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A species approach to marine ecosystem conservation

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ABSTRACT

1. The concept of integrated ecosystem conservation is widely supported as a framework to achieve sustainable management of biodiversity. However, paucity of data and limited methodological tools reduce its application in approaches that integrate scientific knowledge, enhance international cooperation, and promote a rationale that appeals to stakeholders.

2. The landscape species concept (LS), a species-based conservation planning tool developed for patterns and processes of terrestrial conservation, is applied to the Extended Patagonian Marine Ecosystem (E-PME) in the SW Atlantic. The E-PME encompasses the Patagonian continental shelf, shelf break front and part of the Argentine Basin (*ca.* 3 000 000 km^2).

3. This ecosystem is influenced by oceanographic patterns of currents and bathymetry as well as by the overlapping geographies of national and international conventions, including those that govern use of the High Seas. The interactions of these oceanographic and jurisdictional structures, and the distribution and seasonal movements of biological species, drive present conservation opportunities and threats.

4. Here, an analysis of 33 candidate species in terms of their area requirements, heterogeneity of their habitat use, vulnerability to threats, ecological functions, and socioeconomic importance is reported, and a suite of ‘seascape species’ is developed around which to build conservation efforts. Preliminary geographic representations of the human and biological aspects of the seascape are provided, and how their spatial intersection affects conservation approaches is discussed.

5. The application of a focal species approach in an ecosystem framework complements space–habitat perspectives (e.g. the Large Marine Ecosystem concept) and may lead to more efficient planning of marine protected areas.

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INTRODUCTION

The main purpose of this work is to contribute to the long-term viability and sustainable management of the biodiversity in a large, temperate ocean ecosystem in the south-west Atlantic (the Extended Patagonian Marine Ecosystem (E-PME)). Most of the tools available for an integrated perspective on ecosystem-based biodiversity management focus on bio-regionalization and highlight marine protected areas, management and mitigation plans (Banks *et al*., 1999; NRC, 2001; WCPA, 2005; Conservation Law Foundation and WWF-Canada 2006; Grant *et al*., 2006; World Bank, 2006). To better address these goals, a focal-species approach was applied that promotes an integrated, multi-species based understanding of the target seascape. This approach can also help to guide conservation actions in the context of international cooperation, despite gaps in the knowledge and the complexity of jurisdictional issues. Here, the first application of the landscape species approach (LSA), a site-based, wildlife-focused conservation-planning tool, to a marine ecosystem, is described.

The LSA is based on the premise that landscape heterogeneity, considered broadly, is critical to effective conservation (Pickett *et al*., 1997; Sanderson *et al*., 2002). The method is typical of a recent generation of 'landscape-scale' conservation planning tools developed for terrestrial environments (Groves, 2003; Loucks *et al*., 2004). The goal is to select a suite of 'landscape species' that together capture the full range of habitat types, management units, and threats in a target landscape and use those species to decide how much and which parts of the landscape need to be conserved. Because landscape species require large, wild and heterogeneous areas, it is posited that they serve a significant umbrella function (*sensu* Caro and O'Doherty, 1999). Through conservation of the suite of landscape species' habitat requirements, this approach aims to conserve other species dependent on the same landscape (or seascape) system (Figure 1), although this is as yet an unproven assertion. The LSA is a surrogate species method, similar to the 'focal species approach' (Lambeck, 1997) and other tools based on umbrella, keystone and flagship species (Caro and O'Doherty, 1999; Beazley and Cardinal, 2004; Roberge and Angelstam, 2004).

The landscape/seascape species concept is applied here for the first time to an open ocean system: the E-PME. The limits of the target area, despite some unavoidable arbitrariness involved in zoning a mobile habitat continuous in three dimensions, are firmly based on existing definitions, such as the Patagonian Large Marine Ecosystem concept (Sherman and Alexander, 1986 and *http://www.edc.uri.edu/lme*; see also Esteves *et al*., 2000; Boersma *et al*., 2004, and articles in *Aquatic Conservation: Marine and Coastal Ecosystems* **12**(1): 2002). Because ocean conservation may require consideration of patterns and processes expressed over spatial and temporal scales, it is distinctly different from terrestrial conservation planning. Marine systems have less discrete boundaries and experience variation on shorter time scales than terrestrial ecosystems (NAS, 2001; Glover and Earle, 2004; Gregr and Bodtker, 2007). As a result, marine organisms typically experience habitat at broader spatial scales, and their life histories are adapted to the more open attributes of marine ecosystems (Boltovskoy *et al*., 2005).

Given these characteristics, it is interesting that most marine conservation planning is done for near-shore areas, at scales smaller than regions, and within politically defined, rather than ecologically defined, units, like Exclusive Economic Zones (EEZs) (Beck, 2003). Much recent work has focused specifically on marine protected areas (MPAs) (Hyrenbach *et al*., 2000; Hooker and Gerber 2004; see also: Glover and Earle 2004 and references therein; WCPA, 2005; The World Bank, 2006) which are generally limited in size relative to oceanographic processes. Although Halpern (2003) demonstrated that even small MPAs can

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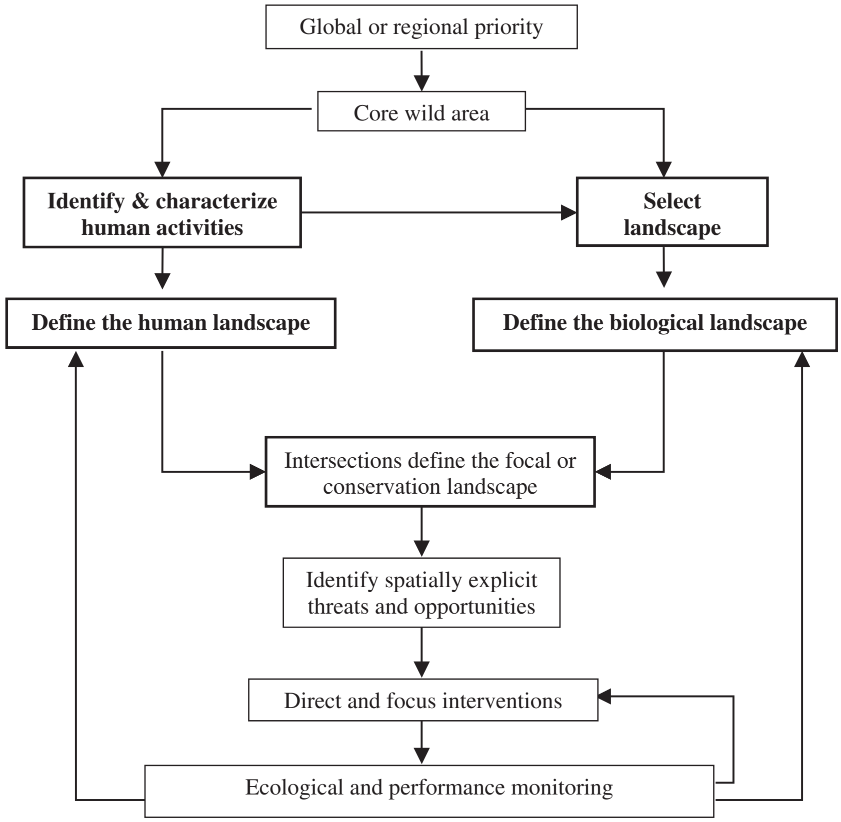

Figure 1. Procedural steps in the Landscape Species Approach (LSA; Sanderson *et al*., 2002; Coppolillo *et al*., 2004). The LSA focuses conservation on a core wild area selected through a global or regional prioritization process. Once selected, human activities and the biological characteristics of the landscape are characterized and an assessment of landscape species is made. These assessments drive the development of the human landscapes — describing spatially key human activities — and the biological landscapes — describing the areas in terms of their productivity for the landscape species. The intersection between the human and biological landscapes defines areas of conservation concern and enables one to direct conservation interventions. These actions take place in the context of ecological monitoring of the landscape species and other targets, outcome monitoring for tracking changes in threats, and performance monitoring of our efforts. This paper emphasizes the boxes shown in **bold**.

have surprisingly positive conservation outcomes (see also World Bank, 2006), the connectivity of marine systems leads us to consider the same questions that drove terrestrial conservation planners to the landscape level: what should we do when protected areas are too small? What about the huge areas — encompassing most of the oceans — that we cannot protect?

These questions are particularly pertinent given the recent focus on ecosystem-based management of the oceans (NRC, 2001; Pew Oceans Commission, 2003; WCPA, 2005; see also Glover and Earle, 2004 and references therein), a movement away from management paradigms that emphasize the EEZs of individual nations and limited sets of economically important species (e.g. whales, tuna, or 'highly migratory' species). Ecosystem-based management, as with terrestrial applications, begins with choosing targets and setting meaningful long-term conservation goals across the relevant spatial and temporal frames (Babcock and Pikitch, 2004).

