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No. 12, Thiruvannamalai Nagar, Saravanampatti - Kalapatti Road, Saravanampatti,
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Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

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Cover: *Saproamanita praeclara*: Sporocarp in habitat © Kantharaja. R.

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COMMUNICATION

Study on the diversity of birds in the new abode of wetlands created by the 2004 tsunami in South Andaman

Neelam Purti [1], V. Shiva Shankar [2], G. Narshimulu [3], Satyajit Halder [4], C. Ramayya [5] & Ravi Pratap Singh [6]

[1,4] Department of Environment & Forest, Manglutan Range, South Andaman Forest Division, Andaman & Nicobar Islands 744105, India.
[2] Department of Coastal Disaster; [6] Department of Ocean Studies and Marine Biology;
Pondicherry University, Brookshabad Campus, Andamans, Andaman & Nicobar Islands 744112, India
[3] Department of Geography, JNRM, Port Blair, Andamans, Andaman & Nicobar Islands 744104, India.
[5] Department of Environment & Forest, Mahatma Gandhi Marine National Park, Wandoor Wildlife Division,
Andaman & Nicobar Islands 744105, India.
[1] neelam.purti@gmail.com, [2] shivashankarvj@gmail.com, [3] narshi.ani@gmail.com, [4] hSatyajit1985@gmail.com,
[5] ramayya.cr@gmail.com, [6] ravi29031994@gmail.com ([1,2] corresponding authors)

Abstract: Subsidence and upliftment of landmass were encountered in Andaman & Nicobar Islands due to the 2004 tsunami. The subsided landmass at the coastal front was permanently waterlogged ensuring a conducive new habitat for wetland birds. Pre- and post-tsunami Landsat satellite data products were used to demarcate the permanently waterlogged areas. A total of 63 bird species belonging to nine families comprising of five orders were identified and documented through direct observation technique in six stations of the 2004 post-tsunami-created wetlands in South Andaman. Order Charadriiformes and Anseriformes recorded the highest (47.62%) and least (4.76%) taxonomic composition of wetland birds, respectively. Scolopacidae family recorded the highest (56.67%) species composition. Among the six stations, the highest diversity of birds was observed in Sippighat and Ograbraj stations.

Keywords: Andaman birds, geographic information system (GIS), landmass subsidence, remote sensing, Tsunami-created wetlands (TCW), wetland biodiversity.

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Author details: Neelam Purti—Forest Ranger, A Wildlife photographer and bird watcher, Department of Environment and Forest, Manglutan Range, South Andaman forest division. Dr. V. Shiva Shankar—Independent researcher, Department of Coastal Disaster Management, Pondicherry University. Presently involved in studying the anthropogenic influence on the tsunami-created wetlands in Andaman and its impact on the floral and faunal diversity. Also, working on the impact of marine plastics on the coastal ecosystems of Andamans. Dr. G. Narshimulu—A guest faculty in the Department. Geography, at Jawaharlal Nehru Rajkeeya Mahavidyalaya College. Presently involved in studying the tsunami induced shoreline and geomorphic changes in south Andaman. Satyajit Halder—Forest Guard, A Wildlife photographer and bird watcher, Department of Environment and Forest, Mayabunder Forest Division, North & Middle Andaman. C. Ramayya—Forest Guard, a wildlife photographer and bird watcher, Department of Environment and Forest, Mahatma Gandhi Marine National Park, Wandoor Wildlife Division, south Andaman. Ravi Pratap Singh—PhD scholar in the Department of Ocean Studies and Marine Biology, Pondicherry University. His research focused on marine wetlands, their associated biodiversity, coastal pollution, and biodiversity monitoring.

Author contributions: NP and VSS—concept, and documentation of manuscript. NP, VSS, SH and CR—Bird watching and documentation. GN—GIS mapping. RPS—reference collection and graphing.

INTRODUCTION

The 26 December 2004 (Sumatra-Andaman) was one of the two recent tsunamigenic mega earthquakes that unleashed a tremendous catastrophic impact on the human race and the environment (Malik et al. 2019) which struck near Indonesia with a magnitude of 9.3 on the Richter scale (Stein & Okal 2005; Garay & Diner 2007). The epicenter was situated 80 km west of the coast of northern Sumatra (at approximately 95.85W and 03.41N). The seismic wave thereafter advanced approximately northward rupturing the 1,300-km Andaman-Sunda plate (with an average rupture speed of 2.5 to 3 km/s) in about 8 to 10 minutes (Ammon et al. 2005; Bilham et al. 2005; Lay et al. 2005; Subarya et al. 2006; Malik et al. 2011) resulting in up to ~6 m of bottom subsidence and ~10 m of upliftment parallel to the rupture and about 100–150 km wide across the subduction area (Malik & Murty 2005; Ioualalen et al. 2007; Malik et al. 2011, 2015). Upliftment and subsidence of landmass were caused as a consequence of earthquake elastic rebound, offshore of Banda Aceh, the northern tip of Sumatra (Bilham 2005). The tsunami waves which surged across the ocean with a velocity of 900 km/h and took a devastating wave height of 10 m with a speed of 40 km/h along the coastal frontiers (Bahuguna et al. 2008) resulting in permanent waterlogging in landmass subsided zones (Shankar et al. 2019).

