

SUSTAINABLE TOURISM BASED ON CARRYING CAPACITY AND ECOLOGICAL FOOTPRINT AT SAPEKEN ARCHIPELAGO, INDONESIA

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ABSTRACT

As sustainability has become an important policy issue in small island tourism, there is need to understand the natural limits. These used to know how much small island with their limitation could accommodate tourism needs. Based on that fact, this research aimed to: 1) quantify the environmental carrying capacity for several type of ecotourism in Sapeken archipelago; 2) assessing Sapeken archipelago ability to accommodate ecotourism activities using ecological footprint based from emergy approach; and 3) evaluate sustainability ecotourism activities in Sapeken archipelago. Result showed: 1) Sapeken archipelago have different carrying capacity for each type of ecotourism. For dive tourism 5.330 persons/day, snorkelling 3.590 persons/day, fishing tourism 14,900 persons/day, mangrove tourism 32,100 persons/day and beach tourism 1,990 persons/day; 2) The largest accommodate for tourism are Paliat island (844,000 persons/year) Sepanjang island (217,000 persons/year) and smallest in Sapeken island (50.5 persons/year); and 3) Ecotourism activities in Sapeken archipelago has sustainability ($RCC > EF$) which indicated by carrying capacity as natural limit is greater than EF as a representation number of tourist can be met.

Keywords Sapeken archipelago, carrying capacity, ecological footprint, sustainability, ecotourism

INTRODUCTION

Sapeken Archipelago is an area consisting of a number of small islands with a several supporting ecosystems such as coral reefs, mangrove ecosystems, coastal ecosystems and fisheries resources [1], indicated as a region with high diversity and susceptible to utilization activities as well [2]. In this regard, the utilization of Sapeken archipelago is in accordance with their limitation as small islands. One of the utilization of small islands is ecotourism activities.

Ecotourism is defined as trip activity to places that are relatively not interfere the places, with the purpose of observing and enjoying biological resources, by minimizing environmental impact so as to encourage respect for the local culture and produce benefits that are fair to all users [3]. Moreover, The International Union for Conservation of Nature (IUCN) said that an ecotourism activity is not only nature-based, but also as an effort to maintain biodiversity while improving the welfare of the local community. However, without adequate planning, the purpose of the ecological balance, social, and economic in

ecotourism will not materialize and instead the implementation will be causing damage to the environment [4];[5];[6].

Based on reason above, the planning of ecotourism activities at Sapeken Archipelago requires an assessment of the ability of their ecosystems to provide all aspects required to implement sustainable tourism activities. The assessment approaches used are in the form of: 1) an assessment of the regional carrying capacity (RCC), 2) an assessment of touristic ecological footprint (TEF), and 3) an assessment of the sustainability of ecotourism activities.

METHODOLOGY

This research was conducted at Sapeken Archipelago that formed from a series of small islands chain totalling 201.887 Km² areas. The islands chain are located at 6⁰ 46 ' - 70 ⁰6' LS 115⁰ and 115⁰ 10'-44 'E, part of the District of Sapeken, Sumenep regency, East Java Province (Figure 1). Primary and secondary data were collected from the study sites as well as from various agencies in Sumenep Government and other relevant agencies.

The method in this research as a new quantitative approach with combine ecological footprint and emergy approach. Ecological footprint analysis measures agregat land area required for a given population to exist in sustainable manner.[7];[8]. Furthermore, emergy is a unit of resource use and work potential, is used to quantitatively evaluate intensity of development [9];[10]. Based on ecological footprint and emergy approach, used for determine carrying capacityfor ecotourism in Sapeken archipelago.

