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THE PRESENT EXTENT OF MANGROVE FORESTS IN SINGAPORE

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INTRODUCTION

The mangrove forest or mangal is a tropical to subtropical, shrub- and tree-dominated, intertidal, saltwater community mostly consisting of members from the Rhizophoraceae, *Avicennia* species, *Lumnitzera* species, and others (Lincoln et al., 1998). Mangrove forests are important habitats that support a unique assemblage of organisms and provide many ecosystem functions such as coastal protection, and serving as nurseries for marine fishes (Rönnbäck, 1999). The coasts of primeval Singapore were extensively covered by this unique habitat (Wee & Corlett, 1987; Corlett, 1992). The area of mangrove forests in 1819 was estimated to be 75 km^2 (7,500 ha) (Fig. 1). Most of the mangrove forest area (approximately 70 km^2), was found on Singapore Island (Corlett 1987, 1992). During the British colonisation, about 11.60 km^2 of mangrove forest was lost to charcoal and firewood exploitation, and land reclamation. After Singapore separated from Malaysia in 1965, rapid urban development and land-use changes occurred to meet the urgent and growing needs of a developing nation. During this period of national growth, mangrove forests suffered considerable losses owing to conversion to prawn ponds, further land reclamation projects, and damming rivers

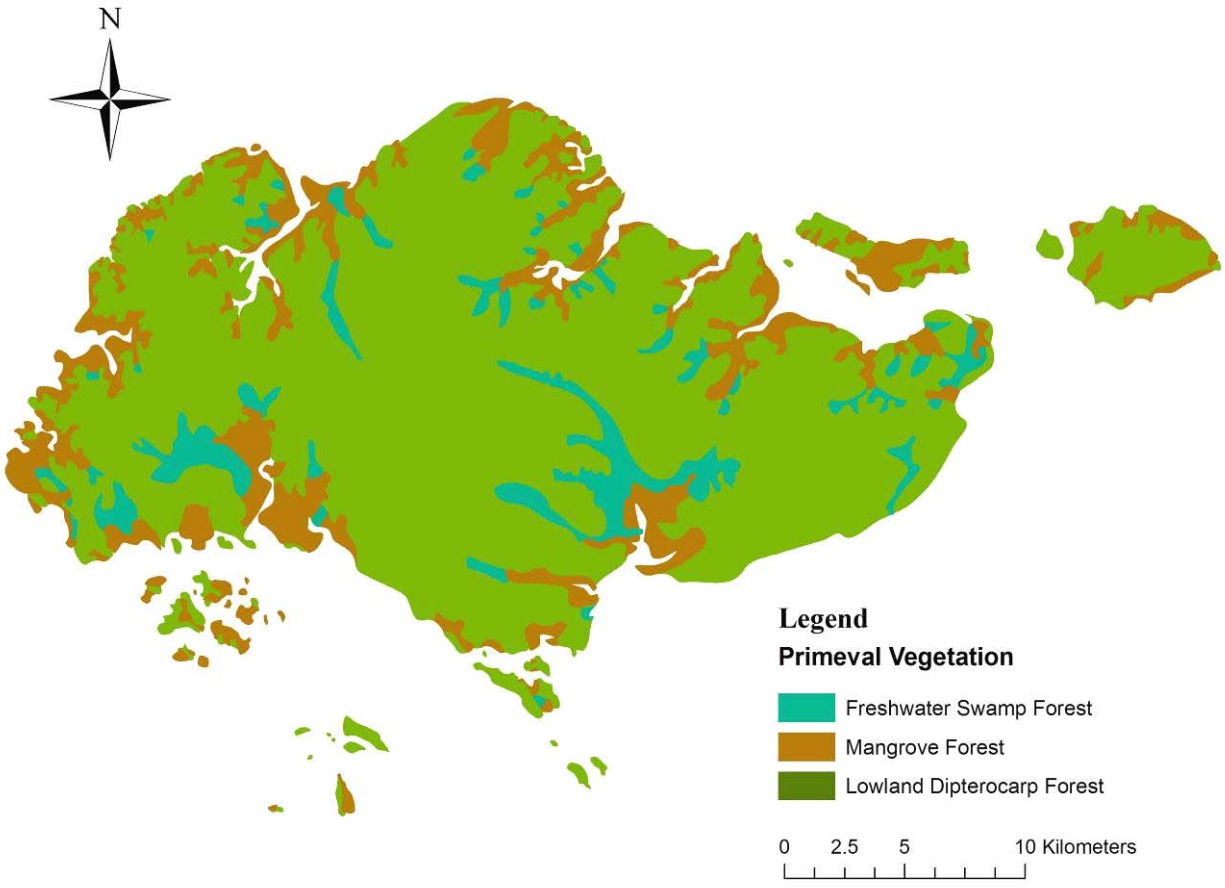

Fig. 1. Vegetation types in primeval Singapore. [Reconstructed from Corlett (1991)].

for the creation of the Kranji, Lower Seletar, Murai, Poyan, Sarimbun and Tengeh Reservoirs (Wee & Corlett, 1987; Hails, 1989; Hilton & Manning 1995). Here, we seek to document the present extent of mangrove forests in Singapore.

MATERIAL AND METHODS

The Republic of Singapore has an area of 710.30 km^2 with population of 4,987,600 as at 2009 (Singapore Department of Statistics, 2007). It has a coastline 268 km long (EarthTrends, 2003). It is located at 1º22′N 103º48′E. The mangrove forest fragments were categorised either as "mangrove forest" or "mangrove fringe" here. "Mangrove forest" is defined as a vegetation area dominated by mangrove plants with a minimum patch size of about 0.01 km^2 (1 ha). On the other hand, a "mangrove fringe" is a thin strip of mangrove lining the coast, river, canal or a prawn pond. Remnants of mangrove patches that are not influenced by the tides (either land-locked or within a reservoir) are not considered in this study.

