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Tourism Carrying Capacity for Beaches of South Andaman Island, India

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Additional information is available at the end of the chapter

Abstract

The Andaman and Nicobar Islands (ANI) is one of the largest tourist areas in India attracting both the international and domestic tourists each year. The Island Administration has a vision to develop the islands as an upmarket island destination for ecotourism. Among the island group, the South Andaman region is the most visited tourist destination and beaches of these islands have great potential for tourism attractions. The present work is an attempt to understand the potential of these beaches by assessing the carrying capacity in terms of number of visitors that can be allowed over a period of time, which will further help with better tourism management. The methodology used to estimate the tourism carrying capacity (TCC) is based on the physical and ecological conditions of each site and the existing infrastructure. The total effective carrying capacity (ECC) estimated for the beaches of Port Blair area (126,301 visitors/day) reveals that the current tourism activity is in lower level compared to its carrying capacity. Such carrying capacity assessments can be used as an input into the regular planning process. Preliminary estimates suggest that A&N Islands can be promoted for high value-low volume, eco-friendly, and environmentally sustainable tourism.

Keywords: Andaman, beaches, carrying capacity, tourism, islands

1. Introduction

Tourism is one of the driving forces of global economic growth and has become increasingly competitive in the global arena. Tourism accounts for almost 10% of global GDP, generates more than US$ 1.5 trillion in trade income or 30% of the world's services exports, and provides one

in eleven jobs worldwide [1]. As per the India's Tourism Statistics Report (2014), India's foreign exchange earnings from tourism is US$ 20.24 billion at annual growth rate of 4.0%. India's position in the World Tourism Receipts is at 15th place, and in the Asia and Pacific Region, India retains seventh place. During 2014, the number of Foreign Tourist Visits (FTVs) to the States/ Union Territories (UTs) was 22.57 million as compared to 19.95 million in 2013 and 18.26 million in 2012 and registered a growth of 13.12% over 2013 as compared to a growth of 9.24% in 2013 over 2012 (MoT, 2014). The top 10 source countries for Foreign Tourist Arrivals in India in 2014 include United States (14.57%), Bangladesh (12.27%), United Kingdom (10.92%), Sri Lanka (3.20%), Russian Federation (3.51%), Canada (3.50%), Malaysia (3.41%), France (3.20%), Australia (3.12%), and Germany (3.11%) and other countries (38.44%).

Similar to the Foreign Tourist Arrival, "domestic tourism also plays an important role in overall tourism development in the country. The number of domestic tourist visits increased from 462 million in 2006 to 740 million in 2010. In 2009, when the country witnessed a negative growth of 2.2% in foreign tourists arrivals, domestic tourist visits registered a growth of 18.8%. This growth of domestic tourist visit sustained tourism infrastructure during the lean period of tourism sector [2]. There has been a continuous increase in India's domestic tourist visit to its all states/UTs from 1991 to 2012, with the Compound Annual Growth Rate (CAGR) being 13.96%.

India is one of the few countries that offer a wide range of destinations for potential tourists. Tourism has grown in leaps and bounds over the years with each region of India contributing to its splendour and exuberance. In India, the Ministry of Tourism (MoT) is the nodal agency for the development and promotion of tourism in the country and also responsible for international cooperation in tourism (Government of India (Allocation of Business) Rules, 1961 as amended up to 12th Feb 2016). The MoT formulates national policies and programs and coordinates activities of various government and private agencies for the development and promotion of tourism in the country. The National Tourism Policy, formulated in the year 2002, aims for tourism development in India in a systematic manner, positioning it as a major engine of economic growth and to harness its direct and multiplier effects for employment and poverty eradication in an environmentally sustainable manner.

National Council of Applied Economic Research (2014) [3], using the data from International Passenger Survey 2010–2011, observed that monuments, forts, palaces, museums, hill stations, and beaches are some of the motivational factors that are influencing the decision of potential tourists visiting India. The ANI is one of the largest tourist areas in India that provide for a unique combination of terrestrial, mangrove, coastal, and marine ecosystems. The bays, coral reefs, mangroves, seagrass meadows, beaches, and caves make these islands special and attract both international and domestic tourists each year. "The Island Administration has the vision to develop the islands as an upmarket island destination for ecotourism through environmentally sustainable development of infrastructure without disturbing the natural ecosystem with the objective of creating more employment opportunities and synergize socio-economic development of the islands" [4]. Tourist visit including foreign visitors to ANI is on the increasing trend. The year 2000 witnessed a total number of 86,066 visitors to ANI which has grown up to 146,990 in the year 2007 and 218,035 in the year 2011 and 256,237 in the year 2012

[5]. The tourist arrival to ANI for the year 2013–2014 is 258,418 (with 17,811 foreign tourists). With the continuous increase in tourist flow to Andaman Islands and subsequent population pressure, there is a need to understand the tourism carrying capacity (TCC) for various tourist destinations in the island in addition to the importance given toward environmental protection, while planning for tourism development particularly in areas such as wildlife sanctuaries, beaches, and other fragile ecosystems.

