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Managing mangroves with benthic biodiversity in mind: Moving beyond roving banditry

Aaron M. Ellison *

Harvard University, Harvard Forest, 324 North Main Street, Petersham, MA 01366, USA

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Abstract

This review addresses mangrove management activities in the broader context of the diversity of the mangrove benthos. Goals for mangrove ecosystem management include silviculture, aquaculture, or 'ecosystem services' such as coastal protection. Silvicultural management of mangroves generally neglects the benthos, although benthic invertebrates may affect tree establishment and growth, and community composition of benthic invertebrates may be a reliable indicator of the state of managed mangrove forests. Similarly, mangrove aquaculture focuses on particular species with little attention paid either to impacts on other trophic levels or to feedbacks with the trees. Exploitation of mangrove-associated prawns, crabs, and molluscs has a total economic value >US $4 billion per year. These aquaculture operations still rely on wild-collected stock; world-wide patterns of exploitation fit the well-known process of 'roving banditry', where mobile agents move from location to location, rapidly exploiting and depleting local resources before moving on to other, as-yet unprotected grounds. Collection of brood stock and fishing for other external inputs required by aquaculture (e.g., 'trash fish') removes intermediate trophic levels from marine food webs, may destabilize them, and lead to secondary extinctions of higher-order predators. Increased attention being paid to the role of mangroves in coastal protection following the 2004 Indian Ocean tsunami provides an opportunity to reassess the relative merits of management focused on short-term economic gains. Managing for ecosystem services may ultimately preserve benthic biodiversity in mangrove ecosystems.

Keywords: Aquaculture; Brachyura; Food web; Management; Mangroves; *Penaeus*; Roving bandits; *Scylla*

1. Introduction

Mangroves are salt-tolerant trees that grow on sheltered tropical coastlines throughout the world. These trees - ~70 species in ~27 genera and ~19 flowering plant families (Tomlinson, 1986) - once covered nearly 200 000 km^2 of riverbanks, estuaries, and seacoasts as well as carbonate sands and coral rubble islands (Ellison and Farnsworth, 2001). Their extraordinary high rates of productivity, often exceeding 2 t ha^{-1} y^{-1}, support both terrestrial and marine (both pelagic and benthic) food webs and contribute significant carbon to some offshore fisheries (Manson et al., 2005a,b). Mangrove forests significantly reduce coastal erosion and may provide protection from tropical cylones and tidal waves (UNESCO, 1979; Danielsen et al., 2005). And like other forested ecosystems throughout the world, mangrove forests are disappearing at 1–2% y^{-1} (Farnsworth and Ellison, 1997; Alongi, 2002). What are the consequences of this rapid deforestation for the biodiversity and management of the marine benthic fauna that is

* Tel.: +1 978 724 3302; fax: +1 978 724 3595.
E-mail address: aellison@fas.harvard.edu.

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associated with mangrove forests for all or part of their life cycle?

Mangroves and non-timber products from mangrove ecosystems have been exploited for centuries (Watson, 1928; Biagi and Nisbet, 1992; Kathiresan and Bingham, 2001). Until the 1970s, management schemes focused almost exclusively on wood products, especially charcoal, lumber, and pulpwood, but by the 1980s, it was generally recognized by ecologists, fisheries scientists, managers and policy-makers that mangrove forests are tightly linked with adjacent ecosystems, and that managing them in isolation is unsustainable (Rao, 1987). Thus the 1992 Charter for Mangroves explicitly asserted that *[m]angrove ecosystems that are utilized by people shall be managed to achieve and maintain sustainable productivity without degrading the integrity of other ecosystems with which they coexist* (ISME, 1992). Despite this clarion call, degradation and outright destruction of mangroves has continued virtually unabated (Alongi, 2002). Although the 2003 global assessment of mangrove forests suggested a modest decline in their deforestation rates (Wilkie and Fortuna, 2003), this overall 'improvement' is due only to the substantial slowing of mangrove deforestation in two countries - Brazil and Pakistan - each of which had lost ~50% of their mangroves in the preceding decade (Fig. 1). Nonetheless, renewed optimism in the ability of people to manage mangroves was reiterated in 2005: *The fundamental objective of mangrove management is to promote conservation, restoration or rehabilitation and sustainable use of mangrove ecosystems and their associated habitats, supported where necessary by ecological restoration and rehabilitation* (World Bank et al., 2004).

