inhabit: The Pehuenche are the people of the *pehuen* or monkey-puzzle tree (*Araucaria araucana*) forests of the volcanic Andean range (37°–40° S); the Lafkenche are the people of the *lafken* or coastal ecosystems (36°–40° S); and the Huilliche are the people of the *huilli* or south, and they inhabit the evergreen Valdivian rain forests (38°–42° S). All Mapuche groups speak Mapudungun, the "land-language"—literally, the language (*dungu*) of the land—that onomatopoeically corresponds with bird sounds, and many words resonate with the sounds of other biotic and physical components of the regional ecosystems (Rozzi et al. 2010b).

Farther south, in the archipelagoes of the sub-Antarctic Magellanic ecoregion, a highly threatened group of indigenous cultures and languages is found: the Fuegian ethnic complex. Prior to European colonization, the Kaweshkar or Alacaluf inhabited most of the archipelago region from the Gulf of Penas to the Darwin Cordillera (47°–55° S), the Selknam or Ona occupied most of Tierra del Fuego, and the Yahgans—the world's southernmost ethnic group—navigated and lived throughout the islands south of Tierra del Fuego to Cape Horn (55°–56° S) (Hidalgo et al. 1996). Today, only two small communities of Fuegian descendents can be found in the whole ecoregion: a Kaweshkar community in Puerto Eden on Wellington Island (49° S) and a Yahgan community in Puerto Williams on Navarino Island (55° S). These two communities are highly acculturated; today, the Kaweshkar and Yahgan languages are each spoken fluently by fewer than 10 inhabitants (Rozzi et al. 2010b).

(10) The largest area of parks and biosphere reserves in the temperate Southern Hemisphere. Providing opportunities for conservation and scientific research within the austral temperate forest biome are several large protected areas in the Chilean Magellanic region. These protected areas include the second largest national park in Latin America, the Bernardo O'Higgins National Park (3.5 million ha). If the area of that park were added to a contiguous national reserve and two other adjacent national parks, the entire protected area would be 7.3 million ha—nine times larger than Yellowstone National Park. This represents the largest continuous territory under protection at nontropical latitudes in the Southern Hemisphere. However, this extensive protected-areas system suffers from four substantial shortcomings: (1) Only four park rangers are employed to protect 7.3 million ha of land; (2) located in a largely uninhabited region, these protected areas are vulnerable to boundary changes or land decommissioning for development purposes; (3) these three parks, like others in the southern rain forests region, have until recently excluded indigenous and local communities from access to their ancestral lands, to their traditional resources, and to participation in territorial planning and other decisionmaking processes; and (4) Chilean national parks include only terrestrial ecosystems and do not include marine coastal areas or biotically rich intertidal zones in the archipelago region.

Current threats to forests and waters in the archipelago region

New access roads being constructed through primeval forests in the Patagonian archipelago and the decreasing presence of the Chilean navy in the sub-Antarctic islands and channels are contributing to growing development and, consequently, to environmental and social pressures (Barros and Harcha 2004). The region now faces the following impending threats.

Construction is projected for seven large hydroelectric dams on the remote Cuervo and Baker Rivers; the latter is the largest river in the South American temperate forest biome. This project will require building 5000 towers to support a transmission line running more than 2400 km on a 120-meter-wide strip and will include one of the world's biggest clearcut corridors, fragmenting ancient forest ecosystems (Vince 2010).

The present road system is being expanded to connect development centers in the Patagonian archipelago region. These roads will open new access from the mouth of the Baker River (47° S) to Puerto Natales (52° S) (Martinic 2004) and will stretch south through Tierra del Fuego Island to the recently established Cape Horn Biosphere Reserve (Barros and Harcha 2004).

The rapid growth of nonnative salmon farming industry with large numbers of floating cages anchored directly to the seabed is disrupting the austral sea and landscapes (40°–54° S). Salmon farming has major ecological and social impacts, including antibiotic pollution, eutrophication of lake and marine waters, introduction of a voracious nonnative predator fish species, viral infections, and displacement of traditional fishing communities from their ancestral grounds (León-Muñoz 2007).

