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Assessing social-ecological system carrying capacity for urban small island tourism: The case of Tidung Islands, Jakarta Capital Province, Indonesia

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A R T I C L E I N F O

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A B S T R A C T

The use of small islands for marine tourism is one of Indonesia's development strategies. The carrying capacity (CC) of islands is an essential parameter for achieving sustainable tourism management and development. CC can be incorporated into policy models and management strategies to reduce the impact on tourist areas. This study aims to assess the suitability of using social-ecological system CC (SES-CC) model to calculate optimal CC, using the Tidung Islands of Jakarta, the urban capital city of Indonesia as a case study. The SES-CC was assessed per tourist activity, using the impact perspective of the social-ecological system of the islands through a coupled model of social CC and ecological CC. The social CC was estimated using the perceptions of tourists, and the ecological CC was estimated using the physical CC. The real CC and effective CC were then estimated based on correction factors. Finally, a simple double attribute weighting method is used to develop coupled Social-Ecological System CC (SES-CC). A small urban island of Jakarta Capital Province, namely the Tidung Islands, was used for testing the method. The results will be used to improve sustainable tourism management in the islands, particularly national coastal and marine tourism policies.

1. Introduction

"Ecotourism" or "sustainable tourism" has for a long time been a label used for small island development programs. Sustainable tourism assessment requires indicators and tools for management and decision-making integrated with sustainable development principles (Torres-Delgado and Palomeque, 2014). Nevertheless, tourism is regularly used to encourage economic growth, despite ecological and social limitations (Higgins-Desbiolles, 2018). Regional economic activities are strongly associated with environmental carrying capacity because economic activities are influenced by ecological systems that produce various services (Arrow et al., 1995). The number of tourists is generally increasing in relation to tourism development (Wang et al., 2020). Small islands are sensitive and vulnerable; hence, sustainable development principles are vital (Adrianto and Matsuda, 2002; Kurniawan et al., 2016, 2019). However, measuring sustainability requires intricate knowledge of existing systems (i.e., social-ecological systems), which differ for each location (Franzoni, 2015), including the difference between rural and urban regions (Torres-Delgado and Palomeque, 2014).

The carrying capacity (CC) is an essential consideration for achieving sustainable tourism management and development, making it easier to communicate with relevant stakeholders and managers (Arrow et al., 1995; Cupul-Magaña and Rodríguez-Troncoso, 2017; Jurado et al., 2013; Ma et al., 2017; Sousa et al., 2017; Zelenka and Kacetl, 2014). The United Nations World Tourism Organization ((UNWTO 2018)) describes "tourism CC (TCC) as the maximum number of people that may visit a tourist destination at the same time, without causing destruction of the physical, economic, and sociocultural environment and an unacceptable decrease in the quality of visitors satisfaction." In addition, TCC can be defined as the ability of a destination to absorb and manage increasing

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tourism activities without degradation in the tourism sector of the urban economy (Wang et al., 2020). The TCC concept creates a satisfactory experience for tourism with an acceptable or minimum impact on the resources of the area, with both social and ecological implications (Cupul-Magaña and Rodríguez-Troncoso, 2017). Explicitly, managers must understand the CC of the area used for tourism (Chen and Bau, 2016; Higgins-Desbiolles, 2018) to and understand the impacts caused in the tourism area and formulate policy models and management strategies based on CC (Sharma, 2016).

The CC is not new in research or policy management for coastal resources and small islands. The concept emerged in the 1930s and evolved into a widely used methodology with various approaches, such as physical, social, and impact (Butler, 1996; Getz, 1983; O'Reilly, 1986). Presently, the assessment of TCC is more comprehensive; it uses a

Table 1
Several studies of tourism carrying capacity.

No.	Authors	Measurement object	Methods/indexes	Geographical applications	Dimensions	Main variable/indicator
1	Wang et al. (2020)	Cities	Tourism economy carrying capacity; Resource carrying capacity system; Ecological carrying capacity system; System dynamic model	China	Economy; Resource; Ecological	Per capita tourism income; Tourism labor force; Tourism capital; Tourism infrastructure; Transportation; Per capita GDP; Tourism resource; Water supply; Land supply; Ecological resilience; Environmental pollution; Environmental treatment
2	Corbau et al. (2019)	Beach	Physical carrying capacity; Real carrying capacity; Effective carrying capacity	Asinara Island, Italy	Physical area; Social	Area; Number of tourist; Correction factor
3	Cupul-Magaña and Rodríguez-Troncoso (2017)	Coral reef	Physical carrying capacity; Real carrying capacity; Effective carrying capacity	Small island, Islas Marietas National Park	Physical area	Area; Number of divers; Number of snorkelers; Correction factor
4	Sousa et al. (2017)	Estuarine beaches	Recreational carrying capacity	Amazon Macrotidal Mangrove coast of the coastal zone of Pará	Physical area	Area; Water quality; Environmental quality; Ecological quality; Quality of services
5	Chen and Bau (2016)	Beach	Fuzzy analytical hierarchy process (AHP)	Nanwan, Taiwan	Environmental	Cleanliness of beach; Safety; Beach protection and management; Facilities and services
6	Chen and Teng (2016)	Beach	Limits of acceptable change (LAC); Social carrying capacity	Baisha, Taiwan	Social	Cleanliness of beach; Safety; Availability of information; Sediment and habitat management; Density
7	Cisneros et al. (2016)	Beach	Physical carrying capacity; Real carrying capacity; Effective carrying capacity; Image analysis	Monte Hermoso, Argentina	Physical area	Area; Number of visitors
8	Nakajima and Ortega (2016)	City	Emergy analysis; Ecological footprint	Ibiúna, Brazil	Social	Consumption of resources
9	Viñals et al. (2016)	Small island: Beach and heritage buildings	Recreational carrying capacity	Small Mediterranean Islands	Physical area	The physical condition of the object; Island morphology; Area; Population; Sensitive ecosystem; Potential impact; Social restrictions; Biological climate and safety
10	Zhang et al. (2016)	Coral reef	Ecological carrying capacity	Mabul Island, Malaysia	Ecology	Coral cover; Coral growth forms; Coral damage
11	Jurado et al. (2013)	Beach	Social Carrying Capacity	Costa del Sol, Spain	Social	Crowding; Attitude
12	Salerno et al. (2013)	Mountain area	Social carrying capacity; Environmental carrying capacity	The Sagarmatha (Everest) National Park and Buffer Zone (SNPBZ), Nepal	Social; Environment	Crowding; Water quality; Energy management; Solid waste management; Local tradition; Satisfaction
13	Jurado et al. (2012)	Beach	Tourism sustainability; Multi-criteria evaluation techniques	Costa del Sol, Spain	Social; Economic; Ecological	Residents' satisfaction index; Tourist satisfaction index; Tourist spending; Social carrying capacity of residents; Social carrying capacity of tourists; Perception of future social carrying capacity of residents; Regulated places; Non-regulated places; Annual growth rate of regulated places; Annual growth rate of total tourist and residential places; Per capita rent; Gibbs-Martin index; Municipal budgets-Per capita income evolution; Municipal budgets-Per capita expenditure evolution; Profitability index; Beach stability; Morphodynamic index; Beach quality; Wealth landscape; Built-up areas in the first kilometer coastal strip; Ecological capital (vegetation and fauna); Waterproofing grade in potential tourist area; Indicator of potential tourist area
14	Zacarias et al. (2011)	Beach	Physical carrying capacity; Social carrying capacity; Effective carrying capacity	Praia de Faro, Portugal	Physical area; Social	Area; Rainfall; Strong wind; Sunshine; Temporal closure; Beach erosion

holistic and technocratic approach, and the variables used are also increasingly complex. However, the TCC of small urban islands is rarely discussed (Table 1). Nevertheless, tourists' perspectives are still needed and have to be developed into a basis for tourism suitability, management priorities, and management evaluation, although prior socioeconomic status, cultural ties, and experiences greatly influence environmental quality perceptions (Chen and Teng, 2016; Sharma, 2016). This improvement method is also a separate consequence, where CC analysis becomes more complicated, but is considered more accurate.

