Ecologically benign parameters: setting Bangka Island, East Likupang for a nature ecotourism destination

Christin R. M. Malinggas[1,2*], *Anik M.* Hariati[3], *Luchman* Hakim[4], *Dewa Gede Raka* Wiadnya[5], and *Riski Agung* Lestariadi[6]

[1]Post Graduate Programme of Fisheries and Marine Science, Universitas Brawijaya Malang, Indonesia
[2]Department of Research and Development of North Sulawesi Province, Indonesia
[3]Department of Aquaculture, Faculty of Fisheries and Marine Science, Universitas Brawijaya Malang, Indonesia
[4]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya Malang, Indonesia
[5]Department of Fisheries and Marine Resources Utilization, Faculty of Fisheries and Marine Science, Universitas Brawijaya Malang, Indonesia
[6]Department of Fisheries Agrobusiness, Faculty of Fisheries and Marine Science, Universitas Brawijaya Malang, Indonesia

Abstract. Likupang was established as a new super-priority tourism destination through the ministerial regulation of Indonesia. This study aims to analyze the tourism benign performance of Bangka Island, a small island targeted as the main underwater attraction within Likupang. Six dive sites were selected from 21 sites available for dive tourism. Tourism Sustainability Index (SI) was estimated based on eight attributes: coral health, coral life-forms, number of fish species, fish diversity index, fish dominance index, water current, water visibility, and water depth. Coral health and life-forms were measured using a point intercept transect of 50 m with three replicates. Fish diversity was measured based on a line-imagery transect of 50 × 10 m^2 with three repetitions, and species richness was based on total species count. Fish diversity index was calculated based on the presence of each species at each sampling site. Analysis resulted in an average life-coral cover of 37.7±5.7 %, indicating *moderate* health status. There were 227 fish species found in all dive sites, with a high diversity index of 3.28, and a low dominance index of 0.07. With water depths range between 4-10 m, coral reefs were visible from the surface. These all attributes resulted a sustainability index of 32.4, categorized as *almost sustainable*. Fish diversity is considered to be the most sensitive attribute affecting the sustainability of a destination. As tourism creates more jobs, local tourism management may involve local fishermen. This new compensation may reduce fish and coral reef extraction.

* Corresponding author: malinggas_ch78@student.ub.ac.id; dgr_wiadnya@ub.ac.id

1 Introduction, local tourism management

In recent decades, the tourism sector has become one of the driving sectors of a country's economic growth, affecting the global economy [1]. Based on data from World Travel and Tourism [2], the growth of the Gross Domestic Product (GDP) of the tourism sector globally exceeded economic growth from 2011 to 2018. In Indonesia, the tourism sector is one of the largest contributors to foreign exchange after oil and gas [3]. To develop tourism in Indonesia, Government Regulation Number 50 of 2011 was issued, concerning the National Tourism Development Master Plan 2010-2025. The regulation includes ten priority tourism destinations to be developed, and Likupang is one of the priority tourism destinations in North Sulawesi. More specifically, Likupang is also part of five super priority tourism destinations according to the Ministry of Tourism and Creative Economy (MTCE) (National Plan of Action). White sand beaches, panoramic views, coral gardens, and cultural heritage sites are the main attractions of Likupang [4]. The most attractive site, yet less explored, is Bangka Island within Likuang. It has at least 21 spectacular dive sites on its island.

As a super priority tourism development, Likupang, including Bangka Island, is predicted to receive a tremendous increase in tourism arrivals due to progressive promotion and a diversion from the already overcrowded visit of Bunaken National Park, a nearby area [5]. Consequently, Likupang may ultimately turn into mass tourism, a negative risk that should be prevented. The marine waters of Bangka Island have been recently declared as a Marine Protected Area (Ministerial Regulation of Marine Affairs and Fisheries, MMAF, No. 128/2023). Tourism arrivals to Bangka Island will soon be regulated to ensure the sustainable use of natural resources within and surrounding protected areas.

