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Short-term mangrove browsing by feral water buffalo: conflict between natural resources, wildlife and subsistence interests?

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SUMMARY

Management of the natural environment and its resources leads to conflicts between different stakeholders worldwide. Recently mangrove browsing by feral water buffalo in the East-Godavari Delta (India) has been considered a threat to the regeneration of mangroves by the local Forest Department, which led to conflicts between the authorities and local herdsmen who have an ancient tradition involving feral water buffalo. The impact of browsing and grazing of mangroves by feral water buffalo was monitored. Feral water buffalo consumed mangroves, but not to the extent claimed by the Forest Department, prefering *Avicennia alba, A. marina* and *A. officinalis*. Their browsing behaviour was not linked to a height zone, and buffalo preferred the fresh leaves from previously undamaged branches. Under experimental and natural conditions, browsing induced compensatory regrowth in *Avicennia*. The carrying capacity of the mangrove appears to be sufficient to accumulate impact. There are both positive and negative impacts of livestock animals on forest ecosystems, and sociocultural consequences must be carefully assessed prior to enforcing a change in natural resource or environmental management. Before banning feral water buffalo from the mangrove, forest managers should confront their prejudices about the real impact of feral herbivores on these forests.

Keywords: *Bos bubalis*, browsing, ethnozoology, grazing, herbivore, India, woody vegetation

INTRODUCTION

Along tropical coasts, mangrove forests function as breeding, spawning, hatching and nursery grounds for juvenile fish and shellfish, protect against erosion and are subsistence sources of wood and fuel. Worldwide, humans directly threaten mangroves with overexploitation, land reclamation or pollution (Farnsworth & Ellison 1997; Alongi 2002; Walters 2003). Indirect adverse anthropogenic influences on mangrove forests resulting in loss of services (Rönnbäck 1999) include classic changes in terrestrial hydrology (see Tack & Polk 1999; Dahdouh-Guebas *et al.* 2005*a*), exploitation (Naylor *et al.* 2000; Dahdouh-Guebas *et al.* 2004) and consequences of oceanic and climatic hazards (Dahdouh-Guebas *et al.* 2005*b*).

Enforcement of environmental management laws that are based on unvalidated claims can lead to conflicts between different stakeholders. A case study by the Indian Forest Department (Bhujanga Rao, Social Forestry, personal communication 1999) recently claimed that mangrove browsing (the consumption of leaves and woody tissue of trees and shrubs *sensu* Calow 1998) by feral water buffalo was dangerous for the regeneration and productivity of mangroves in the East-Godavari Delta (India). Local herdsmen have used the domesticated or feral water buffalo *Bos (Bubalus) bubalis* L. in a traditional way for more than 5000 years (BOSTID [Board on Science and Technology for International Development] 1981; Fahimuddin 1989; Singh 1966). Around the Godavari Delta, about 100 000 people with a GNP of US$ 260 per caput (World Bank, personal communication 1983) spread over 46 mangrove villages, live with and from these animals, which are traditionally used for milk, meat and agricultural labour (MSSRF [MS Swaminathan Research Foundation] 1997). As a consequence, the banning of feral water buffalo from the mangrove forest by the Forest Department creates an ethical conflict between the authorities and local herdsmen.

Considering the known tolerance of plants to herbivore damage (Tiffin 2000), questions remain as to whether browsing of mangrove leaves by feral water buffalo occurs, and whether it indeed has a negative effect on the mangroves and should be managed along with its long-standing domestication tradition. Herbivory by large mammals can affect vegetation assemblages, for example grazing may alter plant species richness (see Harper 1969; Gill 1992*a*, *b*). Browsing may inhibit development of woody vegetation and slow regeneration of certain species. Several plant species have developed either tolerance against herbivory, or morphological or chemical defence mechanisms to withstand it (Juenger & Lennartsson 2000). Mangroves may be unpalatable to animals (Tomlinson 1986) because of secondary plant metabolites such as tannins (Rosenthal & Janzen 1979). In contrast, mangroves may be used as fodder and feed (Morton 1965; Malik *et al.*

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1966; T. Kurian & J.S. Patiola, personal communication 1980; Allen 1981; Janick *et al.* 1981; Perry 1981; Saifullah 1982). Overexploitation or pressure as a result of grazing activities has been observed in mangrove areas in Australia, Indonesia, Pakistan, north-west India and the Sundarbans (Hamilton & Snedaker 1984; Hogarth 1999; J. Davie, M. Ghose, V. Kulkarni, D.M. Pania & S. Snedaker, personal communication 1999).