A well as measuring the number of people that a region can accommodate, TCC also studies the types of activities carried out and social-ecological impacts tolerable; it allows managers to minimize impacts to the environment, the tourism industry, and local communities (Cisneros et al., 2016; Jurado et al., 2012; Salerno et al., 2013; Zhang et al., 2016). CC in nature is not fixed or static and does not consist of simple correlations; therefore, it is not pragmatic and cannot be generalized (location specific) (Arrow et al., 1995; Chen and Bau, 2016; Cupul-Magaña and Rodríguez-Troncoso, 2017; Sharma, 2016; Zelenka and Kacetl, 2014). O'Reilly (1986) explained that CC is an essential indicator of the threshold needed to remove uncontrollable obstacles. Furthermore, small urban islands are naturally complex social-ecological systems, especially from an impact perspective.

Coastal and marine tourism to small islands was put forth as one of the strategic national economic development plans in Indonesia in Presidential Regulation No. 18/2020 in the Midterm National Development Plan, 2020–2024. According to this document, tourism should be developed as an economic locomotive under Indonesia's maritime fulcrum, which is targeted to earn USD 30 billion in 2024, up from USD 19.3 billion in 2018 (BAPPENAS, 2019). Therefore, it is crucial to ensure that tourism activities are professionally managed, both socially and ecologically, by using CC. Moreover, tourism on small islands includes many tourist activities (Kurniawan et al., 2016, 2019). In this regard, this paper aims to calculate the value of optimal CC using a social-ecological system CC (SES-CC) model of the Tidung Islands of Jakarta, the urban capital city of Indonesia, as a case study to provide real evidence for SES-CC status in small islands. The SES-CC was assessed per activity to understand the tourism ecosystem services.

2. Case study – Tidung Islands

The Tidung Islands are located in the Seribu Islands chain in Jakarta Bay, North Jakarta, Indonesia (Fig. 1). Administratively, they are part of the special capital province of Jakarta. As a group of islands located in the country's capital city, the Tidung Islands are a favorite tourist destination among the urban people of Jakarta and the surrounding area. Popular attractions on the islands are beaches (including intertidal zones), with tourist activities including swimming, sightseeing, jet skiing, canoeing, kayaking, boating, and sunbathing, and coral reefs which have snorkeling and diving activities. The Tidung Island group consists of two islands, namely Tidung Besar and Tidung Kecil. Tidung Besar Island has an area of 63.96 ha and is a settlement island; whereas, Tidung Kecil Island is a conservation area of 20.57 ha. The two islands are connected by a bridge called *Jembatan Cinta* (Love Bridge) which is a tourism spot.

The population of the Tidung Islands continues to increase annually. In 2018, the population reached 4866 people, an increase of 6.08 % since 2015 (Statistics of Tidung Islands Sub-District, 2018). Using data

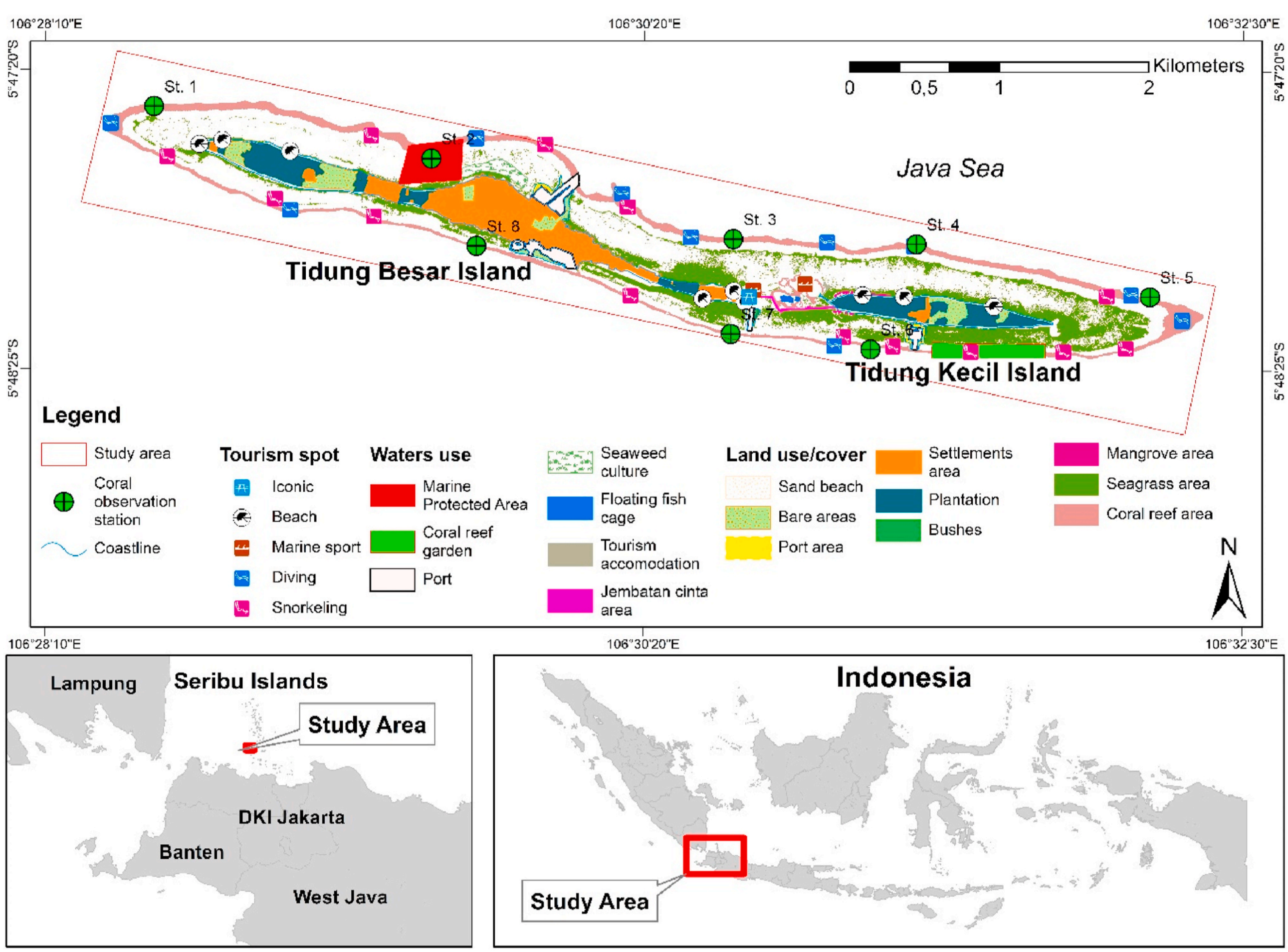

Fig. 1. Study area.

from the Tidung Island Sub-District (2018), the number of tourists visiting the islands in 2017 was 149,691, with the peak tourism seasons occurring around June and December. The peak day for tourist visits to the islands is on Saturdays and Sundays, with the highest daily number of visitors at 3207 (Table 2). This shows how overcrowded the Tidung Islands are during the peak tourism season.

