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RESEARCH ARTICLE

Fish colonization of the artificial reef at Gusung Batu Lampe Muara Badak, Kutai Kartanegara, East Kalimantan, Indonesia: a preliminary study [version 1; peer review: 1 not approved]

Iwan Suyatna, Nova Andika Saptura, Ristiana Eryati, Adnan Adnan,
Muchlis Effendi, Tedy Hanjoko, Achmad Syafei Sidik

Laboratory of Hydrooceanography, Faculty of Fisheries and Marine Science, Mulawarman University, Samarinda, Indonesia, Indonesia

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Abstract

Background: Artificial reefs can be utilized as new habitats to restore fish populations in degraded coral reef environments. This study evaluated the restoring ability of the artificial reef set at Gusung Batu Lampe should be investigated by observing the fish population colonizing the reef.

Methods: A fish visual census was applied to identify the species and count their numbers at the site. Underwaterline transect was used to limit the observation area to 200 m² measured with 50m roll meter. The reef structure comprised 34 tetrahedral concrete blocks arranged in a row, which was 60 cm x 60 cm at the base, 35 cm x 35 cm on top and 60 cm high, and has four holes. Two scuba divers descended, one to ensure the safety of the divers and the other to observe the fish. Each dive took place over 30–45 minutes, and was conducted at 09:00, 13:00 and 17:00. Surveys were performed four times: in November and December 2016, and in January and July 2017.

Results: Results showed that fish colonization composed of 180 to 283 individual number with taxa between 13 and 25 species. Number of fish in colonization was found significant difference among observation times, and fish species from the family Chaetodontidae were observed in every survey.

Conclusions: A total of 38 fish species from 16 families were identified colonizing the reef during surveys, and in four month observation the fish colonization size increased from the fish density of 1/4.444 m² to 1/1.481 m², confirming the ability of the reef to restore fish population.

Keywords

Line transect, fish visual census, unit of artificial reef, fish species, Chaetodontidae, Gusung Batu Lampe, Mahakam Delta, Kutai Kartanegara

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1. **Ken Collins**, University of Southampton,
National Oceanography Centre,
Southampton, UK

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Corresponding author: Iwan Suyatna (isuyatna@gmail.com)

Author roles: **Suyatna I:** Conceptualization, Data Curation, Methodology, Project Administration, Resources, Supervision, Validation, Writing – Original Draft Preparation, Writing – Review & Editing; **Saptura NA:** Data Curation, Investigation, Methodology, Software; **Eryati R:** Data Curation, Formal Analysis, Methodology, Validation, Visualization; **Adnan A:** Data Curation, Formal Analysis, Investigation, Software, Validation, Visualization; **Effendi M:** Data Curation, Formal Analysis, Investigation, Methodology, Software, Validation; **Hanjoko T:** Data Curation, Formal Analysis, Funding Acquisition, Investigation, Methodology, Resources, Software, Validation, Visualization; **Sidik AS:** Conceptualization, Project Administration, Resources, Supervision, Validation, Writing – Original Draft Preparation, Writing – Review & Editing

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Introduction

Artificial reefs, especially in East Kalimantan, are rarely utilized despite their ability to create new habitats. Nowadays, artificial reefs had been tried by the province of East Kalimantan at a particular area to rehabilitate fish habitat degradation, such as at Gusung Batu Lampe in Pangempang water, Kutai Kartanegara district. The degradation of coral reefs in the area was primarily caused by the practices of bottom trawling and blast fishing. In 2011 and 2012, the condition of coral reefs in Pangempang water was reported for the first time by [Suyatna *et al.* \(2017a\)](#), and convinced that the live coral (LC) form was recorded in only 21.0% of the area of 41.84 ha. Pangempang water belongs to the Mahakam delta which homes many of fish species. [Suyatna *et al.* \(2010\)](#) identified 43,340 fish caught by minitrawl and noticed 131 species from 87 genera, 61 families and 10 orders. A total of 13 species were observed in Mahakam river 40 km behind the river mouth ([Suyatna *et al.*, 2017b](#)), and among of them, the longfin anchovy *Setipinna* sp., was found 230 km from the coastline ([Suyatna *et al.*, 2017c](#)). Fish found in the Mahakam delta were also recognized along the coastal waters of East Kalimantan. At least 22 families from 8,291 fish were also observed at the industrial estate in Bontang, 75 km north of the delta ([Suyatna *et al.*, 2016](#)) and 29 species in the coastal water of East Kutai district ([Juliani & Suyatna, 2014](#)).

