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CARRYING CAPACITY ASSESSMENT OF DIVE SITES IN BALI, INDONESIA

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Abstract

The diving tourism industry in Bali is experiencing rapid growth, and this is important for Bali tourism. To ensure the sustainability of coral reefs as a core attraction for diving tourism, it is necessary to have the policy to control diving tourism activities through the application of the carrying capacity concept. In this regard, the focus of this study is to assess the carrying capacity of dive sites in Bali to support the application of the carrying capacity concept as an instrument for sustainable diving tourism management. The methodology used to assess the carrying capacity was based on the physical and biological conditions of each location and the management capacity provided by destination management authorities and dive operators. The carrying capacity is assessed using the model developed by Cifuentes (1992) which includes three levels, namely physical carrying capacity, real carrying capacity, and effective carrying capacity. The estimated carrying capacity of 12 dive sites in Bali ranges between 81 and 156 divers/site/day. The number of visitors to the most popular dive sites during the peak season is higher than the estimated carrying capacity. It is important to distribute the number of divers to sites where the number of actual visitors is lower than the carrying capacity value to reduce environmental stresses at the sites that exceed the capacity.

Keywords: Diving tourism, tourism management, coral reefs, sustainable

INTRODUCTION

Diving tourism is an important component for Bali as one of the best island tourism destinations in the world. This region is located on the southern edge of the Coral Triangle, renowned for its globally outstanding marine biodiversity (Allen and Erdmann, 2012). The direct influence of the global current namely the Indonesian through-flow, transporting Pacific Ocean water through the Indonesia Archipelago to the Indian Ocean, makes Bali waters host diverse coral reef fauna, with a total of 406 reef-building species (hermatypic), being the migration corridor of marine mammals, and the gathering of manta rays and ocean sunfish (*Mola mola*) (Turak and DeVantier, 2012).

The diving tourism industry in Bali is growing rapidly and most of the coral reefs in Bali have been developed as dive sites to serve divers who increase every year. This growth significantly increases employment and the regional economy. In the future, Bali's diving tourism industry will likely continue to increase in terms of the number of visitors along with the increasing popularity of diving tourism. Several factors contribute to the popularity of diving tourism, including technological advances that allow access to dive sites more easily and increased interest in learning and gaining experience in the marine environment (Dimmock, 2009; Musa and Dimmock, 2012). Supported by national policies that put tourism as a leading sector, especially marine resource-based tourism, Bali as the main gateway for tourist arrivals to Indonesia has the potential to become a leading diving tourism destination in the Coral Triangle region.

Unfortunately, coral reefs as a resource and a core attraction in diving tourism tend to experience increased damage. The rapid growth of the tourism industry has contributed to accelerating environmental damage. Physical damage to coral reefs by divers and anchorage increases significantly in various world diving destinations along with the increasing popularity of diving tourism (Serour and Kanga, 2005; Musa, 2002; Szuster et al., 2011).

Given these increasing levels of threats and impacts on coral reefs, the Government of Bali is currently working towards a comprehensive long-term development strategy through the development of marine protected areas. This effort is intended to conserve this important ecosystem for sustainable tourism and at the same time to strengthen the competitiveness of Bali diving destination. The principle is to maintain a balance between tourism and the environment. According to White et al. (2006), the core of the balance between tourism and the environment is the carrying capacity. The carrying capacity approach of diving tourism in principle is to control the number of divers at the level where the impact is still ecologically, economically and socially acceptable. The carrying capacity approach has been commonly used in diving tourism management (Davis and Tindell, 1995; Hawkins and Roberts, 1997). The concept of tourism carrying capacity applied to dive tourism based on coral reef ecosystems aims: 1) to identify the determinants of coral reef capacity, and subsequently allow the reduction or elimination of causes of damage (Salm, 1988; Hawkins and Robert, 1997; Zhang et al., 2016); 2) to increase diver's satisfaction; and 3) for sustainable use of dive sites (Zhang et al., 2016).

This research was conducted by considering that the application of carrying capacity is very important as a management tool to balance the use and protection of coral reefs which are ecologically very sensitive and vulnerable from disturbances. This research was an attempt to initiate the process of assessing the carrying capacity of diving tourism for sustainable tourism development. While the main objective of this research is to assess the carrying capacity of popular dive sites in Bali.

