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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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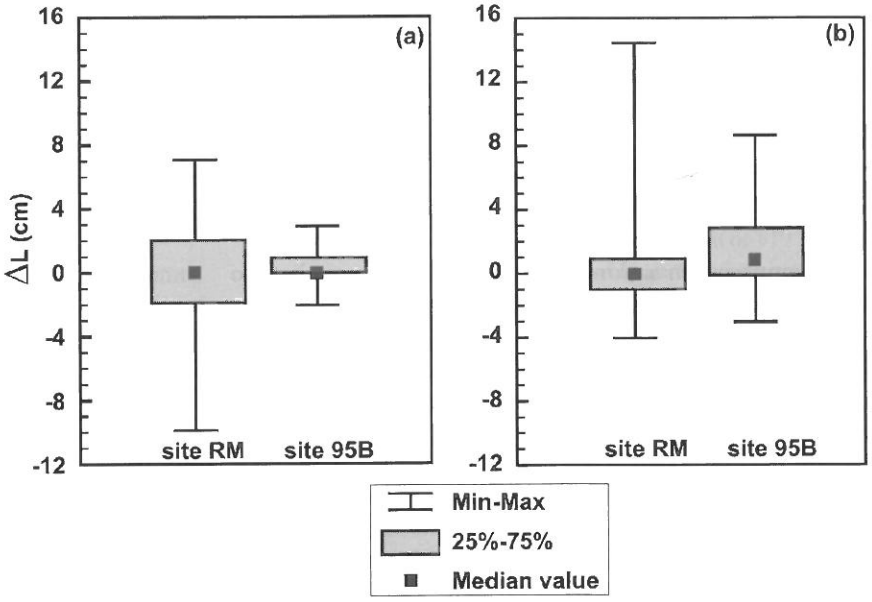

Figure 2 Box and whisker plots of the branch length change of *Avicennia* mangroves compared between impact site RM and impact site 95B in two consecutive periods of 16 days. (*a*) First period of 16 days, in which buffalo were present at impact site RM but not at impact site 95B. (*b*) Second period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

