The potential of buoyant fish attractor (BFA) substrates in supporting aufwuchs growth as a new food source in eutrophic zones of Lake Maninjau

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Abstract. "Buoyant Fish Attractor" (BFA) is an artificial floating substrate placed in the euphotic zone of a lake. This substrate is expected to support the conservation of native fish in a lake. The BFA used in this study was an inverted pyramid which was made of wood or bamboo with a size of about 200 cm in length, 200 cm in width, 80 cm in height and equipped with PVC pipes as a buoy. Three types of a substrate mounted on BFA were wood frames, plastic brushes with 40 cm in length and a diameter of 15 cm, and palm fibers placed in six brick roster. Aufwuch samplings were carried out by four times after a month of BFA installation: in July, August, September, and November 2018. The result showed that on the wood media 37 taxa of benthic microalgae were identified which was consisted of Bacillariophyta 55%, Chlorophyta 18%, Cyanophyta 25%, Protista 2% and dominated by Synedra ulna. On plastic brush media, 11 taxa of invertebrates were identified: Insecta 72%, Crustacea 18%, Annelida 5%, Bryozoa 5%, Mollusca 0.3% dominated by Chironomus sp. On the palm fiber media, 16 taxa of invertebrates were identified: Crustacea 85%, Insecta 7%, Annelida 6%, and Mollusca 2%, dominated by Chydorus sp. Buoyant Fish Attractor (BFA) has a potential to support the growth of aufwuch as a new food source in the lake's euphotic zone. The variety of media installed on BFA technology could affect the structure and composition of the aufwuch community.

1. Introduction
Lake Maninjau is a type of caldera lake that has a surface area of 9997.5 ha, an average depth of 105 m, the water volume of 10,226,001,629.2 m$^3$, the water retention time of 25.04 years and at an altitude of 461.50 m above sea level [1]. Lake Maninjau, located in the regency of Agam, West Sumatra, has an important role in the life of the surrounding community. Moreover, Lake Maninjau is one of the fifteen priority lakes in Indonesia that has several economic functions such as power generation, irrigation, capture fisheries and aquaculture with floating net cage techniques and tourist destinations [2]. As an ecological function, Lake Maninjau plays as a role in controlling groundwater balance, microclimate and as a habitat for various species of organisms [3].
There are at least ten species of native fish that live on various trophic strata as herbivores, omnivores, and carnivores in Lake Maninjau [1]. Meanwhile, *Cyprinus carpio, Oreochromis* sp is a species of fish commonly cultivated in floating cages and produces organic waste around 111,899.84 tons from 2001 to 2013 [4].

Habitat loss and foodweb damage in aquatic ecosystems are caused by several factors, such as pollution, over-exploitation, climate change and invasive species. The pollution caused by the activity of floating net cages in Lake Maninjau is increasingly worrying, the condition is characterized by high concentrations of phosphorus and chlorophyll-a, the level of water brightness is very low and the trophic status of these waters is classified as severe eutrophic [1]. In addition, organic waste from fish feed and feces also covers the substrate as a habitat for benthic organisms and its decomposition decreases the concentration of dissolved oxygen [3], pollution by several types of heavy metals [5], and decreases the flora and fauna population including fish native in waters [6].

Fishing by using Fish Attraction Devices (FADs) and Fish Aggregation Devices (FAD) have been reported since 1978, and it is generally still a fixed FAD rather than drifting [9]. Some studies reported that the FAD could increase fish catch [7, 8, 9], change the prey fish behavior towards predators [10]. Yet, the concern about the dynamics of biota populations that grow on FADs as an attraction and design development related to the dynamics of fish populations [11] is still relatively very low.

In this study, a new design of such devices called Buoyant Fish Attractor (BFA) would be applied in Lake Maninjau. This BFA technology is a habitat engineering that consists of several types of artificial substrates which are mounted on a wooden frame with a fairly unique shape (inverted pyramid) and placed float in the lake's euphotic zone. In this zone, BFA devices could optimally utilize sources of sunlight, temperature, and nutrients for the growth of photo-autotrophic organisms such as aufwuch. Aufwuch growth on this substrate would attract the looking for food-fish to come and the BFA also functioned as a shelter for fish from predators. Thus, this study aims to develop a floating artificial substrate model, and to quantify its potential as a growing medium for the aufwuch community. The BFA is expected to be useful as *in situ* conservation technology to improve the native fish communities that are already endangered in Lake Maninjau.