The mangrove forest patches in Singapore were drawn based on Singapore's 1:50,000 topographic map (Singapore Armed Forces Mapping Unit, 2006), satellite images from Google Earth (Google, 2009) and a 2007 SPOT5 ("Satellite Pour l'Observation de la Terre 5") multispectral satellite image of Singapore. The 2004–2008 satellite images from Google Earth were used for analysis. Three spectral bands (red, NIR, and SWIR) from the SPOT5 satellite image were utilised to generate a rough map of the mangrove forest patches in Singapore. The map was drawn using the software ENVI 4.4 (ITT Visual Information Solutions, 2007) and ArcGis 9.3 ArcGis 9.3 (ESRI®, 2008).

Ground-truthing was conducted for all accessible mangrove forest areas from Sep.2009 to Dec.2009 with the aid of a GPS receiver (Garmin GPSMAP® 60CSx, with a maximum error of 10 m). For inaccessible mangrove forest areas, the extent of the mangrove forest fragments was ascertained by various observers who have visited the site, or have knowledge of the vegetation of that site.

RESULTS AND DISCUSSION

The total area of mangrove forest in Singapore is estimated to be 6.59 km^2 (659 ha), which is about 0.95% of Singapore's total land area. The largest fragment of mangrove forest is found at Sungei Buloh Wetland Reserve, with size of 1.17 km^2 (116.8 ha) (Table 1). The mangrove forest patches are mostly clustered at the north of Singapore (Fig. 2) presumably owed to the lower wave energy in the Straits of Johor, making the establishment of mangrove propagules easier, and allowing better growth of the trees.

The total mangrove forest area reported here (6.59 km^2) is larger than the most recent estimate of 4.83 km^2 by Hilton & Manning (1995). However, the authors hesitate to reach the conclusion that this increment of 166 ha is all attributed to new or regenerated mangrove forests around Singapore as the methodologies employed for the area estimations are drastically different. The data sources of Hilton & Manning (1995) were topographic maps in 1993 while the present study utilised satellite images, and determined mangrove forest areas based on their unique spectral signature. Hence, certain mangrove forest areas that were not marked out in present and past topographic maps are reflected here in this study (e.g., Sungei Buloh Besar extension, see Fig. 3), and borne out by ground-truthing.

