Tourism Carrying Capacity of Community Based Ecotourism: Case Study of Olo-Olo Mangrove Forest, and Eco-Park in Lobo, Batangas, Philippines

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ABSTRACT

The purpose of this research is to analyze the Tourism Carrying Capacity of recreational activities in a community-based tourism destination and determine the sustainability of the ecotourism management in Olo-Olo Mangrove Forest and Eco Park in Lobo, Batangas, Philippines, by calculating the physical ecological and social carrying capacity of the recreational activities of the community-based ecotourism site. The method utilized in this research is mixed, measuring quantitative analysis of Carrying capacities using Boullon's Model applied with the Limits of Acceptable Change (LAC) framework. A qualitative approach was used in determining the social and ecological carrying capacity and recorded preferences of the site manager and the visitors. The study reveals that the total physical carrying capacity may range from 79 to 2488 tourists per day; ecological- solid wastes capacity of 333 tourists daily; ecological- water availability capacity of 20 tourists daily; and social carrying capacity of 900 to 1200 tourists daily. The combined tourism carrying Capacity of OMFE shows that the mangrove park can accommodate a wide range of tourists per day depending on which LAC scenario. The current tourist influx in OMFE is only 26 visitors daily on average, which is far below the computed combined carrying capacity. It is still directed towards sustainable ecotourism.

Keywords: Tourism Carrying Capacity, Mangrove Eco Park, combined carrying capacity, Community-Based Ecotourism

INTRODUCTION

Ecotourism attractions continuously face overcrowding issues (Chávez et al., 2022). As these destinations become increasingly popular, there is a growing concern about the negative impacts on their natural environments and local communities. It is crucial to carefully manage and monitor these areas to ensure sustainable tourism practices are in place. This involves considering factors such as carrying capacity, visitor typology, and conservation efforts to protect the ecological integrity and the social and economic well-being of surrounding communities (Cheung & Jim, 2020; Yotsumoto et al., 2017). Considering these concerns, determining the tourism carrying capacity of ecotourism attractions has become a key component in their management. Determining the tourism carrying capacity of ecotourism attractions is vital to their management. Studies conducted in various countries, including Brazil, Zanzibar, and Vietnam, have highlighted how urban coastal mangrove forests can serve as an excellent platform for ecotourism and eco-education initiatives benefiting local communities. These initiatives have created job opportunities while promoting cultural-based tourism through activities such as traditional house preservation (Asrial et al., 2022). However, as the popularity of mangrove ecotourism continues to grow, it is crucial to assess these areas' carrying capacity to ensure visitors' sustainability and comfort. In order to effectively manage and develop mangrove ecotourism, it is necessary to determine the carrying capacity of these areas (Towoliu et al., 2020).

On the other hand, it is essential to acknowledge that population growth and crowding can positively impact ecotourism destinations. While these factors may pressure natural resources and the environment, proper planning and management strategies can mitigate any adverse effects. Sustainable practices are crucial in preserving environmentally sensitive areas, particularly within community-based tourism destinations more vulnerable to increased tourist activity potential impacts. Nature-based attractions, such as Mangrove forests, have been developed through community-based tourism. These ecosystems are often found alongside popular tourist destinations, like sandy beaches and coral reef areas. In specific locations, snorkeling expeditions allow visitors to observe the diverse array of species found in the mangrove area. Along with providing recreational services for tourists, these forests also offer various activities and products that benefit residents and visitors alike (Askar et al., 2021).

Mangrove forests' complex ecological, physical, or socioeconomic functions make them an essential ecosystem in coastal areas (Suprakto et al., 2014). These unique attributes of the mangrove ecosystem have pushed many countries with abundant marine and coastal resources to tap into the development of a community-based ecotourism market. Tourism management in mangrove ecosystems is crucial to ensure the sustainable development and conservation of both environmental resources and the well-being of local communities (Sari et al., 2023).

Olo-Olo Mangrove Forest and Ecopark (OMFE) is a mangrove forest promoted as a community-based ecotourism site in Olo-Olo, Lobo, Batangas. This 21-hectare mangrove forest was recently developed in 2017 and intended for ecotourism activities. It is managed by the Olo-Olo Seaside Workers' Association (OSWA). Visitors can enjoy various recreational and nature-based tourism activities. As the area of a mangrove ecosystem gradually becomes famous as a new nature-based tourism destination, a sustainable management system should be comprehensively developed to effectively manage the natural resources and limit the threats of potential deterioration and exploitation. Interest in meeting tourist and economic demand directly or indirectly impacts the natural environment and local community.

Managing tourist numbers is crucial in balancing development and the environment, which is vital to achieving sustainable tourist destination management. Hence, it is necessary to determine the tourism carrying capacity of the site. However, tourism carrying capacity is more than just a notion of physical space. Tourism carrying capacity must be viewed as an interacting, dynamic concept. Furthermore, complexities and interacting dimensions of the destinations' attributes must be integrated into the system, such as the physical, ecological, economic, and social environment drawn from the tourists and local community. Such factors are also mentioned in the study (Calanog, 2015). The multidimensional and dynamic nature of carrying capacity has drawn attention in the literature, particularly on tourism, due to the complexity and varying attributes of tourism destinations in tourist-centric approaches and destination environment systems. In the study of Zelenka & Kacetl (2014), different research concludes that carrying capacity varies in each destination. Furthermore, multiple interacting factors are considered based on the dynamic concept of the environment, social aspects, and visitor capacity.