The objectives of this study were threefold. First, we aimed to measure the impact of feral water buffalo consumption of mangroves. Second, we sought to develop and test an approach to monitor the impact of browsing and grazing of mangroves. We had three questions: (1) Does a height zone exist to which buffalo browsing is confined? (2) Do buffalo prefer undamaged branches (i.e. fresh leaves) as opposed to recently damaged branches? (3) Do browsed branches display quick compensatory regrowth? In the absence of prior published scientific research in the East-Godavari Delta or elsewhere concerning the impact of feral water buffalo on mangroves, and considering the sociocultural and socioeconomic importance of this to the local people, a third *post hoc* objective consisted of comparing our results with the management strategy of the local authorities.

MATERIAL AND METHODS

Study area and experimental sites

The study was carried out in India's East-Godavari District located in the state of Andhra Pradesh. According to the Forest Department, the eastern delta of the Godavari has *c.* 316.38 km^2 of mangrove forest, of which 235.70 km^2 lie within the Coringa Wildlife Sanctuary. The area has been designated for conservation for more than 100 years (by the Madras Forest Act of 1883, the Coringa Forest Block of 1888, the Coringa Extension Forest Reserve of 1921, the Bhairavapalem Reserve Forest of 1957 and the Coringa Wildlife Sanctuary in 1978), but recent studies estimate the mangrove area to occupy less than 100 km^2 of seriously degraded forest (Mittal 1993; Blasco & Aizpuru 1997).

Field measurements

We noticed that local herdsmen offered the water buffalo leafy branches of various mangrove species, in particular *Avicennia alba* Blume, *A. marina*, (Forsk.) Vierh. *A. officinalis*, L. *Lumnitzera racemosa* Willd. and *Sonneratia apetala* Buch.-Ham. In order to check whether animals indeed consumed mangroves and to assess their preferences, we asked the herdsmen to present two randomly chosen species to 16 different buffalo.

To study the impact of mangrove browsing by buffalo, we first assessed above-ground 'branch length', 'branch tip height' and leaf numbers >1 cm long. Fast regeneration of leaves, which could be browsed with the same probability as the existing leaves, meant reduction in leaf numbers would be undetectable. Thus, we adopted branch length (measured along the branch between a reference tag at the main stem of the tree and the tip of the branch) and branch tip height (measured perpendicular to the soil, starting from an average reference point on the trampled soil). Measurements were carried out to the nearest millimetre using a 3-m steel ruler. The standard deviation of branch length data (95% probability; Taylor 1982) was 1.26 cm. A total of 119 branches on different trees were tagged and branch length and branch tip height were monitored over a period of 33–34 days; the trees selected were all within or accessible from the buffalo's foraging area, all being 1–2 m high and of similar vigour. Below 1.7 m, which corresponds to the average height to which a buffalo can reach, branches were selected at random with respect to height and orientation.

We subdivided the trees into two so-called 'impact sites'. The first impact site was located on a mangrove island near the river mouth (hereafter referred to as 'site RM') of the Gaderu river (16° 43′ 13.0″ N; 82° 19′ 55.0″ E), whereas the second impact site was located in the Forest Department's plantation 95B (hereafter referred to as 'site 95B'), a mixed *Avicennia marina* and *A. officinalis* area planted in November 1995 (16° 53′ 20.8″ N; 82° 14′ 52.0″ E). Buffalo impacted the former site, whereas in the latter, no buffalo or buffalo tracks were observed during our stay from December 1998 to February 1999. The 119 trees could therefore be distinguished into a group of 60 impacted by buffalo (impact site RM), and a group of 59 free of impact (impact site 95B), and they were analysed accordingly. Branch tip height and branch length measurements were carried out for a period of 33 (site RM) or 34 (site 95B) days, with buffalo in site RM present during the first 16 days of observation only. Site 95B, which was free of buffalo during the research period, served as a negative control (no buffalo impact) in our analysis.

