

System development of fish attractor (sound and light combination) in fixed lift net fisheries

Tamrin Tamrin^{1,*}, Arham Rumpa¹, Muhammad Maskur¹, Bongbongan Kusmedy², Amir Yusuf³, Dika Rachmat Tamrin¹

¹ Department of ~ Polytechnic of Marine and Fisheries Bone, Bone Regency 92718, Indonesia

² Department of ~ Jakarta Technical University of Fisheries, South Jakarta, 12520, Indonesia

³ Department of ~ Politeknik Pertanian Negeri Pangkep, Pangkep Regency 90761, Indonesia

Abstract

Sound wave-based attractions at certain frequencies with a combination of lighting as a medium of fishing aids can attract the attention of fish to approach the fishing area. The use of a fixed lift-net fishing gear requires innovation that can help small-scale fishermen to increase the catch. The purpose of the study was to design fish-caller model with optimal sound waves when operated. The results showed that the design of the attractor which then named "APILBAG" was efficient enough to use because it could save the operational costs of light fishing and could be operated for 34 h. The sound wave used was recording and imitating the sound model of the sea water bubbles released by the fish species under the fixed lift-net, with sound frequency ranged from 40–1,800 Hz and the frequency peak was 753 Hz with relative amplitude ranges from 40 dB to 60 dB. At a distance of 1–5 m in the air. The frequency of the sound affected attractor was the fish to approach the attractor and combination of red-colored light on the attractor was quite effective to attract fish collected under the fixed lift-net.

Keywords: Attractor, Sound frequency, Light-fishing, Lift-net

Introduction

Currently, international attention is increasing on the effects of using human-made sound waves on fish and other aquatic organisms (Popper & Hastings, 2009). Reports from (Carriço et al., 2019; la Manna et al., 2021; Rountree et al., 2006) state that more than 800 fish species worldwide have been identified as having sound, which plays an important role as a means of communication between species, so it is necessary to studied

extensively (Ladich, 2019; Ladich & Winkler, 2017). Fish species produce sounds to interact with each other, have sex/mate, find locations, defend themselves, avoid predators, or as natural cues (Amorim et al., 2008; Longrie et al., 2013; Marques et al., 2013). The development of manufacture of electronic aids use in the field of fisheries, especially fishing, is increasing. The development of science and research carried out related to the engineering of fishing aids encourages traditional fishermen to study these tools to increase their catches on a daily basis.

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*Corresponding author: Tamrin Tamrin

Department of ~ Polytechnic of Marine and Fisheries Bone, Bone Regency 92718, Indonesia

Tel: +62-812-4214152, Fax: +62-481-2920204, E-mail: tamrinpoltekkpbone@gmail.com

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In Indonesia, fish attractor tools have begun to be researched and developed by the government and the private sector. Some fish-calling devices that have been developed imitate the sound of species or groups of fish that are experiencing pain as bait. These tools are: fishing equipment, alpine and electrofish, each of which has different specifications (Rosana & Suryadhi, 2017). Attractors based on sound waves at a certain frequency work as how fishing gear is used to attract fish. Rosana & Suryadhi (2017) tested electronic fish aggregating devices (FADs), with attractors in the form of light (LED, 5 Watt) and sound (10–1,000 Hz, 1–20 kHz, and 20–100 kHz). This experiment managed to collect an average of 4.60 kg of fish for an hour's installation time, and an average of 4.07 kg for half an hour's installation time. In the same year, testing of electric fish attractor (EFA) at a frequency of 10–1,000 Hz resulted in bigeye trevally fish (*Caranx sexfasciatus*) and black sword fish (*Trichiurus* sp), while EFA with a frequency of 1,000–20,000 Hz had the potential to catch yellowfin tuna, *Thunnus albacares* (Rosana & Suryadhi, 2017). Another study revealed that an electric fish attractor used sound frequencies of 1,000–5,000 Hz, 6,000–10,000 Hz, 11,000–15,000 Hz combined with 3 fishing line units resulted in catches in the form of tuna (*Euthynnus affinis*), mackerel (*Rastrelliger brachysoma*), swordfish (*Xiphias gladius*), great barracuda (*Sphyrna barracuda*), and yellow tail fish (*Caesio cuning*) (Yusfiandayani et al., 2018). One of the effective fishing gear for collecting fish is fixed lift-net fishing gear which generally uses lighting media to collect fish in certain areas. The principle of catching is the use of the behavioral response of fish that are attracted to light sources in the form of phototaxis positive (Sudirman et al., 2019).