3. Methodology – The SES-CC model

Three steps were required to create the SES-CC (Fig. 2). First, TCC from the social perspective, called social CC, was estimated. Second, ecological CC was measured. Finally, two SES-CC models were assessed to measure the optimal number of tourists from the perspective of coupled SESs.

3.1. Social carrying capacity model

Social CC is "the maximum level of use (in terms of numbers and activities) that can be absorbed by an area without an unacceptable decline in the quality of experience of visitors and without an unacceptable adverse impact on the society of the area" (Saveriades, 2000). In this study, social CC was assessed using the visitors' perception to the Tidung Islands. Data were gathered using questionnaires on weekdays and weekends with 74 tourists as selected respondents in total. The questionnaire included visiting motivation, the main tourist objects visited, the level of importance and satisfaction with the tourist attraction, the level of tourist acceptance to the level of crowds in a tourism area, and the minimum and optimum area requirements expected in one tourist location to obtain enjoyment and time spent on activities (Appendix 1).

Data were analyzed using descriptive statistical analysis and analysis of variance (ANOVA) at a p-value <0.05. The approach to the level of satisfaction and encounter acceptability were assessed to estimate the social CC. Simultaneously, area requirements and time spent was assessed to measure tourists' needs to achieve the expected pleasure and satisfaction.

Satisfaction assessment was based on a three-point Likert-scale questionnaire. Crowding analysis was performed using six photographs showing differing levels of people per ha. These photographs were (Photograph A), 50 (Photograph B), 100 (Photograph C), 200 (Photograph E), 300 (Photograph F), and 500 (Photograph F) people per ha, as described by Needham et al. (2008). Values for both the satisfaction and acceptance/crowding analysis were standardized based on the formula developed by Adrianto and Matsuda (2002). Additionally, in-depth interviews and focus group discussions (FGDs) were conducted with stakeholders to understand the structure and implementation of existing management, and to determine appropriate management strategies based on social CC.

3.2. Ecological carrying capacity model

Ecological CC is defined as "the maximum number of visits to an area based on the biological, physical, and management conditions of the area to withstand recreational use without unacceptable damage to its ecological components" (Zacarias et al., 2011; Zhang et al., 2016). Wang et al. (2020) also described the ecological CC as a visitor limit for maintaining ecological functions. Therefore, ecological CC was estimated using "the maximum number of visitors that can physically fit into a defined area over a particular time" or the physical CC (PCC) (Zacarias et al., 2011).

Ecological CC analysis was carried out in two stages. First, a suitability analysis was conducted to develop a suitability map, followed by PCC analysis. Suitability analysis was approved to estimate the suitable area for estimating the PCC, which measures the area available to support tourist activities. In this case study, because of the absence of marine spatial planning to allocate areas for tourism activities on the islands based on ecological and environmental conditions, we conducted a suitability analysis of tourism activities. Spatially, the ecological and environmental data was built based on WorldView-2 satellite image in year 2018. Field survey and ground checkpoint were conducted to evaluate beach characteristics, coastal water quality for physical parameters, and coral reef ecosystem based on study of Adrianto et al. (2019). The data analysis was based on the three main tourism activities of the Tidung Islands: beach, diving, and snorkeling. Suitability assessment was performed using a suitability index modified from Yulianda et al. (2010) and mapped using ArcMap 10.2.2. Second, we conducted PCC analysis to estimate the relationship between the time and duration of the visit with the available area. PCC was calculated based on the formula reported by Zacarias et al. (2011) and Corbau et al. (2019), in which the value of the area needed per user (Au) was modified from Yulianda et al. (2010) and adjusted to tourist perceptions.

3.3. Social-ecological system carrying capacity (SES-CC) model

The SES-CC was calculated by coupling the social CC and ecological CC, which involves a two-step calculation. First, correction factors (CFs) were applied based on the attractions and aspects of the tourism. CFs are independent variables limited tourism activities and affect the level of tourist sustainability of the area based on eco-environmental and social factors. The CF assessment was based on the model developed by Cupul-Magaña and Rodríguez-Troncoso (2017) and Zacarias et al. (2011). The CFs were measured by appraising the correlation coefficients and significance levels using qualitative analysis by considering the principles of safety, ecological sensitivity, and tourists' hospitality and satisfaction.

The CFs were applied based on the main tourism activities of small islands, that is, coral-based tourism (snorkeling and diving) and beach tourism. For snorkeling and diving tourism, the CFs were: (1) social factors, (2) fragility of coral reef lifeforms, (3) coral damage, and (4) weather conditions. Whereas, the CFs for beach tourism were: (1) social factors, (2) rainfall, (3) wind conditions, and (4) sunshine. Social factor data were gathered using questionnaires (Appendix 1), fragility and damage to coral reefs were obtained from primary data taken at eight observation stations in the Tidung Islands (Fig. 1) using the underwater photo transect (UPT) method (Giyanto, 2013). Data of weather conditions, rainfall, wind conditions, and sunshine were obtained from the Jakarta Capital Province Agency for Statistics in 2018 and from interviews with tourism actors. Calculations for the correction of social factors, weather, rainfall, strong winds, and sunshine were as follows (modified from Zacarias et al., 2011; Cupul-Magaña and Rodríguez--Troncoso, 2017; Corbau et al., 2019):

$$CF_x = 1 - \left(\frac{Lv_x}{Tv_x}\right) \quad (1)$$

where CF_x is the correction factor of variable x, Lv_x is the limiting value of variable x, and Tv_x is the total value of variable x. The correction factor for the fragility and damage of coral reefs was calculated using the following equation:

$$CF_x = 1 - Rc_x \quad (2)$$

where Rc_x is the reef condition of variable x, that is, fragile coral life form and coral damage.

The description of factors used in the assessment of CFs was given as follows:

1) Social factor. The CF for social aspects (CFsc) was assessed based on the enjoyment and satisfaction of tourists, both in groups and individuals. The CFsc value was calculated from the minimum area needed by individuals or groups of tourists (m^2) compared to the total area needed for tourism activities (m^2).

Table 2
The number of visitors by day visiting the Tidung Islands 2017 and 2018.

