Hydrobiologia (2017) 803:345–358
DOI 10.1007/s10750-017-3309-x

Mangrove timber use as an ecosystem service in the Colombian Pacific

Martha L. Palacios · Jaime R. Cantera

Received: 21 November 2016 / Revised: 6 July 2017 / Accepted: 12 July 2017 / Published online: 25 July 2017

Abstract Mangroves provide ecosystem services for local communities. However, in coastal systems it is yet unknown how human settlements are directly interacting with mangroves. We assessed the use of mangroves as an ecosystem service at Málaga and Buenaventura bays, on the Colombian Pacific coast, by interviewing local communities and examining the impact of mangrove harvest on the structure of the forest, an often overlooked effect. Results showed that mangroves are mainly harvested for their wood. *Rhizophora* spp. are the main source of wood for fuel purposes, whereas *Mora oleifera* (Triana ex Hemsl.) Ducke, a mangrove associate, provides 100% of the wood used for the construction of stilt houses. The selective extraction of these species has altered the composition and structure of the forest. Sample sites undergoing harvest have relatively low densities of mangroves; however, one site at Quebrada Valencia shows signs of copious regeneration (>9000 seedlings/ha). Due to the importance of mangroves for the subsistence of coastal communities, and the threat that mangroves are exposed to in Colombia, the management of mangroves should be a priority. Managers must address the sustainability of critical species as part of conservation strategies in order to maintain ecosystem services for local communities.

Keywords Building material · Colombia · Fuel wood · Interview surveys · *Mora oleifera* · *Rhizophora* spp.

Introduction

Mangroves are highly productive biological habitats supporting marine and terrestrial species (Nagelkerken et al., 2008) and local human communities. Due to their importance to local livelihoods, mangrove natural resources have been also considered an important economic source as well for local communities. Mangroves have been very important for subsistence economies since Pre-Columbian times; there are accounts of mangrove/human interactions for more than 95% of the known history of the human-occupied Neotropics (López-Angarita, et al., 2016). They provide a variety of ecosystem services related to soil formation; the dense root systems of mangrove forests

Electronic supplementary material The online version of this article (doi:10.1007/s10750-017-3309-x) contains supplementary material, which is available to authorized users.

Guest editors: K. W. Krauss, I. C. Feller, D. A. Friess, R. R. Lewis III / Causes and Consequences of Mangrove Ecosystem Responses to an Ever-Changing Climate

M. L. Palacios (✉)
Departamento de Ciencias Ambientales, Universidad Autónoma de Occidente, Cali, Colombia
e-mail: mlpalacios@uao.edu.co

J. R. Cantera
Departamento de Biología, Universidad del Valle, Cali, Colombia

trap sediments flowing down rivers and off the land. This helps stabilize the coastline and prevents erosion from waves and storms. Breeding sites, refuge, nesting, and feeding areas of many faunal species are provided by mangrove forests. Mangroves are highly valuable as breeding and nursery habitats for juvenile and migratory marine fish and mammal species, and are responsible for producing as much as 600 kg/ha of fish in nearby coastal ecosystems (Melana et al., 2000; Kathiresan & Bingham, 2001; Krumholz & Jadot, 2009; Valle et al., 2011). These fisheries form an essential source of food for thousands of coastal communities around the world.

Mangrove forests perform crucial ecological functions in coastal areas, including protection of coastal communities against natural hazards such as cyclones, tsunamis, and shoreline erosion (Saenger, 2002; FAO, 2007). These human communities also collect medicinal plants from mangrove ecosystems and use mangrove leaves as animal fodder. Additionally, mangrove forests are significant oxygen producers and CO_2 fixers, one of the gases that generate the greenhouse effect contributing to global warming (Ulloa-Delgado et al., 1998; Sanchez-Páez et al., 2000; MMA, 2002). Mangrove ecosystem services also include provisioning human societies for aquaculture, agriculture, alcohol, medicines, fodder, and other local subsistence use (Spalding, 1998; Hogarth, 1999; Alongi, 2002; Walters et al., 2008). Mangroves are increasingly utilized for wood products such as timber, poles, posts, fuel wood, and charcoal. The wood is resistant to rot and insects, making it extremely valuable. Many coastal and indigenous communities rely on this wood for construction material as well as for fuel and charcoal (Field, 1998; Bosire et al., 2008).

Despite the highly recognized functional importance of mangrove forests, in the last decades, there has been a rapid degradation of the mangrove forest resource. Kauffman & Donato (2012) estimate 14.7 million ha of mangrove forest ecosystems extend along tropical shorelines of the world, with annual losses of about 2% since 1990 (Valiela et al., 2001; Alongi, 2002, Duke et al., 2007; Bosire et al., 2008). The global decline of mangrove habitats has impaired at least three critical ecosystem services: (1) fisheries (33% decline); (2) nursery habitat, including effects on associated ecosystems such as oyster reefs, sea grass beds, and other wetland types (69% decline); and (3) filtering and detoxification services provided by suspension feeders, including influences on associated ecosystems such as submerged vegetation and other wetland types (63% decline) (Worm et al., 2006; Barbier et al., 2011).

The largest area of mangroves in western South America covers the tropical coastline of the Colombian Pacific and the northern Ecuador (Esmeraldas region) (Spalding, et al., 2007; Spalding et al., 2010). Although the geographic distribution of species composition and structural characteristics of mangroves are mainly determined by interactions between regional factors (e.g., tides, freshwater hydrology) and geomorphology (Krauss et al., 2008), anthropogenic exploitation has substantially altered the biological characteristics of individual forests. As a result, these forests are among the most threatened ecosystems worldwide (Dahdouh-Guebas, 2000; Álvarez-León, 2003; Blanco, 2009). Polidoro et al. (2010) report that the highest proportion of threatened mangrove species in the world occurs in Costa Rica, Colombia, and Panama, with 25–40% of mangrove species classified as threatened under the IUCN Red List Categories of Critically Endangered, Endangered and Vulnerable. The most prejudicial human activities for mangrove forests include (a) construction of dwellings, docks, and roads, and (b) harvesting of mangrove wood to be used as fuel or construction material for homes, boats, and aquaculture ponds.

Colombia holds 379,954 ha of mangrove habitat, of which 292,724 ha extend along the Pacific coast (INDERENA, 1991). Mangrove forests are composed mainly of seven species: *Avicennia germinans* (L.), (black mangrove), *Rhizophora mangle* L., (red mangrove), *Laguncularia racemosa* (L.) C. F. Gaertn., (white mangrove), *Conocarpus erectus* L. (button mangrove), *Pelliciera rhizophorae* Planch. & Triana, (piñuelo), *Rhizophora racemosa* G. Mey., and *Mora oleifera* (Triana ex Hemsl.) Ducke (nato) (Prahl, 1989; Peña et al., 2014). The Cauca Valley Environmental Corporation (CVC) regulates coastal forest conservation, and since 1999, mangrove wood use has been prohibited (INDERENA, 1991; CVC, 2007). Only local communities are authorized to use mangrove wood for non-commercial purposes.

The aim of this study was to evaluate mangrove wood use as an ecosystem service for local communities in three localities in Málaga and Buenaventura bays of the Colombian Pacific coast. Additionally, the

study surveyed the structure and composition of mangrove forests, and correlated the impact of wood use with forest composition. These data will contribute to establishment of appropriate conservation policies along the Pacific coast of Colombia. The compilation of basic information of mangrove use, identification of different practices of wood collection and the mangrove species affected could be address for a wider scientific audience.