Due credit must be given to various governmental, non-governmental organisations for mangrove protection and reforestation. The successful protection and preservation of mangrove forests in any country can only come about through the political will and commitment by the government with the participation of its citizens (Liow, 2000). This is usually demonstrated through public awareness and education of the natural environment by the citizens, followed by the gazetting of these areas by the government as reserves, thus rendering legal protection. The first mangrove forest reserves in Singapore were established in 1885, though by then most of these areas were already badly degraded (Corlett, 1987). However, this protection did not persist long as most of these reserves were abolished in 1938, being exploited for shrimp farming, and making way for various urban developments (Tan et al., 2010). The last stronghold of legally protected mangrove forest in Kranji was lost for reservoir damming in 1973 (Corlett, 1987). So by 1992, mangrove forests in Singapore were estimated only to cover 4.83 km^2 (Hilton & Manning, 1995). The imminent threat to this habitat and its ecosystem services was later realised by the Singapore government because efforts to preserve the remnant mangrove forests were shown through the official gazetting of the mangrove forest area at Sungei Buloh in 2002 and also the incorporation of mangrove forest strips in urban parks (e.g., Admiralty Park, Pasir Ris Park, Sengkang Park and Woodlands Town Park) (Corlett, 1991; Murphy & Sigurdsson, 1990; Tan et al., 2010).

Mangrove reforestation has also been carried out in heavily degraded mangrove areas as part of the government's effort to conserve the natural environment and biodiversity heritage in Singapore (Chua, 2002). The reforestation programmes in Pasir Ris Park, Pulau Semakau, and Pulau Ubin have sped up the regeneration process, thus increasing the extent of mangrove forests in Singapore. Patches of mangrove forests have nature reserve (Sungei Buloh Wetland Reserve) or