2. Tourism carrying capacity: A review of concept

The concept of TCC, though emerged in the 1970s and 1980, has received significant attention in recent years as part of an effective strategy to address environmental, economic, and social issues [6–8].

There have been many attempts to define carrying capacity. It was stated that TCC is a specific type of environmental carrying capacity and refers to the biophysical and social capacity of the environment with respect to touristic activity and its development [9–10]. Middleton and Hawkins (1998) [11] defined carrying capacity as "a measure of the tolerance a site or building are open to tourists activity and limit beyond which an area may suffer from the adverse impacts of tourism." TCC can also be defined as "the maximum number of people that use tourism site without unacceptable effect on environmental resources while meeting the demand" [12].

Chamberlin (1997) [13] defines it as "the level of human activity an area can accommodate without the area deteriorating, the resident community being adversely affected or the quality of visitors experience declining." Clark [14] defines carrying capacity as a "certain threshold level of tourism activity beyond which there will occur damage to the environment, including natural habitats." He also states that the "actual carrying capacity limit in terms of numbers of visitors or any other quota or parameter is usually a judgement call based upon the level of change that can be accepted, regarding sustainability of resources, satisfaction of resource users, and socio-economic impact" [14]. The TCC represents "the maximum level of visitor use that an area can maintain, that is, the limit of human activity: if this level is exceeded, the resource will deteriorate" [15].

The UN World Tourism Organisation (WTO) defines TCC as "the maximum number of people that may visit a tourist destination at the same time, without causing destruction of the physical, economic, socio-cultural environment and an unacceptable decrease in the quality of visitors' satisfaction." Tourism operations in protected areas need to be planned carefully and monitor regularly to ensure their long-term sustainability. Otherwise, such operations will have negative consequences and tourism will contribute to the further deterioration of these areas. Many of the protected areas have promoted tourism for their social, economic, and livelihood opportunities of the local residents [15–19].

Individual tourist destinations were studied assessing the TCC all over the world [20–24]. It has been suggested that development of a tourist destination should be based on their innate

capacities for tourism. TCC was considered as an appropriate tool for management and remains one of the most useful and applied techniques for tourism and recreation planning, if combined with other management tools [25, 26].

Coccossis and Mexa [6] showed that carrying capacity assessment remains a powerful concept that can be used for planning and management of sustainable tourism. Many studies calculated carrying capacity using physical, ecological, psychological, and economical approach. Because of expanding degree of environmental threat with growing tourism, a suitable method needs to be carried out and carrying capacity stays one of the applied and effective methods [27]. Hamed and Fataei [28] estimates the TCC to Fandoqloo forest in Iran using physical, real, and effective carrying capacities. Results of their study showed that each tourist spot has its specific priorities and the carrying capacity of each region differs according to the environmental conditions. Nghi et al. [23] assessed the environmental carrying capacities for Phong Nha-Ke Bang and Dong Hoi using three basic components: ecological, economic, and social. The authors have calculated the TCC in Dong Hoi and Phong Nha centers by using the adjustment from physical carrying capacity (PCC) to real carrying capacity (RCC) based on various limiting factors such as infrastructure and management capacities. Their results show that Dong Hoi center has the highest TCC and Phong Nha has a lower TCC than other centers in Quang Binh.

Lagmoj et al. [29] in their study evaluated TCC in three ways viz., PCC, RCC, and ECC, and found that "ECC is in low range due to lack of required facilities and infrastructures as well as manpower for management and providing tourism services for tourists." They estimated the "PCC in Khorma forest as 3712 persons/day while RCC, considering limiting factors including the number of very hot days and the number of wet days, is 2001 persons/day. The ECC, taking the management capabilities including the number of manpower and the budget, 69 persons/day was calculated for Khorma forest". Armin and Calichi [30] in their study of PCC, the factors viz., tourist flows, the size of the area, the optimum space available for each tourist and the visiting time, were considered. Their results showed that the total visitors to the park in 2012 were 220 visitors per day that actual average park visitation are higher than the estimated carrying capacity and stated that the expanding recreational use would affect production and other forest benefits in the long term and suggested that a recreational forest use plan must be adjusted by the planner to keep the park more exploiting.