Bangka Island covers a total land area of approximately 4,788 ha and is inhabited by 2,749 local populations. Eight resorts were present to support underwater tourism, each with a dive center, a dive instructor, and some local dive guides. The Island is surrounded by 1,062 ha of coral reef ecosystems, which are attractive for tourism. This study aims to analyze coral health, fish diversity, and other attributes that determine tourism sustainability. This information is important for determining management strategies that are in line with sustainable tourism principles.

2 Material and Methods

2.1 Research Location and Data Collection

This study was conducted between April and December of 2023. Six dive sites were selected from 21 dive sites currently available for tourism; two dive sites were located inside the marine protected area (ST4 and ST5), and four of the remaining sites were selected randomly from 19 dive sites (Figure 1). The selection was based on the fact that only 20 % of coral reefs located inside the protected area.

The supporting policy documents were based on Government Regulation No. 50/2011, Ministerial Regulation of MTCE No. 11/2022, and MMAF No. 128/2023. Tourism amenities were investigated through resorts and local accommodations on the island. Coral reef examination uses the point intercept transect (PIT) method [6], and fish diversity through underwater visual censuses [7]. These were completed by two experienced dive instructors (MSDT-424341 and PRO-SSI-80816) who were certified in coral reef and fish examinations.

2.2 Parameters and attributes

Coral reef examinations were conducted using coral-life forms and detailed forms of Hard Coral Life. A line transects of 50 m was deployed at each dive site parallel to the coastline, with three repetitions (total transect line of 150 m). A total of 12 coral life-form categories were identified in every 50 cm of point in the transect line: Hard Coral Life (HCL), Soft Coral (SC), Others (OT), Sponge (SP), Zoanthids (ZO), Rubble (R), Sand (S), Rock (RC), Dead Coral (DC), Dead Coral with algae (DCA), Halimeda (HA), and Turf Algae (TA) [8]. This summarized a total of 300 life-form data points within the site. Hard Coral Life (HCL) was further separated into 10 categories: Acropora Branching (ACB), Acropora Submassive (ACS), Acropora Tabulate (ACT), Acropora Digitate (ACD), Coral Branching (CB), Coral Massive (CM), Coral Submassive (CS), Coral Encrusting (CE), Coral Mushroom (CMR), and Coral Heliophore (CHL) [9]. All parameters were examined via scuba diving following the transect line. Each life form was recorded using a special form attached to a slate.

Fish diversity was based on species identification within the transect line with an additional imagery transect of 5 m to the left and 5 m to the right of the transect line (total imagery area of 150 × 10 m^2) [7]. Species confirmation was performed by direct identification and video scanning of the transect line. Divers identified and recorded the species in the slate. The second diver video scanned all the fish along the transect line. The species name was determined following species correction from the scanned video.

Substrate depth (m) was measured using a dive watch (gauge) during coral examination by the divers. The data consisted of minimum and maximum depths along the transect line. The water current was measured using a Flowatch FL-03 current meter (cm sec^{-1}). The water visibility was measured using a Secchi Disk. This indicates transparency of coral reefs, which can be seen from surface water, when 100 % of visibility.

