Impact of sea level rise on the 10 insular biodiversity hotspots
Céline Bellard*, Camille Leclerc and Franck Courchamp

ABSTRACT

Aim Despite considerable attention to climate change, no global assessment of the consequences of sea level rise is available for insular ecosystems. Yet, over 180,000 islands world-wide contain 20% of the world’s biodiversity. We investigated the consequences of sea level rise for the 10 insular biodiversity hotspots world-wide and their endemic species. This assessment is crucial to identify areas with the highest risk of inundation and the number of endemic species at risk of potential extinction.

Location Ten insular biodiversity hotspots including the Caribbean islands, the Japanese islands, the Philippines, the East Melanesian islands, Polynesia-Micronesia, Sundaland, Wallacea, New Caledonia, New Zealand and Madagascar and the Indian Ocean islands (i.e. 4447 islands).

Methods We investigated four scenarios of projected sea level rise (1, 2, 3 and 6 m) on these islands. For each scenario, we assessed the number of islands that would be entirely and partially submerged by overlying precise digital elevation model and island data. We estimated the number of endemic species for each taxon (i.e. plants, birds, reptiles, mammals, amphibians and fishes) potentially affected by insular habitat submersion using the endemic–area relationship.

Results Between 6 and 19% of the 4447 islands would be entirely submerged under considered scenarios (1–6 m of sea level rise). Three hotspots displayed the most significant loss of insular habitat: the Caribbean islands, the Philippines and Sundaland, representing a potential threat for 300 endemic species.

Main conclusions With the current estimates of global sea level rise of at least 1 m by 2100, large parts of ecosystems of low-lying islands are at high risk of becoming submerged, leading to significant habitat loss world-wide. Therefore, the threat posed by sea level rise requires specific policies that prioritize insular biota on islands at risk as a result of near future sea level rise.

Keywords Biodiversity hotspots, climate change, endemic–area relationship, endemic species, islands, sea level rise.

INTRODUCTION

Global rise in sea levels is one of the most certain consequences of global warming (Nicholls & Cazenave, 2010), yet it remains one of the least studied topics in ecology. Sea level change is of considerable interest because of its potential impact on human populations living in coastal areas (50% of the world population will live within 100 km of the coast by 2030 (Small & Nicholls, 2003; Bindoff et al., 2007), and because of the potential associated economic losses (9% of global gross domestic product; Hanson, 2010). In addition, sea level rise is of major importance for ecosystems and human populations surrounded by seas, as it will directly reduce habitat availability, sometimes drastically for the smallest islands. The 180,000 islands world-wide harbour over 20% of the world’s biodiversity (Kier et al., 2009), and a direct reduction of their habitat therefore will have major
consequences. Such reduction, and the subsequent decrease of biodiversity, will be the most direct and inevitable outcome of sea level rise. Ongoing research suggests that the conclusions of the last Intergovernmental Panel on Climate Change (IPCC) report concerning the future increase of global mean sea level rise ((18–59 cm between present day, assuming a 1980–1999 baseline and 2090–2099; IPCC et al., 2007) may be too conservative, because they do not account for the melting and sliding of land ice in Greenland and the Antarctic. Several more recent studies strongly suggest that sea level rise could be substantially greater, i.e. an increase of 0.5 to 2.3 m by the end of this century (Rahmstorf, 2007; Pfeffer et al., 2008; Grinsted et al., 2009; Nicholls & Cazenave, 2010; Traill et al., 2011). Worst case scenarios of ice sheet melting and sliding lead to estimates of sea level rise of 4 to 6 m in the next centuries (Overpeck et al., 2006). Such increases could lead to the immersion of very large portions of many low-elevation islands, and in many cases to their total submersion, obviously threatening the most dramatic consequences for local biodiversity. Already, studies on specific archipelagos, large oceanic regions or continental regions show that sea level rise will have important consequences and should be more deeply studied (Hanson, 2010; Hinkel et al., 2010; Menon et al., 2010; Webb & Kench, 2010; Traill et al., 2011; Wetzel et al., 2012). So far, no studies have focused on the consequences of sea level rise for insular biota on a global scale. Estimates of the number of islands that are globally at risk for complete or significant submergence due to sea level rise are required in order to evaluate the consequences for insular biodiversity. These results are of major importance to identify and prioritize conservation actions on islands that are particularly vulnerable to sea level rise. Islands are generally considered centres of biodiversity, due to very high rates of endemism (9.5 and 8.1 times higher than continents for vascular plants and vertebrates, respectively) (Kier et al., 2009). Overall, about 70,000 vascular plant species are endemic to islands (Kier et al., 2009). Biodiversity hotspots have been defined as the 34 regions where biodiversity is both the richest and the most threatened (Mittermeier et al., 2004). Recently, one hotspot has been added to this list (the forest of the north–east part of Australia) (Mittermeier et al., 2012). Together, these hotspots harbour an exceptionally high number of vascular plant species, notably over 164,200 endemic species (Mittermeier et al., 2004). Within these regions, 10 are constituted only or mainly by islands (insular hotspots). We expect considerable loss of insular biodiversity consisting exclusively or mainly of islands under the currently admitted sea level rise scenarios through the permanent inundation of low-lying regions. We define inundation as due to shoreline retreat when low-lying areas are gradually submerged by ocean waters. This assessment is crucial to identify areas at the highest risk of inundation and the potential number of endemic species at risk of extinction.