3. Andaman and Nicobar Islands (ANI)

The ANI form an important group of oceanic islands, situated in the Bay of Bengal, extending between 92° to 94° East and 6° to 14° North latitude, with rich biodiversity and high degree of endemism. It is presumed that these islands had a former land connection from Cape Negris at south part of Burma to Achin Head (Cape Pedro) in Andalas (Sumatra). Since pre-historic times, these islands were the home of aboriginal tribes. The vulnerable tribal groups who have been identified in the Andaman group of islands are the Great Andamanese, Onges, Jarawas, and Sentinalese, all of Negrito origin, while the tribes in the Nicobar group are the Nicobarese and Shompens, both of Mongloid origin. These islands have the total geographical area of 8249

km^2 and total coastline of 1962 km. These islands have been designated as one of the "Endemic Bird Areas" of the world [31–35].

"The Chinese knew of these islands over a thousand years ago and called it the 'Yeng-t-omag' in the First Millenium" [36]. These islands also find a place in the first map of the world drawn by Ptolemy, the renowned Roman geographer during the second century [36]. The famous Forester Champion has passionately remarked, "If tropical rain forests are to be seen in their pristine glory anywhere in the world, it is in the Andamans." The forests are quite rich with tropical evergreen, semi-ever green, moist-deciduous and littoral forests, mangroves, bamboo, and cane brakes. Mr. Jacques Coustoue, the famous marine explorer, who made a film on these islands titled "The Invisible Islands," said that he had never come across such clear waters during his many voyages across the globe, as in Andaman he could see live corals even at a depth of 60–100 m off the Narcondam Islands.

To preserve the rich natural, cultural, and wilderness areas of the ANI, the UT Administration is bringing ecotourism policy guidelines. A tourism management plan was prepared for various islands of the UT of A&N by the MoT, GoI, in 2003, indicating the potential tourism sites and recommending various options for the development of the tourism sector keeping in view of environmental protection. In a study conducted by Sridhar et al [37], it was observed that tourism sites in Andaman region exhibit a cluster distribution pattern. They suggested that tourism activities need to be promoted and expanded in other potential areas of Andaman through the establishment of necessary infrastructure. However, there have been little or no study on assessing the TCC of these islands. The main objective of this paper is to assess the recreational carrying capacity of some popular beaches around South Andaman by means of assessing the PCC (assuming that every beach has a limiting size of people that it can accommodate), RCC, and the effective carrying capacity (ECC).

4. South Andaman Islands

The South Andaman Island is the third largest island in the island group, located at latitude of 11° 47′N and longitude 92° 39′E and immediately south of Middle Andaman Island, from which it is separated by a narrow channel, a few hundred meters wide. The island is 93 km long and 31 km in width with an area of 1348 km^2. According to 2011 Census, the total population of the South Andaman District is 238,142, of which South Andaman Island (part) of Ferragunj Tehsil has a population of 53,560 and South Andaman island (part) of Port Blair Tehsil is 155,937. The town of Port Blair, the administrative headquarters of the Union Territory of the ANI, is situated at the south east coast of South Andaman. The population at Port Blair is steadily increasing. The main tourist season in the region is between the months of November and April. Being the entry point, Port Blair has a constant stream of visitors and tourist accommodation facilities are available both of the government and private sector.

5. Methodology

In the present study, the methodology followed for carrying capacity assessment is based on Cifuentes's methodology [9]. This framework developed by Cifuentes [9] was also applied by several authors [15, 23, 26, 38–42]. This methodology was also followed by Ceballos-Lascurain (1996) for estimating protected area carrying capacity (IUCN Publication 1996 "Tourism, Ecotourism and Protected Areas"). This methodology is traditionally followed for the many TCC studies such as Zacarias et al. [26] for beach recreation. Sayan and Atifk [15] used this methodology for recreation carrying capacity of protected areas. The approach is to establish the capacity of an area for a maximum visits based on the physical, biological, and management conditions through the PCC, RCC, and the effective or permissible carrying capacity [39]. TCC is divided into the following levels:

5.1. Physical carrying capacity (PCC)

PCC is the maximum number of tourists that can physically fit into or onto a specific area, over a particular time.

$$PCC = A / Au \times Rf$$

where PCC is the physical carrying capacity; A is the size of the study/visited area; Au, area required per user; Rf, rotation factor, is the number of visitor visiting per day.

An optimum area required per tourists (Au) is 5 m^2.

Rf = daily open period / average time of visit

Rf = 12 hours /3 hours

Rf = 4

5.1.1. Geospatial techniques

The area between the shoreline and landward extent of the sandy beach was taken for estimating the PCC. The satellite images of the LISS IV for the year 2013 with spatial resolution of 5.8 m were used for calculation of the beach area along with extensive field verifications. Onscreen digitization of beaches was made using visual interpretation techniques. The field surveys were carried out using GPS track mode in each of the beaches for calculating exposed areas of beaches during high and low tides.

5.2. Real carrying capacity (RCC)

The RCC was determined using equation

$$RCC = PCC \times (Cf1 \times Cf2 \times Cf3 \dots Cfn)$$

where RCC = real carrying capacity; PCC = physical carrying capacity.