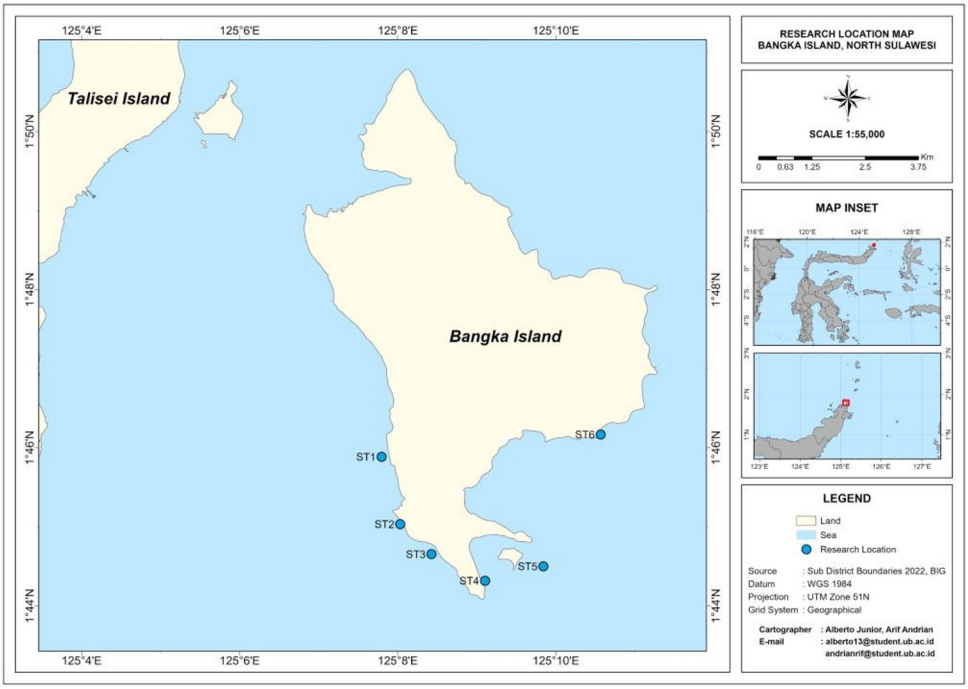

Fig. 1. Bangka Island and dive site locations selected for this research. ST1 = Linggua, ST2 = Coral Eye, ST3 = Busabora, ST6 = Areng Kambing, ST4 = Tanjung Husi, ST5 = Sahaung. ST4 and ST5 are dive sites located inside the protected area (Ministerial Decree of MMAF No. 128/2023).

2.3 Data Analysis

Coral health status was calculated based on the percentage ratio between total HCL divided by total life form in each 100 points of transect, using the following formula 1 [8]:

$$CH = \frac{\sum_{i=1}^{100} HCL}{\sum_{i=1}^{100} TLF} * 100\ \% \ldots\ldots\ldots\ldots (1)$$

where CH = Coral Health, HCL = Hard Coral Life, and TLF = total life form (100).

Coral Health (CH) is divided into four categories [10]: (1) CH < 25 % is categorized as bad, (2) CH < 50 % is Moderate, CH < 75 % is good, and (4) CH ≥ 75 % is excellent [10]. The Hard Coral Life Form was calculated based on the total number of HCL forms found within the 50 m transect. The categories are (Table 1): (1) life forms < 4, are categorized as bad; (2) life forms < 6, moderate; (3) life forms < 8, good; and life forms ≥ 8, as excellence.

The Fish Diversity Index (FDI) is calculated using Shannon and Weaver [11] based on the following formula 2:

$$H' = \sum_{i=1}^{s} - P_i \ln P_i \,; where\ P_i = \frac{n_i}{N} \ldots\ldots\ldots\ldots (2)$$

where H' is Fish Diversity Index, P_i is the probability of the presence of the i^{th} species, n_i is the number of i^{th} species, S is the number of species, and N is the total number of individual species.

The Fish Dominance Index (FDoI) describes the extent to which a species dominates the community. The formula to calculate the FDoI value uses Simpson [11] based on the following equation 3.

$$FDoI = \sum_{i=1}^{n} p_i^2 = \sum_{i=1}^{n} \left(\frac{n_i}{N}\right)^2 \ldots\ldots\ldots\ldots (3)$$

where FDoI = Dominance Index, P_i is the probability of the presence of the i^{th} species, n_i is the number of i^{th} species, and N is the total individual number of all species. The total fish species were summed from all six sampled dive sites. This value was used to score the sustainability index, as shown in Table 1.

The sustainability status of the six dive sites on Bangka Island, Likupang, was analyzed using the Rapfish method with a Multi-Dimensional Scaling (MDS) approach [12]. All the attribute criteria, scores, and indicators used to determine the categories are presented in Table 1.