Here, we assess the impacts of sea level rise on the 4447 islands included in the 10 insular biodiversity hotspots. This sample includes islands of various sizes, geological types and elevations, and covers virtually all latitudes in the Pacific, Indian and Atlantic oceans. We investigated four scenarios of projected sea level rise on these islands and provide estimations of entire and partial island loss and its associated endemic biodiversity. We used the endemic–area relationship (EAR) to obtain an estimate of the number of endemic species for each taxon considered to be potentially affected by submersion of insular habitat (Harte & Kinzig, 1997). Since sea level rise based on the IPCC scenarios (0.35 m) is now considered too conservative (Nicholls & Cazenave, 2010), we considered four different homogeneous projections including a rise of 1, 2, 3 and 6 m (Overpeck et al., 2006; Rahmstorf, 2007; Grinsted et al., 2009). Yet our estimates of insular habitat loss are conservative since we did not consider horizontal erosion loss and extreme events (e.g. storms, tsunamis, hurricanes, centennial tides). Digital elevation models constructed by overlaying precise elevation data with sea level projections enables the assessment of the number of islands entirely and partially submerged under different sea level rise scenarios. This illustrates the extent to which coastal areas are susceptible to permanent inundation. We also highlight the case study of New Caledonia to compare potential loss of endemic species predicted both by the EAR and the use of precise endemic species distribution data for New Caledonia. More precisely, we intend to explore these three questions: 1. What is the effect of four sea level rise scenarios (1, 2, 3 and 6 m) on the distribution and magnitude of insular habitat loss (i.e. partial and complete losses of islands) for the 4447 islands of the insular biodiversity hotspots? 2. Which insular hotspots are the most threatened by an increase in sea level in terms of partial loss and/or entirely inundated islands as a consequence of the different scenarios of sea level rise? 3. How many endemic plant, mammal, reptile, bird, fish and amphibian species may be at risk of global extinction due to sea level rise in both insular hotspots and globally?