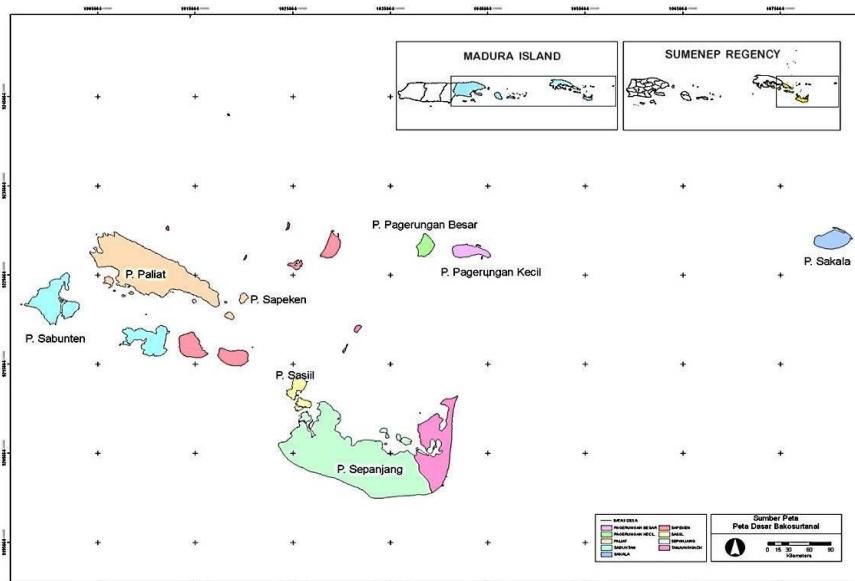


Figure 1 Map of study area at Sapeken Archipelago

Utilization Carrying Capacity (UCC)

UCC was used to determine the maximum number of visitors that physically can be accommodated in the specific space and time without causing interference with the natural and human. UCC and RCC were calculated with following equation [11]:

$$RCC = K \times \left[\frac{L_p}{L_t} \right] \left(\frac{W_t}{W} \right)$$

where :

- RC : Regional carrying capacity
- K : Potential visitors per unit area
- L_p : The utilization area
- L_t : Area for a particular category
- W_t : The time provided by the region for tourism activities in one day
- W : Time spent by visitors to particular activity

$$UCC = RCC \times 0.1 \quad (2)$$

The ability of Sapeken Archipelago Ecotourism Activities

The ability of Sapeken Archipelago ecotourism activities was assessed using ecological footprint (EF) based on the concept of energy synthesis consists of three stages, i.e : 1) calculate or assess their biocapacity, covering energy capacity and resources capacity, 2) calculate or assess community ecological footprint, and 3) calculate or assess touristic ecological footprint.

– Biocapacity of Sapeken Archipelago

Emergy is one form of energy that has undergone a transformation in the form of energy flow [12];[13]. Emergy biocapacity was calculated following.[14]. include solar energy, wind, rain energy, wave energy, and tidal waves. Meanwhile, the resources capacity includes food energy, energy forest and fishery energy [15].

The unit used of energy is *solar em joules* (seJ). The conversion of energy and / or mass to emergy, calculated using emergy intensity factors (eif)

$$\text{Emergy} = \text{Energy}_i \times \text{eif}_i \quad (3)$$

where

- eif_{sun} : 1 (Odum,2000)
- eif_{wind} : 2450 seJJ⁻¹ (Odum,2000)
- eif_{rain} : 30500 seJJ⁻¹ (Odum,2000)
- eif_{tidal} : 51000 seJJ⁻¹ (Odum,2000)
- eif_{wave} : 73900 seJJ⁻¹ (Odum,2000)
- eif_{food} : 1.14 x 10⁵ seJJ⁻¹ (Pereira,2012)
- eif_{forest} : 3.49 x 10⁴ seJJ⁻¹ (Pereira,2012)
- eif_{fish} : 3.36 x 10⁶ seJJ⁻¹ (Pereira,2012)

$$\text{Energy Capacity} = (\text{Emergy}_i / n) \times \text{EED}$$

where

- n : Number of population
 EED : 3.1×10^{14} (seJJ⁻¹ ha⁻¹)

– *Community Ecological footprint of Sapeken Archipelago*

The calculation refers to the ecological footprint assessment and analysis conducted by Scotti *et. al* [16]. Equations used are as follows:

$$EF_i(\text{ha}) = \text{Area}_i \times \text{Equivalence Factor}_i \quad (5)$$

– *Touristic Ecological Footprint*

EF of ecotourism plan products is the total accumulated value of the seven components of the previously mentioned [17]. The total value was shown by the following equation:

where

- Equivalence factor_{land}
 Equivalence factor_{forest}
 Equivalence factor_{fishing ground}

$$TEF = TEF_f + TEF_a + TEF_t + TEF_s + TEF_p + TEF_e + TEF_w \quad (6)$$

where :