Date	2017												2018						
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
1	**1498**	123	118	610	291	112	**1848**	177	746	252	102	**1420**	706	107	165	201	240	561	507
2	**2679**	90	108	152	185	118	483	331	**938**	90	94	**1201**	266	186	202	192	457	231	603
3	481	394	190	319	153	176	532	236	404	131	554	85	707	742	**1104**	156	323	188	388
4	**832**	**887**	681	157	112	88	628	118	110	232	**1793**	117	210	168	146	191	477	96	582
5	274	110	145	261	197	97	757	**1997**	124	149	187	102	445	171	260	111	**1484**	153	250
6	659	234	197	182	**1493**	36	541	233	315	131	142	106	**1345**	97	122	213	507	75	668
7	**837**	163	101	216	150	71	459	170	213	**1829**	164	94	428	125	171	**1384**	253	111	**1764**
8	231	149	132	**775**	228	52	**1619**	189	210	254	227	203	121	53	68	190	364	88	435
9	179	102	116	189	391	79	316	237	**1442**	159	78	524	121	143	123	312	511	285	617
10	197	91	568	680	448	171	592	228	158	191	180	171	104	722	**956**	172	503	456	316
11	216	879	692	107	636	91	540	299	124	158	**1835**	100	93	101	170	253	680	535	544
12	143	110	251	627	236	119	370	**1333**	188	74	204	110	235	90	220	192	**1539**	538	309
13	127	134	225	197	**1536**	127	338	196	107	330	99	256	**1141**	145	169	619	498	**873**	393
14	**912**	121	165	**1868**	296	62	218	188	120	**1123**	130	125	248	215	214	**3087**	257	**1083**	**1420**
15	175	135	85	**963**	301	70	**1203**	130	272	233	116	196	162	140	83	240	166	**1244**	279
16	104	120	92	198	335	62	193	432	169	164	155	**918**	167	**1276**	326	272	207	**1743**	220
17	351	225	150	190	142	115	329	492	**1293**	85	374	188	164	**894**	**2749**	351	103	**2840**	211
18	215	410	**792**	223	152	120	189	402	118	80	**978**	202	249	205	92	237	68	**2702**	121
19	86	160	122	193	143	223	218	**1751**	241	169	152	338	143	111	142	245	171	**1512**	165
20	118	97	146	203	**1361**	158	156	192	98	245	82	215	662	142	117	526	118	**1044**	209
21	726	189	86	209	147	124	171	287	346	**788**	127	130	273	132	412	**1511**	61	460	**1092**
22	277	105	125	**1618**	253	289	948	186	387	197	133	305	209	149	187	141	55	**970**	385
23	220	63	138	**2258**	182	466	277	310	**967**	83	102	**1292**	128	243	163	218	49	**1799**	214
24	252	102	212	301	251	**747**	236	163	214	97	418	**1649**	112	582	**1099**	383	80	458	–
25	155	678	**1118**	230	241	**1125**	117	277	220	155	**1377**	700	82	170	320	248	49	475	–
26	185	139	457	412	161	**1435**	280	**1331**	108	71	220	504	240	204	258	181	167	257	–
27	376	105	255	187	205	**2616**	132	231	122	245	107	446	**878**	142	133	634	189	293	–
28	**1982**	76	183	108	74	**2552**	292	191	136	**1303**	21	457	137	158	233	**2173**	81	407	–
29	–	–	258	**1776**	140	**1854**	**1512**	134	139	90	105	415	195	–	164	**895**	116	500	–
30	–	–	109	**2492**	70	979	241	83	**1665**	74	144	**2145**	116	–	**2611**	700	92	**1825**	–
31	–	–	214	–	52	–	231	210	–	88	–	**3207**	113	–	**1073**	–	99	–	–
Total	14,487	6191	8231	17,901	10,562	14,334	15,966	12,734	11,694	9270	10,400	17,921	10,200	7613	14,252	16,228	9964	23,802	11,692

Source: Monograph of Tidung Island Kelurahan Pulau Tidung/Pulau Tidung Village (2018).
Note: Shaded block = over carrying capacity based on the SES-CC value of Tidung Island, that is, 747 visitors per day.

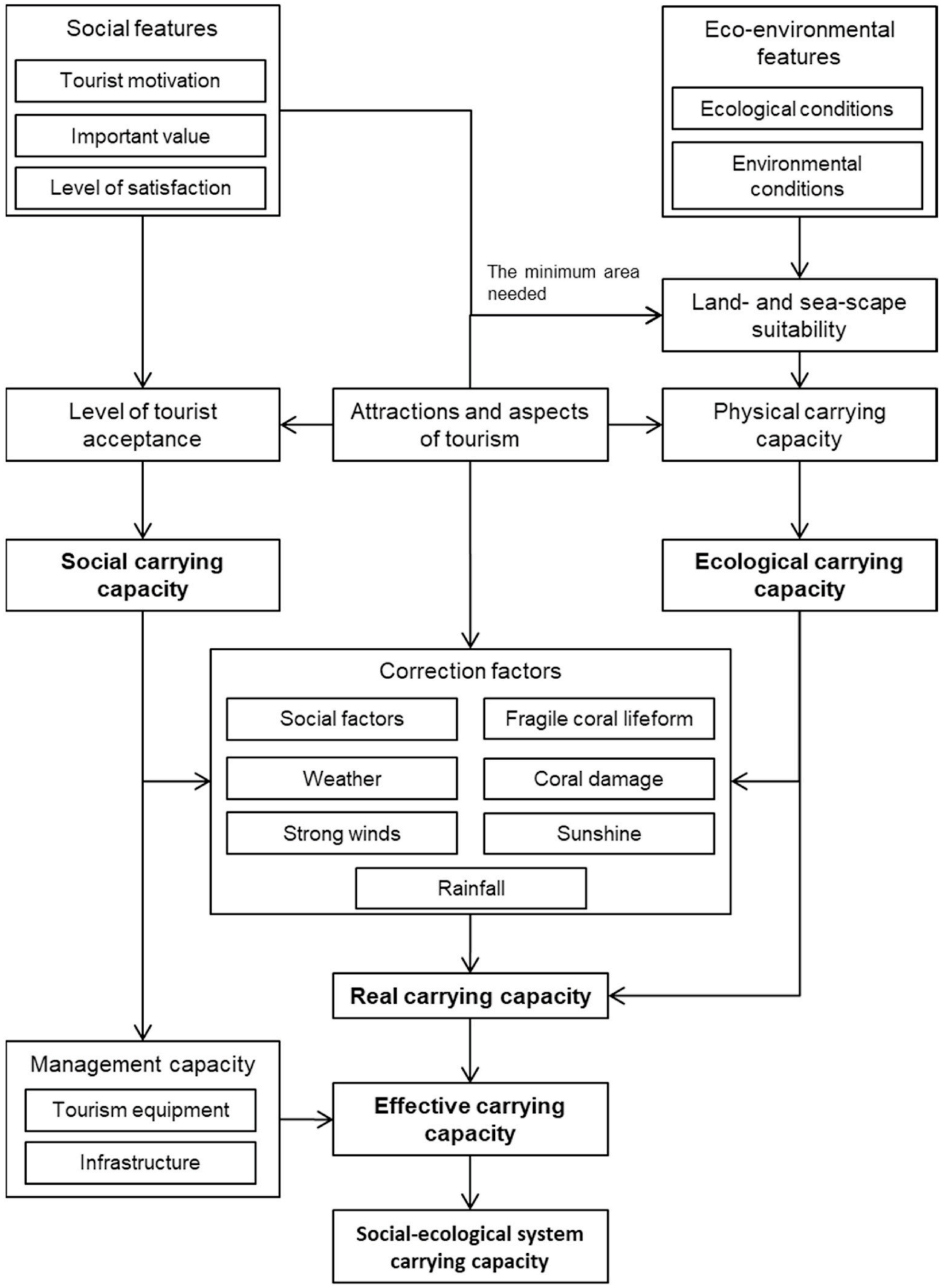

Fig. 2. Framework diagram of Social-Ecological System CC model.