Exponential growth of the tourism industry through cruise ships in areas previously restricted by the Chilean navy has led to an increasing number of tourists' disembarking on uninhabited islands and to unregulated tourism in channels and protected areas, which lack basic, infrastructure, tour-guide information and park rangers. Today, this type of unregulated tourism poses a threat to the most secluded spots in this remote wilderness region (García 2004).

The rapid spread of deliberately or accidentally introduced exotic species, such as *Castor canadensis*, *Neovison vison*, and *Ondatra zibethicus* among the most common vertebrates (Anderson et al. 2006) and *Ulex europaeus*, *Eucalyptus* spp., and *Cytisus scoparius* among the most widespread vascular plants (Armesto et al. 2010).

The demand for growing volumes of woodchips from subsidized eucalyptus plantations (presently covering 3 million ha in Chile) by major industrial paper mills is meanwhile encouraging the southward expansion of cold-resistant eucalyptus monocultures into areas of native forest (Armesto et al. 2010).

The nascent Chilean LTSER network

The lack of knowledge; baseline information; field stations; and—foremost—long-term research programs with an interdisciplinary team interacting with the community, schools, authorities, and policymakers on a daily basis in this remote region severely limits our responses to the aforementioned development pressures. To address this regional challenge and to fill in the critical global latitudinal gap in ILTER, in 2008 we formalized the creation of the first Chilean LTSER network, supported by a new publicly funded research center in Chile, the Institute of Ecology and Biodiversity (IEB, *www.ieb-chile.cl*). The establishment of this Chilean LTSER network took advantage of the existence of three long-term study sites that have worked for more than a decade to generate local partnerships that integrate ecological research, education, and conservation (Anderson et al. 2008, 2010): Bosque Fray Jorge National Park (30° S; Gutiérrez et al. 2010), Senda Darwin Biological Station on Chiloé Island (42° S; Carmona et al. 2010), and the Omora Ethnobotanical Park in the Cape Horn Biosphere Reserve (55° S; Rozzi et al. 2010a) (figure 4). In 2004, these research programs were linked and strengthened by the participation of researchers from five Chilean universities associated with IEB, which was awarded a 10-year grant from the Chilean Millennium Scientific Initiative (MSI). Later, in 2008, IEB was awarded an additional grant from CONICYT (the Comisión Nacional de Investigación Científica y Tecnológica in Chile) with a horizon of 10 years (see the supplemental material, available online at *http://dx.doi.org/10.1525/bio.2012.62.3.4*).

Since the 1990s, interdisciplinary research teams associated with the Chilean LTSER network have developed working partnerships with the Chilean government. Providing the government with ongoing baseline information on biodiversity and ecosystem functioning in both perturbed and pristine ecosystems has catalyzed direct, *in situ* interactions with the Chilean authorities, educators, and local stakeholders. One central initiative has involved the creation of the United Nations Educational, Scientific and Cultural Organization (UNESCO) Cape Horn Biosphere Reserve (CHBR) to protect the sub-Antarctic ecoregion as a resource of high potential for ecotourism and global ecosystem services in the context of worldwide biotic and cultural homogenization (Rozzi et al. 2006). On the basis of this and other initiatives in the region, we identify three key principles for the goals of integrating science and policy.

Interdisciplinary and interinstitutional integration. A first level of academic interdisciplinary work involves the integration of methods, perspectives, and data from natural and social sciences, as well as from the humanities. A second level of collaboration involves transdisciplinarity, strengthening interactions among academic and nonacademic actors, including governmental and nongovernmental agencies, and other public- and private-sector representatives involved in policy- and decisionmaking (Frodeman et al. 2010). Complementing interdisciplinary knowledge with transdisciplinary decisionmaking involving multiple national and international partners (e.g., UNESCO) was essential to achieving the creation of the CHBR. For example, including a diversity of professionals and institutions with the knowledge and authority to administer terrestrial, coastal, and ocean areas permitted the integration of land and—for the first time—marine ecosystems in a Chilean biosphere reserve (Barros and Harcha 2004).

