



e-ISSN: 2722-3787

Tomini Journal of Aquatic Science

Homepage: <http://ejurnal.ung.ac.id/index.php/tjas>



Determining the Optimal Number of Tourist Boats Based on Carrying Capacity of Whale Shark Tourism (*Rhincodon typus*) in Botubarani Village, Gorontalo

Karmila Datau^{1*}, Azis Salam¹, Cahniar Djamil¹

¹Faculty of Marine Science and Fisheries Technology, Gorontalo State University, Indonesia

*Corresponding author: karmiladatau2021@gmail.com

ARTICLE INFO

Keywords:

whale shark; carrying capacity; optimization; Botubarani.

How to cite:

Datau, K., Salam, A., & Djamil, C. (2026). Determining the Optimal Number of Tourist Boats Based on Carrying Capacity of Whale Shark Tourism (*Rhincodon typus*) in Botubarani Village, Gorontalo. *Tomini Journal of Aquatic Science*, 5(1), 07–15

ABSTRACT

Whale shark (*Rhincodon typus*) is a globally distributed, migratory pelagic species and a major tourism attraction in Botubarani Village, Gorontalo. Uncontrolled growth in the number of tourist boats, however, risks injuring whale sharks and degrading the visitor experience, yet no evidence-based limit on boat numbers has previously been established for this site. This study aimed to determine the regional carrying capacity (DDK) of the Botubarani whale shark tourism area and the optimal number of boats (JPO) that can operate without compromising ecological safety or operator welfare. Data were collected in April–May 2025 through field observation and structured interviews, and analyzed using the DDK and JPO formulas of Yulianda (2007). The area's theoretical carrying capacity was 686 visitors/day, with actual utilization at only about 20% of this capacity. The optimal operating range was determined to be 10 boats (minimum, based on the safety-adjusted permitted boats, Pt) to 42 boats (maximum, the highest boat count that still keeps average operator income at or above the Bone Bolango Regency minimum wage). These findings provide a quantitative basis for regulating boat numbers to balance whale shark conservation, tourist experience, and operator livelihoods.



INTRODUCTION

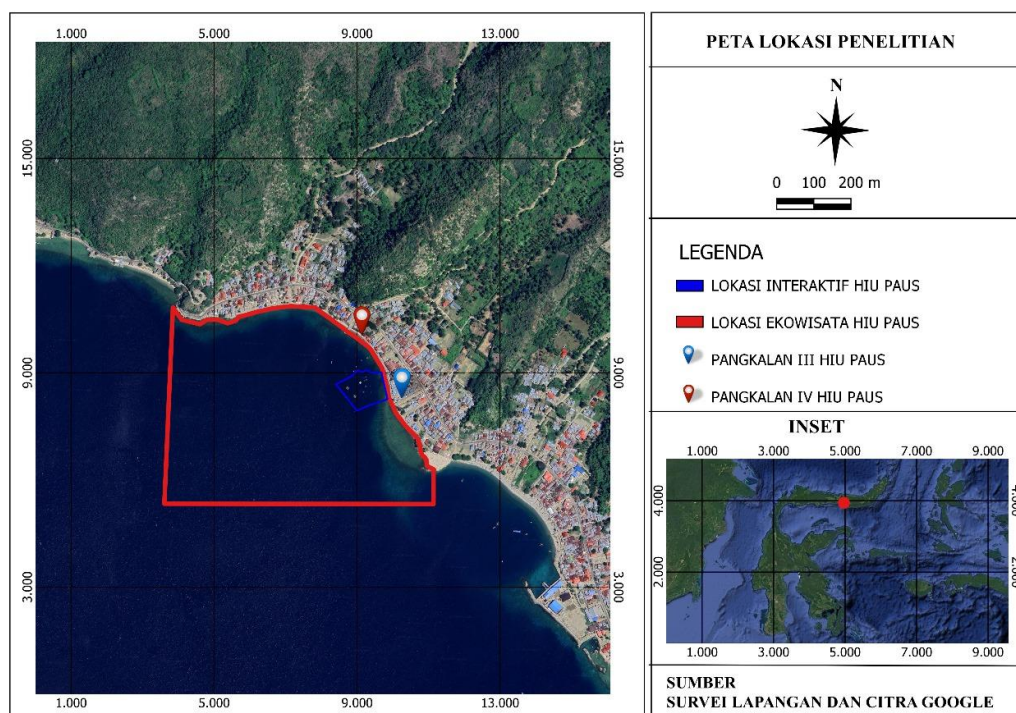
Indonesia's diverse coastal scenery makes it a prime destination for marine tourism development. Gorontalo Province, and Botubarani Village in particular, has become a nationally recognized whale shark tourism site because the species is docile and unusually approachable, attracting government officials, artists, and both domestic and international tourists (Eraku et al., 2023). The presence of whale sharks has substantially benefited the local economy and strengthened the area's potential as a tourist destination (Mile et al., 2017), with the site located only 15–20 minutes from downtown Gorontalo. However, the number of whale sharks sighted varies unpredictably from day to day.