In this review, I examine the consequences of ongoing mangrove forest loss for the diversity and sustainable management of the communities of the benthic invertebrates that are associated with mangroves. Some of these benthic invertebrates, such as tiger prawns and mud crabs themselves are exploited or managed for profits exceeding US $4 Billion per year. Because our understanding of the distribution and ecology of the mangrove macrobenthos in general lags well behind our knowledge of mangrove forests, the impact of managing the mangrove macrobenthos for overall benthic biodiversity in mangrove ecosystems is largely unknown. I thus evaluate current knowledge on the biodiversity of the mangrove macrobenthos, and discuss whether or not we can manage, conserve, restore, or rehabilitate the mangrove macrobenthos and provide for their sustainable use. I also assess some of the broader consequences of managing the mangrove macrobenthos for mangrove-associated food webs. Throughout the text, I identify key data gaps and priorities for research that are required before we can realistically conserve and sustainably manage the mangrove macrobenthos.

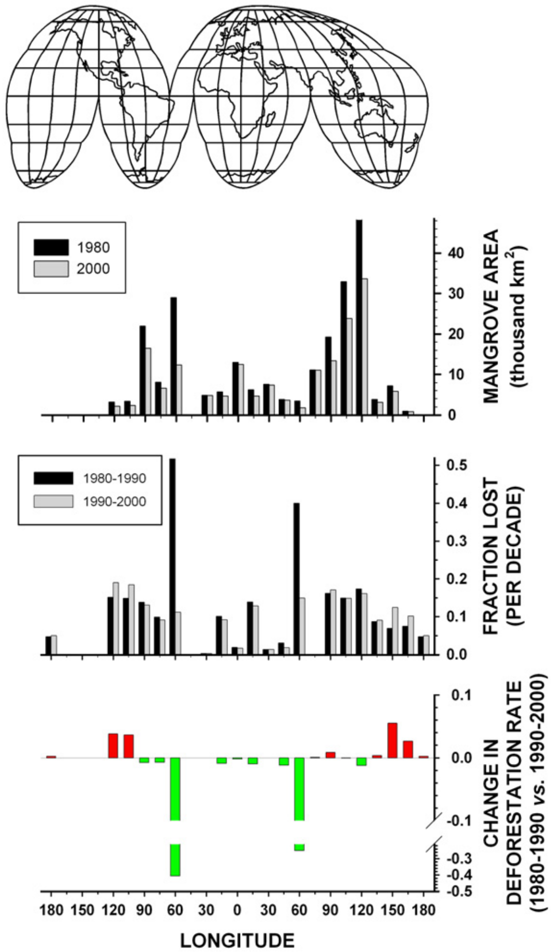

Fig. 1. Loss of mangroves 1980–2000. The **top** graph shows estimated mangrove area per 15° of longitude in 1980 (black bars) and 2000 (grey bars). The **middle** graph shows the fraction of mangroves area lost per 15° of longitude between 1980–1990 (black bars) and between 1990–2000 (grey bars). The two extreme values are Brazil, which lost 56% of its mangrove area between 1980 and 1990, and Pakistan, which lost 40% of its mangrove area in the same decade. The **bottom** graph shows the change in deforestation rate between the two decades. The value shown is the simple difference between deforestation rates 1990–2000 and 1980–1990. A positive value (shown in red) indicates a faster deforestation rate, and a negative value (shown in green) indicates a slower deforestation rate in 1990–2000 than in 1980–1990. All data are derived from 113 country-by-country summaries published by Wilkie and Fortuna (2003).

2. Biodiversity of the mangrove macrobenthos

The mangrove macrobenthos - those species that live in mangrove muds or depend on mangroves for all or