Marine Pollution Bulletin 109 (2016) 691–699

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Virtual increase or latent loss? A reassessment of mangrove populations and their conservation in Guangdong, southern China

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ARTICLE INFO

Article history:
Received 27 December 2015
Received in revised form 7 June 2016
Accepted 22 June 2016
Available online 29 June 2016

Keywords:
Mangrove
Guangdong China
Habitat degradation
Species loss
Introduced species
Regional extinction

ABSTRACT

Contrary to the global trend, the area of mangrove in Guangdong Province, southern China, has been increasing over the last two decades. Currently, three exotic mangrove species have been introduced for large-scale afforestation since 1985. A reassessment of the overall status of the mangrove species, habitat change, population of introduced species, was conducted through a comprehensive literature review as well as field investigations covering 96 sites. The success of conservation efforts is also evaluated. Upstream and high intertidal habitats are more vulnerable than downstream and lower intertidal ones, with habitat alteration being the biggest threats. Five mangrove species have narrow distributional extents with small populations, which could incur regional extinction. With the introduced species having naturalized at 42 sites, their role in mangrove management needs to be reconsidered. These findings collectively suggest a need to manage latent species loss and habitat degradation beyond the apparent increase in mangrove area and protection.

1. Introduction

In the last two decades, mangroves, a globally important ecological habitat (Duke et al., 2007; McLeod et al., 2011; Duarte et al., 2013), have suffered degradation and annual loss of between 0.16 and 0.39% due to rapid coastal development (Hamilton and Casey, 2016). In southern China, the area of mangrove has shrunk from over 40,000 to 15,122 ha in the 40-year period between the mid 1950s and 1990s (Peng et al., 2008). As the province with the longest coastline and largest mangrove forests in China, Guangdong Province has been subjected to an overall mangrove loss of 82.1% between 1956 and the early 1990s (Zheng et al., 2003).

Although continuous degradation and loss of mangrove have lasted for three decades in China since the 1950s, more recently, the significance of mangrove ecosystems has been gradually recognised by researchers and local administrations in southern China (Chen, 1991). From 1984 to 2005, a total of 15 nature reserves related to mangrove or coastal wetland conservation has been set up in Guangdong, covering an area of 63,356 ha. (Ministry of Environmental Protection of China, 2013). Simultaneously, small-scale introduction of mangroves was attempted to seek species with fast growth and high adaptability for use in plantation against storm surges and land protection, resulting in the introduction of *Sonneratia apetala* to mainland China from Bangladesh in 1985 (Liao et al., 2004). Besides, another two exotic species (*Sonneratia caseolaris* and *Laguncularia racemosa*) have also been introduced successfully to the coast of Guangdong Province in the following two decades for mangrove afforestation development (Li et al., 2016). To date, as a result of natural conservation and afforestation, the area of mangrove wetland in Guangdong has reached 21,438.3 ha, which is

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http://dx.doi.org/10.1016/j.marpolbul.2016.06.083
0025-326X/

2.57 times that in 1989 (Chen, 1991; Guo, 2011). The increasing area of mangroves within the last 20 years of mangrove conservation and restoration strongly contrasts the annual loss of mangroves at 0.16% and 0.18% per annum in the world and Southeast Asia, respectively (Hamilton and Casey, 2016; Richards and Friess, 2016). Nevertheless, behind the increasing acreage of mangroves, some key issues should be addressed to reveal the latent state of mangrove ecosystems in Guangdong Province.

Firstly, a reassessment of the population dynamics of mangrove species is needed. The total area of mangroves is increasing continuously. However, the status of certain mangrove species or populations is poorly known, especially for the rarer species. This may lead to a deficiency of comprehensive and species-specific information to support mangrove conservation (Polidoro et al., 2010).

Secondly, the anthropogenic alteration of habitats may impact on the distribution of mangroves, also their survival conditions. Currently, the annual reclaimed area will possibly increase by over 50% in the upcoming decade (Ma et al., 2014), incurring tremendous environmental pressure on coastal wetlands (Kirwan and Megonigal, 2013). Habitat conversion and modification may lead to shift of vegetation structure, jeopardize ecosystem sustainability, and finally cause loss of mangroves (Alongi, 2002; Heatherington and Bishop, 2012). The exact amount of mangroves impacted by such anthropogenic disturbances is still unclear. Wang and Wang (2007) estimated over 80% of mangroves in China have been affected by dykes and seawalls. However, the lack of precise and site-specific data does hinder decision-making in mangrove conservation.

Thirdly, the future of mangrove plantations with introduced species is uncertain. In Guangdong Province, the non-native *Sonneratia* and *Laguncularia* species are playing more and more important roles in mangrove afforestation. To date, the ecological effects and ecosystem services of *Sonneratia* plantations have been surveyed locally (Chen et al., 2012; Peng et al., 2012; Wang et al., 2013; Yang et al., 2014), while such research on *Laguncularia racemosa* is still absent. A more extensive analysis is necessary to make a comprehensive assessment of these introduced species on their development.

