Best Practices for Determining Tourism Carrying Capacity in Marine and Coastal Ecosystems

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Abstract

Best Practices for Determining Tourism Carrying Capacity in Marine and Coastal Ecosystems

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Finding the tourism carrying capacity of a given area can inform sustainable levels of tourism and management objectives. The goal of this review is to develop a framework for studying tourism carrying capacity in coastal and marine ecosystems that follows the best practices of previous studies. This systematic literature review takes the varied definitions of tourism carrying capacity into specific consideration, suggesting how studies with different concepts of tourism carrying capacity might be integrated. For the purposes of this review, tourism carrying capacity will be defined as the maximum number of individuals that can visit a given area simultaneously without causing unacceptable deterioration of the biophysical and sociocultural environment or the quality of tourist satisfaction. Within this definition, there are four main subcategories of tourism carrying capacity: 1) biophysical carrying capacity, 2) sociocultural carrying capacity, 3) managerial carrying capacity, and 4) experiential carrying capacity. This review examines the varied methodologies used to determine these carrying

capacities, the studies reviewed differ in procedures, overall focus, and variables included. Although few studies considered multiple sectors of tourism carrying capacity, this review also examines how subcategories influence one another and will explore options for more holistic assessments of tourism carrying capacity, culminating in recommendations for assessing tourism carrying capacity in the Nusa Penida MPA in Indonesia based on the best practices of previous studies.

1. INTRODUCTION & METHODOLOGY

Tourism is one of the fastest growing global sectors, promoting conservation through the alternate, non-extractive use of marine resources, however, negative social and ecological impacts could threaten the sustainability of the tourism industry in the long run. It is vital that we understand the nature of these relationships, the negative and positive effects of tourism, to ensure there is a net benefit to local communities. Through a careful examination of tourist density, and its impact on local socioecological systems, managers can estimate sustainable rates of tourism in marine and coastal ecosystems.

Tourism is a powerful economic force, accounting for a sizable percentage of global GDP, providing jobs, and creating opportunities for newly industrialized and small island nations. Travel and tourism supported 319 million jobs globally in 2018; in 2019 that number rose to 334 million and accounted for 10.4% of global GDP (WTTC 2019, WTTC 2021). Between 2014-2019 tourism accounted for one in four jobs created every year (WTTC 2021). In a global estimate of marine recreational areas in 2003, around 2% of the world, 121 million people, participated in marine tourism activities, which resulted in 47 billion USD in revenue (0.1% of global GDP in 2003). The development of marine ecotourism can provide new employment opportunities, which can be especially beneficial to newly industrialized countries and small island developing states (Roudi et al. 2018; Yacob et al. 2007). Tourism can also promote conservation measures due to these local economic drivers. Tourism promotes conservation by incentivizing the non-extractive use of natural resources through increased local income in the tourism sector (Ziegler et al. 2020).

While tourism plays an important economic role, it can have lasting impacts on the environmental and sociocultural environment of a given area. Excess tourism can negatively influence sociocultural conditions and lead to local conflicts (Bello et al. 2017; Juhasz et al. 2010;

Milazzo et al. 2002; Ziegler et al. 2020). Tourism can also lead to habitat degradation and coastal pollution if mismanaged (Gonson et al. 2017; Juhasz et al. 2010; Milazzo et al. 2002, Zang et al. 2016). One of the key factors in determining the effect tourism has on local ecosystems and communities is the number of tourists. Active planning and resource management are essential to promote and sustain indefinite tourist use (Marion and Rogers 1994). Defining local tourist carrying capacities can help inform managers on how to keep these detrimental effects in check while maximizing the net benefit of tourism, helping to ensure its future viability.

Defining Tourism Carrying Capacity

Finding the tourism carrying capacity of a given area can help determine appropriate rates of tourism, where the positive benefits of tourism, such as economic opportunities and conservation incentives, are not outweighed by negative ecological or social impacts. Here, sustainable tourism carrying capacity will be defined as the number of individuals that can visit a given area at the same time without causing unacceptable deterioration of the biophysical and sociocultural environment or of tourist satisfaction. The biophysical environment describes the non-human biotic and abiotic factors of a given ecosystem; the sociocultural environment encapsulates the social and cultural factors of local residents at a given site. Tourism carrying capacity is identified by using a variety of methodologies to determine thresholds within the social and ecological systems of tourism destinations. Specific management objectives and context affect these thresholds. This review categorizes past studies of tourism carrying capacity and analyzes their methodologies to determine the best practices for assessing tourism carrying capacity in marine environments.

1.1 Literature Review Methodology

I conducted a systematic literature review of tourism carrying capacity assessments in marine ecosystems, keeping detailed records of search terms, dates accessed, and databases used to find publications. Systematic literature reviews are developed to follow a replicable protocol that limits bias in findings (O'Brien & McGuckin 2016). Searches were conducted using three search engines: Web of Science, ProQuest Agricultural & Environmental Science Collection, and the University of Washington Library. Search terms were separated into Primary and Secondary terms: primary: touris* carr* capacity and secondary: marine protect* are*, islan*, and marine. The asterisks in these terms allow search engines to account for various endings, for example, touris* would return results including tourism, tourist, and touristic. Searches were formulated so the primary terms could be matched with secondary terms using and/or arguments, yielding 179 unique results over the three databases searched. After literature searches were completed, articles of relevance were selected based on titles, abstracts, and finally, full text sifts (Figure 1). Relevance was determined if a source included a study that estimated tourism carrying capacity in a marine environment. Results were excluded if

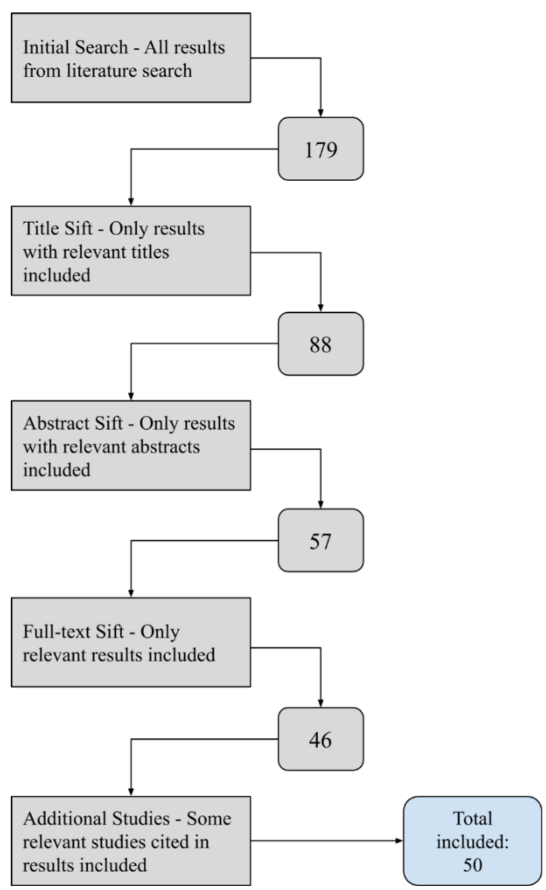

Figure 1 process of study selection

they did not include a carrying capacity assessment or examined terrestrial environments.

Scope of Review

This review was limited to peer-reviewed English language sources relating to marine ecosystems or their surrounding tourism areas. Studies on terrestrial systems are not covered in this review.

1.2 Categorizing Studies of Tourism Carrying Capacity

For the purpose of this review, tourism carrying capacity is defined as the number of individuals that can visit a given area at the same time without causing unacceptable deterioration of the biophysical and sociocultural environment or of tourist satisfaction. Specific management objectives and context affect these thresholds. Within this definition, there are four main subcategories of tourism carrying capacity: 1) biophysical carrying capacity, 2) sociocultural carrying capacity, 3) managerial carrying capacity, and 4) experiential carrying capacity (Table 1). Results from the literature review are divided into these four subcategories and are explored in the following sections in further detail. Table 1, below, gives a general overview of the subcategories, and the general variables that are considered. All of these factors are context-specific, depending on site and ecosystem type. Throughout this review, studies spanning various ecosystems and site types will be examined within these four categories.

Table 1: Brief description of Tourism Carrying Capacity subcategories

BIOPHYSICAL CARRYING CAPACITY *The maximum number of tourists a given site can hold without surpassing the limits of acceptable biotic and abiotic environmental change.* A. Physical space B. Tourist environmental impact C. Ecosystem fragility & recovery capacity	**SOCIO-CULTURAL CARRYING CAPACITY** *The threshold at which tourism rates meet local residents' limits of acceptable change in regards to negative social and cultural impacts.* A. Local cultural effects B. Local economic effects C. Tourist-resident relationships and conflicts
MANAGERIAL CARRYING CAPACITY *The number of tourists an area can have at a time given its infrastructural, service, and accommodation capacity.* A. Available infrastructure B. Equipment C. Personnel & regulations	**EXPERIENTIAL CARRYING CAPACITY** *The number of tourists an area can accommodate without negatively impacting the enjoyment of other tourists.* A. Perceived crowding B. Perceived conditions and capacity of natural resources and infrastructure C. Tourist Norms

1.3 Overview of Findings

Incongruency in the Definition of Tourism Carrying Capacity

Tourism carrying capacity has many definitions, focusing on different aspects of the tourism industry or environment depending on the circumstances. Few studies considered holistic views of tourism carrying capacity. The majority of the studies reviewed primarily examined either experiential carrying capacity (32%) or biophysical carrying capacity (40%) . Approximately one-third of the studies reviewed primarily focused on carrying capacity as a factor of user experience—how increased tourism impacts the perception and preferences of other tourists. Very few studies (8%) addressed sociocultural carrying capacity in tourism areas and while 26% of studies examined managerial carrying capacity many of those were either by the same group of authors using the same methodology (8/13) or in conjunction with biophysical carrying capacity (4/13).

Limits of Acceptable Change or Disturbance

To determine tourism carrying capacity for a given area, managers must determine the limits of acceptable change. Limits of acceptable change denote the degree of change or variation from the current state that is considered permissible under management objectives. These should be determined for not only the biophysical environment but also for sociocultural norms and tourist experiences. Carrying capacity can be determined by examining management objectives for the limits of acceptable change and determining indicators. These limits of acceptable change must be determined based on the specific conditions of an area. For example, in Lee (2011) the limit of acceptable change for the volume of tourism wastewater in Suncheon Bay, South Korea, is based on the survival conditions of specific organisms within the bay and the rate at which pollutants are flushed from the bay. In this case, the management objective was ensuring that local species could be maintained, and the limit of acceptable change was based on their survivability threshold. Another threshold might be maintaining the current coral cover, based on species recovery capacity, the limit of acceptable change, in this case, would be no change (Ríos-Jara et al. 2013) While this example is biological, these thresholds can, and should, be applied to other management objectives. For example, Bentz et al. (2015) based their threshold of experiential carrying capacity on the point where tourists feeling so crowded they seek out other tourism sites or experiences (probability of displacement). Managers and planners should consider biological, social, and managerial factors that impact a given system when determining the thresholds for acceptable change.

2. BIOPHYSICAL CARRYING CAPACITY

Tourism incentivizes conservation by creating non-extractive and lucrative opportunities for local communities, however, it is vital that tourism planning accounts for the ability of tourism to cause lasting damage to local ecosystems, through both direct and indirect impacts. Coastal tourism has grown especially popular in recent years and is often considered less invasive and destructive to reef ecosystems than extractive practices such as fishing (Zhang et al. 2016). Additionally, the ecosystem value of tourism and incoming revenue can both directly fund conservation and provide incentives to maintain natural beauty and biodiversity (Zhang et al. 2016). However, if rates of tourism exceed certain thresholds, tourism can have a variety of negative impacts on local ecosystems, including habitat degradation, physical destruction, altered animal behavior, and more (Araujo et al. 2014; Gonson et al. 2017; Juhasz et al. 2010; Milazzo et al. 2002). Coastal tourism can promote development that leads to sewage runoff, increased rates of sedimentation, and other pollutants in coastal waters (Zhang et al. 2016). Additionally, tourists can cause damage to corals and other organisms through direct contact, and cause changes in animal behavior (Araujo et al. 2014; Zhang et al. 2016). For example, in the Philippines, the main draw of marine tourism to Oslob is whale shark viewing, but the coral reefs are negatively impacted by tourism (Araujo et al. 2014). Ecological surveys of sites where people feed sharks ('provisioning sites') have lower coral diversity and density, and higher macroalgal cover than surrounding areas (Wong et al. 2018). Coastal and marine tourism can have cascading and unanticipated effects on ecosystem health. In these cases, the rate of tourism surpassed the recovery capacity, the ability of the reef to recover from external disturbances, of the reef leading to lasting damage. It is therefore vital that managers and researchers quantify the impacts of tourism on biotic and abiotic factors of the ecosystem to determine appropriate rates of tourism for given management objectives. This section will outline and compare previous methodologies used to determine biophysical carrying capacity in marine ecosystems and coastal areas.

Defining Biophysical Carrying Capacity

For the purposes of this review, biophysical carrying capacity (BCC) of tourism is the maximum number of tourists a given site can hold without surpassing the limits of acceptable biotic and abiotic environmental change, which is a factor of both the rate of environmental impacts and an ecosystems' recovery capacity. These limits of change are also impacted by management objectives, where subjective judgments of what is 'acceptable' change in a given area may be used to determine these thresholds. The biophysical carrying capacity of an area is determined by physical space, tourist impact on natural ecosystems, and the recovery capacity of ecosystems.

2.1 Methodologies to Determine BCC

Cifuentes Methodology

The methodologies used by Cifuentes (1992) and Cifuentes et al. (1999) were modified by many researchers to determine the BCC of various marine environments (Cisneros et al. 2016; Cupul-Magaña & Rodríguez-Troncoso 2017; Gallo et al. 2001; Ríos-Jara et al. 2013; Sousa et al. 2014). This methodology splits carrying capacity into three-tiered levels: physical carrying capacity, real carrying capacity, and effective carrying capacity. Unfortunately, many of the studies published using the Cifuentes methodology are outside the scope of this English language-based review due to the methodology's popularity in Latin America. However, four English language publications using this methodology were examined (Cisneros et al. 2016; Cupul-Magaña & Rodríguez-Troncoso 2017; Gallo et al. 2001; Ríos-Jara et al. 2013; Sousa et al. 2014).

