THE ROLES OF VERTEBRATES IN FOREST DYNAMICS: A NEW CTFS PROGRAM

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Research at Pasoh as well as most other sites in the worldwide network of the Centre for Tropical Forest Science (CTFS-SIGEO) is traditionally focused on the diversity and dynamics of vegetation. Large-scale forest plots in which trees are mapped, measured and monitored are the key standardized methodology (Condit 1998). This approach, however, does not completely fulfill the primary goal of the CTFS-SIGEO global network, which is to understand the diversity and dynamics of forests in the face of global change. In particular, vertebrates and their roles should be systematically studied across the network but are not.

The first reason to study vertebrates is that they are a crucially important component of forest ecosystems, even if “forest” is narrowly interpreted as “vegetation dominated by trees”, vertebrates influence the woody vegetation in many ways. They directly influence vital rates of plants through seed dispersal, seed predation, browsing of seedlings and saplings, rooting and burrowing. Indirect influence on vital rates of plants arises from predation of herbivores by carnivores, competition between herbivores, and predation on insects by insectivorous vertebrates, amongst others (Terborgh & Wright 1994). Because tree species are impacted differentially by different vertebrate species, these interactions influence the species composition of recruitment and hence co-determine the species composition of future forest, their (functional) diversity, and many ecosystem services. Very high population densities of vertebrates, in conjunction with fire, may even turn forests into woodland and savanna (Van Langevelde *et al.* 2003). Clearly, the species composition and abundance of vertebrate communities shapes vegetation.

A second reason to study vertebrates in the CTFS-SIGEO network is that vertebrate populations are dramatically affected by global change, both in land use and in climate (Collen *et al.* 2009). Forest habitats are increasingly fragmented to the point that they can no longer sustain viable populations of larger species. Fragments often get isolated by non-forest habitat to the point that many species are unable to re-colonize these forests. Also, gigantic tracts of seemingly intact tropical forests are subject to intense hunting for trade in bush meat, pets and medicine, and for prosecution. Over hunting leads to the local extinction of larger vertebrate species and sometimes even their global extinction, and is one of the key threats to global biodiversity. This produces so-called “empty forests” with “silent springs” where animals and their sounds are noticeably lacking. Indirect impacts on the ecosystem abound. For example, seeds of vertebrate-dispersed tree species may fail to reach sites suitable for survival and growth, which indirectly favors recruitment of wind-dispersed species that do not experience such increased dispersal limitation. Also, trees that normally experience high levels seed and seedling mortality may be ecologically released (Wright *et al.* 2007b, Jansen *et al.* 2010).

Many studies have shown that the community composition of vertebrates affects vegetation and ecosystem functioning and service of forests. For example, regeneration of particular tree species failed after extinction of top-predators that bother herbivores browsing recruits of those species in North American forests (Ripple & Larsen 2000). Small-island ecosystems with a reduced mammal community completely collapsed in Venezuela (Terborgh *et al.* 2001). Forests with hunting showed clear shifts in seedling recruitment towards wind-dispersed species and lianas in Panama, which might in turn affect carbon sequestration by these forests (Wright *et al.* 2007a). And infectious diseases emerge out of wildlife populations in degrading tropical forests as a possible result of vertebrate diversity loss (Keesing *et al.* 2006). The consensus expectation is that vertebrate diversity loss may have dramatic cascading effects on tree communities, ecosystem functioning and services to mankind. Global change may even be affecting tree species composition via land-use impacts on vertebrate communities more than via climate-impacts on trees.

CTFS has initiated a new Vertebrate Program, aimed to systematically study vertebrates and their impacts on forests in the network. A first task will be to assess the species composition; abundance and diversity of vertebrates at each CTFS site through compilation of existing data and new inventories. A second component will be the monitoring of changes in community composition over time, parallel to the tree-plot censuses, to allow for comparisons. Experiments replicated across multiple sites are needed to better understand the impact of vertebrates on plant diversity. Responses of vertebrate communities to climate and land-use change must be addressed by comparing sites that differ in their levels of such changes. Finally, cross-site experiments are needed to address cascading effects of vertebrate diversity loss on tree diversity and ecosystem functions.