As a highly vulnerable species, whale sharks are susceptible to disturbance from excessive human interaction, and unmanaged boat traffic can disrupt their habitat and behavior (Gatra and Furqan, 2024). Yasir et al. (2024) documented that 74% of whale sharks in Botubarani waters showed external injuries, more than half of them abrasions consistent with boat and human contact — direct evidence that current boat operations already pose a measurable risk to the population. Despite this, no official limit currently exists on the number of tour boats permitted to operate at Botubarani at any one time, and prior studies on the site (Ninasafitri et al., 2023; Eraku et al., 2023; Mile et al., 2017) have focused on geodiversity, community participation, and perception, without quantifying the area's carrying capacity or an evidence-based boat limit. Comparable carrying-capacity studies exist for other whale shark sites, such as Cenderawasih Bay National Park (Prihadi et al., 2017), but their area-specific parameters cannot be directly transferred to Botubarani given differences in interaction-zone size, boat capacity, and operating hours.

This gap — the absence of a quantified carrying capacity and boat-number limit for Botubarani, despite documented injury risk to whale sharks — is the problem this study addresses. Its novelty lies in jointly quantifying (1) the area's regional carrying capacity (DDK) and (2) an optimal boat-number range (JPO) that simultaneously protects whale shark safety and sustains tour operators' income at or above the regional minimum wage, an economic dimension absent from prior Botubarani studies. Accordingly, this study aims to assess the carrying capacity of the Botubarani whale shark tourism area and to determine the optimal number of tourist boats that can operate based on that carrying capacity.

MATERIAL AND METHODS

Research Location. This research was conducted in April–May 2025 in the whale shark tourism area of Botubarani Village, Kabila Bone District, Bone Bolango Regency, Gorontalo Province.



Picture 1. Research Location Map

Data Collection Technique. Data were collected through direct field observation and structured interviews using questionnaires (Febriani et al., 2023). Observation was used to record actual field conditions at the whale shark tourism site, while the questionnaire-guided interviews were administered to tour boat operators and site managers.

Data Analysis. Data obtained from interviews and field observations were systematically organized and analyzed (Fadilla and Wulandari, 2023) using two quantitative formulas following Yulianda (2007):

(1) Regional Carrying Capacity (DDK)

$$DDK = K \times (L_p / L_t) \times (W_t / W_p)$$

Where: K = potential ecological carrying capacity coefficient (number of visitors per boat unit, here equal to boat passenger capacity, $K_p = 3$ persons/boat); L_p = area of the whale shark interaction zone (17,202.83 m²), measured via Google Earth from GPS Essential coordinates; L_t = area required per boat/tourist unit (1,257 m²), following DOT-DA-DILG-DENR (2020) marine wildlife tourism standards; W_t = total daily operating time of the tourism area (8 hours / 480 minutes); W_p = average duration of one tourist boat trip within the interaction zone (21 minutes, from field observation).

(2) Number of Boats Permitted to Operate Simultaneously (Pt)

$$P_t = (L_p / L_t) \times S$$

Where S is a dimensionless safety factor (0.7–0.9) that adjusts theoretical capacity to actual, ecologically safe field capacity (Yulianda, 2007); lower values apply to areas with higher ecological sensitivity. Given that 74% of whale sharks in Botubarani show external injuries (Yasir et al., 2024), a conservative $S = 0.7$ was applied.