Overcoming the linear sequence from research to policy. A second central principle for effective conservation or ecological-stewardship actions has been the systematic integration of the generating scientific knowledge and preparing policy documents as a simultaneous process conducted by one interinstitutional, collective team. The combination of these activities contrasts with the prevailing approach of conservation programs, which is based on sequential steps, beginning with the production of knowledge and followed by its communication and use by policymakers. Working partnerships with authorities and government agencies to synchronically produce the scientific and policy documents significantly increased the decisionmakers' involvement and commitment to the goals. For example, it was critical to the achievement of a consensus on the definition of core, buffer, and transition areas in the CHBR. In consultation with multiple regional and national stakeholders and with technical advice from UNESCO, a shift from prioritizing salmon farming toward favoring ecotourism in most coastal areas of the CHBR was achieved. Moreover, cooperation

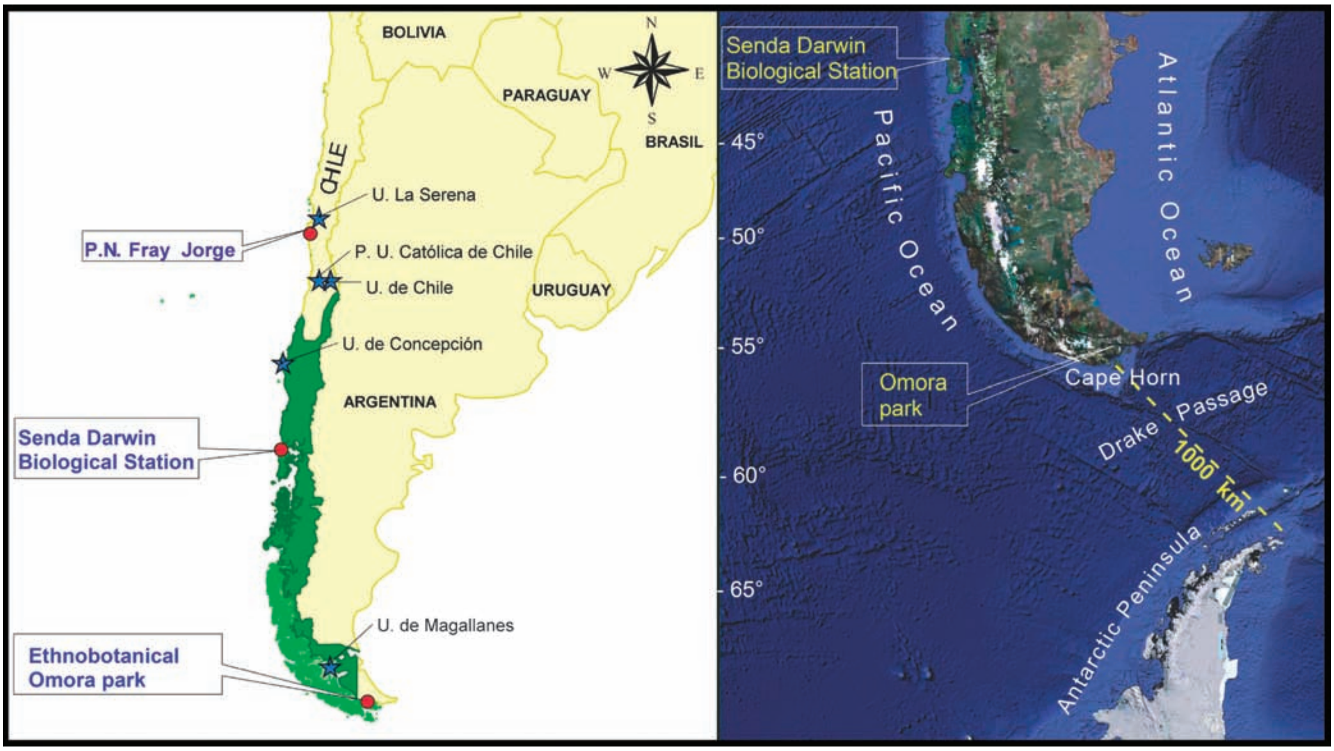


Figure 4. The Chilean Long-Term Socio-Ecological Research network includes three main field sites distributed over a latitudinal range of 30°–55° south (S) (red dots) and academics from five universities (blue stars). The sites are situated in the South American temperate forest biome (green), including the Magellanic sub-Antarctic ecoregion (light green). The southernmost site is located in the United Nations Educational, Scientific and Cultural Organization's Cape Horn Biosphere Reserve, which represents the closest forested area to Antarctica and provides an ideal platform for sub-Antarctic–Antarctic comparisons. Abbreviations: km, kilometers; P. U. Católica de Chile, Pontifical Catholic University of Chile, Santiago; U. de Chile, University of Chile, Santiago; U. de Concepción, the University of Concepción, Chile; U. de Magallanes, University of Magallanes, Punta Arenas, Chile; U. La Serena, University of La Serena, Chile.

on the sensitive decisionmaking task of zoning allowed the incorporation of indigenous and other local inhabitants for the first time in a Chilean protected area (Barros and Harcha 2004).