Among these variables are dependent on converging factors that contribute not only to tourist satisfaction but more so to the synergistic interconnection of the protection of nature and landscape management, biodiversity promotion, types of tourism facilities and ways of their utilization and dimensions related to physical, ecological, socio-cultural and economic environment. Tourism activity also depends on its destination since it is dynamic regarding the space and time seasonality, area and type of activities, and non-tourism-related activities that may coincide. There is no fixed standard of measure in tourism carrying capacity due to the dynamic attributes of the environment of a specific destination (Pбskovб et al., 2021). It was recognized in the literature that the determination of tourism carrying capacity considers the physical, ecological, social, and economic aspects. Meanwhile, the Limits of Acceptable Change (LAC) considers that aside from putting a threshold on visitor number, management of an ecotourism area should be based on future conditions desired (i.e., resource, social and managerial conditions) for an area and the actions prescribed to protect or achieve those conditions, rather than on how much use such an area can tolerate.

Therefore, the present study sought to determine a community-based ecotourism destination's combined tourism carrying capacity using physical, ecological and social aspects of the carrying capacity of Olo-Olo Mangrove Forest and Eco Park in Lobo Batangas, Philippines. The study further investigated the potential use of the combined tourism carrying capacity framework in managing community-based ecotourism sites.

METHODOLOGY

Study Design

This research utilized a mixed-methods approach to assess the carrying capacity of the Olo-Olo Mangrove Forest and Eco Park, focusing on three vital recreational activities. By combining quantitative and qualitative data, the study aimed to provide valuable insights for sustainable management and planning of ecotourism activities in the area. The primary data collection involved several methods. Firstly, on-site observations were conducted to identify the activities offered at the location. The study focused on three specific activities, recreational fishing, rafting, and eco-walking, which were frequently availed by visitors and assumed to be mutually exclusive regarding space utilization.

Study Participants

A self-administered survey was conducted on participants using the convenience sampling method. Included in the study were 18 years old and above tourists visiting the ecotourism site. Additionally, interviews were conducted with two distinct groups of respondents: tourists who had visited Olo-Olo Mangrove Forest Ecopark (OMFE) and members of the local community who were also volunteers in the area. A focus group discussion consisting of seven local community members was organized to collect the responses about space preferences for each recreational activity and factors influencing satisfaction with each activity. The interviews with community members aimed to assess current livelihoods, perceptions of area crowding, and future organizational plans.

Data Analysis

In calculating the carrying capacity, this study utilized a combination of two models: Boullon's (1985) carrying Capacity mathematical model and the Limits of Acceptable Change (LAC) model. Boullon's model evaluates carrying capacity at three levels: essential carrying capacity, potential carrying capacity, and real carrying capacity. The Basic Carrying Capacity (BCC) is computed by dividing the total area visitors use by the average or standard size/space requirement per visitor. The Potential Carrying Capacity (PCC) involves calculating the rotation coefficient (RC) for a specific tourism activity using Equation 2. The Real Carrying Capacity (RCC) represents the maximum permissible number of visitors using an area, considering the limiting factors (Lf1, Lf2,...Lfn) identified during interviews and on-site observations. The formula for the combined tourism carrying capacity is as follows:

Equation 1-3. The formula used in computing Basic Carrying Capacity (BCC), Potential Carrying Capacity (PCC), and Real Carrying Capacity (RCC) from Boullon's Carrying Capacity Mathematical Model (BCCMM)

$$\text{Basic Carrying Capacity (BCC)} = \frac{\text{Area used by visitors } (m^2)}{\text{Average area used by visitors } (m^2)}$$

$$\text{Potential Carrying Capacity (PCC)} = \text{BCC x RC}$$

$$\text{Rotation Coefficient (RC)} = \frac{\text{Total no. of hours as the specific area is open for use}}{\text{Average no. of hours area is used by visitors.}}$$

$$\text{Real Carrying Capacity (RCC)} = \text{PCC} \times \frac{(100). - Lf_1}{100} \times \frac{100 - Lf_2}{100} \times \frac{100 - Lf_3}{100}$$

$$\text{Limiting Factors (Lf) } (Lf_{1,2,\ldots,n}) = \frac{(M_{a,b,\ldots,n})}{MT} \times 100$$

Where:

$(M_{a,b,..n})$ = limiting magnitude of the factor/variable, and

MT = Total magnitude of the factor/variable

Study Area

The Olo-olo Mangrove Forest and Ecopark (OMFE) was developed in 2017 for ecotourism activities and managed by a people's organization (PO) – Olo-olo Seaside Workers Association (OSWA). Most activities are within the vicinities of *Bakawang Lalaki Point, Sihi Farm, Oyster Farm, Talabahan Bridge, Red Tilapia- -Mudcrab-Milkfish Farm,* and the *Puktol Point. Bakawang* Babae Point is a tourist site for mangrove planting but is not yet fully accessible for tourism activities (i.e., eco-walking). OSWA is considering expanding the mangrove boardwalk up to *Bakawang Babae Point* to increase the recreational area for tourists.