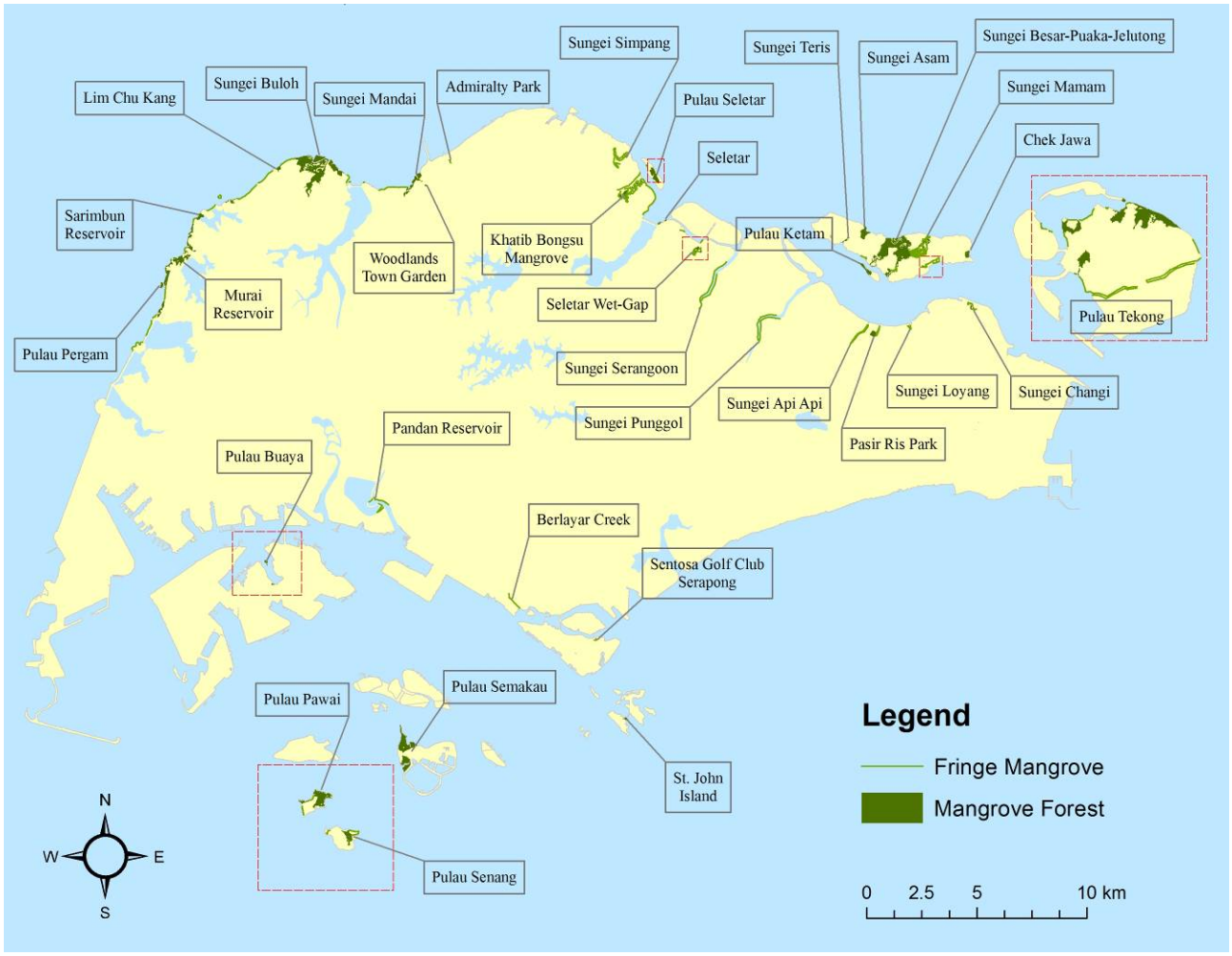

Fig. 2. Mangrove forest sites in Singapore. Patches within red-boxes were not groundtruthed but based on expert opinion and the literature.

Table 1. Areal data of mangrove forest patches that are larger than 10 ha (0.1 km^2) in Singapore.

Mangrove Forest Patch	Area (ha)	Area (km^2)
Sungei Buloh	116.8	1.168
Sungei Puaka	106.4	1.064
Sungei Belang- Sungei Chek Mat Noh	90.4	0.904
Pulau Pawai	34.2	0.342
Pulau Semakau North	32.7	0.327
Sungei Tanjung	27.4	0.274
Murai Reservoir	26.9	0.269
Sungei Unum	25.7	0.257
Sungei Seminei	24.3	0.243
Pulau Semakau South	17.4	0.174
Sungei Mandai	15.4	0.154
Pulau Senang	13.8	0.138
Pulau Seletar	13.4	0.134
Sungei Asam	13.0	0.130
Sungei Gadong	11.0	0.110

parks (e.g., Pasir Ris Park). These patches have regenerated well as they are generally isolated from intrusive anthropogenic influences.

In a land-scarce nation like Singapore, every effort is made to either maximise land use in existing areas or increase the area of the city state. The damming of the Kranji, Pandan and Seletar Rivers, for the creation of freshwater reservoirs to meet the needs of the nation significantly decreased the extent of contiguous mangrove forests in the north of Singapore Island. Land reclamation at the west of Singapore Island and the cluster of islands off Jurong has also destroyed pristine mangrove forests which were important feeding grounds for migratory birds (Hesp, 1995). With the announcement of more damming projects at the northeastern part of the main island (e.g., Sungei Punggol, and Sungei Serangoon) to create freshwater reservoirs (Foo, 2006), and the possibility of more land reclamation in Jurong Island, Pulau Ubin, and Pulau Tekong (Urban Redevelopment Authority, 2008), Singapore is definitely set to lose more mangrove forests and fringes in the future. The possibility of losing mangrove areas to meet the demands of the nation remains till today. As such, there is an urgent need to find a compromise between interests of national development and biodiversity conservation in Singapore.

