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Ecological Restoration and Livelihood: Contribution of Planted Mangroves as Nursery and Habitat for Artisanal and Commercial Fishery

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Summary. — Restoration of degraded and depleted mangrove habitats and planting of mangroves over coastal mudflats is happening at many places, but there are few studies that evaluate the flow of ecosystem services from these regenerated ecosystems. The state of Gujarat in Western India has planted thousands of hectares of mangroves over the coastal mudflats and, today, the state's mangrove cover is nearly double that in the 1930s. However, these mangroves have limiting features: for example, these are mostly single-species, *Avicenna marina*, and are sparse, and lack freshwater supply. Mangroves provide multiple ecosystem services including nursery and habitat services for fish fry that enhances fish growth. This study evaluates the regenerated forests' contribution to the fishery sector of Gujarat, both inshore, and offshore, using the difference-in-differences technique, and panel regression estimates. Commercial catch data from secondary sources and primary survey diary on the daily catch of artisanal fishermen are used in the analysis. The results show that the planted mangroves have significantly increased the catch of mangrove-dependent fish in both sectors, and that young planted strands contribute nearly one-fourth of the contribution of natural strands. Despite the limiting features, the contribution of the planted mangroves' nursery ground and habitat service to the fishery sector of Gujarat state is valued at INR36.04 billion (USD0.57 billion) annually.

Key words — ecosystem service, fishery, Gujarat, nursery and habitat, regenerated mangrove, value of planted mangroves

1. INTRODUCTION

Mangrove forests provide many ecosystem services that increase the welfare of both local and global consumers, like protection to lives and property during coastal disasters, enhancement of fisheries, promotion of biodiversity as mangroves are habitats to numerous flora and fauna, climate control through carbon sequestration, waste processing, food production, recreation, etc. (Aburto-Oropeza *et al.*, 2008; Barbier *et al.*, 2008, 2011; Blaber, 2007; Das & Crépin, 2013; Das & Vincent, 2009; MEA, 2005; Meyfroidt & Lambin, 2009; Mukherjee *et al.*, 2014; Valiela, Bowen, & York, 2001). After 1950s, the world witnessed rapid mangrove loss due to various reasons like overharvesting, clearing for developmental uses, or for other high-yielding land uses like aquaculture, agriculture, tourism, etc. (FAO, 2008). However, the rates of mangrove loss have slowed down—the latest estimate is that the world lost 0.19 million hectares of mangroves during 2001–12, much less than the 3.09 million hectares lost during 1980–2000 (FAO, 2008). Based on these data, the annual rates of mangrove loss are also seen to be declining steadily—1.04% during 1980–90 to 0.72% during 1990–2000, and then from 0.66% during 2000–05 to 0.13% during 2001–12.[1] In recent years, probably with an increase in environmental knowledge and awareness on mangrove values, there has been a revival of mangrove forests in many parts of the world—either through ecological restoration of degraded mangrove areas or mangrove planting over non-mangrove areas like mud flats, salt marshes, or degraded coastal lands (like rejected aquaculture ponds) (Field, 1999; Lewis, 2001, 2009). Such policies are also partly instigated by global policy commitments such as the Convention on Biological Diversity.[2]

However, there are limited studies that evaluate the flow of ecosystem services from planted mangroves and compare them with the flow of services from natural mangroves. Further, mud flats have been widely used for mangrove planting (Erftemeijer & Lewis, 1999), though in reality, sub-tidal mudflats are inappropriate for mangrove forest restoration, as was evident from a mangrove restoration project in Philippines where the survival rate was very low and the surviving mangroves showed abysmally stunted growth (Lewis, 2010). Mud flats are proven productive ecosystems with high economic and ecological values (Erftemeijer & Lewis, 1999; Naber, Lange, Hatziolos, & UNEP/WCMC, 2008; UNEP, 2005) and reclaiming these habitats for planting mangroves may prove to be a poor resource allocation decision if the flows of ecosystem services from these planted mangroves are found to be inadequate. Such dilemmas also make evaluation of ecosystem services from planted mangroves an important area of research. Though, there are limited evaluations of planted mangroves from the viewpoint of societal benefits, the

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success of mangrove plantation has been evaluated through ecological parameters like

1. biodiversity richness—composition of microbes, fungi, plants, tropical guilds as well as invertebrates and mud crab populations (Ellison, 2008; Walton, LeVay, Lebata, Binas, & Primavera, 2007);
2. the composition of forest structure through vegetation cover and height, woody density, biomass, basal area, or litter structure (Bosire *et al.*, 2008; Kairo, Lang'at, Dahdouh-Guebas, Bosire, & Karachi, 2008; Macintosh, Ashton, & Havanon, 2002; McKee & Faulkner, 2000); and
3. biotic and abiotic features like soil pH level, organic content, or moisture content between planted and natural mangroves (Khayat & Jones, 1999; Walters, 2000), etc.

