Climate Change and Biodiversity in Melanesia

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CLIMATE CHANGE IN NEW GUINEA AND ITS POTENTIAL EFFECTS ON FRESHWATER ECOSYSTEMS

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Introduction

Although it is clear that long-term climate changes will have an effect on freshwater ecosystems in New Guinea, there is little data at hand by which to directly or objectively evaluate such patterns. Both precipitation and stream gauging data is inconsistent and widely scattered in terms of geographic coverage, and for the most part does not provide information across sufficiently long time intervals to accurately project trends. It is possible, however, to assess potential impacts from studies conducted in other parts of the Pacific, most notably Hawaii.

In general, it is possible to consider potential impacts of long-term climate to New Guinea freshwater systems in the context of two alternative outcomes – increasing or decreasing precipitation regimes. The relative consequences of each are evaluated below.

Decreasing precipitation regimes

New Guinea is currently an area of high precipitation, with many sites receiving 2,500-3,500 mm annually (Prentice & Hope, 2007). In general, the highest rainfall occurs at intermediate elevations on the northern and southern slopes of the central mountains, with many sites in such zones reporting over 4,000 mm per year and some exceptionally wet sites logging over 10,000 mm per year. By contrast, a few lowland regions in the southeastern portion of the island, such as that surrounding Port Moresby, receive less than 1,000 mm annually, although these are anomalies in the context of the generally wet climate regime prevailing at present.

Any change in precipitation regime will in turn have an effect on freshwater ecosystems in New Guinea. As noted by Polhemus & Allen (2007b), such ecosystems can be divided into two broad classes: lotic, or flowing, and lentic, or standing. The functional responses of each ecosystem class in regard to climate change will differ due to the underlying differences in the structure and flow dynamics of such systems.

Lotic ecosystems

In lotic ecosystems, any long-term trend of decreasing precipitation will produce marked effects on stream discharge in New Guinea. Discharge in turn has two components: base flow and total flow. During periods where rainfall is low or absent, the flow in any given stream is primarily dependent on groundwater discharges; this is known as base flow. By contrast, the aggregate of amount of flow in a stream resulting from base flow plus any direct-runoff contribution from precipitation is referred to as total flow. In general, stochastic year-to-year variations in precipitation will primarily affect total flow values by increasing or decreasing surface runoff, whereas long-term changes in climatic regime will eventually affect underlying aquifer discharges, thereby altering base flow.

The latter trend has been demonstrated in Hawaii by Oki (2004), who utilized a 90 year record of precipitation and stream gauging accumulated by the sugar plantations to assess long-term trends. He concluded that precipitation and stream base flow had decreased throughout the main Hawaiian Islands between 1913 and 2002; over this same period data from other studies clearly indicate that temperature and atmospheric carbon dioxide had increased (Keeling et al., 1995; Keeling & Whorf, 2004). Oki (2004) also concluded that for Hawaiian systems, the effects of El Niño-Southern Oscillation (ENSO) events were more strongly correlated to variations in base flow than to variations in total flow, indicating that the direct-runoff component of overall stream flow is more sensitive to ENSO events than is underlying aquifer discharge.

Determining whether similar climate dynamics have had corresponding effects on base flow and total flow in New Guinea streams is difficult due to the lack of similarly long-term gauging data. However, it is clear that for the island as a whole, the occurrence of El Niño events does correlate with decreased precipitation and reductions in total flow, while the effects are reversed during La Niña. For instance, during the 1997 El Niño event, precipitation at recording stations across Papua New Guinea ranged from 23-78 percent below normal (Barr, 1999). During this period, the Fly River at Kiunga dropped to essentially base flow levels, forcing the operators of the Ok Tedi mine to declare *force majure* because they could not move barge traffic upriver to service their operation. Conversely, Marshall (2005) provided good evidence that the alternating La Niña events lead to increased precipitation in the Fly River basin, resulting in higher than average total flows, and consequent dieback of riparian forests due to prolonged flooding. Similar patterns of ENSO-related drought are also documented for the Solomon Islands, which lie in the same general latitudes as New Guinea.