The focus ecosystem in this case, the E-PME, is a large, temperate ocean in the Southern Hemisphere the size of the Mediterranean Sea (Figure 2(a)). A diverse community of resident top predators, as well as many

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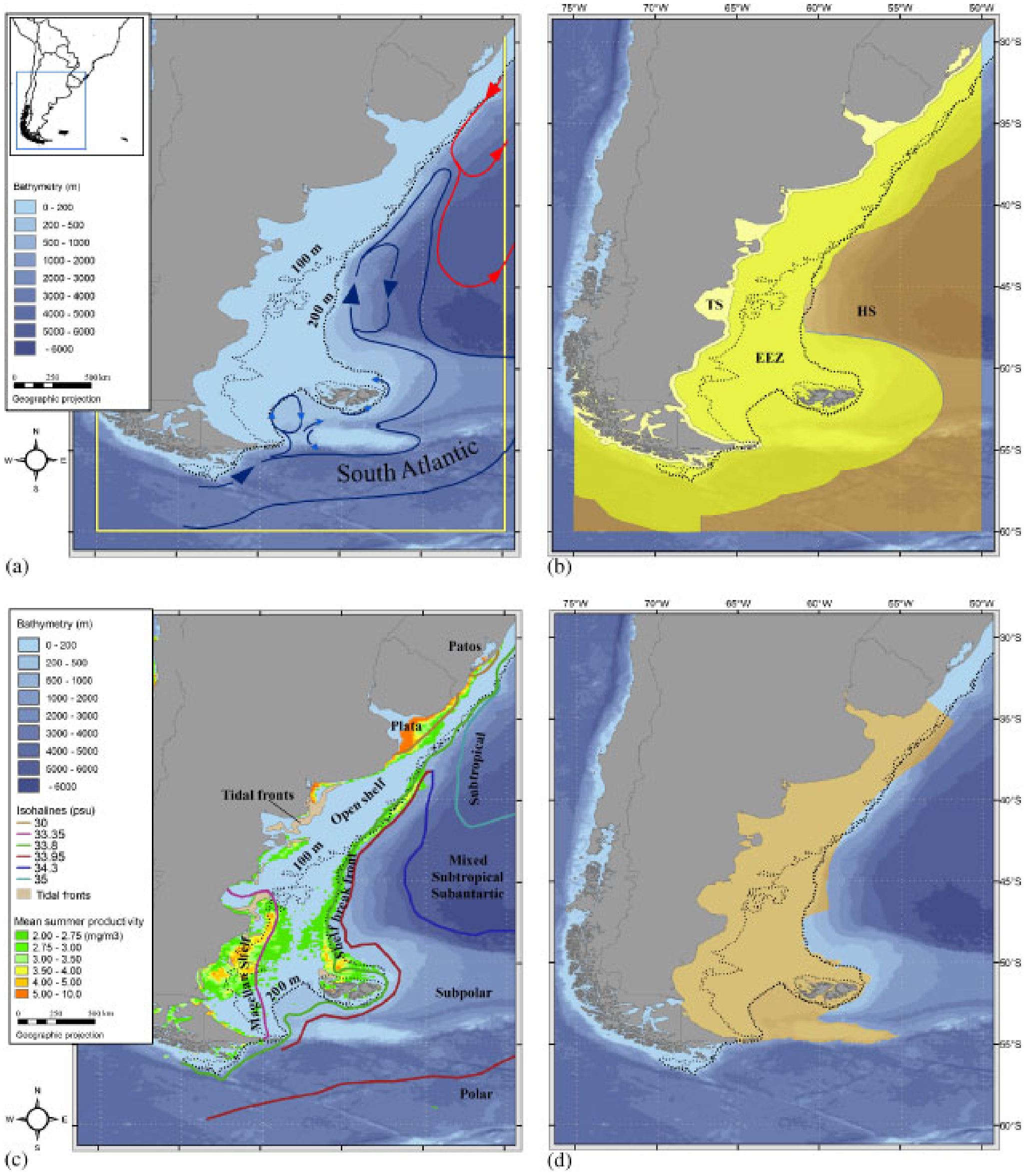

Figure 2. (a) Bathymetric profile and currents focusing the South Atlantic Ocean, off the coast of the Southern Cone. The 200 m isobath indicates the approximate offshore edge of the continental shelf. Lines and arrows illustrate the circulation of the cold Falkland/Malvinas and Return Current (blue), and the warm Brazil Current (red; adapted from Piola and Matano, 2001). Yellow lines mark the limits of the area generically defined in this paper as the Extended Patagonian Marine Ecosystem. Note: Maps are approximate only and are non-authoritative regarding sovereignty issues of the represented countries. (b) Major jurisdictional zones for Patagonian Shelf Large Marine Ecosystem (based on UNCLOS; see *http://www.un.org/Depts/los/index.htm*): territorial seas (TS), economic exclusive zones (EEZ) and high seas (HS). (c) Oceanographic regimes described for the target area as habitat heterogeneity (developed from Piola and Matano, 2001) overlapped with areas of major productivity (Acha *et al*., 2004). Productivity is shown as summer mean concentration of chlorophyll-*a* in mg m^{-3} for the period 1998–2004 (SeaWiFS, *http://oceancolor.gsfc.nasa.gov/SeaWiFS*). The isohalines separating different regimes are shown with coloured lines and labeled with salinities expressed in practical salinity units (psu). (d) The Patagonian Shelf Large Marine Ecosystem (source: *http://www.edc.uri.edu/lme/gisdata.htm*) is limited in most of its extension by the 200 m isobath (approximate offshore edge of the continental shelf). It encompasses most of the EEZ of Argentina and Uruguay. It does not include the Argentine Basin, an area widely used by some of the candidate seascape species (see Figure 3).

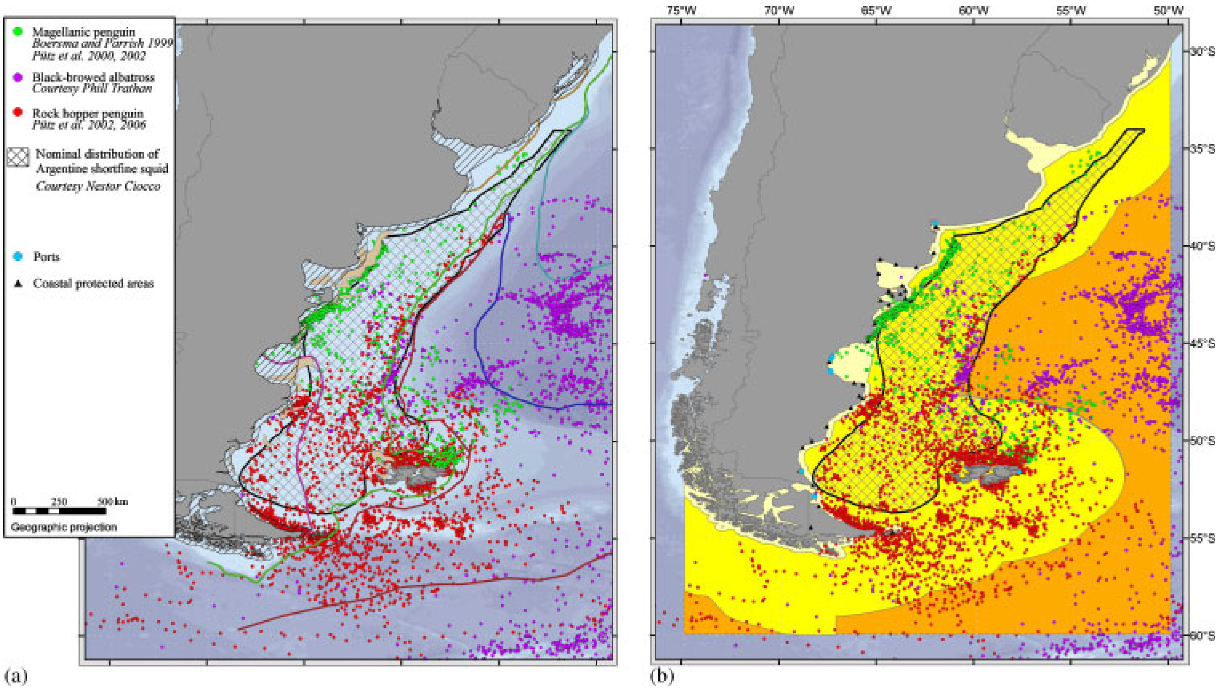

Figure 3. Pelagic distribution of four seascape species (Magellanic and rockhopper penguins, black-browed albatross and Argentine shortfin squid; Tables 3 and 4) as a function of (a) oceanographic regimes (Figure 2(c)); and (b) major jurisdictional zones for the south-west Atlantic (Figure 2(b)) according to UNCLOS (see http://www.un.org/Depts/los/index.htm).

seasonal migrants (Croxall and Wood, 2002), depend on the high biological productivity of this region (Brandini *et al*., 2000; Acha *et al*., 2004). The breeding and feeding aggregations of charismatic species, such as albatrosses, penguins, whales and seals, constitute one of the greatest wildlife spectacles on earth. However, populations of some species are declining and many have already been included in the IUCN's Red List of Threatened Species (*http://www.iucnredlist.org*). Fish and squid stocks of major regional or global commercial importance are being exploited unsustainably (FAO, 1994), Figure 3.

