does not condone or support the illegal or unethical culling of any animals. Publishing this paper is not intended as an endorsement or encouragement of illegal or unethical methodologies. In particular, I do not want other researchers to assume that it is acceptable or justifiable to perform illegal or unsanctioned culls. There is a rule of law for reasons and there are appropriate ways to cull both ethically and legally, not liking the rules does not exempt one from them (Fulton and Ford 2001). I am well aware that some journals would refuse to publish this paper on the basis that the cull was not sanctioned by an ethics committee. However, in this case the author has simply piggybacked onto a cull that was conducted outside an experimental or scientific framework. In this case, I considered the results worth reporting even though they arose from an unsanctioned cull.

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*Singing Honeyeater.* Illustration by Judy Blythe.

# Biodiversity consequences of sea level rise in New Guinea

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Climate change poses a growing threat to biodiversity globally. Under changing conditions, affected species must either shift spatially to track changing conditions, adapt in terms of ecological tolerances, or become extinct. Currently, most climate change studies focus on direct climate effects on biodiversity and little attention is paid to the effects of sea level rise. We explore two scenarios of sea level rise (1 m and 6 m) and their implications for biodiversity across a major biodiversity hotspot, New Guinea. Marine intrusion at just 1 m of sea level rise is widespread, affecting large sectors of New Guinea. Protected areas (0–58.3% loss), ecoregions (0–90.0% loss) and endemic species (e.g., *Pitohui incertus*, 41–50% loss) across New Guinea would be affected by sea level rise within the projected range of likely occurrence.

## INTRODUCTION

GLOBAL climate change poses a growing threat to biodiversity globally (Hansell *et al.* 1998; Walther *et al.* 2002; Gopal and Chauhan 2006; Pounds *et al.* 2006). Vivid examples include Harlequin Frog *Atelopus varius* populations of Central America (Pounds 1994; Pounds *et al.* 2006), butterfly populations of Europe (Ryrholm *et al.* 1999; Wilson *et al.* 2007), the Sachem Skipper *Atalopedes campestris* of Mexico and the southern United States (Crozier 2003), and cloud forest bats in Costa Rica (LaVal 2004). Generally, under changing conditions, populations of affected species must either shift spatially to track changing conditions, adapt in terms of ecological tolerances, or become extinct (Holt 1990).

Most studies to date of climate change effects on biodiversity have focused on climatic effects (Hansell *et al.* 1998; Jones *et al.* 2004; Botkin *et al.* 2007). Little attention has been paid to the secondary, but perhaps more absolute, effects of sea level rise (Castaneda and Putz 2007; LaFever *et al.* 2007). The few studies that do consider sea level rise have looked at single species in low-lying areas (LaFever *et al.* 2007), effects on biodiversity-rich estuaries (Kennish 2002; Gopal and Chauhan 2006), or changes in forest structure (Castaneda and Putz 2007). Rising sea levels will clearly affect coastal ecosystems most severely—intertidal flats, salt marshes, sand dunes, coastal lowlands, and mangroves all will be particularly affected; still no regional assessments have as yet been developed.

During the past century, sea level rise has resulted largely from thermal expansion of the ocean, melting of mountain glaciers, and accelerated discharge of glacial ice from the major ice sheets to the ocean (Dyurgerov and Meier 1997). Among these factors, continued ice sheet melt has potential for substantial global impacts. The Greenland Ice Sheet contains a volume of water equivalent to 6 m of sea level rise, and the West Antarctic Ice Sheet, an unstable ice sheet grounded well below sea level, contains a volume of water equivalent to 5 m of sea level rise (Bindschadler 1998). Both the Greenland Ice Sheet and the West Antarctic Ice Sheet are currently showing rapid increases in mass loss that will significantly increase sea level if such mass loss continues (Thomas *et al.* 2004; Rignot and Kanagaratam 2006). Present-day sea level rise is linked to loss of mass from the major ice sheets of Antarctica and Greenland (Shepherd and Wingham 2007). Greenland and Antarctica are estimated to contribute 0.35 mm/yr of sea level rise globally, a relatively modest amount compared to the present rate of increase of 3.0 mm/yr of sea level rise (Shepherd and Wingham 2007). While these rates may seem trivial, even slight increases in sea level may translate ultimately into devastating impacts on human populations. For instance, with a 1 m sea level rise and associated temperature increases, economic losses in the United States are estimated to total 1.0–2.5% of the gross domestic product, or $48.6–121.3 billion (Knogge *et al.* 2004).