Secondary data and statistical analysis

We interviewed local herdsmen (10 group interviews with about six people per group), and six representatives from governmental and non-governmental organizations (amongst which the Forest Department), in order to obtain administrative, demographic, socioeconomic and policy information. The herdsmen were asked questions about the differences between feral water buffalo and hybrid cows (care, yield and health), and about changes to their traditional lifestyle.

Non-parametric statistics on the branch-length measurements were used to compare both within (Wilcoxon signed rank-matched pairs test) and between the so-called 'impact sites' (Mann-Whitney-U and McNemar tests). The following comparisons were made: (1) original height of branch tips for (*a*) branches that had decreased in length in comparison with branches that had not decreased in length, and (*b*) branches that had decreased in length in comparison with branches that had increased in length; (2) chance of branch-length decrease in branches that had previously decreased in length (first 16 days) and branches that had not; and (3) branch-length evolution in (*a*) branches that had previously decreased in length, (*b*) branches that had previously not decreased in length and (*c*) branches that had previously increased in length.

RESULTS

Mangrove browsing

Consumption of mangrove vegetation by feral water buffalo was observed in natural conditions and in feeding experiments. The feeding experiment ($n = 16$) confirmed consumption of the three *Avicennia* species, as well as preference for these species over *Sonneratia apetala* and *Lumnitzera racemosa*, the last not being eaten at all.

The branch length after four days of monitoring was significantly smaller than after 16 days ($t = 296.0$; $p < 0.05$) and after 33 days ($t = 390.5$; $p < 0.02$) at site RM ($n = 60$). At site 95B ($n = 59$), the initial branch-lengths were significantly smaller than those after 16 days of monitoring ($t = 75.5$; $p < 0.02$), after 22 days ($t = 160.5$; $p < 0.005$) and after 34 days ($t = 121.0$; $p < 0.001$). At day 34 there were also significantly lower branch lengths than at 16 days ($t = 201.5$; $p < 0.001$) and after 22 days of monitoring ($t = 189.0$; $p < 0.001$) (Fig. 1).

Since no buffalo were observed at either site after 16 days of monitoring, prior to which only site RM had buffalo, we subdivided the total monitoring time into two periods of 16 days. During the first 16 days, there was no significant difference (Mann-Whitney-U test; $p = 0.89$) in branch length change between the site impacted by buffalo (RM) and that not impacted by buffalo (95B). However, the spread of the changes and the decrease in branch length was evidently larger in site 95B (Fig. 2). During the second period of 16 days, the change in branch length was significantly smaller at site RM (Mann-Whitney-U test; $p < 0.05$).

The three hypotheses can be tested using the data obtained from the buffalo-impacted site RM. There was no significant difference ($U = 337$; not significant) between the original branch tip height for the 23 branches that decreased in length after four days of monitoring and the 37 branches that did not (Fig. 3*a*). There was also no significant difference ($U = 146.50$; not significant) in original branch tip height when the 23 branches that decreased in length after four days of monitoring were compared to the 19 branches that had increased in length (Fig. 3*b*).

Branch length decrease from day 5 to day 16 was compared to branches that either had, or had not decreased in length during the first four days of observation (Table 1). We observed that there was an equal chance for both types of branches to decrease in the second period ($p = 0.073$) but that there was a significantly lower chance of branches that had decreased in length in the first four days of observation to decrease again during the successive period than branches that had not decreased in length in the first period ($p = 0.000$).