2) Fragile coral lifeform. The CF for fragile lifeform (CFfg) is an absolute value of the percentage of fragile coral lifeform cover (fg) by tourist contacts (snorkelers and divers) that causes coral damage (Barker and Roberts, 2004; Krieger and Chadwick, 2012).
3) Coral damage. The CF of coral damage (CFdm) is the level of coral damage (dm) caused by human factors, especially tourism activities. It is estimated that there is an association between coral damage and tourists' interactions and contact with coral reefs. In addition, the condition of coral damage affects the satisfaction of divers.
4) Weather. The CF of weather (CFwt) refers to poor weather conditions for snorkeling and diving activities. Poor weather is the cumulative number of days from the rainy season, big waves season, strong wind season, and strong current season.
5) Rainfall. The CF of rainfall (CFrf) is the number of rainy days compared to the total number of days of the year (365 days). Rain significantly affects tourists' motivation to engage in tourism activities on the beach.
6) Strong winds. The CF of strong winds (CFsw) can affect the satisfaction of tourists on the beach.
7) Sunshine. The CF of sunshine (CFss) was estimated from tourists' satisfaction and activity on the beach, especially sunbathing. Data on the absence of sunshine were converted from the rainy day data.

Furthermore, real CC (RCC) and effective CC (ECC) were evaluated. RCC was defined by Zacarias et al. (2011) as "the maximum permissible number of visits to a specific site, once CFs derived from the particular characteristics of the site have been applied to the PCC," while ECC was described as "the maximum number of visits that a site can sustain considering the RCC and the management capacity." To appraise RCC based on each activity, the relevant CFs were applied according to the nature of the small island's tourism.

The RCC was calculated based on the PCC value multiplied by CFs for each tourism category. Lastly, ECC was calculated using RCC results multiplied by the factor for management capacity (MC) (Zacarias et al., 2011; Cupul-Magaña and Rodríguez-Troncoso, 2017; Corbau et al., 2019). In small islands, the MC factor is significant because it represents supporting and limiting tourist activities. In this study, tourism equipment (E) and infrastructure (I) for accommodation were used to estimate the MC factor because of its relation to the accommodation capacity of the islands. Tourists/visitors have to stay overnight, especially for islands far from the mainland. This was significant factor for MC. The E value was calculated for diving tourism, while the I value was calculated based on the total room number of guest houses and hotel on the Tidung Islands, that is, 512 rooms. In this study, it was assumed that each room was used by two people; thus, the total number of people available was 1024.

Second, the SES-CC model overlays the results of social CC and ecological CC to estimate the SES-CC for tourism ecosystem services. The estimation used a simple double attribute weighting formula, as presented below:

$$SES - CC = \frac{(SocCC \times w_1) + (EcCC \times w_2)}{(w_1 + w_2)} \quad (3)$$

where SocCC is the social CC, EcCC is the ecological CC, w_1 is the weighting value for the social CC, and w_2 is the weighting value for the ecological CC. The w_1 and w_2 values were calculated using the couple coastal degree model (CCDM) for the Tidung Islands, as reported by Adrianto et al. (2019). The social factor had a higher value (0.59) than the ecological factor (0.41).

4. Results

4.1. Social carrying capacity

The majority of respondents felt that the primary motivation for tourists to come to the Tidung Islands was sightseeing (56.76 %), curiosity about a new destination (48.65 %), and recreational activities (48.65 %) (Fig. 3). These factors had a very significant relationship with tourist motivation for visiting (p = 2E-20).

Tourists considered all tourist attractions to be important (average 61.71 %), notably snorkeling (77.03 %), diving (68.92 %), and beaches (58.49 %) (Fig. 4a), and tourism based on both coral reefs and beaches (p = 1.6E-03 and 1.9E-09, respectively). However, tourists were neither or moderate overall (average 61.26 %) or for beach and diving activities (63.32 % and 60.81 %, respectively). Tourists were only satisfied with snorkeling attractions (50.00 %) (Fig. 4b). This satisfaction level significantly influences the perception and motivation of tourists, both for coral reefs (p = 2.5E-03) and the beach (p-value = 5E-16). Tourists cannot obtain the expected satisfaction, both from objects, facilities, and MC, affecting their willingness to return to travel to Tidung Islands. Based on the survey results, about 5 % of tourists did not want to return to the Tidung Islands, and 8 % were hesitant. The total percentage is considered a potential loss, especially economically.

The importance and satisfaction of tourists were closely related to CC, and CC was closely correlated with management. According to the tourist perception data analysis, the social CC level that can be received ranges from 25 to 75 visitors per ha beach tourism attraction area on the island; the highest acceptance was 50 visitors per ha (Fig. 5). Therefore, with a beach area of 11.32 ha, the total number of tourists that can be socially accepted was 566 visitors per day.

4.2. Ecological carrying capacity

1) Suitability analysis

The physical-ecological conditions in the Tidung Islands are very appropriate for ecotourism, including allowing beach, snorkeling, and diving activities. The suitability level of beach ecotourism ranged from suitable to very suitable, with a total beach area of 113,241.72 m^2. The potential for beach tourism was spread around the islands, particularly on the west and east sides of Tidung Besar Island and all beaches on Tidung Kecil Island, except for the port area (Fig. 6).

Fig. 6 also shows that snorkeling and diving ecotourism had the same potential distribution, and the classification of suitability was quite suitable, suitable, and very suitable. The main limiting factor that differentiates the designation of these activities is water depth. The main objects of these two activities were coral reefs. Almost all of the coral reef areas around the island had the potential for tourism activities, excluding the marine protected area (MPA) and around the sea lanes. The potential areas for snorkeling and diving ecotourism were 530,162.43 and 299,257.88 m^2, respectively.

2) Physical Carrying Capacity (PCC)

The PCC assessment was based on three main tourism activities in the Tidung Islands: beach, snorkeling, and diving. The PCC of the Tidung Islands was estimated at 4530 visitors per day for the beach, 4241 visitors per day for snorkeling, and 599 visitors per day for scuba diving (Table 3). The PCC value was strongly influenced by the area provided for tourism and the rotation factor of tourism (Rf). Rf is the daily number

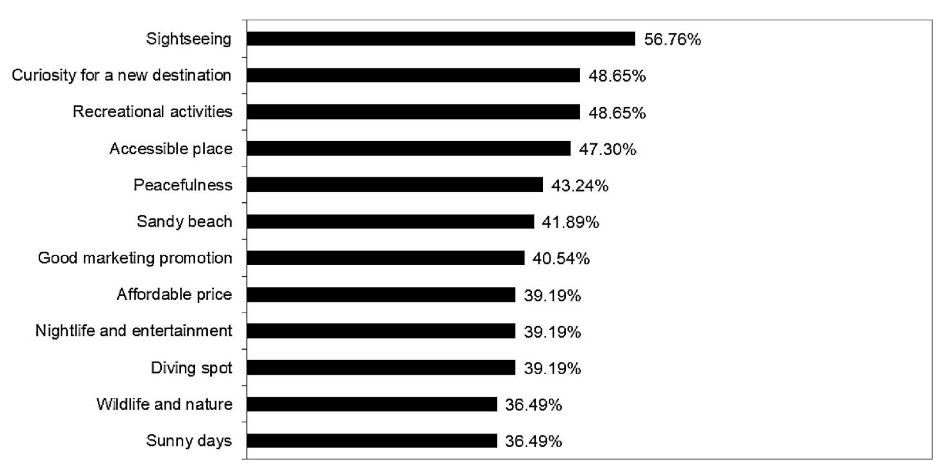

Fig. 3. The motivation for a tourist visit to Tidung Islands.