Small island nations confront sea level-related problems more directly. Already, Tuvalu and other small islands in Papua New Guinea are experiencing storm-caused over-wash and loss of land area by 20 cm/yr, and by 2025 some atolls in the Maldive Islands will be completely inundated by sea level rise (Ghina 2003). Effects of sea level rise in these small island states include loss of estuarine ecosystems, land area, and fresh water (Kennish 2002; Ghina 2003; Knogge *et al.* 2004; Gilman *et al.* 2006; Gilman *et al.* 2007). Only a few studies have emphasized wildlife-related losses related to sea level rise

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(DeVantier *et al.* 2004). Although effects on wildlife may seem less critical than socioeconomic impacts on tourism, living areas, and agricultural systems, most or all of these phenomena are linked, and effects on one ecosystem will eventually affect others as well (DeVantier *et al.* 2004; Gilman *et al.* 2006).

The island of New Guinea comprises Papua New Guinea in the east and the Indonesian province of Papua in the west (Heads 2002). Geologically, the island is complex, its formation resulting from a series of events of drifting, rafting, and sweeping up of islands arcs, which combined to form present-day New Guinea (Charles 1991; Heads 2002; Polhemus 2007). Given its isolation, New Guinea is now a biologically diverse region both in terrestrial and marine systems surrounding the island. New Guinea holds 700–800 species of birds, including globally unique concentrations of birds of paradise (38 species), parrots (46 species), and pigeons and doves (45 species) (Beehler *et al.* 1986; Miller *et al.* 1994; Mack and Dumbacher 2007). Mammal diversity reaches ~200 species, including marsupials, monotremes, rats and bats (Miller *et al.* 1994; Flannery 1995; Beehler 2007). Sixty of these 200 species are endemic, and occupy habitats ranging from lowland rainforest to snow line. New Guinea vegetation includes >20,000 species of ferns and flowering plants, with >3,000 species of orchids (Womersley 1978; Heads 2001; Beehler 2007; Takeuchi 2007). As a consequence, New Guinea has been included among the list of megadiverse regions (Mittermeier *et al.* 1998; Mittermeier *et al.* 2003) and of global biodiversity hotspots (Myers *et al.* 2000).

Included within this diversity are the peoples that inhabit New Guinea and its satellite islands. In all >1,200 language groups and a hyperdiverse cultural base linked to different systems of beliefs, trade, traditional customs, and land tenure systems sprouted since the settlement of New Guinea some 40,000 years ago (West 2005; Mansoben 2007; Pasveer 2007). Dependency on the surrounding forests, seas, rivers, and wildlife has always been key to the survival and well-being of past and present generations of New Guineans (West 2005; Mansoben 2007). Studies such as Carrier and Carrier (1983), Steadman *et al.* (1999), Foale (2005), Mack and West (2005), Case *et al.* (2005), and Cinner *et al.* (2005) indicate the level of dependency on wildlife and forests for sustenance. Given this dependency, a major catastrophic event such as sea level rise could impact both the survival of wildlife and the well-being of humans.

These considerations point to the importance of detailed, quantitative studies assessing effects of sea level rise on wildlife and habitats. Here, we explore two scenarios of sea level rise given global sea level rise (1 m and 6 m) in terms of their implications for biodiversity across New Guinea. We aim to assess the effects given global sea level rise across New Guinea, on ecoregions, endemic species and protected areas. Effects are far from trivial in some areas, emphasizing the need for careful study, and steps towards remediation where possible.