- TEF_f : touristic ecological footprint for food
 TEF_a : touristic ecological footprint for accommodation
 TEF_t : touristic ecological footprint for transport
 TEF_s : touristic ecological footprint for sightseeing
 TEF_p : touristic ecological footprint for purchases component
 TEF_e : touristic ecological footprint for entertainment
 TEF_w : touristic ecological footprint for waste

Sustainability of ecotourism activity

Sustainability assessment for the utilization of Sapeken Archipelago for ecotourism activities performed by comparing the RRC with the EF with following equations:

$$RCC > EF = \text{sustain} \quad (7)$$

RESULTS AND DISCUSSION

UCC of Sapeken Archipelago for Ecotourism Activities

UCC is the maximum number of visitors that limited by the condition of the ecosystem as a natural limit. Ecosystem natural limit for ecotourism based on the results of conformity assessment activities for various types of ecotourism. Table 1 showed the results of UCC assessment of Sapeken Archipelago for ecotourism activities.

Table 1. UCC (person / day) for ecotourism activities in the Sapeken Archipelago

No	Island		Tourist activities				
			Divin g	Snorkell ing	Fishin g	Mangro ve	Beachi ng
1.	Pagerungan Besar	Area wide (m ²) x (10 ⁶)	3.7900	3.6400	1.8500	-	0.0446
		RRC (person/day) x (10 ⁴)	1.5200	1.4600	55.6000	-	0.1780
		UCC (person/day) x (10 ³)	1.5200	1.4600	1.8500	-	0.1780
2.	Pagerungan Kecil	Area wide (m ²) x (10 ⁶)	0.8810	0.8480	6.6900	-	0.0593
		RRC (person/day) x (10 ⁴)	0.3520	0.3390	201.0000	-	0.2370
		UCC (person/day) x (10 ³)	0.3520	0.3390	6.6900	-	0.2370
3.	Paliat	Area wide (m ²) x (10 ⁶)	3.3100	-	1.6700	6.5000	0.0741
		RRC (person/day) x (10 ⁴)	1.3200	-	50.1000	52.0000	0.2960
		UCC (person/day) x (10 ³)	1.3200	-	1.6700	52.0000	0.2960
4.	Sapangkur Besar	Area wide (m ²) x (10 ⁶)	2.7300	2.6900	0.9130	-	0.0423
		RRC (person/day) x (10 ⁴)	1.0900	1.0800	27.4000	-	0.1690
		UCC (person/day) x (10 ³)	1.0900	1.0800	0.9130	-	0.1690
5.	Sapeken	Area wide (m ²) x (10 ⁶)	0.1840	-	0.2550	-	-
		RRC (person/day) x (10 ⁴)	0.0735	-	7.6500	-	-
		UCC (person/day) x (10 ³)	0.0735	-	0.2550	-	-
6.	Saor	Area wide (m ²) x (10 ⁶)	1.9700	0.7470	1.7400	-	0.0133
		RRC (person/day) x (10 ⁴)	0.7890	0.2990	52.2000	-	0.0530
		UCC (person/day) x (10 ³)	0.7890	0.2990	1.7400	-	0.0530
7.	Sepanjang	Area wide (m ²) x (10 ⁶)	0.4610	1.0400	1.8100	33.6000	0.2640
		RRC (person/day) x (10 ⁴)	0.1840	0.4140	54.4000	269.0000	1.0500
		UCC (person/day) x (10 ³)	0.1840	0.4140	1.8100	269.0000	1.0500

UCC of ecotourism activities in the Sapeken Archipelago were depended on the size, condition, and suitability status of the ecosystem for ecotourism. The largest UCC on each type of tourist was mangrove tours (32.100 people); following by fishing (14.900 people); diving (5.330 people); snorkelling (3.590 people), and beaching (1.990 people). Furthermore, those values were the maximum limit of users (tourists) that can be accommodated on the Sapeken

Archipelago in order to provide continuous comfort (leisure) without affecting or causing loss of quality of the resources.