This study attempts a socio-economic evaluation by measuring the contribution of planted mangroves to the fishery sector of the state of Gujarat in India. The state has successfully planted thousands of hectares of mangroves over coastal mudflats and a further 810 sq km have been identified where mangroves can be planted in future (Pandey, Pandey, & Khokhariya, 2012). Mangrove plantation started in 1948 in the state (Gazetteers, 1971) as a pure public sector activity; it is now being pursued under the public–private–partnership (PPP) model. The flow of ecosystem services from regenerated mangroves is argued to depend on multiple factors like slope and height of mud substratum, distribution of freshwater inputs, species composition, abundance, and size structure of mangrove stands, density of detritivorous invertebrates, energy flows, vertical zonation pattern of organisms, etc. (Kaly & Jones, 1998). In contrast, most of the planted mangrove areas in Gujarat, as described below, have no freshwater source, are sparse and single-species and thus, do not possess many of the above-mentioned features. Single-species mangrove plantations have been argued to provide few ecosystem services, show lower capacity to regenerate, and hence, to be unsustainable in the long run (Rovai *et al.*, 2012). Thus, the gain to the state from this massive investment is questionable; and evaluation, as attempted here, forms an important research issue for sustainability and justification of the resources allocated.

Hutchison, Spalding, and zu Ermgassen (2014) provide a comprehensive account of the ecological processes through which mangroves contribute to fishery. "Mangroves enhance fish production via two main mechanisms—the provision of food and of shelter . . . (p. 6)." Mangroves provide nursery, habitat and nutrients to fish fry and juvenile fishes. Thus, near-coast fisheries (like inshore mixed fisheries, and inshore mollusk and crustacean fisheries) are the most likely and immediate beneficiaries of the habitat services of mangroves. Nonetheless, commercial fisheries that operate many kilometers away from mangroves could also benefit from the nursery habitat role of mangroves and their protection service from predation. Thus, mangroves are likely to be an important determinant of fish stock—the potential fishable biomass of a region, and fish catch—though the sustainability of fishery is influenced more by how it is managed. However, the linkage between mangrove habitat and fishery production is reviewed to be location specific, not universally observed (Saenger, Gartside, & Funge-Smith, 2013).This necessitates a careful examination of the mangrove-fishery linkage for every study area. This study tries to do this for both inshore artisanal and offshore commercial fishery. A set of carefully collected data and panel regression methodology are used for artisanal fishery. Offshore commercial fishery is targeted and vessels are acquired to carry out targeted fishing on pelagic, demersal, mollusks, etc. It is thus natural that vessels acquired, which are privately owned, will be guided by species availability and previous experience. As advised by fishery ecologists, the presence of mangrove influences the growth and availability of specific fish species like demersal, crustaceans and mollusks, but not pelagic. Whether mangrove presence yields any benefits to the commercial offshore fishery of Gujarat is thus, discussed in terms of these species.

The mangrove plantation in Gujarat state is described first which is then followed by a review of studies on mangrove fishery linkage and then the planted mangroves' contribution to inshore and offshore fishery of Gujarat is evaluated. Both data and the evaluation methodology for these two sectors are different from each other.

(a) *Mangrove plantation in the state of Gujarat, India*

In order to measure the extent of planted mangroves, this study assessed the mangrove cover of Gujarat state for three different years: 1939, 1990 and 2013. The source of 1939 data was an open access online source, www.lib.utexas.edu/maps/ams/india/nf-45-14.jpg whereas Indian Satellite image LANDSAT--TM–1990 and RESOURCE--SAT–2–LISS-III–2013 with a resolution of 23 m were used to measure the mangrove cover for 1990 and 2013. Table 1 shows the mangrove cover of the coastal districts of Gujarat for these years. Historically, and as can be observed from Table 1, the state had extensive mangrove cover, to the extent of 855 sq km, spread mostly in four districts: Bharuch, Bhavnagar, Jamnagar, and Kutch. By 1990, mangrove cover declined in Bharuch, Bhavnagar, and Jamnagar; whereas they were planted in Ahmedabad, Anand, Kutch, Navsari, Surat, etc., so that the mangrove cover, in 1990, was nearly the same as it was in 1939. By 2013, all coastal districts other than Porbander, Rajkot, and Vadodara had some mangroves. Thus, although natural mangroves have been destroyed in most areas, total mangrove cover has gone up, as plantation is taking place in almost all coastal districts. These estimates also match with the Gujarat Ecology Commission's estimate of 1,027 sq km of mangroves for 2006 (GEC, 2009). Depending on location, different mangrove plantation techniques have been used in the state (Pandey & Pandey, 2009), like

1. poly plot (PP) plantation in open seashore areas;
2. enrichment plantation (EP) in areas generally having existing sparse natural mangrove vegetation;

Table 1. *Mangrove cover (in sq km) of Gujarat as assessed from satellite images*

Districts	Mangrove_ 1939	Mangrove_ 1990	Mangrove_ 2013
Ahmedabad	3	76	34
Amreli	0	0	3
Anand	0	19	9
Bharuch	81	36	56
Bhavnagar	105	19	24
Jamnagar	229	79	300
Junagadh	0	2	12
Kachchh	419	604	1,198
Navsari	0	10	19
Porbandar	2	1	0
Rajkot	15	1	0
Surat	0	27	36
Vadodara	0	2	0
Valsad	0	1	4
Total mangrove cover	855	876	1,694

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