(3) Optimal Number of Boats (JPO)

The minimum of the JPO range is set equal to P_t (the safety-adjusted number of boats permitted to operate simultaneously). The maximum of the JPO range is the largest total number of operating boats (N) at which average operator income, $\text{Income}(N) = P \times f(N)$, remains at or above the Bone Bolango Regency Minimum Wage (UMK), where $P = \text{IDR } 100,000$ per trip and $f(N)$ is the average number of trips per operator per day at N total boats (derived from the observed total daily trip volume divided by N).

RESULTS AND DISCUSSION

Research Location 1. Botubarani Village originated from the expansion of Huangobotu Village on 24 August 2004, first led by Darma Adam, and comprises three hamlets: Tambo'o Barat, Tambo'o Tengah, and Tambo'o Timur. The village lies at approximately 0°28'38.42" N, 123°5'38.79" E, bordered by Huangobotu Village (east), Tomini Bay (south), South Leato/Dumbo Raya District (west), and Buata Village (north) (Ninasafitri et al., 2023).

Whale Shark Tourism Activities 2. The site is 15–20 minutes from downtown Gorontalo. The number of whale sharks sighted varies daily (from none up to five). Management provides a corridor to the beach where fishing boats carry tourists to view the whale sharks, preceded by a safety and sustainability briefing. Tourists must use management-operated boats and may feed the whale sharks with food purchased from providers; diving and snorkeling are permitted only with a diving certificate. Despite these controls, many whale sharks have

sustained minor injuries from boat interactions, underscoring the need for a boat-number limit to protect both whale shark welfare and tourist experience.

Carrying Capacity of the Whale Shark Tourism Area in Botubarani Village 3.

Observation and interviews showed that 10–19 tour boats operate simultaneously during peak periods, each carrying 1–3 tourists per trip (some operators making more than one trip per day), with an average trip duration of 15–35 minutes. No official daily limit on boat numbers currently exists, creating risk of crowding, reduced tourist comfort, and disturbance to whale sharks.

Applying the DDK formula ($L_p = 17,202.83 \text{ m}^2$; $L_t = 1,257 \text{ m}^2$; $K_p = 3 \text{ persons/boat}$; $W_t = 480 \text{ minutes}$; $W_p = 21 \text{ minutes}$) yields a theoretical maximum carrying capacity of approximately 686 visitors/day. Applying the P_t formula with $S = 0.7$ yields $P_t \approx 10$ boats permitted to operate simultaneously at any given time. Because DDK represents a theoretical maximum that does not account for field variables such as actual crowd density, whale shark sighting frequency, weather, and operational dynamics, a more conservative operational threshold — well below the theoretical maximum — is recommended for conservation and visitor-comfort purposes.

Compared with Prihadi et al. (2017), who reported a carrying capacity of 108 visitors/day for whale shark tourism in Cenderawasih Bay National Park, Botubarani's carrying capacity (686 visitors/day) is substantially higher, reflecting differences in interaction-zone area and site-specific operating parameters between the two locations.

Whale Shark Tour Boat Operators Income 4. Community income in the Botubarani whale shark tourism area has increased significantly since the emergence of whale sharks as a major tourist attraction. Whale shark tour boat operators earn income from tourists who come to see or interact directly with whale sharks by renting boats. The boat rental price is IDR 100,000 for a single whale shark interaction with a duration ranging between. Monthly trip counts and revenue for the 30 operators over December 2024–May 2025 are shown in Table 1.