At present, the 21 hectare- mangrove area caters to ecotourism activities such as recreational fishing, rafting, kayaking, stand-up paddle boarding, fish feeding, shell and crab harvesting, bird watching, mangrove planting, eco-walking and snorkeling/ SCUBA diving at seafront. For this study, only three *(3)* activities that are frequently availed by visitors–(1)*ecowalking,* (2) *rafting,* and (3) *recreational fishing* were included in the computation for carrying capacity. On its current tourism operations, OMFE receives 500 visitors per week, including weekends and weekdays, during peak season and receives 20 visitors per week, usually only every weekend, during the lean season. The peak of tourism activities in OMFE is experienced for five (5) months, specifically from March to May and December to January. The remaining seven (7) months of the year are considered lean months for ecotourism activities in the area.

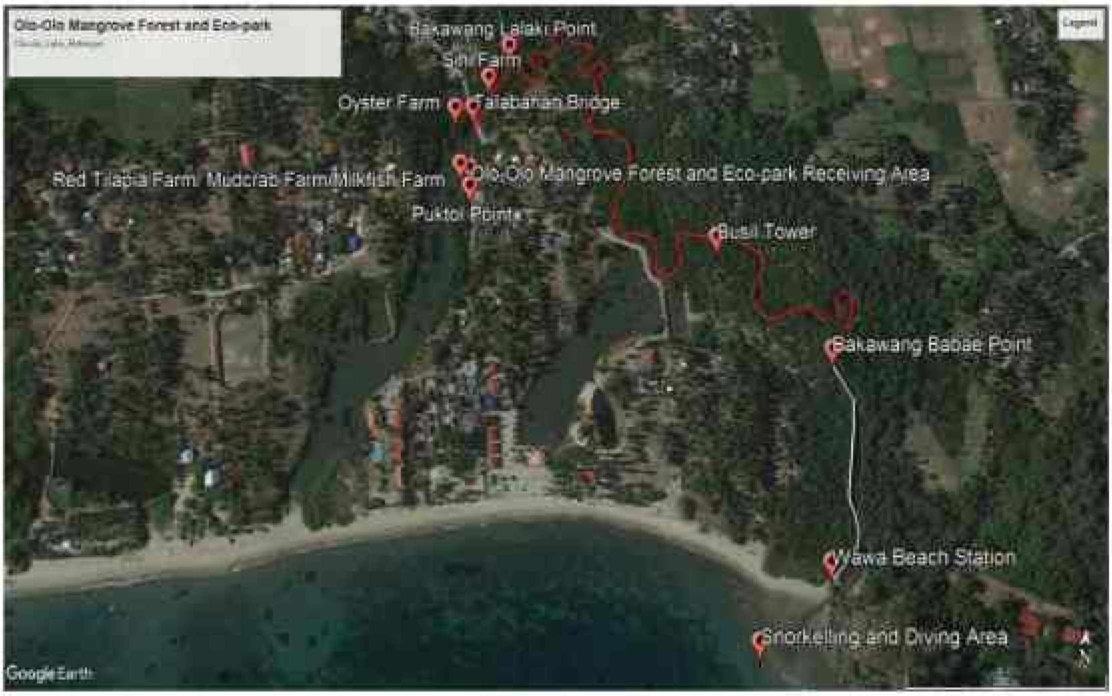

Figure 1. Location and landmarks/ features of the study site, Olo-olo Mangrove Forest Ecopark (OMFE) in Brgy. Olo-olo, Lobo, Batangas

Key Indicators, Criteria, and Parameters Used in Assessing Each Carrying Capacity

Physical Carrying Capacity

The physical carrying capacity of the three (3) recreational activities– eco walking, rafting, and fishing were computed separately. Tables 1, 2 and 3 present the data used in computing carrying capacity for each recreational activity. Each recreational activity's computed physical carrying capacity was summed up to have a total physical carrying capacity, which is possible since the chosen activities are mutually exclusive.

Table 1. Parameters and data used for computing physical carrying Capacity for Eco walking.

	Parameters	Value
Preferred distance of visitors from another group while eco-walking (m)	LAC-1 Business-as-Usual (BAU) or Practice on the site manager/OSWA	10
	LAC-2 preference of the tourist or visitor	25
	LAC-3 Computed preference/ meeting halfway the preference of the manager and the visitor	17.5
	LAC-4 Doubling preference of visitors.	50
Preferred distance/personal space of visitors belonging to the same group while eco walking (m)	LAC-1 Business-as-Usual (BAU) or Practice on the site manager/ OSWA	1
	LAC-2 preference of the tourist or visitor	2
	LAC-3 Computed preference/ meeting halfway the preference of the manager and the visitor	1.5
	LAC-4 Doubling preference of visitors.	4
Length of boardwalk used for eco walking (m)		210
Average number of persons in a group		6
No. of minutes eco walking is offered per day		480
No. of minutes spent by a visitor for eco walking		60
Rotation Coefficient		8
No. of days OMFE is closed in a year		30
No. of days in a year		365
No. of persons that can be accommodated on designated holding area/ cottages for visitors		30
No. of minutes the visitor stays on site		240

Table 2. Parameters and data used for computing physical carrying capacity for rafting.