These studies included examination of the tourism carrying capacity of SCUBA diving sites with coral reefs and of beach recreation sites.

Physical carrying capacity (PCC) represents the maximum number of tourists a site could theoretically hold. Formulas for this tier of carrying capacity describe the available spatial area and use patterns of tourists, such as the following example from Cisneros et al. (2016):

$$PCC = \frac{A}{A_U} * T_f \qquad (1)$$

where A is the size of the study area, $A_U$represents the area available (occupancy criteria), andT_f is the number of times that a person may visit the area in a day (the relation among the visitation schedule and the time required for each visit).

Methods used to assess physical carrying remain fairly constant throughout the literature, with few variations in the input variables. The primary variable in determining Physical Carrying Capacity is the set occupancy criteria. This can be determined subjectively or by using other criteria. For example, Cisneros et al. (2016) estimated PCC based on three different occupancy criteria, determining PCC for the area at high (20 people/100 m^2), medium (10 people/100 m^2), and low occupancy (4 people/100 m^2). Cisneros et al. (2016) also accounts for differences in occupiable beach area due to tidal shifts.

Real carrying capacity (RCC) applies correction factors to the PCC, accounting for the specific features of a study site. These will vary based on location and tourist activities but usually include any environmental factors, seasonal closures, and tourist environmental impact. Many correction factors can be added to the PCC to determine the RCC based on situational inputs of a given site . The basic formula is described in Cisneros et al. (2016) as:

$$RCC = PCC * \frac{100-Cf_1}{100} * \frac{100-Cf_2}{100} * \frac{100-Cf_3}{100} *\ldots* \frac{100-Cf_n}{100} \qquad (2)$$

$$Cf_i = \frac{Ml_i}{Mt_i} * 100 \qquad (3)$$

In Eq. (2) RCC is defined in terms of PCC and several external factors, where Cf_i are the correction coefficients for each generic *i* considered. All Cf_i factors are expressed as percentages using Eq. (3) where Ml_irepresents a measured value for each generic factor *i*, and$Mt_i$is the maximum allowable value. (p. 140)

For example, Ríos-Jara et al. (2013) calculated the correction factor for damage caused by touching coral as:

$$Cf_{dt} = 1 - \left(\frac{(Frequency\ of\ touches/Diver/Minute)}{Dive\ time\ (min)} * 100\right)$$

Where Cf_{dt} is the correction factor for damage caused by touching

Unlike PCC, the variables used to determine the RCC of a given area vary widely between studies (Table 2). The variables used to determine the RCC are context-dependent, based on the ecosystem, environmental conditions, and tourism activities at a given site. Additionally, the management priorities of a given site will influence the factors considered in carrying capacity determination.

Table 2: Variables used to determine real capacity in various studies using methods from Cifuentes (1992) and Cifuentes et al. (1999).

			Cisneros et al. (2016)	*Sousa et al. (2014)*	*Rios-Jara et al. (2013)*	*Cupul-Magana and Rodriguez-Troncoso (2017)*
			Argentina	Brazil	Mexico	
			Beaches		Underwater Dive trails	
Management Variable	**Social**				X	X
	Ecosystem Fragility	Stony Coral Cover				
		Cover of Fragile Species (general)				
		Beach Erosion	X			X
	Tourist Damage	Frequency of Diver Contact			X *	X
		Contact				X
	Environmental Restrictions	Wind	X		X	
		Rainfall	X	X		
		(general)				X
		Park Closure (general)	X			
					* From Alonso-Domingueiz 2009	

Finally, the effective carrying capacity is the number of tourists that a location can support based on its management capacity. Based on the equation:

$$ECC = RCC * \frac{MC}{100}$$

> Equation (4) shows the ECC definition where MC is the management capacity of the zone under consideration. (Cisneros et al. 2016, p. 139)

Management capacity plays an important role in tourist carrying capacity, determining if it is possible to accommodate the maximum number of tourists suggested by the BCC (See section 3: *Managerial Carrying Capacity*).

Benefits of Using the Cifuentes Methodology

One of the primary benefits of using the Cifuentes methodology to assess tourism carrying capacity is its flexibility. Carrying capacity assessments of marine tourism areas often require assessing different types of ecosystems (e.g., beaches, reefs, etc.) and the flexibility of the Cifuentes methodology allows it to be adapted to these different scenarios. The studies reviewed demonstrate that variables can be site-dependent, allowing for increased customization of assessments based on real-world conditions. Additionally, this means that researchers and managers will not need to learn many different carrying capacity methodologies to assess different areas. Because the methodology is modular, it allows researchers to prioritize relevant aspects of the biophysical environment. Another benefit of the Cifuentes methodology is that it can be continuously updated with new correction factors and reassessed based on new information without requiring a completely new study. The flexibility and modularity of the Cifuentes methodology is beneficial for assessing multiple types of tourist areas over different time periods.

2.2 Measuring Tourism Impact

To apply correction factors and determine real carrying capacity, variables, including ecosystem fragility, tourist damage, and environmental restrictions, must be assigned values. Methodology for determining values for correction factors is context-dependent. Sometimes the values are simple calculations, for example, the average number of rainy days per year that would impact beach visitorship. Other values require assessing and monitoring marine ecosystems, such as gathering data on stony coral cover at dive sites (e.g., Cupul-Magaña & Rodríguez-Troncoso 2017).

Determining Diver Damage

The two studies that assessed dive site carrying capacity using the Cifuentes methodology had different approaches to estimating snorkeler and SCUBA diver damage to corals. Cupul-Magaña and Rodríguez-Troncoso (2017) estimated snorkeler and diver damage by observing 50 snorkeling and 25 SCUBA groups, surveying the type of damage (e.g., coral contact, sediment disturbance), frequency, and the substrate damaged. In contrast, Ríos-Jara et al. (2013) used information on diver impacts from a previous study (Alonzo-Dominguez 2009) to assess diver impact. Certain correction factors can be determined based on previous data. Following the previous example, Ríos-Jara et al. (2013) used findings of diver contact from a previous study to create a correction factor, this study examined the impact of experience level on diver contact. While they did not directly measure the impact of divers on their specific sites, they were still able to determine good estimations of diver contact based on the experience levels of divers at their sites. This frees up resources to assess correction factors that are more site-specific. For example, it would be inaccurate to estimate coral cover based on a study conducted at a different location. Researchers can use a combination of site-specific and generalizable variables to construct correction factors.

Before/During/After/Control/Impact Analysis of Macrobenthos

Tourism impact on macrobenthos can be measured on beach ecosystems by comparing populations before and after high rates of tourism. Wu et al. (2018) analyze macrobenthos on sandy beaches during different impact periods (before, during, and after) of the high tourism season. Using macrobenthos as an indicator of ecosystem health, the study compares species richness, density, and diversity by sampling sediment along beach transects (Wu et al. 2018). These transects were completed at different sections along the beach that experience high and low levels of tourism (Wu et al. 2018). The number of tourists was also recorded on sampling days to compare to the impact on beach macrobenthos. While this methodology provides insight to tourism impact, based on different rates of tourism, it did not estimate carrying capacity directly. Cisneros et al. (2016) and Sousa et al. (2014) did not consider any biological variables in their assessment of real carrying capacity. When establishing correction factors for beach carrying capacity, future studies could include macrobenthos' response to more accurately determine biological impacts of beach use.

Analyzing User Impact on Geomorphology

Beach erosion and geomorphology is another impact of tourism that could be considered in the calculation of real carrying capacity. Simeone et al. (2012) calculated the loss of sand on an embayed beach within an MPA and the corresponding morphological changes resulting from beachgoers. They estimated the number of beachgoers on various days by assuming that each car in the parking area accounted for a minimum of two and a maximum of five beachgoers, with parking data provided by the management board of the MPA (Simeone et al. 2012). Sediment displacement was measured through a series of replicated trials where the researchers walked various distances, from the beach to the parking lot, collected the sand that stuck to their feet, dried the sand and then weighed it in the lab. Rates of sediment removal were then averaged over the replicated trials. Additionally, cross-shore transects were carried out during and after the peak season to determine the impact of crowding on the beach profile. In the morning and evening, a Differential Global Positioning System (DGPS) was used to measure the sediment profile; these results were then compared to measure tourism impact. This study illustrates the importance of also taking geomorphological variables into account, especially in areas that are especially vulnerable to change (e.g., embayed beaches).

2.3 Other Methods

Focusing on Physical Carrying Capacity

Some studies only assess the physical carrying capacity of an area as the measure of tourism carrying capacity based on site-specific occupancy criteria. Quicoy & Briones (2009) assessed the physical carrying capacity of beach tourism in Calatagan, Philippines using available standard estimates of individual swimming standards, and available swimming areas. Here, the individual standards are analogous to the occupancy criteria used in the *Cifuentes* methodology. These standards were established using the formula of Boullon (1985), where:

$$Carrying\ capacity\ = \frac{Area\ used\ by\ tourists}{Average\ Individual\ Standard}$$

Using an individual standard of 500 m^2 per swimmer, again from Boullon (1985), Quicoy & Briones (2009) found that Calatagan was over the physical carrying capacity; however, the authors argued that these standards seemed overly conservative, noting that swimmers were rarely seen 500m apart. Quicoy & Briones (2009) decided to reevaluate their results using standards from the Florida Department of Environmental Protection (4.65-9.30 m^2 per swimmer), which they believed was more indicative of the individual preferences of swimmers in Calatagan. Using the smaller area, carrying capacity was not surpassed. Based on in-situ observations, the 4.65-9.30 m^2 standard is likely more suited to tourist site conditions in the Philippines (Quicoy & Briones 2009).

In other studies, specific tourism activities play a role in determining occupancy criteria, creating specific carrying capacities for each type of tourist. Lelloltery et al. (2018) also only examined physical carrying capacity, using occupancy criteria of 500 m^2 per snorkeler and 1000 m^2 per diver. These estimates of occupancy criteria were developed in consultation with local management and are subjective estimates of ecologically appropriate tourism occupancy criteria, or the density of tourism that would not degrade local ecosystems. Here, researchers and managers made the assumption that individual divers would cause more damage than snorkelers. Additionally, Winata et al. (2020) estimate the physical carrying capacity of mangrove forests in Karimunjawa National Park, Indonesia to determine their suitability for mangrove trekking, wildlife viewing, and fishing tourism. Here suitability was defined in terms of tourist enjoyment, or the ability of the ecosystem to provide an enjoyable tourist experience and maintain the ecological integrity of the area. Through grid-cell data collection, they determine tree density, inundation levels, flora & fauna species presence, and abundance. This study then estimated the physical carrying capacity of mangrove forests in Karimunjawa National Park by determining occupancy criteria based on specific tourism uses for given areas, in a similar manner to Lelloltery et al. (2018). These occupancy criteria intended to estimate the maximum tourist density without damaging or disturbing local ecosystems, these values were based on the work of Yulinada (2007) and Douglass (1982). While these values were not determined based on the specific conditions of Karimunjawa National Park, they were specific to the type of tourism activity.

These studies assessed the carrying capacity of tourism sites based on their physical capacity alone and did not include estimates of tourism impacts on ecosystems, however, they are still able to provide insight on how to contextualize occupancy criteria. While they demonstrate methodologies to determine physical carrying capacity, it is inadvisable to use these methods alone as they only subjectively evaluate the appropriate tourist density for a given area or activity. However, Quicoy & Briones (2009) teach us that it is important to use appropriate occupancy criteria when establishing physical carrying capacity, taking site specifics into account. Additionally, Lelloltery et al. (2018) and Winata et al. (2020) demonstrate the importance of taking different tourism uses into consideration.

Focusing on the Bigger Picture: Ecological Footprint Analysis

Measurements of tourism carrying capacity do not consider the area as a whole, focusing on sites and tourists without taking into account the impact local residents have on their environment as well. Chen et al. (2016) used ecological footprint analysis to determine the BCC of the Zhoushan Archipelago, China by comparing the ecological footprint of tourists to residents over 5 years. This assessment of BCC is based on energy consumption and land use in the area, rather than the physical impacts of tourists on ecosystems. Here, the tourism carrying capacity was determined by the following equation:

$$TCC = tourist\ ecological\ footprint - (biological\ capacity - local\ ecological\ footprint)$$

Tourist ecological footprints were measured by quantifying the impact of transportation, accommodation, purchases, food consumption, and sightseeing. Local ecological footprints were determined by quantifying the impact of energy consumption, built-up land, food consumption, and purchases. Biological capacity was estimated by determining the area of various biologically productive lands (e.g., cropland, fishing grounds, forest lands, pastures) and preserving 12% of those land categories, a number taken from *Wackernagel et al. (1999)*. Interestingly, this model allows us to also account for local development over time. Findings of this study show that land use of both locals and tourists continued to grow, and that forested lands and fishing areas were the most impacted by this growth.

2.4 Discussion

BCC Differences Between Similar Sites Driven by Ecosystem Fragility

Ecosystem fragility plays a large role in the biophysical carrying capacity of a given site, but fragility is context-dependent. Ríos-Jara et al. (2013) found that the largest differences in tourism carrying capacity among similar dive sites were accounted for by increased ecosystem fragility. In this case, increased coral cover led to lower tourism carrying capacity due to the fragility of the substrate. In other circumstances, site specifics will affect which characteristics are more vulnerable to damage. Zhang et al. (2016) found that on Mabul Island Malaysia, branching corals were more prone to damage in shallow dive sites (6m) while massive corals had more damage at deeper dive sites (9m). This could be due to the type of tourist frequenting each location. For example, shallower reefs are more likely to be directly impacted by snorkelers than deeper reefs. It is important to consider both the ecosystem fragility and tourist use when assessing BCC.