## METHODS

Shepherd and Wingham (2007) have summarized the recent sea level contributions from the Greenland and Antarctic Ice Sheets, showing a modest but growing component of the current rate of sea level rise. Otto-Bliesner *et al.* (2006) indicate that warming and melting of the Greenland Ice Sheet and other circum-Arctic ice fields likely contributed 2.2-3.4 m of sea level rise during the Last Interglaciation. Overpeck *et al.* (2006) also indicate that the rate of future melting and related sea level rise could be faster than widely thought, and estimate that sea level rise from melting of polar ice sheets could reach 4 to >6 m, similar to sea levels of 130,000 to 127,000 years ago, by the year 2100. In addition, the actual flooding process depends on the level of high water, which can be several meters above mean sea level (Marbaix and Nicholis 2007). Considering the sea level rises reported in the literature and the effects of tidal and storm surge, potential inundation areas were delineated in this study with two scenarios bracketing the likely range of sea level rises of 1 and 6 m; the vertical resolution of the global digital elevation model prohibits calculations finer in resolution than 1 m.

Geographic Information Systems (GIS) have been used in several studies to delineate potentially inundated areas resulting from projected sea level rise (Titus and Richman 2001; Cooper *et al.* 2005; Dasgupta *et al.* 2007). In these analyses, inundation areas are identified if their elevation is below the projected sea level rise. Although the method is simple, it has two shortcomings. First, water connectivity is not considered when inundation areas are delineated, so some areas, although their elevation is below the projected sea level rise, should not be inundated if terrain barriers exist between the ocean and these areas. Other areas at elevations below the projected sea level rise are already inland water bodies, and therefore should not be included in the projection of newly inundated areas. Given these two shortcomings, such simple GIS methods are likely to overestimate potential inundation areas.

A new and robust GIS analysis method developed by Li *et al.* (in press) was used to



overcome these shortcomings. In the method, cells below a projected sea level rise are initially flagged. Of the flagged cells, only those with connectivity to the ocean are selected. The selected cells are then checked to see whether or not they correspond to existing inland water bodies. Only those cells that connect to the ocean and are not inland water bodies are designated as inundation cells. The method was implemented as several steps in a GIS raster analysis framework; full details of the method are provided in Li *et al.* (in press).

We then assembled sets of geospatial data relevant to biodiversity and protected areas across New Guinea. Specifically, we drew information regarding the distribution and configuration of protected areas from the World Conservation Monitoring Center (WCMC 1996), and information on the distribution and configuration of ecoregions from World Wildlife Fund (2006), both in the form of vector shapefiles. These datasets were converted to raster grids with 0.5' pixel resolution, to match the marine intrusion scenarios described above. All coverages were reprojected to an Albers equal-area projection to allow accurate area calculations.

We calculated areal losses for all protected areas and ecoregions under both scenarios of marine intrusion. We neglected two aspects of habitat loss under marine intrusion scenarios: (1) we did not consider habitat changes in areas *not* inundated caused by closer proximity of marine environments, and (2) we did not consider habitat shifts in which additional areas might become habitable for species or habitats. Nonetheless, as this paper is intended as a first-pass analysis, we prefer to maintain our analyses simple and straightforward, dealing only with direct inundation effects.

Finally, using information on ecosystem-level endemism provided in WWF (2006), we summarized likely distributional effects on species (Beehler *et al.* 1986; Flannery 1995) endemic to New Guinea (strictly speaking, i.e., not occurring on outlying islands). Under the assumption that marine intrusion affects distributions of species occurring in an ecoregion proportionally to the overall proportional marine intrusion in the ecoregion, we calculated proportional range losses for each species, via weighted averaging when species were distributed across multiple ecoregions. Species for which the known elevational range did not include sea level were omitted from the analyses, on the assumption that sea level rise would not affect such species.