However, after artificial reef construction, scientific information describing fish colonization factors associated with the reef, such as fish species and fish richness remains unstudied. From the beginning, the reef is expected to restore fish populations in the area, and therefore a preliminary study is urged to be carried out for a certain duration. For this reason, this study was performed to emphasize the importance and benefits of constructing artificial reef and to identify and analyze the fish community structure associated with the reef.

Methods

Study parameters and location

An underwater line transect and fish visual census (FVC) were applied in this survey. FVC method is commonly used at site ([Lim, 2017](#)) and line transect limits the observation area to only 200 m² (20 m long and 10 m wide, 5 m to the right and 5 m to the left), measured using a 50 m roll meter. The distance of the observation area was around 5 km from the coast at the coordinate of 0° 13'02.1" S 117° 29'35.1" E and a 40 HP speed boat was used to transport divers to the site. The artificial reef structure comprised 34 units of tetrahedral concrete block, sizing 60 cm x 60 cm at base, 60 cm high and 35 cm x 35 cm wide on top, with four holes in each block, were placed in a row. Two SCUBA divers descended to the bottom; one ensured the safety of the divers and the other one took photographs while counting the number of fish. Fish photographs were realized with Action Kogan 4K and Nikon AW 130 underwater cameras. These cameras were also used to record the vicinity condition such as a unit of reef, and a GPS device (Garmin) was used to determine the observation site. All observational data were recorded using underwater diving slates. Observation took place for only 30 to 45 minutes in the morning at 09:00, in the early afternoon at 13:00 and at the late afternoon at 17:00, with the total duration

of 90 to 135 minutes for one survey. Surveys were performed four times: in November and December 2016, and in January and July 2017.

Data capture

Recording and taking photographs of fish started about 20 minutes after transect was laid to provide time for fish to react to the natural habitat. Fish species identification was conducted with reference to [Allen \(2000\)](#); [Anam & Mostarda \(2012\)](#); [Masuda *et al.* \(1975\)](#); [Peristiwadi \(2006\)](#).

Water physical parameters such as transparency, salinity and temperature were measured with water quality meter AZ 8603 (Shenzhen Hengkaituo Sci-Tech Co., Ltd, Guangdong, China). Water velocity was assessed by drifting on the surface a small buoy for 10 m distance and noting the time to pass was using a stopwatch. Water depth was measured with a measuring rope.

Data analysis

Palaeontological Statistics version 3.20 ([Hammer *et al.*, 2001](#)) was used to analyze the diversity indices, namely dominance, Shannon's H, evenness, and Margalef species richness index. Bray–Curtis multivariate statistics, which is known to be more effective than other analytical tools ([Kurt & Merlyn, 1998](#)) such as Euclidean, Morisita, Mahalanobis, and Jaccard statistics, was applied to analyze the similarity of fish size colonization among observation times. Fish density (individual/m²) was calculated manually.

Results and discussion

Fish community

Taxonomically, 38 species belonging to 26 genera and 16 families were observed during surveys. A total of 25 species and 12 families were observed in the first survey; 22 species and 9 families in the second survey; 26 species and 11 families in the third survey; and 23 species and 13 families in the last survey ([Table 1](#) and [Table 2](#)). All of the fish were small-bodied. In each survey, the two families Pomacentridae and Labridae were families with the most common and adaptable species as well as the most abundant in individual number, followed by the Chaetodontidae and Acanthuridae families. The remaining 12 families were only represented by one or two species. However, the four families Chaetodontidae, Siganidae, Caesionidae and Nemipteridae were present in every survey. Some families were only present in single surveys. The fish species observed at the fourth survey to represent the fish colonization of the artificial reef at Gosong Batu Lampe are shown in [Figure 2](#).