Limited Discussion of Macrofauna in Carrying Capacity Research

The majority of the studies reviewed based BCC on macrobenthos, sediment, and water quality (e.g., tourist waste, environmental runoff). However, tourism can also impact animals that are often tourist attractions to marine ecosystems such as sharks, turtles, whales, dolphins, rays, and fish assemblages (Burgin and Hardiman 2015). Behavioral alterations can negatively affect mating, foraging, and migration patterns. Tourism can have a huge impact on animal health and behavior, through direct interactions, provisioning, boat traffic, and more, which is well documented throughout academic literature (Burgin and Hardiman 2015; Machernis et al. 2018; Trave et al. 2017). While there are numerous studies that evaluate the impacts of human presence and interaction on macrofauna, none of the studies in the literature review examined tourism carrying capacity for large macrofauna. While some of these studies may suggest the potential benefits of decreasing the number of tourists, none directly measure a carrying capacity for interactions. Some destinations place restrictions on the number of boats that can be within a given distance of certain macrofauna (e.g., whale watching) but these limits seem to be subjectively set through consultation with experts (WDFW 2021). In the future, it would be beneficial to examine the relationship between altered animal behavior and tourist density as these animals are important drivers of marine tourism.

3. SOCIOCULTURAL CARRYING CAPACITY

Understanding Social Impacts

Tourism has both positive and negative sociological, economic, and cultural effects on local communities. Tourism can benefit local communities by boosting GDP, promoting conservation efforts, discouraging excessive extractive use of natural resources, and providing alternate sustainable livelihoods (Bello et al. 2017; Juhasz et al. 2010; Milazzo et al. 2002). Tourism can raise the value of ecosystem services, incentivizing conservation through income from non-extractive use of resources (Roudi et al. 2018; Yacob et al. 2007; Ziegler et al. 2020). However, in coastal areas dependent on tourist income, unsustainable use of resources and environmental deterioration can cause social disruption (Clark et al. 1991). In addition, an influx of tourists from various backgrounds can affect the sociocultural environment of a location. The growth of tourism increases the number of interactions between locals and tourists (Clark et al. 1991). Inequitable distribution of resources can lead to conflicts between residents and tourists, creating local resentment and declining tourist visitation (Clark et al. 1991). Local incomes can increase due to increased rates of tourism (Roudi et al. 2018). However, these increases can occasionally be diminished by economic leakages (Roudi et al. 2018). Economic leakages occur when the growth of tourism raises the demand for external inputs or foreign goods and services (Thomas et al. 2005). Residents can be impacted by other economic effects such as neo-colonialism, where non-local people directly benefit from increased tourism at the expense of local residents (Bello et al. 2017; Cole & Razak 2009). Other negative social effects of tourism include displacement of residents in concentrated tourism areas, the commodification of local cultures, staged-authenticity of local people, and more (Bello et al. 2017; Cole & Razak 2009). Determining the level of tourism that is best for local communities is contingent on how those positive and negative effects weigh out against each other.

In the Global North, marine ecosystems have been seen primarily as open-access resources (Cocklin 1998). The many specific sociocultural impacts of tourism are outside the scope of this review. Instead, we will focus on how to assess sociocultural impacts as they relate to tourist abundance. Even if biophysical carrying capacity is addressed in planning, areas can be overwhelmed by tourists or be the result of inequitable resource distributions, leading to social consequences. Sociocultural carrying capacity must be assessed as part of tourism carrying capacity to account for local impacts.

Defining Sociocultural Carrying Capacity

For the purposes of this review, sociocultural carrying capacity (SCC) will be defined as the threshold at which tourism rates meet local residents' limits of acceptable change in regards to negative social and cultural impacts. SCC is primarily concerned with the quality of life of residents in tourism areas. Limits of acceptable change are discussed in the *Introduction* of this review.

2.1 Methodologies to Determine SCC

Carrying Capacity Based on Tolerance Levels

The opinions of residents themselves should be of primary concern to researchers. The tolerance of local residents to the negative impacts of tourism is used to determine SCC. Resident tolerance is the level of tourism at which negative sociocultural impacts can be accepted by local residents (Kayat et al. 2012). SCC is surpassed once levels of tourism lead to unacceptable economic leakage, cultural change, or tourist conflicts. Like many aspects of tourism carrying capacity, resident tolerance is not uniform, with many heterogeneous groups within local areas having varying tolerance levels. Determining sociocultural carrying capacity relies on managers judging what levels of resident tolerance is acceptable and what impacts are unacceptable. Managers determining these levels should primarily focus on the resources available and the needs of the community (Cole and Razak 2009). In order to make these judgments, they should have a historical perspective of tourism and a deep understanding of the local community (Cole and Razak 2009). This could include conducting in-depth interviews or ethnographies of local stakeholders. Sociocultural carrying capacity is based on the personal values of individual residents (Kayat et al. 2012). SCC can be measured through the evaluation of individual value judgments (Kayat et al. 2012). Determining what residents of different groups deem valuable or detrimental to their communities is vital to determining SCC.

Qualitative Interviewing

In order to accurately determine SCC, managers need to first consult local residents to determine the sociocultural variables that are most important to them. Kayat et al. (2012) assessed perceptions of locals near the growing tourist destination Kampung Kilim, World Geopark, Langkawi through ethnographic interviewing. In this study, researchers asked respondents a variety of open-ended questions related to perceptions of tourism impact (Kayat et al. 2012). Topics covered included dependency on tourism, positive impacts, negative impacts, and perceptions of limiting tourist arrivals (Kayat et al. 2012). Non-formal conversations and formal interviews were conducted over one month while researchers lived in the community (Kayat et al. 2012). Individual respondents were recruited who were both dependent and not dependent on the tourism industry (Kayat et al. 2012). To preserve the meaning of respondents' statements, interviews were translated based on meaning by a native speaker (i.e., not translated word for word) (Kayat et al. 2012). Additionally, Junaid et al. (2018) examined the sociocultural challenges involved in developing ecotourism in Tanjung Karang, Indonesia. Research was conducted through interviews and observation. In-depth interviews (45-60 minutes) were conducted with individuals in the tourism industry. In addition, informal interviews were conducted with local residents. However, all of these interviews took place over two days, in comparison to two months in the Kayat et al. (2012) study. Interviews in the Junaid et al. (2018) study were similarly open-ended in nature. Open-ended questions of this nature allow respondents to discuss their concerns without being limited by researchers' preconceptions of what sociocultural issues might be at play.

2.2 Discussion

Combining Qualitative and Quantitative methods

When determining social carrying capacity it would be beneficial to have quantitative estimates in conjunction with informal or semi-structured interviews, such as those used in Kayat et al. (2012) and Junaid et al (2018). Although these studies brought sociocultural issues to light and estimated that SCC was not being surpassed, they did not give a quantitative estimate of SCC that could be used to determine overall tourism carrying capacity. These interviews could inform the development of a Likert scale-based questionnaire that could be distributed to a larger number of residents. It is important to note that the findings of initial interviews will likely vary by location and level of tourism development. The responses to the Likert scale-based questionnaires could then provide data to determine quantitative measures of socio-cultural tourism carrying capacity.

Impact of Economic Dependency

In Langkawi, residents' acceptance level of tourism was influenced by their economic dependency on the industry (Kayat et al. 2012). Individuals interviewed suggested that there were some negative sociocultural impacts of tourism in the area, however, none of the individuals interviewed believed that tourism should be limited (Kayat et al. 2012). Primarily, residents were concerned about the economic impact limits to tourism may have (Kayat et al. 2012). Residents in this study were tolerant of tourism and its growth in their community due to social and economic benefits of tourism, suggesting that SCC has not been surpassed (Kayat et al. 2012). However, SCC is not a fixed limit, as the infrastructure of tourism adapts so does SCC. As tourism grows and changes throughout time, SCC should be reevaluated to reflect new value judgments.

Polarization of the Community

Economic dependency can lead to polarization within local communities (Cocklin et al. 1998). Occasionally, the strong economic benefits of tourism outweigh the negative impacts of tourism for specific groups of local residents (Junaid et al. 2018). When this occurs, divisions can form between individuals who may benefit from tourism and those who perceive only negative impacts. Some residents objected to the establishment of an MPA in New Zealand for fear that it would lead to mass tourism in the area and subsequently development that would make the town unrecognizable (Cocklin et al. 1998). In Aruba, the tourism market is dominated by international chain hotels and often neglects other tourism opportunities based on local culture and history (Cole and Razak 2009). While sociocultural carrying capacity takes into account both positive and negative effects of tourism, special attention should be paid to how tourism can affect residents in a heterogeneous way. When conducting interviews and surveys it is vital to consider how groups may be impacted differently and make sure that responses are coming from a wide range of groups. Having both the initial interviews that contextualize tourism issues for researchers and quantitative survey results could provide more accurate estimates of SCC in future studies by accounting for both the specific concerns of local residents and the potentially diverse opinions within communities.

3. MANAGERIAL CARRYING CAPACITY

The management capacity of a given area can heavily influence its ability to absorb the increased biophysical and sociocultural impact of higher tourism rates. The deleterious effects of tourism are often intensified by the concentration of tourists in specific areas (Carboni et al. 2015). Management capacity is a measurement that determines the condition of tourist infrastructure and administration of a given area (Ríos-Jara et al. 2013). Where high management capacity indicates the adequate quality of infrastructure and administration to serve tourists to the area (Ríos-Jara et al. 2013). Problems that occur when managerial capacity is low could include littering, non-compliance with park regulations, inadequate treatment of wastewater, and decreased freshwater availability (Ríos-Jara et al. 2013; Tselentis et al. 2005). These issues will vary between sites and the discrepancy between management capacity and the number of tourists. In order to ensure that the limits of acceptable change are not being surpassed in other sectors, managerial carrying capacity has to be taken into account.

Defining Managerial Carrying Capacity

Managerial carrying capacity (MCC) of tourism is defined here as the maximum number of tourists a given site can support given the infrastructure and management capacity of the surrounding area.

3.1 Methodologies to Determine MCC

Management Capacity in the Cifuentes Methodology

Based on the methodology of Cifuentes et al. (1992) and Cifuentes (1999), management capacity calculations in Ríos-Jara et al. (2013) use the following equation:

$$TCC = RCC * MC$$

Where overall tourism carrying capacity (*TCC*) is determined by the real carrying capacity (*RCC)* of a given site and the management capacity (*MC*) of the tourism area (Ríos-Jara et al. 2013). Ríos-Jara et al. (2013) used percentile values to subjectively evaluate managerial components based on quantity, state, functionality, and location. Components were evaluated as a percentage relationship between their current values and optimal values, based on the judgment of the authors (Ríos-Jara et al. 2013). Optimal values are set at tourism carrying capacity estimations, and components of management are assessed based on their ability to serve that many tourists. For example, if tourism carrying capacity was estimated at 1000 individuals and the local area could only accommodate 800 tourists, the accommodation capacity would be 80%. Quantity refers to the number of a given component (Ríos-Jara et al. 2013). State refers to its safety, maintenance, and condition (Ríos-Jara et al. 2013). Functionality is a combined value based on state and location, or the practicality of use by tourists (Ríos-Jara et al. 2013). Although subjective, these estimates are still able to inform managerial carrying capacity by accounting for local conditions. Transparency in the factors used to estimate these capacities is key to replicability and adaptation of future iterations of carrying capacity assessments for a given site. Managerial carrying capacity varies over time with new inputs therefore it is essential to understand the variables included in initial assessments to accurately account for new, or altered, components in the future.

The managerial components considered when determining management capacity vary widely based on the study and location, a comparison of these factors can be found in Table 2. Generally, these variables fall into three categories: 1) infrastructure, 2) equipment, and 3) personnel and regulations.

Table 2: Variables used to determine management capacity in various studies using methods from Cifuentes (1992) and Cifuentes et al. (1999).

			Cisneros et al. (2016)	*Sousa-Melo et al. (2014)*	*Rios-Jara et al. (2013)*	*Cupul-Magana and Rodriguez-Troncoso (2017)*
			Argentina	Brazil	Mexico	
			Beaches		Underwater Dive trails	
Management Variable	Infrastructure	Lifeguards	X			
		Bathrooms	X	X	X	
		Public Lighting	X	X		
		Information Services	X		X	
		Coastal Buildings	X			
		Camping Grounds			X	
		Signage	X		X	
		Beach Access	X	X		
		Wastebaskets	X	X	X	
		Restaurants and Bars	X	X		
		Recreational Areas	X		X	
		Police and Fire Stations	X			
		Residential Area for Personnel			X	
		Recycling			X	
		Site Maps			X	
		Viewpoints			X	
		Docks & Buoys			X	
		Electricity			X	
		Potable Water			X	
		Payphones		X		
		Parking		X		
		Tourist Accommodations		X		
		Infrastructure (general)				X
	Equipment	Navigational Equipment			X	
		Dive Equipment			X	
		Air Compressor			X	
		Radio			X	
		First Aid	X		X	
		Vehicles	X		X	
		Tent Rentals	X			
		Equipment (general)				X
	Personnel & Regulations	Access Regulations	X		X	
		Coastal Management Plans	X		X	
		Building Regulations	X			
		Natural Disaster Preparedness	X			
		Park Rangers			X	
		Dive Guides				
		Personnel (general)				X
	Misc.	Presence of Domestic Animals		X		

Similarly, Carboni et al. (2015) outlined variables that should be considered when evaluating tourism carrying capacity in the Asinara National Park, Sardinia, Italy, which included: park attractions, transportation, information services, catering, number of tourists, duration of stays, sports, trails, diving, fishing, environmental education, and boating. Although these variables are specific to the Asinara National Park, this gives us an idea of the breadth of factors one needs to consider when determining the managerial carrying capacity of a given area. It also corroborates some of the variables used in the Cifuentes methodology.