STUDY AREA

This research was conducted in the Bali Province, Indonesia. The island of Bali is situated to the west of and bordering the deep-water Lombok Strait. The larger region, collectively known as the Lesser Sunda Islands, extends from Bali in the west to Timor in the east and has been characterized as the Lesser Sunda Ecoregion (Green and Mous, 2007). With the main Lesser Sunda island chain, Bali forms part of the north-western boundary to the Indian Ocean and provides a major point of differentiation in several key climatological and oceanographic features (Turak and deVantier, 2012). Unlike the adjacent region to the west, which sits atop the Sunda Shelf, and regions much further east (eg. Papua) located atop the Sahul Shelf, the Lesser Sunda Islands, with islands to their north, have, during the past several million years, always had deep water adjacent to their coasts. These islands have presumably played a major role as biological refugia during the Pleistocene glaciations, with significant biogeographic implications (Barber et al., 2000).

On its eastern shore, Bali borders Lombok Strait, with water depths greater than 1,000m in places. Lombok Strait is a major corridor of the Indonesian Throughflow (ITF), transporting Pacific Ocean water through Indonesia to the Indian Ocean. Although the main direction of water transport is from north-south, there is limited water exchange in the opposite direction. The ITF exports warm, lower salinity water from the North and central-west Pacific, providing a major water source for the north-east Indian Ocean (Turak and deVantier, 2012).

Tourism is a leading sector for the economy of Bali and the main gateway to foreign tourist arrivals to Indonesia. In 2017, Bali received direct arrivals of 5.7 million foreign tourists (40.58% of the total 14.04 million foreign tourists to Indonesia) with a growth rate of 13.25% per year in the last ten years. Tourism through the provision of tourist accommodations and restaurants accounted for 23.33% of Gross Regional Domestic Products in 2017.

Coastal resources contribute significantly to Bali tourism which provides a variety of tourist attractions, whether in the form of coastal landscapes, seascapes, and underwater features. Fifteen of the 16 tourism areas in Bali are located in coastal areas. One of the high-value coastal tourism resources in Bali is the coral reef. According to the Indonesian Institute of Sciences (Giyanto et al., 2017), waters of Bali have a distribution of approximately 8,837 hectares of coral reef. The reefs cover around 75% of the 633 km coastline. Most of the coral reefs in Bali have been used as diving sites. Twelve dive sites in Bali were chosen as the location of this study. The dive sites representative of the most popular diving destinations in Bali (Figure 1).

RESEARCH METHOD

Primary data were collected through field survey and divers survey. Field survey to collect data on coral reefs and dive areas. Data on coral reefs collected are benthic communities of coral reefs using the Line Intercept Transect (LIT) method (English et al., 1994). The benthic communities of coral reefs are characterized using the categories of lifeforms to determine the status of coral reef conditions, the composition of fragile coral cover and coral mortality. Data on the dimensions of the diving area are measured directly in the field with the Global Position System (GPS) and data on the frequency of dives in a day are measured through observations in the fields.

