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Monkeys as propagule predators

Background

Despite field observations that long-tailed macaques (*Macaca fascicularis*) are common in mangroves where they feed as omnivores and herbivores (Macintosh *et al*., 2013), targeted reports of these monkeys as propagule predators are hard to find.

While their niche as foragers for crabs and bivalve molluscs in tropical mangroves is an accepted fact and their destructive role in uprooting planted *Rhizophora* propagules has been reported and is known to forest managers, Hogarth (1999) noted that since few of these propagules are even slightly damaged, much less eaten, the motivation is not clear. However, the same writer added that monkey damage is a major problem for mangrove replanting projects and suggested that this monkey factor may have significance in natural regeneration and community structure of the mangrove ecosystem. This is a big claim. Interestingly, Kitamura *et al.* (1997) did not list monkeys as pests associated with mangrove planting in the rehabilitation of abandoned shrimp ponds. In contrast, crabs and rats were listed as pests for *Sonneratia* seeds. Clearly, quantified studies of the impact of macaques on mangrove propagules in mangrove forests would be a welcome addition to mangrove ecology.

Amongst ecologists, there remains some uncertainty, debate and inconsistency in the way the term predation is applied. It is beyond the scope of this short paper to fully examine how predation is used in the ecological and biological literature. Nevertheless, it is wise to give a concise philosophical justification for the way the term is used and defined in the context of this paper.

A *Rhizophora* propagule is a viviparous seedling and is thus far more than the mere part of a plant like a leaf, fruit or prop root. Thus when eaten or damaged beyond viability, the monkey is functionally a propagule predator. In short, it is a heterotrophic organism that consumes another living organism (Calow, 1999). This paper seeks to assess the impact of the macaques (*M. fascicularis*) on *Rhizophora* propagules in Brunei, Hong Kong and Thailand.

Study sites

The study sites were:
1. Estuary of Tutong River in Brunei
2. Chek Keng mangroves in Hong Kong, China
3. La-Un River of the Mangrove Forest Research Centre (MFRC), Ranong in Thailand.

Methods

Direct observations (by eye or field binoculars) associated with routine and more or less seasonal site visits to the Hong Kong site between 1978 and 2015 provided a long-term observation record of small groups (6−14 individuals) of feral macaque populations at the Sai Kung East Country Park (SKECP). The potential foraging area of mangrove in SKECP is 0.5 ha. However, since the monkey population density is unknown and they typically confine their foraging to the secondary forest and mangrove, the effective foraging area is limited and this restricts population growth. At no time during the observation period here had troops of >14 individuals been seen. These *Macaca* populations are natural as when humans were sighted, they displayed avoidance behaviours and disappeared into the woodland. When a troop of monkeys was observed by field binoculars from camouflaged observation points to be foraging in the mangroves at low tide, the observer could then approach the mangrove *via* a shrub-covered disused paddy field, concealed by a hedge-like belt of bamboo and *Hibiscus tiliaceus*. The stunted (0.4–0.9 m) Chek Keng mangroves enable excellent observation of monkey foraging behaviour. Occasionally, feral cattle and macaques would seek mangrove material (especially leaves and propagules) at the same time; they appeared to ignore each other while working at this site. The relatively firm, stony intertidal substratum here probably contributes to this mangrove as a foraging site.

In Brunei and Thailand, direct field observations were combined with litter trapping, long-term (12−14 month) phenology and experimental work using tethered propagules. In many ways, the Brunei site yielded the most compelling data because it provided a welcome combination of pristine mangrove and natural *Macaca* populations. Macaques in Thailand had experienced some human contact, which was confined to occasional encounters adjacent to or on a constructed walkway within the MFRC, which, itself, includes 6,896 ha of mangrove forest.