### 2. Materials and Methods

#### 2.1. The BFA design and locations

The BFA design used in this experiment was in the form of an inverted pyramid made of a wooden frame with a size of about 200 cm in length, 200 cm in width, 80 cm in height and equipped with PVC pipes as buoys. Three types of substrates mounted on the BFA are a wooden frame, a plastic brush with a length of 40 cm and a diameter of 15 cm, and the palm fibers are placed in eight brick rosters (figure 1). Three BFA substrates were installed in the euphotic zone, which was about 20 meters from the shoreline and 2 meters in depth. Each BFA substrate was bound with four concrete anchors to maintain balance in the water.
Figure 1. Design of Buoyant Fish Attractor.

The trial location was in the southeast of Lake Maninjau precisely in Sungai Batang village, Tanjung Raya District, Agam Regency, West Sumatra. This location is about 100 meters from the mouth of the Ranggeh Stream, next to the rice fields and quite far from the location of floating cage cultivation. Some other activities around the location are fishing and tourist visits (figure 2).

Figure 2. Location of study (Source of Map: Google Map).
2.2. Measurements and sampling

Water quality sampling and measurement were carried out after a month of BFA installation, in July, August, September, and November 2018. The quality parameters measured were water temperature, pH, conductivity, turbidity, and TDS. Those were measured by using Horiba U-10 Water Quality Checker (WQC) and dissolved oxygen (DO) using YSI Dometer at a depth of 10 cm below the surface of the water. Meanwhile, the analysis of P-PO$_4$ concentrations use the ascorbic acid method, TN and TP with the destruction method [12], and N-NO$_3$ with the reduction of cadmium nitrate method [13].

To obtain aufwuch samples, each substrate was raised to the surface and brushed in a certain area. The sample was firstly filtered by using a plankton net (50 µm) and put into a 100 ml plastic bottle, then added 4% formalin and Lugol's solution as a preservative. Aufwuch sample examination was carried out at the Limnology Research Center-LIPI under a binocular microscope and the Nikon Diaphot 300 microscope. Morphological identification of aufwuch was based on several guide books [14, 15, 16, 17, 18, 19] and followed by counting the individual of number each species using Sedgewick Rafter.

2.3. Equations

2.3.1. The aufwuch density [12] :

\[
N = n \times \frac{V_t}{V_{src}} \times \frac{A_{src}}{A_a} \times \frac{1}{A_d}
\]

where, \(N\) = aufwuch density (individual/dm$^2$), \(Ad\) = surface area of brushed substrate (4 cm$^2$), \(V_t\) = volume of rinse water (50 ml), \(V_{src}\) = sample volume in Sedgewick Rafter Counting Cell (1 ml), \(Aa\) = observation area (10 mm$^2$), \(Asrc\) = area of Sedgewick Rafter Counting Cell (1000 mm$^2$), \(n\) = number of aufwuch individuals observed in 10 boxes (individual).

2.3.2. Diversity indexs ($H'$) [20]

The Shannon-Wiener index ($H'$) determines the level of species diversity in a community. The $H'$ value generally ranged between 0 and 5 with a high level of diversity if $H'$ > 3, moderate if 2 ≤ $H'$ ≤ 3, and low if 0 < $H'$ < 2.

\[
H' = - \sum_{i=1}^{S} p_i \ln(p_i)
\]

where, \(p_i\) = proportion of \(i\) th species, i.e. the number of individuals \(i\) th species per total number of individuals of all species.