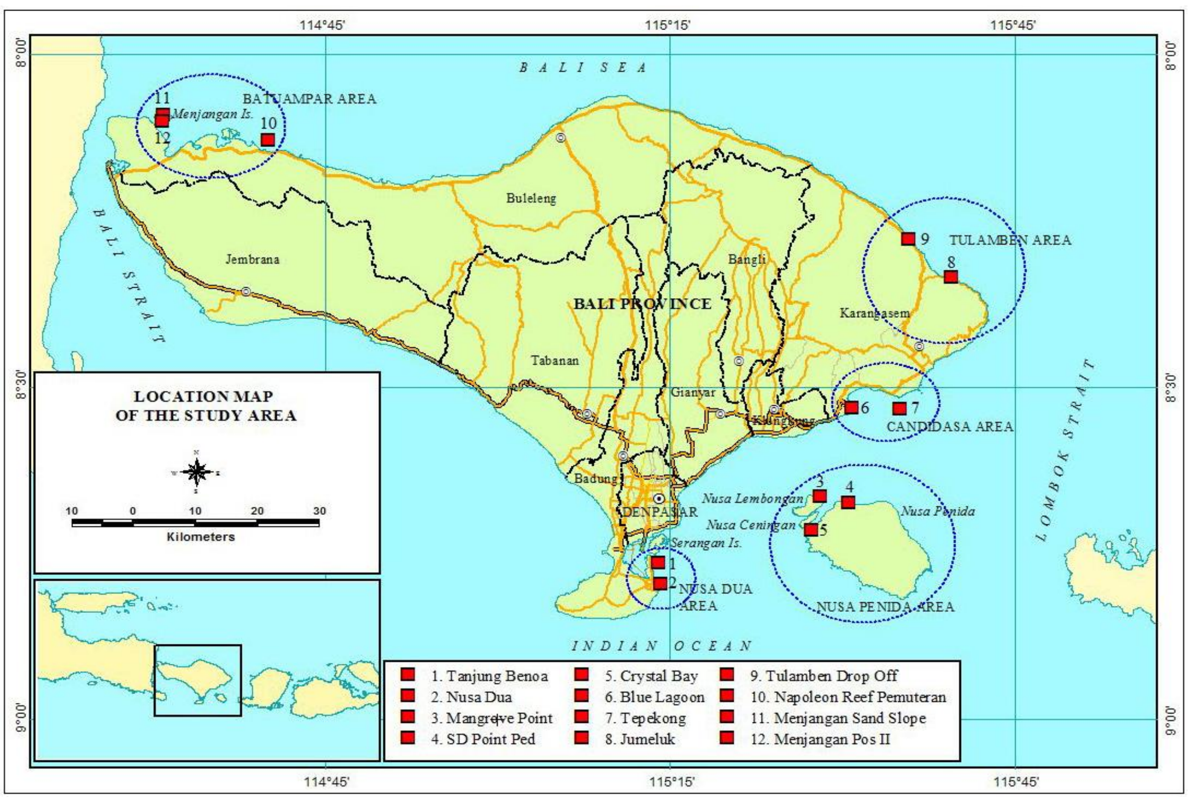

Figure 1. Map of the research location

Survey of tourists to find out the level of satisfaction of divers to diving services using the questionnaire survey method. A hundred and sixty divers are selected as the respondents through purposive technique. The measurement of respondents' satisfaction on the services provided by dive operators and destination management authorities uses a model developed by Martilla and James (1977) and adopted from the research of Bindu and Kanagaraj (2013). Service attributes are measured by the ordinal scale. The format of respondents' responses to satisfaction using a 5-point Likert scale (1-5), where: 1=not at all satisfied; 2=slightly satisfied; 3=satisfied; 4=very satisfied; and 5=very satisfied.

The carrying capacity assessment of dive site in this study used the protected areas carrying capacity model developed by Cifuentes (1992), similar to the study by Gallo et al. (2001) and Rios-Jara et al. (2013) with modification or adjustment of several correction factors. The dive sites carrying capacity assessed includes three levels as follows:

1. Physical carrying capacity (PCC): the maximum number of divers that can physically fit into a dive site over a particular time. The variables needed for PCC assessment are the available areas for diving, areas used by a diver in one dive and the number of rotations or repetitions of the dive in a day. The formula calculates PCC as follows:

PCC = (S/SP) x Nv

Where PCC = physical carrying capacity; S = the total available surface in linear meters; SP = the surface used by each diver in one dive; and Nv = rotation factor or the number of times that the dive could be repeated per day. Nv is calculated by the formula: NV = Hv/Tv

Where Hv = length of time of diving activities that can be done in a dive site in a day; and Tv = length of time used by a diver in one dive.

2. Real carrying capacity (RCC): the maximum permissible number of divers to the specific site by considering the reducing factors of the PCC of the dive site. The reducing factors of PCC are also called correction factors. Variables as correction factors in calculating the RCC of dive sites in this study include social correction factor, coral fragility, coral mortality, and extreme wave. The formula for calculating RCC as follows:

RCC = PCC x CFsoc x CFfrag x CFmort x CFwave

Where PCC = physical carrying capacity; RCC = real carrying capacity; CFsoc = social correction factor; CFfrag = coral fragility correction factor; CFmort = coral mortality correction factor; and CFwave = extreme wave correction factor.

The formula for calculating the correction factors: $CF_x = 1 - (Ml_x/Mt_x)$

Where CF_x = correction factor of variable x; Ml_x = the limiting magnitude of variable x; and Mt_x = total magnitude of variable x.

a) Social correction factor (CFsoc). The social correction factor is intended to guarantee the quality of diving from safety and security risks and conflicts between groups of divers in the same space. To calculate CFsoc, the limiting magnitude (Lm) is calculated, which is the limit of occupancy resulting from the distance between diver groups, as follows:

Lm = S – (P x Ng)

Where S = the distance between groups, P = the number of divers in a group, and Ng = the number of diver groups per diving pathway in one rotation of diving.

CFsoc is calculated by formula: CFsoc = 1 – (Lm/L), where L = the length of available diving pathway.

b) Coral fragility correction factor (CFfrag). Fragile corals are kinds of coral lifeforms that are sensitive to mechanical damage due to diver's touch or due to the anchorage. The coral fragility correction factor is considered because kinds of fragile corals are very susceptible to damage if contact with divers. The coral fragility correction factor is calculated by the formula: CFfrag = 1 – (Cfrag/100%), where Cfrag = percentage of fragile coral cover in a dive site.

c) Coral mortality correction factor (CFmort). This correction factor is considered because the intensity and density of divers influenced the mortality rate of corals. Diving tourism activities, directly and indirectly, contribute to coral damage. The coral mortality correction factor is calculated by the formula: CFmort = 1 – (Cmort/1), where Cmort = coral mortality index in a dive site.

d) Extreme wave correction factor (CFwave). Extreme wave correction factor considers the effect of wave action which makes difficult access to certain dive sites or diving activities temporarily cannot occur in certain dive sites. Extreme wave correction factor is calculated formula: CFwave = 1 – (Cwave/365), where Cwave = the number of days of extreme wave events in each dive site in a year.