Greek Island Studies

Several studies using the same methodology determined the management capacity of several Greek Islands. Tselentis et al. (2005, 2006, 2011) and Prokopiou et al. (2012, 2013, 2015, 2017, 2018) assessed the carrying capacity of various Greek islands by assessing the density of tourists, available accommodations, illegal accommodations, waste management, water supply, and passenger transportation. These values were then compared to the natural tourism resources available, in this case, beach area, to determine both the managerial capacity for tourism and the tourism density. These studies provide a less subjective means of determining managerial carrying capacity as they only account for quantitative variables. These studies focus on the physical capacity of available infrastructure and do not take quality or accessibility into account. There are benefits and drawbacks to this type of methodology, while inherently less subjective, it may also lead to overestimating management capacity by not taking into account deteriorated quality.

3.2 Discussion

It is likely that in the beginning, the managerial carrying capacity in an area will constrain tourism carrying capacity more than other factors. Developing infrastructure, regulations, and equipment takes time and resources, however, managers should consider the potential implications for rapid expansion. Thomas et al. (2005) state that as tourist crowding becomes more significant in Caribbean islands, the appeal of these islands decreases for tourists. Surpassing the carrying capacity leads to irreparable damage that can permanently lower the appeal of destinations to ecotourism, transitioning the market from ecotourism to mass tourism. While managerial carrying capacity can be increased through development and transition to mass tourism, it is important to consider the other factors of tourism carrying capacity as well.

Accounting for management capacity when determining tourism carrying capacity also allows managers to avoid the secondary effects of surpassing the MCC. For example, if a given area is below its BCC and SCC, and decides to push for higher rates of tourism without accounting for the MCC, this could result in increased rates of wastewater and runoff that could then lower the BCC. These systems are all connected and not accounting for one could negatively impact the others as well.

4. EXPERIENTIAL CARRYING CAPACITY

User experience is the final aspect researchers should account for in determining tourism carrying capacity. In previous sections, the effects of the ecosystem, residents, and managers on tourism carrying capacity are discussed. This section will focus on how tourists themselves, and their expectations, impact tourism carrying capacity. In certain circumstances, having too many tourists in a given area can lead to tourist dissatisfaction, increasing the likelihood that tourists will choose different locations for subsequent trips. Tourism experience is intrinsically linked to biophysical carrying capacity, sociocultural carrying capacity, and managerial carrying capacity as tourists are likely to be less satisfied with areas that have degraded ecosystems, inadequate facilities, or conflicts between local residents and tourists. Measuring long-term experiential carrying capacity of tourism (ECC) is difficult as there are many connections to other subcategories of tourism carrying capacity and it is extremely site specific. Measuring ECC at regular intervals could accommodate these challenges.

Defining Experiential Carrying Capacity

ECC will be defined here as the number of tourists an area can accommodate without negatively impacting the enjoyment of other tourists. The primary variable that impacts ECC is perceived crowding in tourist locations. ECC is determined primarily by the perceptions of tourists and how those perceptions relate to their expectations. This aspect of tourism carrying capacity is known by various names throughout academic literature, in other sources, this could be referred to as social carrying capacity (Bentz et al. 2015), aesthetic recreational carrying capacity (Quicoy and Briones 2009), or psychological carrying capacity (Lime and Manning 1999). This review will use the term experiential carrying capacity (ECC) as it more precisely indicates the primary concern, user experience, in relation to the number of tourists.

Tourists Crowding - Norms and Expectations

Individual norms and expectations drive how tourists perceive crowding. Jackson's (1965) *social norm curves* can be used to illustrate acceptable impacts of tourism from a tourist perception, with the *minimum acceptable condition* indicating a point of maximum acceptable crowding (Bentz et al. 2015). Conditions below this point on the curve would represent scenarios in which the majority of tourists felt levels of crowding were unacceptable to them (Bentz et al. 2015). Bentz et al. (2015) illustrated these concepts with the following:

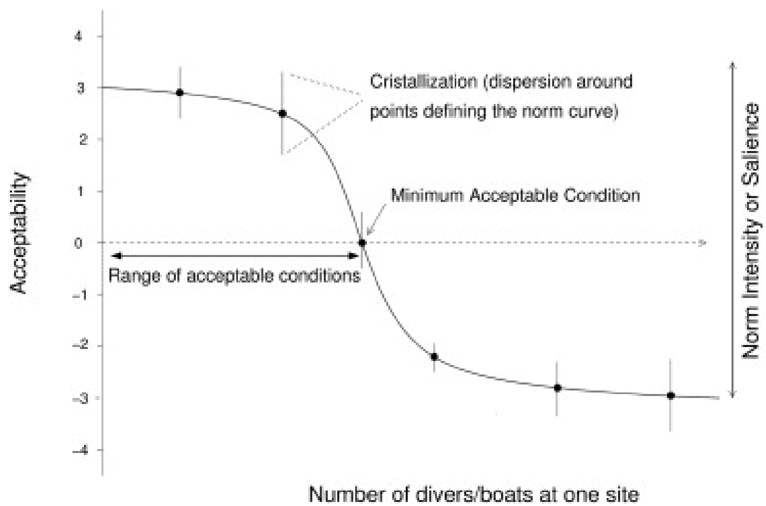

Fig. 2: Hypothetical social norm curve (modified from Manning et al. 1999). Bentz et al. (2015, p. 78)

Here, *Norm intensity* indicates the strength of these preferences, the farther away the curve is from zero the more impact these variables have on respondents on average (Bentz et al. 2015). *Norm crystallization* indicates how similar tourists are in their preferences, high dispersion around the norm curve would indicate that the tourists surveyed had a wide variation in their preferences (Bentz et al. 2015). Higher dispersion equates to lower rates of agreement between users (Bentz et al. 2015). A norm curve with high intensity and low crystallization would indicate a variable that respondents, on average, feel strongly about, but those perceptions are highly variable within the sampled group.

Sociodemographic variables can play a role on social norm curves, however, they often do so in unpredictable ways. Rasoolimanesh et al. (2016) surveyed tourists at Cenang Beach, Malaysia, and found a correlation between crowding perceptions and age, education, nationality, gender, and touristic spending. They found that respondents were less likely to feel crowded if they were: younger, women, educated, or from Western countries. However, some of these findings are not consistent with surveys taken at different sites. For example, Yagi and Pearce (2007) compared the preferences of Japanese tourists and those from western countries using a visual survey depicting a rainforest setting. They found that western tourists were less tolerant of crowding than Japanese tourists (Yagi and Pearce 2007). Additionally, at a different site (Perhentian Islands, Malaysia), Rasoolimanesh et al. (2017) found that individuals with higher education were shown to be less tolerant of crowding, conflicting with their previous research. The most important aspect of this is that sociodemographic variables play a role in perceptions of crowding, that role can be unpredictable, but it should always be considered when assessing norm curves.

Management Judgements

In the case of ECC, managers have to determine the level of acceptable crowding that best fits their circumstances. Different studies suggest different thresholds for ECC. Bentz et al. (2015) based their assessments on the likelihood of tourists feeling so crowded they seek out other tourism sites or experiences (probability of displacement). They suggest that ECC is the level of tourism where somewhere between 50-66% of tourists feel crowded, as tourist displacement is unlikely to occur when under 50% of tourists feel crowded (Bentz et al. 2015). Similarly, Klanjscek et al. (2018) suggested that the minimum value for ECC should be where a tourist is equally likely to feel crowded or not feel crowded, or the level at which around 50% of tourists feel crowded. The limits of acceptable change have to be actively determined and the estimation of carrying capacity, therefore, involves some management judgment (Chen and Tang 2016).

4.1 Methodologies to Determine Experiential Carrying Capacity

Numerical Approach to Reported Encounters & Encounter Norms

In order to determine observed encounters, preferences, and perceived crowding, some studies reviewed distributed questionnaires to tourists after a touristic activity, such as whale watching or beachgoing (Bentz et al. 2015; Gonson et al. 2018; Hallo et al. 2018). Bentz et al. (2015) determine participant crowding by subtracting the tourist's reported number of encounters from individuals' self-reported personal encounter norms (or the number of encounters they deem acceptable), when the perceived encounters outweighed norms, this study assumed that individuals felt crowded.

Bentz et al. (2015) used questionnaire data to plot the linear relationships of encounters and social norms using the following equation:

> Setting encounter norms, N, – represented by perceived acceptability – as a function of reported encounters, R (reported number of divers or boats), the estimate of a linear relationship allows the estimation of the minimum acceptable condition. Formally:
>
> $$N = a_0 + a_1 R + \varepsilon$$
>
> where α1 represents the estimated *minimum acceptable condition* and ε the error term. (Bentz et al. 2015, p. 80)

Ribeiro et al. (2011) and Gonson et al. (2018) completed randomized beachgoer surveys in a similar fashion, in Portugal and New Caledonia respectively. Using self-reported preferred, acceptable, and intolerable thresholds to estimate tourist satisfaction in different scenarios (Gonson et al. 2018).

Visual Approach to Reported Encounters & Encounter Norms

Some studies have updated traditional questionnaires by using photographic representations of crowding (Chen and Teng 2016; Hallo et al. 2018; Zhang et al. 2015; Ziegler et al. 2019). Theoretically, visual representations of crowding in a given location would lead to more accurate estimations by respondents by eliminating some of the biases in respondents' answers. It is difficult for respondents to accurately quantify the number of encounters that would make them feel crowded in a hypothetical situation however, looking at an image and determining whether or not they would feel crowded in that scenario is more reasonable.

Zhang et al. (2015) used this methodology to survey SCUBA divers' perceptions of crowding on Mabul Island, Malaysia, taking into account both the total number of divers and proximity to others. In face-to-face interviews, respondents looked at images of dive site crowding conditions in random order, with each image being shown for a uniform amount of time (Zhang et al. 2015). They were then asked to evaluate crowding on a Likert scale questionnaire (Zhang et al. 2015). Chen and Teng (2016) similarly estimated ECC from tourist perspectives using visual questionnaires. They looked at tourists' perceived sense of overcrowding by showing them photos of beaches with various quantities of people and asked them to rate the level of crowding using a Likert scale questionnaire (Chen and Teng 2016). Hallo et al. (2018) also examined tourist crowding perceptions on Cumberland Island, Georgia, U.S.A. In this study, four separate sites were examined by showing visitors simulated photos of locations on the island in various states of crowding.

Comparing Numerical and Visual Approaches

Numerical and visual approaches have various biases that need to be accounted for when developing an ECC methodology. The appropriate methodology should be determined depending on the conditions of a given site. When asking respondents to state reported encounters and encounter norms in numerical questionnaires, they may have difficulty recalling or visualizing the number of people encountered. Respondents have difficulty accurately estimating the number of encounters especially in high-use areas (Klanjscek et al. 2018). In previous studies, tourists have been found to overestimate the number of visitors and underestimate the number of boats (Gonson et al. 2018). Ziegler et al. (2019) surveyed whale shark watching tourists in Oslob, Philippines. In this study, Ziegler et al. (2019) used both visual and numerical surveys to compare tourist responses using the two different methodologies. Respondents of the numerical approach estimated double or triple the number of tourists than the respondents of the visual approach surveys (Ziegler et al. 2019). However, there was no significant difference between the two groups when reporting the number of tourists that would cause them to feel crowded, their encounter norms (Ziegler et al. 2019). Unsurprisingly, the number of respondents who reported they felt crowded was significantly higher in the numerical group, as they estimated more people in general (Ziegler et al. 2019).

Visual approaches also have biases in estimations as they can only characterize one viewing angle, rather than the environment as a whole (Klanjscek et al. 2018). To combat this Chen and Teng (2016) scaled down their images precisely, showing one-tenth of the area of the beach in their photos and then multiplying the indicated value by ten in order to determine the true encounter value. This in turn makes an assumption that the surroundings are homogenous. Ziegler et al. (2019) presented the issue of two-dimensional representation in visual crowding surveys. Presenting an image to a respondent and asking them if they would feel crowded in a given scenario does not take into account their other surroundings and could lead to response variation depending on assumptions made by the individual respondent. Images are unable to encapsulate other aspects that may affect perceived crowding, such as heat and noise that may increase the feelings of crowding or vistas and social aspects that may decrease feelings of crowding (Klanjscek et al. 2018). Finally, visual surveying may be subject to biases in the questionnaires that result from the order in which the images are placed (Klanjscek et al. 2018). These surveys may be more precise but less accurate depending on how you quantify the crowding represented in the image.

When determining encounter norms for a given site it is important to take into consideration site specific variables such as the size of the destination, expected levels of tourism, and confounding factors that may impact crowding perception. As tourists are less likely to correctly estimate a larger number of tourists it would be advisable to visual approaches in circumstances where a larger number of tourists are expected (high-use areas) (Klanjscek et al. 2018). Conversely, at smaller or less frequently visited sites numerical surveys can be conducted, avoiding some of the biases associated with visual surveys.

Adding In-Situ Observation

Direct observation of tourist abundance can also be used to combat some of the surveying issues, eliminating the need for tourist estimates of abundance. A few studies added measurements of actual tourist numbers, rather than self-reported numbers from respondents, to further reduce estimation errors by respondents (Cabezas-Rabadán et al. 2019; Klanjscek et al. 2018). Researchers can more accurately estimate the actual crowding capacity by taking measurements of the number of tourists frequenting a location at a given time. Then tourists are surveyed on if they felt crowded, how many individuals they estimated were present, and the ideal number of tourists for a given location or activity. Cabezas-Rabadán et al. (2019) conducted face-to-face interviews with beachgoers to determine their perceived crowding. In conjunction, on the days of the interviews, the number of beachgoers was counted during peak beach hours (12 a.m.- 3 p.m.). When determining factors that lead to perceived crowding, Cabezas-Rabadán et al. (2019) were able to compare the actual number of tourists, rather than being reliant on the approximations of respondents.