Cf1…Cfn = correction factors. The correction factors were determined using the equation

$$Cfx = 1 - Lmx \,/\, Tmx$$

where Cfx = correction factor of variable x, Lmx = limiting magnitude of variable x,

$$Tmx = total\,magnitude\,of\,variable\,x.$$

The correction factors are obtained by considering the biophysical, environmental, ecological, social, and management variables. Tourism is dependent on nature, so some variables are considered as correction factors for this study which include rainfall, sunshine, strong winds, cyclone, and beach quality. These factors limit the tourism activities and measurement of the sustainability level of a tourist destination [9, 39]. Therefore, correction factors are also known as limiting factors of tourism. Calculations of correction factors for different limiting variables are described below.

5.2.1. Correction factors

5.2.1.1. Rainfall (Cf1)

The ANI are situated in the equatorial belt and experiences warm and moist tropical climate. These Islands are exposed to both the monsoons, viz. Southwest monsoon from May to September and northeast monsoon from October to December. The average rainfall period of the ANI is 152 days in a year [43, 44]. The total magnitude is the total number of days available in a year (365 days). The correction factor for rainfall was determined by:

$$
\begin{aligned}
Cf1 \quad &= 1 - Lmx \,/\, Tmx \\
&= 1 - 152 \text{ days} \,/\, 365 \text{ days} \\
&= 1 - 0.4164 \\
&= 0.5835
\end{aligned}
$$

5.2.1.2. Strong wind (Cf2)

In ANI under normal condition, the wind speed is fairly constant (9.5 km/h) but during cyclonic events it may go as high as 200–240 km/h. The Islands receive north-easterly wind between the month of May and October, during the time wind speed may exceeds 25 km/h, but the usual range is 5–15 km/h in different months [43, 44].

$$
\begin{aligned}
Cf2 \quad &= 1 - Lmx / Tmx \\
&= 1 - 62 \text{ days} / 365 \text{ days} \\
&= 1 - 0.1698 \\
&= 0.8301
\end{aligned}
$$

5.2.1.3. Excessive sunshine (Cf3)

Sunshine is the most important factor for beach tourism. In ANI, the months of March to May are considered as summer season. During the dry summer period, ANI has recorded the highest temperature. High temperature is recorded consistently during summer between 11 am and 3 pm. This high sunshine may lead to sunburn so the tourist arrival in this time period is almost negligible. Thus, excessive sunshine in the summer season can be considered as a limiting factor for the study area. The limiting magnitude for this parameter was determined as 92 days × 4 hours = 368 hours of excessive sunshine per year. The total magnitude was determined as the total day of the year i.e. 365 days × 12 hours = 4380 hours. Therefore, the correction factor for excessive sunshine was determined as:

$$
\begin{aligned}
Cf3 \quad &= 1 - Lmx / Tmx \\
&= 1 - 368 \text{ hours} / 4380 \text{ hours} \\
&= 1 - 0.02840 \\
&= 0.916
\end{aligned}
$$

5.2.1.4. Cyclone (Cf4)

Cyclone is also an important correction factor that rarely occurs during tourism seasons. The wind speed in normal condition is fairly constant (9.5 km/h) but during cyclonic events wind speeds as high as 200–240 km/h are prevalent. Generally in ANI, monsoon (between May and November) is one of the important limiting factors of tourism. Island to island ferry services and various tourism activities are affected by cyclonic storms during these months. The limiting magnitude for this parameter was determined as 61 days, the total magnitude was 365 days, and the correction factor for cyclone was calculated by

$$
\begin{aligned}
Cf4 \quad &= 1 - Lmx / Tmx \\
&= 1 - 61 \text{ days} / 365 \text{ days} \\
&= 1 - 0.1671 \\
&= 0.8328
\end{aligned}
$$

5.2.1.5. Beach quality (Cf5)

Beach quality is one of the most important parameters which may put direct impact on the quality of beach tourism. Beach quality has negative impact on the tourist's mind and may reduce the satisfactory level of tourists. Beach quality assessment was done taking reference from Nghi et al. [23] who used various geological criteria namely tide, near shore current, mud/ sand, thickness of sand layer, slope, clean sand, and quality of sea water. For the present study,

the beach quality assessment was carried out based on seven parameters, namely, beach materials, beach slope, tide action, beach length, beach color, litter, and seawater quality. The thickness of sand could not be measured. The results of beach quality assessment and correction factor for beach quality were determined separately for all the beaches chosen for the study. The Cf5 varies among different beaches and the results are shown in **Tables 1** and **2**. The estimation for beach quality for South Cinque Island is given below as an example.