Materials and methods

Study area

The study was conducted in Buenaventura, Colombia (Tropical Eastern Pacific), and included two Bays with different levels of human influence: Málaga Bay, which is a National Natural Park, and Buenaventura Bay, which is a main port on the Colombian Pacific coast. Málaga Bay (3°56′–4°05′N, 77°19–7°21′W) is a tectonic estuary covering 126 km^2 (Cantera et al., 2013). It has approximately 12,000 inhabitants, divided into small human settlements, including Juanchaco, Ladrilleros, and La Barra, among others. The economy is based on ecotourism, especially during the whale-watching season (between June and October) when more than 1,100 humpback whales (*Megaptera novaeangliae,* Borowski, 1781) migrate north from the southeast Pacific (Flórez-Gonzalez et al., 2007). Buenaventura Bay (3°54′N, 77°12′W) is a drowned valley estuary covering 70 km^2 (Fig. 1), where Buenaventura is the main cargo port on the Colombian Pacific (moving 9,500,000 Ton/Year), (Perez, 2016). The estuary is surrounded by extensive mangrove swamps, especially in the southern part of the bay (Sánchez-Páez & Álvarez-León, 1997; Cantera & Blanco, 2001). Within Buenaventura Bay, our research was conducted in the area between Bazán—Bocana, which includes approximately 1700 inhabitants distributed in the small towns of Piangüita, Vista Hermosa, La Bocana, and Changai.

Local details and interviews

In Málaga Bay, important local details and the number of people interviewed from La Barra, Ladrilleros and Juanchaco were as follows:

- *La Barra* This is a settlement located at the lower tide limit, with approximately 140 families. Some of the wooden houses are used as hotels with up to twenty rooms, with electricity, refrigeration, stereo, TV, and gas stoves. The area is affected by flooding during the highest tidal events or by tidal surge, and several houses have been lost from erosion. La Barra is connected to Ladrilleros by a 3 km beach that is emergent and accessible only during low tide, or alternatively by a path through the forest. We interviewed 10 people here.
- *Ladrilleros* This is a settlement of about 150 families, whose main source of income is ecotourism. Houses are used mainly for commercial activities, restaurants, craft making, and peddling. Most houses are built of bricks and cement. Ladrilleros is connected to Juanchaco through a 5 km trail accessible to any motor vehicle. We interviewed 60 people here.
- *Juanchaco* This is a settlement located at the northern entrance of Málaga Bay. It historically served as a fishermen´s village, but now is used mainly for ecotourism. Juanchaco has a dock that receives boats carrying tourists and products such as food and fuel. Some hotels, cabins, and residences are used for lodging; some are built with bricks and mortar, and others with wood. We interviewed 40 people here.

In Buenaventura Bay, people from Piangüita, Vista Hermosa, La Bocana and Changai were interviewed. The region itself is often referred to as Punta Bazan, which is a settlement with approximately 1700 people. Most of the residents are natives of the area; afro-descendants have lived in the area for at least three generations. Here also we identified a small population group that depends on the mangrove ecosystem. These individuals depend on the functions of the mangrove as a place for the reproduction, spawning, hatching, and nursery of several marine species. Important local details and the number of people interviewed from Piangüita, Vista Hermosa, La Bocana, and Changai were as follows:

- *Piangüita* This settlement belongs to the Special Natural Reserve of the Collective Territory. It is located in the eastern part of Buenaventura Bay. Buildings are used mostly for tourism, and there are hotels with up to four floors and cabins, mostly built with bricks and mortar. There is no dock for the community to use. We interviewed 40 people here.

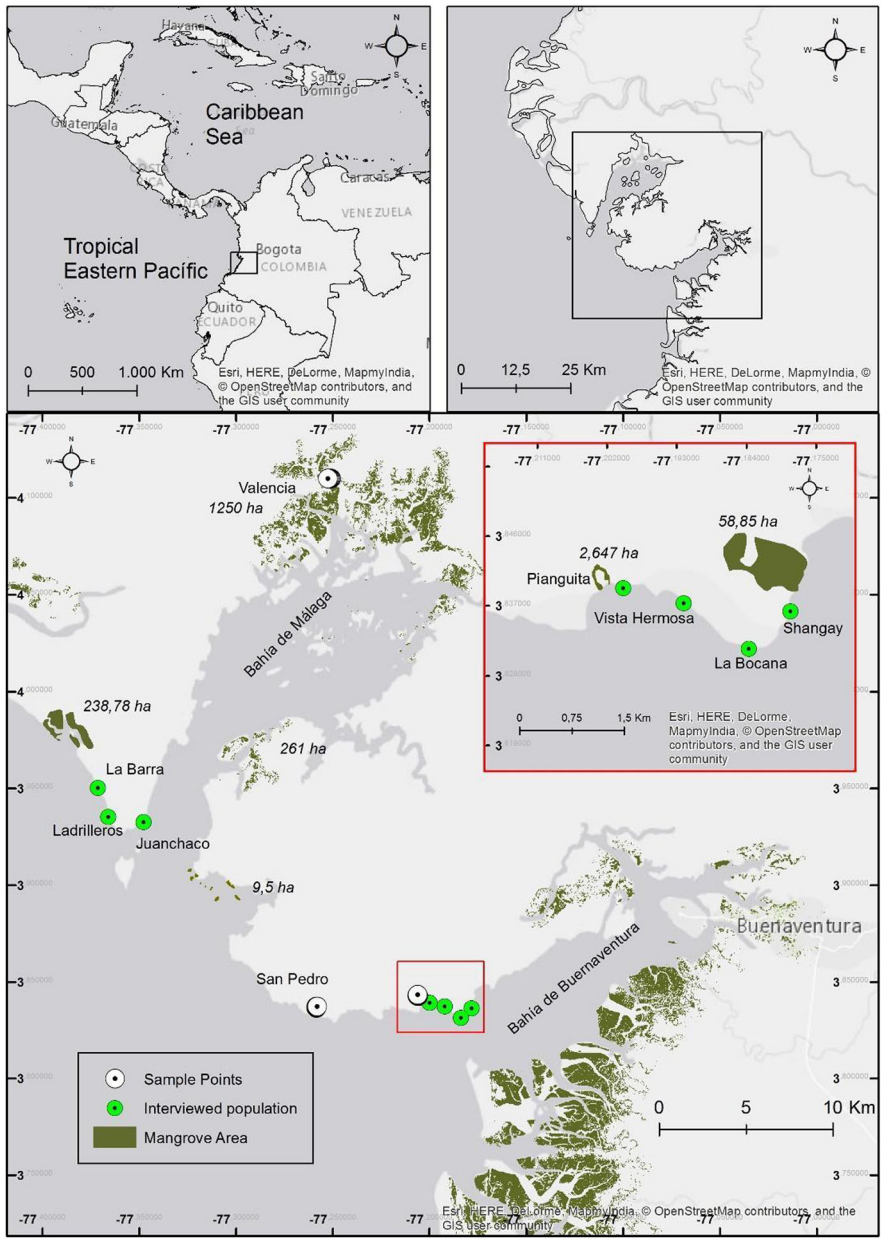

Fig. 1 Map of the study area on the Colombian Pacific. *Green dots* indicate human settlements where surveys took place. White dots indicate where mangrove forest structure was measured *Source* Mangrove cover Giri et al. (2011)

- *Vista Hermosa* This settlement comprises a group of 30 wooden houses along a beach, which lies between Piangüita and La Bocana. Most of the villagers cater to tourists. We interviewed 10 people here.
- *La Bocana* This settlement has buildings for residences, hotels, restaurants, and a variety of stores. Access to the settlement is by boat from Buenaventura City or Málaga Bay. There is a dock for the community to use. We interviewed 20 people here.
- *Changai* This settlement has approximately 160 families, with wooden houses mostly built on stilts (see Figure S1), with an average of five family members in each. These inhabitants are primarily fishermen and shellfish harvesters. We interviewed 30 people here.