Andaman & Nicobar Islands (ANI) is the maritime union territory of India in the Bay of Bengal between Myanmar and peninsular India, distributed in the north-south direction. It is a group of 572 islands, stretching over 700 km and bounded by the geographic coordinates (06.00–14.00 N and 92.00–94.00 E). ANI is located close to Myanmar by 190 km in the north, Sumatra by 150 km in the south, and 1,200 km from mainland India (Shankar et al. 2016). ANI enjoys a tropical climate, and classified as warm and humid. The average annual temperature is in the range of 25°C to 30.5°C and relative humidity is 81%. The average annual rainfall is approximately 3,000–3,500 mm with south-west monsoon (May–September) contributing 76.35%, north-east monsoon (October–December) contributing to 22%, and pre-monsoon (January–April) of 1.64% (Meteorological Statistics 2019).

ANI are distinct eco-regions sandwiched between two major landmasses, namely, the Indian subcontinent and the Malaysian-Indonesian. It is one of the 12 biogeographic zones of India showing great diversity, variety, and high level of endemism in flora and fauna. ANI comprises of nine national parks, 96 sanctuaries, and one biosphere reserve (Rao et al. 2013; FSI 2019).

ANI were the first responders to the 2004 tsunami among other territories of India because of its closest proximity to the epicenter. Due to this tsunamigenic mega-earthquake, the ANI experienced both upliftment and landmass subsidence (Nehru & Balasubramanian 2011, 2018) creating permanently waterlogged areas (Shankar et al. 2019). These waterlogged areas were called tsunami wreated Wetlands (TCW) and they became a favorable habitat for the water birds. The avian diversity of ANI is well documented by various studies (Pande et al. 2007; Sivaperuman et al. 2010, 2018). However, there is a lack of studies about the diversity of birds post 2004 in the TCW thus created and this study is a first of its kind. The study was initiated to understand the diversity and distribution of birds in the six TCWs of South Andaman (Figure 1).

MATERIALS AND METHODS

Pre (2003) and post (2018) tsunami Landsat satellite images, ArcGIS 10.5, Garmin 60 CSx handheld global positioning system (GPS), binocular, and camera were used to comprehend the objective of the present investigation.

Landsat (7 & 8) satellite data products before (2003) and after (2018) tsunami respectively for the study were downloaded from the website (www.earthexplorer.usgs.gov/). The study area is covered by the scene with path (134) and row (52). Mangrove patches and water bodies decipherably picked up very well by band-5 and band-6 by the short-wave infrared (SWIR) sensor of Landsat 7 and 8 satellites respectively from other features like forests and human settlements. six TCWs were chosen for the assessment of wetland avian diversity (Figure 1) using the leads from pre- and post-2004 tsunami satellite images. These six birding locations are Stewartgunj, Ograbraj, Sippighat, Wandoor, Chidiyatapu, and Carbyn's Cove (Table 1, Image 1,2). Field visits were carried out from November 2018 to March 2020. Each of these six sites was periodically revisited every month on weekends (Saturday and Sunday) at 0600–0900 h during the aforementioned period. Upon reaching the field using binocular the birds were observed directly (Altman 1974) and identified using the identification keys by Ali (2002) and Grimett et al. (2012). Also, the identified birds were cross verified with the checklist of Pande et al. (2007) and Sivaperuman et al. (2018). Thus, the distribution of wetland birds in TCWs of six villages