$$
\begin{aligned}
Cf5 &= 1 - Lmx / Tmx \\
&= 1 - 2 / 7 \, parameters \\
&= 1 - 0.29 \\
&= 0.7142
\end{aligned}
$$

Island		Area (ha)	A = Area (m)	A/Au	PCC	Correction factors					Cf	RCC	Mc	ECC
						Rain fall	Strong wind	Beach quality	Sun shine	Cycl one				
South Andaman (Port Blair surroun dings)	South Cinque	6.27	62,720	12,544	50176	0.58	0.8	0.71	0.91	0.83	0.25	41,646	0.37	15424
	North Cinque	4.26	42,607	8521	34,085	0.58	0.8	0.86	0.91	0.83	0.30	28,291	0.37	10,478
	Chidyatapu	0.90	8996	1799	71,97	0.58	0.8	0.86	0.91	0.83	0.30	5973	0.74	4425
	Jolly Buoy	2.33	23,272	4654	18,618	0.58	0.8	0.86	0.91	0.83	0.30	15,453	0.56	8585
	Barabalu	2.56	25,563	5113	20,450	0.58	0.8	0.57	0.91	0.83	0.20	16,974	0.22	3772
	Burmanala	2.49	24,912	4982	19,930	0.58	0.8	0.43	0.91	0.83	0.15	16,542	0.22	3676
	Wandoor	3.80	37,971	7594	30,377	0.58	0.8	0.86	0.91	0.83	0.30	25,213	0.85	21,478
	Carbyns Cove	1.48	14,754	2951	11,804	0.58	0.8	0.57	0.91	0.83	0.20	9797	0.67	6531
	Kurmadera	5.90	58,977	11,795	47,182	0.58	0.8	0.71	0.91	0.83	0.25	39,161	0.19	7252
	Ross Island	0.20	2041	408	1632	0.58	0.8	0.43	0.91	0.83	0.15	1355	0.33	452
	Badagadi	3.78	37,802	7560	30,242	0.58	0.8	1.00	0.91	0.83	0.35	25,101	0.70	17,570
	Jahaji Dera	11.05	11,0500	22,100	88,400	0.58	0.8	0.70	0.91	0.83	0.27	73,372	0.19	13,941
	Colinpur	1.26	12,612	2522	10,089	0.58	0.8	0.57	0.91	0.83	0.20	8374	0.19	1551
	North Bay	1.03	10,326	2065	8261	0.58	0.8	0.43	0.91	0.83	0.15	6856	0.81	5587
	Shoal Bay	1.87	18,681	3736	14,944	0.58	0.8	0.43	0.91	0.83	0.15	12,404	0.07	919
	Red Skin	0.90	9000	1800	7200	0.58	0.8	0.81	0.91	0.83	0.28	5976	0.78	4661
	Total	**50.07**	**50,0733**	**10,0147**	**400,587**							**33,2487**		**12,6301**

PCC = physical carrying capacity; Cf = correction factor; RCC = real carrying capacity; Mc = management capacity; ECC = effective carrying capacity.

Table 1. Tourism carrying capacity of beaches of South Andaman.

Island	Beach type	Beach quality							Total	Estimated
		Material	Slope	Tide	Beach length	Beach Colour	Litter	Quality of Water		
South Andaman (Port Blair surroundings)	South Cinque	Sandy beach with exposed Corals	+	+	−	−	+	+	+	2/7	0.71
	North Cinque	Sandy beach, corals	+	+	−	+	+	+	+	1/7	0.86
	Chidya tapu	Sandy beach, corals	+	+	+	+	+	−	+	1/7	0.86
	Jolly Buoy	Sandy beach, corals, mangroves	+	+	−	+	+	+	+	1/7	0.86
	Barabalu	Sandy beach, Corals	+	+	−	+	−	+	−	3/7	0.57
	Burmanala	Sandy beach, corals, mangroves	−	−	−	+	+	−	+	4/7	0.43
	Wandoor	Sandy beach with coral deposits	+	+	+	+	+	−	+	1/7	0.86
	Carbyns Cove	Sandy beach, Corals, Seaweeds, Mangroves	+	+	−	+	+	−	−	3/7	0.57
	Kurmadera	Sandy beach with exposed rocky shore	−	+	+	+	−	+	+	2/7	0.71
	Ross Island	Pebble beach with sand gravels and coral deposits	+	−	−	−	+	−	+	4/7	0.43
	Badagadi	Sandy beach, mangroves, with coral deposits	+	+	+	+	+	+	+	0/7	1.00
	Jahaji Dera	Sandy beach	+	−	−	+	+	+	+	2/2	0.70
	Colinpur	Sandy beach and	+	+	−	+	−	−	+	3/7	0.57

Island	Beach type	Beach quality							Total	Estimated
		Material	Slope	Tide	Beach length	Beach Colour	Litter	Quality of Water		
	exposed rocks									
North Bay	Sandy beach with exposed rocky shore	+	−	−	+	+	−	−	4/7	0.43
Shoal Bay	Sandy beach, corals	+	−	−	+	−	+	−	4/7	0.43
Red Skin	Sandy Beach, Corals	+	+	+	+	−	+	+	1/7	0.81

'+' denotes good quality; '−'denotes low quality.