Table 1. Number of trips and monthly gross revenue of Botubarani whale shark tour boat operators, December 2024 – May 2025

No.	Total Trips	Trips/Month	Trips/Day	Income/Month (IDR)
1	310	51.7	1.7	5,170,000
2	239	39.8	1.3	3,980,000
3	416	69.3	2.3	6,930,000
4	321	53.5	1.8	5,350,000
5	395	65.8	2.2	6,580,000
6	232	38.7	1.3	3,870,000
7	259	43.2	1.4	4,320,000
8	216	36.0	1.2	3,600,000
9	281	46.8	1.5	4,680,000
10	281	46.8	1.5	4,680,000
11	257	42.8	1.4	4,280,000
12	339	56.5	1.9	5,650,000
13	172	28.7	0.9	2,870,000
14	249	41.5	1.4	4,150,000
15	307	51.2	1.7	5,120,000
16	129	21.5	0.7	2,150,000
17	382	63.7	2.1	6,370,000
18	217	36.2	1.2	3,620,000

19	400	66.7	2.2	6,670,000
20	367	61.2	2.0	6,120,000
21	241	40.2	1.3	4,020,000
22	291	48.5	1.6	4,850,000
23	337	56.2	1.9	5,620,000
24	269	44.8	1.5	4,480,000
25	316	52.7	1.7	5,270,000
26	279	46.5	1.5	4,650,000
27	181	30.2	1.0	3,020,000
28	209	34.8	1.1	3,480,000
29	252	42.0	1.4	4,200,000
30	210	35.0	1.2	3,500,000
Total	8354	46.41	1.5	4,641,667
Min	129	21.5	0.7	
Max	416	69.3	2.3	46

The income of whale shark tour boat operators in Botubarani Village follows a linear equation:

$$P = 100.000 \times f$$

Where:

P = Income

f = Number of trips

The income table above shows that the income of whale shark tour boat operators in Botubarani Village is in accordance with the Bone Bolango Regency Minimum Wage. The Bone Bolango Regency Minimum Wage in 2025 is IDR 3,221,731 (Gorontalo Governor's Decree No. 482/1/2024, referring to the Gorontalo 2025 UMP). In the graph, the lowest income of tour boat operators is around IDR 2,150,000 per month, which indicates that some operators face operational limitations such as a low number of trips per month. Operators with the lowest income are far below the average income of all respondents, thus illustrating the income differences among whale shark tour operators. Meanwhile, the average income of tour boat operators is around IDR 4,641,667.

In contrast, the highest revenue for tour boat operators is around Rp. 6,930,000, due to the large number of trips each month and good operational efficiency. The difference between the lowest and highest revenues indicates that the potential revenue in the tour boat business is very large, but in reality, not all operators can achieve it equally.

When comparing the income of tour boat operators with the Bone Bolango Regency Minimum Wage (UMK) in 2025, a significant income gap is visible. The lowest operator's income was recorded at IDR 2,150,000 per month, while the Bone Bolango Regency UMK in 2025 was set at IDR 3,221,731. Compared to the UMK, the lowest income only reached approximately 66.7% of the UMK, resulting in a gap of IDR 1,071,731. This difference indicates that some tour boat operators, particularly those with a low number of trips or facing operational limitations, are still below the income eligibility standard based on regional labor regulations. This condition illustrates the inequality of operator income and indicates the need for efforts to increase income or more optimal operational arrangements so that all operators can earn income close to or meet the applicable minimum wage standard.

The average income of tour boat operators, which reached Rp. 4,641,667 per month, indicates that most operators earn income above the Bone Bolango Regency Minimum Wage (UMK) in 2025. When compared, the average income has a difference of Rp. 1,419,936, which indicates that in general whale shark boat tourism activities are able to provide a decent level of income

and exceed the regional minimum wage standard. This condition reflects that operators who can run a stable number of trips and have effective operational management tend to earn higher incomes. Thus, overall the whale shark tourism sector in Botubarani Village has quite good economic potential, although income variations between operators still need to be considered to ensure sustainability and equitable distribution of economic benefits at the local level.

In contrast, the highest income of a tour boat operator, which reached IDR 6,930,000 per month, represents a significant difference compared to the 2025 Bone Bolango Regency Minimum Wage (UMK). This highest income is more than double the UMK, indicating that boat operators with high trip frequency and good operational efficiency are able to earn incomes far exceeding the regional wage standard. This comparison demonstrates the enormous economic potential of whale shark tour boat activities for operators who are able to maximize the number of trips and take advantage of peak season tourism opportunities. However, the wide gap between the highest and lowest incomes also indicates that not all operators can achieve optimal income equally, so that better management strategies and equal opportunities are needed so that economic benefits can be felt more fairly by all business actors.