In the last two decades, a number of key threats have impacted species in this region. Large-scale, international fisheries have impacted both commercial targets and other species due to bycatch, entanglement and accidental catch (Croxall and Prince; 1996; Croxall *et al*., 1998; UNEP, 2002; *http://www.un.org/Pubs/whatsnew/14mar03.htm*; Campagna *et al*., 2007). Hydrocarbon resources are actively extracted along the mainland coasts, potential major offshore resources are currently under exploration licence and oil pollution has a chronic negative effect on some marine bird populations (Gandini *et al*., 1994; Richards, 2002; Garcia Borboroglu *et al*., 2006). Offshore MPAs are absent, although extensive areas within EEZs are subject to fishery management regimes and there are various coastal protected areas for species which breed on land (GEF, 1997). The adjacent international waters, on the eastern side of the ecosystem, have little effective management and limited monitoring, except to the south of the Antarctic Polar Front, within the area of application of the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR).

The successful application of the LSA to the E-PME may demonstrate its applicability to other oceans of similar concern, such as the Humboldt and Benguela Current ecosystems (O'Toole and Shannon, 2003; Wolff *et al*., 2003). Boersma *et al*. (2004) adopted the Patagonian Large Marine Ecosystem as a case study

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in an ocean-use planning exercise and suggested that common issues affect a variety of other systems, extending the applicability of planning beyond the target. The LSA tool may help guide zoning, management and mitigation plans and facilitate the integration of data and information within a collaborative endeavour, providing a mechanism for a diverse group of stakeholders to understand and conserve a large oceanic system.

METHODS

Study area

The E-PME was defined for this study as the area that extends from approximately 34° to 58° S, from near the coastal border of Uruguay and Brazil to the south of Tierra del Fuego, and from approximately 48° W to the South American mainland coast, including estuarine waters and coastal colonies of sea-going species on the mainland and the archipelago of the Falkland Islands–Malvinas (hereafter FI(M)[1]; Figure 2(a)). It is conservatively sized at around 3 000 000 km^2, with large-scale structures introduced by the oceanographic patterns of currents and bathymetry and national and international political conventions, and it includes extensive areas of high seas where no country has legal tenure (Figure 2(a)–(c)). In addition, the target area:

a. Comprises the most extensive boundary areas in the SW Atlantic, the Falkland–Malvinas (F-M) and Brazil currents and their confluence.
b. Incorporates all major fisheries of FAO Area 41.
c. Shares boundaries to the south and east with the Southern Ocean, a very large oceanic area subject to active ecosystem-based management by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR; *http://www.ccamlr.org/*).
d. Includes home ranges of the most charismatic groups in the regional biodiversity (albatrosses, petrels, penguins, pinnipeds, cetaceans), which gives this area an international profile.

The system encompasses an extended and shallow shelf, a broad frontal area, the shelf edge, and part of the deep Patagonian basin (Guerrero and Piola, 1997; Rivas and Piola, 2002). Functionally, the region is influenced by the F-M and Brazil Currents (Piola and Matano, 2001). The F-M Current, a northward flowing branch of the Antarctic Circumpolar Current, carries cold, nutrient-rich waters which meet the warm, nutrient-poor waters of the Brazil Current travelling south, at between 40° and 47° S, depending on season (Piola and Matano, 2001; Figure 2(a)). The confluence of these currents occurs over a major bathymetric feature, the Patagonian continental shelf-break, as it sinks from a shallow 100 m depth to nearly 4000 m. This shelf break is located close to and commonly symbolized by the location of the 200 m depth contour. The interaction of the F-M Current with the shelf break drives a seasonally variable, nutrient upwelling zone of biological productivity that spills up and across the Patagonian coastal shelf (Brandini *et al*., 2000). After consideration of several different physical descriptors of the oceans, it was found that the isohalines, based on sea surface salinity measured in practical salinity units

[1]Note: Due to the international nature of this paper, it complies with the UN formal designation of the Archipelago in public documents written in English as Falkland Islands (Malvinas) (A/AC. 109/2002/16 at *http:// www.un.org/Depts/dpi/decolonization/main.htm*) and abbreviated FI(M), with the exception of (a) published materials (papers, technical reports and other scientific citations) that used alternative designations (for which the original version is maintained), (b) affiliations, names of agencies, conventions or similar that respond to other formats (the original name is maintained). Technical names with no formal international designation will be referred as Falklands-Malvinas (e.g. F-M Current). All maps and other representations are approximate only and are non-authoritative.

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(psu), provided the most representative and consistent boundaries throughout the seasons (Figure 2(c)).

A subset of the E-PME defined as the Patagonian Shelf Large Marine Ecosystem (PSLME; Sherman and Alexander, 1986), was also considered. The template has the advantage over the original target area (SW Atlantic/E-PME) of already being the framework of ecosystem approaches rooted in shelf systems. The PSLME template, compared to the larger E-PME (Figure 2(a) and (d), respectively), is focused on the shelf and excludes critical regimes dependent on the F-M and Brazil Currents (Figure 2(a)).

The Landscape Species Approach (LSA)

The Landscape Species Approach to conservation begins with the identification of a wild landscape or seascape of interest through a process of global or regional strategic planning (Figure 1.) For the seascape, important human activities that may be threats to the integrity of the seascape are identified and a set of 'landscape (or in this case, seascape) species' are selected. Landscape species are defined as:

> Landscape species use large, ecologically diverse areas and often have significant impacts on the structure and function of natural ecosystems. Their requirements in time and space make landscape species particularly susceptible to human alteration and use of natural landscapes (Sanderson *et al.*, 2002).

For each landscape species, a biological landscape is mapped, representing its potential distribution in the absence of anthropogenic threats. Threats are mapped as the human landscape. The spatial intersection of the biological and human landscapes defines the 'focal' or 'conservation landscape' where conservation work will occur. Over time, the suite of landscape species may change as further information becomes available and the conservation status of the seascape is modified. This paper focuses on the selection of landscape species, including defining a system of oceanographic-based 'habitat units' and 'jurisdictional units' which provide precedents for biological and human landscapes.

Landscape species are identified based on five main criteria (Coppolillo *et al.*, 2004): heterogeneity, area, ecological function, vulnerability, and socio-economic importance. Heterogeneity is determined by the number of 'habitat units' and 'jurisdictional units' used by the species in the seascape. Area depends on the size of the area used by the species. Ecological functions include interactions with other species and the abiotic environment. Vulnerability represents the species' sensitivity to human activities. Socio-economic importance considers both gains (e.g. economic benefit from exploitation) and losses (e.g. human–wildlife conflict) as well as the flagship representation that some species provide. Coppolillo *et al.* (2004) provide the rationale for choosing these attributes and explain how and why they are combined as they are in the seascape selection process, described below.

Seascape species approach: a collaborative process

The LSA requires the active cooperation of institutions and individual scientists working in a structured Delphic system (Groves, 2003; Coppolillo *et al.*, 2004). The synthesis reported here is an elaboration of information gathered from responses to questionnaires and during four major technical workshops (New York: July 2002, January 2003, and April 2003; Buenos Aires: December 2004), with intervening collaborations over a 3-year period involving over 55 scientists from 26 institutions and eight countries (Appendix 1).

Qualitative assessments from the experts at the workshops were compiled with quantitative distributional data where they were available; eventually creating an extensive, spatially explicit database that describes species use and human use of the seascape (described below). In the species selection process, special attention was given to 'heterogeneity', the proportion of habitat or jurisdictional units within the landscape that an individual uses during its entire life cycle, and to defining those units after extensive discussion (see

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below). Species were also characterized in terms of their area use and movements, ecological functions, socio-economic importance and vulnerability to human activities (i.e. threats).

These data on landscape species criteria were entered into the landscape species selection decision-support software (Strindberg, 2004). The selection software reports summary scores and relative ranks for each species as 'landscape species' based on an aggregate score, which is the sum of the five landscape species selection criteria scores (area requirements, heterogeneity, vulnerability, ecological functionality, and socio-economic significance). The score for vulnerability to threats is based on the urgency, severity, recovery time, proportion of local extent affected and probability that each threat may materialize (based on threats assessment used by the 5-S system; TNC, 2000). Threats were evaluated by summing vulnerability scores across species and tallying the number of species affected by each threat, while the impact for a particular species was gauged by summing these scores across threats. Complementary suites of species were selected by taking the highest-ranking landscape species, then finding the next most complementary species with respect to heterogeneity in the biological and human landscapes and threats (see Coppolillo *et al*., 2004 for details).

Seascape species selection: three scenarios

A list of 33 candidate species (Tables 1–3; scientific names given in Table 3) was considered in the landscape species selection process. These candidates were selected from the overall biodiversity of the system by considering whether a species would meet any of the criteria of the landscape species approach (heterogeneity, area use, ecological function, vulnerability, socio-economic importance) (Coppolillo *et al*., 2004). Only species that spend a significant portion of their life cycle in the PME were considered. The selection criteria for candidate species (Coppolillo *et al*., 2004) allow reducing the potential candidates to a manageable number, usually large-bodied vertebrates, which collectively occupy the full range of habitats defined for the target landscape. Obviously this process was constrained by our knowledge of the biodiversity of the system and may, in light of greater knowledge in the future, need to be revised (Table 4).