3. Effective carrying capacity (ECC): the maximum number of divers that a site can sustain, given the management capacity (MC) available. Management capacity in the study used the divers' satisfaction approach to service quality provided by dive operators and destination management authorities obtained from divers' satisfaction surveys. The formula for calculating ECC as follows: ECC = RCC x MC.

Where RCC = real carrying capacity; and MC = management capacity. Management capacity is calculated by formula: MC = (Csat/Csatmax), where Csat = mean score of divers satisfaction in measurement scale; Csatmax = the theoretical maximum score of satisfaction in measurement scale.

RESULTS

The coral reefs communities at dive sites and diving intensity

The benthic communities of coral reefs are characterized by using a category of lifeforms that gives a morphological description of the reef communities. The coral reef communities in the dive sites can be divided into three categories.

First, the community has moderately to the high cover of living hard and soft corals and is characterized by the dominance of acroporids (*Acropora* and *Montipora*), poritids and pocilloporids. This community is found in the Tanjung Benoa, Nusa Dua, and Blue Lagoon.

Second, the community with strong current flow, high water clarity, high to the very high cover of living hard and soft coral, and is characterized by the dominance of tabular and branching *Acropora*, foliose *Montipora*, mussids, and merulinids. This community is found in Mangrove Point, SD Point Ped, Crystal Bay, and Tepekong.

Third, the community found in the Jemeluk, Tulamben, Napoleon Reef Pemuteran, Menjangan Sand Slope and Menjangan Pos II, particularly characterized by warm water temperature, good water clarity, relatively steep slopes and moderately to a high cover of living hard corals. This particular community is dominated by massive corals including agariciids and faviids. Tabular and branching *Acropora* and foliose *Montipora* are also common.

Living coral cover according to the dive sites ranged between 30.20 and 92.02% (Table 1). Using the categories Gomez and Yap (1988), it is known that the coral reefs at the dive sites are in a "moderate" to "excellent" condition. "Moderate" conditions (living coral cover 25 - 49.9%) are found in the Blue Lagoon, Jemeluk, Tulamben Drop Off, Napoleon Reef Pemuteran, and Menjangan Pos II. A "good" conditions (living coral cover 50 - 74.9%) are located in Tanjung Benoa, Nusa Dua, SD Point Ped, and Tepekong. Meanwhile, coral reefs in "excellent" conditions (living coral cover ≥75%) are found in Mangrove Point and Menjangan Sand Slope.

The dead coral cover according to dive sites ranged between 2.00 and 13.60%. Overall, coral mortality rates are relatively low, however, there are three locations with relatively high dead coral cover (>10%), namely Crystal Bay, Jemeluk and Tulamben Drop Off. From the live coral cover and dead coral cover, the coral mortality index at each dive site can be calculated, ranging between 0.02 and 0.29 (Table 1).

Table 1. Live coral cover, index mortality, and composition of coral fragile at the dive sites

No	Dive sites	Live coral cover (%)	Dead coral cover (%)	Fragile coral cover (%)	Coral mortality index	Composition of coral fragile (%)
1	Tanjung Benoa	51.08	3.60	24,94	0.07	48,83
2	Nusa Dua	66.24	4.40	39,02	0.06	58,91
3	Mangrove Point	92.02	7.00	63,18	0.07	68,66
4	SD Point Ped	59.80	4.04	32,54	0,05	54,41
5	Crystal Bay	64.28	12.62	22,54	0.16	35,07
6	Blue Lagoon	36.08	6.90	16,46	0.16	45,62
7	Tepekong	71.24	3.02	18,30	0.04	25,69
8	Jemeluk	30.20	12.4	12,10	0.29	40,07
9	Tulamben Drop Off	49.40	13.60	18,90	0.22	38,26
10	Napoleon Reef Pemuteran	34.00	5.46	6,68	0.14	19,65
11	Menjangan Sand slope	82.00	2.00	34,00	0.02	41,46
12	Menjangan Pos II	41.00	8.00	8,00	0.16	19,51

Composition of fragile corals according to the dive sites ranged between 19.65 and 68.66% which are identified from all lifeforms of *Acropora*, *Heliopora*, *Millepora*, coral branching, and coral foliose. Coral reefs in Nusa Dua, Mangrove Point, and SD Point Ped are dominated by fragile lifeforms with a portion of more than 50% of total live coral cover (see Table 1). These coral lifeforms are easily broken or fragmented by mechanical disturbances such as storm waves, touched anchors or other objects, and contact with divers or trampled by divers.