There is a need to manage ecotourism system and ecosystem service. It is needed to utilize the small island ecosystems. Ecotourism as a form of utilization should be based on the existing limitations of small island. [18]. The form of management could be adjustments of ecotourism activities to the carrying capacity of small island region by regulating the number of tourists. The control of the number of tourists is intended to regulate the very limited resources and space consumption in the small island in order to give comfort or satisfaction for tourists. This arrangement also minimizes impact of ecotourism activities on the quality of the resource as well as ensuring the ecosystem service in the small islands.

Ecosystem service is the benefits of the existence of an ecosystem to human life [19], which include provisioning service, supporting service, regulating service, and cultural service. Ecosystem service is highly dependent on the condition of the ecosystem. Well-maintained ecosystems will ensure the sustainability of ecosystem services [20]. Referring to that description, the carrying capacity of the Sapeken Archipelago for ecotourism activities represented by the number of tourists per day for diving, snorkelling, fishing, mangrove tour, and beaching, showed that there are limitations in the ability of ecosystems to provide ecosystem services for tourist leisure. The number of tourists who exceed the carrying capacity of the Sapeken archipelago will affect the ability of ecosystems to provide ecosystem services and raise negative impact on the sustainability of ecotourism activities. Furthermore, [21] describes the number of tourists as a form of management to limit the impact of ecotourism activities, ensuring quality of the visitor experience and planning of supporting facilities for ecotourism activities

Regional Capacity of Sapeken Archipelago for Ecotourism

Regional capacity of Sapeken archipelago is the quantity of regenerative capacity of the biosphere that is used by tourist activity, carried out by counting the amount of biologically productive land and catchment area required to support a given population at current levels through the consumption and resource efficiency. These assessments includes: 1) biocapacity, consisting of energy and resource biocapacity as supply and 2) ecological footprint, consists of community and touristic ecological footprint as demand. The results of an assessment of the regional capacity of Sapeken Archipelago for ecotourism were showed in Table 2; 3; 4; 5 and 6.

Table 2 Energy biocapacity of Sapeken Archipelago

N	Island	Energy Biocapacity (gha/capita/year)				
		Sun (x10 ²)	Rain (x 10 ²)	Wind (x 10 ¹⁰)	Wave (x 10 ³)	Tidal (x 10 ²)
1	Pagerungan Besar	0.1040	5.0900	3.0100	0.2110	1.2600
2	Pagerungan Kecil	0.0766	3.7400	2.2100	0.1440	1.1300
3	Paliat	3.0300	148.0000	87.3000	2.7000	0.0000
4	Sapangkur Besar	0.0016	0.0760	0.0449	1.8800	0.9020
5	Sapeken	0.0004	0.0184	0.0109	0.1020	0.1890
6	Saor	0.0023	0.1120	0.0660	2.7600	1.0300
7	Sepanjang	1.8900	92.5000	54.6000	15.5000	2.8800

Source: Analysis result. 2012

Table 3 Resources biocapacity of Sapeken Archipelago

No	Island	Resource Biocapacity (gha/capita/year)		
		Food ($\times 10^{-3}$)	Forest ($\times 10^4$)	Fish ($\times 10^1$)
1	Pagerungan Besar	1.5400	0.0629	1.1400
2	Pagerungan Kecil	1.1400	-	1.3800
3	Paliat	4.3400	2.3500	0.4820
4	Sapangkur Besar	2.4800	1.1600	0.5310
5	Sapeken	2.3300	-	0.8720
6	Saor	5.2800	-	0.8180
7	Sepanjang	6.1700	4.5100	0.5480

Source: Analysis result. 2012

Table 4 Community ecological footprint of Sapeken Archipelago

No	Island	Community Footprint (gha/capita)						
		Food ($\times 10^2$)	Forest ($\times 10^2$)	Fish ($\times 10^{-5}$)	Housing ($\times 10^{-5}$)	Electricity ($\times 10^3$)	Water ($\times 10^{-2}$)	Waste ($\times 10^{-5}$)
1	Pagerungan Besar	2.9000	0.0001	5.5000	0.0006	4.0000	1.2000	6.1000
2	Pagerungan Kecil	3.9000		4.6000	0.0008	3.9000	1.2000	5.9000
3	Paliat	0.1400	8.5000	0.0130	0.0001	1.6000	0.5000	2.5000
4	Sapangkur Besar	0.3400	29.0000	12.0000	0.0100	1.5000	0.4700	2.3000
5	Sapeken	0.3400		0.0070	120.0000	5.1000	1.6000	7.8000
6	Saor	0.1500		0.0031	12.0000	1.5000	0.4400	2.2000
7	Sepanjang	0.2600	4.3000	0.0120	0.0001	5.6000	1.7000	8.6000