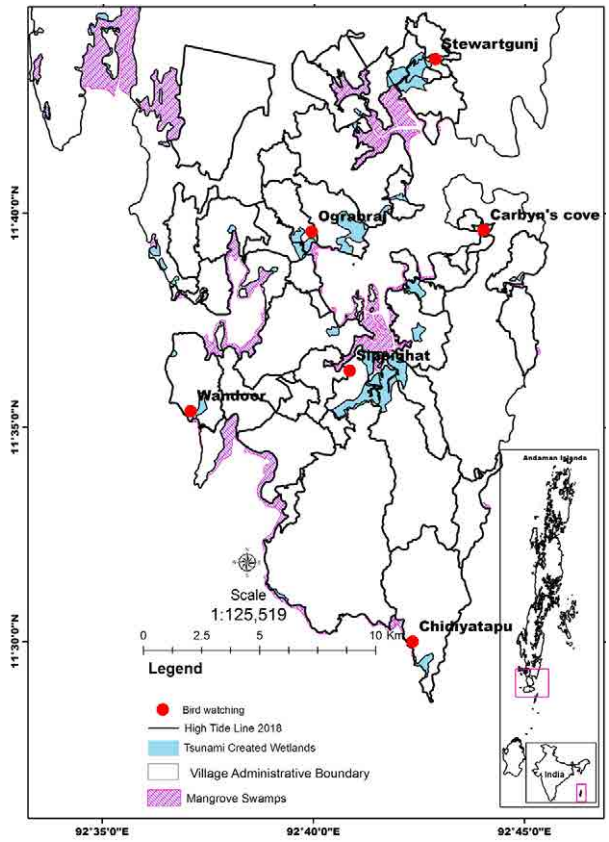

Figure 1. Study area map.

was observed, identified, and documented.

RESULTS AND DISCUSSION

Mangrove swamps were the ancestral abode to the wetland birds of the study area (Figure 1). Physical fury, subsidence of landmass, and permanent water logging due to the 2004 tsunami resulted in massive destruction of mangroves (Roy & Krishnan 2005; Nehru & Balasubramanian 2011; 2018; Shankar et al. 2019). Thus, the wetland birds were flushed out of their original habitat and were resilient to adapt to the post-tsunami newly created habitat. All the six study sites' visual interpretation of pre (2003) and post (2018) tsunami satellite data articulates the loss of mangrove habitat and the areal extent of the TCWs are presented in Table 1. The mangrove swamp at Ograbraj (10.31 ha) was completely wiped out by the 2004 tsunami. On the other hand, the mangrove swamp of Carbyn's Cove (0.66 ha) was spared, while the subsidence of landmass resulted in the creation of wetland after the tsunami at Stewartgunj. Sippighat mangrove swamps were one of the worst affected habitats in the study area (Roy & Krishnan 2005; Yuvaraj & Dharanirajan 2013; Das et al. 2014; Shankar et al. 2019) as only 37.37 ha (2018) of mangroves survived out of the 130.05 ha (2003). The chosen six birding locations have unique importance, Chidiyatapu is an internationally known birding location in Andaman. While Wandoor is covered under the Mahatma Gandhi Marine National Park (MGMNP). Stewartgunj is situated at the foothills of Mt Harriet National Park. Ograbraj located close to Sippighat (~3 km across the sea), massive mangrove habitat destruction was observed in these two locations.

A total of 63 birds were observed through the direct observation technique and identified using keys by Ali (2002) and Grimett et al. (2012). These 63 wetland birds (Figure 2a) encompassed in five orders, viz., Anseriformes (3 species; 4.76%), Coraciiformes (8 species; 12.70%), Gruiformes (9 species; 14.28%), Charadriiformes (30 species; 47.61%), and Pelecaniformes (13 species; 20.63%). Order Anseriformes, Coraciiformes, Gruiformes, and Pelecaniformes comprise of one family each, viz., Anatidae, Alcedinidae, Rallidae, and Ardeidae. Charadriiformes (Figure 2b) was the most diverse order comprising of five families, viz., Burhinidae (1 species; 3.33%), Charadridae (7 species; 23.33%), Jacanidae (1 species; 3.33%), Laridae (4 species; 13.33%), and Scolopacidae (17 species; 56.66%). Among the 63 birds only two species, viz., Andaman Crake *Rallina canningi* and Andaman Teal *Anas albogularis* are endemic.

According to IUCN version 3, of the identified 63 wetland birds majority (57 species; 90.47%) are Least Concern (LC), five species (7.93%) are Near Threatened (NT), and one species (1.58%) is Vulnerable (VU) categories. Chinese Egret *Egretta eulophotes* is the only Vulnerable species belonging to the order

Table 1. Before and after tsunami areal extent of wetlands (Mangrove stand in ha).