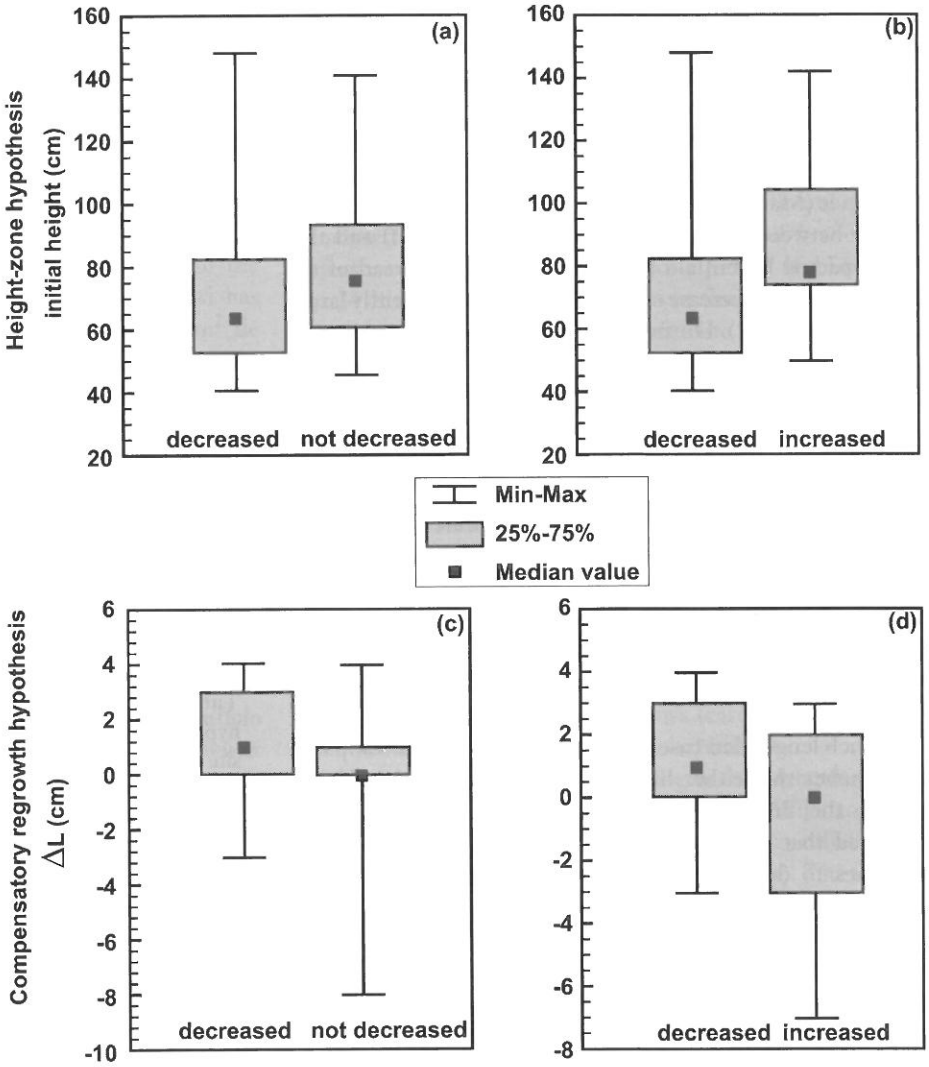

Figure 3 Box and whisker plots for two of the hypotheses investigated (site RM). Height zone hypothesis (top row): original height of branch tips for (*a*) branches that have decreased in length after four days of monitoring versus branches that have not, and (*b*) branches that have decreased in length 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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Factors influencing the sustainability of customary dugong hunting by a remote indigenous community

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SUMMARY

The sustainability of indigenous customary hunting and fishing in remote areas can be influenced by human factors operating at global as well as regional and local scales because of the hybrid nature and sectoral interactions of the local economic environment. The internationally significant population of dugongs (*Dugong dugon* or seacow) in Torres Strait between Australia and Papua New Guinea supports an important indigenous fishery. The economic, socio-cultural and environmental factors that influenced hunting activity in 1998 and 1999 by the members of the community of Mabuiag Island were investigated to inform the sustainable management of the fishery. The landed catch during the eight months March to October of 145 dugongs in 1998 and 170 dugongs in 1999 potentially provided the community with an average of 290 g of dugong meat per person per day. Fifty-seven per cent of adult males on the island participated in dugong hunting, but more than half the catch in each year was caught by only two hunters. The probability of at least one person from the community going dugong hunting in 1998 and 1999 was 0.59 ± 0.02 per day. This probability was influenced by local environmental factors, including the abundance of dugongs in the traditional hunting grounds (affected by wind speed, year, season and lunar day) and the size of the commercial crayfish catch (which is influenced by the global market price, as well as local conditions). Although dugong hunting remains a very important part of the islanders' contemporary culture and customary economy, the capacity to hunt dugongs is facilitated by the ease with which some hunters move between the state, commercial and customary sectors of their local economy. The complexities of the economic, social and cultural environments need to be considered in planning for the sustainable harvesting of threatened species by remote indigenous communities.

Keywords: dugong, hybrid economy, indigenous hunting, marine mammal, sustainability, threatened species

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INTRODUCTION

Increasing recognition that effective management of natural resources for sustainable use requires an understanding of both human and biological systems (Berkes & Folke 2000) has led to cross-disciplinary studies to improve understanding of the interactions between human behaviour and exploited resources. This approach has been used in commercial fisheries research (see Holland & Sutinen 1999; Hilborn & Walters 2001) and anthropological studies of subsistence practices such as hunting (see Winterhaulder & Lu 1997; Fitzgibbon 1998) and fishing (Aswani 1998; Bird *et al.* 2001).

For subsistence fisheries to be sustainable, it is important to understand which conditions cause people to conserve resources and which conditions favour overexploitation (Schmink *et al.* 1992). These influences are complex and may operate at global as well as regional and local scales, even in remote areas. This complexity results from the sectoral interactions between the components of the contemporary local economy.

The predominantly Melanesian peoples of the remote region of Torres Strait between Queensland (Australia) and the Western Province of Papua New Guinea (Beckett 1987) are renowned as some of the highest consumers of seafood in the world. They practise customary specialized marine subsistence involving hundreds of species, including fish, shellfish, sea birds, marine turtles and dugongs (sea cows).

About 200 people live on Mabuiag Island, one of the major dugong hunting islands in Torres Strait (Fig. 1). The community operates in a hybrid economy (*sensu* Altman 2001, 2005) with three sectors: (1) customary (subsistence), (2) market (commercial fishing) and (3) state, rather than the usual two (market and state). The average incomes of Mabuiag Islanders are very low relative to Australian norms (*c.* US$ 7000–9000 per annum; see McLennan & Madden 1999; Arthur 2003), but this value ignores the contribution of the customary sector, which is not monetized and therefore not quantified or recognized in mainstream terms (Altman 2005).

The fishery for the crayfish or tropical rock lobster (*Panulirus ornatus*) is the most important commercial activity for the men living at Mabuiag. Crayfishing occurs all year round with peak catches during March–August. Most fishing activity occurs during neap tides when the currents are slower