The 23 branches that had decreased in length during the first four days of observation displayed significantly higher branch length increase ($U = 280$; $p < 0.05$) in the successive

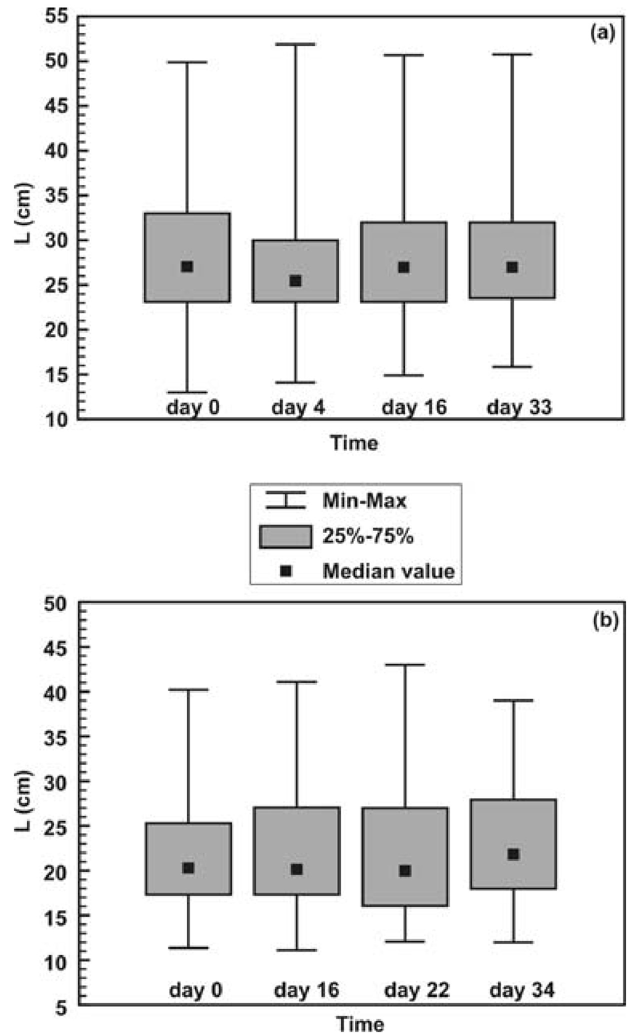

Figure 1 Box and whisker plots of branch lengths of *Avicennia* mangrove trees at four periods in time in (*a*) impact site RM, and (*b*) impact site 95B.

12 days than the 37 branches that had not (Fig. 3*c*); this trend in branch length increase remained significant ($U = 134$; $p < 0.05$) when the 23 branches that had decreased in length

Table 1 Dichotomous data input for the McNemar test (fresh leaves hypothesis). Incidence of browsing between days 0–4 and 5–16 in site RM.

Number of branches on day 4	*Number of branches on day 16*		*Total number of branches*
	With branch length decrease between days 5–16	*Without branch length decrease between days 5–16*	
With branch length decrease	2 (3.3 %)	21 (35.0 %)	23 (38.3 %)
Without branch length decrease	10 (16.7 %)	27 (45.0 %)	37 (61.7 %)
Total	12 (20.0 %)	48 (80.00 %)	60 (100.0 %)

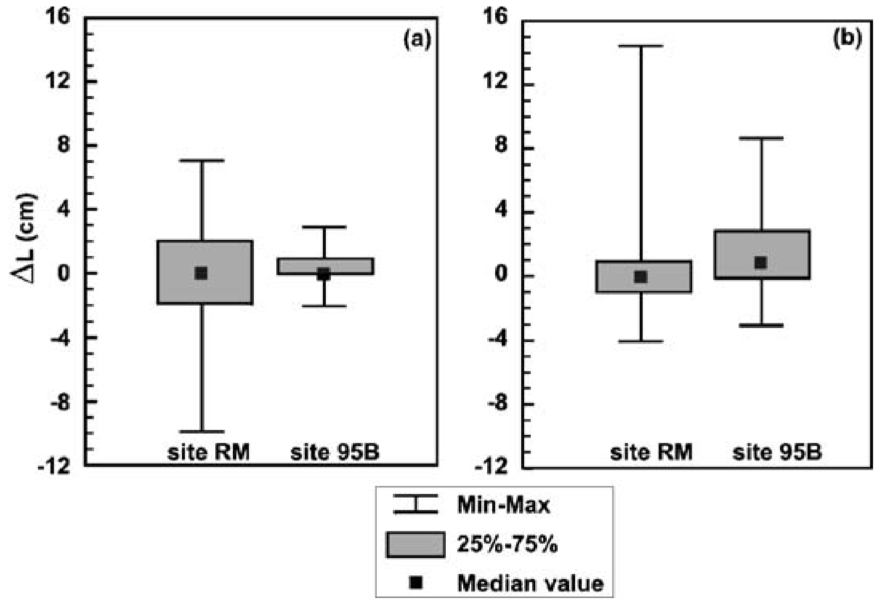

Figure 2 Box and whisker plots of the branch length change of *Avicennia* mangroves compared between impact site RM and impact site 95B in two consecutive periods of 16 days. (*a*) First period of 16 days, in which buffalo were present at impact site RM but not at impact site 95B. (*b*) Second period of 16 days, in which buffalo were absent from both impact sites. ΔL denotes the change in branch length.