Recreation scuba diving is the dominant activity utilizing coral reef resources in Bali. The intensity of dives varies according to the popularity of a dive site and the season of tourist visits to Bali. In the low season (October - May), the intensity of diving in 2015-2017 ranges from 15 to 150 divers/site/day while in high season (June - September) ranges from 25 to 300 divers/site/day. The four dive sites that received the most number of visitors were Tulamben Drop Off, Crystal Bay, Mangrove Point, and SD Point Ped (Table 2).

Table 2. The number of visitors to the dive sites

No	Dive sites	Number of visitors (divers/day)	
		Low season	High season
1	Tanjung Benoa	65	75
2	Nusa Dua	20	35
3	Mangrove Point	120	175
4	SD Point Ped	80	110
5	Crystal Bay	150	280
6	Blue Lagoon	32	48
7	Tepekong	18	30
8	Jemeluk	70	90
9	Tulamben Drop Off	150	300
10	Napoleon Reef Pemuteran	25	40
11	Menjangan Sand slope	30	50
12	Menjangan Pos II	15	25
	Average	65	105

The physical carrying capacity of dive site

The length of the diving pathway (L) according to dive sites ranges from 300 to 600 m, commonly 300 and 400 m. Determination of the surface area used by each diver is calculated based on the maximum human physical length of 2 meters, and, according to international diving regulations, it is assumed that diving is done in pairs. It is also assumed that to dive in rows, the pair members will be separated from each other by about 2 m, so that a diver each pair will occupy an average of 4 m (SP = 4 m).

The number of repetitions of dives in one day that can be done at a dive site is calculated based on the length of time of diving that can be done at a dive site in one day and the length of time needed by a diver for one dive. Diving activity is assumed only during the daylight for safety reasons. Base on the above assumptions, the duration of diving that can be done in one day at dive sites ranges from 9 hours (540 minutes) to 10 hours (600 minutes) depending on the accessibility of dive sites. Jemeluk and Tulamben Drop Off can be dived for 10 hours because diving in these sites can be done through beach searching while diving in other sites is 9 hours due to accessibility factors.

The limiting factor for the duration of one dive is the time available to consume the air supply in an air tank where 40 minutes is the estimated duration of the air tank used by amateur divers at a depth of 10 to 20 m. The total length of time for one dive is added to the time descent and rise of diver groups from and to the boat, as well as the time required by the guide to give instructions before starting the dive and the time required by a diver to adjust him/herself before coming to the surface (safety stop). Overall, the total duration for one dive is 60 minutes. Based on duration of dives that can be done at dive sites and length of time needed for one dive by divers, the number of repetitions of diving according to dive sites ranges from 9 to 10 times/day.

Based on the length of the dive pathway (S), the surface area used by each diver (SP) and the number of diving repetitions in a day (Nv), the PCC according to the dive sites range between 675 and 1,350 divers/site/day or 246,375 and 492,750 divers/site/year (Table 3). The amount of PCC of the dive site is influenced by the length of the dive pathway and durations of diving that can be done in a day.

Table 3. The physical carrying capacity of the dive sites

No	Dive sites	S	SP	Hv	Tv	Nv	PCC divers/day	PCC divers/year
1	Tanjung Benoa	300	4	540	60	9	675	246,375
2	Nusa Dua	300	4	540	60	9	675	246,375
3	Mangrove Point	600	4	540	60	9	1,350	492,750
4	SD Point Ped	400	4	540	60	9	900	328,500
5	Crystal Bay	300	4	540	60	9	675	246,375
6	Blue Lagoon	300	4	540	60	9	675	246,375
7	Tepekong	300	4	540	60	9	675	246,375
8	Jemeluk	400	4	600	60	10	1,000	365,000
9	Tulamben Drop Off	400	4	600	60	10	1,000	365,000
10	Napoleon Reef Pemuteran	300	4	540	60	9	675	246,375
11	Menjangan Sand slope	400	4	540	60	9	900	328,500
12	Menjangan Pos II	300	4	540	60	9	675	246,375
	Average						823	300,365

S = the length of the dive pathway (meter); SP = the surface used by each diver (meter); Hv = the duration of diving in a day (minute); Tv = the length of time needed for one dive (minute); Nv = the number of diving repetitions in a day; PCC = Physical Carrying Capacity

The real carrying capacity of dive site

Social correction factor (CFsoc)

In recreational diving activities, divers are organized in a solid group under a dive guide to keep secure and safe of dive, make it easier for a guide to monitor and control diver's behavior, and to prevent the impact of divers on the environment. According to the rules or standards of the Professional Association of Diving Instructors (PADI), each group consists of a maximum of nine divers (eight tourists and one guide). However, to make it easier to monitor and control diver's behavior by a dive guide, this study uses a 4:1 ratio or the maximum number of divers in one group (P) is five divers (four tourists and one guide). To prevent the buildup of boats at the entry point and meetings or mixing of one group with other groups on the seafloor, the interval of dives between groups is arranged assuming 30 minutes. With an interval of 30 minutes, the distance between groups on the dive pathway (S) is 0.6% of the length of the dive pathway and the number of groups in each dive pathway in one dive rotation (Ng) is 2 groups with the number of divers in one group (P) is 5 divers.