Village name	Before Tsunami	After Tsunami	Area of TCW (ha)	Before tsunami land use apart from Mangrove
Chidiyatapu	18.42	2.43	27.83	Agricultural Land & Settlement
Wandoor	31 .7	21.36	28.89	Agricultural Land
Ograbraj	10.31	0	32.42	Agricultural Land
Sippighat	130.05	37.37	136.96	Agricultural Land & Settlement
Carbyn's Cove	0.66	0.66	4.20	Agricultural Land
Stewartgunj	0	0	10.2	Agricultural Land

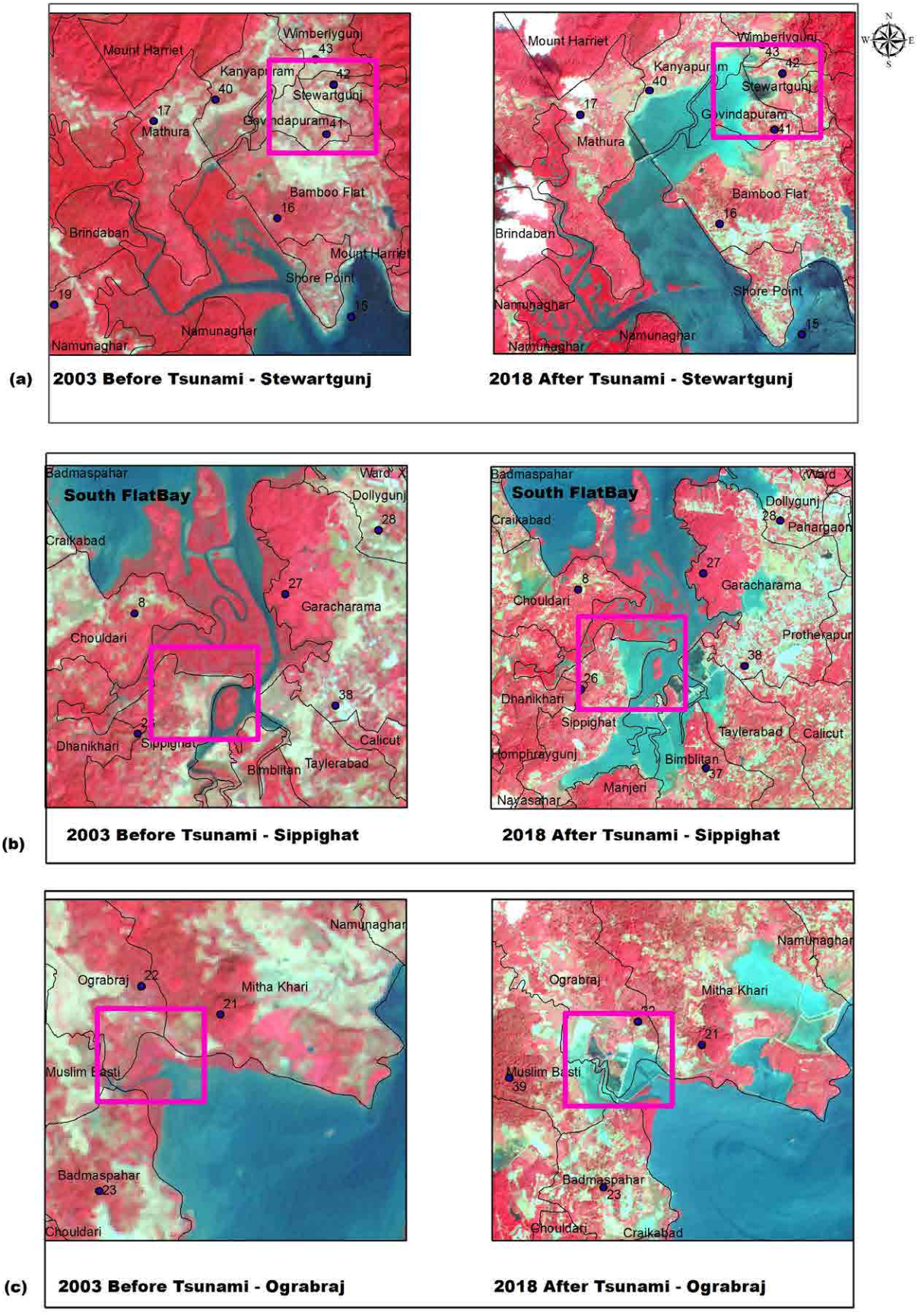

Image 1. Before and after tsunami satellite image: a—Stewartgunj | b—Sippighat | c—Ograbraj.