MATERIALS AND METHODS

Data

Study islands

To qualify as a hotspot of biodiversity a region had to contain at least 1500 vascular plants as endemics (>0.5% of the world’s total) and to have 30% or less of its original vegetation remaining (Myers et al., 2000). Ten insular biodiversity hotspots fall into this definition. In order to be exhaustive, we considered both islands and islets as ‘islands’. First, we included 5792 islands in the 10 insular biodiversity hotspots that are composed mainly of islands or groups of islands (Fig. 1) from ‘The Biodiversity Hotspots - Conservation International’ (2012; http://www.conservation.org/where/priority_areas/hotspots/pages/hotspots_main.aspx). Island size ranges are from less than 22 ha (Surprise Island) to 725,000 km² (Borneo) and they encompass all latitudes and geological types of island ecosystems (Fig. 1). All the islands studied are located in the Atlantic, Indian or Pacific oceans. Island polygon delineations were derived from ‘The Biodiversity Hotspots - Conservation International’ (2012; http://
Sea level rise and insular hotspots

www.conservation.org/where/priority_areas/hotspots/pages/hotspots_main.aspx). The polygons were used as a mask to extract the elevation data.

Elevation data

Our island elevation dataset is based on the digital elevation model (DEM) from NASA’s Shuttle Radar Topography Mission (SRTM). We used the extract function from the raster package (R version 2.15) for all the 5792 islands included in the insular hotspots. We excluded from the analysis 1345 islands for which elevation data were not available (e.g. small islands). These small islands are of minor relevance for the study because they host almost no endemic species. Our study finally included 4447 islands, covering 82% of the total area of the 10 insular hotspots (see Table S1 in Supporting Information for the precise number of islands per hotspot).

Biodiversity data

The 10 insular hotspots contain more than 50,000 endemic plant species and more than 670 endemic mammals. To estimate the biodiversity that is threatened by sea level rise at the hotspot scale, we focused on endemic species (and did not consider total biodiversity in the hotspots). We used the number of endemic species for different taxa present in each hotspot from Mittermeier et al. (2004). For each hotspot, we extracted the number of endemic plants, mammals, birds, reptiles, amphibians and freshwater fishes (see Table S2). Because these estimates are at the hotspot level, we also evaluated the number of endemic species for each taxonomic group per island. Knowing the number of endemic species for each hotspot, we calculated the number of endemic species for each island according to island size (see below).

Assessing impacts of sea level rise on islands

Sea level rise scenarios

We considered four different sea level rise scenarios, ranging from very optimistic to extreme, yet all remaining realistic for the next centuries. We calculated the area of land loss due to inundation by island and by insular hotspot. First, we considered a global sea level rise of 1 m by 2100, which is slightly below the average of six recent projections of sea level rise for 2100 (Overpeck et al., 2006; Rahmstorf, 2007; Pfeffer et al., 2008; Grinsted et al., 2009; Nicholls & Cazenave, 2010). We also explored a realistic upper bound of a 2 m sea level rise (Nicholls & Cazenave, 2010) and a 3 m sea level rise (Hansen, 2007). Finally, we also considered the more extreme scenarios of ice sheet melting that lead to estimates of sea level rise of up to 6 m (Overpeck et al., 2006; Menon et al., 2010; Wetzel et al., 2012). This last scenario represents an extreme limit of sea level rise for the next centuries, but it is unlikely for 2100. More precise sea level rise scenarios are currently unavailable, because data on geomorphology for all these islands are lacking. Even if future sea level rise is likely to be heterogeneous and lunar effects or isostatic rebound could both lead to a fall or rise of sea level at a local scale, the regional variation in sea level rise is hard to predict. Therefore we did not extrapolate heterogeneity, due to these high uncertainties (Nicholls & Cazenave, 2010). It is commonly accepted that homogeneous rise is an acceptable approximation (Wetzel et al., 2012). Further, static drowning conditions of coastal areas are assumed, whereas it is recognized that in reality the coastal response to sea level rise may be more complex, especially in for clastic coast lines (Nicholls et al., 2007). We also did not consider connectivity of cells, and assumed that all areas below sea level will be permanently inundated. We used the DEM for the 4447 islands using R version 2.15 to calculate the sum of the number of pixels under the four sea level rise projections for the 10 insular hotspots, as well as for the 4447 islands individually.