The seascape selection software was run under three different scenarios:

Scenario 1: Candidates were evaluated regarding their distribution and threats in the target area, the E-PME (Figure 2(a)).

Scenario 2: Candidates were evaluated regarding their distribution and threats only within the Patagonian Shelf Large Marine Ecosystem as defined by Sherman and Alexander (1986) (PSLME, Figure 2(d)). The PSLME (*http://www.edc.uri.edu/lme*, Sherman and Alexander, 1986) represents a subset of the larger E-PME, which matches an internationally recognized system of marine ecosystem units.

Scenario 3: A subset of candidate species, considering first subset according to 'feasibility' of conservation, was evaluated for the E-PME. Feasibility, or opportunity of conservation action, was defined as the integration of four criteria: ease of access, charisma, availability of information, and socio-economic relevance. This analysis has practical value to guide conservation action and research. Species were ranked 0–1 for all variables except charisma, which was given more weight (0–3). Final scores ranged from 0 (minimum opportunity) to 6. Species with scores lower than 3 were discarded and those with scores of 3 or higher were considered candidates. The software was then run with only this second selection of candidates and a new suite of species was obtained.

Habitat units: oceanographic regimes and water column

In the LSA, the biological landscapes represent important ecological heterogeneity across the landscape. For the E-PME, this heterogeneity is largely defined by oceanographic features, including bathymetry, currents and productivity. From these features a set of 'oceanic regimes' was drawn (Figure 2(c)) based on

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Table 1. Summary of use of oceanographic regimes by selected candidate landscape species for the Extended Patagonian Marine Ecosystem (Figure 2(a)), based on expert opinion and analysis of available spatially-explicit data. Experts were asked whether the given species regularly occupied or used a particular oceanographic regime, as shown on Figure 2(c) and described in the text. Actual point locations were analysed against a usage criterion, depending on the data type (typically at least 5% of the observations; see text for details.) Expert opinion or meeting the data criteria resulted in a solid black triangle. Documented usage, but not at the level of the 5% criterion, is shown in grey. Proportions compare spatially-explicit data (numerator) and expert opinion for compared candidate species (see Methods). Data sources for each species are provided on-line at wcs.org/sea-and-sky. Highlighted cells show candidate species and habitat types not included in the comparison because expert contribution was limited to data availability

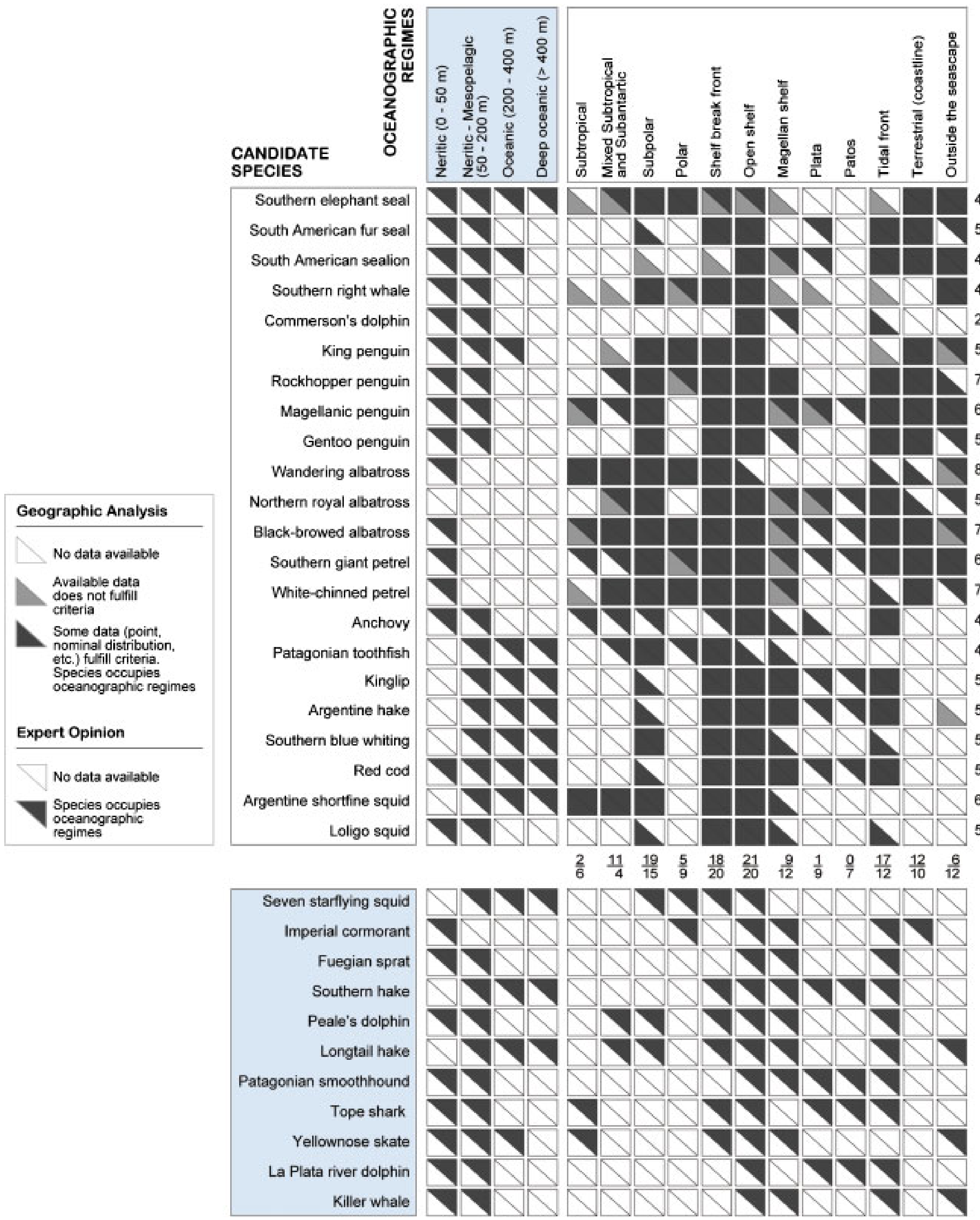

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Table 2. Summary of the vulnerability scores for the species. Each vulnerability score is calculated as (Urgency + Recovery) × Severity × Probability of Occurrence × Proportion Affected. Blanks indicate zero scores

Common name	Oil extraction & transportation	Oil exploration	Demersal Trawling	Demersal Trawling by-catch	Pelagic Trawling	Pelagic Trawling by-catch	Long-lining	Long-lining by-catch	Illex jigging	Gill netting	Gill netting bycatch	Tourism (sea & land)	Pollution — entanglement	Pollution — nutrients	Garbage dumps	Coastal development	Fire	Introduced species	Hunting (birds; whaling)	Disease	Total vulnerability
Southern right whale	4	4	0	0	0	0	0	0	0	0	0	16	8	0	10	20	0	0	30	20	112
Commerson's dolphin	4	4	0	4	0	4	0	0	0	0	0	4	4	0	0	4	0	0	4	4	36
Southern elephant seal	3	3	0	4	0	0	0	0	8	0	0	8	8	0	0	4	0	0	20	20	78
South American fur seal	4	4	0	4	0	4	0	0	0	0	0	4	5	0	0	0	0	0	30	20	75
South American sea lion	4	4	0	10	0	10	0	4	0	0	0	4	8	0	0	4	0	0	15	20	83
Rockhopper penguin	16	4	0	30	0	20	0	0	4	0	0	4	4	30	0	4	20	8	0	20	164
Magellanic penguin	30	20	0	20	0	20	0	4	0	0	10	8	4	30	4	4	4	4	4	20	186
Gentoo penguin	4	4	0	4	0	4	0	0	4	0	0	4	4	30	0	4	4	4	0	4	74
King penguin	16	4	0	4	0	4	0	0	0	0	0	8	4	4	0	0	20	4	0	0	68
Wandering albatross	4	4	0	0	0	0	0	40	0	0	0	0	4	0	0	0	0	0	4	0	56
Black-browed albatross	4	4	0	45	0	12	0	40	24	0	0	4	4	30	0	4	8	0	4	4	187
Southern giant petrel	4	4	0	4	0	4	0	4	24	0	0	4	4	0	0	0	0	4	0	0	56
White-chinned petrel	4	4	0	4	0	4	0	30	4	0	0	0	0	0	0	0	0	4	0	0	54
Imperial cormorant	24	4	0	8	0	8	0	0	0	0	4	4	0	24	8	4	0	4	0	4	96
Argentine shortfin squid	4	4	4	4	4	4	0	0	60	0	0	0	0	4	0	0	0	4	0	0	92
Loligo squid	4	4	60	0	0	0	0	0	0	0	0	0	0	4	0	0	0	4	0	0	76
Seven-star flying squid	4	4	0	0	0	0	0	0	15	0	0	0	0	4	0	0	0	4	0	0	31
Southern hake	4	4	72	4	0	0	0	0	0	0	0	0	0	4	0	0	0	4	0	0	92
Argentine hake	4	4	72	24	0	0	0	0	0	0	0	0	0	4	0	0	0	4	0	0	112
Red cod	4	4	72	4	0	0	0	0	0	0	0	0	0	4	0	0	0	4	0	0	92
King clip	4	4	72	4	0	0	20	0	0	0	0	0	0	4	0	0	0	4	0	0	112
Southern blue whiting	4	4	0	4	72	4	0	0	0	0	4	0	0	4	0	0	0	4	0	0	100
Patagonian toothfish	4	4	0	20	0	0	72	0	0	0	0	0	0	4	0	0	0	4	0	0	108
Peale's dolphin	0	0	0	0	0	0	0	0	0	0	4	0	8	0	0	4	0	0	10	4	30
Fuegian sprat (sardine)	0	4	0	0	4	0	0	0	0	0	0	0	0	4	0	4	0	0	0	0	16
Anchovy	0	0	45	4	4	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	57
Longtail hake	4	4	16	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40
Killer whale	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	4	4	20
Northern royal albatross	4	4	0	0	0	0	0	15	8	0	0	0	8	0	0	0	0	0	4	0	43
Patagonian smoothhound	4	4	36	4	4	4	0	0	0	0	0	8	4	4	0	0	0	0	0	0	72
Tope shark	6	5	72	24	0	0	6	6	0	0	0	12	6	6	0	0	0	0	0	0	143
Yellownose skate	5	5	45	10	20	30	45	0	0	0	0	0	0	0	0	0	0	0	0	0	160
La Plata river dolphin	0	0	0	8	0	0	0	0	0	0	15	0	4	4	0	0	0	0	0	8	39
Total by threat	188	137	566	255	124	136	143	143	151	0	37	92	91	206	22	64	56	68	129	152	
No. species affected	29	30	11	24	7	15	4	8	9	0	5	14	17	20	3	12	5	16	11	13	