Local use of mangroves

To obtain information on the use of mangroves by local communities, we interviewed households from Málaga and Buenaventura bays (Dahdouh-Guebas, et al., 2000; Satyanarayana, et al., 2013). A detailed list of questions posed to each person (head of household) interviewed is provided as On-line Supplementary Material. On each bay 100 interviews were conducted by the authors and a team of five college students, following the protocol of Martínez (2012); One adult person per household was interviewed to avoid repetition among family members. A local guide provided guidance and facilitated communications with respondents. Questions in the interview were intended to provide general information about local economic activities and different uses of mangrove resources. The questions sought to obtain information on how each inhabitant of a given community performs activities in and around the mangrove forests. The main topics covered in the interview included: (1) The socio-demographic and economic situation of the persons interviewed. (2) Their knowledge about mangroves and their main interaction with mangroves (e.g., as individual vegetation and as an ecosystem). (3) The use of mangrove vegetation as wood (for construction or fuel), food, medicine, or the manufacture of handicrafts, and (4) Their use of the mangrove ecosystem for the extraction of fishes, mollusks, and crustaceans.

The people who were interviewed were fishermen, national park officials, educational institutional employees, or members of the general public. Three population groups were identified: Indigenous (10%), afro-descendants (80%), and settlers (10%).

Local impact on mangroves

The anthropogenic impact on mangrove forest structure was assessed by conducting forest surveys on three sampling sites located within the study areas: Quebrada Valencia (Málaga Bay), San Pedro (midway between Málaga and Buenaventura bays), and Piangüita (Buenaventura Bay) (Fig. 1). The composition and structure of the forests were determined following the methods described by Cintrón & Schaeffer-Novelli (1984) and Kauffman & Donato (2012). Transects were established perpendicular to the coastline, on which circular plots with a radius of 7 m were established every 25 m along the transect (i.e., at 10, 35, 60, 85, 110, and 135 m from the coastline). Therefore, along each transect, eighteen plots were established (six locations with three plots each). According to their height, individual mangroves were classified as mature trees (>4 m), young trees (1–4 m), and seedlings (<1 m) (Ashton & Macintosh 2002). Mature trees were identified to species level, and values were expressed as density (number of trees/ha). The height of the trees (m) was measured using a clinometer and trigonometric calculations. The circumference was measured at the standard point for diameter at breast height (DBH, or 1.3 m), using a tape measure following the methods of English et al. (1997).

Results

Local use of mangroves

The local communities at Málaga and Buenaventura bays had different levels of knowledge in regard to the mangrove ecosystem. The first group of people, which we considered "experts," could identify mangrove species using morphological characteristics of the leaves, flowers, and embryos. These people had received training from environmental authorities within the area, having been part of non-governmental organizations (NGOs) or having served as local tour guides (Fig. 2). "Experts" in mangroves represented only 5% of the interviewees in Málaga Bay, but 30% of the interviewees in Buenaventura Bay.

The second group, which we considered as having "good knowledge" about the mangroves, could usually distinguish distinct types of mangroves based

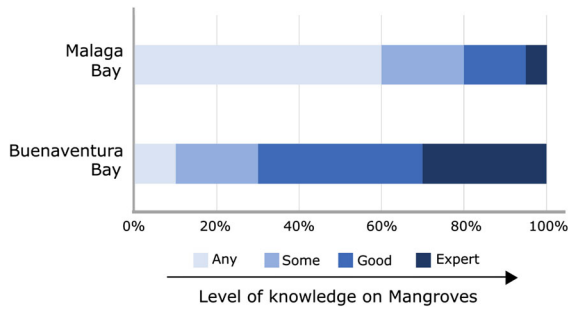

Fig. 2 Levels of knowledge about mangroves among the survey respondents

on the characteristics of the root system and the products they obtain from them. While locals with "good knowledge" represented 15% of the population sampled at Málaga Bay, they represented 40% of the sampled locals from Buenaventura Bay. Results from the interviews showed that most people with "good knowledge" of mangroves had gained empirical knowledge from their direct interactions and visits to the ecosystems. Most lived in the sector of Changai and are mainly bivalve harvesters and fishermen.

The third group, which we considered as having "some knowledge" about the mangroves, represented 20% of the population surveyed at Málaga and Buenaventura bays. These people had heard of the mangrove system, but could not distinguish among species. This group included people who occasionally visit the area, such as merchants, tourists, and technicians (e.g., electricians and systems engineers). Tourists who visit the beach for a few days typically have no knowledge of mangroves.

Use of mangroves

Local communities used mangroves for many purposes: for recreation, and to obtain fishing products, edible plants, and medicine. Different mangrove species are used as fuel wood and building materials (Table 1; Fig. 3).

Fish products The interviewed population recognized the importance of mangrove swamps as a breeding ground for fish species and other organisms

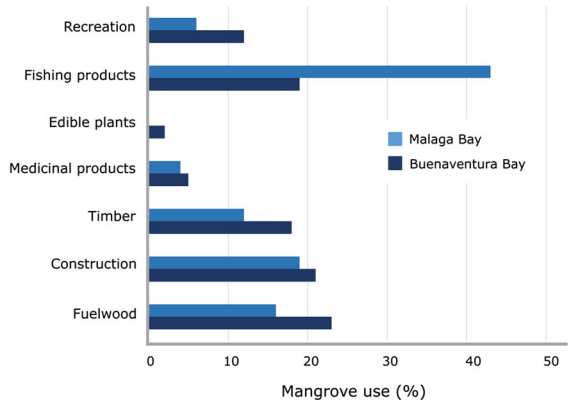

Fig. 3 Uses given to mangrove species found in the study area

of economic as well as subsistence importance to the inhabitants of the area (43% in Málaga Bay and 19% in Buenaventura Bay). This is interesting because the fisherman do not carry out their activity inside the mangrove forest; rather, the fishing takes place in the mouth of the river or in the coastal zone. Nevertheless, the association between mangrove forest area and fishing success was recognized among the interviewed population. In Changai, there is a group of at least 30 women whose economy depends directly on collection of bivalve mollusks. The species commonly collected include *Anadara tuberculosa* (Sowerby) and *Anadara similis* (Adams), which together are locally called "piangua." These species are collected in the soil under *Rhizophora* spp. roots (see Figure S2). Each woman collects

Table 1 Mangrove species wood use in the study area in Málaga and Buenaventura bays, Colombian Pacific

Species	Use	Part used
Mora oleifera (Triana ex Hemsl.) Ducke	Posts, beams, pilings to protect from erosion and tides, bridges and houses. Floors. Staircase steps	Trunk
Avicennia germinans (L.) Stearn	It is used as house columns, canoes, spikes, fences, baskets, tool handles. Fuelwood and charcoal, posts, piles, structural wood, furniture construction, tool handles, musical instruments, craft objects	Trunk
	The bark contains tannins that are used to tan skins	
	The infusion is used in cases of diarrhea, to heal wounds and to treat hemorrhoids.	
	The flowers are rich in nectar and honey, and of excellent quality	
Laguncularia racemosa (L.) C. F. Gaertn.	Its wood is used as firewood, in the construction and manufacture of furniture, house columns, canoes, spikes, fences, baskets, tool handles	Trunk
Rhizophora spp.	Charcoal, mangrove wood for construction, and fuel wood	Branches
	Constructions and rustic instruments, extraction of tannins, construction of fishing gear	
Pelliciera rhizophorae Triana & Planch	Wood used for pitchforks, sills, fence posts, and fuel wood	Trunk

between 20 and 30 dozen piangua per day, with an average size of 5 cm (Delgado et al., 2010a, b). Collections are made during low tide. Piangua are sold to an intermediary at $ 0.70 USD per dozen and the intermediary sells the product to restaurants in the area or in Buenaventura City at $ 5.30 USD a pound or $ 10 USD a dozen. In some households, mollusks or fish species without value in the market are consumed, such as the gastropod mollusk *Littoraria zebra* (Wood, 1828), which is commonly prepared with rice.

Edible plants there is no information on the existence of edible plants in the mangrove, either for Málaga or for Buenaventura Bays.

Medicinal uses It is not common to find medicinal uses of mangrove species. However, during the interviews, native Americans of the Waunan tribe in the Málaga Bay area reported that leaves of *Rhizophora* spp. were chewed before social celebrations to compensate for the consequences of alcohol consumption. In addition, an infusion of *Avicennia germinans* (L.) bark is used in cases of diarrhea and to heal wounds and hemorrhoids.

