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Priority areas for the conservation of coastal marine vertebrates in Chile

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Abstract

In the past decade, there has been growing concern about the rapid degradation of marine ecosystems due to anthropogenic causes. Consequently, identifying priority areas for the conservation of marine biodiversity has become a crucial conservation issue. Taking into account the influence of human population density, we performed complementarity analyses to identify priority areas for the conservation of all coastal marine vertebrate species in Chile (265 species), and evaluated congruence among the different target groups. The distribution ranges of all species were digitized in a geographic information system and analyses were performed on latitudinal bands of 0.5°. Our results show that 12 latitudinal bands (~16% of all latitudinal bands) are necessary to conserve at least one population of each species. Ten of these bands are irreplaceable, whereas two are flexible. Many of the irreplaceable sites lie within areas that have high human population density. In order to conserve all threatened and endemic species, six and three latitudinal bands are needed, respectively. Four latitudinal bands are needed to represent all species of fish, reptiles, and mammals, whereas nine bands are needed to protect all bird species. Taking flexible sites into account, reserve networks that meet the minimum representation goal for each taxonomic group, and for threatened and endemic species, represent subsets of the 12 latitudinal band network selected for all species. Spatial congruence among reserve networks selected for each target group was relatively low and only significantly higher than random in 9 out of 21 pairwise comparisons. However, with the exception of reptiles, conservation areas selected for different surrogate groups represented other groups relatively well, compared to randomly selected sites.

Keywords: Vertebrate diversity; Marine conservation; Chile; Priority areas

1. Introduction

Because biodiversity is distributed heterogeneously, no single area would support all the important processes and species of value for conservation. Moreover, areas containing high numbers of rare, endemic, and endangered species are not congruent in space and vary across taxonomic groups, as has been shown by studies in terrestrial taxa (Prendergast et al., 1993; Dobson et al., 1997; van Jaarsveld et al., 1998). Thus, the problem of identifying and selecting areas for conservation usually requires the application of optimization methods that maximize the preservation of species in the long-term (Williams et al., 1996; Csuti et al., 1997; Prendergast et al., 1999 for a review; Leslie et al., 2003). In this regard, reserve selection strategies, such as those based on the complementarity principle (Kirkpatrick, 1983; Vane-Wright et al., 1991) are particularly useful when resources for conservation are limited and the data available are scant.

The identification of high priority areas for conservation has usually been based on high species richness and high concentrations of endemic, rare or endangered species (Ceballos and Brown, 1995; Rodríguez and Rojas-Suárez, 1996; Ceballos et al., 1998; Reid, 1998; Dobson

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et al., 1997; Myers et al., 2000; but see Olson and Dinerstein, 1998; Kareiva and Marvier, 2003). However, the majority of these analyses concerned terrestrial habitats, and only a few of them have identified priority areas of conservation in marine habitats (Arriaga Cabrera et al., 1998; Sullivan Sealey and Bustamante, 1999; Turpie et al., 2000; Roberts et al., 2003; Leslie et al., 2003). The fact that 37% of the human population worldwide lives within 100 km of a coastline (Cohen et al., 1997) and the increasing recognition of the profound effect of human activities upon marine ecosystems (GESAMP, 1991; Norse, 1993; Lubchenco et al., 1995; Botsford et al., 1997; Coleman and Travis, 2000) have led to a strong marine conservation advocacy (Kelleher et al., 1995; Roberts et al., 2003). Although valuable, the large scale nature of these studies precludes the identification of areas that might be important within a given biogeographic zone or within particular political boundaries which, do not represent natural limits for ecological systems, but are essential to consider in order to turn conservation science into useful conservation policy.

Chile has a coastline about 4200 km long, but, so far, no national marine parks or reserve systems have been developed; only a few small marine areas have been protected to pursue long-term research projects by universities or industrial environmental monitoring (Castilla, 1996; Castilla, 1999). Recently, Fernandez et al. (2000) reviewed the current state of scientific knowledge for biodiversity conservation in Chile. They conclude that studies are needed that assess large-scale patterns in species diversity aimed at identifying key areas for biodiversity conservation. In comparison to other South American countries, Chile has set aside a relatively large proportion of land in natural reserves or protected areas (18%, e.g., Pauchard and Villarroel, 2002), although biodiversity hotspots are under-represented (e.g., Armesto et al., 1998).

Recent studies have shown a positive correlation between human population density and biodiversity (Cincotta et al., 2000; Balmford et al., 2001; Araújo, 2003; Luck et al., 2004), suggesting a spatial conflict between human settlement patterns and conservation goals. Therefore, when selecting areas for conservation, it is crucial to assess the level of overlap between densely populated areas and areas of conservation importance to minimize potential conflicts (Luck et al., 2004). Accordingly, in this study, we use information on the distribution of coastal marine vertebrate species of Chile (mammals, birds, reptiles, and fish), and on human population density to identify priority areas for conservation, and to evaluate the degree of spatial congruence among the different target groups. This is a preliminary analysis, at a broad-spatial scale, that we hope will serve as a framework for more refined analyses leading towards the establishment of a marine protected area network in Chile.

2. Methods

2.1. Data

We compiled data from the published literature on geographic distribution for a total of 265 species (25 species of mammals, 93 species of birds, 13 species of reptiles and 134 species of teleost fish) registered as resident or occasional on the coast of Chile and continental islands located less than 10 km offshore (a list of species and the sources of their distribution is available from the corresponding author upon request). We considered all species inhabiting coastal ecosystems (rocky and sandy intertidal and subtidal areas, cliffs, fjords and estuaries); pelagic species were excluded from the analysis. For birds, we compiled data for all species registered on the Chilean coast, including those that secondarily occupy coastal habitats and that might be more commonly registered in other kinds of environments (e.g. turkey vultures, egrets). For fish, we considered only marine teleost fish inhabiting coastal waters that have been captured from subsurface waters down to a maximum depth of 60 m, excluding species found only in oceanic and deep-water habitats. Additionally, we compiled data on endemism, conservation status, and habitat for each species when available. We considered endemic those species inhabiting the Chilean territory only. Data for each species' conservation status was based on Glade (1993) for birds, reptiles, and fish, on Comisión Nacional del Medio Ambiente (1996) and Glade (1993) for marine mammals, and on the IUCN red list (Baillie and Groombridge, 1996) for turtles. We included species classified as critically endangered, endangered or vulnerable to be threatened species.

We mapped the geographic distribution of each species on the Chilean coast in a grid of 76 coastal latitudinal bands of 0.5° each (approximately 50 km), between 18 and 56°S (Fig. 1). Geographic distribution was assumed continuous between range end points. Species richness was calculated as the number of species recorded in each latitudinal band.

We used the LandScan, 2002 Global Population database (Oak Ridge National Laboratory) to obtain values of human population density. Human population density was measured within the first 10 km inland from the coast. We assume that people living within this distance will have an influence on the coastal marine environment. For each latitudinal band, we calculated the percentage of its coastal length that have high (>10 people/km^2) and low ($\leqslant$10 people/km^2) human population density.

2.2. Analyses

We performed complementarity analysis to determine the "near-minimum" number of latitudinal bands