Source : Analysis result. 2012

Table 5 Touristic ecological footprint of Sapeken Archipelago (gha/capita)

N	Island	TEF food ($\times 10^{-4}$)	TEF accommodation ($\times 10^{-4}$)	TEF transportation		TEF activities ($\times 10^{-1}$)	TEF _w waste ($\times 10^{-5}$)	TEF _w water ($\times 10^{-5}$)	TEF purchase ($\times 10^{-3}$)	TEF entertainment ($\times 10^{-2}$)
				Jakarta ($\times 10^{-2}$)	Bali ($\times 10^{-3}$)					
				1	Pagerungan Besar					
2	Pagerungan	1.8700	4.2900	4.2000	1.6800	1.1300	1.3800	3.1800	4.3500	2.8900

	Kecil									
3	Paliat	0.16 20	4.2900	4.5 700	5.45 00	1.24 00	1.38 00	3.18 00	4.35 00	2.89 00
4	Sapangkur Besar	0.53 40	4.2900	4.1 900	1.60 00	1.24 00	1.38 00	3.18 00	4.35 00	2.89 00
5	Sapeken	0.12 30	4.2900	4.1 800	1.52 00	1.13 00	1.38 00	3.18 00	4.35 00	2.89 00
6	Saor	0.19 30	4.2900	5.1 800	11.5 000	1.13 00	1.38 00	3.18 00	4.35 00	2.89 00
7	Sepanjang	0.08 49	4.2900	4.1 900	1.64 00	1.24 00	1.38 00	3.18 00	4.35 00	2.89 00

Source : Analysis result. 2012

Table 6 Comparison of total biocapacity and total ecological footprint

N	Island	Total Biocapacity (- 12%)	Total Ecological Footprint	Total BC / Total EF (capita/year)
		(Total BC) gha/capita/year (x 10 ¹⁰)	(Total EF) gha/capita/year (x 10 ⁶)	(x 10 ⁴)
1	Pagerungan Besar	2.6500	1.5600	1.6900
2	Pagerungan Kecil	1.9400	1.5700	1.2400
3	Paliat	76.8000	0.9110	84.4000
4	Sapangkur Besar	0.0395	1.6200	0.0244
5	Sapeken	0.0096	1.8900	0.0051
6	Saor	0.0256	0.5360	0.1080
7	Sepanjang	48.1000	2.2200	21.7000

Source : Analysis result. 2012

Total comparative value of total biocapacity with the total ecological footprint in Table 6 was the assumption of ability of each small island in the Sapeken Archipelago to accommodate and meet the needs of tourists. The largest number of tourists that can be accommodated was found in Paliat Island (844,000 persons/year) and Sepanjang Island (217,000 persons/year). while the smallest value was found in the Sapeken Island (50.5 persons/year).

The number of visitors or tourists that can be accommodated as a representation of a small island carrying capacity for tourism activities is strongly influenced by existing conditions. such as area. human population. and resource conditions [22]. This condition is an indicator for possibility of utilizing natural capital asset possessed by Sapeken Archipelago. Planning of ecotourism activities is different for island group (archipelagos) and island (single island). In small island group. the development of ecotourism activities should be able to collaborate on cultural and interests differences as well as different levels of development in each small island [23]. Thus. the planning of ecotourism activities in the Sapeken Archipelago should be based on the ability of each small island to meet a number of parameters as a determinant of the suitability of a particular type of tourism that will be developed and their carrying capacity as a marker of ecological limits as well.