Endemic species at risk of submersion

A precise number of endemic species for each of the 4447 islands individually was not available, thus we used the number of endemics per hotspot. However, the number of endemic species per hotspot provides a robust dataset of endemic species for these islands, contrary to many global datasets. The EAR provides a first approximation to estimate the proportion of endemic species vulnerable on each island per insular hotspot. Ecologists and biogeographers have long recognized that species richness (S) increases with area (A) at a decreasing rate and thus eventually levels off (Rosenzweig, 1995). The EAR performs
better than the species–area relationship (SAR) in predicting the potential number of extinctions due to habitat decrease (Kinzig & Harte, 2000) and is currently preferred over the classic SAR approaches (Harte & Kinzig, 1997). To derive a more realistic relationship under this possibility, the EAR takes into account the number of species expected to be confined to smaller patches within the total area of habitat loss:

\[ f_{\text{EAR}} = \Phi_A z' \]

where \( \Phi_A \) is the ratio of future to present area \( (A_{\text{future}}/A_{\text{current}}) \) and \( z' \) is a constant \( (z' = -\ln(1 - 1/2^z)/\ln(2)) \). \( A_{\text{future}} \) represents the calculated loss of terrestrial area as a result of an increase in sea level by 1, 2, 3 or 6 m and \( A_{\text{current}} \) represents the current area of each island.

Following Kier et al. (2005), we chose a \( z \) value adapted for each hotspot, according to its biome type. We attributed a different \( z \) value for tropical and subtropical moist broadleaf forests in Asia \( (z = 0.26) \), Central America \( (z = 0.33) \), South America \( (z = 0.32) \), Australia and Africa \( (z = 0.24) \), and tropical and subtropical dry broadleaf forests \( (z = 0.21) \).

First, we calculated the fraction of endemic species threatened at the hotspot level. We calculated \( A_{\text{future}} \) and \( A_{\text{current}} \), as the fraction of original habitat lost by insular hotspot. Second, we calculated the fraction of endemic species threatened by sea level rise for each island. Using the fraction of original habitat lost by insular hotspot, we calculated the number of endemic species threatened in each hotspot for six taxa (i.e. plants, freshwater fishes, amphibians, reptiles, birds and mammals) by each sea level rise scenario. We then calculated the number of species threatened of each of these taxa by island, using the EAR fraction calculated at island level. The number of species of each of the six taxonomic groups affected both within each hotspot and island was then inferred from the degree of habitat reduction following an increase in sea level.

Case study: New Caledonia

We decided to validate our model using the New Caledonian hotspot as a case study for which there was the rare availability of precise data for endemic species distribution. We obtained endemic species–area distribution polygons provided by the International Union for Conservation of Nature (IUCN) database (IUCN, 2012). We used polygons of species distributions for 6 mammals, 61 reptiles, 24 birds and 64 plants. Then, we assumed that the species distributions within the hotspot changed proportionally to the degree of marine intrusion in the hotspot and we calculated proportional range losses for each species. The results of this case study analysis were used to help qualify the utility of our EAR methods for predicting potential number of species at risk of extinction.

RESULTS

Potential consequences of sea level rise on insular habitats

Our results indicated that increase in sea level led to a significant impact on insular habitat. On average almost 1% of land area of the hotspot would be permanently inundated under an increase of sea level by 1 m, a figure that rises to 4.1%, for a 6 m rise in sea level (Fig. 2a). This represents roughly 25,200 km² at risk of inundation for a 1 m rise in sea level and more than 167,000 km² at risk of inundation for a 6 m rise in sea level, which is equivalent to the total area of Uruguay. We identified
different patterns of potential insular loss among the hotspots of biodiversity (Fig. 2b). Three hotspots appeared to be particularly threatened: the Caribbean islands, Sundaland and Japan, which, for a 6 m rise in sea level may have 11.1, 5.6 and 4.1%, respectively, of their area inundated (Table S3).