Based on the above assumptions, the CFsoc can be calculated in each dive site as shown in Table 4. The CFsoc value is influenced by the length of the diving pathway because it will affect the limits of underwater occupancy where the length of the diving pathway will be directly proportional to the occupancy limit value. The longer the dive pathway, the higher the occupancy limit and finally the CFsoc value gets smaller, and vice versa.

Table 4. Social correction factor according to the dive sites

No	Dive sites	L	S	P	Ng	Lm	CFsoc
1	Tanjung Benoa	300	180	5	2	170	0.433
2	Nusa Dua	300	180	5	2	170	0.433
3	Mangrove Point	600	360	5	2	350	0.417
4	SD Point Ped	400	240	5	2	230	0.425
5	Crystal Bay	300	180	5	2	170	0.433
6	Blue Lagoon	300	180	5	2	170	0.433
7	Tepekong	300	180	5	2	170	0.433
8	Jemeluk	400	240	5	2	230	0.425
9	Tulamben Drop Off	400	240	5	2	230	0.425
10	Napoleon Reef Pemuteran	300	180	5	2	170	0.433
11	Menjangan Sand slope	400	240	5	2	230	0.425
12	Menjangan Pos II	300	180	5	2	170	0.433

L = the length of the dive pathway (meter); S =the distance between diver groups (meter); P = the number of divers in one group (standard); Ng = the number of diver groups in one dive rotation; Lm = the limits of underwater occupancy; CFsoc = Social correction factor.

Coral fragility correction factor (CFfrag)

Based on the fragile corals composition in Table 1, the coral fragility correction factor (CFfrag) can be calculated for each dive site as shown in Table 5. The CFfrag according to dive sites ranged between 0.313 and 0.805. The higher the fragile corals cover, the lower the CFfrag.

Coral mortality correction factor (CFmort)

Based on the coral mortality index in Table 1, the coral mortality correction factor (CFmort) can be calculated for each dive site as shown in Table 5. The CFmort according to dive sites ranged between 0.709 and 0.976. The higher the coral mortality index, the lower the CFmort.

Table 5. Coral fragility correction factor and coral mortality correction factor according to the dive sites

No	Dive sites	CFfrag	CFmort
1	Tanjung Benoa	0.512	0.934
2	Nusa Dua	0.411	0.938
3	Mangrove Point	0.313	0.929
4	SD Point Ped	0.456	0.952
5	Crystal Bay	0.649	0.836
6	Blue Lagoon	0.544	0.839
7	Tepekong	0.743	0.959
8	Jemeluk	0.599	0.709
9	Tulamben Drop Off	0.617	0.784
10	Napoleon Reef Pemuteran	0.804	0.862
11	Menjangan Sand slope	0.585	0.976
12	Menjangan Pos II	0.805	0.837

CFfrag = coral fragility correction factor; CFmort = coral mortality correction factor.

Extreme wave correction factor (CFwave)

The coastal waters of Bali Province are normally not affected by the occurrence of extreme wave action routinely every year so diving activities can take place throughout the year. Thus the extreme wave correction factor for all dive sites is 1.00.

Real carrying capacity values

Based on the correction factors values, it can be estimated the RCC of the dive sites as shown in Table 6. The RCC values ranged between 113 divers/site/day or 41.245 divers/site/year and 218 divers/site/day or 79,570 divers/site/year, the highest value is in Menjangan Sand Slope and the lowest in Nusa Dua. The average of RCC of the 12 dive sites in Bali is 174 divers/site/day or 63.480 divers/site/year. The RCC value shows the maximum number of divers who can be accommodated in a dive site at a certain time by considering the "crowding effect", biophysical of coral reefs and accessibility of dives.