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Table 3. Summary of landscape species scores for 33 candidate species for the Extended Patagonian Marine Ecosystem (Figure 2(a))

Common name, Scientific name	Rank	Agg	Het	Area	Vul	Func	SE
Magellanic penguin, *Spheniscus magellanicus*	1	4.196	0.952	0.9	0.994	0.636	0.714
Black-browed albatross, *Diomedea melanophris*	2	4.003	0.887	1	1	0.545	0.571
Rockhopper penguin, *Eudyptes chrysocome*	3	3.998	0.774	0.867	0.877	0.909	0.571
Tope shark, *Galeorhinus galeus*	4	3.679	0.806	0.667	0.765	0.727	0.714
Yellownose skate, *Dipturus chilensis*	5	3.447	0.484	0.667	0.855	0.727	0.714
South American sea lion, *Otaria flavescens*	6	3.44	0.79	0.75	0.445	0.455	1
Argentine shortfin squid, *Illex argentinus*	7	3.397	0.823	0.833	0.494	0.818	0.429
Patagonian toothfish, *Dissostichus eleginoides*	8	3.231	0.677	0.717	0.578	0.545	0.714
Southern elephant seal, *Mirounga leonina*	9	3.198	0.903	0.8	0.417	0.364	0.714
Southern right whale, *Eubalaena australis*	10	3.193	0.548	0.733	0.6	0.455	0.857
Argentine hake, *Merluccius hubbsi*	11	3.181	0.726	0.75	0.601	0.818	0.286
Patagonian smoothhound, *Mustelus schmitti*	12	3.168	0.565	0.633	0.386	0.727	0.857
King penguin, *Aptenodytes patagonicus*	13	3.165	0.661	0.75	0.365	0.818	0.571
Southern giant petrel, *Macronectes giganteus*	14	3.1	1	0.967	0.302	0.545	0.286
South American fur seal, *Arctocephalus australis*	15	2.989	0.661	0.667	0.402	0.545	0.714
King clip, *Genypterus blacodes*	16	2.874	0.694	0.75	0.599	0.545	0.286
Southern hake, *Merluccius australis*	17	2.783	0.726	0.733	0.493	0.545	0.286
Gentoo penguin, *Pygoscelis papua*	18	2.782	0.661	0.517	0.397	0.636	0.571
Wandering albatross, *Diomedea exulans*	19	2.748	0.645	0.917	0.302	0.455	0.429
Longtail hake, *Macruronus magellanicus*	20	2.734	0.694	0.85	0.216	0.545	0.429
Loligo squid, *Loligo gahi*	21	2.733	0.371	0.617	0.407	0.909	0.429
Anchovy, *Engraulis anchoita*	22	2.708	0.661	0.767	0.306	0.545	0.429
Imperial cormorant, *Phalacrocorax albiventer*	23	2.705	0.532	0.633	0.514	0.455	0.571
La Plata river dolphin, *Pontoporia blainvillei*	24	2.683	0.548	0.483	0.211	0.727	0.714
Southern blue whiting, *Micromesistius australis*	25	2.658	0.484	0.717	0.535	0.636	0.286
Red cod, *Salilota australis*	26	2.645	0.661	0.75	0.493	0.455	0.286
Killer whale, *Orcinus orca*	27	2.618	0.645	0.733	0.11	0.273	0.857
White-chinned petrel, *Procellaria aequinoctialis*	28	2.502	0.694	0.867	0.291	0.364	0.286
Seven star flying squid, *Martialia hyadesi*	29	2.46	0.516	0.633	0.168	1	0.143
Northern royal albatross, *Diomedea sanfordi*	30	2.352	0.645	0.967	0.233	0.364	0.143
Commerson's dolphin, *Cephalorhynchus commersonii*	31	2.116	0.403	0.533	0.193	0.273	0.714
Peale's dolphin, *Laenorhynchus australis*	32	2.012	0.581	0.567	0.162	0.273	0.429
Fuegian sprat (sardine) *Sprattus fuegensis*	33	1.677	0.452	0.45	0.087	0.545	0.143

Agg = Aggregated landscape species score; a measure of the how well the species meets the landscape species selection criteria relative to other species considered. Het = Heterogeneity score, normalized to 0–1, with highest ranking species assigned 1. Measures the extent to which species uses a variety of oceanographic regimes and management zones (Figures 1 and 2, respectively). Area = Area score, normalized to 0–1, with highest ranking species assigned 1. Aggregate measure of how much area the species uses in the E–PME based on home range descriptions and dispersal distances. Vul = Vulnerability score, normalized to 0–1, with highest ranking species assigned 1. Aggregate measure of total vulnerability to all threats in the seascape, as described in the text. Func = Function score, normalized to 0–1, with highest ranking species assigned 1. Aggregate measure of importance of this species in terms of ecological functions, in this case, trophic relationships and nutrient redistribution. SE = Socio-economic score, normalized to 0–1, with highest ranking species assigned 1. Aggregate score of socio-economic importance including positive and negative economic values, positive and negative local cultural values, and potential to be a regional or global flagship species.

examination of historical hydrographic data (Longhurst, 1998), surface drifting buoys (WOCE, 2002), satellite derived sea surface temperature (SST; Olson *et al*., 1988), and previous numerical simulations (Glorioso and Flather, 1995). These regimes were developed for this particular exercise, were extensively discussed and then further characterized by analysis of their salinity, temperature and productivity (based on monthly SeaWIFs composites, *http://oceancolor.gsfc.nasa.gov/SeaWiFS*). In addition, the habitat was characterized according to the large-scale, bathymetric features of the target system considering four depth

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Table 4. Suite of seascape species (scientific names in Table 3) and associated variables (habitat types, management zones and threats) that explains high ranking scores and complementarity

Seascape species common name	Habitat type	Management zone	Threats (current and potential)
Magellanic penguin	Shallow neritic (0–50 m)	Terrestrial waters	Oil extraction and transportation
	Shelf break front	Economic Exclusive Zones	Oil exploration
	Open shelf	High seas	Pelagic trawling bycatch
	Magellan shelf		Gill netting bycatch
	Plata shelf		Tourism (sea & land)
	Tidal fronts shelf		Pollution (entanglement)
	Coastline terrestrial		Pollution (nutrients)
	Outside the seascape		Introduced species
			Disease
Black-browed albatross	Subtropical oceanic		Demersal trawling bycatch
	Mixed subtropical		Longlining bycatch
	Subpolar oceanic		
	Polar oceanic		
Argentine shortfin squid	Mesopelagic (50–200 m)		*Illex* jigging
	Oceanic (200–400 m)		
	Deep oceanic ($\geqslant$400 m)		
	Patos shelf		
Yellownose skate			Longlining
			Demersal trawling
Rockhopper penguin			Human land-based activities (fire)
Southern right whale			Human land-based activities (garbage dumps)
			Human land-based activities (coastal development)
			Hunting (birds; whaling)
Southern blue whiting			Pelagic trawling

categories for the water column: (a) shallow neritic (0–50 m), (b) mesopelagic (50–200 m); (c) oceanic (200–400 m) and deep oceanic (> 400 m).