We also calculated the loss of habitat per island, starting with the number of islands that may be totally submerged following sea level rise (i.e. number of islands lost). Under the 1-m rise scenario, at least 6% of the islands could be totally and permanently submerged, while the figure rises to 18.6% under the 6-m scenario (Fig. 2). Overall, 267 to 826 islands could be permanently inundated in the future (Table S4). The Caribbean islands hotspot was the most threatened, with 8.7% of its islands entirely submerged with only a 1-m increase (i.e. 63 islands lost). Sundaland and the Philippines were also particularly affected, with a potential loss of 61 (7.7%) and 48 (7.2%) islands, respectively, following the lowest estimate of a 1-m increase in sea level. Under the most extreme scenario for sea level rise (6 m), we predicted the total submersion of up to 356 (49.2%), 122 (15.3%) and 113 (16.9%) islands for the Caribbean islands, Sundaland and the Philippines, respectively. On the contrary, the Japanese hotspot should be the least affected with only 1.2% (i.e. five islands) of the islands predicted to be entirely submerged with a sea level rise of 1 m, and 5.7% (i.e. 23) lost under the highest rise scenario (6 m).

In addition, many islands were predicted to suffer from loss of a very large portion of their habitat: 11.4% (1 m) to 32.1% (6 m) of all islands may have a size reduction of at least 50% in the future. Here again, the Caribbean islands hotspot was the most threatened with 23% (i.e. 165) to 73% (i.e. 533) of its islands half-submerged. Polynesia-Micronesia and Sundaland were also significantly threatened by major submersion, with 10% (i.e. 59 half-submerged islands) to 36% (i.e. 215) of islands half-submerged for Polynesia-Micronesia and with 12% (i.e. 99) to 26% (i.e. 210) of islands half-submerged for Sundaland. Only 58% (1 m scenario) to 29% (6 m scenario) of islands will be spared from partial immersion (no loss) in the future. Japan, the East Melanesian islands and New Zealand were predicted to be the least affected by sea level rise, with fewer than 60 islands combined that are threatened by having 50% of their area inundated in the future. Figure 3(a) gives the distribution of lost area by island for the 10 hotspots predicted under the four scenarios, while Fig. 3(b) gives the median area loss per island for the 10 hotspots predicted under the four scenarios (see also Table S4).

Potential consequences of sea level rise for endemic species

Using the EAR at the hotspot scale, we estimated that from 1 (1 m) to 55 (6 m) endemic species may be at high risk of extinction due to rising seas. The distribution among the six taxonomic groups was very uneven: most of the species predicted to be lost were plants, while almost no amphibians, mammals or fishes were predicted to be lost. This is due to the large number of endemic plants, and relatively (to plants) low numbers of endemic amphibians, mammals and fishes in these islands. In
addition, insular hotspots are not composed of a single large territory, but are divided into many isolated islands, and assessments at hotspot level lead to over-estimations. Figure 4 shows the number of endemic plants, birds, reptiles, mammals, amphibians and fishes likely to be lost following sea level rise in the 10 insular biodiversity hotspots. The EAR also provided an estimate of the number of endemic species – for each taxonomic group – that were threatened at the island level. This estimate was used to deduce the potential number of species at risk of extinction per taxonomic group when individual islands are partially or entirely submerged. For the 1 m rise scenario, the sum of endemic species threatened across all the islands was predicted to be 26 plants, one bird and one reptile, while for the worst scenario (6 m) the loss was predicted to be of six endemic amphibians, two mammals, eight birds, three fishes, 18 reptiles and 300 plants. Overall, a small number of endemic species might be affected by sea level rise, given our estimations. However, our method for estimating the number of endemic species potentially affected is simple and must be considered with caution.

Finally, using New Caledonia as a case study, we showed that the percentage of submerged species–area distribution is likely to be low among the taxa (Table 1). None of the species were predicted to lose their entire species–area distributions, which is consistent with the results from the EAR. However, endemic plants were predicted to be the most vulnerable to sea level rise, 1.25 to 7.65% of submerged areas were predicted, under an increase in sea level of 1 and 6 m, respectively (Table 1). In addition, eight endemic plants that are already classified as critically endangered by the IUCN are likely to be significantly affected by sea level rise in the future (see Table 1).