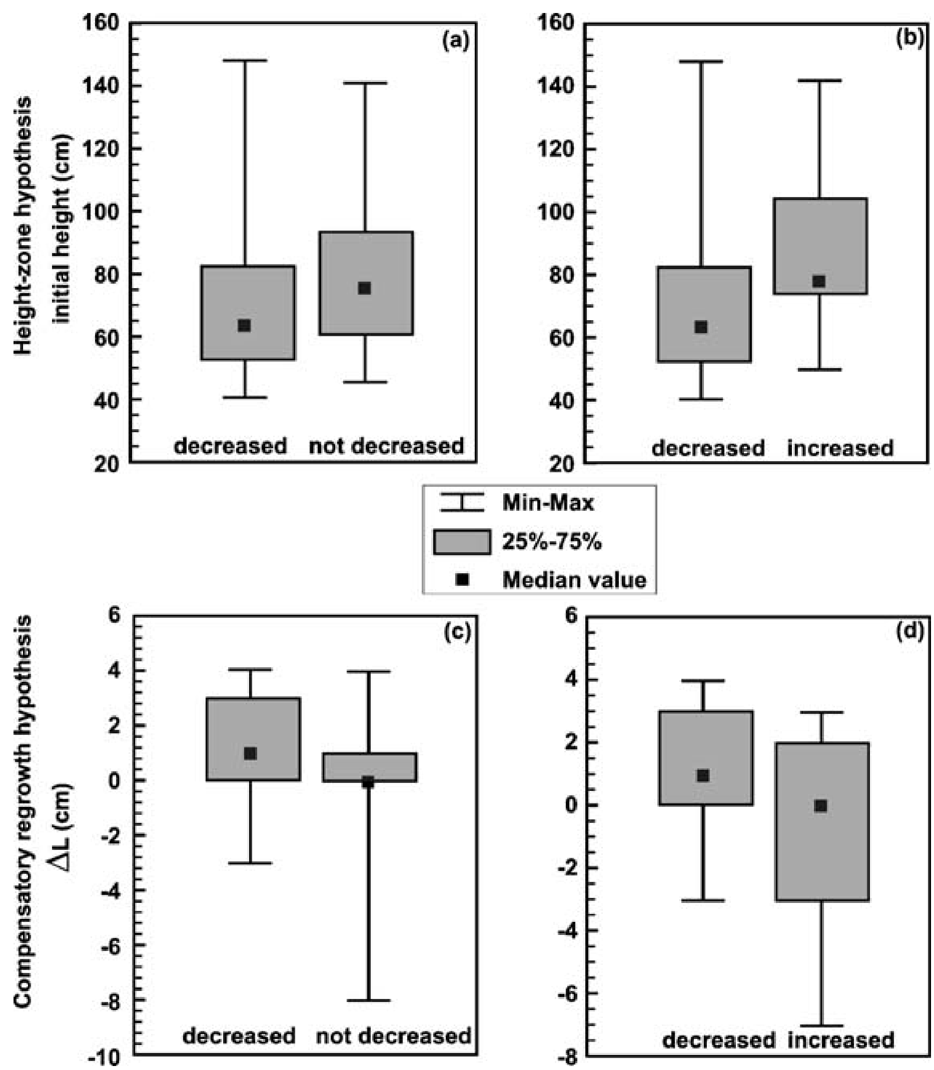

Figure 3 Box and whisker plots for two of the hypotheses investigated (site RM). Height zone hypothesis (top row): original height of branch tips for (*a*) branches that have decreased in length after four days of monitoring versus branches that have not, and (*b*) branches that have decreased in length after four days of monitoring compared with branches that have increased in length. Compensatory regrowth hypothesis (bottom row): comparison of branch-length evolution after four days of monitoring in (*c*) branches that had previously decreased in length compared with branches that had not, and (*d*) branches that had previously decreased in length compared with branches that had previously increased in length. ΔL denotes the change in branch length.

during the first four days of observation were compared with the 19 branches that had increased in length (Fig. 3*d*).