A multiple-scale approach. Ecological and decisionmaking processes take place simultaneously at local and regional scales and at the global scale. Therefore, enhancing the scientific base in order to manage the extensive sub-Antarctic territory and monitoring impending changes resulting from socioeconomic and conservation projects, as well as those resulting from climate change, requires work at multiple scales. To implement a multiple-scale approach, the Chilean LTSER has defined three working levels: (1) the *local scale*, which includes specific research sites and field stations in association with regional universities, national parks, and UNESCO biosphere reserves; (2) the *national scale*, which has been achieved through the creation of the Chilean LTSER network; and (3) the *international scale*, which is being implemented by linking the Chilean LTSER with ILTER and by the establishment of the Sub-Antarctic Biocultural Conservation Program, coordinated by IEB and the University of Magallanes (UMAG) in Chile and by the University of North Texas (UNT) in the United States (*www.chile.unt.edu*). For the academic consolidation of the program, UNT and UMAG are both hiring new professionals to develop international collaborative research.

A series of *in situ* interdisciplinary workshops, jointly funded by the US National Science Foundation and the Chilean MSI and CONICYT, has brought together leading international scholars—mainly ecologists and environmental philosophers—with local-government authorities and graduate students from Latin America and the United States to assess, discuss, and reformulate research programs at the three field stations and to think of effective ways to enhance, from these field sites, the scientific foundations for biocultural conservation in southwestern South America (see the special issues of *Environmental Ethics* 2008, 30[3], and *Revista Chilena de Historia Natural* 2010, 83[1]). In light of the rapid cultural, socioeconomic, and ecological transformations taking place both in the remote austral region of South America and around the globe, the participants of these workshops have emphatically stated the urgent need to develop formal long-term, transdisciplinary, ecological research, education, and conservation networks. Formal networks should enhance the integration of the Chilean

LTSER sites among themselves and with other national and international research networks.

LTSER network sites go beyond LTER sites in their capacity to link biophysical processes to governance and science communication. LTSER networks provide an institutional platform to explore decisionmaking processes at multiple scales and to understand conflict as a basis for reconciling divergent goals among stakeholders, thus enhancing the resilience of local communities, places, and ecosystems (Haberl et al. 2006). In this context, international LTER networks could assist the implementation of Chilean LTSER; in turn, the latter could broaden the socioecological dimensions considered by LTSER networks.

Integrating ecological sciences and environmental ethics: Filling a major conceptual gap in LTSER

In addition to filling a geographical-knowledge gap in ILTER, the nascent Chilean LTSER network sets out to broaden the spectrum of social dimensions included in these programs. Until now, the social component considered in LTSER networks worldwide has been primarily economic (cf. Parr et al. 2002, Redman et al. 2004, Ohl et al. 2007). Indeed, the European LTSER platform was designed "as a research infrastructure to support integrated socioeconomic and ecological research and monitoring of the long-term development of society–nature interaction within the context of global environmental change" (Haberl et al. 2009, p. 1798). The integration of socioeconomic research into the LTSER framework during the last decade represents a significant step forward for the inclusion of the human component in LTER. However, our work in southern South America continuously reveals the importance of noneconomic values (e.g., spiritual and ethical values in decisionmaking; Rozzi et al. 2008b).