In this analysis, we make a critical reassessment of the mangrove resources in Guangdong Province through a comprehensive literature review and on-site investigations. Four major issues will be discussed: (1) mangrove species dynamics as the basis of mangrove expansion in this region; (2) habitat change of natural mangrove communities and its influence on their development; (3) dispersal status of introduced mangrove species and their interaction with native mangroves; and (4) achievement as well as deficiency of recent mangrove conservation and management efforts. A comprehensive profile of regional mangrove resources will be presented to develop feasible strategies for mangrove conservation and restoration on the northern coast of the South China Sea.

2. Materials and methods

2.1. Study area

Mangrove occurs on the coast of Guangdong Province between Raoping County (23°32′21″ N, 116°57′22″ E) and Lianjiang City (21°33′36″ N, 109°45′03″ E). In the current study, mangrove communities exceeding 10 ha were identified by Google Earth Pro (version 6.1.0.5001) imagery interpretation. Systematic studies on mangroves in Guangdong started after World War II (How and Ho, 1953). Then, the research effort increased, focusing on some specific locations such as Leizhou Peninsula and eastern Pearl River Estuary for almost half a century since the mid 1950s. In the last decade, the research focus on mangroves in Guangdong extended to the Hanjiang River Estuary and western Pearl River Estuary and became more diversified in their themes (Chen et al., 2009). The natural mangrove communities are dominated by *Kandelia obovata* (formerly mis-identified as *Kandelia candel*), *Aegiceras corniculatum* and *Avicennia marina* before the early 2000s (Li and Lee, 1997), then large areas of plantations with the introduced *Sonneratia* and *Laguncularia* species have been established since the mid-2000s.

2.2. Methodology

2.2.1. Literature review

Historically, floral composition has been the focus of mangrove researchers in Guangdong for many years. Hence, species descriptions with detailed and attested checklists of mangroves with their distributional patterns represented the bulk of published works. By accessing the database of Web of Science (accessed Nov. 10-Dec. 12, 2015), Google Scholar (accessed Nov. 13-Dec. 12, 2015) and CNKI (http://www.cnki.net, accessed Nov. 21-Dec. 13, 2015), totally 259 literatures published during 1980–2015 has been found with terms of 'Guangdong', 'mangrove' and 'species'. Therein, the following criteria in filtering such literature materials was applied to find the most relevant topics: (1) firstly, the literatures focusing on floral and taxonomic researches were adopted while other topics were not suitable for this study; (2) secondly, only the literatures concerning on species rather than genuses or families were preserved since we need to address the profiles for every mangrove species; (3) finally, only the literatures related to the distributional status at provincial level were used since the occurrence on national or regional level are not coincident with the distribution of species, hence, may not be referential to our research. Finally, five papers providing information on the temporal dynamics of mangrove species are eligible and were used to construct a retrospective perspective of mangrove occurrence in different periods (Ko, 1985; Chen et al., 1988; Miao et al., 1997; Li and Lee, 1997; Wang and Wang, 2007).

2.2.2. Field survey

Prior to the field survey, mangroves along Guangdong coast have been identified via Google Earth imagery, then the area for every patch was measured by Google Earth Pro (version 6.1.0.5001). During July 2012 to October 2014, 96 survey sites with mangrove area exceeding 10 ha were chosen for field survey along the coast of Guangdong Province (Fig. 1, Table S1). At each site, three sampling plots were set up and 288 sampling plots (10×10 m^2) were set up in total. During the plot sampling, those individuals over 1.5 m and 0.5 m were recorded for tree and shrubby/ferny species, respectively. Totally, 22,441 individuals of mangroves were recorded onsite. The location of boundaries of each mangrove population were logged via a GPS loggers lifted with a carbon-fiber fishing rod for better reception through the canopies. Then, the population area of each species was evaluated separately with their boundaries recorded by GPS. However, 89 of the 96 sites are monocultures (which is easier to evaluate the population extent), while the other 7 sites are mixed stands. When conducting mapping and measurements in the mixed stands, we located the boundaries of each species population separately by GPS logging. However, for those scattered or occasional individuals interspersed within the other populations, their occurrence was ignored in the calculation of population area. Finally, the area of different populations at each site was measured by analysis via Google Earth Pro in the laboratory.

The following information was collected at each site for a comprehensive assessment on the condition of mangroves: (1) the area of the major mangrove communities was evaluated through on-site measurement, accompanied by estimation based on the corresponding imagery; (2) the habitats associated with the mangrove sites were categorized according to their estuarine and tidal positions by referring to the criteria of habitat position colonized by mangrove species proposed by Duke (1992) and used in Duke et al. (1998, 2006) and Polidoro et al. (2010) to evaluate the occurrence of mangrove taxa. The types of habitat position were categorized in two dimensions according to their location within an estuary (i.e. upstream-downstream gradient) and position along the intertidal zone (i.e. gradient perpendicular to the