	Parameters	Value
Preferred distance of rafts from one another while traversing/ moving in the river (m)	LAC-1 Business-as-Usual (BAU) or Practice on the site manager/OSWA	5
	LAC-2 preference of the tourist or visitor	15
	LAC-3 Computed preference/ meeting halfway the preference of the manager and the visitor	10
	LAC-4 Doubling preference of visitors.	30

preferred no. of passengers in a raft	LAC-1 Business-as-Usual (BAU) or Practice on the site manager/OSWA	20
	LAC-2 preference of the tourist or visitor	10
	LAC-3 Computed preference/ meeting halfway the preference of the manager and the visitor	15
	LAC-4 Doubling preference of visitors.	5
Length of river used for rafting (m)		290
Length of raft (m)		3
No. of minutes rafting is offered per day		480
No. of minutes spent by a visitor for rafting		60
Rotation Coefficient= (No. of minutes rafting is offered per day) ч (No. of minutes spent by a visitor for rafting)		8
No. of rafts available		2
No. of life vests available		10
No. of available personnel/ rafting tour guides per day		10
No. of required rafting tour guide every trip		2
No. of ports/ boat anchorage		3
No. of days river is closed in a year		30
No. of days in a year		365
No. of persons that can be accommodated on designated holding area/ cottages for visitors		30
No. of minutes the visitor stays on site		240
No. of minutes OMFE is open per day		480

Table 3. Parameters and data used for computing physical carrying capacity for fishing.

	Parameters	Value
Preferred distance of a visitor from another visitor while fishing	LAC-1 Business-as-Usual (BAU) or Practice on the site manager/OSWA	2
	LAC-2 preference of the tourist or visitor	10
	LAC-3 Computed preference/ meeting halfway the preference of the manager and the visitor	6
	LAC-4 Doubling preference of visitors.	20
Area along streambanks and boardwalks that can be used for fishing (sq.m.)		290
standing area used per individual (sq.m.)		0.5

Parameters	Value
No. of minutes fishing is offered per day	480
No. of minutes spent by a visitor for fishing	60
Rotation Coefficient= (No. of minutes rafting is offered per day) ÷ (No. of minutes spent by a visitor for rafting)	8
No. of fishing rods available	10
No. of packs of bait available per day	20
Average no. of packs of bait being consumed by 1guest	2
No. of days OMFE is closed in a year	30
No. of days in a year	365
No. of tour guides that can assist for recreational fishing	5
No. of minutes the visitor stays on site	240
No. of minutes OMFE is open per day	480

Ecological Carrying Capacity

Ecological status to carry out the optimum condition of the population, natural resources and environment are critical areas to address the sustainable development of a destination (Tsou et al., 2017). Two (2) main environmental problems/ issues identified were covered in this study, including (1) waste generation and management (2) water availability. In the Philippines, the estimated waste generation per person in urban areas is 0.5kg and 0.3kg daily (Castillo & Otoma, 2013), while water consumption is estimated to be an average of 300L daily (Hussein, 2018). The average monthly tourist influx was multiplied by 0.3kg of daily waste generation per individual to calculate the estimated monthly waste generated by tourists in the area. Similarly, the 300L daily water consumption will be multiplied by the number of tourists to estimate water consumption.

Social Carrying Capacity

Social interaction and quality of life of tourist and host destination are critical factors considered in the social carrying capacity (Yusoh et al., 2021). Generally, the social carrying capacity of a tourist site is set as the optimum number of visitors per day to which the maximum social utility due to congestion corresponds. Two different points of view specifically define the SCC of a tourist area. From the point of view of residents, the SCC represents the social interaction between residents and visitors, and it is the maximum number of visitors (MNV) tolerated by the host population without reducing their quality of life. This study focused on analyzing the social carrying capacity in the Eco-park based on the level of social space preference and satisfaction of the tourists and the community stakeholders.

Overall, the combined tourism carrying Capacity of the Olo-olo Mangrove Forest Ecopark was obtained through an operational research approach by relying on linear programming of the eco-parks physical, ecological and social carrying aspects.

RESULTS AND DISCUSSION

Physical Carrying Capacity

In Table 4, results showed that applying the distance of 10 m between groups of six persons with an allowable 1-meter personal space for each visitor (LAC1), the eco-walking activity could accommodate as many as 286 visitors a day. If there is a 25 m distance between groups of six persons with a 2-meter personal space for each visitor (LAC2), the number of visitors that can be accommodated is only 132 per day. At a 17.5 m distance with 1.5-meter personal space for each visitor in a group of six (LAC3), the computed carrying capacity is 176 daily visitors. For a 50 m distance between groups (LAC4) with 4-meter personal space for each individual, the allowable limit is computed at 66 visitors only per day.

Physical Carrying capacity for rafting shows that for the rafting activity, if the Business-as-Usual (BAU) practice is implemented, with a distance of 5 m between boats and a maximum of 20 passengers per raft (LAC1), 1862 visitors per day can be accommodated by rafting alone. However, if visitors prefer a 15m distance between rafts and a maximum of 10 passengers will be implemented, this means that 219 visitors a day can be accommodated by rafting activity. Meeting halfway the preferences of the site manager and the visitors, a 10 m distance and a maximum of 15 passengers (LAC3) resulted in 648 visitors a day. Moreover, we doubled visitors' preferences, with a 30 m distance requirement between boats and a maximum of 5 passengers (LAC4). In that case, OMFE can only cater to rafting up to 10 visitors per day.

It was shown that applying LAC 1 in recreational fishing in OMFE can accommodate a maximum of 340 fishing visitors. If visitors' preferences will be considered(LAC2), only 35 fishing tourists should be accommodated daily. Meanwhile, averaging the site manager and visitors' preferences

(LAC3), 89 tourists can avail of the fishing activity daily. However, if visitors' preferences are doubled, compromising the distance between fishing visitors (LAC4), the maximum number of fishing tourists that OMFE should cater to is only six per day.