2.3.3. Evenness indexs ($E$) [20]

The Pielou evenness index ($E$) illustrates the stability of a community. The species evenness index values ranged from 0 to 1. A value of $E$ <0.4 indicates low species evenness, 0.4 ≤ $E$ ≤ 0.6 indicates moderate species evenness, and $E$ > 0.6 indicates high species evenness. A value of $E$ = 0 means that the number of individuals possessed by each species is very much different, meanwhile $E$ = 1 means that the species are relatively evenly distributed or the number of individuals of each species is relatively equal.

\[
E = \frac{H'}{\ln S}
\]

where, $H'$ = Shannon-Wiener diversity index and \(S\) = number of species in the sample.
2.3.4. **Dominance index (D)** [20]

Dominance (D) is measured using the Simpson index with the formula:

\[
D = \sum_{i=1}^{S} \left( \frac{N_i}{N_s} \right)^2
\]

where, \( N_i \) = the number of individuals of \( i \)th species and \( N_s \) = the total number of individuals in the sample.

The D values range from 0 to 1. If D values ≤ 0.5 means that no dominant species or community is in a stable condition, whereas if 0.5 <D <1.0 means there is a dominant species or the community is in an unstable condition because ecological pressure occurs.

Dominance (d) was also measured by using the Berger-Parker index [21] with the formula:

\[
d = \frac{N_s}{N_T}
\]

where, \( N_s \) = number of individuals in the most abundant species and \( N_T \) = the total number of individuals in the sample.

An increase in the value of the Berger-Parker index accompanies the escalation in dominance and the decline in evenness. In a sample with a large number of species (> 100), "d" does not depend on the number of species, but if the number of species in the sample is smaller, the value of "d" will tend to decrease with an increase in the number of species. High dominance might show low diversity.

3. **Results and Discussion**

Overall, the presence of the aufwuch community shows a different structure and composition on each substrate. The community that grew well on woody media was benthic microalgae. This group was documented thirty-seven species of which twelve species are classified as Bacillariophyta, eleven species of Cyanophyta, twelve species of Chlorophyta and two species of Protista (table 1). The percentage of presence and species that dominate also varies as the Bacillariophyta group 55% dominated by *Synedra ulna* species, Cyanophyta 25% dominated by *Rivularia* sp., Chlorophyta 18% dominated by *Cladophora* sp. and *Stigeoclonium* sp. and Protista 2% (figure 3). The total abundance of benthic microalgae showed different peaks, the highest peak reaching 212,625 indiv/dm\(^2\) in November, followed by 193,188 indiv/dm\(^2\) in July, 182,500 indiv/dm\(^2\) in September and 179,500 indiv/dm\(^2\) in August. Meanwhile, the monthly average abundance of benthic microalgae is around 191,953 indiv/dm\(^2\) where Bacillariophyta occupies 104,250 indiv/dm\(^2\), Cyanophyta 47,953 indiv/dm\(^2\), Chlorophyta 36,094 indiv/dm\(^2\) and Protista 3,656 indiv/dm\(^2\) (figure 2). Benthic microalgae as primary producers in waters [22] are also the main source of nutrition for invertebrate animals in lakes [23].

| Table 1. Aufwuch composition in wood media in July, August, September, and November. |
| --- |
| **Taxa** | **July** | **August** | **September** | **November** |
| **Cyanophyta** |   |   |   |   |
| *Anabaena* sp. | 0 | 0 | 938 | 0 | 1125 | 0 | 0 | 0 | 750 | 0 | 3375 | 2250 |
| *Chroococcus* sp. | 0 | 750 | 0 | 0 | 563 | 0 | 0 | 750 | 0 | 1125 | 0 | 4500 |
| *Lyngbya* sp. | 8250 | 15750 | 4688 | 14625 | 28125 | 15000 | 750 | 18750 | 6000 | 5625 | 2250 | 4500 |
| *Merismopedia* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 750 | 0 | 1125 | 2250 |
| *Microcystis* sp. | 0 | 1500 | 0 | 0 | 0 | 1500 | 1500 | 3000 | 750 | 0 | 0 | 0 |
Aufwuchs that grew well on plastic brush media was the invertebrate group. This group was documented eleven species of which five species belong to Insecta, three species of Crustacea and one species each from Bryozoa, Annelida, and Mollusca (table 2). The percentage of Insecta presence around 72% was dominated by *Chironomus* sp., followed by Crustaceae 18%, Bryozoa 5%, Annelida 5% and Mollusca 0.3% (figure 3). The total abundance of invertebrates showed the same peak as benthic microalgae in November with the highest abundance up to 48549 indiv/m³, followed by 30149 indiv/m³ in
September, 15853 indiv/m³ in August and 15711 indiv/m³ in July (figure 2). Meanwhile, the monthly average abundance was around 27565 indiv/m³ where Insecta occupies 18377 indiv/m³, Crustaceae 5638 indiv/m³, Bryozoa 2147 indiv/m³, Annelida 1321 indiv/m³ and Mollusca 83 indiv/m³ (figure 2).