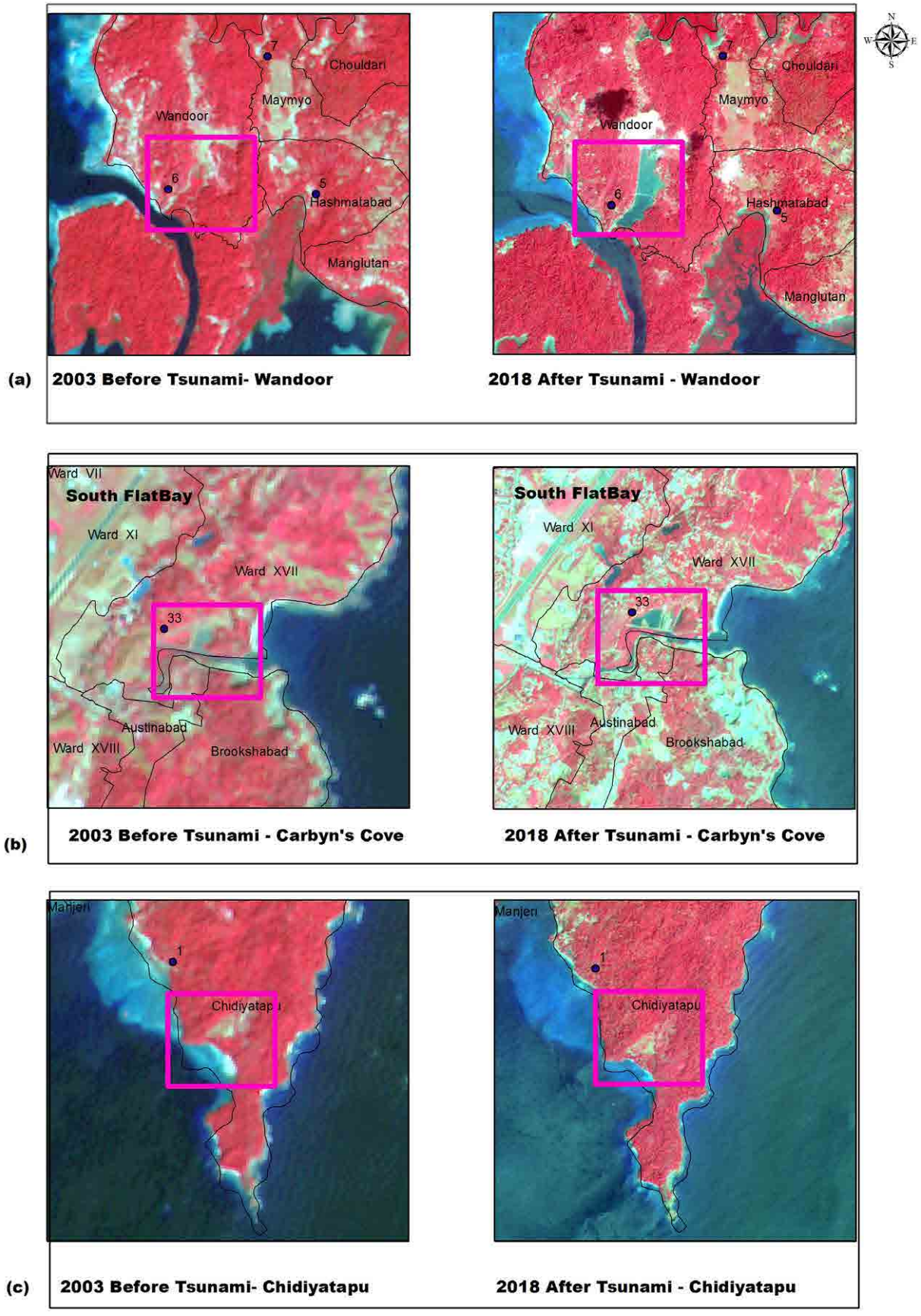

Image 2. Before and after tsunami satellite image: a—Wandoor | b—Carbyn's Cove | c—Chidiyatapu.

Pelecaniformes. Whereas, Andaman Teal *Anas albogularis*, Curlew Sandpiper *Calidris ferruginea*, Eurasian Curlew *Numenius arquata*, Bar-tailed Godwit *Limosa lapponica*, and Beach Thick-Knee *Esacus magnirostris* are Near Threatened. The complete list of birds is in Table 2, Image 3. According to the Indian Wildlife (Protection) Act, 1972, one species (Andaman Teal) was listed under Schedule I; and all the 63 species were included in Schedule IV.

Wards cluster analysis (Figure 2c) articulates two distinct clusters. Cluster 1 comprises Wandoor and Carbyn's Cove. Eleven and 18 wetland birds were identified from two sites of Wandoor and Carbyn's Cove. The species diversity was found to be low in these two sites when compared to the other four locations. Low levels of species diversity in Carbyn's Cove and Wandoor are probably due to the frequent movement of tourist vehicles and fishing boats in these two sites. In addition to tourism, the movement of vehicles and the closest proximity of human settlements around the wetlands has threatened the birds in Carbyn's Cove. Cluster 2 is further classified into two sub-groups. Ograbraj and Sippighat exhibit a high degree of species diversity. These two stations comprise 53 and 54 wetland birds, respectively. Before the 2004 tsunami, Sippighat was the abode for wetland birds. The massive mangrove habitat loss (80%) in Sippighat (Roy & Krishnan 2005) and a complete wipe of the mangrove swamp in Ograbraj (Shankar et al. 2019) flushed the wetland birds to the newly created habitat of TCW. The vast expanse of permanent waterlogging with suitable prey base availability in these sites would have the wetland birds adapt to the new environment. We assume this could be the reason for the high diversity observed in both Sippighat and Ograbraj sites. Stewartgunj and Chidiyatapu form another subgroup of cluster 2. A retrospection of pre-and post-tsunami satellite data products (Image 1) articulates that the shoreline has migrated inwards to Stewartgunj due to the subsidence of landmass thus responsible for the migration of wetland birds to the new habitat.

