These adaptations for internidal competitive ability no doubt result in a colony-level fitness cost. Perhaps the only reason that the *A.m. capensis* zone on the Cape has not been overrun by the more competitive *A.m. scutellata* is that the latter is vulnerable to parasitism by *A.m. capensis* workers.

Further information

The work by Martin *et al.* has demonstrated the two key mechanisms by which clone workers can parasitize *A.m. scutellata* hosts: the host fails to recognize the clone's eggs as being worker laid, and the clone activates its ovaries even in the presence of brood. However, there is much more that can be understood about social control and the population genetics of hybridization from this fascinating system. Readers interested in learning more about the *Apis mellifera capensis* invasion are recommended to read the upcoming special issue of *Apidologie*, which contains reviews and original research from most of the South African and international researchers interested in the *A.m. capensis* problem.

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Meeting Report

A precarious future for Amazonia

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The meeting The Future of the Amazon: Impacts of Deforestation and Climate Change was held in Panamá from 29 to 31 January 2002.

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The Amazon not only sustains 60% of the world's remaining tropical rainforests, but also stores billions of tonnes of carbon in its living biomass and soils that are emitted as greenhouse gases when forests are razed by ranchers and slash-and-burn farmers [1,2]. The Amazon is also a vast heat engine, driving large-scale patterns of atmospheric circulation and rainfall [3–5]. Such global links suggest that Amazonian deforestation will have complex and unanticipated effects on distant regions of the world, although the most striking impacts of deforestation might be local. Up to 50% of the rains falling on Amazonian forests are rapidly recycled back into the atmosphere via plant evapotranspiration [6,7]. This process helps to maintain a humid, productive regional climate and prevents catastrophic flooding and soil erosion. Because the luxuriant vegetation of Amazonia is reliant on rainfall that it itself helps to generate, will ongoing deforestation eventually disrupt the regional ecosystem? Could forest loss drive a regional drying process that leaves forests ever more vulnerable to devastating droughts and fires? How much forest destruction can the Amazon tolerate before its rainforest falls into desperate retreat?

Such compelling questions galvanized participants at a recent meeting in Panama. Co-sponsored by the World Wildlife Fund-US and the Smithsonian Tropical Research Institute, the meeting brought together an eclectic group of ecologists, climatologists and ecosystem modelers involved in cutting-edge studies in Amazonia.

The future of Amazonia

The meeting began with a public symposium in Panamá City during which it was argued that Brazil could potentially earn billions of dollars if international agreements were made to allow rich, heavily polluting nations to pay developing countries to conserve their forests, as part of an overall strategy to reduce global greenhouse emissions (Philip Fearnside, National Institute for Amazonian Research, Manaus, Brazil). Some recent improvements in environmental protection in Brazil were also highlighted, the most notable of which being a reduction of illegal forest burning along the so-called 'arc of deforestation' in southeastern Amazonia (Daniel Nepstad, Woods Hole Research Center, MA, USA).

There is no doubt that humans have a devastating effect on Amazonia, and William Laurance (Smithsonian Tropical Research Institute, Panama) showed that human population density, highways and dry-season severity were the strongest correlates of Amazon deforestation. He argued that current Government programs that promote rapid immigration and infrastructure development pose serious threats to these forests. Wim Sombroek (Pilot Program to Protect the Brazilian Rainforest, The Netherlands) then demonstrated that, whereas most Amazonian soils are very nutrient poor, scattered patches of black soil ('terra preta') created by centuries of Amerindian cultivation are more fertile and could be used for sustainable agriculture, thus reducing the need to clear virgin forest.

The impacts of deforestation on large-scale water and energy fluxes were also discussed. Pedro Silva Dias (University of São Paulo, Brazil) reviewed the known effects of deforestation on the radiation balance of the forest, whilst Roni Avissar (Duke University, NC, USA) summarized current efforts to predict the impacts of Amazonian deforestation on regional and global precipitation.

Forest loss and climatic deterioration

During an intensive two-day workshop that followed the symposium, delegates struggled to understand the complex interactions between forest conversion and local and regional climatic processes. Ultimately, the central question of the workshop – exactly how much Amazonian forest should be retained to maintain a stable regional climate and hydrology – remained elusive. But other key insights emerged.

Paradoxically, deforestation might initially cause a rise in regional rainfall, because pastures and other agricultural lands reflect more heat back into the atmosphere than do forests, which, in turn, creates low-pressure systems that promote the formation of rain-producing clouds. At some unknown threshold of deforestation, however, this effect might suddenly be reversed as regional evapotranspiration declines, leading to a precipitous drop in rainfall. Because of such nonlinearities, increasing deforestation could render the Amazon vulnerable to an abrupt and unpredictable deterioration in climate.

Equally alarming is the notion of a 'vegetation breeze,' whereby moist air is pulled away from forests into adjoining pastures and clearings. The humid air over forests is drawn into the clearing and condenses into rain-producing clouds, which is then recycled – as dry air – back over the forest. This effect has been observed in clearings as small as a few hundred hectares, but extensive clearings spanning 50–100 km apparently cause much larger scale forest desiccation.

The vegetation breeze is of particular concern because forest fragmentation is increasingly rapidly in Amazonia [8,9]. Fragmented forests have dry, fire-prone edges and are often juxtaposed with pastures, which are regularly burned to control weeds. During dry periods, these pasture fires frequently burn into adjoining forests, penetrating up to several kilometers [10] (Fig. 1) and causing severe plant mortality [11]. As a result, fragmented forests are exceptionally vulnerable to fire – an effect that might be exacerbated by the vegetation breeze. A recent study suggests that 45 million hectares of forest in Brazilian Amazonia are already vulnerable to destructive edge-related fires [12].

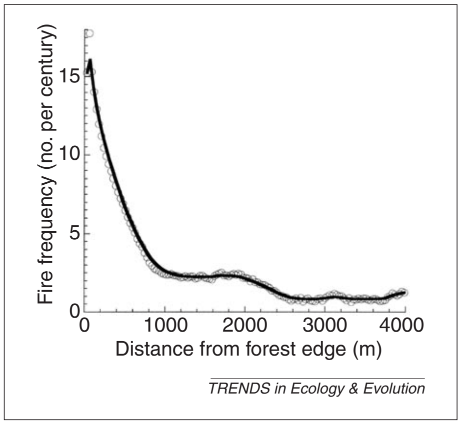

Fig. 1. Fire frequency (estimated number of fires per century) as a function of distance from forest edge in a fragmented landscape in eastern Amazonia. The curve was fitted by using a smoothing function. Adapted, with permission, from [10].

Not all threats to the Amazon arise locally; an even greater wildcard in the area's future is anthropogenic climate change. Recent studies suggest that global warming might hasten the frequency of El Niño events [13], an occurrence that would dramatically increase the vulnerability of Amazonian forests to droughts and fires [14]. In concert with rampant forest destruction and its complex effects on local climate, such global changes could pose alarming new threats to the Amazon ecosystem.

Although some important questions remained unresolved, all who participated in the meeting felt that it was a resounding success. Forcing ecologists, climatologists and ecosystem modelers to grapple with a common problem produced scores of novel insights; the most frequent remark was 'I really learned something new here'. As illustrated by the complex and far-reaching effects of Amazonian deforestation, collaborations among people with disparate skills will be needed to deal with the challenging environmental crises that face us all.

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