Calls for an integration of ecological sciences and environmental ethics have older roots both in Latin America and in the United States. For example, Frank Golley, president of the Ecological Society of America (ESA) in the 1970s, concluded that the ecosystem concept has provided a basis for "a dialogue about how humans value nature" and for "moving beyond strictly scientific questions to deeper questions of how humans should live with each other and the environment" (Golley 1993, p. 205). Later, other presidents of the ESA have emphasized that many of the choices faced by human society are ethical ones, for which the ecological sciences provide essential knowledge to inform responsible societal decisions (e.g., Likens 1991, Lubchenco 1998). However, the drastic diminution of the teaching of ethics within science-education programs (both graduate and undergraduate) in Latin America, the United States, and other regions of the world severely constrains disciplinary integration (Leopold C 2004). The paucity of ethics in academic curricula has led to a loss of the vocabulary and methods for ethical deliberation (Hargrove 2008). To address this limitation, the Chilean LTSER network, in collaboration with UNT, has developed a field environmental philosophy (FEP) methodology as a way to integrate environmental ethics and ecological research into graduate education and biocultural conservation. The FEP methodology began in 2000 at the Omora Ethnobotanical Park and was formalized by a long-term working partnership between UMAG and the world-leading environmental-philosophy program at UNT in 2005 (box 1).

Today, fairly pristine high-latitude regions offer humanity a unique opportunity to make an ethical shift. The FEP methodology provides an orientation for graduate students and other participants to research and respect the "otherness" in such remote wildernesses—the expression of ancient cultures, life forms, and habitats not yet immersed in global society. This can help recontextualize the global economy, politics, and culture. This research could stimulate an ethical–ecological shift from the current tendency to overlook vital bonds between humans and nature toward a new understanding of humans as cohabitants of ecosystems, which possess a culturally and biologically diverse array of human and other-than-human life forms that sustain ecosystem processes, as was envisioned by the mid-twentieth-century president of the ESA and celebrated architect of the "land ethic," Aldo Leopold (1949).

The FEP methodology stresses a closer examination of actual and historical forms of knowledge and ethics. The word *ethics* originated from the Greek term *ethos*, which, in its more archaic form, meant "den." Later, *ethos* also acquired a second meaning, the practice of a particular way of habitation. This dual interpretation of the Greek term *ethos* can be expressed in two Latinate terms that today have clear ecological significance: *habitat* and *habit*. Inhabiting a particular habitat generates recurrent forms of *habitation* over time—that is, the habits that configure the identity of humans and other animals. Through an ecological hermeneutic of the language, FEP allows the recovery of an understanding of *ethics* as a concept that considers not only the human habits—as most modern interpretations of *ethics* would have it—but also the habitats, where these habits emerge (Rozzi et al. 2008b).

The interrelationships among the identity and well-being of the inhabitants, their habits, and their regional habitats are also deeply rooted in Amerindian worldviews and ecological knowledge. For instance, as we mentioned above, the Pehuenche inhabit the monkey-puzzle or *pehuen* tree forests of southern South America. Their social organization and the ancestral distribution of the clans are closely associated with the particular distribution of patches of *pehuen* trees. A vital habit is the gathering of the monkey-puzzle tree cones, the seeds of which provide the nutritive foundation of the Pehuenche's diet. From medical and biogeochemical perspectives, the *pehuen* seeds are peculiar, given their rich contents of two essential amino acids—cysteine and methionine—that contain sulfur, which presumably originated in the volcanic lands. Therefore, scientific and traditional ecological knowledge converge in the understanding of the Pehuenche as the "people of the *pehuen*" and, at the same time, of the Mapuche as the "people of the land" (including

Box 1. Field environmental philosophy.

To enhance understanding of biocultural diversity, at the Omora Ethnobotanical Park (OEP, 55 degrees south), we developed a methodological approach that we call *field environmental philosophy* (FEP; Rozzi 2001). FEP emphasizes ecologically and philosophically guided field experiences in local habitats, sociocultural communities, and regional institutions and is designed to stimulate the perception of and valuation of biological and cultural diversity in specific places and moments. To achieve this integration, researchers at OEP, the University of Magallanes (UMAG), and other academic institutions had to face the challenge of designing new methodologies and curricula. As a result, in 2003, we created the first graduate program in southern Patagonia: a masters of science degree in sub-Antarctic conservation at UMAG.

To incorporate FEP into this graduate program, it was essential to include field experiences in which philosophers, authorities, students, and other participants had an opportunity to share the biological and cultural singularities of the remote Cape Horn archipelago with members of the Yahgan indigenous community, as well as with ecologists and other researchers. On the basis of these experiences, we designed new methodologies and curricula, which allowed graduate students to systematically integrate environmental ethics and ecological research into innovative biocultural education and conservation activities, including ecotourism, through an interrelated four-step cycle, which we briefly summarize below.