Before the 2004 tsunami impact, agriculture was extensively practiced on the coastal plains of Sippighat and Ograbraj (Rajan & Pramod 2017). The loss of natural habitat due to tsunami had led to the migration of the wetland birds to the new habitat (permanently waterlogged subsided landmass).

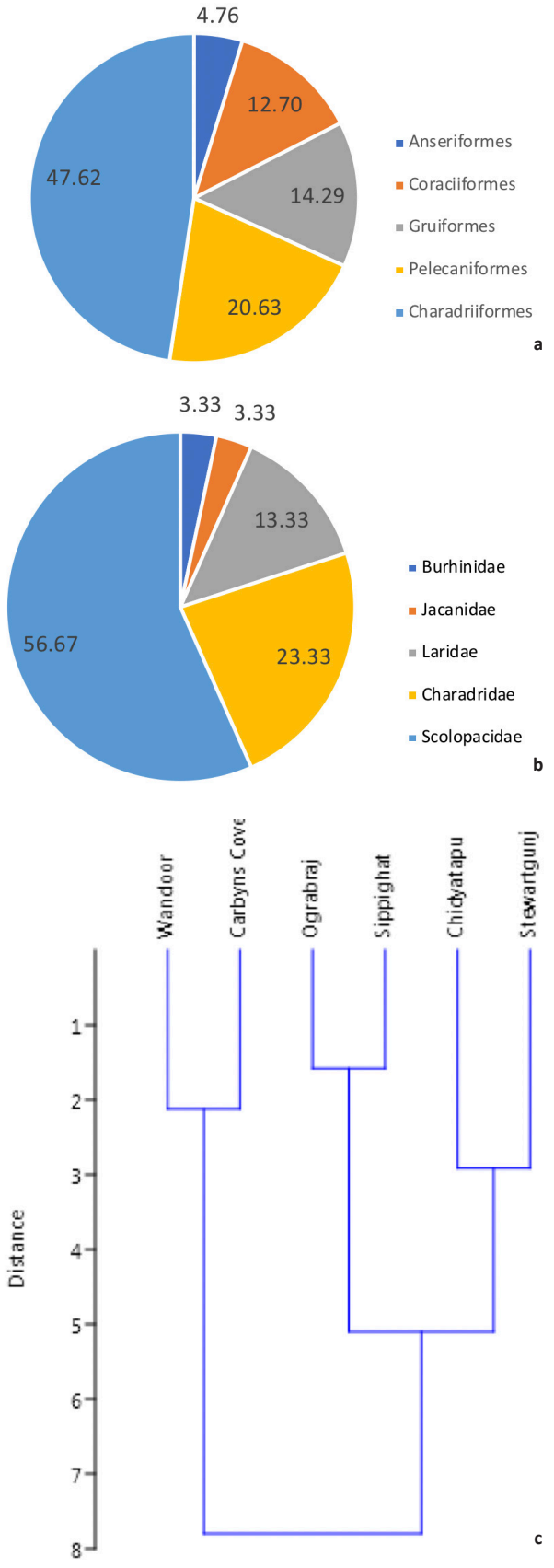

Figure 2. a—Taxonomic composition of wetland birds | b—Species composition of order Charadriiformes | c—Cluster analysis.

Table 2. wetland-wise avian diversity.