## RESULTS

Marine intrusion associated with sea level rise of 1 m is relatively widespread, affecting large sectors of New Guinea (Fig 1). Low-lying areas, especially parts of the Merauke region are heavily affected, leading to the formation of many small islands and an extensive loss of land area. Waterways, streams, and rivers are altered, leading to rivers forming sea straits between newly-formed islands. Additionally, sea level rise is projected to inundate Dolok Island (Papua, Indonesia) completely, while giving rise to a

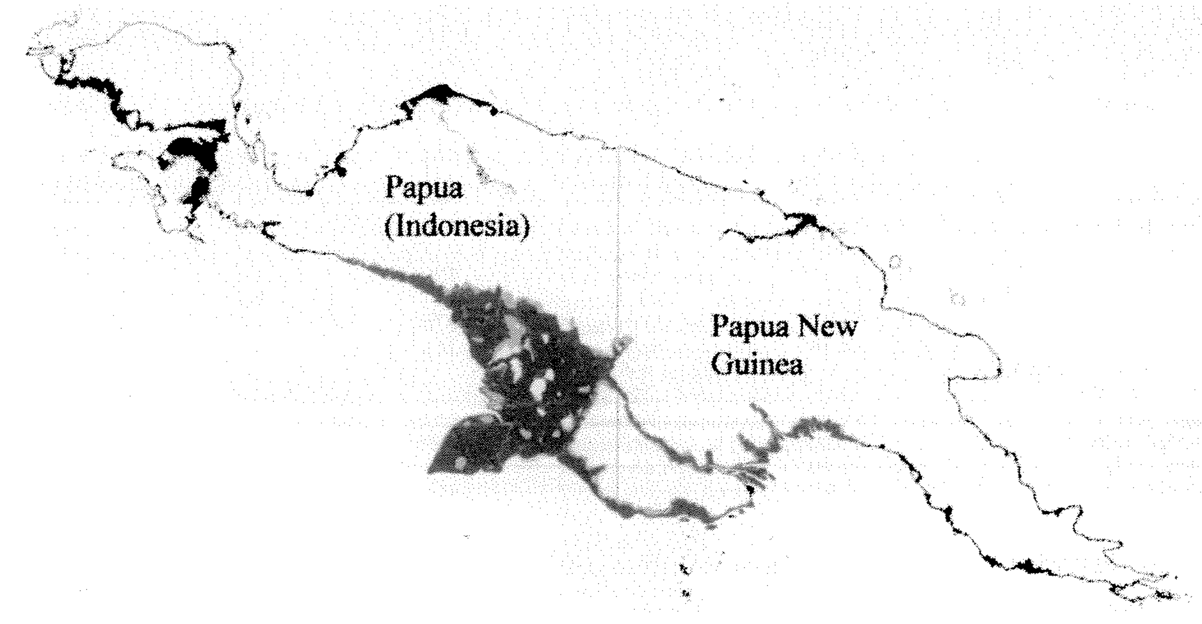


*Fig. 1.* Map of New Guinea showing marine intrusion projections under scenarios of 1 m and 6 m sea level rise. Black areas are projected to be affected under 1 m sea level rise scenario; grey areas are projected to be affected by a 6 m rise in sea level.

larger island that forms as rising sea levels link the Fly River with Sungai (river) Merauke and other rivers and lakes in Mimika and the Merauke districts. Fakfak, Sorong, and the Mamberamo River valley (Indonesian Papua) also experience changes. In the Papua New Guinea part, effects of 1 m sea level rise are less dramatic: the Gulf and Western provinces are the areas most affected, as well as the Sepik Plains and low-lying areas along the coast of Central and Milne Bay provinces. With 6 m sea level rise, surprisingly, marine intrusion is not dramatically more extensive, although areas already mentioned are affected somewhat more broadly.

Among New Guinea's protected areas, expected proportional losses ranged from 0-58.3% under both scenarios of sea level rise (Table 1). Maza Wildlife Management Area in southwestern Papua New Guinea showed the highest proportional area loss under the 1 m scenario (58.3%), but no increase in loss under the 6 m scenario (58.3%). Sidei Wibain Nature Reserve, in the Indonesian part of New Guinea, follows with large losses (25.9-31.5%). Teluk Laut Cendrawasih National Park and Palau Dolok Game reserve, both in Indonesia, would experience losses of >10%, and the remaining protected areas show losses of <10% under both scenarios (Table 1).