Table 2. Composition of aufwuch in plastic brush media in July, August, September, and November.

| Taxa          | July     | August   | September | November |
|---------------|----------|----------|-----------|----------|
|               | BFA1     | BFA2     | BFA3      | BFA1     | BFA2     | BFA3      | BFA1     | BFA2     | BFA3      |
| Insecta       |          |          |           |          |          |           |          |          |           |
| Chironomidae  | 991      | 2831     | 1840      | 1699     | 2689     | 2123      | 3255     | 6369     | 3397      |
| Chironomus sp.| 8917     | 13730    | 10333     | 8209     | 14579    | 4954      | 9200     | 33263    | 8068      |
| Ephemerotera  | 425      | 0        | 283       | 425      | 142      | 425       | 142      | 142      | 283       |
| Insect larvae | 0        | 142      | 0         | 0        | 283      | 0         | 0        | 0        | 142       |
| Zygoptera sp. | 142      | 283      | 0         | 142      | 283      | 142       | 425      | 708      | 991       |
| Crustacea     |          |          |           |          |          |           |          |          |           |
| Chydorus sp.  | 142      | 0        | 283       | 0        | 0        | 425       | 708      | 425      | 2123      |
| Cyprinotus sp.| 0        | 0        | 283       | 0        | 0        | 708       | 991      | 3255     | 0         |
| Dolerocypris sp.| 1415   | 991      | 2548      | 2406     | 2265     | 3255      | 3255     | 2406     | 1840      |
| Bryozoa       |          |          |           |          |          |           |          |          |           |
| Plumatella sp.| 142      | 0        | 283       | 425      | 0        | 142       | 0        | 283      | 991       |
| Annelida      |          |          |           |          |          |           |          |          |           |
| Tubifex sp.   | 991      | 142      | 0         | 708      | 142      | 991       | 1557     | 3255     | 2406      |
| Molusca       |          |          |           |          |          |           |          |          |           |
| Physella sp.  | 0        | 0        | 0         | 0        | 283      | 0         | 142      | 0        | 425       |

The invertebrate group still grew well on palm fiber but with a different composition. This group documented sixteen species of which six species of Insecta, six species of Mollusca, and two species each for Crustacea and Annelida (table 3). The percentage of Crustacean presence up to 85% was dominated by Chydorus sp. species, followed by Insecta 7%, Annelida 6% and Mollusca 2% (figure 3). The total abundance of this community showed different peaks, the highest peak was up to 966,667 indiv/m³ in August, followed by 840,432 indiv/m³ in November, 674,691 indiv/m³ in July and the lowest is 527,469 indiv/m³ in September (figure 2). The average monthly abundance was around 752,315 indiv/m³ of which Crustacea occupies 645,525 indiv/m³, Insecta 51,543 indiv/m³, Annelida 41,667 indiv/m³ and Mollusca 13,580 indiv/m³ (figure 2).
### Table 3. Composition of aufwuch in palm fiber media in July, August, September, and November

| Taxa             | July   | August  | September | November |
|------------------|--------|---------|-----------|----------|
|                  | BFA1   | BFA2   | BFA3      |          |
| **Insecta**      |        |         |           |          |
| Chironomus sp.   | 23148  | 12037   | 27778     | 41667    |
| Micronecta sp.   | 0      | 0       | 0         | 0        |
| Ephemerotera     | 0      | 9259    | 0         | 0        |
| Laccophilus sp.  | 0      | 0       | 2778      | 0        |
| Synaptonecta sp. | 0      | 0       | 0         | 0        |
| Zygoptera sp.    | 0      | 0       | 0         | 0        |
| **Crustacea**    |        |         |           |          |
| Chydorus sp.     | 18519  | 446296  | 575926    | 664815   |
| Dolerocypris sp. | 4630   | 296296  | 400000    | 43519    |
| **Annelida**     |        |         |           |          |
| Helopdella       | 0      | 0       | 3704      | 0        |
| **Molusca**      |        |         |           |          |
| Corbicula sp.    | 0      | 0       | 0         | 0        |
| Gyraulus sp.     | 0      | 0       | 8333      | 0        |
| Lymnaea sp.      | 0      | 0       | 0         | 0        |
| Melanoides       | 0      | 0       | 0         | 0        |
| Physella sp.     | 19444  | 0       | 2778      | 13889    |
| Thiara sp.       | 2778   | 0       | 926       | 0        |
| **Total Indiv/m3** | 109259 | 868519  | 1046296   | 808333   |