Order	Family	Common name	Scientific name	Status	IUCN Red List status	CT	WD	OB	SG	CC	ST
Anseriformes	Anatidae	Lesser Whistling Duck	*Dendrocygna javanica*	R/LM	LC	P	P	P	P	A	P
Anseriformes	Anatidae	Andaman Teal*	*Anas albogularis*	R	NT	P	A	P	P	A	P
Anseriformes	Anatidae	Cotton Teal	*Nettapus coromandelianus*	R	LC	P	A	P	P	A	A
Coraciiformes	Alcedinidae	White throated Kingfisher	*Halcyon smyrnensis*	R	LC	P	P	P	P	P	P
Coraciiformes	Alcedinidae	Stork-billed Kingfisher	*Pelargopsis capensis*	R	LC	P	P	P	P	P	P
Coraciiformes	Alcedinidae	Ruddy Kingfisher	*Halcyon coromanda*	R	LC	A	P	P	P	A	P
Coraciiformes	Alcedinidae	Black capped Kingfisher	*Halcyon pileata*	R/LM	LC	P	P	P	A	A	A
Coraciiformes	Alcedinidae	Blue Eared Kingfisher	*Alcedo meninting*	R	LC	P	A	P	P	A	P
Coraciiformes	Alcedinidae	Common Kingfisher	*Alcedo atthis*	WM	LC	P	P	P	P	P	P
Coraciiformes	Alcedinidae	Collared Kingfisher	*Todiramphus chloris*	R	LC	P	P	P	P	P	P
Coraciiformes	Alcedinidae	Oriental Dwarf Kingfisher	*Ceyx erithaca*	R	LC	P	A	P	P	A	P
Gruiformes	Rallidae	Andaman Crake*	*Rallina canningi*	R	LC	P	P	A	A	A	P
Gruiformes	Rallidae	Baillon's Crake	*Zapornia pusilla*	WM	LC	A	A	A	P	A	A
Gruiformes	Rallidae	Ruddy Breasted Crake	*Zapornia fusca*	WM	LC	P	A	P	P	A	A
Gruiformes	Rallidae	Common Coot	*Fulica atra*	R/LM	LC	P	A	P	P	A	A
Gruiformes	Rallidae	Purple swamphen	*Porphyrio poliocephalus*	R	LC	P	A	P	P	P	P
Gruiformes	Rallidae	Eurasian Moorhen	*Gallinula chloropus*	R	LC	A	A	P	P	A	P
Gruiformes	Rallidae	Slaty-breasted Rail	*Lewinia striata*	R	LC	P	P	P	P	P	P
Gruiformes	Rallidae	Water Cock	*Gallicrex cinerea*	R/LM	LC	P	A	P	P	A	P
Gruiformes	Rallidae	White-breasted Waterhen	*Amaurornis phoenicurus*	R	LC	P	P	P	P	P	P
Charadriiformes	Scolopacidae	Common Snipe	*Gallinaga gallinago*	WM	LC	P	P	P	P	A	P
Charadriiformes	Scolopacidae	Pin tailed Snipe	*Gallinago stenura*	WM	LC	P	P	P	P	P	P
Charadriiformes	Scolopacidae	Curlew Sandpiper	*Calidris ferruginea*	WM	NT	P	A	P	P	A	A
Charadriiformes	Scolopacidae	Common Sandpiper	*Actitis hypoleucos*	WM	LC	P	P	P	P	P	P
Charadriiformes	Scolopacidae	Green Sandpiper	*Tringa ochropus*	WM	LC	P	A	P	P	A	A
Charadriiformes	Scolopacidae	Terek Sandpiper	*Xenus cinereus*	WM	LC	A	A	P	P	A	A
Charadriiformes	Scolopacidae	Wood Sandpiper	*Tringa glareola*	WM	LC	P	A	P	P	A	P
Charadriiformes	Scolopacidae	Eurasian Curlew	*Numenius arquata*	WM	NT	P	P	P	P	P	P
Charadriiformes	Scolopacidae	Little Stint	*Calidris minuta*	WM	LC	A	A	A	P	A	A
Charadriiformes	Scolopacidae	Long-toed Stint	*Calidris subminuta*	WM	LC	P	A	P	P	A	P
Charadriiformes	Scolopacidae	Marsh Sandpiper	*Tringa stagnatilis*	WM	LC	P	A	P	P	A	A
Charadriiformes	Scolopacidae	Bar tailed Godwit	*Limosa lapponica*	WM	NT	A	A	P	A	A	A
Charadriiformes	Scolopacidae	Common Greenshank	*Tringa nebularia*	WM	LC	P	A	P	P	A	P
Charadriiformes	Scolopacidae	Common Redshank	*Tringa totanus*	WM	LC	P	A	P	P	A	P
Charadriiformes	Scolopacidae	Spotted Redshank	*Tringa erythropus*	WM	LC	A	A	P	P	A	A
Charadriiformes	Scolopacidae	Eurasian Whimbrel	*Numenius phaeopus*	WM	LC	P	P	P	P	P	P
Charadriiformes	Scolopacidae	Ruddy Turnstone	*Arenaria interpres*	WM	LC	P	A	A	A	P	A
Charadriiformes	Burhinidae	Beach Thick-knee	*Esacus magnirostris*	R	NT	A	P	A	A	A	A
Charadriiformes	Jacanidae	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	WM	LC	P	A	P	P	A	P
Charadriiformes	Charadridae	Greater Sand Plover	*Charadrius leschenaultii*	WM	LC	P	P	P	P	P	P
Charadriiformes	Charadridae	Grey-headed Lapwing	*Vanellus cinereus*	WM	LC	A	A	A	P	A	A
Charadriiformes	Charadridae	Grey Plover	*Pluvialiss quatarola*	WM	LC	A	A	A	A	P	P