Another potential effect of prolonged precipitation decreases is a contraction of stream order hierarchies within any given drainage basin. First order streams are considered to be the smallest individual segments within any given drainage basin. Thus all headwater streamlets are first order segments. Segments of equal rank combine to create a segment of the next highest rank, thus two first order streams would join to form a second order stream. By contrast, if a first order stream joined a second order stream, the downstream segment would still be considered to be a second order stream, because the two segments that merged were not of equal rank. In a decreasing precipitation regime, former first order segments would become intermittent, and segments previously considered second order would become first order instead. Thus there would be a contraction in both the extent of perennial drainage networks, and the number of higher order segments within them.

Given the size of the New Guinea mountain chains, the extent of the aquifers lying beneath them, and the general absence of water development schemes such as tunnels and wells, it is likely that base flows will be insulated from direct climate effects for many years to come. As such, these underlying aquifers could be considered near-term “drought buffers.” However, a prolonged regime of decreasing precipitation will eventually impact recharge to such systems, therefore water use and conservation strategies should be developed proactively if modeling indicates that long-term climate change in the New Guinea region will produce a drying pattern.

Lentic ecosystems

For lentic ecosystems, a decreasing precipitation regime would likely have negative effects on both lacustrine (lakes and ponds) and palustrine (swamps, marshes, and other wetlands) ecosystems. The extent of lacustrine ecosystems in New Guinea is considerable. Chambers (1987) recorded over 5000 lakes with a surface area greater than 0.1 ha in Papua New Guinea alone. Over 80% of these lakes lie below 40 m altitude, and only 4% are found at altitudes above 2,000 m. The majority of these lakes are oxbow or tributary lakes associated with lotic ecosystems, particularly large lowland rivers, and as such may be directly affected by decreasing stream flows as described previously.

For palustrine (wetland and swamp) systems (as defined and classified by Polhemus & Allen, 2007) the effects of a decreasing precipitation regime are likely to include reduction in the extent of such systems, and possible transformation of some wetlands to grassland or savanna, particularly south of the central mountains, where patterns of wet and dry seasonality are more pronounced. Several recent studies (Bualia, 1990; Chappell, 1990; Hughes & Bualia, 1990; Pernetta & Osborne, 1990) have offered predictions in regard to the possible effects of climate change on wetlands in Papua New Guinea. Under decreasing precipitation regimes, potential consequences identified include shoreline retreat and increasing salt water intrusion.

Mangrove ecosystems and sea-level rise

The same studies (Bualia, 1990; Chappell, 1990; Hughes & Bualia, 1990; Pernetta & Osborne, 1990) predicted that mangrove habitats fringing the Gulf of Papua are likely to undergo substantial reduction in area, with compression of existing zones as a result of sea-level rise. This could in turn lead to a reduction in the diversity and abundance of estuarine fish communities, and a possible decrease in nursery areas for penaeid prawns, which could impact this commercially exploited fishery. The scope of the potential impact of such changes on mangroves may be gauged by the fact that mangrove swamps are estimated to cover 34,739 km^2 on the island of New Guinea as a whole (Alongi, 2007), with Papua New Guinea possessing between 162,000 and 200,000 ha of such ecosystems (including nipa palm stands). The largest areas of mangroves in Papua New Guinea occur along the southern coast, especially bordering the Gulf of Papua into which many large rivers, including the Fly, Kikori and Purari, discharge via extensive deltas. For instance, Purari Delta is estimated to contain 134,000 ha of mangroves, while Central Province, including the National Capital District, has an estimated 57,770 ha of mangrove swamps. In Papua (Indonesian New Guinea) the area of mangroves is even more extensive than PNG, although less accurately mapped. Large stands border the Arafura Sea in the south, while the largest mangrove estuary on the island, covering 618,500 ha (Alongi, 2007), occurs along the margins of Bintuni Bay in the west. Clearly, any climate-mediated impacts to such important systems, which serve as both buffers to shoreline erosion and critical nursery grounds for food fish species, would have profound ecological, social, and economic consequences.