Among ecoregions, large area losses are expected in areas at lower elevations, such as the New Guinea Mangrove ecoregion, which is projected to experience the largest loss of area under both sea level rise scenarios (76.9-90.0%; Table 2). Other ecoregions projected to see large area losses include Southern New Guinea Freshwater Swamp Forests, Southern New Guinea Lowland Rain Forests, Trans Fly Savanna and Grasslands, and the Vogelkop-Aru Lowland Rain Forests. Ecoregions at higher elevations and in inland areas showed negligible effects under both inundation scenarios (Table 2).

We then focused on ecoregions projected to experience large area losses and that contain endemic species: Southern New Guinea Freshwater Swamp Forests, Trans Fly Savannah and Grasslands, and Vogelkop-Aru Lowland Rainforests (Table 3). Endemic species that are currently critically endangered and in ecoregions highly threatened by marine

*Table 1.* Summary of protected areas across New Guinea (WCMC 1996), their overall area (km²), and projected loss in km² and on a proportional basis, under scenarios of 1 m and 6 m of sea level rise. Note: the following protected areas were projected as not seeing areal loss owing to sea level rise: Balek, Batanta Barat, Beriat, Enarotali, Finisterre, Gunung Lorentz Addition, Gunung Meja, Jamursba-Mandi, Jayawijaya, Jayawijaya Addition, Jimi Valley, Klamono, Kumbe-Merauke, McAdam, Mingima, Mt. Bangeta, Mt. Bosavi, Mt. Capella, Mt. Menawa, Mt. Michael, Mt. Onuare, Mt. Suckling, Mt. Wilhelm, Mts. Albert Edward/Victoria, Pegunungan Arfak, Pegunungan Cyclop, Pegunungan Tamrau Selatan, Pegunungan Tamrau Utara, Pegunungan Weyland, Rawa Biru, Sorong, Strickland River, Varirata, and Yakopi Nalenk Mts.

| Area name | Area | Area lost (6 m) | Area lost (1 m) | % loss (6 m) | % loss (1 m) |
|---|---|---|---|---|---|
| Maza | 292 | 170 | 170 | 58.3 | 58.3 |
| Sidei-Wibain | 40 | 13 | 10 | 31.5 | 25.9 |
| Teluk Laut Cendrawasih | 617 | 116 | 94 | 18.9 | 15.3 |
| Pulau Dolok (Extension) | 3926 | 470 | 470 | 12.0 | 12.0 |
| Pulau Dolok | 58,290 | 6622 | 6190 | 11.4 | 10.6 |
| Teluk Bintuni | 14,710 | 1318 | 1057 | 9.0 | 7.2 |
| Mubrani-Kaironi | 113 | 9 | 7 | 7.8 | 6.5 |
| Danau Bian | 8920 | 536 | 447 | 6.0 | 5.0 |
| Tonda | 46,618 | 2722 | 1606 | 5.8 | 3.4 |
| Sungai Seram | 119 | 6 | 2 | 4.9 | 1.9 |
| Wasur (Extension) | 15,181 | 692 | 393 | 4.6 | 2.6 |
| Abau | 3668 | 162 | 111 | 4.4 | 3.0 |
| Wasur | 21,548 | 946 | 529 | 4.4 | 2.5 |
| Teluk Yotefa | 60 | 2 | 1 | 3.7 | 2.5 |
| Kikori River | 32,246 | 986 | 876 | 3.1 | 2.7 |
| Bamu River | 12,681 | 350 | 181 | 2.8 | 1.4 |
| Cape Wom International Memorial Park | 431 | 12 | 7 | 2.7 | 1.5 |
| Sepik River | 34,209 | 570 | 252 | 1.7 | 0.7 |
| Gunung Lorentz | 185,058 | 2512 | 2006 | 1.4 | 1.1 |
| Popondetta | 6168 | 88 | 43 | 1.4 | 0.7 |
| Morobe | 10,864 | 83 | 71 | 0.8 | 0.7 |
| Salawati Utara | 5438 | 36 | 10 | 0.7 | 0.2 |
| Foja | 60,035 | 371 | 0 | 0.6 | 0.0 |
| Gunung Wagura-Kote | 1545 | 8 | 3 | 0.5 | 0.2 |
| Wondi Boy | 3906 | 21 | 16 | 0.5 | 0.4 |
| Mamberamo-Pegunungan Foja | 106,161 | 399 | 0 | 0.4 | 0.0 |
| Wondiwoi | 4702 | 16 | 14 | 0.3 | 0.3 |
| Pegunungan Kumawa | 16,567 | 24 | 16 | 0.1 | 0.1 |
| Pegunungan Fakfak | 16,375 | 5 | 4 | 0.0 | 0.0 |