Order	Family	Common name	Scientific name	Status	IUCN Red List status	CT	WD	OB	SG	CC	ST
Charadriiformes	Charadridae	Kentish Plover	*Charadrius alexandrinus*	WM	LC	A	A	P	P	A	A
Charadriiformes	Charadridae	Lesser Sand Plover	*Charadius mongolus*	WM	LC	P	A	P	P	A	P
Charadriiformes	Charadridae	Little Ringed Plover	*Charadrius dubius*	WM	LC	P	A	P	P	A	A
Charadriiformes	Charadridae	Pacific Golden Plover	*Pluvialis fulva*	WM	LC	P	P	P	P	P	P
Charadriiformes	Laridae	Black Naped Tern	*Sterna sumatrana*	R/LM	LC	P	A	A	A	P	P
Charadriiformes	Laridae	Lesser Crested Tern	*Thalasseus bengalensis*	WM	LC	P	A	A	A	A	A
Charadriiformes	Laridae	Little Tern	*Sternula albifrons*	WM	LC	P	A	P	P	A	A
Charadriiformes	Laridae	Whiskered Tern	*Chlidonias hybrida*	WM	LC	A	A	P	P	A	A
Pelecaniformes	Ardeidae	Black Bittern	*Ixobrychus flavicollis*	WM	LC	A	A	P	P	A	A
Pelecaniformes	Ardeidae	Cattle Egret	*Bubulcus ibis*	R/LM	LC	P	A	P	P	P	P
Pelecaniformes	Ardeidae	Chinese Egret	*Egretta eulophotes*	WM	VU	A	A	P	P	A	A
Pelecaniformes	Ardeidae	Chinese Pond Heron	*Ardeola bacchus*	WM	LC	A	A	P	P	A	P
Pelecaniformes	Ardeidae	Cinnamon Bittern	*Ixobrychus cinnamomeus*	R/LM	LC	P	P	P	P	A	P
Pelecaniformes	Ardeidae	Great Egret	*Ardea alba*	R/LM	LC	P	A	P	P	P	P
Pelecaniformes	Ardeidae	Yellow Bittern	*Ixobrychus sinensis*	WM	LC	P	A	P	P	P	P
Pelecaniformes	Ardeidae	Purple Heron	*Ardea purpurea*	R/LM	LC	A	A	P	P	A	A
Pelecaniformes	Ardeidae	Striated Heron	*Butorides striata*	R	LC	P	P	P	P	P	P
Pelecaniformes	Ardeidae	Pacific Reef Egret	*Egretta sacra*	R	LC	P	P	P	P	P	P
Pelecaniformes	Ardeidae	Little Egret	*Egretta garzetta*	R/LM	LC	P	P	P	P	P	P
Pelecaniformes	Ardeidae	Indian Pond Heron	*Ardeola grayii*	R/LM	LC	P	A	P	P	A	P
Pelecaniformes	Ardeidae	Intermediate Egret	*Ardea intermedia intermedia*	R/LM	LC	P	P	P	P	P	P

*—Endemic to Andaman Nicobar Islands | LC—Least Concern | NT—Near Threatened | VU—Vulnerable | R—Resident | R/LM—Resident with local movement | WM—Winter Migration | —Present | A—Absent | CT—Chidiyatapu | WD—Wandoor | OB—Ograbraj | SG—Sippighat | CC—Carbyn's Cove | ST—Stewartgunj.

CONCLUSION

The present study is the first of its kind to document the diversity of wetland birds in the last two decades. This study contributes to the rich bird diversity recorded in earlier studies of the Andaman & Nicobar Islands. Various tools like GIS, remote sensing, and on-field direct observation were comprehended to achieve the objective of the present investigation in pre and post-tsunami bird diversity and TCW. Land reclamation from these newly created wetlands is on the rise since it is in private ownership thus threatening the diversity of these wetland birds. A conservation drive is recommended for the conservation of these wetland birds.

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Image 3. Field photos of wetland birds. a—Common Moorhen | b—Purple Swamphen | c—Andaman Teal | d—Striated Heron | e—Lesser Whistling Duck | f—Pheasant-tailed Jacana.

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