Additionally, this allows researchers to determine the estimation error of users or the discrepancy between the observed number of encounters and respondents' estimated number of encounters (Gonson et al. 2018). Gonson et al. (2018) use the following formula to estimate this error:

$$a_i = \frac{N_i^{est} - N_{ti}^{obs}}{N_{ti}^{obs}}$$

> with α_i, the estimation error N_i^{est} is the number of visitors (or boats) estimated by user i, and N_{ti}^{obs} is the number of visitors (or boats) observed during the survey on the day t_i when user i was interviewed. A positive (resp. negative) value of α_i indicates an overestimation (resp. underestimation) by user *i*. (Gonson et al. 2018 p. 149)

This individual error estimation can then be used to modify respondent's threshold values obtained through interviews or surveys. As Gonson et al. (2018) assess using the following formula:

$$E_i^c = E_i + a_i E_i$$

> with as E_i^c the modified estimation, E_i is the estimation given by user i for a given threshold, and α_i is the estimation error. This ensures that E_i^c relates to the actually observed numbers and that the estimations from all users are consistent. (p. 149)

Klanjscek et al. (2018) counted beachgoers using an entry/exit method, tracking individuals arriving and leaving the study site, questionnaires were additionally time stamped to get the most accurate estimates of tourist density experienced.

Questionnaire Design

Most studies of ECC use a questionnaire to assess user experience. Some used open-ended questions in face-to-face interviewing, however, the majority used some form of Likert scale questions that had a defined range of answers. For example, the Klanjscek et al. (2018) methodology emphasizes efficiency, with simple 3 question mini-surveys answered on a nine-point Likert scale, as below:

1. *The number of visitors at this location (Salt Lake Mir) is:* The provided 1-9 scale beneath the statement had 1 noted as Extremely small, and 9 as Extremely large.

2. T*o what extent does the number of visitors at this location (Salt Lake Mir) bother you?* The provided 1-9 scale beneath the question had 1 as Not at all and 9 noted as Extremely.

3. *How satisfied are you with your visit to this location (Salt Lake Mir)?* The provided -4 to +4 scale beneath the question had -4 noted as Extremely dissatisfied, 0 as Neutral, and 4 as Extremely satisfied. (pg. 4)

Basic information can also be collected to determine the user profile of an individual, this includes age, nationality, residence, companions, and education level (Cabezas-Rabadan et al. 2019). Additionally, many studies assessed the specialization level of respondents. This was done through self-reporting (Bentz et al. 2015), external classification systems such as diving certifications (Lucrezi et al. 2013), and activities partaken in, for example snorkeling versus diving (Ziegler et al. 2019). Questionnaires should be created based on site specifics, management objectives, and sampling method. For example, shorter surveys, such as above, are beneficial for time restricted in-situ surveys where researchers are attempting to get the largest sample sizes possible, it still provides adequate information on ECC and correlating variables, while minimizing the time spent per person.

Method variations due to environment

The methods vary in different ECC studies due to environmental constraints. For example, while it is reasonable to determine the actual number of tourists on a beach, this may not be feasible for studies in less accessible environments, such as dive sites. When determining methodology to assess experiential carrying capacity, it is vital to take into account the factors that may limit the accuracy of estimations. However, Klanjscek et al. (2018) determined the perceived number of tourists has a stronger impact on perceptions of crowding than the actual number of tourists. Therefore, it is likely more important to determine the perceived number of tourists than the actual number.

4.2 Discussion

Wide Variation in Tourist Perceptions

Tourist perceptions vary widely, potentially due to tourist diversity in sociodemographic variables or tourist use values. There is little *norm crystallization* in perceived crowding, as personal standards are found to be more influential than observed crowding in perceptions of crowding (Bentz et al. 2015). This means that tourists are more influenced by their own personal norms and expectations than the level of crowding itself. As the number of tourists increases, there is less agreement among respondents in crowding perceptions (Hallo et al. 2018).

Specialist Tourists are More Likely to Feel Crowded

There are also diverse norms between various groups, impacting their perceptions of crowding. Multiple studies have found that self-identified, specialist tourists are more susceptible to crowding than generalists (Bentz et al. 2015; Hallo et al. 2018; Ziegler et al. 2019). Bentz et al. (2015) found that perceived crowding only impacted the overall satisfaction of SCUBA divers, not snorkelers. Additionally, multiple studies have surmised that individuals who are primarily interested in nature or wilderness experiences are more likely to feel crowded than generalist tourists (Hallo et al. 2018; Ziegler et al. 2019). Bentz et al. (2015) found that while crowding impacted the overall satisfaction of divers in the Azores, the overall satisfaction of whale watchers was not impacted by boat crowding. Specialists, such as divers, are more willing to pay for limited site access via entry fees than generalist tourists (David and Tisdell 1995). Zhang et al. (2015) found that while both the number of divers, and the proximity of those divers to one another, significantly impacted perceptions of crowding, the total number of divers was more influential than proximity. Depending on the objectives of a given area, managers may want to weigh their options for determining ECC. For example, while specialist tourists may make up a small percentage of tourism, an area could be attempting to promote ecotourism and nature-based tourism, using the ECC values of generalist tourists in this scenario could potentially alienate specialist tourists, causing them to seek out other areas for travel. Like sociodemographic variables, tourist use and activities need to be taken into account when assessing ECC.

Expectations of Setting Impact Perceptions

Cabezas-Rabadan et al. (2019) found that semi-natural beaches are more likely to have perceived overcrowding than urban beaches, even if the beach has fewer people. Perceptions of crowding and ECC are dependent on individual norms but also on expectations of a given location.

This also impacts the tourists that are drawn to a given location. Urban beaches, with more amenities, are more likely to draw families and older patrons while semi-natural beaches with more natural surroundings and water activities draw more groups of friends and younger patrons (Cabezas-Rabadan et al. 2019). This can, in part, be explained by expectations of semi-natural beaches to be less crowded than urban beaches. Perceptions of facilities also played into tourist satisfaction in Cabezas-Rabadan et al.'s 2019 study, linking ECC to the MCC of tourism. Crowding is site specific, there are significant relationships between location and perceived crowding in multiple studies (Bentz et al. 2015; Cabezas-Rabadan et al. 2019)). As tourism transitions from ecotourism or small-scale tourism to mass tourism in a given area the ECC will increase, likely to a level much higher than other sectors of tourism carrying capacity (Leujak and Ormond 2007). This, again, is why it is important to consider intended and envisioned use of marine areas by managers when assessing the experiential carrying capacity of tourist areas.

Other Aspects that Impact Tourist Satisfaction

While crowding is the main variable that has been studied in relation to ECC, other social and ecological variables have been shown to impact tourist satisfaction. Beach cleanliness, safety, information provision, sediment, and habitat management were found to impact perceptions of tourist crowing (Chen & Teng 2016). People who feel more crowded are more likely to perceive the negative impacts of tourism activities on local communities and illustrate higher levels of support for management interventions (Ziegler et al. 2019). Interestingly, perceived crowding of sites did not impact the perceived environmental impacts of divers and whale watchers in the Azores (Bentz et al. 2015). Bentz et al. (2015) suggest this is due to limited understanding of the environmental impacts of diving and snorkeling by tourists. This, again, emphasizes the interconnectedness of the sectors of tourism carrying capacity, by surpassing one limit, other limits are likely to decrease in kind.

Limiting Tourist Crowding

Zoning could also help manage expectations and reduce perceived crowding by implementing different standards at different locations. This would enable specialists to go to areas with stricter crowding guidelines while still allowing generalists areas with fewer restrictions (Bentz et al. 2015). Creating varied management frameworks for sites would better account for diverse user needs, values, and social norms (Bentz et al. 2015; Cabezas-Rabadan et al. 2019). For example, one potential way to reduce perceived crowding at popular dive sites is to implement spacing guidelines between groups while allowing other areas to be open for snorkeling (Bentz et al. 2015). In this way, you could account for the needs of both specialists and generalists, diversifying local tourism.

5. CASE STUDIES: USE OF TOURISM CARRYING CAPACITY IN MANAGEMENT

5.1 Montague Island Nature Reserve, Australia

The Montague Island Nature Reserve was established, off the coast of Australia, to protect populations of threatened sea birds who nest on the island. Additionally, there are important sociocultural landmarks that are protected on the island, both european and aboriginal (Eagles et al. 2001; IUCN Green List 2021). The New South Wales National Parks and Wildlife Service developed a means to estimate carrying capacity regularly, comparing visitor use and environmental conditions to insure continued (Eagles et al. 2001) Carefully established tourist carrying capacity limits are set on the island, and about 6,000 annual visitors are allowed on the island (Eagles et al. 2001; IUCN Green List 2021) Monitoring shows high compliance with these limits on visitor numbers (IUCN Green List 2021). Additionally, populations of threatened seabirds and fur seals have been rebounding on the island since the establishment of these tourist limits (IUCN Green List 2021). Occasionally, the New South Wales National Parks and Wildlife Service has had to limit or ban certain touristic activities that were causing undue harm to the ecosystem (IUCN Green List 2021). The case of Montague island demonstrates that through careful monitoring and management of tourism carrying capacity vulnerable species can be protected while still benefiting from tourism.

5.2 The Medes Islands Archipelago, Spain

The Medes Islands marine protected area, off the coast of Catalonia, Spain, is a touristic area mostly przed for its SCUBA diving and underwater biodiversity. Although a marine reserve was established in the early 1990s, visitor limitations were not initiated until 2008 (Llausàsa et al. 2019). Based on assessments of carrying capacity throughout the archipelago, a limit of 446 daily scuba divers was put in place, down from a peak number of 1000 tourists in the 1980s (Llausàsa et al. 2019). Tourist abundance was monitored through the establishment of small entry fees, which also funded the operating costs of the national park (Llausàsa et al. 2019).

Although the ecosystem, overall, seemed to be recovering from previous periods of unlimited tourism, certain, slow growing, species were not recovering to optimal population sizes (Llausàsa et al. 2019). Managers decided to reassess their strategies, creating a new plan based on more specific carrying capacity assessments. The 21.5ha marine protected area was split up into 13 distinct zones, based on ecological features and resilience (Llausàsa et al. 2019). These zones had individual carrying capacities assessed, and tourist limits were placed on dive sites based on these new assessments (Llausàsa et al. 2019). Additionally, sites were regularly monitored, and tourist limits were flexible, allowing managers to account for any inaccuracies in the estimation of tourism carrying capacity (Llausàsa et al. 2019). Ecosystem conditions of monitored tourist dive sites were compared to a closed site that was used as a baseline for monitoring (Llausàsa et al. 2019). Through this new scheme, the Medes Islands MPA was able to open additional dive sites and increase their overall capacity while still protecting their ecosystems through tourist limits and monitoring programs (Llausàsa et al. 2019). Creating smaller scale management plans helped this MPA meet their ecological objectives and increase their tourism levels.

6. CONCLUSIONS

6.1 Formulation of Management Objectives

TCC Flexibility - Education and Changing Expectations

Tourism carrying capacity is not a fixed or stagnant number, but one that evolves with education, management, and new inputs. For example, biophysical carrying capacity usually has a correction factor based on tourist impact, educating visitors about their environmental impact may decrease the strain of that variable on biophysical carrying capacity, increasing the biophysical carrying capacity of the site as a whole. Similarly, when coastal infrastructure is improved, and maintains a high quality, the managerial carrying capacity of a given area is increased. This could include updating wastewater treatment facilities or simply increasing accommodation capacity through the construction of a new hotel. Over time, it is important to take these fluctuations into account as previous estimates of carrying capacity may no longer reflect the current circumstances at a site.

Additionally, individual norms vary by location and tourist expectations (Cabezas-Rabadan et al. 2019). Increasing the amount of information available, and giving realistic expectations of crowding, can increase experiential carrying capacity thresholds (Cabezas-Rabadan et al. 2019). A high number of marine protected areas, for example, may impact the experiential carrying capacity of those areas more substantially than the biophysical carrying capacity (David and Tisdell 1995). As individuals looking for 'nature' experiences are more likely to feel crowded than generalist tourists, a high number of protected areas could lead tourists to believe these areas will be less crowded (Cabezas-Rabadan et al. 2019). Giving tourists informed and realistic expectations of crowding will likely increase experiential carrying capacity in areas with higher densities of tourists (Cabezas-Rabadan et al. 2019).

Changing the system inputs, through education, management, or expectation setting, alters the tourism carrying capacity of a given site. Managers can use these factors to their advantage, increasing carrying capacity while maintaining the same limits of acceptable change by instituting projects like tourist environmental education programs. As tourism carrying capacity is constantly changing with new inputs, it is important to revisit assessments periodically to reassess tourism carrying capacity.

6.2 Importance of Spatial and Temporal Scale

Seasonality

Temporal variation in determining tourism carrying capacity can impact results. It is extremely important to consider the tourism carrying capacity not only per month or year but at any given time. Carboni et al. (2015) emphasized the importance of seasonality in determining tourism carrying capacity. While data may show that carrying capacity is not being surpassed annually there could be many instances of the capacity being exceeded at smaller time frames, this could be especially prominent in areas with distinct high and low tourist 'seasons' (Cupul-Magaña and Rodríguez-Troncoso 2017) For example, Ríos-Jara et al. (2013) estimate the tourism carrying capacity of dive trails in Isabel Island National Park, Mexico, by the number of 45-minute SCUBA dives per individual diver. Their estimated carrying capacity per year was between 1,252 to 1,642 dives per trail. However, this is estimated over an entire year, this many dives occurring during a short period of time would surpass the tourism carrying capacity. This also assumes all divers have the same 45-minute dive time. Tracking diving hours of tourists might be a better way to determine and track these thresholds. Based on the Ríos-Jara et al. (2013) example, capacity of dive trails in Isabel Island National Park, Mexico could also be measured as 939 to 1231.5 diver-hours. Although these limits may be more difficult to track and enforce, they are able to accommodate heterogeneity in diving. As tourism patterns are often heterogeneous it is important to know tourism carrying capacity at smaller time scales to effectively manage these areas.

Focus on Localized Impacts

While this review focuses on impacts at smaller spatial scales, such as specific dive sites or beaches, managers could also look at wide scale impacts such as the ecological footprint analysis of Chen et al. (2017). Due to heterogeneity in larger areas it is important to recognize that these estimates would be informative for the impacts of larger scale tourism but would not be appropriate for determining tourist limits at specific tourist destinations. As the Medes Islands MPA case study demonstrated, examining finer scale impacts allows managers to more precisely determine tourist limits in given environments, increasing the chances of successful preservation while maximizing the socioeconomic benefits.