Table 2. Beach quality assessment matrix of beaches of South Andaman.

5.3. Effective carrying capacity (ECC)

ECC is the maximum number of tourists that a site can sustain, given the management capacity (Mc) available. The Mc indicates the present condition of tourism management in the respective beaches and was estimated based on the available infrastructure, facilities, and amenities. Zacarias et al. [26] stated that the ECC is a result of the combination of the RCC with the Mc of the area, as described by the following equation:

$$ECC = RCC \times Mc$$

where ECC = effective carrying capacity; RCC = real carrying capacity; Mc = management capacity. Mc was determined using infrastructure and equipment's available, assessed by means of tourist perception and evaluation during the survey period.

6. Results and discussion

Estimation of total area, area required per tourists, PCC, RCC, and ECC for various beaches of the South Andaman was worked out based on the methodology described above and the results are shown in **Table 1**. The beach quality assessment of matrix of each locations and the management measure analysis are given in **Tables 2** and **3**, respectively. **Figures 1** and **2** provide the assessment of TCC for beaches of Port Blair region. The beaches chosen for the present study are the existing tourism sites declared by the Andaman Administration.
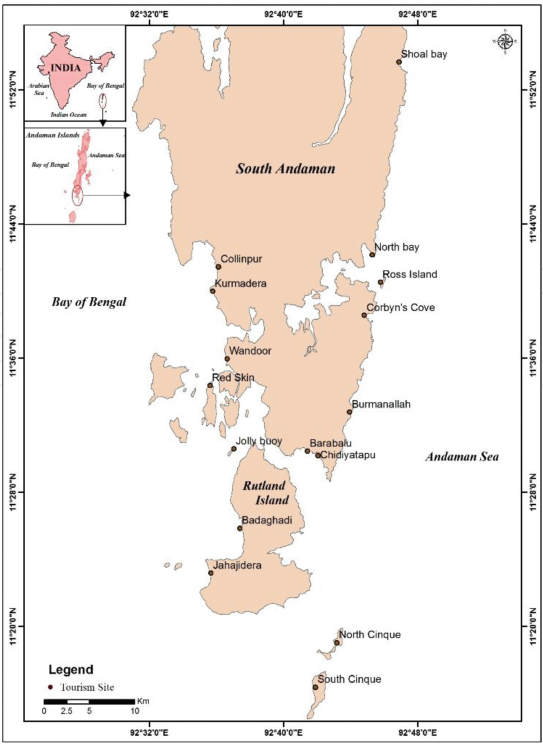
Figure 1. Study area map showing the locations of the beaches in South Andaman.
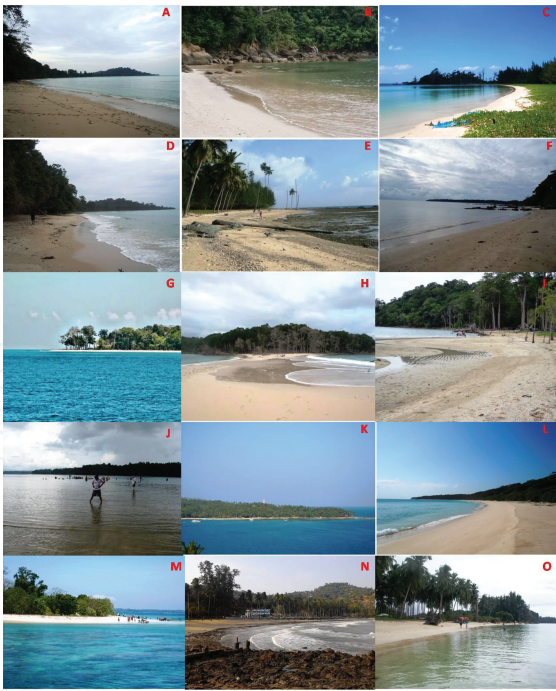

Figure 2. Tourist favorite beaches in South Andaman.A—Shoal Bay; B—Colinpur; C—Jahaji Dera; D—Barabalu; E—Burmanala; F—Kurmadera; G—South Cinque Island; H—North Cinque Island; I—Chidyatapu; J—Red Skin; K—North Bay; L—Badagadi; M—Jolly Buoy; N—Carbyns Cove; O—Wandoor.