**DISCUSSION**

Studying 4447 islands world-wide in 10 different insular hotspots over three oceans, we showed that predicted rises in sea level should lead to the total loss of hundreds of these islands and to a very large reduction in their habitat for hundreds of others. The number of endemic species potentially affected by habitat reduction as a result of sea level rise determined by this study is relatively low compared with other climate change threats (Bellard et al., 2012). Yet it is highly probable that inclusion of non-endemics as well as endemics living on islands beyond these hotspots would increase the number of species...
threatened. In addition to the number of endemic species, insular hotspots harbour a number of non-endemic species; and additional 95,000 plant, 1200 mammal, 2100 reptile and 900 amphibian species inhabit these 10 hotspots alone (Myers et al., 2000).

Our approach has already been used successfully in similar studies. For example, Menon et al. (2010) used similar methods to analyse the effects of sea level rise world-wide on marine intrusion in terrestrial ecoregions. Wetzel et al. (2012) also used this approach to study the effect of sea level rise on the extinction risk for 54 mammals of the Indo-Malaysian islands. In both cases, results were of the same order of magnitude regarding the percentage area loss predicted for 1 and 6 m of sea level rise, with the highest area losses concentrated in the same geographic regions (i.e. Southeast Asia and associated islands and northeastern South America). Regarding the potential number of endemic species at risk, our results were also on the same order of magnitude as those of Menon et al. (2010). The vertical resolution of our global DEM was limited to a vertical resolution of 1 m; a higher-resolution DEM would yield more precise predictions of area change. Also we did not consider connectivity of cells, and assumed that all areas under sea level would be permanently inundated, which is not necessarily the case. Some areas may be completely surrounded by higher-elevation areas and thereby protected from marine intrusions, and other areas with elevations below the scenario of sea level rise are already inland water bodies, which therefore should not be included in calculations of newly inundated areas. However, in this last case, species that are salt-intolerant may be at risk of extinction. Using current endemic species distribution data for New Caledonia, we showed that our results from EAR approaches were likely to be consistent regarding the number of species that are at risk of extinction.

### Table 1

The percentage of species–area distribution submerged under four different scenarios of sea level rise for mammals, reptiles, birds and plants endemic to the New Caledonia hotspot. Among the different taxa, we selected the species that were predicted to have at least 10% of their species–area distribution submerged under an increase of sea level by 6 m.

<table>
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<th>Sea level rise by 2 m</th>
<th>Sea level rise by 3 m</th>
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</tbody>
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loss are realistic. In fact, many of our assumptions may lead to underestimations of insular habitat loss. In particular, we assumed no lateral erosion, no tidal range, no centennial tides or floods, nor associated increased salinity on new shorelines. The nonlinear response of clastic coastlines to sea level rise may influence a larger inland area compared with a reconstructed study based on the drowning of static coastlines (Nicholls et al., 2007). Indeed, although a small increase in sea level can be balanced by sediment supply and morphological adjustments, especially for reef islands (see Webb & Kench, 2010), exceeding a critical sea level threshold can lead to an irreversible process of drowning. In addition, an acceleration in sea level rise will widely exacerbate beach erosion around the globe (Brown & McLachlan, 2002). Wetzel et al. (2012) considered such erosion that could potentially affect zones for at least 20 m above mean sea level vertically and 100 km horizontally. In addition, the vulnerability of an island to morphological change varies according to differences in island topography and geomorphological characteristics, such as reef elevation (Webb & Kench, 2010). Due to the complexity of these phenomena, we did not infer potential morphological adjustment or resilience of islands in our study. We also did not consider the indirect loss of habitat that will result from the displacement of human populations from submerged areas, nor the potentially devastating ecological consequences of urban and intensive agricultural areas being relocated from coastal zones to the hinterlands. This impact has, however, recently been shown to be of a similar magnitude, and sometimes greater, than the losses directly due to sea level rise (Wetzel et al., 2012). Because insular hotspots are densely populated islands (about 2.08 billion people, 31.8% of all humanity, in just 15.9% of earth’s land area), they might be more threatened by these secondary effects than the primary effects. In addition, we did not consider the consequences of sea level rise on local populations of insular biota that may lead to higher risk of extinction for some vulnerable non–endemic species. We also did not consider the effects of fragmentation or secondary extinctions due to the loss of important species (e.g. resources, pollinators, dispersers, etc.). Finally, we omitted additional, and sometimes synergistic, effects of other aspects of climate change, and other drivers of global change (such as biological invasions), which are now known to be major threats for biodiversity in hotspots in general and on islands in particular (Courchamp et al., 2003; Malcolm et al., 2006).