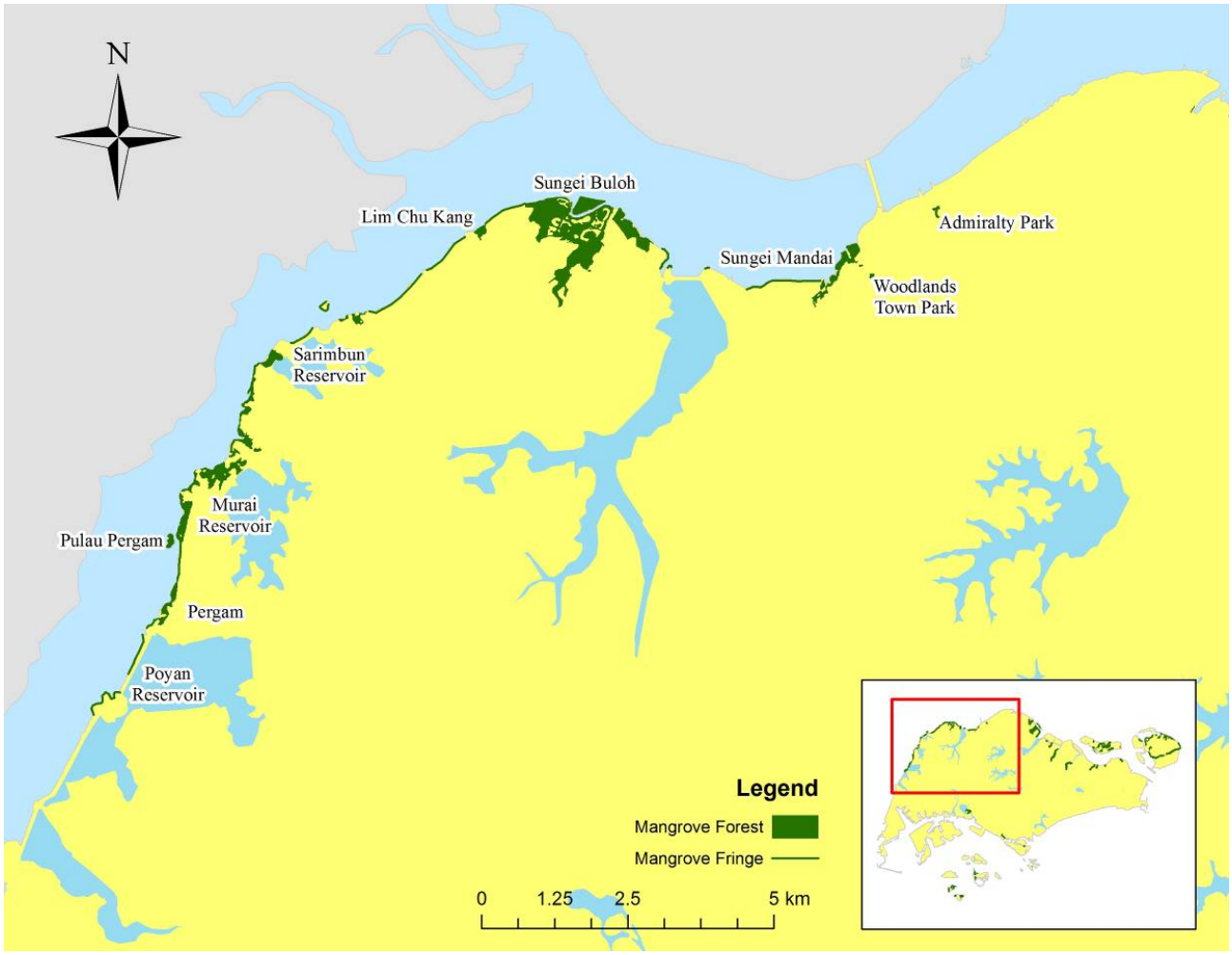

Fig. 3. Mangrove forest fragments in northwest Singapore Island.