Island		Management activities			Tourism activities							Esti.	Mc
		Transpor tation	Security/s Safety mMeasures	Dining/ refresh ment	Bay watch	Swim ming	Snorkel ling	Scuba	Kaya king	other water sports		Credit	
South Andaman (Port Blair)	South Cinque	+	−	−	+	+	+++	+++	+	−		10	0.37
	North Cinque	+	−	−	+	+	+++	+++	+	−		10	0.37
	Chidyatapu	++	++	+	+++	+++	+++	+++	++	+		20	0.74
	Jolly Buoy	+	+	−	+++	+	+++	+++	++	+		15	0.56
	Barabalu	+	−	−	+++	+	+	−	−	−		6	0.22
	Burmanala	+++	+	+	+	−		−	−	−		6	0.22
	Wandoor	+++	+++	++	+++	+++	+++	+++	++	+		23	0.85
	Carbyns Cove	+++	+++	+++	+++	++	−	−	+	+++		18	0.67
	Kurmadera	+	−	−	+++	+	−	−	−	−		5	0.19
	Ross Island	++	+	++	++	−	−	−	+	+		9	0.33
	Badagadi	+	−	−	+++	+++	+++	+++	+++	+++		19	0.70
	Jahaji Dera	+	−	−	+++	+	−	−	−	−		5	0.19
	Colinpur	++	−	−	++	+	−	−	−	−		5	0.19
	North Bay	++	++	++	+++	++	+++	+++	++	+++		22	0.81
	Shoal Bay	−	−	−	++	−	−	−	−	−		2	0.07
	Red Skin	++	++	+	++	+++	+++	+++	++	+++		21	0.78

+++ = Fine; ++ = Moderate; + = Low; − = Not available.

Table 3. Management measure analysis and tourisms activities for beaches of South Andaman.

PCC includes the maximum number of tourists that can physically be present at a certain time and place and shall not exceed this range. Rotation factor is considered as an important indicator for the development of management strategies for beach tourism, as it influences the tourism capacity of a certain place. The numbers of the PCC are only theoretical and RCC was calculated to check the extreme value of PCC considering some correction factors. Correction factors that have been considered for this study include rainfall, strong wind, sunshine, cyclone, and beach quality. Excluding beach quality, all correction factors considering for RCC are same on all over the islands.

The total RCC of Port Blair area is 332,487 visitors/day, which in other words is the maximum permissible number of people that should be allowed in the concerned area. Port Blair region (including Ferragunj) spreads over an area of 3106 km² with ~45% of ANI's population. Port Blair, besides being the only town in ANI, is also the only entry point. Being the capital city,

Port Blair houses all the government and administrative offices of the UT. The main tourist season in the region is between the months of November and April. Port Blair has a constant stream of visitors (almost all the current tourists arrivals happen through Port Blair). The tourists arrival for the year 2013–2014 was 258,418 (with 17,811 foreign tourists). This translates to an average of ~700 visitors a day.

The places of tourist interest in the south Andaman district include place of historical interest such as Cellular Jail and Rose Island (Port Blair), creeks, beaches, trekking, anthropological museum, forest museums, emporiums and garden and parks. Cellular Jail is located on the North East of Port Blair town was completed in 1906 and is a National Memorial. It derives its name for its individual cells for the solitary confinement of India's freedom fighters and prisoners. Ross Island was the original capital during the British regime and this tiny island (0.6 km^2 area) is 10 minutes ferry journey from Port Blair. This island has remnants of the ball room, chief commissioner's house, government house, church, cemetery, hospital, bakery, press, swimming pool, and troop barracks all in extreme dilapidated condition reminiscent of bygone British era. Chatham Saw Mill is the Asia's largest saw mill and is located North of Port Blair and in the Chatham Island. The mill is the storehouse of a variety of wood species. Carbyn's Cove is a beach located 7 km from Port Blair. Historical Japanese bunkers can be seen here. Snake Island is also located in the vicinity and it is recommended for scuba diving. Red Skin and Jolly Buoy Islands are located southwest of Port Blair and can be approached from Wandoor jetty. The Mahatma Gandhi National Park, it offers tourist attractions on coral marine life which can be best viewed with the help of the glass bottomed boats. The North Cinque Island is located south of Port Blair and linked to the South Cinque Island by a sand bar. North Cinque Island has a wildlife sanctuary and underwater coral is the main interest of the tourists.

The Mc was estimated for various beaches based on the analysis of the tourism activities and facilities available at each tourist destination. It varied among the different destinations ranging from 0.07 to 0.85. It is observed that the beaches of the Port Blair region, namely, Shoal Bay, Colinpur, Jahaji Dera, Burmanala, Barabalu, Kurmadera, and Cinque Islands, with low Mc (<0.5), may be given priority for infrastructure development such as transportation and hotel facilities and tourist's safety to be ensured. The other beaches (having Mc > 0.5) such as Chidyatapu, Red Skin, North Bay, Badagadi, Wandoor, Carbyns Cove, and Jolly Buoy have adequate facilities for tourism operations and such activities need to be continued (**Table 3**).