Analysis of the Optimal Number of Boats 5. Across 182 days (December 2024–May 2025), the 30 operators recorded 8,354 total trips, an average of 46 trips/day, corresponding to roughly 138 visitors/day at 3 tourists per boat. This actual visitor volume represents only about 20% of the area's carrying capacity (686 people/day), indicating that current operations remain within the site's ecological safe limit.

The minimum of the optimal boat range equals $P_t = 10$ boats, the safety-adjusted number of boats permitted to operate simultaneously at any given time. The maximum is constrained by operator welfare: as the total number of operating boats increases, trips — and therefore income — per operator decline. Table 2 shows the relationship between trips per operator per day, the corresponding total number of boats, and resulting operator income at the observed 20% DDK utilization level (46 total trips/day).

Table 2. Relationship between trips per operator per day, number of boats, and operator income at 20% DDK utilization (46 trips/day).

Trip/Operator/Day	Number of Boats	Operator Income (IDR/month)
4.6	10.0	13,953,333
4.5	10.2	13,650,000
4.4	10.5	13,346,667
4.3	10.7	13,043,333
4.2	11.0	12,740,000
4.1	11.2	12,436,667
4	11.5	12,133,333
3.9	11.8	11,830,000
3.8	12.1	11,526,667
3.7	12.4	11,223,333
3.6	12.8	10,920,000
3.5	13.1	10,616,667
3.4	13.5	10,313,333
3.3	13.9	10,010,000
3.2	14.4	9,706,667
3.1	14.8	9,403,333
3	15.3	9,100,000
2.9	15.9	8,796,667

Trip/Operator/Day	Number of Boats	Operator Income (IDR/month)
2.8	16.4	8,493,333
2.7	17.0	8,190,000
2.6	17.7	7,886,667
2.5	18.4	7,583,333
2.4	19.2	7,280,000
2.3	20.0	6,976,667
2.2	20.9	6,673,333
2.1	21.9	6,370,000
2	23.0	6,066,667
1.9	24.2	5,763,333
1.8	25.6	5,460,000
1.7	27.1	5,156,667
1.6	28.8	4,853,333
1.5	30.7	4,550,000
1.4	32.9	4,246,667
1.3	35.4	3,943,333
1.2	38.3	3,640,000
1.1	41.8	3,336,667
1	46	3,033,333

Table 2 At the minimum boat count (10 boats), an operator averaging 4.6 trips/day could earn up to IDR 13,953,333/month. Under current actual conditions (~30 boats, 1.5 trips/operator/day), average income is about IDR 4,550,000/month. Table 2 shows that 42 boats is the highest total boat count at which operator income remains at or above the UMK; beyond 42 boats, average income falls below the minimum wage. The maximum of the optimal range is therefore set at 42 boats.

Combining both constraints, the optimal number of boats for simultaneous operation in the Botubarani Whale Shark Tourism Area, at the current 20% DDK utilization level, is between 10 boats (the safety-based minimum, Pt) and 42 boats (the welfare-based maximum total operating boats). It should be noted that these two figures describe different quantities: the minimum (10) is the number of boats permitted near whale sharks simultaneously at any moment, while the maximum (42) is the total number of boats that may operate (in rotation) across the full day without reducing operator income below the regional minimum wage.

CONCLUSION

This study determined that the Botubarani whale shark tourism area has a theoretical regional carrying capacity (DDK) of 686 visitors/day, of which current tourism activity utilizes only about 20%. Based on the safety factor for whale shark protection, a maximum of 10 boats may operate simultaneously near whale sharks at any given time (Pt), while based on the operator income constraint relative to the Bone Bolango Regency Minimum Wage, a total of up to 42 boats may operate across a full day without reducing average operator income below the regional minimum wage. The optimal operating range for tourist boats in Botubarani is therefore 10 to 42 boats, a range that jointly satisfies the objectives of protecting whale shark safety and sustaining tour operator welfare.

ACKNOWLEDGEMENT

The authors thank the managers of Botubarani Village Whale Shark Tourism and the local community for their support and cooperation throughout the research process, as well as colleagues who assisted with interviews and supervisors who supported the preparation of this report.

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