Jurisdictional units and management zones

Heterogeneity is also created by the distribution of jurisdictions and management zones defined by people. Recognizing this heterogeneity is significant because differences in management can have strong effects on landscape structure (Schonewald-Cox and Bayless, 1986; Schonewald-Cox, 1988; Landres *et al*., 1998), which in turn will affect ecological processes (Wiens *et al*., 1985; Wiens, 1992), and therefore conservation, across jurisdictional boundaries (Landres, 1998; Briggs, 2001). Jurisdictional units for the E-PME were based on three management zones that comply with international conventions (UNCLOS, i.e. United Nations Convention on the Law of the Sea, *http://www.un.org/Depts/los/index.htm*; Figure 2(b)): territorial sea (within 12 nautical miles of the coast), exclusive economic zones (up to 200 nautical miles from the baselines from which the breadth of the territorial sea is measured), and high seas (all parts of the sea that are not included in the exclusive economic zone, in the territorial sea, or in the internal waters of a State or in the archipelagic waters of an archipelagic State; Figure 2(c)). The first two areas are managed under particular national regimes whereas the high seas are open to fishing vessels worldwide; although in limited cases restrictions are provided under international fisheries agreements (UNCLOS). A conflict of

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sovereignty exists over the FI(M) Archipelago between Argentina and the UK that affects EEZ management regimes.

Description of biological uses in the seascape

Experts shared a wide variety of biological data on species movements and distributions (see on-line summary at *http://www.wcs.org/sea-and-sky*). The database includes major summaries of colony distributions and abundance (Woods and Woods, 1997; Yorio *et al*., 1998) and numerous satellite-tracking studies that provide extensive information on foraging patterns (Campagna *et al*., 1995, 1998, 1999, 2001, 2006; Prince *et al*., 1998; Boersma and Parrish, 1999; Putz *et al*., 2000, 2002a, 2002b, 2006; Quintana and Dell Árciprete, 2002; Thompson *et al*., 2003). Although many of the individual data sets derive from small samples of individuals from a few sites at restricted times of year, taken together they represent over 80 000 locations identified for animals foraging at sea in the E-PME. In addition, quantitative estimates of abundance from surveys of seabirds and marine mammals were also available around the FI(M) from various survey programmes (White *et al*., 2002). These data are biased taxonomically toward seabirds and marine mammals, but do include fishery catch data as described in the next section.

Description of human activities in the seascape

Technical fishery reports published by the Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP, *http://www.inidep.edu.ar/home.htm*) were used to analyse the fisheries activity in the Argentine Exclusive Economic Zone (Cordo *et al*., 2004; Sánchez and Bezzi, 2004). Summaries of catches by species (or groups of species), on quarter-degree by half-degree grids, are available for the waters surrounding the FI(M) (*http://www.fis.com/falklandfish*). Night-time light satellite data have been used to monitor squid jigging activity through the seascape (Rodhouse *et al*., 2001; Waluda *et al*., 2002). Nominal distributions of other processes/events (e.g. tanker traffic, some fish and invertebrate species) were selectively available (Boltovskoy, 1981; Cousseau and Perrotta, 2000).

Data analysis and summary

The abundance of spatially explicit data available on the movements of the candidate landscape species within the E-PME complemented the experts' qualitative assessments of oceanographic regimes and management zones used by these species. In the case of point data (e.g. locations at sea), all the data available for a given species were combined and if more than 5% of the available observations fell within a given oceanographic regime or management zone, it was considered to be used by that species. For data collected over survey grids or nominal descriptions of species ranges, if more than 5% of the area of the grid where the species was observed or described fell within a given regime or zone, it was considered used. If a species might be found within an area, but not to the 5% criteria, it was noted. These cut-offs are somewhat arbitrary and the data quality is variable, so these comparisons should be interpreted with care; however, they do provide a preliminary basis for comparing the products of a Delphic system with actual data on species movements.

RESULTS

The selection of oceanographic regimes

Habitat heterogeneity ('habitat units'), in terms of physical patterns, was best captured by dividing the E-PME into 12 different oceanographic regimes (Figure 2(c)):

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1. *Subtropical*. Subtropical waters, with salinities greater than 35 psu, are carried into the region by the southward flowing Brazil Current, the western limb of the South Atlantic subtropical gyre. These waters are characterized by high surface temperature and salinity, a well-developed permanent thermocline and low nutrient concentrations in the upper layer. The transition between subtropical water and the subtropical–subpolar mixed water (the 35 psu isohaline) is also referred to as the Subtropical Front; its extension seaward is called the South Atlantic Current.

2. *Subtropical–Subpolar*. This region is the mixed-water transition zone between the subtropical and subpolar regimes. It occupies a wide area emerging from the interaction between the western boundary currents and extends eastward between 40 and 47°S. The western part of this region is characterized by high eddy variability due to large-scale meanders of the Brazil Current and the offshore side of the F-M Current, as well as isolated eddies. This variability, however, decreases further east. This region is marked by moderate surface chlorophyll-*a* concentrations (Brandini *et al*., 2000).

3. *Subpolar*. A vast region of subpolar waters extends from the coastal shelf front eastward; these waters are relatively cold, low in salinity and high in nutrient concentration, entering the region as part of the F-M Current branch of the Antarctic Circumpolar Current.

4. *Polar*. The polar regime lies south of the 33.95 surface isohaline, whose location is close to the Antarctic Polar Front. Cold waters (temperature less than 4°C), low salinity and high nutrient concentrations characterize this region.

5. *Shelf break front*. The shelf break front is a narrow transition region between subpolar and shelf waters, immediately west of the western edge of the F-M Current. This area is characterized by frequent chlorophyll-*a* maxima in summer that extend from 50 to 40°S, resulting from the upwelling zone created by the F-M Current striking the coastal shelf break. The shelf break front does not extend north beyond 35°S. The band of high chlorophyll-*a* concentration along the shelf break front is a ubiquitous feature of the south-west Atlantic (Longhurst, 1998).

6. *Open shelf*. Shelf waters are relatively shallow (<200 m), sub-Antarctic waters diluted by the influence of continental runoff. Due to wind mixing and heat exchange with the atmosphere, shelf waters undergo large seasonal temperature fluctuations, from strongly stratified in the summer to well-mixed in the winter. Surface salinity increases onshore near gulfs and semi-enclosed areas. The mean flow over the shelf ($\sim 10\,\mathrm{cm\,s^{-1}}$) is substantially slower than east of the shelf break.

7–9. *Low salinity outflows* (*Plata, Patos, and Magellan shelves*). Large freshwater outflows from the La Plata near 35°S and the Patos Lagoon at 32°S dilute sub-regions of the open shelf, lowering the surface salinity below 30 psu. Continental runoffs from these regions enhance the vertical stratification of the coastal ocean and are a significant source of nutrients, thus having a potential impact on the growth of marine algae. Direct flow from the south-east Pacific via the Magellan Straits induces a tongue of low salinity that extends to the NE from 52.5°S.

10. *Tidal fronts*. On the Patagonian coastal shelf, tidal mixing induces fronts which separate well-mixed waters onshore from stratified waters offshore. The tidal front regions are indicated by areas where the summer surface temperature gradients are higher than $0.05^{\circ}\mathrm{C\,km^{-1}}$ (Glorioso and Flather, 1995). These tidal fronts are relatively intense in the summer, when the open shelf is well-stratified due to the increased temperature in the upper layer, and thus are important feeding areas for seabirds and marine mammals along the coast (Campagna *et al*., 1999; Acha *et al*., 2004).

11. *Terrestrial coastline*. The terrestrial coastlines provide important breeding and resting habitats for many different species that use the E-PME, particularly many of the marine mammals and birds. Different species use different kinds of terrestrial habitats, varying in terms of their ease of access to the ocean, their inaccessibility from land, their substrate (rocky or sandy), and potentially their proximity to tidal fronts.

The LSA was originally designed to conserve populations of species that could be contained within a landscape — that is, individuals of the population could find all they needed to thrive within the well-conserved landscape in question (Sanderson *et al*., 2002). This definition therefore ruled out highly

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migratory species, but ruling out migratory species would necessitate abandoning the approach for many marine species, especially in the E-PME. Therefore a planning convention was adopted, the 'outside the seascape' box, to represent conservation of the species populations whenever they are outside of the landscape. This additional area on the map serves to remind the conservation planner that conservation of a given species within the E-PME, though necessary, is not sufficient to conserve the species population in its entirety.

Use of 'habitat units' by candidate species

The oceanographic regimes that were important to the greatest number of species were the open shelf and shelf break front — nearly all of the 33 species examined used these oceanographic areas (Table 1). Only coastally restricted species (e.g. Commerson's dolphin, *Cephalorhynchus commersonii*) were unlikely to use the shelf break front. Use of the open shelf is more widespread, because species from the Argentine coast must cross the shelf to reach the shelf break front. Other areas used by a majority of the species considered are the nutrient-rich subpolar waters, Magellan shelf and the tidal fronts. The High Seas area was of widespread importance to many species: southern elephant seals (*Mirounga leonina*), wandering albatrosses (*Diomedea exulans*), black-browed albatrosses (*Diomedea melanophris*), rockhopper penguin (*Eudyptes chrysocome*), Magellanic penguin (*Spheniscus magellanicus*), *Illex* squid (*Illex argentinus*), and Patagonian toothfish (*Dissotichus eleginoides*).

There was good agreement between the experts' qualitative assessments and the quantitative picture provided by the data for the most important areas (e.g. shelf break front, open shelf, etc.). Comparing the numerators and denominators of the ratios at the bottom of each column and end of reach row on Table 1 indicates the precise extent to which there was agreement.