Table 4. Physical Carrying Capacity for Eco-walking in OMFE.

Level of Carrying Capacity of Eco Waking	***LAC 1***	***LAC 2***	***LAC 3***	***LAC 4***
Basic Carrying Capacity	78	36	48	18
Potential Carrying Capacity	624	288	384	144
Realm Carrying Capacity	286	132	176	66
Level of Carrying Capacity of Rafting	***LAC1***	***LAC2***	***LAC3***	***LAC4***
Basic Carrying Capacity	720	160	330	45
Potential Carrying Capacity	5760	1280	2640	360
Real Carrying Capacity	1862	219	648	10
Level of Carrying Capacity of Recreational Fishing	***LAC 1***	***LAC 2***	***LAC 3***	***LAC 4***
Basic Carrying Capacity	116	28	45	14
Potential Carrying Capacity	928	224	360	112
Real Carrying Capacity	340	35	89	3

Total Physical Carrying Capacity for OMFE

Each recreational activity's computed physical carrying capacity was summed up to have a total physical carrying capacity. This was possible since the three (3) activities are mutually exclusive regarding space. Moreover, an average stay of four (4) hours was included as a limiting factor in computing the fundamental carrying capacities of eco-walking, rafting, and fishing in OMFE. The physical carrying capacity of the three (3) activities is presented in the Table below.

Table 5. Physical Carrying Capacities of the Three (3) Activities– Ecowalking, Rafting, and Recreational Fishing offered in OMFE.

Level of Carrying Capacity	***LAC 1***	***LAC 2***	***LAC 3***	***LAC 4***
Ecowalking	286	132	176	66
Rafting	1862	219	648	10
Recreational Fishing	340	35	89	3
Total Physical Carrying Capacity	2488	386	913	79

Based on computations, the total physical carrying capacity of the Olo-olo Mangrove Forest Ecopark (OMFE) ranges from 79 to 2488 tourists per day, depending on the type of management intervention, particularly on space preferences applied. Notably, the Business-as-Usual (BAU) scenario or the site managers' preferences produced the highest physical carrying capacities for all recreational activities. However, shedding importance on considering the visitors' preferences on space requirements shows a significant decline in its physical carrying capacity, from 2488 tourists per day in LAC 1 to only 386 tourists per day in LAC 2. A more drastic decline in carrying capacity is observed when visitor preference doubles, resulting in a maximum of 79 tourists daily. The LAC 3, a computed preference of the site manager and the visitors, provides a considerable physical carrying capacity of 913 tourists daily.

Ecological Carrying Capacity

Ecological carrying capacities considering two (2) main environmental concerns that may affect tourism in OMFE– (1) waste generation and management (2) water availability identified were computed separately in this study. The solid waste generation of tourists was estimated based on the actual tourist influx record in the previous months of operation of OMFE (Table 9). Estimates were obtained by multiplying the number of tourists by 0.3 kg. This was a standard value for a Filipino's estimated daily waste generation, according to Otoma, S. (2013).

Based on the results, on average, tourism in OMFE generates 7.76 kg. of solid waste daily and 232.90 kg of solid waste monthly. As per the interview with the Olo-olo Seaside Workers Association (OSWA) officials and the observations on the actual site visit, the park has only two (2) sacks serving as trash bins. One (1) sack is placed near the Tourist Receiving Area before the boardwalk, while the other sack is located on the other end of the boardwalk near the resting areas/ cottages. Each sack has a storage capacity of 50 kg, which could contain seven (7) times more than the computed estimate of daily tourist waste generation in OMFE, 7.76kg/ day. Suppose the computation is based on the calculated physical carrying capacity with different Limits of Acceptable Change (LAC). In that case, the current ecological carrying capacity of the mangrove eco park is only 333 tourists daily, generating approximately 99.9 kg of waste. This is when the practice of only two (2) sacks, with a total of 100 kg storage capacity, will remain as a means of storage and collection of solid wastes in OMFE.

Table 6. Estimates of monthly and daily solid waste generation in Olo-olo Mangrove Forest Ecopark (OMFE) based on tourist influx from March 2019 to October 2019.

Month	*Monthly Number Of Tourists*	*Estimated Monthly Waste Generation (Kg)*	*Estimated Daily Waste Waste Generation (Kg)*
March 2019	1,032	309.6	10.32
April 2019	1,488	446.4	14.88
May 2019	1,402	420.6	14.02
June 2019	495	148.5	4.95
July 2019	385	115.5	3.85
August 2019	479	143.7	4.79
September 2019	389	116.7	3.89
October 2019	540	162.0	5.4
TOTAL	**6,210**	**1,863.0**	**62.1**
AVERAGE	**776**	**232.9**	**7.76**

Based on solid waste generated, this ecological carrying capacity is below the computed physical carrying capacity of 2488 visitors daily when LAC 1, Business-as-Usual (BAU), or site managers' preference is applied on OMFE (Table 10). The 2488 visitors will incur an estimated 746.4 kg. of waste, requiring approximately 15 sacks of 50kg storage capacity placed within OMFE. A similar was observed when LAC 3, computed preference of physical carrying capacity will be applied, which is 913 tourists daily, resulting in 273.9 kg. of waste generated. This will need 5.5 sacks to be able to store the accumulated solid wastes. Meanwhile, applying LAC 2, based on visitor's preference, the 386 tourists daily, equating to 115.8 kg of waste, slightly exceeded the storage capacity of the currently placed two sacks in OMFE. Moreover, this ecological carrying capacity of 333 tourists daily is still within the recommended physical carrying capacities when LAC 4, doubled visitor preference management interventions, will be applied. With 79 tourists daily, solid waste accumulated is estimated to be only 23.7 kg daily and can fill up only 0.5 sacks of waste.