DISCUSSION

It difficult to estimate reliably the damage or impact that herbivores inflict on plants or vegetation owing to of the lack of a standard variable or parameter for assessment. Reimoser *et al.* (1999) emphasized the anthropocentric undertone of the term 'damage', requiring the identification of a desired condition. According to Putman (1996), 'damage' is the factor inhibiting forest regeneration and this can occur when the density threshold of an animal population is exceeded (Gill 1992*a*; Putman 1994; Reimoser & Gossow 1996; Náhlik *et al.* 2005), which is in turn dependent on the vegetation structure (Putman 1994). Within a forest, certain areas are relatively resistant to damage by the same herbivore or predator density, and it should be highlighted that regardless of the definition of the term 'damage', its in-depth study necessitates long-term research.

Blasco and Aizpuru (1997) estimated the woody vegetation in a 100 km^2 (or 10 000 ha) area of the East-Godavari mangrove. From secondary data obtained from the M.S. Swaminathan Research Foundation (MSSRF 1997), we estimated the number of feral water buffalo in villages adjacent to this area at 793, indicating an average feral water buffalo density of 0.08 ha^{-1} in the East-Godavari mangrove.

Despite the subsistence livelihood of the people, the strategy of the Forest Department to protect the mangrove was to exclude feral water buffalo by issuing fines from Rs 100–500 (US$ 1 = 46.86 Indian rupees in 1999), or to slaughter any buffalo caught (Forest Department, personal communication 1999). In financial collaboration with the World Bank, the local population was offered highly productive hybrid cows as an alternative. This was not popular, reportedly because of more intensive daily care, lower resistance to disease and the lower milk quality of hybrid cows in comparison with feral water buffalo (local people in Tallarevu-Mandal, personal communication 1999). More importantly, the financial implications of 15 000–20 000 Indian rupees per hybrid cow posed a non-realizable financial limitation.

Many observations of herbivore (*sensu lato*) attacks on mangrove systems pertain to invertebrates (Johnstone 1981; Rau & Murphy 1990; Farnsworth & Ellison 1991; Dahdouh-Guebas *et al.* 1999) with relatively few communications including mammals. Only observations on the distribution of large herbivores and their effect on mangrove seedlings in Bangladesh have been published (Siddiqi & Faizuddin 1981; Siddiqi & Husain 1994; Siddiqi *et al.* 1994). The present study is the first to investigate the effect of browsing by large herbivores on adult mangrove trees. Our evaluation of browsing damage, assessed by measuring branch-length decrease, is interpreted as follows. (1) Branch length increase occurs both in presence and in absence of buffalo (Fig. 1), so growth takes place in both sites. (2) Browsing is responsible for the larger negative spread of branch length change during the first 16 days of observation in site RM (Fig. 2*a*). The lack of statistical difference in the branch length change between the sites, and the fact that site RM is impacted by buffalo, indicate that the conditions for growth may be more favourable in site RM than in the buffalo-free site 95B. (3) There appears to be no specific height zone in which buffalo browse (Fig. 3*a*, *b*) and therefore the height zone hypothesis is rejected. (4) The results of the McNemar test support the hypothesis suggesting that buffalo prefer undamaged and therefore fresh branches and leaves (Table 1). (5) Since browsed branches display a larger length increase than non-browsed branches (Fig. 3*c*, *d*), we can also accept the compensatory regrowth hypothesis. Browsing thus induces growth in *Avicennia* mangrove, at least within the experimental conditions in which this research was conducted (season, climatic conditions, number of buffalo). Such stimulated growth over six months has also been observed in *Fagus sylvatica* L., *Prunus avium* (L.) L. and *Acer pseudoplatanus* L. browsed by deer (Putman 1996). Since short-term studies that use branches as experimental units have underestimated the tolerance of woody plants to herbivory (Haukioja & Koricheva 2000), the regrowth results of the present study are at least remarkable. However, branch-length decrease or damage as a result of browsing can be underestimated owing to the growth stimulated by browsing. Branch length decrease could be larger as a result of less favourable growth conditions, but could also be smaller through the absence of buffalo. Low grazing intensities usually increase productivity, whereas large grazing intensities decrease growth (Putman 1996). If browsing or predation occurs in the regeneration phase (destruction of flowers and/or fruits), or at a time when regeneration is necessary, damage occurs (Reimoser & Gossow 1996; Dahdouh-Guebas *et al.* 1998).