Table 1. Criteria (ecological attributes), scores, indicators, and measures used to assess sustainability index of in Bangka Island for dive site

No	Attribute	Score	Indicator / Measure	References
1	Coral Health	1 - 4	Percent life-coral cover < 25 % = 1, bad < 50 % = 2, moderate < 75 % = 3, good ≥ 75%, = 4, excellence	[13]
2	Coral-life form	1 - 4	Number of life form < 4 life form = 1, bad < 6 life form = 2, moderate < 8 life form = 3, good ≥ 8 life form = 4, excellence	[14]
3	Fish Diversity Index (FDI)	1 - 4	FDI < 1, score = 1, is bad FDI < 2, score = 2, is moderate	[14]

No	Attribute	Score	Indicator / Measure	References
			FDI < 3, score = 3, is good FDI ≥ 3, score = 4, excellence	
4	Number of fish species	1 - 4	≤ 20 fish species = 1, bad < 50 fish species = 2, moderate ≤ 100 fish species = 3, good ≥ 100 fish species = 4, excellence	[14,15]
5	Fish Dominance Index (FDoI)	1 - 4	≤ 1 dominance index = 1, bad ≤ 0.7 dominance index = 2, moderate ≤ 0.5 dominance index = 3, good ≤ 0.3 dominance index = 4, excellence	[14]
6	Water Current (cm sec^{-1})	1 - 4	> 50 cm sec^{-1} = 1, bad > 30 cm sec^{-1} = 2, moderate > 15 cm sec^{-1} = 3, good ≤ 15 cm sec^{-1} = 4, excellence	[13]
7	Water visibility (%)	1 - 4	< 20 % = 1, bad < 50 % = 2, moderate < 80 % = 3, good ≥80 % = 4, excellence	[16]
8	Water depth (m)	1 - 4	≥ 30 m = 1, bad < 30 m = 2, moderate < 20 m = 3, good < 10 m = 4, excellence	[13]

The (SI) was calculated as the average value from all eight attributes. The field values from all eight attributes are fed into Table 1. It should match one of the following four categories: 1 (bad), 2 (moderate), 3 (good), or 4 (excellence). The score value of each attribute was calculated as the percentage ratio to the highest score value, which was 4. This value means sustainability index of a specific attribute. The Sustainability Index (SI) in this context is the average sustainability index for all eight attributes. The SI was divided into four categories, as presented in Table 2 [14].

Table 2. Range of Sustainability Index (SI) and meanings per category index

No	Sustainability Index (SI)	Category
1	0.0 – 25.0	not sustainable
2	26.0 – 50.0	almost sustainable
3	51.0 – 75.0	simply sustainable
4	76.0 – 100.0	very sustainable

The sustainability index for each attribute was then fed into the RapFish Excel WorkBook model [12]. Through RapFish modeling, leverage analysis can be performed to identify sensitive attributes that can increase or decrease the sustainability index. The leverage value was calculated as the percentage of the Root Mean Square (RMS) of each attribute. The Leverage values would vary between 0 – 10. The higher the RMS value, the more sensitive the attribute that affects the sustainability index.

3 Results and Discussion

Bangka is an island with a total land area of approximately 4,788 ha. The island is inhabited by 2,749 a population. The coastal area is surrounded by coral gardens and seagrass beds. The clear water, diverse fish species, and beach panorama all provided visitor satisfaction with a unique experience. As tourism grows, eight resorts are equipped with rooms and villas. Each resort anchors a speed boat to pick reserved visitors from Likupang and accompany dives or snorkeling within 21 available dive sites. Back packers can use regular boats at low cost. The island is now included in the super-priority tourism destination part of Likupang (MTCE Regulation No. 11/2022). The increase in tourism visits is mainly due to progressive promotion from the local government and overflow visitors from Bunaken National Park, which is already overcrowded. On the other hand, part of the coastal marine area has been declared a marine protected area (MMAF Regulation No. 128/2023). To maintain the sustainability of Bangka Island as a tourist destination, visitors must be regulated.

3.1 Coral Health

Data on the percentage coral coverage and other physical parameters are presented in Table 3. Line transects were deployed at 4-10 m water depth. Almost all the coral reefs can be seen in the surface water (visibility of 100 %).