All of the above scenarios present the prospect of adverse effects on native freshwater and estuarine organisms due to loss of habitat. Lowered water levels in major rivers may also serve to concentrate harvested species such as catfishes, rendering them more vulnerable to overexploitation by locally-based fisheries.

Increasing precipitation regimes

In contrast to the negative effects identified above for decreasing precipitation regimes, the consequences of an increasing precipitation regime in New Guinea due to global climate change would in all likelihood be less ecologically traumatic. Overall, one would predict an increase in the extent of both lotic and lentic ecosystems, in particular lacustrine and palustrine systems. Stream order hierarchies within catchments would likely increase, as tributaries that currently flow intermittently become perennial instead. Bed competence of major rivers might also be expected to increase, potentially leading to increased sediment deposition in deltaic areas, which could mitigate to some extent the effects of rising sea level.

By contrast, the social consequences of an increasing precipitation regime would be far more negative. For lotic ecosystems, the most obvious manifestation of this would be more frequent and severe flooding along major rivers, which could lead to the relocation of certain settlements. In addition, expansion of temporary pools along overflow channels could increase the incidence of mosquito-vectored diseases, and prolong the duration of such disease outbreaks. Finally, increased seasonal flooding could require relocation or modification of current airstrips and roads, rendering the maintainence of transportation services and infrastructure more costly and difficult.

For palustrine and lacustrine ecosystems, there would in all likelihood be an increase in their extent in lowland basins north of the central mountains, particularly the Meervlakte (Lakes Plain / Mamberamo) basin of Papua province, and the Sepik and Ramu basins of Papua New Guinea. Also under an increasing sea level regime coupled with global warming, rising sea levels could interact with increased riverine discharges to create more back pressure at river mouths, promoting expansion of oxbow and tributary lakes along the lower reaches of large rivers.

Another effect of an increasing precipitation regime could also be a larger number of logs washed out of large rivers and into surrounding ocean waters. An increased number of floating logs could in turn have an effect on regional fisheries, since such floating objects attract fish, and are often the target of purse seine sets. Although a larger density of floating logs could increase fisheries production in Melanesian waters, this would need to be weighed against the fact that several tuna stocks in the region, specifically bigeye and yellowfin, are already in declared states of overfishing. Therefore, increasing catch rates related to increasing numbers of floating logs could in fact prove counterproductive to current efforts to reduce mortality for such stocks.

In general, the effects of an increasing precipitation regime would probably be less severe in terms of impacts on the native New Guinea freshwater biota, but equivalent to or more severe in terms of social displacements and associated cultural impacts.

Conclusion

The analyses presented above in terms of both increasing and decreasing precipitation regimes in New Guinea and their consequent effects on freshwater ecosystems and their associated human social networks are admittedly hypothetical and based on extremely limited data. Far more baseline information in terms of the present distribution of both inland water ecosystem types and their associated biota is required before the extent of any changes can be accurately assessed. For the biological components of such systems, recent synthetic analyses by Polhemus & Allen (2007a, 2007b) provide a solid framework from which to progress. Given that climate regimes appear to be changing rapidly, the collection of such baseline data, and the subsequent monitoring of key sites in regard to temperature, precipitation, ecological data is imperative, and should be undertaken as soon as possible. Otherwise, we will be faced with the consequences of climate change in New Guinea, but will have no accurate metrics by which to assess the true magnitude of the changes with which we are confronted. Donor agencies may wish to consider requiring that such data be collected and disseminated via standardized protocols as part of their grant review and acceptance process.

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