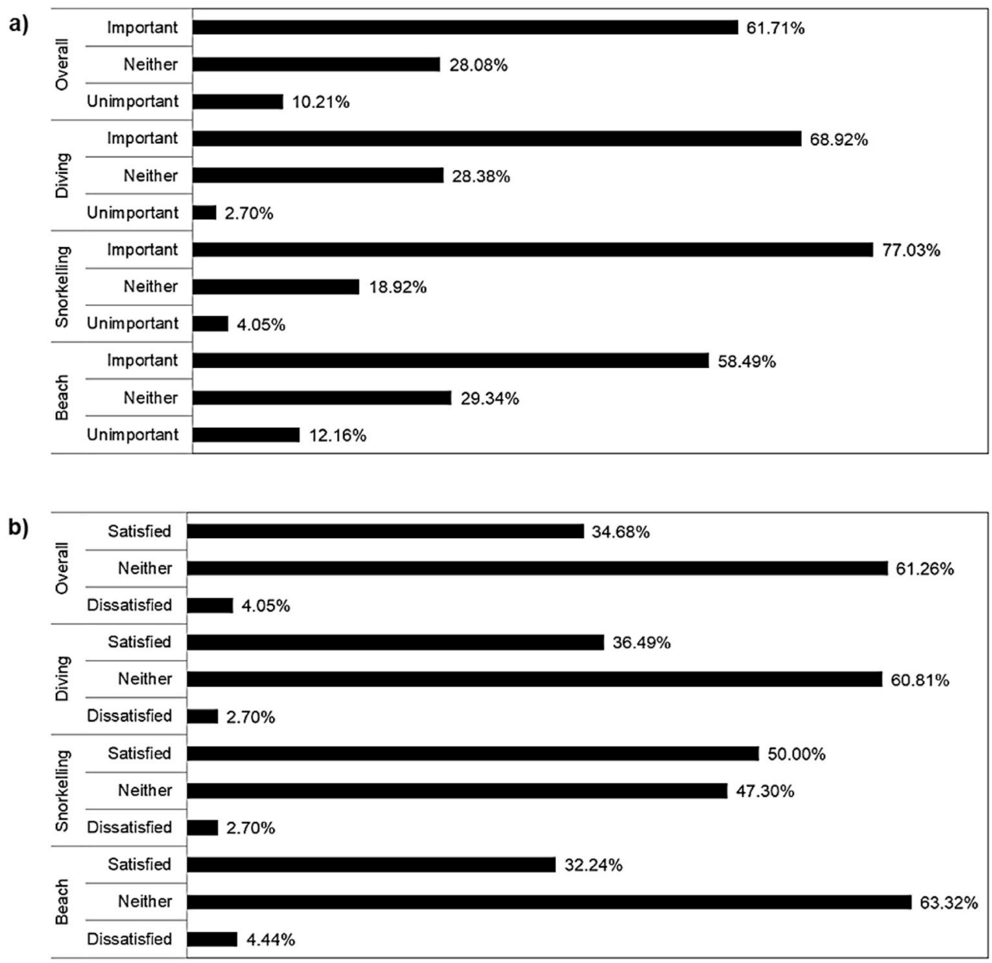

Fig. 4. Tourist' perception of a) Important value of tourist attraction on Tidung Islands, and b) Value of tourist satisfaction with the object visited at Tidung Islands.

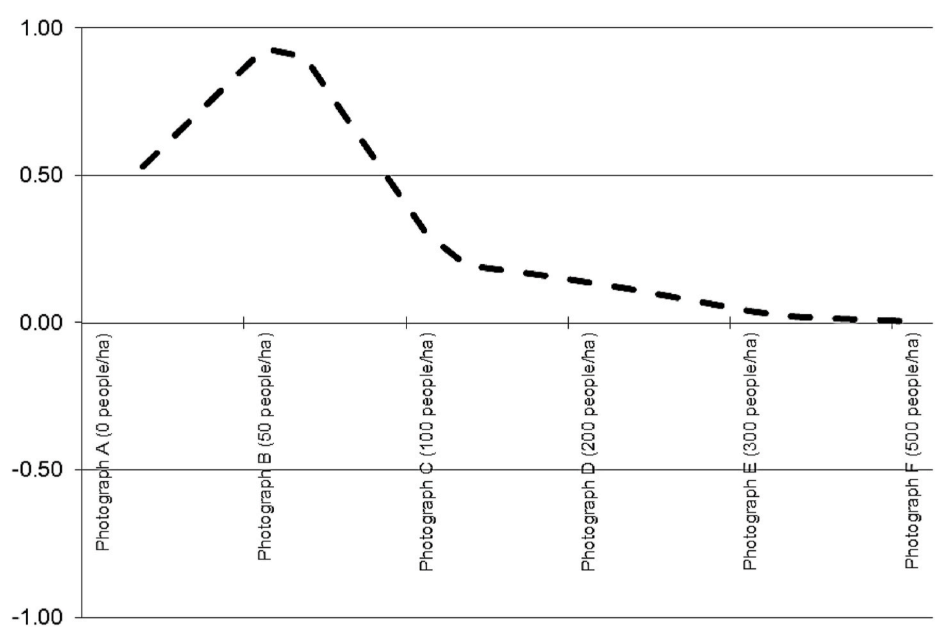

Fig. 5. The level of tourist acceptance of overcrowding in tourist destination Tidung Islands.

of visits. The size of the area and the values of these two parameters affect the PCC.

Table 3 shows that a suitable area required per user (Au) was estimated at 500 m^2 for snorkeling, 2000 m^2 for diving, and 50 m^2 for beach tourism. Also, the Rf value for a snorkeling and diving spot was four times a day with a duration of 8 h per day and 2 h per group of

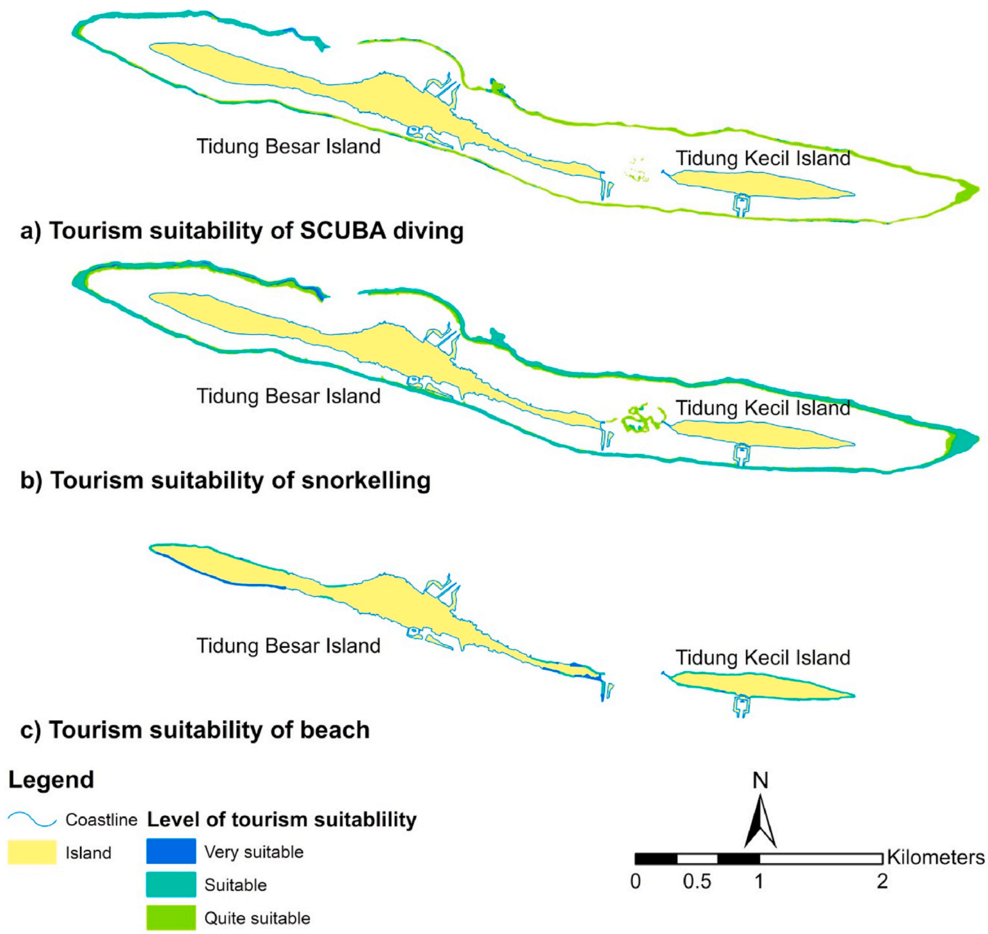

Fig. 6. Suitability map of tourism in Tidung islands.