Wood Depending on the mangrove species, part of the mangrove plant is used to obtain building materials or fuel wood. The trunk is the most useful part of the mangrove tree, as it is used for construction or fuel. Mangrove wood harvesting activities occur in different parts of the forest. Harvesting depends on where the required species is located and on the size and availability of timber, rather than on accessibility. Harvesting usually occurs when planks or logs for different uses in the home are needed; harvest is not a recurring activity, nor is it seasonal. Harvesting activities vary according to the level of formality. A local level of formality in harvesting involves the interested party approaching a professional sawyer, who is authorized by the community council to carry out wood cutting activities in the forest. The sawyer cuts and piles trees and sells them to the person who requests them; this wood is sold unpolished. Otherwise, harvested wood must be taken to Buenaventura or purchased directly there, which adds value to the wood.

Wood for construction Wood is the main building material for the construction of stilt houses (also known as pile dwellings) (Figure S1). Since mangroves produce very hard and solid wood, the local community uses it to build the foundations, floor, walls, and roof of their houses. According to the surveys, *Rhizophora* spp. (red mangrove), *Laguncularia racemosa* (L.) C. F. Gaertn (white mangrove), *Avicennia germinans* (L.) (black mangrove), *Pelliciera rhizophorae* Planch. & Triana (piñuelo) and *Mora oleifera* (Triana ex Hemsl.) Ducke (nato) are the main species used for this purpose.

Ceiling beams of homes are built with mangrove wood (48% at Málaga Bay vs. 61% at Buenaventura Bay); the walls of dwellings of most people interviewed in Málaga Bay and in Buenaventura Bay were built with wood (40% Málaga Bay, 74% Buenaventura Bay). Concrete was also used in some instances, such as for hotel construction, where better foundations are required. In most cases, houses built on stilts (9% in Málaga Bay, 30% in Buenaventura Bay) and floors are made of wood (38% Málaga Bay, 56% Buenaventura Bay), whereas taller dwellings and hotels had floors covered in concrete or ceramic tiles (Fig. 4).

The construction of stilt houses, which are found mainly in Changai, requires the use of wood posts and planks. A standard house requires ≥16 posts of *Mora oleifera* (Triana ex Hemsl.) Ducke, each >6 m long. Each post costs $ 5 USD. The posts are buried approximately 1.5 m deep in the mud, with >6 m above ground, due to the high tide. The floor of the house is built on top of these posts using wooden planks. Each plank is about 25×400 cm long and costs $ 5 USD. When buying a dozen, each unit costs $ 3 USD. At least 36 planks are needed to build a room. Taking into account that a standard stilt house requires 16 posts of *Mora oleifera* (Triana ex Hemsl.) Ducke at the base, and that in the town of Changai there are about 160 houses, we can estimate that in this sector, at least 2560 trees have been logged to support this unique activity.

Wood for fuel The direct use of *Rhizophora* spp. was recorded as fuel wood for cooking in places where there is no electric energy or where people do not have the money to pay for energy or gas. The average monthly payment for energy consumption in a dwelling where approximately five persons live is about $10 USD. The species of mangrove most used as fuelwood are from the taxonomic genus *Rhizophora*, with 62% of the users in Málaga Bay and 45% of the users in Buenaventura Bay, followed by *Laguncularia racemosa* (23% in Málaga Bay and 33% in Buenaventura Bay; Fig. 4). A low proportion

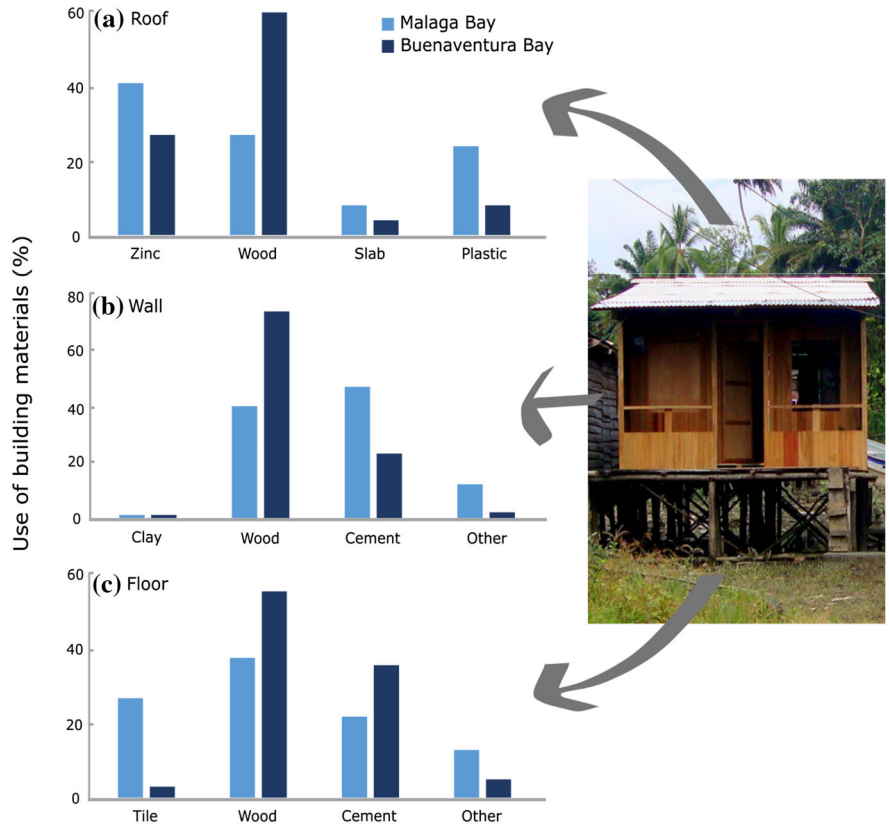

Fig. 4 The relative use of mangrove wood as a building material among survey respondents

of the population used *Avicennia germinans*(L.) (15% Málaga Bay and 22% in Buenaventura Bay). No monetary value was registered for purchase or sale of this wood, as it is taken directly from the mangrove forest (Fig. 5).

Local impact on mangrove forests

The composition and structure of mangrove forest were analyzed at three sites. The species present in the sampling sites were *Rhizophora* spp., *Pelliciera rhizophorae* Planch. & Triana, and *Mora oleifera* (Triana ex Hemsl.) Ducke. The most common and important species were *Rhizophora* spp. (including *R. mangle* and *R. racemosa*, which are very difficult to distinguish from each other during field surveys) (Table 2). The density of mangrove trees in Quebrada Valencia was 28,000 ± 413 (mean ± standard deviation) individuals/ha; in San Pedro, it was 15,400 ± 1335 ind/ha, and in Piangüita was

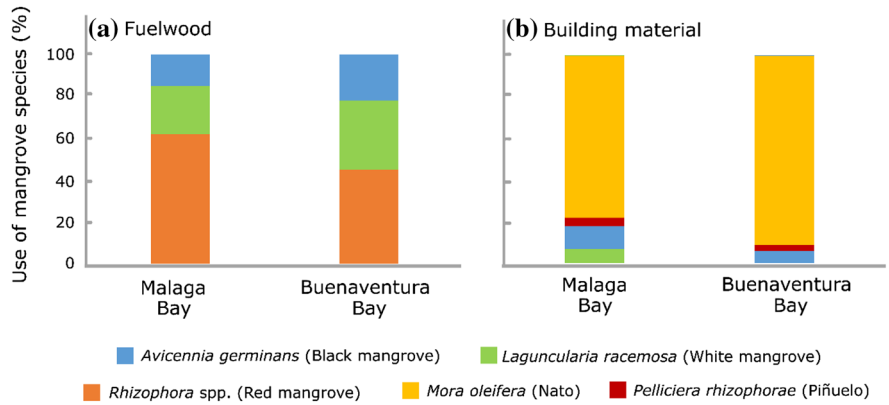

Fig. 5 Proportion of mangrove species use as fuel wood and construction material in Málaga and Buenaventura bays

Table 2 Importance Value Index (I.V.I) corresponding to plant species of Quebrada Valencia, Piangüita y San Pedro, Colombian Pacific

Species	Quebrada valencia	San Pedro	Piangüita
Mora oleifera	32.68	0	36.30
Pelliciera rhizophorae	0	76.00	58.00
Rhizophora spp.	168.32	125.04	106.76

8100 ± 3,110 ind/ha (Fig. 6), with this result attributed to forest maturity. The main height of the canopy (5.9 ± 2.6 to 17.5 ± 1.1 m) and the basal area (2.03 ± 2.6 to 1082.80 m^2/ha) were higher in Quebrada Valencia, followed by San Pedro, and then Piangüita (Table 3), indicating that the trees of Quebrada Valencia riverine forest are mature.