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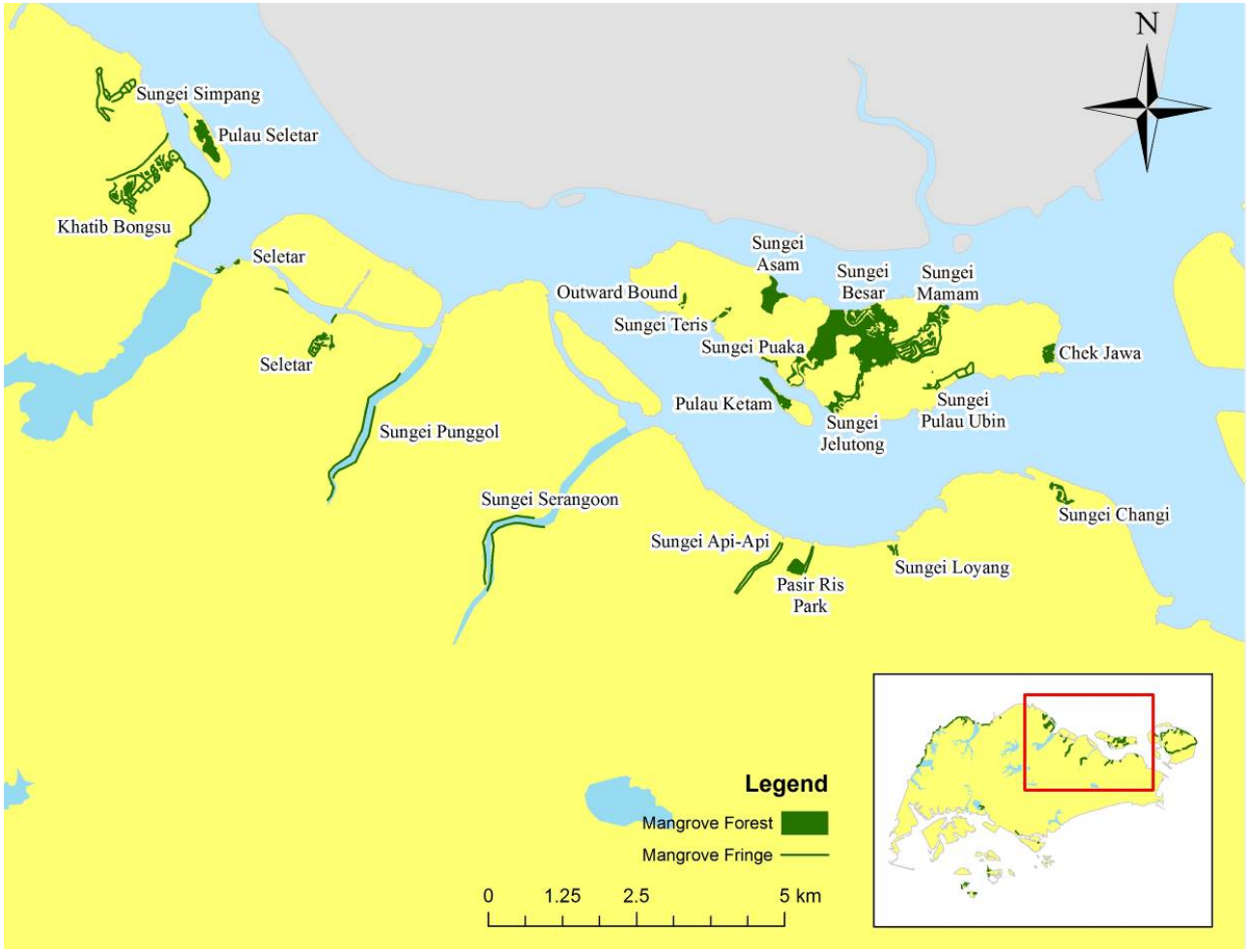

Fig. 4. Mangrove forest patches in northeastern Singapore.