tourists. Although for beach tourism, tourist rotation only occurred twice with a duration of 7 h a day. Accordingly, tourists can spend time up to 3.5 h a day on the beach.

4.3. Social-ecological system carrying capacity (SES-CC)

1) Real Carrying Capacity (RCC)

As a correction factor (Appendix 2), the survey results show that tourists' minimum area for satisfactory traveling on the Tidung Islands was 50 m^2 for snorkeling and diving tourism and 4 m^2 for beach tourism. In comparison, the total area needed per tourists was 500 m^2 for snorkeling, 1000 m^2 for diving, and 250 m^2 for beach tourism. Thus, the CFsc value was 0.90 for snorkeling, 0.95 for diving, and 0.98 for beach tourism, respectively (Table 3).

From the perspective of coral fragility for snorkeling and diving tourism activities, the types of lifeforms categorized as fragile are branched corals (Krieger and Chadwick, 2012), including *Acropora branching*, *Acropora encrusting*, *Acropora tabulate*, *Coral branching*, and *Coral foliose*. The average value of fragile coral lifeform cover (fg) and CFfg was 38.86 % and 0.61, respectively. In addition, the survey results indicated that the average values of damage coral life form cover (dm) and CFdm were 42.48 % and 0.58, respectively.

Weather is another correction factor for RCC. Cumulatively, four harmful weather events occurred in November, December, January, and February. High rainfall intensity also occurred in August. Accordingly, the total weather hours of the waters in the bad condition were 2880 h and in good condition were 5760 h. Consequently, CFwt was 0.5. As a tropical region, rainy days are recorded almost every month and strong winds occur in January, February, August, November, and December; hence, the total number of rainy days and strong winds was 151 days in 2018 (BPS DKI Jakarta, 2018). From the number of days, the CFrf and CFsw values were 0.59. Thus, there was no daylight for 214 days or 5136 h per year. If divided by the total hours in one year (8760 h), the Cfss value was 41 % (0.41).

By using the CFs, the RCC values for beaches, snorkeling, and diving were estimated at 634, 671, and 100 visitors per day, respectively (Table 3). The RCC value was significantly corrected, decreasing by 85.01 % from the PCC. This value is very good from an ecological and management perspective because it will minimize the pressure on the ecology and advance management efficiency based on the MC.

2) Effective Carrying Capacity (ECC)

The next step of the ECC calculation was conducted by considering the MC in the calculation. Lack of MC can lead to uncontrolled situations. At the Tidung Islands, equipment for diving and infrastructure was a limiting factor in terms of MC. There was only 78 units of scuba equipment (0.78 of total E), and available accommodation was 1024 visitors per day (0.73 of total I). Thus, the ECC value of the Tidung Islands was calculated as 1008 visitors per day. This value was 71.74 % for RCC and 89.24 % for PCC. From a management perspective, this ECC value can be accepted as a limitation of the number of visitors to Tidung Island, considering the social-ecological system features. From a coastal management perspective, anthropogenic pressure and natural processes in coastal and sea areas are spatially and temporally related to CC (Wang et al., 2017).

Table 3
Ecological carrying capacity for tourism activities in Tidung Islands.

Description		Carrying capacity		
Tourism activities		Beach	Snorkeling	Diving
A (m^2)		113,241.72	530,162.43	299,257.88
Au (m^2)		50	500	2000
A/Au (m^2)		2264.83	1060.32	149.63
Rf		2	4	4
PCC (visitors per day)		4530	4241	599
Cf[a]	sc	0.98	0.90	0.95
	fg	–	0.61	0.61
	dm	–	0.58	0.58
	wt	–	0.50	0.50
	rf	0.59	–	–
	sw	0.59	–	–
	ss	0.41	–	–
RCC (visitors per day)		**634**	**671**	**100**
MC	E	–	–	**78 (0.78)**
	I	**1383 (0.73)**		
ECC (visitors per day)		**1008**		
SES-CC (visitors per day)		**747**		

Note.
A = area of potential/suitable for tourism activities.
A_u = area available per user.
Rf = rotation factor.
PCC = physical carrying capacity.
Cf = correction factor.
sc = social.
fg = fragile.
dm = damage.
wt = weather.
rf = rainfall.
sw = strong wind.
ss = sunshine.
RCC = real carrying capacity.
MC = management capacity.
E = equipment.
I = infrastructure.
ECC = effective carrying capacity.
SES-CC = social-ecological system carrying capacity.
[a] Correction factor calculations are shown in appendix 2.

3) Couple value

According to the social and ecological CC estimation and weighting, the value of SES-CC was estimated as 747 visitors per day.

5. Discussion

The Tidung Islands are part of the Seribu Islands districts of the Special Capital Province of Jakarta. The Seribu Islands District has been appointed as a national strategic tourism area (KSPN) according to Presidential Decree No. 18/2020 regarding National Medium Term Development Plan 2020–2024 and Government Regulation No. 50/2011 regarding Grand Strategy on National Tourism Development. Simultaneously, the Ministry of Tourism and Economic Creative launched the national strategic plan for tourism development for 2020–2024, promoting quality tourism as one of the national pillars. Therefore, this study of SES-CC can contribute to maintaining the economic viability of marine tourism in the islands while protecting the capacity of the ecosystem for tourism itself.

Based on the SES-CC value, the number of tourists exceeded the CC in 2017 and 2018, especially on Saturdays (Table 2 and Fig. 7). By looking at the academic calendar of Indonesia, we can see that occasions where the number of visitors exceeded the CC often occurred during school holidays. Based on the existing policy and management, the number of tourists has never exceeded the SES-CC on weekdays, but does exceed the SES-CC on all weekends. Consequently, there is a need for policy intervention to improve the quality of small island tourism by decreasing the number of tourists or visits to prevent environmental damage (Nakajima and Ortega, 2016).