[Mallet *et al.* \(2016\)](#) examined reef fish assemblages during daylight hours, 10 times a day for 34 consecutive days in a branching coral and they discovered fish abundance and taxa richness were greater in the early morning, in which the most frequent observed families was Pomacentridae and Labridae (in 100% and 99.6% of cases, respectively). In our study these two families were also encountered in every survey, and were the most specious and populous families, followed by Acanthuridae and Chaetodontidae families. [Honda *et al.* \(2013\)](#) reported that the most dominant families on the basis of species number in coral

Table 1. Fish observed colonizing the reef during the first two surveys at the Gusung Batu Lampe Pangempang water, Muara Badak sub district.

Family and species*	Survey 1 (Nov 2016)			Survey 2 (Dec 2016)		
	09:00	13:00	17:00	09:00	13:00	17:00
Labridae (1)						
<i>Thalassoma lunare</i> (1)	7	14	3	20	7	11
<i>Halichoeres hortulanus</i> (2)	2	0	0	3	0	0
<i>H. timorensis</i> (3)	2	1	0	1	0	1
<i>Cheilinus chlorourus</i> (4)	0	1	0	1	0	0
<i>Labroides dimidiatus</i> (5)	0	3	1	3	1	0
<i>Scarus rubroviolaceus</i> (6)	1	0	0	3	2	0
Acanthuridae (2)						
<i>Acanthurus nigrofusus</i> (1)	0	1	0	4	5	3
<i>A. nigricanda</i> (2)	0	0	0	0	0	0
<i>A. bariene</i> (3)	0	0	0	0	0	0
<i>A. grammoptilus</i> (4)	0	0	0	0	0	0
Pomacanthidae (3)						
<i>Centropyge tibicen</i> (1)	1	0	1	0	0	0
Pomacentridae (4)						
<i>Amphiprion ocellaris</i> (1)	3	3	3	3	3	3
<i>Cromis weberi</i> (2)	1	1	3	1	1	1
<i>C. xanthochira</i> (3)	0	0	3	4	3	0
<i>Dascyllus trimaculatus</i> (4)	2	2	17	10	19	2
<i>D. reticulatus</i> (5)	22	19	14	30	3	12
<i>Pomacentrus amboinensis</i> (6)	1	1	0	2	1	2
<i>P. mollucensis</i> (7)	1	4	4	2	0	2
<i>P. chrysurrus</i> (8)	0	0	0	0	0	0
<i>Plectroglyphidodon lacrymatus</i> (9)	1	0	1	4	1	0
Chaetodontidae (5)						
<i>Chaetodon vegabundus</i> (1)	0	0	4	1	0	0
<i>Chaetodon kleinii</i> (2)	1	1	1	4	1	2
<i>Chaetodon lunulatus</i> (3)	0	0	0	0	0	0
Tetraodontidae (6)						
<i>Canthigaster papua</i> (2)	0	0	0	0	0	0
Gobiidae (7)						
<i>Amblyeleotris periphthalma</i> (1)	0	0	0	0	0	0
<i>A. guttata</i> (2)	0	0	0	0	0	0
<i>Rigilius goby</i> (3)	1	1	0	0	0	0
Mullidae (8)						
<i>Upeneus tragula</i> (1)	0	0	0	0	0	0
Siganidae (9)						
<i>Siganus virgatus</i> (1)	2	2	2	2	2	2
<i>S. punctatus</i> (2)	0	0	0	0	0	0

Family and species*	Survey 1 (Nov 2016)			Survey 2 (Dec 2016)		
	09:00	13:00	17:00	09:00	13:00	17:00
Caesionidae (10)						
<i>Caesio teres</i> (1)	0	0	5	0	18	0
Nemipteridae (11)						
<i>Scolopsis ciliata</i>	1	3	5	5	0	1
Scorpaenidae (12)						
<i>Pterois mombasae</i> (1)	0	0	0	0	0	0
Serranidae (13)						
<i>Cephalophosis boenak</i> (1)	0	0	0	0	0	0
Lutjanidae (14)						
<i>Lutjanus decussates</i> (1)	0	0	1	3	0	0
Zanclidae (15)						
<i>Zanclus cornutus</i> (1)	2	1	2	1	0	3
Lethrinidae (16)						
<i>Lethrinus harak</i> (1)	0	0	1	0	0	0
Number of fish	51	58	71	107	67	45
Number of taxa	17	16	18	21	14	13

* Family shown in bold, species in italics.