Results and discussion

The pooled data shown in Table 2 are based on findings in Brunei and Hong Kong. In the pristine, mangrove stands of Brunei where both mangroves and monkey populations are undisturbed by anthropogenic factors, propagule damage due to monkey foraging and herbivory is low. The data suggested that propagules of *Rhizophora mucronata* are the preferred choice by *Macaca fascicularis*.

Table 1 Location and description of field sites

Country	Site, location & description	Dominant mangrove vegetation
Brunei Darussalam	Estuary of Tutong River (04° 47' N; 114° 36' E). A 1−6 m wide *Kandelia* belt of 1.3 km in length.	*Kandelia candel* dominant as a riverine stand in front of pristine *Avicennia alba* and *Rhizophora* spp.
Hong Kong, China	Chek Keng (22° 25' N; 114° 21' E). A small coastal patch of 0.4 x 0.1 km and variable intertidal width of up to 100 m.	*Avicennia marina* and *Kandelia candel* as dwarf shrubs
Thailand	La-Un River (10° 11' N; 98° 43' E). A narrow discontinuous *Kandelia* belt of 1 km in length of the Mangrove Forest Research Centre (MFRC), Ranong.	Riverine La-Un mixed *K. candel* and *Aegiceras corniculatum* belt beside *Rhizophora* dominated forest

Table 2 Propagule damage due to monkey foraging (exploratory, herbivory and predation)

Mangrove species [no. of propagules sampled]	% Damage		% Non-damage	% Other damage *[3]	Remarks
	Teeth wound *[1]	Hypocotyl cut through *[2]			
Ra [211]	6.1	5.1	87.7	1.1	Cut propagules indicate predation, and teeth wound exploratory activity.
Rm [266]	4.6	14	80.4	1.3	
Kc [393] (Brunei)	9.2	0.0	85.2	5.6	2.8% of other damage had crab scrapes and 2.7% had insect-type wounds
Kc [57] (Hong Kong)	1.8	5.3	90.0	3.0	Only very small troops of *Macaca* (6−8 members)
Ct [40]	0.0	2.2	97.8	0.0	A minor species
Bg [37]	0.0	0.0	99.0	1.0	A minor species
Ac [44]	0.0	0.0	98.0	2.0	Propagules unattractive

Key Ra = *Rhizophora apiculata*; Rm = *Rhizophora mucronata*; Kc = *Kandelia candel*; Ct = *Ceriops tagal*; Bg = *Bruguiera gymorrhiza*; Ac = *Aegiceras corniculatum*

*[1] Teeth wound was superficial being an opening in epidermis and cortex of the propagule only

*[2] Propagule hypocotyl but by teeth action and parts missing presumed eaten; typically the upper portion of propagule near calyx cap was the portion consumed

*[3] Other damage included crab scrapes, insect holes and plant-to-plant abrasion

The absence of cut through *Kandelia candel* propagules in Brunei (Table 2) may back up the hypothesis that *Rhizophora* propagules are selected over *K. candel*, even when the latter was more readily available. A 2−6 m wide, riverine continuous belt of *K. candel* occupies a 1.3 km stretch of Tutong River, interspersed with small patches (2−30 m long) of *Nypa fruticans* and *Heritiera globosa* (Maxwell, 1993). Monkeys were observed actively foraging in patrol-like troops of 10−20 members at this Tutong site during routine monthly phenology visits. Much of the monkey foraging seemed to involve testing and sampling behaviours with minimal actual eating. Further into the Tutong mangrove forest, small groups of 2 or 3 monkeys could be observed visiting *Rhizophora* trees and spending more time in what was active feeding behaviour rather than sampling or testing.

The nature of foraging in the *Kandelia* belt was somewhat destructive since some of the adult-sized members were engaged in breaking small branches during their exploratory searching for desirable propagules. The Brunei macaque populations seemed to show a preference for foraging in the *Kandelia* riverine mangroves; the reasons for this appeared to include relative ease of movement at ground level compared to that of the inner *Rhizophora* forest and the availability of *Kandelia* propagules at arm's reach on smaller trees. When the troop moved from the *Kandelia* belt into the inner forest and encountered *Rhizophora*, the pace of foraging slowed slightly. The same observation – a slower foraging pace – was noticed when a *Rhizophora* propagule patch was encountered in or near the *Kandelia*-dominated river edge.