6.3 Holistic Approaches to Tourism Carrying Capacity

Sustainable tourism is dependent on a balance between resident values, visitor use, and ecosystem preservation; depending on any one aspect of tourism carrying capacity does not facilitate this balance. In Aruba, a tourism strategy that focused on Aruban needs yielded the highest per capita income of three modeled tourism scenarios, even though tourism development and population growth was the slowest (Cole and Razak 2009). When initiating a study of tourism carrying capacity in a given area, it would behoove managers to conduct qualitative semi-structured interviews within the community first, in order to assess the concerns within the community. Additionally, modeling different possible outcomes based on various tourism scenarios allows managers to better visualize the results of tourist limits.

Adapting the Cifuentes Methodology

The Cifuentes methodology is easy to use and modify to a wide variety of sites, making it a valuable tool for assessing carrying capacity due to its contextual nature. However, this model is lacking in a few of the subcategories of tourism carrying capacity. By adding in comprehensive estimates of experiential and sociocultural carrying capacity to the Cifuentes methodology, this approach could be made more holistic and provide a more accurate estimate of tourism carrying capacity.

Rios-Jara et al. (2013) use experiential carrying capacity in their estimation of real carrying capacity by creating a ‘social correction factor’, incorporating diving group guidelines of the Recreational Scuba Training Council (RSTC) and the Professional Association of Diving Instructors (PADI). This limits the number of divers on a diving trail at any given time. Rios-Jara et al. (2013) also calculated for adequate time intervals between groups to prevent accidental overlap between groups. These factors are added to real carrying capacity to diminish dive site crowding. Managers could use a similar methodology by creating a correction factor to add results of ECC questionnaires into the Cifuentes methodology. Another option is adding experiential carrying capacity into the assessment of physical carrying capacity by determining occupancy criteria based on the minimum acceptable conditions determined for tourist crowding. As physical carrying capacity is set by determining occupancy criteria, or how much physical space an individual tourist uses, one could incorporate tourist crowding preferences into this measurement by setting the occupancy criteria based on experiential carrying capacity surveys.

Following initial qualitative sociocultural carrying capacity interviews, managers could also take more quantitative measurements by surveying residents using Likert scale questionnaires. The results of this could be used to determine a sociocultural capacity that could be added into the last step of the Cifuentes methodology with management capacity.

The Nusa Penida Marine Protected Area

The Nusa Penida Marine Protected Area (MPA), located in Klungkung District, Bali Province, Indonesia was established by the Klungkung District government in 2010, however, management transferred to the provincial government in 2014 (CTC 2019; IUCN 2014). Nusa Penida's ~48,000 residents depend on fisheries, aquaculture, and tourism as sources of income (CTC 2019). Tourism has grown from approximately 200,000 in 2014 to 650,000 in 2018 and, although coastal residents rely on tourism's economic opportunities, the negative impacts of tourism threaten local communities, ecosystems, and livelihoods. The Coral Triangle Center, in partnership with the Seattle Aquarium, is interested in assessing the tourism carrying capacity of the Nusa Penida MPA to determine if any procedural changes that need to be established to limit the negative impacts of tourism to ecosystems within the MPA and to the surrounding coastal communities. This project has established a general framework for tourism carrying capacity studies and developed recommendations for a holistic assessment of tourism carrying capacity in the Nusa Penida MPA (Appendix 1). Nusa Penida consists of many multi-use areas and, like the Medes Islands, the Nusa Penida MPA has a variety of ecosystems with differing ecosystem fragilities. This review suggests a holistic, local-scale approach to assessing the tourism carrying capacity of Nusa Penida (Appendix 1).

6.4 Tourism Rates and the COVID-19 Pandemic

From 2019 to 2020, tourism rates dropped in an unprecedented and extreme manner due to the COVID-19 pandemic. Between these two years, there was a 49.1% drop in tourism expenditures globally (WTTC 2021). This accounted for 62 million jobs lost globally. The decrease in tourism during the COVID-19 pandemic was especially prominent in the Caribbean and the Asia Pacific regions, with decreases of 58.0% and 53.7% respectively (WTTC 2021). Additionally, of the 62 million jobs lost, 34.1 million were lost in the Asia Pacific region (WTTC 2021). Although COVID-19 has had a huge impact on the socioeconomic and local aspects of tourism, researchers are unsure how tourists themselves will be psychologically impacted by social distancing (Sigala 2020). Experiential carrying capacity could potentially be impacted by the extended time social distancing, making individuals more aware of potential health risks involved with overcrowding (Sigala 2020). However, there is also ample evidence that tourists may return to their previous norms once it is safe to do so (Sigala 2020). Although the immediate economic and social impacts of COVID-19 on travel have been extreme, it is still unclear how COVID-19 will impact tourism in the future.

Appendix 1: Recommendations for the Coral Triangle Center

Determining Tourism Carrying Capacity in Marine and Costal Ecosystems:

Recommendations for the Nusa Penida MPA

The four sectors of tourism carrying capacity:

BIOPHYSICAL

The maximum number of tourists a given site can hold without surpassing the limits of acceptable biotic and abiotic environmental change.

- Physical space
- Tourist environmental impact
- Ecosystem fragility & recovery capacity

SOCIOCULTURAL

The threshold at which tourism rates meet local residents' limits of acceptable change in regards to negative social and cultural impacts.

- Local cultural effects
- Local economic effects
- Tourist-resident relationships and conflicts

MANAGERIAL

The number of tourists an area can have at a time given its infrastructural, service, and accommodation capacity.

- Available infrastructure
- Equipment
- Personnel & regulations

EXPERIENTIAL

The number of tourists an area can accommodate without negatively impacting the enjoyment of other tourists.

- Perceived crowding
- Perceived conditions and capacity of natural resources and infrastructure
- Tourist's social norms

DETERMINING LIMITS OF ACCEPTABLE CHANGE

To determine tourism carrying capacity for a given area, managers must determine the limits of acceptable change. Limits of acceptable change denote the degree of change or variation from the current state that is considered permissible under management objectives. In some circumstances, no change could be deemed the only acceptable option (e.g. coral cover). The limits of acceptable change will be highly context- specific, taking into account specific sites and management goals. Limits should be determined for not only the biophysical environment but also for sociocultural norms and tourist experiences.

PLANNING A CARRYING CAPACITY ASSESSMENT

The next page details the methodologies recommended by this review for the Nusa Penida marine protected area. First, there are a few things to keep in mind when planning the assessment itself.

CONSIDERING MANAGEMENT OBJECTIVES

While management objectives will play a role in the determination of limits of acceptable change, there are a few additional areas where management objectives should be reviewed.

Management objectives will play a role in the determination of experiential tourism carrying capacity thresholds. As specialist and nature-based tourists are less tolerant of crowding than generalists, managers will have to consider if certain types of tourism are preferred and should be prioritized.

Managers should primarily focus on the resources available and the needs of the community when determining what resident tolerance is acceptable and what impacts are unacceptable. They should have a historical perspective of tourism and a deep understanding of the local community, which can be strengthened through initial informal interviews.

SEASONAL & TEMPORAL SCALE

Examining finer scale impacts allows managers to more precisely determine tourist limits in given environments, increasing the chances of successful preservation while maximizing the socioeconomic benefits. This occurs in both the spatial and temporal scale.

When looking at carrying capacity over large scale areas or long time scales, tourism pressures can be unevenly loaded on certain sites or seasons, as tourism is not homogeneous. This could lead to tourism carrying capacity being surpassed at specific times or locations. Examining carrying capacity at finer scales allows for more certainty in estimations.

ASSESSMENT ORDER

The first step in assessing tourism carrying capacity should be conducting qualitative interviews with local residents to determine biophysical and sociocultural variables of particular interest to the community. The results of these interviews will be important in determining the correction factors included in the tourism carrying capacity estimation.

Correction factors can then be assessed through direct observation of marine ecosystems, local surveying, or findings from previous studies.

Occupancy criteria of physical carrying capacity (PCC) can be established to reflect the crowding preferences of tourism by estimating the tourist density of experiential carrying capacity at a given site, resulting in a more holistic assessment of carrying capacity.

Real carrying capacity (RCC) can be assessed with newly established PCC and correction factors. from this the overall tourism carrying capacity can be estimated by including the area's management capacity.

FLEXIBILITY

Changing the system inputs, through education, management, or expectation setting, alters the tourism carrying capacity of a given site. Managers can use these factors to their advantage, increasing carrying

Altering correction factors, through education, management, or expectation setting, alters the tourism carrying capacity of a given site. Managers can use these factors to their advantage, increasing carrying capacity while maintaining the same limits of acceptable change by instituting projects like tourist environmental education programs. As tourism carrying capacity is constantly changing with new inputs, it is important to revisit assessments periodically to reassess tourism carrying capacity.

Methodology

Reccomened methodology is based of the Cifuentes (1992) and Cifuentes et al. (1999) methodology.

BIOPHYSICAL

PHYSICAL CARRYING CAPACITY

Physical carrying capacity (PCC) represents the maximum number of tourists a site could theoretically hold.

$$PCC = \frac{A}{A_U} * T_f$$

where A is the size of the study area, A_U represents the area available (occupancy criteria), and T_f is the number of times that a person may visit the area in a day

When determining occupancy criteria, it is important to take site-specifics and tourist activities into account.

REAL CARRYING CAPACITY

Real carrying capacity (RCC) applies correction factors to the PCC, accounting for the specific features of a study site. These will vary based on location and tourist activities but usually include any environmental factors, seasonal closures, and tourist environmental impact.

$$RCC = PCC - \frac{100 - Cf_1}{100} \quad \frac{100 - Cf_2}{100} \quad \frac{100 - Cf_3}{100} \ldots \frac{100 - Cf_n}{100}$$

where C_f are the correction factors

To apply correction factors and determine real carrying capacity, variables, including ecosystem fragility, tourist damage, and environmental restrictions, must be assigned values. Methodology for determining values for correction factors is context-dependent. Some values are simple calculations, for example, the average number of rainy days per year. Other values require assessing and monitoring marine ecosystems, such as stony coral cover.

One of the primary benefits of using the Cifuentes methodology to assess tourism carrying capacity is its flexibility, this methodology can be used in multiple ecosystems and with however many correction factors are feasible to determine.

MANAGERIAL

Researchers should subjectively evaluate managerial components based on quantity, state, functionality, and location. Components can be evaluated as a percentage relationship between their current values and optimal values.

Components of this assessment should include infrastructure (e.g., accommodation, emergency services, potable water), equipment (e.g., vehicles, first aid, dive equipment rentals), and personnel & regulations (e.g., park rangers, natural disaster preparedness).

This percentile value is the area's management capacity (MC). Management capacity can be added to previous calculations of real carrying capacity through the following equation:

$$TCC = RCC * MC$$

Where overall tourism carrying capacity (TCC) is determined by the real carrying capacity (RCC) of a given site and the management capacity (MC) of the tourism area.

Transparency in the factors used to estimate these capacities is key to replicability and adaptation of future iterations of carrying capacity assessments for a given site.

SOCIOCULTURAL

Resident tolerance is the level of tourism at which negative sociocultural impacts can be accepted by local residents.

Initial interviews should be open-ended and informal, related to perceptions of tourism impact. Topics covered included could include dependency on tourism, positive impacts, negative impacts, and perceptions of limiting tourist arrivals. Respondents should represent people both dependent and not dependent on the tourism industry.

These interviews should inform the development of a Likert scale based questionnaire that could be distributed to a larger number of residents. It is important to note that the findings of initial interviews will likely vary by location and level of tourism development. The responses to the Likert scale based questionnaires could then provide data to determine quantitative measures of sociocultural tourism carrying capacity that can be made into correction factors and added to real carrying capacity assessments.

Special attention should be paid to how tourism can affect residents in a heterogeneous way. When conducting interviews and surveys it is vital to consider how groups may be impacted differently and make sure that responses are coming from a wide range of groups.

EXPERIENTAL

Use Likert scale questionnaires to quantitatively assess individual norms, there are two main methodologies:

NUMERICAL SURVEY

Using self-reported numerical estimations of preferred, acceptable, and intolerable thresholds to estimate tourist satisfaction in different scenarios

VISUAL SURVEY

Respondents view images of sites with various crowding conditions in random order, and are asked to identify their preferences for crowding based on the number, and proximity of people in the images.

When determining encounter norms it is important to take into consideration site-specific variables that may impact crowding perception. As tourists are less likely to correctly estimate a larger number of tourists it would be advisable to visual approaches in circumstances where a larger number of tourists are expected (high-use areas). Conversely, at smaller or less frequently visited sites numerical surveys can be conducted, avoiding some of the biases associated with visual surveys.