The highest coral cover was found at Linggua dive site (56.7±5.5 %). This was significantly higher than the coral cover at Tanjung Husi and Sahaung (Figure 1), both of which are located inside the protected area (Table 3). The establishment of the area as a marine protected area may increase coral cover in the future. The lowest coral cover was found at Site6, Areng Kambing (Figure 1), categorized as *Bad* (Ministerial Decree of Environment No. 4/2001). Most coral cover was categorized as *Moderate* (37.7 %) (Table 3). The average percentage of coral cover at 6 dive sites on Bangka Island was higher than the percentage of coral cover in Bunaken National Park (32.9 %) [17].

Most coral reefs in Indonesia are threatened by destructive overfishing activities [18]. The community on Bangka Island is mainly dependent on marine resources, especially fish, as a source of food and livelihood [19]. Destructive fishing is the most effective and cheapest method to harvest fish. This is probably the reason for the bad and moderate life coral cover surrounding the island. The presence of eight resorts with dive centers may create new alternative jobs for locals. More frequent visits to dive sites may indicate the presence of management. This may prevent local fishermen from using destructive fishing equipment. Hence, more tourism activities within dive sites can increase coral coverage [20]. The coral cover surrounding the island that was investigated 10 years ago [21] was significantly lower than that found in this study.

Table 3. Hard coral coverage (%-HCL) together with coral life forms and other physical parameters measured at all the selected dive sites

Location	Depth (m)	Current (cm sec^{-1})	Water visibility (%)	Total Life Form	Hard Coral Coverage (%)	Coral Health categories
ST 1	5-7	20.69	100	8	56.7±5.5^{a}	good
ST 2	4-6	10.39	100	10	46.7±3.0^{ab}	moderate
ST 3	5-7	12.18	100	8	32.3±7.9^{b}	moderate
ST 4	5-7	13.89	100	9	34.3±1.9^{b}	moderate
ST 5	7-10	21.49	83	8	40.3±4.8^{b}	moderate
ST 6	5-7	13.58	100	8	16.0±1.5^{c}	bad

Remark: ST1, Linggua dive site, ST2 = Coral Eye, ST3 = Busabora, ST4 = Tanjung Husi, ST5 = Sahaung, ST6 = Areng Kambing

Ten categories of coral life forms were measured in this study. At least eight life forms were found at almost all dive sites. All ten life forms were found specifically at the Coral Eye (Table 3). This indicates good coral diversity within the area. Bangka Island is located at the heart of the coral triangle [22] within the Sulu Sulawesi Eco-Region [23]. This area is recognized as having the most diverse marine biodiversity. Specific to Bangka Island, a new sponge species (*Dercitus bangkae*) associated with mangroves was recently identified [24].

Coral life forms were distributed unevenly between and among dive sites (Table 4). Branching coral (CB), especially Acropora, together with massive coral (CM), were the most dominant in all dive sites. Acropora branching (ACB) can easily crack into rubble under strong currents [25]. The average current in the area was considered moderate (Table 3) and favorable for the growth of branching corals. However, Coral Massive (CM), which can survive in strong currents [26] also dominates the dive site. Acropora digitata (ACD) and mushroom coral (CMR) were rarely found at all dive sites. Mushroom corals are typical of solitary corals. However, its presence may never be dominant in the area. Generally, under favorable environmental conditions, every life form competes with each other, and there is an opportunity for every life form to dominate in the system.

Table 4. Distribution of coral life form (%) among dive sites

Dive Site	ACB	ACS	ACT	ACD	CB	CM	CS	CE	CMR	CHL
ST 1	5.9	26.5	2.9	0.0	29.4	25.9	2.9	5.3	1.2	0.0
ST2	23.6	8.6	1.4	2.1	15.7	17.9	7.1	5.0	1.4	17.1
ST 3	6.2	41.2	0.0	1.0	5.2	35.1	5.2	1.0	0.0	5.2
ST 4	12.6	21.4	3.9	1.9	20.4	24.3	0.0	11.7	1.0	2.9
ST 5	15.7	15.7	3.3	3.3	21.5	9.9	0.0	20.7	0.0	10.0
ST 6	50.0	2.1	6.3	2.1	16.7	18.8	0.0	2.1	2.1	0.0
Average	19.0[a]	19.3[a]	3.0[b]	1.7[b]	18.2[a]	22.0[a]	2.5[b]	7.6[b]	1.0[b]	5.9[b]
Error	16.5	13.9	2.2	1.1	8.0	8.6	3.7	7.4	0.8	6.7