Table 6. Real carrying capacity according to the dive sites

No	Dive sites	PCC	CFsoc	CFfrag	CFmort	CFwave	RCC divers/day	RCC divers/year
1	Tanjung Benoa	675	0.433	0.512	0.934	1	140	51,100
2	Nusa Dua	675	0.433	0.411	0.938	1	113	41,245
3	Mangrove Point	1,350	0.417	0.313	0.929	1	164	59,860
4	SD Point Ped	900	0.425	0.456	0.952	1	166	60,590
5	Crystal Bay	675	0.433	0.649	0.836	1	159	58,035
6	Blue Lagoon	675	0.433	0.544	0.839	1	133	48,545
7	Tepekong	675	0.433	0.743	0.959	1	208	75,920
8	Jemeluk	1,000	0.425	0.599	0.709	1	180	65,700
9	Tulamben Drop Off	1,000	0.425	0.617	0.784	1	206	75,190
10	Napoleon Reef Pemuteran	675	0.433	0.804	0.862	1	203	74,095
11	Menjangan Sand slope	900	0.425	0.585	0.976	1	218	79,570
12	Menjangan Pos II	675	0.433	0.805	0.837	1	197	71,905
	Average	823					174	63,480

PCC = Physical Carrying Capacity; CFsoc = Social correction factor; CFfrag = Coral fragility correction factor; CFmort = Coral mortality correction factor; RCC = Real Carrying Capacity.

The effective carrying capacity of dive site

Management capacity, besides affecting the level of satisfaction of divers, also affects the level of impact of tourists activities on the environment. Management capacity in this study was assessed based on the satisfaction of divers to the service attributes provided by destination authorities and dive operators. These attributes include dive equipment settings, comfort onboard, costs, the professionalism of human resources, safety measures, dive briefing, the accuracy of customer service, infrastructures/facilities of destination, the security of destinations, implementation of an environmentally friendly diving management, and information about the destination.

The average score of satisfaction of divers to service attributes as a measure of management capacity ranges from 3.19 to 3.95 with the total average being 3.58 (Table 7). Based on the total average satisfaction score of divers to the services, a correction factor of the management capacity of 0.716 was obtained. Thus the ECC value of the dive sites as shown in Table 8. The ECC value of dive sites in Bali ranges between 81 divers/site/day or 29,565 divers/site/year and 156 divers/site/day or 56,940 divers/site/year with an average value of 124 divers/site/day or 45,412 divers/site/year.

Table 7. Average of divers satisfaction score to the attributes of management capacity

No	Attributes of management capacity	N	Average satisfaction score of divers*)
1	Dive equipment settings	236	3,95
3	Professionalism of crew	236	3,87
4	Professionalism of divemaster	236	3,81
5	Safety measures	236	3,72
6	Pre-dive briefing	236	3,70
7	Destination infrastructures/facilities	236	3,51
8	Security of destination	236	3,44
9	Implementation of an environmentally friendly diving standard	236	3,21
10	Information about destination	236	3,19
	Average		3.58

N = number of respondents (divers)

*) satisfaction level is measured by a Likert-5 scale, 1-5: the higher the scale the higher the level of satisfaction.

Table 8. Effective carrying capacity according to the dive sites

No	Dive sites	RCC	MC	ECC divers/day	ECC divers/year
1	Tanjung Benoa	140	0.716	100	36,500
2	Nusa Dua	113	0.716	81	29,565
3	Mangrove Point	164	0.716	117	42,705
4	SD Point Ped	166	0.716	119	43,435
5	Crystal Bay	159	0.716	114	41,610
6	Blue Lagoon	133	0.716	95	34,675
7	Tepekong	208	0.716	149	54,385
8	Jemeluk	180	0.716	129	47,085
9	Tulamben Drop Off	206	0.716	147	53,655
10	Napoleon Reef Pemuteran	203	0.716	145	52,925
11	Menjangan Sand slope	218	0.716	156	56,940
12	Menjangan Pos II	197	0.716	141	51,465
	Average	174		124	45,412

RCC = real carrying capacity (divers/site/day); MC = management capacity; ECC = effective carrying capacity

DISCUSSION

The main approach of this study is to estimate the carrying capacity of coral reefs for diving tourism using a holistic methodology based on the physical, biological characteristics and management capacity of the dive sites. According to Sayan and Atik (2013), the logic of the method is based on site-specific factors that reduce the level and quality of visitation and which are considered as the limitations of the area.

The PCC value for 12 dive sites in Bali was calculated ranged between 675 and 1,350 divers/site/day, meaning that the maximum number of divers who are allowed to enter a dive site should never exceed this range. Physically, the longer the surface area available for diving, the higher the PCC value. The rotation factor is an important indicator that affects the PCC value in addition to the length of the dive pathway. Therefore, setting the frequency of dives that are possible to do at a site in a day can be used as a starting point for the management strategy of diving tourism through the application of the carrying capacity to limit the number of divers.