Sustainability of Ecotourism Activities in Sapeken Archipelago

Based on the understanding of ecotourism as social-economic-environmental complex system. an assessment of the sustainability of ecotourism activities in the Sapeken Archipelago were based on the value of RCC that represented the ecological/environmental carrying capacity as the loading capacity and the aggregate value of the ecological footprint (EF) that characterized the socio-economic carrying capacity as a supporting capacity. RCC value and EF aggregate value were compared to obtain the sustainability status of ecotourism activities in the Sapeken Archipelago. Furthermore.[24] described the carrying capacity and the ecological footprint was measured in the same units that can be compared directly. If the value of the ecological footprint (EF) is less than the carrying capacity value. ecotourism activities will be sustainable and vice versa. The results of the comparative value of the RCC and EF at Sapeken Archipelago were showed in Table 7.

Table 7. Comparison of regional carrying capacity (persons/year) and ecological footprint (persons/year) at Sapeken Archipelago

N	Island	Regional Carrying Capacity (RCC) x 10 ⁶	Ecological Footprint (EF) x 10 ⁴	Sustainability status	
1	Pagerungan Besar	1,8300	1,6900	RCC > EF	sustain
2	Pagerungan Kecil	2,7800	1,2400	RCC > EF	sustain
3	Paliat	20,2000	84,4000	RCC > EF	sustain
4	Sapangkur Besar	1,1900	0,0244	RCC > EF	sustain
5	Sapeken	0,1200	0,0051	RCC > EF	sustain
6	Saor	1,0500	0,1080	RCC > EF	sustain
7	Sepanjang	99,4000	21,7000	RCC > EF	sustain

Source : Analysis result. 2012

RCC > EF : sustain
 RCC < EF : not sustain

The results of the sustainability assessment of ecotourism activities in the Sapeken Archipelago showed that RCC value is greater than the value of EF. This result implies that ecotourism activities that will be carried out in this island group will not decrease the quality of the ecosystems. but providing benefits to the local community. and able to provide a level of comfort (leisure) to tourists.

Small island tourism is tourism activities undertaken by considering the constraints of a small island. For it sustainability. development in small island tourism activities should be able to bring together all the existing needs.

Furthermore, synchronization between the utilization activities and quality of the environment is an important condition to be created in order to ensure the economic, social, and ecological sustainability [25]. Limiting factor of the development of ecotourism activities in the Sapeken Archipelago is maximum loading capacity of existing ecosystems. Utilization that exceeds the maximum loading capacity will decline the quality of ecosystems in providing a number of ecosystem services.

Restriction on the number of tourists is management strategies which most plausible to be done on the existing ecotourism activities in the Sapeken Archipelago. Aside from the limitations as a small island, the management steps taken will reduce the pressure on the ecosystem as tourist destinations such as coral reefs, mangroves, and coastal fish resources. Furthermore, restrictions on the number of visitors will make the services associated with the presence of existing infrastructure in the Sapeken Archipelago will be optimally utilized by visitors. Strategy of limiting the number of visitors or other travellers can be done directly or indirectly by applying seasonal visit limitation, zoning, and charges for visitors, as a form of mitigation against the impact of the presence of tourists [26].

CONCLUSION

Sapeken Archipelago has utilization carrying capacities (UCC) which vary for different types of ecotourism activities. The largest UCC on each type of tourist activities was mangrove tours (32.100 persons/day), following by fishing (14.900 persons/day), diving (5.330 persons/day), snorkelling (3.590 persons/day), and beaching (1.990 persons/day).

Total comparative value of total biocapacity with the total ecological footprint represents the ability of each small island in the Sapeken Archipelago to accommodate and meet the needs of visitors in tourism activities. The largest number of tourists that can be accommodated were found in Paliat Island (844.000 persons/year) following by Sepanjang Island (217.000 persons/year), while the smallest value were found in the Sapeken Island (50.5 persons/year).

Related to the planning of ecotourism activities (ecotourism) in Sapeken archipelago by looking at the availability status of ecosystem services (budgets), it is possible to be developed. Conditions of some natural capital assets that is still able to provide a number of ecosystem services that can be used as a tourism attraction.

Lastly, assessment of carrying capacity for ecotourism based on ecological footprint should be integrated in the planning of tourism activities, in order to provide existing condition in-depth overview related to small island ability for tourism as sustainable development.

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