3.2 Reef fish

Based on records from underwater visual censuses and confirmed with video scanning, 227 reef fish species were found in all dive sites. It consisted of 36 families. The family with the highest number of species was Pomacentridae (45 species), followed by Labridae (36 species) and Chaetodontidae (21 species). The total reef fish species in Indonesia may account for more than 500 species [27]. Indonesia has exported more than 600 ornamental reef fishes [28]. However, under a total dive coverage of approximately 9,000 m^2, this finding can be considered rich [29]. High coral diversity with colorful ornamental fish is the most attractive for underwater tourism, leading the area to become a favorite destination after Bunaken National Park.

Total reef fish species between dive sites varied between 88 - 124 species, and between 21 - 30 families (Table 5). The Fish Diversity Index was excellent (Table 2) for all sites. Most species belong to the family Pomacentridae, commonly called Damselfish and Clownfish. Both groups are very common in the aquarium trade for ornamental reef species [28]. Wrasses are a common name for the family Labridae. It is popular in aquarium trade fishes, mainly because of its abundance. In contrast, members of the family Chaetodontidae (butterfly fishes) are recognized for their unique and attractive body shape and behavior.

Species of the family Chaetodontidae are well-known as indicator species for coral health [30]. The more species found in an area, the healthier the reef [31].

Table 5. Diversity index, dominance index, total species count and total family of reef fishes in each dive site

Parameters	Dive Site					
	ST 1	ST 2	ST 3	ST 4	ST 5	ST 6
Diversity index	3.08	3.37	3.43	3.11	3.06	3.65
Dominance index	0.08	0.07	0.07	0.09	0.09	0.04
Total species	88	124	120	92	93	97
Total family	21	30	24	22	26	22

The diversity index at each dive site ranged from 3.06 to 3.65, with an average value of 3.28, and the dominance index ranged from 0.04 to 0.09, with an average of 0.07 (Table 5). The ecological index analysis indicated that the coral reef fish diversity level on Bangka Island, Likupang, is high, with an uneven distribution of individuals among species, resulting in a stable community. This was demonstrated by the average value of the fish dominance index < 0.09. These findings suggest the presence of an ecosystem balance and equitable distribution of different fish species [10]. The high fish diversity in Bangka Island's coral reef ecosystem is the main attraction for underwater ecotourism [29].

3.3 Sustainability status

The Sustainability Index (SI) analysis resulted in an average score of 32.4. This value matched the category of *almost sustainable* (Table2) [13][14][15][16]. Sustainable tourism is defined as tourism together with associated infrastructures that both now and in the future operate within natural capacities for the regeneration and future productivity of natural resources; recognize the contribution that people and communities, customs, and lifestyles make to the tourism experience; and accept that these people must have an equitable share in the economic benefits of local people and communities in the host areas [32]. Tourism infrastructure includes, attractions among others. The eight parameters currently used to measure the sustainability index for Bangka Island are only for underwater attraction. Therefore, it only matches the underwater activities.

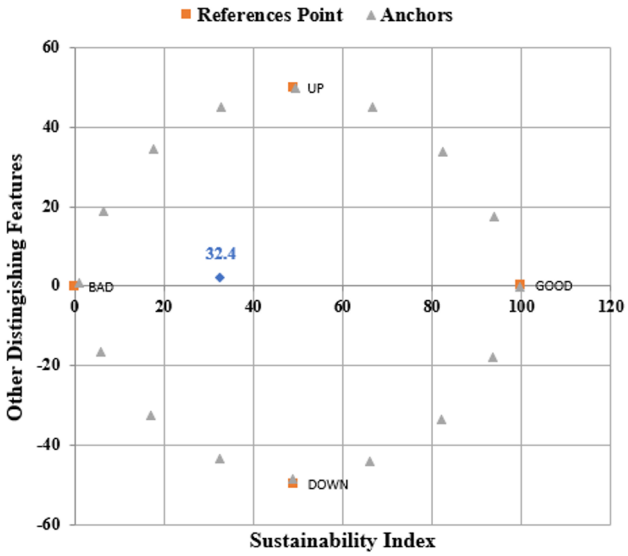

Fig 2. Sustainable Index (SI) of tourism at Bangka Island based on RapFish analysis [15]