A major problem with studying vertebrate communities is that quantitative census requires completely different methods for the various vertebrate groups. Birds are typically censused through mist netting and visual surveys along transects, small mammals by live trapping, larger mammals by distance sampling along transect and camera trapping, amphibians and reptiles by pit falls and transect counts, bats with mist nets and bat detectors, and fish by netting. Thus, monitoring of an entire vertebrate community requires a variety of parallel studies by differentially specialized students. The amount of work involved begs to prioritization. CTFS has chosen to first develop a program for medium- to large-sized terrestrial vertebrates because they have a relatively large impact on the vegetation, and are under threat. Besides that, this group is appealing to students and to the general audience. Using camera-trapping technology, this group can be censused relatively easily in a standardized manner.

One of the first projects in the new vertebrate program involves annual camera trapping of terrestrial mammals at a subset of the CTFS sites that will become part of the Tropical Ecology Assessment and Monitoring (TEAM) network (www.teamnetwork.org). This network, in which CTFS collaborates with Conservation International, the Wildlife Conservation Society, and Missouri Botanical Gardens, is planned to comprise about 40 tropical sites with contrasting levels of projected global change. The goal of TEAM is “to provide a consistent free and public long-term global data set in near real-time of biodiversity for scientific and conservation communities worldwide".

Pasoh is among the ten CTFS sites that will be part of TEAM. Here, we will run modern camera traps in two areas: the Forest Reserve of which Pasoh is part, and the Kenaboi forest area. Where the lowland Dipterocarp forest of Pasoh has gotten entirely isolated by oil palm and rubber plantations and is subject to heavy poaching, it is not far from hill Dipterocarp forest that is still connected to the large tracts of forests that cover the Central Forest Spine of the Malaysian Peninsula, and may have low levels poaching thanks to poor accessibility. A comparison between the two forests over the years will give insights on how much the vertebrate community at Pasoh has changed and how it will continue to change.

In each study area, camera trapping will be undertaken annually at each of 30 points that are separated by 1.4 km (i.e., 1 camera per 2 km^2). Each year, at each point, a modern camera trap will record all passing animals that are large enough to trigger the infra-red motion sensor during 30 consecutive days in a dry season. The cameras take series of digital pictures at 1-second intervals, generating near-video photo sequences. The cameras have an invisible infrared flash that allows taking photos during the night (TEAM Network 2011). Camera traps allow the non-invasive monitoring of terrestrial mammals that are and often not detected with other methods. The photographs are to some degree analogous to museum specimens, representing a permanent record of date, location, and species. Several new mammal species have been discovered with camera traps during the past decade, and some species believed extinct were reconfirmed. For example, the Giant sable antelope, unique to Angola, was captured on camera trap after not being been seen for >20 years (Pitra *et al*. 2006).

The cameras should yield standardized measures of diversity and community composition that can be compared across years and sites. These include species presence, occupancy and potentially even density and biomass. The TEAM project generates these metrics for monitoring of changes in abundance over time. Also, the set-up that we have also allows comparisons along gradients within sites, for example using the Wildlife Picture Index (O'Brien *et al*. 2010). Besides monitoring, camera trapping can yield a wealth of information on behavior (Bridges & Noss 2011). For example, camera-trap footage contains information on animal activity, allowing the study of daily routines and how these are affected by interactions with habitat, food competitors, predators and people. Pilot studies at Barro Colorado Island, one of the CTFS sites in Panama, have been conducted to explore some of these opportunities.

Vertebrate-focused studies can help to increase our understanding of forest functioning and dynamics. They will undoubtedly highlight the importance of protecting not only the trees in forest and nature reserves, but also the vertebrates that are native to these ecosystems. Restoration and protection of the forest fauna will be one of the major future challenges at Pasoh.

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