Beach quality is one of the most important parameters, which may have direct impact on the quality of beach tourism as it has negative impact on the tourist's mind and may reduce the satisfactory level of tourists. The beach quality of the study site was examined based on several indicators viz., material of the beaches, slope, tide, beach length, beach color, litter, and quality of water. It was observed that the beaches of Badagadi, Jahaji Dera, Chidaytapu, Jolly buoy, Wandoor, Red Skin, Kurmadera, and Cinque islands (Mc > 0.7) have good beach quality, support tourism activities (**Table 2**).

7. Effective carrying capacity (ECC)

Analysis indicates that each level constitutes a corrected capacity level of the preceding level and showed that PCC is greater than the RCC and RCC is greater than the ECC. ECC seems more acceptable than two other types of carrying capacity and is useful for development of policy for beach tourism management, as it indicates the optimum number of tourists that should be allowed on the beach with existing conditions and Mc. The total ECC for beaches of Port Blair area is 126,301 visitors/day. But the available tourist accommodation in these islands is well below the ECC of the region and needs to be increased considering the overall environmental quality. Tourist accommodation facilities are available both from the government and private sectors. There are approximately 2840 beds available comprising 16 private hotels affiliated to State Tourism Department, 19 government accommodation affiliated to State Tourism Department, and 45 budget accommodation affiliated to State Tourism Department [45]. There is a need for comprehensive survey on existing accommodation facilities at ANI to update the status. The tourist arrival at ANI is constantly increasing every year. The total tourist arrivals including domestic and foreign, for the year 2013–2014, is ~2.5 lakhs and it was around 9596 in the year 1980 and 33716 in the year 1990 and 86,116 in the year 2000. The international tourist arrivals have grown at a compounded annual growth rate of 4.1% p.a. over the last 20 years. The Port Blair Master Plan—2030 prepared by the A&N Administration states that the average occupancy rate of organized accommodation has hardly reached 65% and the peak occupancy rate records 2667 beds as against available 2837 beds (94%). It also states that tourism has not reached its full potential in generation or acceleration of economy in the Island though it offers vast scope for development. Considering the total ECC as well as the yearly tourist flow (2.5 lakhs approximate), it can be concluded that the TCC is preserved to accommodate a higher level of yearly tourist infiltration with adequate accommodation provisions and management facilities in future. The assessment of TCC is also being refined by us, based on local socio-economic, cultural, and ecological considerations to achieve a balance between ecotourism development and safeguarding ecological conservation.

8. Conclusion

Assessment of carrying capacity is imperative for the coastal zone of India which is facing rapid changes due to various developmental activities. Broadly, the concept of carrying capacity refers to the ability of a system to support an activity or feature at a given level. Coastal zones provide a variety of services and tourism is being practiced increasingly along many coastal states of India. The tourism industry has environmental, social, cultural, and economic impacts. Tourism carrying capacity assessment remains one of the most useful tool when measures taken for management of coastal areas. Overall measuring TCC does not have to lead to a single number (threshold), like the number of visitors. Even when this is achieved, this limit does not necessarily obey to objectively, unchangeable, everlasting criteria. An upper and a lower limit of TCC can be of more use than a fixed value. They are dependent on

technology, preferences, and the structure of production and consumption. They are also varying with the changing nature of interaction between the physical and biotic environment.

The present assessment of the TCC for the beaches of south Andaman showed that the tourism activity is in lower level with its carrying capacity. This type of carrying capacity assessment can be used as an input into the regular planning process. The ANI can be promoted for high-value low-volume eco-friendly and environmentally sustainable tourism. There are other issues related to water supply, sewage disposal, electricity and energy which are to be given additional importance on a sustainable basis while planning for tourism development in these islands, as tourism activity will add additional burden with regard to available infrastructure and resources. The present requirement of water for Port Blair is 28.80 MLD. At present, only 90% of the total demand is available for supply. Sewerage and drainage system in Port Blair and surrounding region is challenges in terms of land availability, rainfall runoff to the sea because of the terrain. Sewage discharge has been projected to be 45 MLD for Port Blair surrounding region by the year 2041 [45]. A comprehensive analysis on land use and water availability, fresh water management, alternative sewage disposal methods considering the island sensitive ecology, biodiversity extent and status, seawater quality and pollution level for every island would further help for developing better tourism development strategies. The Administration should ensure that the tourist resorts and homes and related establishments should promote (i) self-generation of electricity using renewable energy sources such as solar panels, bio-gas systems, etc.; (ii) development of additional freshwater resources through rain water harvesting; and (iii) provisioning for sewage treatment plants.

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