Human activities and threats to candidate species

Twenty human activities that potentially threaten species in the E-PME were identified through the expert workshops (Table 2). From these human activities, severe threats were identified as having total vulnerability scores of >100. In rank order, the four most severe threats to the list of potential seascape species were demersal trawling, demersal trawling bycatch, pollution — nutrients, and oil extraction and transportation. Taken together, these severe potential threats impact all but one of the species considered. Demersal trawling was the most serious in terms of total species vulnerability. This fishing method impacts most of the bottom-dwelling fish species and species like penguins that may be caught incidentally.

The human activities that actually or potentially affect the broadest range of species are oil extraction and transportation, and oil exploration (affecting 24 and 30 of 33 species, respectively), followed by demersal trawling bycatch (24), pollution-nutrients (20), pollution entanglement (17) introduced species (16) and pelagic trawling bycatch (15).

Ecological functions and socio-economic importance of species

The most prominent functions are trophic relationships, including top predators (e.g. seals, sea lions, odontocetes, albatrosses, petrels and penguins), predators at an intermediate trophic level (e.g. squid and most fin fish) and species that function as critical prey items in the food web (e.g. anchovies, Fuegian sprat; Forero *et al*., 2004; Wilson *et al*., 2005). Experts also considered whether each species had a role in nutrient redistribution or was a strong competitor with other species.

Socio-economic importance was evaluated for a species' potential as a flagship species for the region, including its negative and positive cultural and economic values to local people. Note that many of the

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species considered are commercially harvested, and are thus of high economic value to people both locally and worldwide.

Seascape species selection

The three selection scenarios provided largely overlapping suites of species as described below.

SCENARIO 1: The Patagonian Marine Ecosystem (E-PME)

Using the data from the expert assessment, the selection software calculated the aggregate score, which is the sum of the five selection criteria scores, for each species and ranked them accordingly (Table 3). The three highest-ranking landscape species were Magellanic penguin, black-browed albatross and rockhopper penguin. The black-browed albatross was the highest-ranking species for two of the criteria scores: area requirements and vulnerability to human activities. The Magellanic penguin obtained the highest scores for heterogeneity and socio-economic value. The wide-ranging patterns resulting in the use of most habitat types, relative sensitivity to threats, and worldwide and local profiles raised the score of Magellanic penguins above other candidates. The highest-ranking species in terms of its socio-economic importance was the South American sea lion, *Otaria flavescens*, because of both its positive and negative local cultural and economic values.

Based on the aggregate score and how well each species complements the habitats, management zones, and threats represented by those species already selected for the suite (Coppolillo *et al*., 2004), the decision-support software then yielded the following suite of seascape species: Magellanic penguin, black-browed albatross, Argentine shortfin squid, yellownose skate, rockhopper penguin, southern right whale (*Eubalaeana autralis*), and southern blue whiting (Table 3).

SCENARIO 2: Patagonian Shelf Large Marine Ecosystem (PLME)

When the template target area was the Patagonian Shelf Large Marine Ecosystem, rather than the E-PME, the suite of seascape species remained the same. This was despite the fact that seven oceanographic regimes were left out of the target ocean: subpolar, polar, mixed subtropical–subAntarctic, subtropical, Patos shelf and part of the shelf break front. Most of the high seas and part of the economic exclusive zones of Argentina and Uruguay were also excluded from the analysis. Also, two of the candidate species (wandering albatross and *Loligo* squid, *Loligo gahi*) were eliminated as their major habitats of distribution were beyond the limits of the LME.

SCENARIO 3: Opportunity for conservation action

The application of the feasibility criteria for the 33 original candidates yielded a restricted list of 21 species with scores greater than 3. The new suite of selected species was composed of the Magellanic penguin, black-browed albatross, Argentine shortfin squid, rockhopper penguin, southern right whale and Argentine hake (*Merluccius hubbsi*). Two of the original seascape species (southern blue whiting and yellownose skate) were discarded and one (Argentine hake) that did not make the first list appeared in this second alternative.

After applying the feasibility criteria, the first three species of the suite coincided with those from the original sample (Magellanic penguins, Argentine shortfin squid and black-browed albatross). These seascape species covered all the oceanographic regimes and 13 of the 19 identified threats. The Argentine hake added the threat of demersal trawling to the above set, but long-lining was eliminated as a threat as it did not affect any of the chosen candidate species. An additional species might need to be added to the suite to cover this threat.

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DISCUSSION

Translating landscape species conservation to the sea

The Landscape Species Approach (LSA) is a wildlife-focused, spatially explicit, landscape conservation planning tool developed originally in terrestrial ecosystems. At the outset of the exercise, experience suggested that the LSA could provide a mechanism to share the data and experience across a broad group of scientists and build consensus around core landscape issues, particularly heterogeneity and species use. It was felt that these same core issues were applicable to seascapes as well and that the LSA could help us develop 'handles,' comprising species, oceanographic regimes, and jurisdictional zones that scientists, managers and eventually the public could use to grasp the complexities of a large marine ecosystem, laying the foundation for its future conservation.

At the end of this exercise, we feel increasingly confident that the basic principles that have driven terrestrial conservation planning in the last few years also have a place in the seas. Concepts such as landscape/seascape heterogeneity, considering human activity in the context of biological importance of different areas, mechanisms of characterizing threats, and even surrogate species, can have roles in marine conservation planning. The application of the LSA to the E-PME encourages its use in other large marine systems that may share similar characteristics, particularly as a consensus-building step prior to systematic conservation planning with specific ends (like MPAs) in mind. In the Southern Hemisphere, obvious candidates would be the Humboldt Current and Benguela Current systems. The Benguela system is the closest well-studied analogue to the Patagonian seascape (*http://www.bclme.org* and cited publications and reports; Shannon *et al*., 2006). The Humboldt system is an equally rich, cold water temperate-to-tropical pelagic domain, which urgently needs to establish critical conservation priorities (*http://www.edc.uri.edu/lme/Text/humboldt-current.htm*).

The application of the LSA to an open ocean system highlights several features of seascape planning that are in contrast to terrestrial LSA applications. These features are reviewed in general, and then a discussion is given regarding the specific conservation significance of this work to the E-PME.

Seascapes are big

The E-PME, as a defined target area that integrates oceanographic, biological and jurisdictional units, is more than three million km^2 in extent; that is two orders of magnitude larger than most terrestrial landscapes where the LSA has been applied (e.g. the Adirondacks Park, 25 000 km^2; the Madidi landscape of north-western Bolivia, 40 000 km^2; the Ndoki-Likouala landscape of Congo, $\sim$70 000 km^2; see Coppolillo *et al*., 2004). The E-PME seascape is larger even than most ecoregions on land (Olson *et al*., 2001). This assertion holds independent of the module chosen as a target area, as, for example, most of the 64 large marine ecosystems of the world (http://www.edc.uri.edu/lme/intro.htm) are larger than the above cited landscapes.

Describing the E-PME over such an extended area requires capturing the interplay of currents, the seasonal dynamics of plankton growth, and the extensive movements of foraging animals, which characterize the physical and biological dynamics of the system. The laminated gyres of cold and warm water spun off from the confluence of the Brazil and F-M Currents are as large as many terrestrial landscapes ($\sim$500 km across), and though less persistent than terrestrial structures – as they dissolve in a matter of days and weeks — they last long enough for species such as southern elephant seals to find and exploit them (Campagna *et al*., 2006).

Given the spatial scales involved in marine modules suited to a seascape species approach, one might expect that a different kind of conservation planning would be required. On land one usually thinks in terms of nested hierarchies: sites within landscapes, landscapes within regions, regions as divisions of the globe (Poiani *et al*., 2000); however, one recent study suggested that there may not be as many sharp

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discontinuities in scales as one might think (Redford *et al*., 2003). Our experience of applying the LSA to the E-PME indicates that as long as the basic principles of the approach are still met, the approach will still apply across scales. Our exploration of the E-PME speaks to three key premises of the LSA: (1) habitat heterogeneity is critical; (2) the intersection of 'biological' heterogeneity and 'human' heterogeneity structures the conservation opportunities and challenges; and (3) species, if selected in suites and with explicit criteria in mind, can input spatial models of conservation.

Building landscape heterogeneity into seascape conservation

Given the oft-mentioned complexity of the spatial and temporal dynamics of marine systems, it is a surprising result that a relatively simple characterization of the biological landscape — the oceanographic regimes — would be satisfactory. In fact, our system of 12 units seems to have spatial coherence and stability in relation to the intra- and inter-annual variability in the system (A. Piola, unpublished data). It is not suggested that there is not internal turnover within these units over the course of the year; rather it was found that the boundaries between the units are relatively stable through time. Though further subdivision in the future will certainly be warranted, as an initial approximation, the oceanic regimes recognized seem robust at a macro-scale.

In contrast to terrestrial systems, the total number of landscape patches, and consequently their interspersion in the E-PME seascape is relatively low; in fact, most elements occur uniquely within the seascape. Though the number of different kinds of patches is analogous to terrestrial landscapes with 8–16 cover classes (a common result from various remote sensing analyses), having only one or a few examples of each type limits conservation planning options including portfolios of sites (*sensu* Groves, 2003). Future analyses focusing on the fate of different water masses characterized by their temperature, nutrient status and productivity will likely produce a more complex, moving picture of the biologically important features of the seascape, enabling more precise conservation planning.