The effect of browsing is dependent on the intensity of browsing and the herbivore carrying capacity of a forest. It is known that the threshold for the carrying capacity depends on the ecosystem, the vegetation structure, the natural or artificial nature of the vegetation, the type of herbivore and even the type of investigation (Gill 1992*a*; Putman 1996; Reimoser & Gossow 1996; Náhlik *et al.* 2005). No figures exist for the carrying capacity of a mangrove forest with respect to feral water buffalo, and since mangrove forest productivity has been shown to be in the order of that of tropical forests (Lear & Turner 1977), we approximate its carrying capacity to that of domesticated cattle in a tropical forest (i.e. 0.8–2.5 buffalo ha^{-1}; De Zutter 1998). Our figure of 0.08 feral buffalo ha^{-1} for the carrying capacity of feral water buffalo in the East-Godavari mangroves seems reasonable in this respect. In response to our initial question, there appears to be no conflict between natural resources, wildlife and local subsistence, as it has not been demonstrated that feral water buffalo are indeed a threat to the mangrove forest's regeneration. However, the lack of threat to regeneration does not mean that there is no damage whatsoever. Although not investigated in this study, there are other effects from feral water buffalo that possibly play a damaging or influential role in the ecology of the Godavari mangroves. The resources that a plant uses for regeneration of branches and leaves cannot be used for flowering and fruiting, and these may in turn be affected. Non-selective feeding behaviour has been shown to jeopardize mangrove regeneration at seedling level (Dahdouh-Guebas *et al.* 1997), and conversely the selective preference for a particular plant species may also lead to ecological consequences, such as changes in species composition or abundance. This may be followed by shifts in faunal assemblages and changes in traditional use. The trampling or mixing of the soil substrate by large herbivores may result in the redistribution of nutrients and the creation of paths through the mangrove. However, this should be investigated before drawing conclusions or drafting regulations with respect to buffalo foraging.

From interviews with local people it is clear that the removal of feral water buffalo from the mangrove is seen as a profound socioeconomic change. The Forest Department, however, has a more drastic view, probably inspired by the conversion of almost 40% of the mangroves along the west coast of India to agriculture and urban development (Upadhyay *et al.* 2002). Local non-governmental organizations are attempting a compromise between the differing view points.

This study contributes as a scientific support to the assessment of the impact of feral water buffalo on the mangrove forest. A spatial and temporal extension of this type of investigation, combined with remotely sensed buffalo migrations, may lead to a better understanding of the carrying capacity of the mangrove forest. The simulated or real possibility of coexistence of 'damaging' herbivores with nature management practices has been reported before (Jorritsma *et al.* 1999; Van Oene *et al.* 1999). It is important, however, to conduct parallel research to the socioeconomic status of the surrounding communities to assess the local and global demand of mangrove products, and to assess the efficacy of existing and alternative mangrove management schemes (Walters 1997, 2004; Dahdouh-Guebas *et al.* 2000; Dahdouh-Guebas *et al.* 2006). This type of holistic approach would be conducive for integrated management in which local herdsmen and their feral water buffalo, as well as the national Forest Department, would be key actors. When synthesizing the key elements for a successful management scheme in any community with long-standing ethnobiological traditions, and particularly in subsistence-based communities, any policies should consider ecological, as well as the economic and socioeconomic factors involved. Even socio-cultural elements, such as religion, could be used to match the actions of local inhabitants with the desired policy (Palmer & Finlay 2003).

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