The total number of seedlings and juveniles up to 4 m is shown in Fig. 6. In Quebrada Valencia, there were 10,400 ± 2.2 ind/ha, followed by San Pedro with 4,700 ± 932.6 ind/ha, and Piangüita with 4,100 ± 717 ind/ha.

Discussion

This study documents the importance of mangrove resources for local communities of the Colombian Pacific coast. Surveys were conducted to ascertain mangrove knowledge and local dependence on mangrove wood for subsistence, including household needs, fuel wood, and income. These findings contribute to a greater global appreciation for identifying what mangrove forests provide to people. Indeed, the importance of the mangroves as an ecosystem service has been reported worldwide (Dahdouh-Guebas & Koedam, 2006; FAO, 2007; Nagelkerken et al., 2008; Walters et al., 2008).

The difference in knowledge about mangroves among the respondents is very clear. The two populations have a rather different pattern of knowledge: in Málaga Bay, the majority of the respondents do not know about mangroves, since very few people visit the ecosystem; their relationship is based on fishery products obtained indirectly from this ecosystem. In Buenaventura Bay, most respondents have a good or excellent knowledge about the mangrove. Here, we found more people who work as ecotourism guides in the mangrove area, or who use mangrove wood directly or collect shellfish.

In the study area, the collection of mangrove resources differs between men and women. Women and children mostly devote their time to bivalve harvesting, especially *Anadara tuberculosa* (Sowerby), *Anadara similis* (Adams), and in some cases *Grandiarca grandis* (Broderip & Sowerby, 1829) and *Striostrea prismatica* (Gray, 1825). Not many studies have focused on these gender divisions in mangrove resource exploitation, with some exceptions in fishery related activities (Howard, 2003;

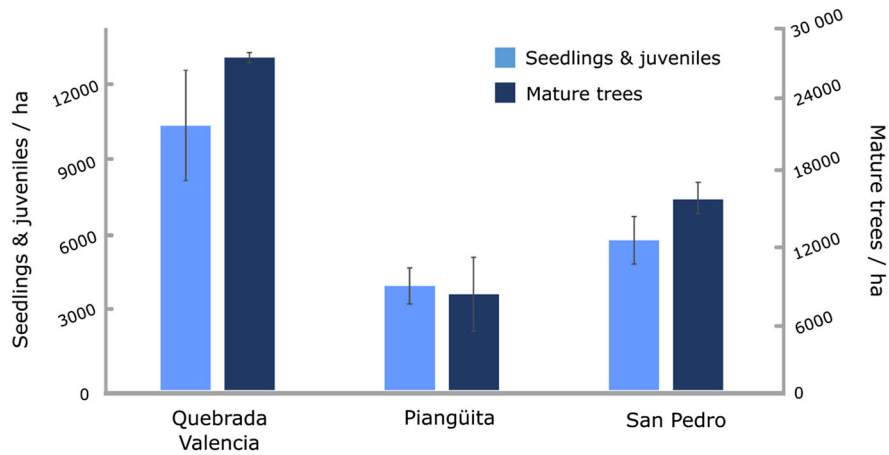

Fig. 6 Total mangrove density in three sites of the Colombian Pacific coastal zone

Table 3 Average and standard deviation for density (Ind/ha), height (m), and basal area (m^2/ha) of the mangrove trees in three sites of Colombian Pacific coastal zone

Sample site/species	Density (Ind/ha) Total species	Height (m)	Basal Area (m^2/ha)
Quebrada Valencia			
Rhizophora spp.	28000 ± 414	11.3 ± 8.9	235.1 ± 24.8
Mora oleifera		17.3 ± 8.5	1082.8 ± 38.9
San Pedro			
Rhizophora spp.	15400 ± 1335	17.5 ± 1.1	28.1 ± 76.8
Pelliciera rhizophorae		6.1 ± 3.8	93.6 ± 4.1
Piangüita			
Rhizophora spp.	8100 ± 3110	6.8 ± 5.1	6.0 ± 6.0
Mora oleifera		6.8 ± 3.6	2.0 ± 2.6
Pelliciera rhizophorae		5.9 ± 2.6	3.25 ± 55.6

Magalhães et al., 2007). This also was observed by Feka et al. (2011), where women, harvest small mangrove tress near their homes and men, whose harvesting practices are less frequent, practice small scale, selective harvesting of larger trees. In this study, men are usually involved in fishing activities; women play an important role in subsistence collection of mollusks and food preparation. Of the 100 people interviewed in Buenaventura Bay, 30 women are mainly involved in activities related to mollusk collection, while men are engaged in collecting timber or fishing.

Mangrove wood

Among coastal communities globally, fuel wood is one of the major extractable uses of mangroves (Dahdouh-Guebas et al., 2000; Glaser, 2003; Walters, 2005; Lopez-Hoffman et al., 2006; Rönnbäck et al., 2007; Walters et al., 2008), but this use is also a major threat along with timber for the mangroves in Asia and Africa (Hernández-Cornejo et al., 2005). In the Philippines, it is common to make charcoal or to use mangrove wood as fuel (Walters, 2006; Walters et al., 2008). In the Colombian Pacific, local users also use mangrove wood to make charcoal. The consequences of the use of wood as fuel and for the construction of pile dwellings in the study area should be analyzed to establish appropriate conservation policies, and to identify the main affected mangrove species. The use of wood in the study area resulted in selective cutting of mangrove trees, especially *Rhizophora* spp., *Laguncularia racemosa* (L.) C. F. Gaertn and *Avicennia germinans* (L.), which are used primarily as fuel wood. *Mora oleifera* (Triana ex Hemsl.) Ducke is used in greater proportion in the construction of houses and as posts for basement construction and for area-specific erosion control.

The mangrove forest of Málaga and Buenaventura bays have low structural development compared with other mangrove forest on the Colombian Pacific coast in terms of height and basal area (Sánchez-Páez & Álvarez-León, 1997; Peña–Salamanca et al., 2014). These data suggest the influence of selective mangrove cutting for construction and timber resources near local settlements. Measurements of basal area and mean height of all mangrove individuals indicated the possible influence of anthropogenic effects, mainly due to selected extraction of mature individuals, which have better wood. Similar patterns have been shown in Brazilian mangroves (Calegario et al., 2015). The most abundant tree in the study area was *Rhizophora spp*. (red mangrove), followed by *Pelliciera rhizophorae* (piñuelo) and *Mora oleifera* (Triana ex Hemsl.) Ducke (nato). At present, *Rhizophora* spp. is strongly dominant. This study did not record the presence of *Laguncularia racemosa* (L.) C. F. Gaertn or *Avicennia germinans* (L.). The number of adult individuals and seedlings of *Pelliciera rhizophorae* Planch. & Triana and *Mora oleifera* (Triana ex Hemsl.) Ducke in the three localities is low, and for *Mora oleifera* (Triana ex Hemsl.) Ducke only a few of the oldest trees survive, indicating a low regeneration rate of the forest. The structural properties of this mangrove forest imply that there has been over-exploitation of *Mora oleifera* (Triana ex Hemsl.) Ducke, which is the main wood resource in the study area.