Table 7. Potential Waste Generation of OMFE and 50-kg sacks for trash bins based on computed physical carrying capacities in OMFE

Level of Carrying Capacity	*LAC 1*	*LAC 2*	*LAC 3*	*LAC 4*
Total Physical Carrying Capacity	2488	386	913	79
Estimated Solid Waste Generated Daily (kg)	746.4	115.8	273.9	23.7
No. of Sacks (50kg - capacity) Needed	14.9	2.3	5.5	0.5
No. of TC60NDS Trash Bins (28.86 kg-capacity) Needed	25.9	4.0	9.5	0.8

Meanwhile, as OMFE is a recreational site, structured trash bins can be recommended to replace sacks. Structured trash bins are more noticeable than sacks. Figure 4 is the TC60NDS trash bin, an example of a garbage bin usually seen in establishments that are also color-coded to facilitate the segregation of solid wastes. It has dimensions: width: 330 mm, length 330 mm, height 889 mm, and storage capacity of up to 60 L volumes of waste, or equivalent to 28.86 kg. of waste. Assuming an average of 7.76 kg of waste generated daily, the bin can store more than thrice the estimated daily waste generation from tourists alone. However, when applied with LAC management interventions, 25.9 trash bins for LAC 1, 4 trash bins for LAC 2, 9.5 trash bins for LAC 3, and 0.8 trash bins for LAC 4 will be needed to store the potential waste generation based on computed physical carrying capacity. This will cost the OSWA site managers a lot to provide several trash bins, and at least two (2) bins should be placed next to each other to facilitate waste segregation, at least between biodegradable and non-biodegradable wastes.

However, the problem of solid waste is not just about storing and segregating. No schedule of waste collection was noted. Based on the interview, the solid wastes, when collected, are placed in an open space in front of the residential area or one of the residential lots and are burned together with the accumulated solid wastes from the locales of the barangay. From here, the implementation of ecological solid waste management should be strengthened in the area. Barangay Olo-olo is estimated to have a population of 1,420 (Lobo et al. Office, 2016), with an estimated total solid waste generation of 426 kg monthly and 14.2 kg daily. Since there is an estimated hefty volume of waste, a waste collection schedule and active participation of tourists and locales on proper waste segregation is encouraged. It is suggested that the community must have its own Material Recovery Facility (MRF), which could serve as a temporary station where they can receive, separate, or sort recyclable materials for marketing to end-user manufacturers to lessen residual waste collected by municipal garbage collectors.

Ecological Carrying Capacity for Water Availability

Water availability is crucial for tourist satisfaction and recreational experiences at a site. To estimate the water requirement of tourists at OMFE, actual tourist influx data from previous months (Table 10) was used, assuming 300 liters as the daily water consumption per tourist, as Hussein (2018) reported. The results indicate that, on average, tourists in OMFE consume 7762.5 liters of water daily and 232875 liters monthly. OMFE has two comfort rooms, but only one can access a flowing water source from a nearby house. According to OSWA, tourists typically use about 20 gallons (75.7 liters) of water, specifically in the comfort rooms. When this is averaged for the actual tourist influx (26 tourists daily), each tourist consumes only three (3) liters of water during their visit, significantly below the projected daily water consumption of 7762.5 liters for OMFE.

The observed low demand for water at OMFE is due to several factors: many tourists do not use water during their activities in the Eco Park, they do not require the use of comfort rooms, and some have short stays at OMFE, leaving them with little time to use water sources. Only a small percentage of tourists visiting OMFE utilize the bathing/showering facilities on site. Interestingly, the top three recreational activities—eco walking, rafting, and fishing—do not directly require water usage, thus not increasing the demand for water availability at the site.

When inquired about the maximum volume of water that can be stored within OMFE and made available for tourists, especially in comfort rooms, OSWA members mentioned that there are six (6) drums with a capacity of 1000 liters each, providing a total storage capacity of 6000 liters.

Table 8. Estimates of monthly and daily water demand in Olo-olo Mangrove Forest Ecopark (OMFE) based on tourist influx from March 2019 to October 2019.

Month	*Monthly Number Of Tourists*	*Estimated Monthly Waste Generation (Kg)*	*Estimated Daily Waste Waste Generation (Kg)*
March 2019	1,032	309.6	10.32
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October 2019	540	162.0	5.4
TOTAL	6,210	1,863.0	62.1
AVERAGE	776	232.9	7.76

The current ecological carrying capacity of the mangrove eco park, considering the availability of water for tourists, is only 20 tourists daily, estimated to use up approximately 6000 liters of water. This is far below any of the computed physical carrying capacities with LAC options. Computing the water demand for different physical carrying capacities of LAC management interventions (Table 11), OMFE's current capacity having six (6) drums with 6000-liter storage capacity is seen to fall short by projected tourism water demand when any of the four (4) LAC management interventions are applied because these scenarios will require 746.4 drums, 115.8 drum, 273.9 drums, and 23.7 drums respectively, is able to provide at least 300 liters of water available for each potential tourist.