**Figure 3.** The abundance of the aufwuch community in several media at BFA.

**Figure 4.** Percentage of aufwuch's presence in several media at BFA.


Table 4. Aufwuch population indexes for three types of media in July, August, September, and November.

|                           | July  | August | September | November |
|---------------------------|-------|--------|-----------|----------|
| **Shannon-Wiener Index (H')** |       |        |           |          |
| Wood                      | 1.903 | 1.494  | 1.982     | 2.561    |
| Plastic brush             | 1.020 | 1.303  | 1.525     | 1.364    |
| Palm fibers               | 1.279 | 0.954  | 1.186     | 0.979    |
| **Pielou Index (E)**      |       |        |           |          |
| Wood                      | 0.648 | 0.496  | 0.650     | 0.835    |
| Plastic brush             | 0.523 | 0.627  | 0.694     | 0.610    |
| Palm fibers               | 0.631 | 0.459  | 0.525     | 0.433    |
| **Simpson Index (D)**     |       |        |           |          |
| Wood                      | 0.218 | 0.359  | 0.235     | 0.103    |
| Plastic brush             | 0.517 | 0.390  | 0.322     | 0.387    |
| Palm fibers               | 0.348 | 0.525  | 0.440     | 0.554    |
| **Berger-Parker Index**   |       |        |           |          |
| Wood                      | 0.356 | 0.546  | 0.394     | 0.183    |
| Plastic brush             | 0.696 | 0.559  | 0.507     | 0.586    |
| Palm fibers               | 0.454 | 0.660  | 0.620     | 0.721    |
| **Number of species**     |       |        |           |          |
| Wood                      | 19    | 21     | 21        | 22       |
| Plastic brush             | 7     | 8      | 9         | 9        |
| Palm fibers               | 8     | 8      | 10        | 10       |

Note: underlined = max-min value

The Shannon-Wiener index (H') shows the level of diversity of species in a community. Species diversity in a location depends on the number of species observed (species richness) and the total number of individuals. "H" values generally range between 0 and 5 with a high level of diversity if H > 3, moderate if 2 ≤ H' ≤ 3, and low if 0 <H' <2. The "H" value of this study ranges from 1.494-2.561 for wood media, 1.020-1.525 for plastic brush media and 0.954-1.279 for palm fiber media. These results indicate that the species diversity index of the aufwuch community that grows on wood media tends to be higher than those that grow on the plastic brush and palm fibers.

The species evenness index (E) ranges from 0 to 1. E value <0.4 indicates low species evenness, 0.4 ≤ E ≤ 0.6 indicates moderate species evenness, and E > 0.6 indicates high species evenness. Evenness refers to the relative abundance of species. Evenness index values will be high if all species have similar distributions, for example, similar population densities. The similar thing, where the value of "E" for the aufwuch community in the wood media ranged from 0.496 to 0.835 is higher than the community in the plastic brush and fibers which were 0.523-0.694 and 0.433-0.631, respectively. Species diversity and evenness may be related to species richness which is also greater, 16-24 in wood media compared to 6-10 and 6-12 in plastic brush and fibers.
The Simpson dominance index (D) was obtained 0.103-0.359 for wood media which turned out to be lower than the plastic brush and fibers media which were 0.322-0.517 and 0.348-0.554, respectively. The Berger-Parker dominance index clarifies the dominance that occurs, besides being more suitable for use in ecosystems that have been influenced by anthropogenic activity [21].