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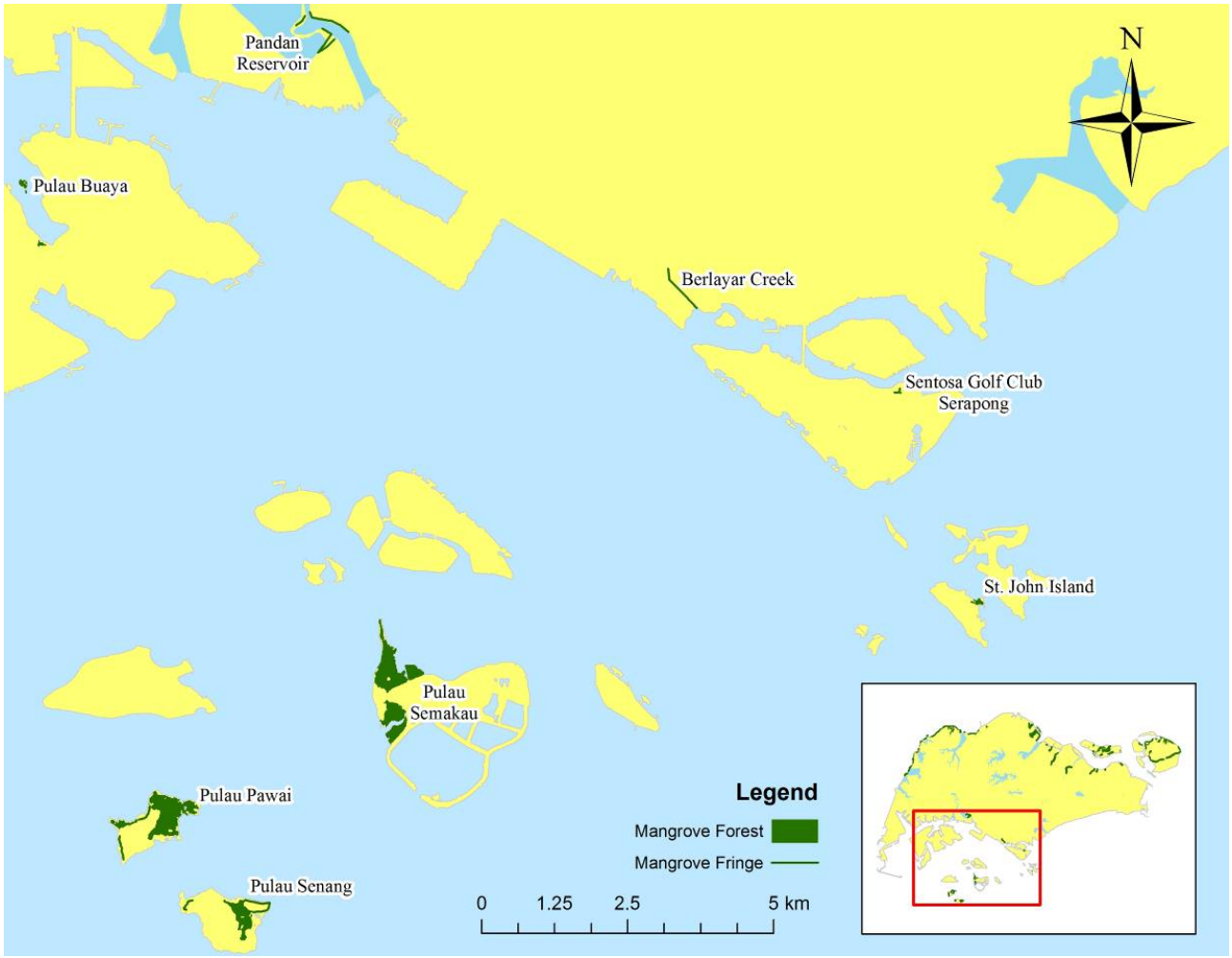

Fig. 5. Mangrove forest patches in southwest Singapore.