However, our analysis does confirm the importance of the shelf break front (Croxall and Wood, 2002) — clearly the functional and oceanographic heart of the system (Acha *et al*., 2004; Rivas, 2006; Romero *et al*., 2006; Signorini *et al*., 2006). The shelf break front provides critical resources to nearly all of the species considered, including all the species of the seascape species suite. It is the key part of the ecosystem that makes all other parts of the seascape work.

Managing accidents of geography

The management zones of the E-PME are analogous to the political and protected area boundaries that characterize human landscapes of terrestrial conservation areas. In this seascape, as in many landscapes, management areas are complicated by multiple overlapping jurisdictions, political and legal boundaries, historical legacies of dispute, and areas licensed or restricted from certain kinds of human use. On land, management boundaries often follow natural landscape features, e.g. rivers, mountain range divides, that may also have biological meaning; in the marine system, these boundaries are legally-defined distances extending from the seaward edge of the land, and are thus drawn without recognition of the oceanographic features that are meaningful to species. As a result, potentially serious conservation situations can arise from the 'accidental' ways that human management and politics overlap the way species use the oceans.

These accidents of law and biology are particularly critical given the existence of the 'High Seas' or international waters. In the E-PME, the most important oceanographic feature, the shelf break front, is contained within the Argentine EEZ for much of its length, but because of the shape of the Argentine coastline, lies in the High Seas for several hundred kilometres. Recent remote sensing studies, which detect the bright lights used during squid jigging, have shown that the High Seas area, where there is no effective management, is heavily utilized for the squid fishery (Rodhouse *et al*., 2001). Although data to confirm this are limited, it seems reasonable to assume that fin-fisheries take similar advantage of this absence of oversight.

'Landscape' species selection for seascapes

In selecting a list of species to represent the E-PME, it was found that the same basic criteria (heterogeneity, area requirements, vulnerability, ecological function and socio-economic potential) could be applied to marine organisms as well as terrestrial ones. The analysis of threats in this system revealed nothing unusual compared to threats in other marine systems. A wide range of human activities, both land and sea-based, threaten species in the ocean, across vast stretches of sea; many of these threats are harmful to multiple species. Demersal trawling in particular is highlighted for the damage that it does to various species in this system (Gandini *et al*., 1999).

In terms of ecological functions, many fewer functional aspects of seascape species were recognized than for their terrestrial counterparts, largely because seascape species have little impact *per se* on the structure of the seascape. In the E-PME, there is no 'ecosystem architect' equivalent to elephants or beavers in terrestrial or aquatic habitats, because the physical environment of the seascape is dominated by currents and climate determined at a planetary scale. In its place, ecological relationships between species are driven by trophic relationships, many of which are known, some quantitatively; while others remain to be explored more fully. This emphasis on the trophic cascade, though surely important, may also represent our poor understanding of the ecological functions of species in this part of the ocean.

Marine species, like terrestrial wildlife, can be characterized by their economic and cultural values and their potential as flagship species. Many of the potential landscape species have large economic importance for local and global markets; this economic imperative drives many of the conservation threats, and potential threats, in the E-PME. In particular, the Argentine shortfin squid, which is harvested in several jurisdictions including High Seas waters, has a one-year life cycle, moving south along the shelf break front each year from its breeding waters off Brazil (Hatanaka *et al*., 1985; Basson *et al*., 1996; Arkhipkin, 2000). If too many squid are taken in any given year, then the number left to recruit could be too low to sustain the following year's stock. Unfortunately, however, setting fishing quotas is complicated by the patchwork of relevant national and international policies and conventions and by limited understanding of how variability in squid production relates to environmental, climatic and other factors (Rodhouse, 2001).

Using surrogate species for conservation planning remains an imperfect science, on land and at sea. Here the analysis identified the Magellanic penguin, black-browed albatross, Argentine shortfin squid, yellownose skate, rockhopper penguin, southern right whale and the southern blue whiting as a suite of seven complementary species for conservation planning. In theory, if these species are conserved and managed effectively, across all the habitat units, management zones and threats that they represent, a substantial contribution will have been made to the conservation of the entire system. Some have questioned the validity of surrogate or focal species approaches for conservation (Roberge and Angelstam, 2004); in fact, no system of representation will ever perfectly capture all aspects of ecological systems, but using a suite of 'umbrella species' rather than a single species makes a key difference (Andelman and Fagan, 2000). This remains an open question for the E-PME, but it provides us with an initial hypothesis to focus future efforts toward testing. Later, it may be necessary to supplement these species with others, to fill in under-represented phenomena and seascape characteristics.

Conceptualizing migratory species in a landscape context

Potentially interesting components of this study are the incorporation of the habitat units related to the water column and the 'outside the seascape' box. The bathymetric profile creates habitats that must be considered as part of the heterogeneity perceived by the candidate species. The concept of 'outside the seascape' is not a spatially referenced feature, but rather a conservation planner's convenience, to remind us

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that conservation of many of the species in the seascape require areas and resources outside the seascape at some point in their life histories. It is a half-measure; comprehensive conservation planning for migratory species requires planning across all the spatially separated sites that the species needs. However, for one such site, like the E-PME, the LSA may still be applied through a convention that facilitates links to other such sites.

Conservation significance of the E-PME

The LSA helps us approach the E-PME as a seascape of heterogeneous and integrally linked sections, knitted together by a set of species, changing constantly but also subject to explication, understanding and conservation. It is a seascape of remarkable diversity, abundance and beauty, troubled by conservation threats that occur across various jurisdictions. In particular, the process of selecting seascape species yielded the following conclusions:

1. The SW Atlantic/Patagonian Marine Ecosystem can be characterized by a relatively stable system of oceanographic boundaries, jurisdictions, and species.
2. When oceanographic and jurisdictional boundaries are viewed from the perspective of use by species in the E-PME a few critical areas emerge, especially the open shelf and shelf front.
3. There is some overlap between the list of seascape species for the system, chosen via a complex process integrating data and expert-based Delphic assessments, and some of the most charismatic species typically used to guide conservation priorities.

The seascape species suite for the E-PME

Magellanic penguin, black-browed albatross, Argentine shortfin squid, yellownose skate, rockhopper penguin, southern right whales and the southern blue whiting comprise the suite of species that use all oceanographic regimes and all jurisdictions of the E-PME seascape (Scenario 1) and which represent all the potential threats. Therefore, conservation of these species may enable conservation of the entire area.

An alternative attempt to build pragmatic constraints into the process is to focus on a smaller target area that captures a similar breadth of biodiversity and conservation needs. A smaller surface area diminishes the complexities of management and monitoring, for example, the PSLME (Scenario 2). The PSLME is one of the 64 LMEs defined by Sherman and Alexander (1986). The template has the advantage over the original target area (SW Atlantic/E-PME) of already being the framework of ecosystem approaches rooted in shelf systems (Sherman and Alexander, 1986). The PSLME template, compared to the larger E-PME (Figure 2(a) and (d), respectively), excludes critical regimes dependent on the F-M and Brazil Currents (Figure 2(a)). The shelf as focal target leaves out the deep waters of the continental edge and the Argentine Basin.

Departing from the same sample of candidates, the suite of seascape species is identical for the PSLME and the SW Atlantic/E-PME. This is a consequence of the large scale typical of the migratory pattern of candidates. However, as LMEs are mostly within national jurisdictions, management strategies that target only the PSLME will leave out critical habitats that migratory species use for their foraging and reproduction.

It is thus concluded that the target system (E-PME) encompasses a much better representation of habitats; and therefore encourages a more inclusive ecosystem perspective. Results are also robust in terms of the level of detail of the analysis. Considering additional details, such as including special management areas within the area under sovereignty conflict between Argentina and the UK, does not change the composition or the order of relevance within the suite of selected species.

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Alternative suites: opportunity for conservation

The suite of selected species, based on a sample of candidates with high conservation profile (Scenario 3), was composed of the Magellanic penguin, black-browed albatross, Argentine shortfin squid, rockhopper penguin, southern right whale and Argentine hake. This new suite of seascape species is similar to that from a less restrictive sample, but has the further benefit of including a group of focal species that are susceptible to measurable improvement with respect to management or conservation action. To our knowledge, this is the first attempt to integrate data on the SW Atlantic in an ecosystem framework focusing on species. This ocean is a typical case of disarticulated management; a system in which fisheries, for example, are decided species by species with no concern for biodiversity conservation. Results have conservation relevance as they allow planning and monitoring processes under a comprehensive rationale resulting from a participative process. The experience can be replicated in other large systems with similar structure (Boersma *et al.*, 2004).

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APPENDIX A

Authors who contributed with data or expertise to the process of selecting seascape species

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William Conway[*,†]	WCS	USA
John Croxall[*,†,‡]	BAS and BirdLife International	UK
Mariela Chervin[*]	Secretaría de Ambiente y Desarrollo Sustentable	Argentina
Gustavo Chiaramonte[*,†]	Museo Argentino de Ciencias Naturales	Argentina
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