The dominance index value according to Berger-Parker obtained 0.183-0.546 for wood media, while plastic brushes and palm fibers were respectively 0.507-0.696 and 0.454-0.721. Here it could be seen that during this research, there was always a dominant species. The dominant species in each medium were *Synedra ulna*, *Cladophora* sp., *Stigeoclonium* sp., and *Rivularia* sp. for wood media, *Chironomus* sp. for plastic brush media and *Chydorus* sp. for palm fibers. *Synedra ulna* is a group of Bacillariophyceae or commonly known as Diatom and *Cladophora* sp. is a group of Chlorophyceae or green algae, both species are often found in freshwater with uncontaminated conditions. Meanwhile, *Stigeoclonium* sp. and *Rivularia* sp. of the Chlorophyceae and Cyanophyceae groups tend to be in slightly acidic waters and polluted by organic matter [24]. *Chydorus* sp. is a group of Cladocera that found in almost all littoral zones of the lake. Although this micro shrimp can swim in short distance, most of its life attached to the filament algae [25]. *Chydorus* sp. can survive in low light conditions and found in lakes with high eutrophication. Ecologically, Cladocera plays an important role in the food chain. Almost all the initial phases of carnivorous fish are highly dependent on these invertebrates [26].

The structure and composition of aufwuch show differences according to the type of media available at BFA. The taxonomic structure of benthic microalgae differs according to the type of substrate and the morphology of vegetation which also determines the species of algae that will grow [27,28]. The difference in the composition of the aufwuch in each media at BFA enriches the availability of live food in the euphotic zone at Lake Maninjau. An underwater video also recorded various fish at BFA and this might be correlated with the diversity of aufwuch at BFA, as one of BFA functions is a source of food for fish. According to [7] the floating FADs are related to pelagic fish populations.

**Table 5.** Lake water quality during the trial.

| Parameters   | Unit | July          | August        | September     | November      |
|--------------|------|---------------|---------------|---------------|---------------|
| Total N      | mg/L | 0.679±0.126   | 0.478±0.032   | 0.383±0.031   | 0.676±0.121   |
| Total P      | mg/L | 0.090±0.60    | 0.046±0.017   | 0.039±0.002   | 0.040±0.018   |
| NO3          | mg/L | 0.066±0.007   | 0.010±0.000   | 0.009±0.002   | 0.009±0.002   |
| PO4          | mg/L | 0.008±0.001   | 0.019±0.002   | 0.005±0.001   | 0.005±0.001   |
| Temperature  | °C   | 28.350±0.636  | 30.07±0.742   | 28.667±0.503  | 28.233±0.115  |
| pH           |      | 8.575±0.191   | 8.59±0.131    | 8.803±0.031   | 8.327±0.006   |
| DO           | mg/L | 7.258±0.059   | 8.48±0.282    | 6.39±1.188    | 7.747±0.157   |
| Conductivity | mS/cm| 0.133±0.000   | 0.068±0.003   | 0.133±0.001   | 0.106±0.001   |
| Turbidity    | NTU  | 3.543±0.429   | 19.878±13.500 | 5.491±1.102   | 8.367±7.390   |
| TDS          | g/L  | 0.086±0.000   | 0.045±0.002   | 0.087±0.002   | 0.065±0.367   |

Total phosphorus (TP) between 0.383 ± 0.031 to 0.679 ± 0.126 mg/L indicates that Lake Maninjau is classified as eutrophic waters so that the water is slightly alkaline with a pH of 8.803 ± 0.031 to 8.59 ± 0.131 reflecting the high photosynthetic activity in the waters. However, the water quality during trial is generally good for supporting the growth of aufwuch. The availability of nutrients will affect the abundance of autotrophic biomass in waters [29] and it is believed that the N: P ratio is potentially a limiting factor. If seen from the TN and TP values in table 5, the N:P ratio is around 11.2:1 or greater than 7:1 which means that phosphorus
will function as a limiting factor. If it is smaller than 7:1, nitrogen is likely to be a limiting factor in water [30].

4. Conclusion
Buoyant Fish Attractor (BFA) has the potential to support the growth of aufwuch as a new food source in the lake's euphotic zone. The variety of media installed on BFA technology affects the structure and composition of the aufwuch community.

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