Although OMFE is not yet experiencing high water demand with their recreational activities, it is suggested that the community must have enough water supply for the expected number of tourists that will be catered on-site, and preferably a higher volume of water available than the computed water demand per day.

Table 9. Potential Water Demand of Tourists of OMFE and Demand for Drums for Water Storage based on computed physical carrying capacities in OMFE

	LAC 1	*LAC 2*	*LAC 3*	*LAC 4*
Total Physical Carrying Capacity	2488	386	913	79
Estimated Water Demand Daily (liters)	746400	115800	273900	23700
No. of Drums used for storage (1000 liter capacity) Needed	746.4	115.8	273.9	23.7

Social Carrying Capacity

Alternative Livelihood

The advantages of tourism activity in the local community of Barangay Olo Olo, as perceived by participants, included improved quality of life for the members of the people's organization, Olo-Olo Seaside Workers' Association (OSWA), by providing an alternative source of income apart from their usual work. Most of the organization's members are the locals residing in the barangay. Farming and fishing are their primary source of livelihood. Relative advantage varies depending on the seasonality and number of park visitors. They reported that income was divided among the rest of the members of the OSWA that manage and maintain the park, and the number of tourist visits and the amount of their donation determine the members' equity. Participants describe that 40 percent of the donation will be allotted for the member's equal share, and 60 percent will be used for maintenance and management of the park. Many participants shared that they are grateful for having an alternative source of income because of the current situation in agricultural farming. They said they are happy being a member of the organization and having alternative sources. The activity area, especially the water body, allowed them to harvest shellfish, crabs, and fish and sell them in the market or to make their meal for the day. According to the locals' perception, the advantages of the tourist activity help them benefit from alternative sources of income and livelihood. The support from the members of each organization in the park contributes to the management and maintenance of the park and succeeding tourism activity.

Potential Risks and Benefits with Increased Tourist Arrivals

Respondents reported that increasing tourist arrivals could meet Olo Olo Park's and its stakeholders' needs. Tourist donation for the park's maintenance and management helps them have a better income share. Community organizations were asked to identify the number of guests they could accommodate individually, and most answered 15 guests, or 25% of the total number of OSWA members. The more significant number is preferred, but only a maximum of 20, which is 33.33% of OSWA members, can be entertained simultaneously. Although respondents reported beneficial effects on tourist arrivals, The problem with garbage disposal of tourists is observed. The respondents have reported inadequate trash bins and lack of garbage collection in the park as one of the problems they encountered in managing the park. The local member suggested that part of the waste management implemented in the eco-park was dumping the trash in a pit and combusting. This can pose a further problem in managing the eco-park in the future.

Capacity of Olo-Olo Seaside Workers Association (OSWA) in Handling Increased Tourist Arrivals

The Olo-Olo Seaside Workers Association (OSWA) currently comprises 60 members. Through interviews, it was found that each OSWA member preferred to cater to 15 to 20 tourists per hour. They expressed feeling comfortable and undisturbed while interacting with tourists within this range. Table 14 presents a hypothetical allocation of tour guides to tourists. Based on the actual tourist influx in OMFE, OSWA members handle an average of 26 daily tourists, translating to approximately three (3) tourists per hour. When groups of fifteen (15) members visit, only two (2) tour guides are required, with one (1) local guide accompanying them during their tour in the mangrove eco-park.

The total physical carrying capacity, considering the top 3 activities enjoyed by tourists and four (4) scenarios of the limit of acceptable change (LAC), are presented in Table 14 as follows: LAC1 (Business-as-Usual or Practice on the site manager/OSWA) is 2,488; LAC2 (based on the views/ preference of the visitors or users) is 386; LAC3 (Computed preference/ meeting halfway the preference of the manager and the visitor) is 913; and LAC4 (doubling preference of visitors) is 79.

When implementing Limits of Acceptable Change (LAC) management interventions (Table 15), each of the 60 OSWA members will accommodate 42 tourists in LAC 1, 6 tourists daily in LAC 2, 15 tourists daily in LAC 3, and 1 tourist daily in LAC 4. On an hourly basis, the LAC 1 scenario will result in 311 tourists per hour, equating to 5 tourists per hour per OSWA member. For LAC 3, 114 tourists per hour implies that each OSWA member will handle two tourists per hour. On the other hand, LAC 2 and LAC 4 would have one or less than one tourist per hour assigned to each OSWA member. Since the total carrying capacity for LAC 2 and LAC 4 is less than the total number of OSWA members, not all workers could have individual guests simultaneously. They may choose to work as a group in assisting the guests. Tasks could be distributed equally among members, including the option of accepting an uneven number of tourists to assist or interact.

Overall, the estimated total carrying capacity is still highly acceptable for the workers based on their preferred rate of social acceptance in accommodating and interacting with guests. Applying the limit of encountering 15 to 20 individuals in a group of tourists at a rate of one hour, the social carrying capacity of the local community/OSWA, which consists of 60 members, ranges from 900 to 1200 tourists per day.

Table 10. Potential need/ allocation of tour guides to tourists based on computed carrying capacities in OMFE.