Table 2. Fish observed colonizing the reef during the last two surveys at the Gusung Batu Lampe Pangempang water, Muara Badak sub district.

Family and species*	Survey 3 (Jan 2017)			Survey 4 (July 2017)		
	09:00	13:00	17:00	09:00	13:00	17:00
Labridae (1)						
<i>Thalassoma lunare</i> (1)	3	6	2	6	7	4
<i>Halichoeres hortulanus</i> (2)	3	2	0	2	2	2
<i>H. timorensis</i> (3)	0	2	2	2	3	0
<i>Cheilinus chlorourus</i> (4)	2	2	2	2	0	0
<i>Labroides dimidiatus</i> (5)	1	3	2	0	0	0
<i>Scarus rubroviolaceus</i> (6)	0	1	0	0	0	0
Acanthuridae (2)						
<i>Acanthurus nigrofuscus</i> (1)	6	3	2	3	4	2
<i>A. nigricanda</i> (1)	0	0	0	3	2	3
<i>A. bariene</i> (2)	0	0	0	0	2	0
<i>A. grammoptilus</i> (3)	3	1	0	0	0	0
Pomacanthidae (3)						
<i>Centropyge tibicen</i> (1)	0	3	0	2	2	2

Family and species*	Survey 3 (Jan 2017)			Survey 4 (July 2017)		
	09:00	13:00	17:00	09:00	13:00	17:00
Pomacentridae (4)						
<i>Amphiprion ocellaris</i> (1)	3	3	3	0	0	0
<i>Cromis weberi</i> (2)	3	2	0	6	6	3
<i>C. xanthochira</i> (3)	2	0	0	0	0	0
<i>Dascyllus trimaculatus</i> (4)	11	11	14	9	6	9
<i>D. reticulatus</i> (5)	5	27	24	11	7	8
<i>Pomacentrus amboinensis</i> (6)	4	2	1	7	8	5
<i>P. mollucensis</i> (7)	2	3	4	0	0	0
<i>P. chrysurrus</i> (8)	0	0	0	4	4	2
<i>Plectroglyphidodon lacrymatus</i> (9)	2	2	1	0	0	0
Chaetodontidae (5)						
<i>Chaetodon vegabundus</i> (1)	1	2	0	2	0	2
<i>Chaetodon kleinii</i> (2)	2	3	1	1	1	1
<i>Chaetodon lunulatus</i> (3)	0	4	0	0	0	0
Tetraodontidae (6)						
<i>Canthigaster papua</i> (2)	0	0	0	2	2	0
Gobiidae (7)						
<i>Amblyeleotris periophthalma</i> (1)	0	0	0	0	3	2
<i>A. guttata</i> (2)	0	1	0	0	2	0
<i>Rigilius goby</i> (3)	0	3	2	0	0	0
Mullidae (8)						
<i>Upeneus tragul</i> (1)	0	0	0	0	2	0
Siganidae (9)						
<i>Siganus virgatus</i> (1)	0	0	0	0	0	0
<i>S. punctatus</i> (1)	0	2	2	2	0	2
Caesionidae (10)						
<i>Caesio teres</i> (1)	4	0	0	27	64	4
Nemipteridae (11)						
<i>Scolopsis ciliate</i> (1)	5	2	2	4	4	3
Scorpaenidae (12)						
<i>Pterois mombasae</i> (1)	0	1	0	0	0	0
Serranidae (13)						
<i>Cephalopholis boenak</i> (1)	0	0	0	3	2	0
Lutjanidae (14)						
<i>Lutjanus decussatus</i> (1)	0	0	0	0	2	1
Zanclidae (15)						
<i>Zanclus cornutus</i> (1)	1	2	0	0	0	0
Lethrinidae (16)						
<i>Lethrinus harak</i> (1)	0	0	0	0	0	0
Number of fish	63	93	64	98	135	55
Number of taxa	18	25	15	19	21	17

* Family shown in bold, species in italics.