To conclude, from 6 to 19% of the 4447 islands of insular hotspots could be entirely submerged following an increase in sea level by 1 to 6 m, respectively. In addition, more than 10% of all islands will lose at least 50% of their area in the future. The relative effect of sea level rise on habitat differs substantially among geographic regions. We identified three hotspots that were predicted to suffer the most important potential loss of insular habitat: the Caribbean islands, Sundaland and the Philippines. In contrast, the East Melanesian islands hotspot was predicted to be the least affected by sea level rise. The resulting loss of biodiversity is expected to be significant, with the potential for loss of dozens of endemic species within these islands under the most conservative estimates, this loss rising up to hundreds of species depending on the scenario used. When we summed the potential number of species at risk of extinction for each island, endemic plants were the most affected, with 26 to 300 at risk of submersion compared with the other groups. Given the enormous potential impact on vulnerable and unique endemic species, it is striking that studies assessing the effects of future sea level rise are relatively rare. It is therefore crucial to investigate the predicted effects of sea level rise globally in order to anticipate adequate conservation programmes. We have predicted that sea level rise is likely to lead to the loss of large portions of insular habitat that harbour several unique subspecies. New prioritization programmes for islands have to be established in order to mitigate the impacts of sea level rise. For example, in order to anticipate threats and prepare adequate conservation actions (e.g. local protection, identification of refuges or translocation programs), conservation managers have to prioritize specific islands that are threatened by permanent inundation and those that harbour vulnerable endemic biodiversity. The Caribbean islands, Sundaland and the Philippines have to be monitored and protected in this regard. For example, collecting seeds of endemic plant species from these islands could be considered a priority in the next decades. Moreover, in the context of species translocation, regions that are less vulnerable to sea level rise, such as the East Melanesian islands, could be selected. Given the logistic, human and economic efforts allocated to island restoration programmes, also in the context of alien invasive species, prioritization of islands should take into account their vulnerability to sea level rise. It may not be optimal to invest first in islands that will be destroyed by inundation within merely a few decades.

To conclude, with accepted projections of sea level rise now far exceeding 1 m (Overpeck et al., 2006; Rahmstorf, 2007; Pfeffer et al., 2008; Grinsted et al., 2009; Nicholls & Cazenave, 2010), the improvement of estimates of the associated loss of insular habitat and biodiversity becomes essential, and its negative effects must be added to the increasing list of factors threatening biodiversity in the future.

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REFERENCES


SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher’s web-site.

Table S1 Table indicating for the 10 insular hotspots: their original extent (km$^2$), the number of islands contained in each of them, the number of islands with elevation data and the percentage of area that studied islands covered in the hotspot.

Table S2 Number of endemic species of six different groups (i.e. plants, mammals, birds, reptiles, amphibians and fishes) in the 10 hotspots obtained from Mittermeier et al. (2004).

Table S3 Number of cells (one pixel = 0.22 km$^2$) and endemic species that are potentially threatened by sea level rise among the hotspots.

Table S4 Partial losses of insular habitat in the 10 different hotspots. We classed the number of islands according to their potential percentage area inundated per island. We divided them into six different classes: islands that may be completely inundated (i.e. 100%), between 75 and 100%, between 75 and 50%, between 50 and 25%, between 25 and 0%, and islands that are safe from any inundation.

BIOSKETCH

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