	LAC 1	*LAC 2*	*LAC 3*	*LAC 4*
Total Physical Carrying Capacity Daily	2488	386	913	79
Average Number of Tourists per Hour[a]	311	48	114	10
Estimated Number of Tourists assigned to OSWA members per day	42	6	15	1
Estimated Number of Tourists assigned to OSWA members per hour	5.2	1	2	0.2
No. of OSWA member needed daily when tourists are grouped	166	26	61	5

Legend: a- 8 hours OMFE operation hours; b- 60 OSWA members; b- 15 visitors in a group

Combined Tourism Carrying Capacity

Utilizing an optimization approach, the Tourism Carrying Capacity of Olo-olo Mangrove Forest and Ecopark (OMFE) is determined, considering physical, social, and ecological considerations. The optimal combined carrying capacity is the number of tourists visiting OMFE that minimizes resource degradation, such as waste generation and water demand, while promoting positive local community engagement in ecotourism activities and enhancing tourist experiences. Additionally, ecological constraints and social capacities are incorporated into the optimization process.

The optimized scenario for the combined carrying capacity is illustrated in Table 18, wherein OMFE is recommended to accommodate 151 tourists per day, comprising 67 tourists for eco walking, 74 for rafting, and ten for fishing. This equates to a monthly total of 4530 tourists, with 67 tourists for eco walking, 74 tourists for rafting, and 10 tourists for fishing.

Table 11. Example of optimized minimum number of tourists monthly and daily that can be accommodated by OMFE.

	Ecowalking	*Rafting*	*Fishing*	*Total*
No. of tourist (monthly)	2010	2220	300	4530
No. of tourist (daily)	67	74	10	151
Ranges of Physical Carrying Capacity Daily (depending on LAC)	66- 286	10-1862	3-340	79-2488
Estimated Daily Solid Waste Generation (kg)	20.1	22.2	3	45.3
Estimated Daily Water Use (liters)	20100	22200	3000	45300
No. of Tour Guides/OSWA member to be assigned	5	5	1	10

Among the three activities, fishing is the most limiting due to the availability of only ten fishing rods. Even if the number of fishing tourists could be increased, practical constraints hinder the possibility of accommodating more than ten tourists fishing simultaneously. In contrast, rafting allows flexibility in adhering to visitor preferences, including maintaining longer distances between rafts and reducing passenger numbers.

Ecowalking faces its challenge since its lower fee generates less revenue, making it insufficient to sustain the operational needs of the eco-park. Although the optimized tourist influxes only partially meet the doubled visitor preferences set by LAC 4, the accommodation of 151 tourists daily remains acceptable when compared to upper limits set by other LAC scenarios. Assessing the ecological aspect, the estimated solid waste generated by the visitors can be accommodated by two sacks with a total storage capacity of 100 kg. However, it is essential for site managers to ensure adequate availability of solid waste handling and storage facilities to avoid exceeding the ecological carrying capacity. Installation of additional trash sacks and the establishment of a Material Recovery Facility (MRF) should be considered.

On the other hand, water demand for 151 tourists daily amounts to 45,300 liters, surpassing the Capacity of OMFE's current water storage facilities, which holds a total of 6,000 liters. Water availability emerges as the most restrictive factor among all computed carrying capacities. The current facility can only support 20 tourists, with a maximum water allotment of 300 liters each. Dividing the available 6,000 liters among the proposed 151 tourists resulted in an individual allocation of 39.7 liters, a substantial amount compared to the computed water use of tourists in OMFE, which was only 3 liters per individual.

Regarding the social carrying aspect, guided tours with 15 to 20 visitors at a time are recommended, with ten tourist guides available within the eco park's organization of 60 members. Staff rotation can ensure task performance, including construction of boardwalks, repair of pathways, installation of additional temporary trash bins and MRF, and training of members for environmental briefings with tourists.

CONCLUSION

The establishment of the Mangrove Eco Park aimed to achieve ecological and economic sustainability for the local community. Given the increasing importance of sustainability in ecotourism management, comprehending natural limits and constraints in the physical, ecological, and social environments becomes crucial for guiding sustainable ecotourism practices.

This study highlights that applying a combined Tourism Carrying Capacity using the Limits of Acceptable Change (LAC) framework can offer valuable recommendations at any stage of ecotourism area development. In the case of Olo-olo Mangrove Forest and Ecopark (OMFE), the subcategories of Tourism Carrying Capacity, namely physical, ecological, and social carrying capacities with LAC opportunity classes, play a significant role in planning and policy interventions, tourism operations and management, environmental conservation, and monitoring the impacts and benefits of ecotourism.

Community-based ecotourism sites like OMFE are encouraged to incorporate public participation and use LAC-based planning for tourism destination management. This approach allows local community managers to implement policy interventions in providing recreational services and goods to visitors while safeguarding their socioeconomic welfare, resources, and immediate environment.

Promoting active community involvement and environmental awareness among stakeholders and tourists is crucial, as most eco-park and community development rely on ecotourism activities. Lastly, the study emphasizes that physical, ecological, and social carrying capacities are essential for estimating waste generation and developing appropriate waste management plans to address current and future ecological challenges.

Limitations and Suggestions for Future Research

The framework for assessing the combined tourism carrying capacity of community-based ecotourism destinations could be a good reference for future studies. However, the study is subject to limitations in terms of size and scope. One of the main limitations identified in the study was limited in terms of the number of participants. Therefore, it would be necessary for further valuation studies to consider an adequate sample size to improve the generalization of the results and their implications. Future research should also focus on the economic carrying capacity of the Olo-Olo Mangrove Forest and Eco-Park. This would involve assessing the economic viability of tourism activities in the area and identifying the limits beyond which tourism development becomes unsustainable or detrimental to the local economy.

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