The higher proportion of seedlings and juveniles also indicates higher growth rate of the seedlings.

Gan (1995) recommends a density of 5000–10,000 seedlings per hectare to ensure good regeneration potential for logged areas, while Srivastava & Bal (1984) indicate a minimum of 2500 seedlings per hectare to ensure natural regeneration. In this case, the natural regeneration potential of mangroves is low in San Pedro (4700 seedlings/ha) and Piangüita (4100 seedlings/ha), indicating that harvesting pressures might not be sustainable in the long term.

Edible and medicinal mangrove plants

Wild food plants are used by agricultural societies because of their rich contribution to culinary and cultural diversity as well as for food security and nutrition (Cotton, 1996; Price, 2003). In the study area, *Rhizophora* spp. leaves are used to avoid hangovers after excessive alcohol consumption. An infusion of *Avicennia* leaves is used as medicine in cases of diarrhea, as well as to heal wounds and hemorrhoids. Flowers of this species are also used for honey and nectar extraction, although local communities consider it bitter to the taste.

Mangrove fishery resources

Mangrove ecosystems have proven to be important as food and shelter for several finfish and shellfish communities (Adeel & Pomeroy, 2001; Primavera et al., 2004; Crona & Rönnbäck, 2005; Dahdouh-Guebas et al., 2006; Dahdouh-Guebas & Koedam 2008, Walters et al., 2008; Cannicci et al., 2008; Mwandya et al., 2009). In the Colombian Pacific, fishermen sell the products to restaurants directly or to intermediaries who transport the products to Buenaventura and other cities.

Mangrove conservation and management

The lack of accurate information on the part of environmental managers and policymakers, coupled with the fact that these environments have been classified often as uncultivated land, explains the poor management of mangroves in many developing countries (Sánchez-Páez et al., 2000; Adeel & Pomeroy, 2001; Gammage et al., 2002; Lynagh & Urich, 2002; Sánchez-Páez et al., 2004). In Colombia, national and regional environmental authorities are responsible for forest protection and management. Artisanal uses and community-based use of mangrove resources are permitted, such as the integrated management Bazan—Bocana District, which includes the natural protected areas in which exploitation by ethnic populations is permitted. This is an example in which local communities are involved in environmental planning and programs of mangrove conservation and management.

In Colombia, there have been many projects for mangrove conservation (MMA, 2002; Álvarez-León, 2003; Flórez & Etter, 2003), but there is evidence of some loss caused by different human activities along the Pacific coastline. The decrease of mangrove cover causes a variety of problems, ranging from environmental degradation and loss of diversity, to the breakdown of socio-economic systems. Pressure on coastal areas can exceed the carrying capacity of these areas and cause resource and environmental quality degradation (Valiela et al., 2001; Barbier & Cox, 2003; Polidoro et al., 2010).

Conclusions

The results of this study show that the main uses of mangroves in the study area are fuel wood, construction, and fishery products. Of these three categories of use, the local population depends on fishing resources (30%), use of wood for fuel (15–21%) and for construction (42–75%). These data indicate that these mangrove uses are mainly determined by the economic situation of the local communities. Local communities also use the mangrove creeks as fishing areas.

Mangrove management strategies in the Colombian Pacific area must be applied with adequate scientific management. Considering the importance of mangrove resources for the livelihoods of local peoples, it is necessary to prioritize participatory approaches with local communities in a planning, decision making and implementation of forestry activities. It is necessary to provide alternatives to the use of mangrove species as fuel wood and the construction of dwellings, which will permit both the conservation of mangrove forests and the subsistence of populations.

Acknowledgements This study was supported by a grant from COLCIENCIAS (Code 1106-659-44115) in call 659 of 2014 "Análisis de la dinámica trófica en dos manglares del Pacífico colombiano mediante el uso integrado de isótopos estables y modelación ecosistémica,". We thank the Universidad Autónoma de Occidente and the Universidad del Valle for their financial and logistical support during the study, the local communities of Málaga and Buenaventura Bays for their participation in the interviews, and the community leaders for their help during the fieldwork in the mangrove forest, especially the women "Piangueras" for sharing such a valuable experience. We thank Juan C. Mejia for his help with cartography and Enrique J. Peña and Maria del Mar Palacios for their insightful comments on earlier versions of this manuscript. This study was presented at the 2016 Mangrove and Macrobenthos Meeting (MMM4), Saint Augustine, Florida, U.S.A.

References

Adeel, Z. & R. Pomeroy, 2001. Assessment and management of mangrove ecosystems in developing countries. Trees 16: 235–238.

Alongi, D. M., 2002. Present state and future of the world's mangrove forests. Environmental Conservation 29: 331–349.

Álvarez-León, R., 2003. Los manglares de Colombia y la recuperación de sus áreas degradadas: revisión bibliográfica y nuevas experiencias. Madera y Bosques 9(1): 3–25.

Ashton E. C. & Macintosh D. J. 2002. Preliminary assessment of the plant biodiversity and community ecology of the Sematan mangrove forest, Sarawak, Malaysia. Forest Ecology and Management 166: 111–129.

Barbier, E. B. & M. Cox, 2003. Does economic development lead to mangrove loss? A cross-country analysis. Contemporary Economic Policy 21(4): 418–432.

Barbier, E. B., S. D. Hacker, C. Kennedy, E. W. Koch, A. C. Stier & B. R. Silliman, 2011. The value of estuarine and coastal ecosystem services. Ecological Monographs 81(2): 169–193.

Blanco, J. F., 2009. Banana crop expansion and increased river-borne sediment exports to the Gulf of Urabá, Caribbean Coast of Colombia. AMBIO: A Journal of the Human Environment 38: 181–183.

Bosire, J. O., F. Dahdouh-Guebas, M. Walton, B. I. Crona, R. R. Lewis III, C. Field, J. G. Kairo & N. Koedam, 2008. Functionality of restored mangroves: a review. Aquatic Botany 89(2): 251–259.

Calegario, G., M. S. Salomao, M. B. Rezende & C. E. Bernini, 2015. Mangrove forest structure in the São João River Estuary, Rio de Janeiro, Brazil. Journal of Coastal Research 31(3): 653–660.

Cannicci, S., D. Burrows, S. Fratini, T. J. Smith III, J. Offenberg & F. Dahdouh-Guebas, 2008. Faunistic impact on vegetation structure and ecosystem function in mangrove forests: a review. Aquatic Botany 89: 186–200.

Cantera, J. R. & J. F. Blanco, 2001. The estuary ecosystem of Buenaventura Bay, Colombia. In Seeliger, U. & B. Kjerfve (eds), Coastal Marine Ecosystems of Latin America, Ecological studies. Springer, New York: 265–280.

Cantera, J. R., E. Londoño-Cruz, L. M. Mejía-Ladino, L. Herrera-Orozco, C. A. Satizabal & N. Uribe-Castañeda, 2013. Environmental issues of a marine protected area in a tectonic Estuary in the Tropical Eastern Pacific: Uramba (Málaga Bay Colombia): context, biodiversity, threats and challenges. Journal of Water Resource and Protection 5: 1037–1047.

Cintrón, G. & Y. Schaeffer-Novelli, 1984. Methods for studying mangrove structure. In Snedaker, S. C. & J. G. Snedaker (eds), The mangrove ecosystem: research methods On behalf of the UNESCO/SCOR working group 60 on mangrove ecology. United Nations Educational and Cultural Organization, Bungay: 251.

Corporación Autónoma Regional del Valle del Cauca (CVC). 2007. http://www.avancejuridico.com/actualidad/documentosoficiales/2007/46652/a_cvc_0015_2007.html.

Cotton, C. M., 1996. Ethnobotany: Principles and Applications. Wiley, Singapore.