Leverage is one or more sensitive attributes, resulting in a negative or positive impact on the sustainability index. It is calculated as the Root Mean Square (RMS) of each attribute [15]. The values vary between 0 and 10. The leverage results are shown in Figure 3. Two attributes, the number of fish species and fish dominance index, were recognized as the most sensitive indices that determine underwater tourism arrivals. This means that a high number of fish species and low fish dominance (high fish diversity) are the main motivations for tourists to visit Bangka Island [33]. To maintain underwater activities that are attractive to tourism, local tourism management should keep reef fish rich in species. Consequently, fishing on ornamental reef fish should be limited or prohibited.

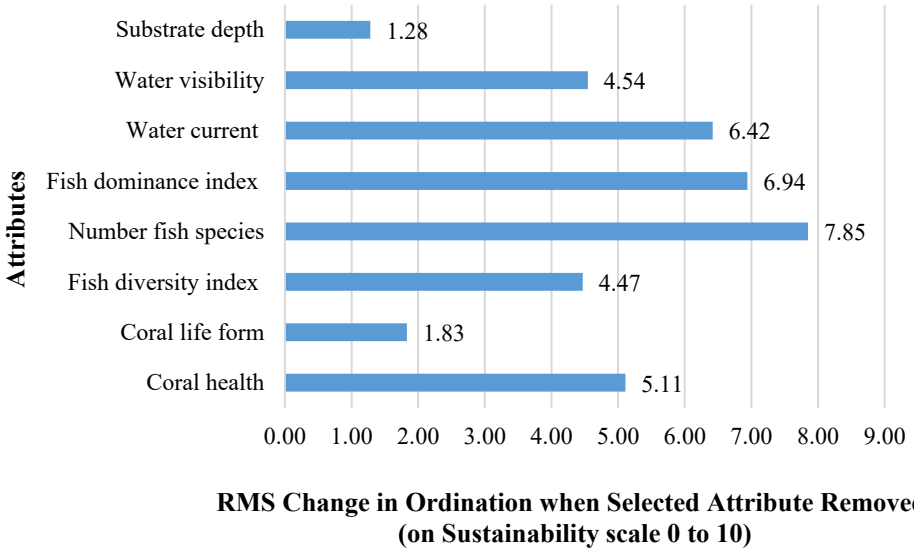

Fig 3. Leverage attributes that sensitive to the sustainability of Bangka Island as tourism destination

Through MMAF Regulation No. 128/2023, approximately 20 % of marine waters of Bangka Island were set aside as protected areas. This actually covers two dive sites (Tanjung Husi and Sahaung) where fishing or any extraction will soon be prohibited. However, the other 19 dive sites were still open for extraction by local ornamental reef fishermen. To reduce further extraction by fishermen, the government or local tourism management should introduce a compensation path into a new alternative livelihood. As the number of tourism visits increases, this can be achieved through their involvement in tourism activities. Resorts, accommodations, restaurants, and local transport and services create jobs that can be fulfilled by locals [34]. To meet all the criteria of a specific job, local tourism management must conduct skill and capacity training.

4 Conclusion

Based on these eight attributes, it can be concluded that tourism in Bangka Island was categorized as almost sustainable with a sustainability index of 32.4. Fish species richness and diversity were the most sensitive attributes that could maintain tourism. Setting aside part of Bangka Island's surrounding waters as protected area can affect only two dive sites (Tanjung Husi and Sahaung). As tourism creates many job opportunities for locals, local tourism management and the government must conduct skill and capacity training to meet the criteria required for the job.

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