The numbers of the PCC are only theoretical can visit a site per day. It is practically impossible to admit this number of divers in a site per day. The PCC only provides a base level to calculate the following level of carrying capacity (Bera et al., 2015; Sayan and Atik, 2011). In this study, the PCC value is worn to estimate the RCC value of a dive site constrained by several correction factors. Methodologically, the value of the RCC will be determined by the number of correction factors used according to the purpose of managing diving destinations safely, satisfying divers and being environmentally friendly. In accordance with the Cifuentes methodology framework, the correction factors in the RCC assessment in this study involved four variables, namely the comfort of divers and ease of organizing diving groups in the underwater through regulating occupancy limits, the possible impact on coral reef damage represented by composition of fragile corals, the rate of recovery of coral health from damage represented by coral mortality, and diving access represented by extreme wave conditions.

With these correction factors, the RCC value decreased to an average of 174 divers/site/day from 823 divers/site/day. The social correction factors cause the most reduction of the PCC. This means that the occupancy limits setting to achieve greater satisfaction during diving and to enable diver's behavior control to prevent the impact on the environment have a profound effect on the RCC value of the dive site. This is in line with the objective of diving destinations management through regulating carrying capacity to overcome the problem of excessive diver density in popular dive sites which can have implications for the decline in the quality of experience and damage to coral reefs caused by direct divers contact.

By involving management capacity variables, both provided by destination authorities and dive operators, the effective or permissible carrying capacity of the dive sites decreased to an average of 124 divers/site/day. The estimated carrying capacity has decreased by an average of 28.74% from the RCC value as a result of management capacity provided by destination authorities and dive operators who have not provided maximum levels of diving satisfaction. The disadvantages are mainly in the attributes of infrastructures/facilities, security measures, implementation of environmentally friendly diving, and information about the destination.

The results demonstrate that three dive sites have received visitors that exceed the ECC both during low season and high season, namely Mangrove Point, Crystal Bay, and Tulamben Drop Off. These dive sites face a high risk of long-term environmental damage if there are no interventions to limit the number of visitors. Besides limiting the number of divers as a management tool for sustainable of coral reefs use, it is important to distribute the number of divers to dive sites whose actual number of visitors is lower than the estimated carrying capacity to reduce environmental pressure on dive sites that exceed capacity. Furthermore, destination management authorities need to develop new dive sites to accommodate the number of divers who tend to increase visiting Bali. There are still many coral reef areas that have the potential to be promoted as dive sites with unique characteristics.

The use of the Cifuentes methodology for the assessment of the carrying capacity of diving tourism is still limited (e.g., Gallo et al., 2002; Sausa-Melo et al., 2006; Reyes-Bonilla et al., 2012; Rios-Jara et al., 2013). The values of tourism carrying capacity obtained from the previous studies were very varied, ranging from 3-4 diver/site/day (Rios-Jara et al., 2013) to 41-79 divers/site/day (Reyes-Bonilla et al., 2012). In the end, the carrying capacity of the dive site using the Cifuentes method depends on the biophysical and ecological characteristics of an area and the managerial factors considered. The assessment of the carrying capacity of dive sites from previous studies were mostly constructed based on the relationship between diving intensity (number of divers) and the level of coral damage (e.g., Dixon et al., 1993; Hawkins and Robert, 1997; Zakai and Chadwick-Furman, 2002; Schleyer and Tomalin, 2000; Zhang et al., 2016). The ecological carrying capacity of the dive sites obtained from these studies ranged from 3,900 - 7,000 divers/site/year.

CONCLUSION

The methodology of Cifuentes provides a perspective on the importance of characteristics of coral reef community structures and management capacity in influencing the capacity of dive sites to accommodate the number of divers that are ecologically acceptable and provide a satisfactory quality of tourism experience. The amount of carrying capacity of a dive site is very closely related to the limits of underwater occupancy and characteristic of coral reef communities, thus its application is site-specific, cannot be generalized for other locations.

From a managerial perspective, the carrying capacity of dive sites is not static, the amount depends on the management capacity factor. Theoretically, the carrying capacity of dive sites can be increased through increased management capacity, both structurally (by destination authority) and non-structural (by dive operators). Good destination governance and standardized service quality are not only important in the context of carrying capacity and controlling environmental impacts caused by diving activities but can also increase long-term competitiveness. Therefore, to realize the competitive and sustainable of diving tourism destinations through the application of the concept of carrying capacity, synergic and effective cooperation is needed among stakeholders.

LIMITATIONS OF THE STUDY

The limitations of our study are as follow:

1. The assessment of dive's carrying capacity did not involve technical diving at certain location such as at the shipwreck location and muck dive sites;
2. The death or damages to corals at the dive site is assumed directly and/or indirectly by diving activities; and
3. The correction factor for management capacity is measured solely based on the satisfaction of divers.

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