Crona, B. I. & P. Rönnbäck, 2005. Use of replanted mangroves as nursery grounds by shrimp communities in Gazi Bay, Kenya. Estuarine, Coastal and Shelf Science 65: 535–544.

Dahdouh-Guebas, F. & N. Koedam, 2006. Coastal vegetation and the Asian Tsunami. Science 311: 37–38.

Dahdouh-Guebas, F. & N. Koedam, 2008. Long-term retrospection on mangrove development using transdisciplinary approaches: a review. Aquatic Botany 89: 80–92.

Dahdouh-Guebas, F., C. Mathenge, J. G. Kairo & N. Koedam, 2000. Utilization of mangrove wood products around Mida Creek (Kenya) amongst subsistence and commercial users. Economic Botany 54: 513–527.

Dahdouh-Guebas, F., S. Collin, D. Lo Seen, P. Rönnbäck, D. Depommier, T. Ravishankar & N. Koedam, 2006. Analysing ethnobotanical and fishery-related importance of mangroves of East-Godavari Delta (Andhra Pradesh, India) for conservation and management purposes. Journal of Ethnobiology and Ethnomedicine 2: 24.

Delgado, M. F., W. Gualteros, S. Espinosa, C. Lucero, A. M. Roldan, L. A. Zapata, J. R. Cantera, C. Candelo, C. Palacio, O. Muñoz, G. Mayor & D. L. GilAgudelo, 2010a. Potencial productivo de las poblaciones naturales de la piangua *Anadara tuberculosa* y *Anadara similis* dentro de una perspectiva espacio-temporal en la costa Pacífica colombiana-Informe Final. INVEMAR, ASCONAR, WWF Colombia, Universidad del Valle, UAESPNN – PNN Sanquianga; Co-financiado por el Ministerio de Agricultura, Cali: 20.

Delgado, M. F., W. Gualeter, S. Espinosa, C. Lucero, M. Cortes, A. M. Roldan, L. A. Zapata, J. R. Cantera, C. Candelo, C. Candelo, O. Muñoz, G. Mayor & D. L. Gil-Agudelo, 2010b. Pianguando- Estrategias para el manejo de la piangua" (cartilla). INVEMAR, ASCONAR, WWF Colombia. Universidad del Valle, UAESPNN-PNN Sanquianga; Co-financiado por el Ministerio de Agricultura. Serie de publicaciones generales INVEMAR N°.45, Cali.

Duke, N., S. Meynecke, J. Dittmann, M. Ellison, K. Anger, U. Berger, S. Cannicci, E. Diele, C. Fierd, N. Koedam, S. Lee, C. Marchand, I. Nordhaus & F. Dahdouh-Guebas, 2007. A world without mangroves? Science 317: 41–42.

English, S., C. Wilkinson & V. Baker, 1997. Survey Manual for Tropical Marine Resources, 2nd ed. Australian Institute of Marine Science, Townsville.

Feka, N. Z., M. G. Manzano & F. Dahdouh-Guebas, 2011. The effects of different gender harvesting practices on mangrove ecology and conservation in Cameroon. International Journal of Biodiversity Science, Ecosystem Services & Management 7(2): 108–121.

Field, C. D., 1998. Rehabilitation of mangrove ecosystems: an overview. Marine Pollution Bulletin 37: 383–392.

Flórez, A. & A. Etter, 2003. Caracterización ecológica de las islas Múcura y Tintipán, archipiélago de San Bernardo, Colombia. Revista de la Academia Colombiana de Ciencias 27(104): 343–356.

Flórez-González, L., I. C. Ávila, J. Capella, P. Falk, F. Félix, J. Gibbons, H. Guzmán, B. Haase, J. Herrera, V. Peña, L. Santillán, I. C. Tobón & K. Van Warebeek, 2007. Estrategia para la conservación de la ballena jorobada del Pacífico Sudeste. Lineamientos de un plan de acción regional e iniciativas nacionales. Fundación Yubarta, Cali: 106.

Food and Agriculture Organization, FAO, 2007. Evaluación de los recursos forestales mundiales 2005. Estudio temático sobre manglares, Colombia: 14.

Gammage, S., M. Benítez & M. Machado, 2002. An Entitlement approach to the challenges of mangrove management in El Salvador. Ambio 31(4): 285–294.

Gan, B. K., 1995. A Working Plan for the Matang Mangrove Forest Reserve (fourth revision). Published by the State Forest Department of Perak Darul Ridzuan, Malaysia: 214.

Giri, C., Ochieng, E., Tieszen, L. L., Zhu, Z., Singh, A., Loveland, T., Masek, J., & Duke, N., 2011. Status and distribution of mangrove forests of the world using earth observation satellite data (version 1.3, updated by UNEPWCMC). Global Ecology and Biogeography 20(1): 154–159. doi:10.1111/j.1466-8238.2010.00584.x.

Glaser, M., 2003. Interrelations between mangrove ecosystem, local economy and social sustainability in Caeté Estuary, North Brazil. Wetlands Ecology and Management 11: 265–272.

Hernández-Cornejo, R., N. Koedam, A. Ruiz-Luna, M. Troell & F. Dahdouh-Guebas, 2005. Remote sensing and ethnobotanical assessment of the mangrove forest changes in the Navachiste-San Ignacio-Macapule lagoon complex, Sinaloa, Mexico. Ecology and Society 10(1): 16.

Hogarth, P. J., 1999. The Biology of Mangroves. Oxford University Press, Oxford: 228.

Howard, P. L. (ed.), 2003. Women and Plants: Gender Relations in Biodiversity Management and Conservation. Zed books, London: 298.

Instituto Nacional de los Recursos Naturales Renovables (INDERENA). 1991. Diagnostico exploratorio de los manglares en Colombia. Instituto Nacional de los Recurso Naturales Renovables y del Ambiente/Subgerencia de Bosques y Aguas. Santa Fe de Bogotá D.C. Informe. Técnico: 1–43.

Kauffman, J. B. & D. C. Donato. 2012. Protocols for the Measurement, Monitoring and Reporting of Structure, Biomass and Carbon Stocks in Mangrove Forests. Working Paper 86 CIFOR, Bogor, Indonesia.

Kathiresan, K. & B. L. Bingham, 2001. Biology of mangroves and mangrove ecosystems. Advances in Marine Biology 40: 81–251.

Krauss, K. W., C. E. Lovelock, K. McKee, L. López-Hoffman, S. M. L. Ewe & W. P. Sousa, 2008. Environmental drivers in mangrove establishment and early development: a review. Aquatic Botany 89: 105–127.

Krumholz, J. & C. Jadot, 2009. Demonstration of a new technology for restoration of red mangrove (*Rhizophora mangle*) in high-energy environments. Marine Technology Society Journal 43(1): 64–72.

López-Angarita, J., R. Callum, M. Tilley, A. Hawkins, J. Cooke & G. Richard, 2016. Review and synthesis: mangroves and people: Lessons from a history of use and abuse in four Latin American countries. Forest Ecology and Management 368: 151–162.

Lopez-Hoffman, L., I. E. Monroe, E. Narvaez, M. Martinez-Ramos & D. D. Ackerly, 2006. Sustainability of mangrove harvesting: how do harvesters' perceptions differ from ecological analysis? Ecology and Society 11(2): 14.

Lynagh, F. M. & P. B. Urich, 2002. A critical review of buffer zone theory and practice: a Philippine case study. Society and Natural Resources 15: 129–145.

Magalhães, A., R. M. da Costa, R. da Silva & L. C. C. Pereira, 2007. The role of women in the mangrove crab (*Ucides cordatus*, Ocypodidae) production process in North Brazil (Amazon region, Pará). Ecological Economics 61: 559–565.

Martínez-Bencardino, C., 2012. Estadística y muestreo, 13a ed. Ecoe Ediciones, Bogotá: 900.