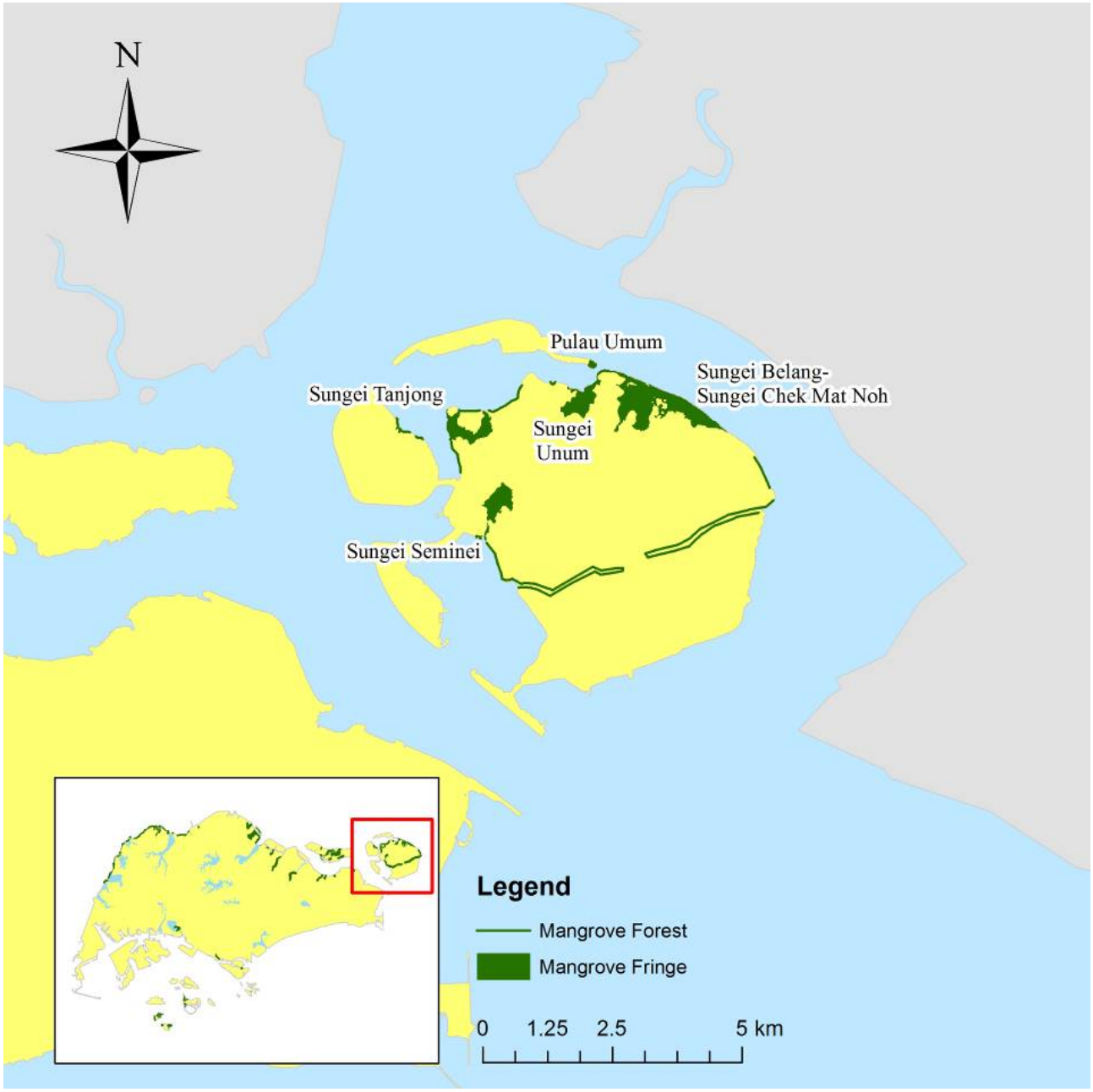

Fig. 6. Mangrove forest patches in Pulau Tekong.