Figure 1. Map showing the study location of Gusung Batu Lampe in Pangempang water, Muara Badak.

reefs were Labridae, Pomacentridae and Chaetodontidae. There were nine families identified in all surveys, but with only one species in each family, and according to [Hernández-Velasco et al. \(2016\)](#) the families distributed in tropical regions inhabit shallow coral reefs. *Chaetodon kleinii* and two other species of Chaetodontidae identified in our study indicated that Gusung Batu Lampe has potentiality to attract more coral reef fish. *Chaetodon* sp. are known to be obligate corallivores, which feed entirely on coral polyps ([Kulbicki et al., 2011](#); [Yusuf & Ali, 2004](#)), and rely on reefs for breeding, nursing and shelter ([Muhammad et al., 2017](#)). In term of single species, *Caesio teres*, of the family Caesionidae (Fusilier), was the most abundant species and fed primarily on plankton; this species is included commercially as an important food fish. Some species of this family are distributed widely in mid-water over reefs ([Bawole et al., 2014](#)) and are utilized as bait fish to catch Tuna ([Rajasuriya, 2014](#)). *Acanthurus*, of the family Acanthuridae, commonly known as surgeonfish, was encountered in this study as the third major group. This group feeds upon algae.

Fish colonization size

Based on the Bray–Curtis index, the number of fish at 09:00 in the morning and at 13:00 in the early afternoon was 95.0% similar, but declining less to 80.0% at 17:00 in the late afternoon ([Table 3](#)). This phenomenon of retreat of coral fish in the late afternoon could be an effect of light intensity ([Rickel & Genin, 2005](#)). Light may influence and increase water temperature ([Mcleod et al., 2013](#)), and such condition could affect the

performance of coral reef fish, said otherwise they which tend to harbor or hide in reef holes and unseen ([Suyatna et al., 2016](#)). Likewise, the number of taxa between two observation times was 99.0% similar, but the similarity in the late afternoon was only 91.0%.

Fish density in a unit area (individual/m²) increased from the first to the last survey, from 1/4.444 m² to 1/1.481 m² ([Table 4](#)). This indicates that the reef at Gusung Batu Lampe potentially provide a valuable area for coral reef fish population since the availability of refuge sites of reefs may increase fish number ([Grossman et al., 1997](#)), and reef size did not significantly affect the density of colonists ([Borntrager & Farrell, 1992](#)).

Fish group structure

The diversity index was applied to describe regarding of how many different species are present over the surveys among the observation times. This study revealed that the number of colonists, species richness and species diversity was highest in at 09:00 in the morning and at 13:00 in the afternoon, and the highest species richness arose in the 3rd survey, particularly at 13:00 ([Table 5](#)). The other diversity indices showed a different population sizes of the colonists during this study.

Some relevant water quality parameters measured at the location showed favorable water conditions for fish to live ([Table 6](#)). This is notable, since water quality factors such as

Figure 2. Fish species associated with the artificial reef at Gusung Batu Lampe taken from the fourth survey.

Table 3. Similarity of mean individual number and taxa of fish colonization associated with the artificial reef during the study at Gusung Batu Lampe Pangempang water, Muara Badak sub district.

Time	Mean density			Mean taxa		
	09:00	13:00	17:00	09:00	13:00	17:00
09:00	1	0.949405	0.848375	1	0.993377	0.913043
13:00	0.949405	1	0.799320	0.993377	1	0.906475
17:00	0.848375	0.799320	1	0.913043	0.906475	1

Table 4. Density of fish during surveys.

Time	Survey 1		Survey 2		Survey 3		Survey 4	
	Density	Equal to (1/m ²)	Density	Equal to (1/m ²)	Density	Equal to (1/m ²)	Density	Equal to (1/m ²)
09:00	0.255	3.922	0.535	1.869	0.315	3.175	0.490	2.041
13:00	0.290	3.448	0.335	2.985	0.465	2.151	0.675	1.481
17:00	0.355	2.817	0.225	4.444	0.320	3.125	0.275	3.636

Table 5. Diversity indexes of fish colonization at Gusung Butu Lampe, Pangempang water, Muara Badak subdistrict.