*Table 2.* Summary of ecoregions across New Guinea, their overall area (km²), and projected loss in km² and on a proportional basis, under scenarios of 1 m and 6 m of sea level rise.

| Ecoregion | Area | Area 1 m loss | Area 6 m loss | Area 1 m loss (%) | Area 6 m loss (%) |
|---|---|---|---|---|---|
| New Guinea Mangroves | 23,074 | 17,751 | 20,770 | 76.9 | 90.0 |
| Southern New Guinea Freshwater Swamp Forests | 98,520 | 32,153 | 40,414 | 32.6 | 41.0 |
| Southern New Guinea Lowland Rain Forests | 122,225 | 29,234 | 35,898 | 23.9 | 29.4 |
| Trans Fly Savanna and Grasslands | 26,428 | 5,604 | 8,555 | 21.2 | 32.4 |
| Vogelkop-Aru Lowland Rain Forests | 61,154 | 9,020 | 13,029 | 14.7 | 21.3 |
| Southeastern Papuan Rain Forests | 76,457 | 1,819 | 2,868 | 2.4 | 3.8 |
| Northern New Guinea Lowland Rain and Freshwater Swamp Forests | 133,978 | 2,777 | 5,940 | 2.1 | 4.4 |
| Huon Peninsula Montane Rain Forests | 16,374 | 47 | 283 | 0.3 | 1.7 |
| Vogelkop Montane Rain Forests | 21,748 | 64 | 81 | 0.3 | 0.4 |
| Northern New Guinea Montane Rain Forests | 23,139 | 57 | 186 | 0.2 | 0.8 |
| Central Range Montane Rain Forests | 171,115 | 0 | 0 | 0.0 | 0.0 |
| Central Range Sub-Alpine Grasslands | 15,502 | 0 | 0 | 0.0 | 0.0 |

*Table 3.* Summary of species endemic to single ecoregions in New Guinea and their endangerment status, according to World Wide Fund (2006). Ecoregions not projected to see significant marine intrusion are not included in this summary

| Ecoregions | % loss | Species | Critical | Endangered | Near threatened | Vulnerable |
|---|---|---|---|---|---|---|
| Southern New Guinea Freshwater Swamp Forests | 32.6-41.0 | Pritchard's Snakeneck Turtle *Chelodina pritchardi* | | 1 | | |
| | | Fly River Leptomys *Leptomys signatus* | 1 | | 1 | |
| Trans Fly Savanna and Grasslands | 21.2–32.4 | Bronze Quoll *Dasyurus spartacus* | | | | 1 |
| | | Lined Frog *Litoria quadrilineata* | | | 1 | |
| | | Parker's Snakeneck Turtle *Chelodina parkeri* | | | 1 | |
| Southeastern Papuan Rain Forests | 2.4–3.8 | Large Leptomys *Leptomys elegans* | 1 | | | |
| | | Large Eared Nyctophilus *Pharotis imogene* | 1 | | | |
| Northern New Guinea Lowland Rain and Freshwater Swamp Forests | 2.1–4.4 | Pale-billed Sicklebill *Epimachus bruijnii* | | | 1 | |
| | | Brass's Friarbird *Philemon brassi* | | | 1 | |
| Vogelkop-Aru Lowland Rain Forests | 14.7–21.3 | Wilson's Bird of Paradise *Cicinnurus respublica* | | | 1 | |
| | | Red Bird of Paradise *Paradisaea rubra* | | | 1 | |
| | | Waigeo Brush Turkey *Aepypodius bruijnii* | | | | 1 |
| Huon Peninsula Montane Rain Forests | 0.3–1.7 | Huon Tree Kangaroo *Dendrolagus matschiei* | 1 | | | |
| | | Emperor Bird of Paradise *Paradisaea guilielmi* | 1 | | | |
| Vogelkop Montane Rain Forests | 0.3–0.4 | White-striped Forest Rail *Raillina leucospila* | | | 1 | |
| | | Grey-banded Mannikin *Lonchura vana* | | | | 1 |
| Northern New Guinea Montane Rain Forests | 0.2–0.8 | Northern Glider *Petaurus abidi* | | | | 1 |
| | | Fire-maned Bowerbird *Sericulus bakeri* | | | | 1 |