Melana, D. M., J. Atchue III, C. E. Yao, R. Edwards, E. E. Melana & H. I. Gonzales, 2000. Mangrove Management Handbook. Through the Coastal Resource Management Project, Cebu City, Phillipines. Department of Environment and Natural Resources, Manila: 96.

Ministerio del Medio Ambiente (MMA). 2002. Uso sostenible, Manejo y Conservación de los Ecosistemas de Manglar en Colombia. Programa Nacional. Dirección General de Ecosistemas—Ministerio del Medio Ambiente. Bogotá, pp 59.

Mwandya, A. W., M. Gullström, M. C. Öhman, M. H. Andersson & Y. Mgaya, 2009. Fish assemblages in Tanzanian mangrove creek systems influenced by solar salt farm constructions. Estuarine Coastal and Shelf Science 82: 193–200.

Nagelkerken, I., S. J. M. Blaber, S. Bouillon, P. Green, M. Haywood, L. G. Kirton, J. O. Meynecke, J. Pawlik, H. Penrose, M. Sasekumar & P. J. Somerfield, 2008. The habitat function of mangroves for terrestrial and marine fauna: a review. Aquatic Botany 89: 155–185.

Peña–Salamanca, E. J., J. R. Cantera-Kintz & P. A. Silverstone-Sopkin, 2014. Mangrove forest of the Pacific coast of Colombia. Páginas 12–20 en. In Cornejo, X. (ed.), Plants of the South American Pacific Mangrove swamps. Publicaciones del Herbario GUAY, Facultad de Ciencias Naturales de la Universidad de Guayaquil, Guayaquil.

Pérez, C. 2016. Buenaventura, Cartagena, Santa Marta y Barranquilla, los puertos claves del comercio exterior colombiano. http://revistadelogistica.com/actualidad/buenaventura-cartagena-santa-marta-y-barranquilla-los-puertos-claves-del-comercio-exterior-colombiano/.

Polidoro, B. A., K. E. Carpenter, L. Collins, N. C. Duke, A. M. Ellison, J. C. Ellison, E. J. Farnsworth, E. S. Fernando, K. Kathiresan, N. E. Koedam, S. R. Livingstone, T. Miyagi, G. E. Moore, V. N. Nam, J. E. Ong, J. H. Primavera, S. G. Salmo III, J. C. Sanciangco, S. Sukardjo, Y. Wang & J. W. Hong-Yong, 2010. The loss of species: mangrove extinction risk and geographic areas of global concern. PLoS ONE 5(4): 1–10.

Price, L. L., 2003. Farm women's rights and roles in wild plant food gathering and management in Northeast Thailand. In Howard, P. L. (ed.), Women and Plants: Gender Relations in Biodiversity Management and Conservation. Zed books, London: 101–114.

Primavera, J. H., R. B. Sadaba, M. J. H. L. Lebata & J. P. Altamirano, 2004. Handbook of Mangroves in the Philippines—Panay. SEAFDEC Aquaculture Department, Iloilo: 106.

Rönnbäck, P., B. Crona & L. Ingwall, 2007. The return of ecosystem goods and services in replanted mangrove forests—perspectives from local communities in Gazi Bay, Kenya. Environmental Conservation 34: 313–324.

Saenger, P., 2002. Mangrove ecology, silviculture and conservation. Kluwer Academic publishers, The Netherlands: 360.

Sánchez-Páez, H. & R. Álvarez-León, 1997. Diagnóstico y zonificación preliminar de los manglares del Pacífico colombiano. Ministerio del Medio Ambiente-OIMT, Santa Fé de Bogotá: 343.

Sánchez-Páez, H., R. Álvarez-León, O. A. Guevara-Mancera & G. A. Ulloa-Delgado, 2000. Lineamientos estratégicos para la conservación y uso sostenible de los manglares de Colombia. Ministerio del medio ambiente, ACOFORE, OIMT, Bogotá. D.C: 290.

Sánchez-Páez, H., G. Ulloa-Delgado & H. Tavera-Escobar, 2004. Manejo integral de los mangles por comunidades locales Caribe de Colombia Ministerio de Ambiente Vivienda y Desarrollo Territorial, Corporación Nacional de Investigación y Fomento Forestal-CONIF, Organización Internacional de Maderas Tropicales-OIMT. Proyecto Manejo Sostenible y Restauración por las Comunidades Locales del Caribe de Colombia, Bogotá: 335 pp.

Satyanarayana, B., S. Mulder, L. P. Jayatissa & F. Dahdouh-Guebas, 2013. Are the mangroves in the Galle-Unawatuna area (Sri Lanka) at risk? A social-ecological approach involving local stakeholders for a better conservation policy. Ocean & Coastal Management 71: 225–237.

Spalding, M. D. 1998. Patterns of biodiversity in coral reefs and mangroves: global and local scales. PhD thesis, University of Cambridge.

Spalding, M. D., H. E. Fox, G. R. Allen, N. Davidson, Z. A. Ferdana, M. Finlayson, B. S. Halpern, M. A. Jorge, A. L. Lombana, S. A. Lourie, K. Martin, E. McManus, J. Molnar, C. A. Recchia & J. Robertson, 2007. Marine ecoregions of the world: a bioregionalization of coastal and shelf areas. Bioscience 57: 573–583.

Spalding, M. D., M. Kainuma & L. Collins, 2010. World Atlas of Mangroves. Earthscan, London.

Srivastava, P. B. L. & H. S. Bal, 1984. Composition and distribution pattern of natural regeneration after second thinning in Matang mangrove reserve, Perak Malaysia. In: Soepadimo, E., A. N Rao, D. J. Macintosh, (eds), Proceedings of the Asian Symposium on Mangrove Environment: Research Managements, Kuala Lumpar, Malaysia, pp 761–784.

Ulloa, G., H. Sánchez-Páez, W. Gil-T, J. C. Rengifo, H. Rodríguez & R. Álvarez León, 1998. Conservación y uso sostenible de los manglares del Caribe colombiano. Ministerio del Medio Ambiente, ACOFORE, OIMT, Bogotá D.C: 224.

Valiela, I. & J. L. Bowen Yor, 2001. Mangrove forests: one of the world's threatened major tropical environments. Bioscience 51: 807–815.

Valle, A. G., A. M. Osorno & D. L. Gil, 2011. Estructura y regeneración del bosque de manglar de la Ciénaga de Cholón, Isla Barú, Parque Nacional Natural Corales del Rosario y San Bernardo, Caribe colombiano. Boletín de Investigaciones Marinas y Costeras 40(1): 115–130.

von Prahl, H., 1989. Manglares de Colombia. Villegas Editores, Bogotá: 205.

Walters, B. B., 2005. Patterns of local wood use and cutting of Philippine mangrove forests. Economic Botany 59: 66–76.

Walters, B. B., 2006. Mangrove forests and environmental security. In Innes, J. I., I. K. Edwards & D. J. Wilford. (eds), Forests in the balance: linking tradition and technology. Abstracts, XXII IUFRO World Congress, Brisbane, Australia, August 8–13, 2005. International Union for forest organizational Research. 7(5): 290.

Walters, B. B., P. Ronnback, J. M. Kovacs, B. Crona, S. A. Hussain, R. Badola, J. H. Primavera, E. Barbier & F. Dahdouh-Guebas, 2008. Ethnobiology, socio-economics and management of mangrove forests: a review. Aquatic Botany 89: 220–236.

Worm, B., E. B. Barbier, N. Beaumont, J. E. Duffy, C. Folke, B. S. Halpern, J. B. C. Jackson, H. K. Lotze, F. Micheli, S. R. Palumbi, E. Sala, K. A. Selkoe, J. J. Stachowicz & R. Watson, 2006. Impacts of biodiversity loss on ocean ecosystem services. Science 314: 787–790.

Wood, W., 1828. Index testaceologicus, or a catalogue of shells, British and foreign, arranged according to the Linnean system: with the Latin and English names, references to authors, and places where found: illustrated with 2300 figures.