Statistic	1st Survey			2nd Survey			3rd Survey			4th Survey		
	09:00	13:00	17:00	09:00	13:00	17:00	09:00	13:00	17:00	09:00	13:00	17:00
Taxa	17	16	18	21	14	13	19	25	15	19	21	17
Individual number	51	58	71	107	67	45	63	93	64	98	135	55
Dom. <i>D</i>	0.220	0.183	0.122	0.136	0.178	0.156	0.077	0.117	0.203	0.119	0.243	0.086
Shan. <i>H</i>	2.131	2.145	2.456	2.469	2.081	2.184	2.751	2.720	2.078	2.535	2.185	2.641
Evenness	0.495	0.534	0.648	0.562	0.572	0.683	0.824	0.607	0.533	0.664	0.423	0.825
Margalef	4.069	3.694	3.988	4.280	3.092	3.152	4.345	5.295	3.366	3.926	4.077	3.993

Table 6. Results of water quality parameters measured at the Gusung Batu Lampe Pangempang water.

Number and time measurement		Parameters				
		Velocity, m/s	Transparency, m	Salinity, ppt	Temperature, °C	Depth, m
1	09:00	0.30	4.64	32	28	6.30
	13:00	0.50	3.90	32	30	4.70
	17:00	0.49	4.00	33	29	5.60
2	09:00	0.30	4.70	32	29	5.20
	13:00	0.50	4.30	32	30	6.70
	17:00	0.60	3.80	32	28	7.30
3	09:00	0.40	4.20	33	28	5.20
	13:00	0.50	4.80	32	29	4.90
	17:00	0.30	4.60	32	28	6.20
Average		0.40	4.30	32	29	5.80

current velocity may affect food intake (Belal, 2015), water transparency determines underwater visibility and fish assemblage (Enrique de Melo *et al.*, 2009), and temperature and salinity may decrease species richness and fish abundance (Bruet *et al.*, 2012). Fish can live in various places, but they often occupy a particular place and certain depth (Costa *et al.*, 2013).

Dataset 1. Raw water quality data for each survey

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Conclusions

Overall, 38 fish species from 16 families were successfully identified during surveys. Distribution of taxa and colonists were more frequently occurred at 09:00 and 13:00 than at 17:00. In 4 months of observation, fish density increased from 1/4.444 m² to 1/1.481 m² indicating the increase of fish colonization size. The most populous families were Pomacentridae and Labridae, and the obligate corallivore discovered was *Chaetodon kleinii*. The artificial reef should be elevated or extended to provide a more available water column for fish to be more colonized.

Data availability

Dataset 1. Raw water quality data for each survey. DOI: <https://doi.org/10.5256/f1000research.16736.d226152> (Suyatna *et al.*, 2018).

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Ken Collins

School of Ocean and Earth Science, University of Southampton, National Oceanography Centre, Southampton, UK

I have many concerns about this paper:

- When was this reef deployed, and was this close to the time of the first survey?
- What is the nature of the seabed?
- What is the distance to natural reefs?
- How does the survey transect relate to the artificial reefs?
- Tables 1 & 2 are unnecessary and could simply be summarised as a single species list ranked in order of total abundance over the whole study. The raw data could be given as a separate Dataset as with the "Raw water quality data for each survey".
- Page 7: "Fish colonisation size" describes numbers, not the dimensions of the fish.
- Figure 2 is not particularly useful, better would be a larger version the *Caesio teres* photographs showing the fish in relation to the reef structure.
- Table 3: limit similarity to 3 significant figures.
- Table 6: shows very similar conditions throughout and could be summarised in a single sentence.
- The biggest issue, which makes the study of limited scientific value is the lack of any control data. This 1985 paper highlighted this issue (Bohnsack and Sutherland, 1985¹).
- Arguably, the control is the first survey and the study tracks the fish community development over the subsequent 3 surveys. I would expect a parallel study of seabed

distant from the artificial structure to show the value of creating a reef. Equally direct comparisons with natural reefs in the area would be useful.

- The timescale of the whole study is very short; November 2016 to July 2017.
- I consider that the main value of this study is in describing the partial diurnal behaviours with the 3 set times 09:00, 13:00 and 17:00.

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Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: artificial reef materials and ecology, seagrass, invasive species

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

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