*Table 3* — continued

| Ecoregions | % loss | Species | Critical | Endangered | Near threatened | Vulnerable |
|---|---|---|---|---|---|---|
| Central Range Sub-Alpine Grasslands | 0 | Calaby's Pademelon *Thylogale calabyi* | | 1 | | |
| | | Snow Mountain Quail *Anurophasis monorthonyx* | | | 1 | |
| | | Alpine Woolly Rat *Mallomys gunung* | 1 | | | |
| | | Long-bearded Honeyeater *Melidectes princeps* | | | | 1 |
| Central Range Montane Rain Forests | 0 | Telefomin Cuscus *Phalanger matanim* | | 1 | | |
| | | Archbold's Bowerbird *Archboldia papuensis* | | | 1 | |
| | | Narrow-mouthed Toad *Albericus siegfriedi* | 1 | | | |
| | | Lesser Small-toothed Rat *Macruromys elegans* | 1 | | | |
| | | Michael Rainforest Frog *Cophixalus nubicola* | | | | 1 |
| | | Wissel Lakes Treefrog *Litoria wisselensis* | | | | 1 |
| | | Great-tailed Triok *Dactylopsila megalura* | | | | 1 |
| | | Telefomin Horseshoe Bat *Hipposideros corynophyllus* | | | | 1 |
| | | Red-bellied Melomys *Melomys fellowsi* | | | | 1 |
| | | Small-toothed Nyctophilus *Nyctophilus microdon* | | | | 1 |
| | | Short-haired Hydromyine *Paraleptomys wilhelmina* | | | | 1 |

intrusion include the Fly River Leptomys *Leptomys signatus*, Large Leptomys *L. elegans*, and Large-eared Nyctophilus *Pharotis imogene*. We also summarized species endemic to multiple ecoregions that face risks of marine intrusion. For example, the White-bellied Pitohui *Pitohui incertus*, found in 2 ecoregions (New Guinea Mangroves and Southern New Guinea Freshwater Swamp Forests), is projected to experience inundation of 41.0–50.3% of its two host ecoregions; the Western Crowned Pigeon *Goura cristata* follows in likely effects (32.2–40.6% reduction; 2 ecoregions in the Vogelkop-Aru Lowland Rainforests); many additional multiple-ecoregion endemic species see more subtle effects (Table 4).

## DISCUSSION

The analyses presented in this paper are preliminary, and their limitations demand some discussion. Our scenario development is limited to sea level rise of >1 m integer values because of the limitation of the vertical resolution of the digital elevation models (DEMs), and as such does not permit interpolation at elevations finer than 1 m. More importantly, our analyses are limited by the lack of detailed information on distributions of each of the species of particular concern in conservation. Replacing our ecoregion-based estimates with real distribution-loss estimates would greatly improve the utility of these analyses.

This paper is designed as a first-pass analysis of the biodiversity consequences of global climate change in New Guinea. At difference with most previous analyses (Thomas *et al.* 2004; Thuiller *et al.* 2005; Araújo and Rahbek 2006), we focus on effects of marine intrusion caused by sea level rise. We also do not consider the effects that marine intrusion may (or may not) have on migrating shorebirds that use coastal ecosystems. As such, our estimates of biodiversity consequences are conservative, in that we are considering but one of the major causes of negative effects; it probably would interact with climatic effects on species' distributions to produce yet more dramatic (negative) effects.