The number of visitors exceeding the CC on Tidung Island has impacted the condition of the coral reef ecosystem. There has been a year to year decline in coral cover around Tidung Island; as the baseline figure in 2007, the percentage of coral cover reached 68.2 % (Estradivari et al., 2009) and declined to 52.66 % in 2014, 48 % in 2017, and 32.84 % in 2018 (DKPKP DKI Jakarta, 2018). The trend shows a decline in the coral reef condition based on hard coral cover from 2007 to 2018, which decreased by approximately 51.85 %. The results of field measurements in this study also showed that the average percentage of live hard coral cover was 23.58 % ± 23.51 % and the average seagrass cover was 31.89 ± 15.91 %. Hayati et al. (2020) showed that tourism is one of the largest waste-generating sources in the Tidung Islands, i.e., 1.83 items/m^2, or in the 'extremely dirty' category. This shows that the impact of tourism, both directly and indirectly, is not based on CC for aquatic and coastal ecosystems. The number of visitors was not restricted by any regulation. For this reason, management efforts are urgently needed that can be adjusted to the ecological and social status and vulnerability of Tidung Island and that consider the impacts that tourism causes.

From a future perspective, the use of the SES-CC value is recommended to limit the number of tourists/visitors to maintain the long-term social-ecological benefits of tourism in the Tidung Islands. In this regard, a quota system can be adopted (Viñals et al., 2016). Tourist visits can also be distributed on days that are currently below the SES-CC. This value can also be used as a basis for developing a quota system. Tourists can be distributed to other islands in the vicinity but still see objects on Tidung Island, while still paying attention to the rotation factor. Careful exploitation of this arrangement will minimize environmental damage and social conflicts. At the same time, tourist satisfaction will increase, and simultaneously, the economic quality of tourism of the islands will also increase.

SES-CC, ECC, and RCC can be used as a spectrum for developing tourism management strategies for small islands (Fig. 7). As a safe limit, the SES-CC value can be used for an effective sustainability strategy by advising on the total number of visitors who can come simultaneously, as it provides a balance between social and ecological boundaries. Meanwhile, the ECC value can be used as a tolerance limit at certain visiting times or tourist seasons, if needed, or as a medium-term economic development target. The strategy implementation of the ECC value pays more attention to the social system; in this case, MC, visitor satisfaction, and comfort are the main considerations. The ECC value can be increased through improvised MC, especially from the equipment aspect. However, increasing the value of the ECC must still consider manager capabilities.

The RCC values allow a softer strategy to limit the number of visitors. This strategy is carried out by reducing the existing MC considerations. For example, for large events, such as cultural events and festival, that are targets for economic improvement in the short term. However, to ensure that the RCC values can accurately estimate the impact and allow effective management, the CFs of the existing ecological conditions must be considered and counted for.

The application of CC will lead to a decrease in income from tourism, especially for the island community, however it will ensure sustainability. Therefore, economic improvement is also needed to improve the quality of tourist objects, attractions, and the environment. Visitor preferences were mapped. Micro zoning of islands can be made based on the potential and existing development needs by considering the sustainability of resources. An inter-island integration program can also be implemented so that tourists do not focus on one island or the same tourist attraction, including conservation programs on coral reefs, seagrass and mangroves. Conservation strategies can also be implemented in tourism activities, such as the adoption of corals, mangroves, and others.

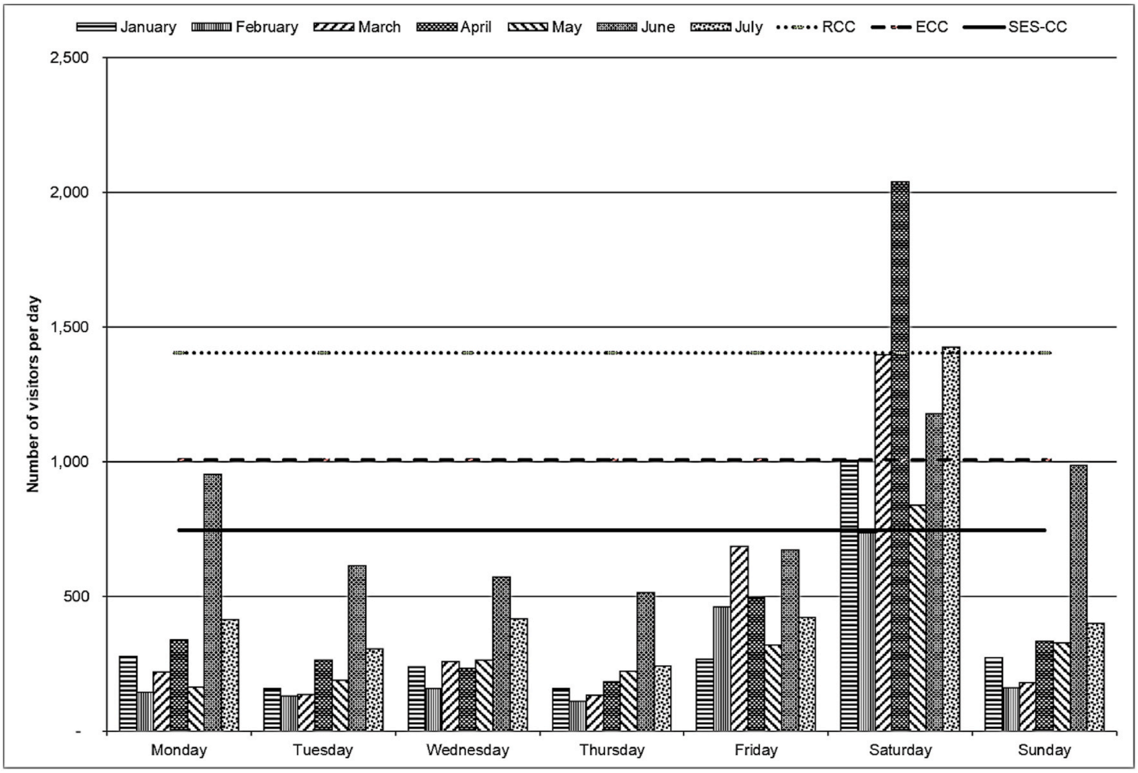

Fig. 7. Average days that exceed the effective CC of the Tidung Islands in 2018.

6. Conclusion

In the context of the ocean and coastal systems, including the small islands, managing their ecosystem services would not be only related to the magnitude of the uses but also can be connected to the social-ecological system of the islands as their consequence. In this paper, tourism activities as part of cultural ecosystem services uses are not solely focused on limiting the number of tourists but also on the social and ecological impact on the island, as well as tourists' and residents' satisfaction. In this regard, TCC is not a single number but rather a threshold. According to the CC spectrum, restrictions on the number of tourists can be adjusted based on existing management conditions and targets as long as not exceeding the acceptable tolerance limits of the social-ecological system. By this, the value of tourism can increase gradually by not reducing the benefits of tourism obtained by the community and tourism managers. In the long run, it also can improve the regional economy of the small islands. This equilibrium can be achieved through ecological and MC development to improve TCC by involving multi-stakeholders, including government, managers, residents, and tourists.

Assessment of SES-CC can be the basis for comprehensively determining the policies and management of tourism on small islands. SES-CC provides an overview of the current utilization levels and warnings of impacts. The SES-CC approach is an applied method for supporting the sustainable management of small tourism islands. The coupled social-ecological system analysis method used in this study demonstrates the importance of using multiple approaches and integrated assessment for analyzing tourist sustainability. Therefore, the SES-CC can be considered an acceptable limit for the number of visitors for small urban islands, such as the Tidung Islands.

Further research should investigate the best policy scenarios based on SES-CC estimation by adding analysis of social carrying capacity from stakeholders' perspectives, including islanders, tourism operators, and local government. Estimating correction factors using local climate measurement should be considered to increase the accuracy of small islands context. Finally, policy and scenario analysis using system dynamics can be applied to provide a temporal simulation of management setting for tourism sustainability in the islands.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2021.105844.

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