Tourist perceptions vary widely, potentially due to tourist diversity in sociodemographic variables or tourist use values. There is little *norm crystallization* in perceived crowding, as personal standards are found to be more influential than observed crowding in perceptions of crowding

Zoning could help manage expectations and reduce perceived crowding. This would ensure specialists have areas with stricter limits while allowing generalists areas with fewer restrictions. Creating varied management frameworks for sites would better account for diverse user needs, values, and social norms

Appendix 2: Sources Examined in Literature Review and Primary Sector(s)

	Author	Year	Title	Publication Title	Primary Sector(s)
1	Bentz et al.	2015	Crowding in marine environments: Divers and whale watchers in the Azores	Ocean & Coastal Management	ECC
2	Cabezas-Rabadan et al.	2019	Assessing users' expectations and perceptions on different beach types and the need for diverse management frameworks along the Western Mediterranean	Land Use Policy	ECC
3	Carboni et al.	2015	Asinara National Park. An Example of Growth and Sustainability in Tourism	Journal of Environmental and Tourism Analyses	MCC
4	Chen & Teng	2016	Management priorities and carrying capacity at a high-use beach from tourists' perspectives: A way towards sustainable beach tourism	Marine Policy	ECC
5	Chen et al.	2017	Ecological footprint analysis on tourism carrying capacity at the Zhoushan Archipelago, China	Asia Pacific Journal of Tourism Research	BCC
6	Cisneros et al.	2016	Beach carrying capacity assessment through image processing tools for coastal management	Ocean & Coastal Management	BCC
7	Clark	1991	Carrying Capacity and Tourism in Coastal and Marine Areas	Parks-International Union for the Conservation of Nature and Natural Resources	SCC
8	Cocklin et al.	1998	Marine Reserves in New Zealand: Use rights, public attitudes, and social impacts	Coastal Management	SCC
9	Cole & Razak	2009	How far, and how fast? Population, culture, and carrying capacity in Aruba	Futures	SCC/MCC
10	Cupul-Magaña & Rodríguez-Troncoso	2017	Tourist carrying capacity at Islas Marietas National Park: An essential tool to protect the coral community	Applied geography	BCC/MCC
11	Davis & Tisdell	1995	Recreational scuba-diving and carrying capacity in marine protected areas	Ocean & Coastal Management	BCC/ECC
12	Gonson et al.	2018	Social carrying capacity assessment from questionnaire and counts survey: Insights for recreational settings management in coastal areas	Marine Policy	ECC

13	Gossling et al.	2002	Ecological footprint analysis as a tool to assess tourism sustainability	Ecological Economics	BCC
14	Hallo et al.	2018	The Experiential Carrying Capacity of a Barrier Island: A Norm-Based Approach at Cumberland Island National Seashore	Tourism in Marine Environments	ECC
15	Han et al	2018	A study on evaluation the marine carrying capacity in Guangxi Province, China	Marine Policy	BCC
16	Junaid et al.	2018	The carrying capacity for the development of marine ecotourism	Masyarakat Kebudayaan Dan Politik	SCC
17	Kayat et al.	2012	Social Tourism Carrying Capacity In Kampung Kilim, World Geopark, Langkawi	WIT Transactions on Ecology and the Environment	SCC
18	Klanjscek et al.	2018	Predicting perceived level of disturbance of visitors due to crowding in protected areas	Plos One	ECC
19	Lankford et al.	2008	Exploring Social Carrying Capacity Based on Perceived Levels of Crowding: A Case Study of Hanauma Bay, Hawaii	Tourism in Marine Environments	ECC
20	Lee	2011	Carrying Capacity of Sustainable Tourism Based on the Balance Concept between Ecological Damage Loading and Recovery Capacity	Journal of Coastal Research	BCC
21	Lee & Chang	2015	A model for predicting tourist carrying capacity and implications for fish conservation	Environmental Biology of Fishes	BCC
22	Lelloltery et al.	2018	Study of coral reef for marine ecotourism development based on region suitability and carrying capacity in Marsegu Island Nature Tourism Park, Maluku, Indonesia	Biodiversitas (Surakarta)	BCC
23	Leujak & Ormond	2007	Visitor Perceptions and the Shifting Social Carrying Capacity of South Sinai's Coral Reefs	Environmental Management	ECC
24	Lucrezi et al.	2013	Perceived Diving Impacts and Management Implications at a Popular South African Reef	Coastal Management	ECC
25	Liu et al.	2009	Research on Tourism Environmental Carrying Capacity of ChongMing Island	ESIAT	BCC
26	Mohamed & KaiXin.	2016	A historical review of recreational carrying capacity model (RCC) in island tourism.	TEAM Journal of Hospitality and Tourism	BCC

27	Navarro Jurado et al.	2012	Carrying capacity assessment for tourist destinations. Methodology for the creation of synthetic indicators applied in a coastal area	Tourism Management	BCC
28	Prokopiou et al	2012	Comparative Analysis Of Carrying Capacity Indices For The Central Aegean Islands	WIT Transactions on Ecology and the Environment	MCC
29	Prokopiou et al.	2015	Carrying Capacity As A Tool To Design Tourism Policy: Case Study For The Island Of Rhodes	WIT Transactions on Ecology and the Environment	MCC
30	Prokopiou et al.	2013	Carrying Capacity Assessment In Tourism: The Case Of Northern Sporades Islands	WIT Transactions on Ecology and the Environment	MCC
31	Prokopiou et al.	2018	Tourism Development Of The Cyclades Islands: Economic, Social And Carrying Capacity Assessment And Consequences	WIT Transactions on Ecology and the Environment	MCC
32	Prokopiou et al.	2017	Sustainable Tourism And Destination Management: The Greek Island Of Poros	WIT Transactions on Ecology and the Environment	MCC
33	Quicoy & Briones	2009	Beach Carrying Capacity Assessment of Coastal Ecotourism in Calatagan, Batangas, Phlippines	Journal of Environmental Science and Management	BCC
34	Rasoolimanesh et al.	2017	Tourist's perceptions of crowding at recreational sites: the case of the Perhentian Islands	Anatolia-International Journal of Tourism and Hospitality Research	ECC
35	Rasoolimanesh et al.	2016	How Visitor and Environmental Characteristics Influence Perceived Crowding	Asia Pacific Journal of Tourism Research	ECC
36	Ribeiro et al.	2011	The Sustainable Carrying Capacity as a Tool for Environmental Beach Management	Journal of Coastal Research	BCC
37	Rios-Jara et al.	2013	The Tourism Carrying Capacity of Underwater Trails in Isabel Island National Park, Mexico	Environmental Management	BCC/MCC
38	Santana-Jimenez & Hernandez	2011	Estimating the effect of overcrowding on tourist attraction: The case of Canary Islands	Tourism Management	ECC
39	Sharma, R.	2016	Evaluating total carrying capacity of tourism using impact indicators	Global Journal of Environmental Science and Management-	BCC

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40	Simanjuntak et al.	2018	Analysis Of Suitability And Carrying Capacity Of Tourism In Tidung Island, Kepulauan Seribu Of Indonesia	Russian journal of agricultural and socio-economic sciences	BCC
41	Simeone et al.	2012	Impact of frequentation on a Mediterranean embayed beach: Implication on carrying capacity	Ocean & Coastal Management	BCC
42	Thomas et al.	2005	Tourist Carrying Capacity Measures: Crowding Syndrome in the Caribbean	Professional Geographer	ECC
43	Tselentis et al.	2011	Tourism Carrying Capacity Assessment And Environment: The Case Of Crete	WIT Transactions on Ecology and the Environment	MCC
44	Tselentis et al.	2006	Carrying Capacity Assessment For The Greek Islands Of Kalymnos, Kos And Rhodes	WIT Transactions on Ecology and the Environment	MCC
45	Tselentis et al.	2006	Carrying Capacity Assessment In Tourism: The Case Of The Dodecanese Archipelago	WIT Transactions on Ecology and the Environment	MCC
46	Winata et al.	2020	Assessment of mangrove carrying capacity for ecotourism in Kemujan Island, Karimunjawa National Park, Indonesia	Advances in Environmental Sciences	BCC
47	Wu et al.	2020	Assessing the response of sandy-beach macrobenthos to recreation and the ecological status of the beach ecosystem at Liandao, China	Marine Ecology	BCC
48	Zhang et al.	2016	Ecological carrying capacity assessment of diving site: A case study of Mabul Island, Malaysia	Journal of environmental management	BCC
49	Zhang et al.	2015	Assessing perceived crowding of diving sites in Hong Kong	Ocean & coastal management	ECC
50	Ziegler et al.	2019	Measuring Perceived Crowding in the Marine Environment: Perspectives from a Mass Tourism "swim-With" Whale Shark Site in the Philippines	Tourism in Marine Environments	ECC

BIBLIOGRAPHY

Bentz, J., Rodrigues, A., Dearden, P., Calado, H., & Lopes, F. (2015). Crowding in marine environments: Divers and whale watchers in the Azores. *Ocean & Coastal Management*, 109, 77–85. https://doi.org/10.1016/j.ocecoaman.2015.03.001

Burgin, S., & Hardiman, N. (2015). Effects of non-consumptive wildlife-oriented tourism on marine species and prospects for their sustainable management. *Journal of Environmental Management*, *151*, 210–220. https://doi.org/10.1016/j.jenvman.2014.12.018

Cabezas-Rabadan, C., Rodilla, M., Pardo-Pascual, J. E., & Herrera-Racionero, P. (2019). Assessing users' expectations and perceptions on different beach types and the need for diverse management frameworks along the Western Mediterranean. *Land Use Policy*, 81, 219–231. https://doi.org/10.1016/j.landusepol.2018.10.027

Carboni, D., Congiatu, P., & De Vincenzi, M. (2015). Asinara National Park. An Example of Growth and Sustainability in Tourism. *Journal of Environmental and Tourism Analyse*s, 3(1), 45.

Chen, C.-L., & Teng, N. (2016). Management priorities and carrying capacity at a high-use beach from tourists' perspectives: A way towards sustainable beach tourism. *Marine Policy*, 74, 213–219. https://doi.org/10.1016/j.marpol.2016.09.030

Chen, J., Ye, G., Jing, C., Wu, J., & Ma, P. (2017). Ecological footprint analysis on tourism carrying capacity at the Zhoushan Archipelago, China. *Asia Pacific Journal of Tourism Research*, 22(10), 1049–1062. https://doi.org/10.1080/10941665.2017.1364276

Cisneros, H.M., Revollo Sarmiento, N. V., Delrieux, C. A., Piccolo, Mc., & Perillo, G. M. (2016). Beach carrying capacity assessment through image processing tools for coastal management. *Ocean & Coastal Management*, 130, 138–147. https://doi.org/10.1016/j.ocecoaman.2016.06.010

Clark, J. R. (1991). Carrying Capacity and Tourism in Coastal and Marine Areas. *Parks-International Union for the Conservation of Nature and Natural Resources*, 2(3), 13.

Cocklin, C., Craw, M., & McAuley, I. (1998). Marine Reserves in New Zealand: Use rights, public attitudes, and social impacts. *Coastal Management*, 26(3), 213–231. https://doi.org/10.1080/08920759809362353

Cole, S., & Razak, V. (2009). How far, and how fast? Population, culture, and carrying capacity in Aruba. *Futures,* 41(6), 414–425. https://doi.org/10.1016/j.futures.2008.11.013

Commercial whale watching rulemaking. (n.d.). Washington Department of Fish & Wildlife. Retrieved May 31, 2021, from https://wdfw.wa.gov/species-habitats/at-risk/species-recovery/orca/rule-making

CTC (Coral Triangle Center). Nusa Penida – A Tropical Marine Paradise [online]. Available from: https://www.coraltrianglecenter.org/nusa-penida-mpa/ [Accessed December 2019]

Cupul-Magaña, A. L., & Alma Paola Rodríguez-Troncoso. (2017). Tourist carrying capacity at Islas Marietas National Park: An essential tool to protect the coral community. *Applied Geography,* 88, 15–23. https://doi.org/10.1016/j.apgeog.2017.08.021

Davis, D., & Tisdell, C. (1995). Recreational scuba-diving and carrying capacity in marine protected areas. *Ocean & Coastal Managemen*t, 26(1), 19–40.

Douglass, R.W. (1975). Forest Recreation. 2nd ed. Pergamon Press Inc., New York.

Fama, A., Haeruddin, & Purwanti, F. (2017). Suitability and carrying capacity of kartini beach jepara as coastal tourism destination. *Jurnal Ilmu Dan Teknologi Kelautan Tropis*, 9(2), 805–813. https://doi.org/10.29244/jitkt.v9i2.19312

Gonson, C., Pelletier, D., & Alban, F. (2018). Social carrying capacity assessment from questionnaire and counts survey: Insights for recreational settings management in coastal areas. *Marine Policy*, 98, 146–157. https://doi.org/10.1016/j.marpol.2018.08.016

Gossling, S., Hansson, C. B., Horstmeier, O., & Saggel, S. (2002). Ecological footprint analysis as a tool to assess tourism sustainability. *Ecological Economics*, 43(2–3), 199–211. https://doi.org/10.1016/S0921-8009(02)00211-2

Hallo, J. C., Brownlee, M. T. J., Hughes, M. D., Fefer, J. P., & Manning, R. E. (2018). The Experiential Carrying Capacity of a Barrier Island: A Norm-Based Approach at Cumberland Island National Seashore. *Tourism in Marine Environments*, 13(2), 121–140. https://doi.org/10.3727/154427318X15276699095989

Han, Y., Wei, F., Ye, G., Yang, S., Ma, P., & Hu, W. (2018). A study on evaluation the marine carrying capacity in Guangxi Province, China. *Marine Policy*, 91, 66–74. https://doi.org/10.1016/j.marpol.2018.02.003

IUCN Green List. (n.d.). Montague Island Nature Reserve [online]. Retrieved June 2, 2021, from https://iucngreenlist.org/sites/montague-island-nature-reserve/

IUCN (International Union for Conservation of Nature) (2014). Nusa Penida: A Blue Solution to learn from [online]. Retrieved December 2019. Switzerland, Gland. from: http://www.iucn.org/about/work/programmes/gpap_home/?14703/Nusa-Penida-A-Blue-Solutionto-learn-from

Junaid, I., & Fauziah, A. N. (2018). The carrying capacity for the development of marine ecotourism. *Masyarakat Kebudayaan Dan Politik*, 31(2), 190–200. https://doi.org/10.20473/mkp.V31I22018.190-200

Kayat, K., & R. Mohd Radzi. (2012). Social Tourism Carrying Capacity In Kampung Kilim, World Geopark, Langkawi. *WIT Transactions on Ecology and the Environment*, 166, 93–102. https://doi.org/10.2495/ISLANDS120081

Klanjscek, J., Gecek, S., Marn, N., Legovic, T., & Klanjscek, T. (2018). Predicting perceived level of disturbance of visitors due to crowding in protected areas. *Plos One*, 13(6), e0197932. https://doi.org/10.1371/journal.pone.0197932

Llausàsa, A., Vila-Subirós, J., Pueyo-Rosb, J., & Fraguell, R. M. (2019). Carrying Capacity as a Tourism Management Strategy in a Marine Protected Area: A Political Ecology Analysis. *Conservation & Society*, *17*(4), 366–376.