*Table 4.* Summary of endangered species found in multiple ecoregions and projected proportional loss of distributional areas under 1 m and 6 m sea level rise scenarios.

| Species | % loss (1 m) | % loss (6 m) |
|---|---|---|
| White-bellied Pitohui *Pitohui incertus* | 41.0 | 50.3 |
| Western Crowned Pigeon *Goura cristata* | 32.2 | 40.6 |
| Black Mannikin *Lonchura stygia* | 30.2 | 39.2 |
| Fly River Grassbird *Megalurus albolimbatus* | 30.2 | 39.2 |
| Black-necked Stork *Ephippiorhynchus asiaticus* | 28.3 | 35.8 |
| New Guinea Flightless Rail *Megacrex inepta* | 20.7 | 26.8 |
| Yellow-eyed Starling *Aplonis mystacea* | 18.5 | 23.1 |
| Oriental Darter *Anhinga melanogaster* | 17.0 | 22.0 |
| Large Pogonomelomys *Pogonomelomys bruijni* | 15.5 | 19.7 |
| Banded Yellow Robin *Poecilodryas placens* | 14.8 | 19.3 |
| Fly River Horseshoe Bat *Hipposideros muscinus* | 13.9 | 17.7 |
| Salvadori's Fig Parrot *Psittaculirostris salvadorii* | 13.1 | 17.0 |
| Gurney's Eagle *Aquila gurneyi* | 12.7 | 16.5 |
| Doria's Hawk *Megatriorchis doriae* | 12.7 | 16.5 |
| New Guinea Harpy Eagle *Harpyopsis novaeguineae* | 12.5 | 16.2 |
| Greater Tube-nosed Bat *Nyctimene aello* | 11.0 | 15.8 |
| Fly River Trumpet-eared Bat *Kerivoula muscina* | 10.6 | 13.6 |
| New Guinean Quoll *Dasyurus albopunctatus* | 10.3 | 13.3 |
| Vulturine Parrot *Psittrichas fulgidus* | 9.4 | 12.2 |
| Mantled Mastiff Bat *Otomops secundus* | 7.4 | 10.0 |
| Papuan Planigale *Planigale novaeguineae* | 7.2 | 11.1 |
| Brown-headed Crow *Corvus fuscicapillus* | 6.0 | 9.7 |
| Nicobar Pigeon *Caloenas nicobarica* | 5.5 | 8.8 |
| Dwarf Cassowary *Casuarius bennetti* | 2.7 | 4.3 |
| Black-spotted Cuscus *Spilocuscus rufoniger* | 1.7 | 3.7 |
| Mottled-tailed Shrew Mouse *Neohydromys fuscus* | 0.7 | 1.1 |
| Long-beaked Echidna *Zaglossus bruijni* | 0.0 | 0.0 |

The major results showing changes in waterways, loss of landmass, and formation of islands may lead to dramatic changes in nutrient cycles in current watersheds. These changes could mean that large freshwater ecosystems may change to saline environments over time as a result of saline water influx, hence leading to the extinction of freshwater species, or could give rise to a rather contrasting ecosystem than that known by resident species of flora and fauna (IPCC 2001; Kennish 2002; LaFever *et al.* 2007; Dasgupta *et al.* 2007).

Analysis of 2 surrogates for biodiversity (protected areas, ecoregions) suggests that sea level rise will be a nontrivial agent of biodiversity loss in coming decades in New Guinea. The most recent Intergovernmental Panel on Climate Change (IPCC 2001) report projects a global increase of ~60 cm, which will come close to our 1 m sea level rise scenario, but several considerations of interactive effects and accelerated ice cap loss suggest that sea level rise of considerably greater magnitude is quite possible (Smarty and Sahagian 2000; Hall and Fagre 2003; Dyurgerov and McCabe 2006). As such, climate change-based analyses (Peterson *et al.* 2002; Thomas *et al.* 2004) should take into account the complimentary negative effects of marine intrusion as well.

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