Observations and photographic evidence from the MFRC of Ranong, Thailand showed that macaques do select *R. mucronata* propagules as food, which presents a management challenge in terms of conservation forestry (Figs. 1, 2 & 3). There is evidence that the resident *Macaca* populations are increasing perhaps above that of former times in 1990's when immigrant workers hunted them for food. At present, the monkeys do not have natural enemies. The natural propagule productivity of *Rhizophora* spp. and *K. candel* ensures that these mangroves are reproductively and ecologically competitive. This together with an omnivorous dietary niche of *Macaca* implies, that under current conditions, the monkey predation is not yet of ecological concern. Should monkey populations expand exponentially due to say a change from a no-feeding to a feeding-allowed policy at the MFRC to cater for tourist interests, then this monkey factor could negatively impact on mangrove conservation.

Fig. 1 Monkey actively investigating a *Rhizophora* propagule on forest floor, MFRC, Ranong, 2014

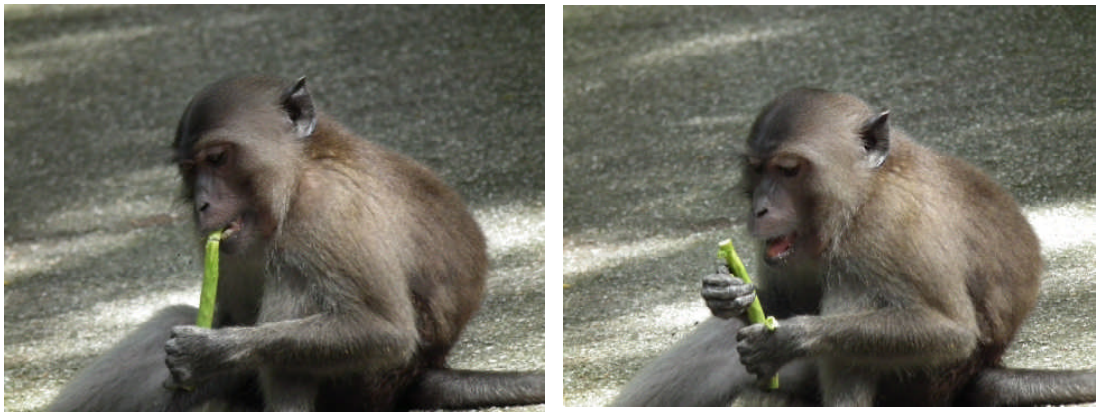

Fig. 2 Monkey predation targeting the plumule end of *Rhizophora* propagule (left), and predation and consumption continue far more than random damage (right)

Fig. 3 Sustained predation with propagule ingested in bite-sized lots

The pristine Tutong mangroves are not a tourist intensive site and the *Macaca* populations at the Chek Keng mangroves in Hong Kong site have a long history of low densities due to the absence of lush tropical forest and presence of struggling, small sub-tropical mangroves dominated by *Avicennia marina* and *K. candel* (Maxwell, 1993). Based on observations in northern Vietnam (Maxwell, 1994; Hong & San, 1993) and recent work in New Zealand with dairy cattle (Maxwell & L**a**i, 2012), the visits of the few *Macaca* to the Chek Keng mangroves may be more about satisfying occasional mineral salt needs rather than herbivory or predation *per se*.

From the findings reported in this paper, it would be hard to conclude that monkey predation and damage to mangrove propagules may have significant impacts on natural regeneration and community structure within tropical and sub-tropical mangrove ecosystems. In contrast, the mud-lobster *Thalassina anomala* can become an important ecological factor impacting on both mangrove succession and regeneration (Havanond, 2000).

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