Lankford, S. V., Inui, Y., & Whittle, A. (2008). Exploring Social Carrying Capacity Based on Perceived Levels of Crowding: A Case Study of Hanauma Bay, Hawaii. *Tourism in Marine Environments,* 5(1), 43–53.

Lee, L. H., & Chang, Z. Y. (2015). A model for predicting tourist carrying capacity and implications for fish conservation. *Environmental Biology of Fishes*, 98(3), 871–884. https://doi.org/10.1007/s10641-014-0335-7

Lee, S. (2011). Carrying Capacity of Sustainable Tourism Based on the Balance Concept between Ecological Damage Loading and Recovery Capacity. *Journal of Coastal Research*, SI(64), 1297.

Lelloltery, H., Pudyatmoko, S., Fandelli, C., & Baiquni, M. (2018). Study of coral reef for marine ecotourism development based on region suitability and carrying capacity in Marsegu Island Nature Tourism Park, Maluku, Indonesia. *Biodiversitas (Surakarta)*, 19(3), 1089–1096. https://doi.org/10.13057/biodiv/d190342

Leujak, W., & Ormond, R. F. G. (2007). Visitor Perceptions and the Shifting Social Carrying Capacity of South Sinai's Coral Reefs. *Environmental Management*, 39(4), 472–489. https://doi.org/10.1007/s00267-006-0040-1

Liu Shi-dong, Sun Rui-hong, & Gao Jun. (2009). Research on Tourism Environmental Carrying Capacity of ChongMing Island. *ESIAT,* 3, 177–181. https://doi.org/10.1109/ESIAT.2009.340

Lucrezi, S., Saayman, M., & Van Der Merwe, P. (2013). Perceived Diving Impacts and Management Implications at a Popular South African Reef. *Coastal Management*, 41(5), 381–400. https://doi.org/10.1080/08920753.2013.822278

Machernis, A. F., Powell, J. R., Engleby, L., & Spradlin, T. R. (2018). *An updated literature review examining the impacts of tourism on marine mammals over the last fifteen years (2000-2015) to inform research and management programs.* https://doi.org/10.7289/V5/TM-NMFS-SER-7

Mai, T., & Smith, C. (2015). Addressing the threats to tourism sustainability using systems thinking: A case study of Cat Ba Island, Vietnam. *Journal of Sustainable Tourism,* 23(10), 1504–1528. https://doi.org/10.1080/09669582.2015.1045514

Mai, T., & Smith, C. (2018). Scenario-based planning for tourism development using system dynamic modelling: A case study of Cat Ba Island, Vietnam. *Tourism Management*, 68, 336–354. https://doi.org/10.1016/j.tourman.2018.04.005

Marion, J. L., & Rogers, C. S. (1994). The applicability of terrestrial visitor impact management strategies to the protection of coral reefs. *Ocean & Coastal Management*, 22(2), 153–163. https://doi.org/10.1016/0964-5691(94)90017-5

Mohamed, B., & KaiXin, T. (2016). A historical review of recreational carrying capacity model (RCC) in island tourism. *TEAM Journal of Hospitality and Tourism*, 13(1), 27–39.

Navarro Jurado, E., Tejada Tejada, M., Almeida Garcia, F., Cabello Gonzalez, J., Cortes Macias, R., Delgado Pena, J., Fernandez Gutierrez, F., Gutierrez Fernandez, G., Luque Gallego, M., Malvarez Garcia, G., Marcenaro Gutierrez, O., Navas Concha, F., Ruiz de la Rua, F., Ruiz Sinoga, J., & Solis Becerra, F. (2012). Carrying capacity assessment for tourist destinations. Methodology for the creation of synthetic indicators applied in a coastal area. *Tourism Management,* 33(6), 1337–1346. https://doi.org/10.1016/j.tourman.2011.12.017

Patterson, T., Gulden, T., Cousins, K., & Kraev, E. (2004). Integrating environmental, social and economic systems: A dynamic model of tourism in Dominica. *Ecological Modelling*, 175(2), 121–136. https://doi.org/10.1016/j.ecolmodel.2003.09.033

Prokopiou, D. G., Tselentis, B. S., & Toanoglou, M. (2012). Comparative Analysis Of Carrying Capacity Indices For The Central Aegean Islands. *WIT Transactions on Ecology and the Environment,* 161, 79–90. https://doi.org/10.2495/ST120071

Prokopiou, D. G., Tselentis, B. S., & Toanoglou, M. (2013). Carrying Capacity Assessment In Tourism: The Case Of Northern Sporades Islands. *WIT Transactions on Ecology and the Environment*, 169, 115–123. https://doi.org/10.2495/CP130101

Prokopiou, D. G., Tselentis, B. S., Mavridoglou, G., & Zougla, S. (2015). Carrying Capacity As A Tool To Design Tourism Policy: Case Study For The Island Of Rhodes. *WIT Transactions on Ecology and the Environment,* 193, 905–914. https://doi.org/10.2495/SDP150761

Prokopiou, D., Mavridoglou, G., Toanoglou, M., & Tselentis, B. (2018). Tourism development of the cyclades islands: economic, social and carrying capacity assessment and consequences. *WIT Transactions on Ecology and the Environment*, 217, 509–521. https://doi.org/10.2495/SDP180451

Prokopiou, D., Nikolaidou, E., Mavridoglou, G., Manologlou, S., & Tselentis, B. (2017). Sustainable tourism and destination management: the greek island of poros. *WIT Transactions on Ecology and the Environmen*t, 226, 505–515. https://doi.org/10.2495/SDP170441

Quicoy, A. R., & Briones, N. D. (2009). Beach Carrying Capacity Assessment of Coastal Ecotourism in Calatagan, Batangas, Phlippines. *Journal of Environmental Science and Management,* 12(2), 11–26.

Rasoolimanesh, S. M., Jaafar, M., Marzuki, A., & Abdullah, S. (2017). Tourist's perceptions of crowding at recreational sites: The case of the Perhentian Islands. Anatolia-International *Journal of Tourism and Hospitality Research*, 28(1), 41–51. https://doi.org/10.1080/13032917.2016.1247288

Rasoolimanesh, S. M., Jaafar, M., Marzuki, A., & Mohamad, D. (2016). How Visitor and Environmental Characteristics Influence Perceived Crowding. *Asia Pacific Journal of Tourism Research*, 21(9), 952–967. https://doi.org/10.1080/10941665.2015.1084348

Ribeiro, M. F., Ferreira, J. C., & Silva, C. P. (2011). The Sustainable Carrying Capacity as a Tool for Environmental Beach Management. *Journal of Coastal Research,* SI(64), 1411–1414.

Rios-Jara, E., Galvan-Villa, C. M., Rodriguez-Zaragoza, F. A., Lopez-Uriarte, E., & Munoz-Fernandez, V. T. (2013). The Tourism Carrying Capacity of Underwater Trails in Isabel Island National Park, Mexico. *Environmental Management*, 52(2), 335–347. https://doi.org/10.1007/s00267-013-0047-3

Roudi, S., Arasli, H., & Akadiri, S. S. (2019). New insights into an old issue – examining the influence of tourism on economic growth: Evidence from selected small island developing states. *Current Issues in Tourism*, *22*(11), 1280–1300. https://doi.org/10.1080/13683500.2018.1431207

Santana-Jimenez, Y., & Hernandez, J. M. (2011). Estimating the effect of overcrowding on tourist attraction: The case of Canary Islands. *Tourism Management*, 32(2), 415–425. https://doi.org/10.1016/j.tourman.2010.03.013

Sha, S. (2020). The Early Warning Model of Tourism Environmental Carrying Capacity Measurement in Coast and Island Regions. *Journal of Coastal Research*, 1042–1046. https://doi.org/10.2112/SI103-217.1

Sharma, R. (2016). Evaluating total carrying capacity of tourism using impact indicators. Global *Journal of Environmental Science and Management-Gjesm, 2*(2), 187–196. https://doi.org/10.7508/gjesm.2016.02.009

Sigala, M. (2020). Tourism and COVID-19: Impacts and implications for advancing and resetting industry and research. *Journal of Business Research*, 117, 312–321. https://doi.org/10.1016/j.jbusres.2020.06.015

Simanjuntak, S. W., Supriharyono, & Haeruddin. (2018). Analysis of suitability and carrying capacity of tourism in tidung island, Kepulauan Seribu of Indonesia. *Russian Journal of Agricultural and Socio-Economic Sciences*, 78(6), 151–159. https://doi.org/10.18551/rjoas.2018-06.16

Simeone, S., Palombo, A. G. L., & Guala, I. (2012). Impact of frequentation on a Mediterranean embayed beach: Implication on carrying capacity. *Ocean & Coastal Management*, 62, 9–14. https://doi.org/10.1016/j.ocecoaman.2012.02.011

Sulaiman, F. C., Jaini, N., Jamaluddin, E. R., & Hashim, N. I. (2018). The Impact of Marine Tourism Towards the Local Community at Pulau Pangkor, Perak. *Asian Journal of Quality of Life*, *3*(13), 168–176. https://doi.org/10.21834/ajqol.v3i13.174

Thomas, R. N., Pigozzi, B. W., & Sambrook, R. A. (2005). Tourist Carrying Capacity Measures: Crowding Syndrome in the Caribbean. *Professional Geographer,* 57(1), 13–20.

Trave, C., Brunnschweiler, J., Sheaves, M., Diedrich, A., & Barnett, A. (2017). Are we killing them with kindness? Evaluation of sustainable marine wildlife tourism. *Biological Conservation*, *209*, 211–222. https://doi.org/10.1016/j.biocon.2017.02.020

Tselentis, B. S., Prokopiou, D. G., & Toanoglou, M. (2006). Carrying Capacity Assessment For The Greek Islands Of Kalymnos, Kos And Rhodes. *WIT Transactions on Ecology and the Environment,* 97. https://doi.org/10.2495/ST060331

Tselentis, B. S., Prokopiou, D. G., Em. Gyalirakis, & Bouga, D. (2011). Tourism Carrying Capacity Assessment And Environment: The Case Of Crete. *WIT Transactions on Ecology and the Environment, 1*44, 177–189. https://doi.org/10.2495/ECO110161

Tselentis, B. S., Prokopiou, D. G., Toanoglou, M., & D. Bousbouras. (2005). Carrying Capacity Assessment In Tourism: The Case Of The Dodecanese Archipelago. *WIT Transactions on Ecology and the Environment,* 99. https://doi.org/10.2495/RAV060221

Wackernagel, M., Onisto, L., Bello, P., Callejas Linares, A., Susana López Falfán, I., Méndez García, J., Isabel Suárez Guerrero, A., & Guadalupe Suárez Guerrero, M. (1999). National natural capital accounting with the ecological footprint concept. *Ecological Economics*, *29*(3), 375–390. https://doi.org/10.1016/S0921-8009(98)90063-5

Winata, A., Yuliana, E., Hewindati, Y. T., & Djatmiko, W. A. (2020). Assessment of mangrove carrying capacity for ecotourism in Kemujan Island, Karimunjawa National Park, Indonesia. *Advances in Environmental Sciences*, 12(1), 83–96.

Wong, C. W. M., Conti-Jerpe, I., Raymundo, L. J., Dingle, C., Araujo, G., Ponzo, A., & Baker, D. M. (2019). Whale Shark Tourism: Impacts on Coral Reefs in the Philippines. *Environmental Management,* 63(2), 282–291. https://doi.org/10.1007/s00267-018-1125-3

WTTC (World Travel & Tourism Council) (2019). Travel & Tourism continues strong growth above global GDP [online]. Available from: https://www.wttc.org/about/media-centre/press-releases/press-releases/2019/travel-tourism-continues-strong-growth-above-global-gdp/ [Accessed January 2020]

WTTC (World Travel & Tourism Council) (2021). Economic Impact [online]. Available from: https://wttc.org/Research/Economic-Impact [Accessed May 18, 2021]

Wu, X., Zou, X., Zhong, C., Yu, W., Li, Y., & Wang, T. (2020). Assessing the response of sandy-beach macrobenthos to recreation and the ecological status of the beach ecosystem at Liandao, China. *Marine Ecology*, 41(1). https://doi.org/10.1111/maec.12580

Yacob, M. R., Shuib, A. H. M. A. D., Mamat, M. F., & Radam, A. L. I. A. S. (2007). Local economic benefits of ecotourism development in Malaysia: The case of Redang Island Marine Park. *International Journal of Economics and Management*, 1(3), 365-386.

Yagi, C., & Pearce, P. L. (2007). The Influence of Appearance and the Number of People Viewed on Tourists' Preferences for Seeing Other Tourists. *Journal of Sustainable Tourism*, *15*(1), 28–43. https://doi.org/10.2167/jost528.0

Yulianda, F. (2007). Marine Ecotourism as an alternative to Conservation Based Resource Utilization. Department of Waters and Resources Management Faculty of Fisheries and marine Sciences, Bogor Agricultural University, Bogor.

Zhang, L.-Y., Jian-Wen Qiu, & Shan-Shan, C. (2015). Assessing perceived crowding of diving sites in Hong Kong. *Ocean & Coastal Management,* 116, 177–184. https://doi.org/10.1016/j.ocecoaman.2015.07.025

Zhang, L.-Y., Jian-wen Qiu, & Shan-shan, C. (2016). Ecological carrying capacity assessment of diving site: A case study of Mabul Island, Malaysia. *Journal of Environmental Management,* 183, 253–259. https://doi.org/10.1016/j.jenvman.2016.08.075

Ziegler, J. A., Araujo, G., Labaja, J., Legaspi, C., Snow, S., Ponzo, A., Rollins, R., & Dearden, P. (2019). Measuring perceived crowding in the marine environment: perspectives from a mass tourism "swim-with" whale shark site in the Philippines. T*ourism in Marine Environments*, 14(4), 211–230. https://doi.org/10.3727/154427319X15677721896465

Ziegler, J., Araujo, G., Labaja, J., Snow, S., King, J. N., Ponzo, A., Rollins, R., & Dearden, P. (2020). Can ecotourism change community attitudes towards conservation? *Oryx*, 1–10. https://doi.org/10.1017/S0030605319000607