Step 1: Interdisciplinary ecological and philosophical research. Students conduct ecological, ethnoecological, and philosophical research, including research on the diversity of values and perceptions about biocultural diversity held by participants from different disciplines, institutions, and sociocultural groups, who speak different languages and hold different forms of ecological knowledge and practices.

Step 2: The composition of metaphors and communication through narratives. Graduate students compose metaphors and narratives with two complementary intentions: to establish an engaging and clearer dialogue with the general public and to integrate the ecological and philosophical findings (step 1) through analogical thinking that leads to a conceptual synthesis of facts, values, and action in biocultural education or conservation. The practice of composing metaphors has helped students to understand the dialectic relationships between inventions and discoveries into their research and conservation work.

Step 3: Field activities guided with an ecological and ethical orientation. For students and other participants in FEP, the experience of direct or face-to-face encounters with living beings in their habitats has been essential for understanding biocultural diversity not only as a concept but as an awareness of cohabitating with diverse human and other-than-human beings. Ecologically and philosophically guided field activities transform not only the knowledge about biocultural diversity but also the ethics of living together with the diverse inhabitants with whom we coexist in regional ecosystems.

Step 4: Implementation of areas for *in situ* biocultural conservation. FEP requires students to participate in the implementation of *in situ* conservation areas for three reasons: (1) to protect native habitats, species, and ecological interactions; (2) to enable visitors to observe and enjoy these habitats and ecological interactions; and (3) to foster in the students a sense of responsibility as citizens who are ecologically and ethically educated and who proactively participate in the care of the diversity of habitats and their various forms of life.

In summary, FEP offers a methodological approach to integrate ecological sciences and environmental ethics at long-term socioecological research sites through interdisciplinary work that fosters the consideration of interrelated habitats, cultures, and biological species into a biocultural ethics, which is ecologically and culturally contextualized. The FEP four-step cycle helps students to gain not only an understanding about scientific and traditional ecological knowledge but also an *in situ* ethical practice.

the volcanoes). As symbolic (linguistic) and physical (biotic) bodies, respectively, the logosphere and the biosphere are interwoven in this profound integration of habitats, habits, and cohabitants.

The FEP methodological approach allows students to gain an experiential understanding of the vital links among the inhabitants, their habits, and their habitats at the southern end of the Americas, as well as in other regions of the planet. In the field, researchers and students can perceive and investigate components and processes of biocultural diversity that are—inadvertently or deliberately—omitted in formal education. By integrating their senses and emotions with their rationality, students and researchers achieve a more integral *in situ* perception of biocultural diversity. In this perception, biocultural diversity ceases to be a mere concept or object of study and begins to be an experience and awareness of cohabitation with diverse living beings with their own life histories, which regularly remain outside the experiential domain of formal education. We add the adjective *environmental* to overcome the prevailing modern reduction of ethics to purely human affairs. FEP is a philosophical practice for epistemological and ethical reasons. We say *epistemological* because students and researchers not only investigate biological and cultural diversity, but they also investigate the methods, languages, and worldviews through which scientific and other forms of ecological knowledge is forged. We say *ethical* because the aim is not only to research and learn about biological and cultural diversity but, foremost, to learn to respectfully cohabitate within it (box 1).

Under an FEP approach, Earth stewardship is intended to maintain not only human welfare but the welfare of the whole community of life (Rozzi and Massardo 2011).

Amerindian worldviews, ancient Western philosophy, many traditional Asian philosophies, and contemporary ecological sciences affirm the inextricable links among human habits or behaviors, habitats or socioecological contexts, and the identity and fulfillment of the lives of human and other-than-human cohabitants (Callicott 1994). Earth stewardship requires that global phenomena and regional biocultural heterogeneity be linked. To fulfill this goal, LTSER networks should aim to forge appropriate "conceptual lenses" as much as these networks aim to forge appropriate technological sensors to research and monitor socioecological systems. In this mission, environmental philosophy and ethics undertake a task that is as relevant as the one undertaken by environmental engineering and the environmental sciences. The nascent Chilean LTSER network aims to collaborate with similar networks to better integrate local and global forms of ecological knowledge to promote a stewardship ethics on a bioculturally diverse planet.

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