The operation of the fishing gear is only carried out at night. In this case, several studies have shown that the use of lights (light fishing) as the main attraction in lift-net fishing gear is very effective in collecting schooling fish that are attracted to light sources in a fishing area (Adam et al., 2018; Sulaiman et al., 2006). On the other hand, the use of lamps certainly requires complex lighting installations and also require no small amount of cost to operate them. In addition, the cathabel condition of the lift-net area is very narrow, so it requires a light source that is able to concentrate fish species under the lift-net before hauling. The use of lift net fishing gear is an interesting phenomenon to study, because the presence and accumulation of fish around the light source may be caused by factors other than the influence of light intensity. The phenomenon of fish schooling bubbles sound with a certain frequency causes the

accumulation of schooling fish in the cathabel area below the lift-net surface. In developing and streamlining lift net fishing gear, innovations that can assist fishermen in applying simple, inexpensive and easy fishing aids are needed in order to increase fish catches. One technology that needs to be developed in the application of fishing aids is an attractor based on sound waves at a certain frequency, which is installed in the waters.

Based on this phenomenon, the purpose of this study is to identify how the design model of fish calling equipment with optimal sound waves is operated and to determine the tone and frequency of sound waves on fish attraction in fixed lift-net areas with no lighting treatment and lighting combination treatment. In fact, the available information relating to this study is limited. Therefore, experimental fishing research needs to be carried out and is expected to be useful information for the further progress of capture fisheries. One alternative to achieve the research objectives in order to understand and observe the relationship of sound waves to the behavior of fish below sea level is to use a passive acoustic approach (PAM), such as recording and acoustic analysis models (Carriço et al., 2019; Kurnia et al., 2017) and recording sea water bubbles with video (Rountree et al., 2018). We tried to combine echosounding and experimental fishing techniques in this study.

Materials and Methods

The location of this research was carried out in a pond in the laboratory room of the Polytechnic of Marine and Fisheries Bone (4°28'44.56 "S–120°22'50.19"E) and in the waters of Bone Bay, South Sulawesi-Indonesia (4°29'56.70 "S–120°24'1.16"E) with Fixed Lift Net fishing gear (Fig. 1). This type of research was experimental fishing with an acoustic approach that went down directly following the fishing operation. The methodology used in solving the problem was to make a sound wave-based fish calling device and test it on a fixed lift-net fishing gear.

The attractor is constructed using two models; further specifics regarding the building model and its electrical components are illustrated in Fig. 2.

The stages of the research were carried out for 6 months. The initial research was carried out with a theoretical study of sound wave-based fishing gear and the use of lift-net fishing gear. Next, the design of the attractor was carried out. The frequency measurement of sound coming from water bubbles, whether there was a fish reaction to sound and the sound frequency, was tested in the laboratory and fish ponds by

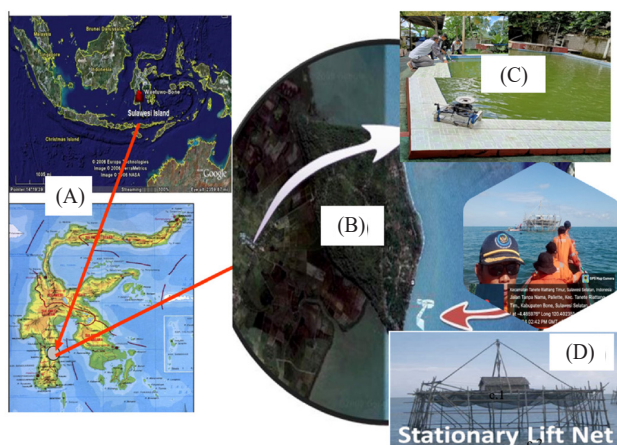


Fig. 1 . ~ ~ . (A) Map of the research location, (B) location of research containers, (C) fish pond basin, (D) hook and line angling equipment.

lowering the attractor into the water. The testing phase in the waters was carried out to observe the fish's response to sound with no lighting treatment and the combination of lighting treatment on the lift-net.

The tools used as experimental fishing media were one container like a fish pond, which acted as a laboratory medium to test the fish's response to sound waves, two lift-net units and two attractor units. The fixed lift-net fishing gear used in this study measured $8 \times 8 \times 7$ m, with a depth of water as a fishing ground, which was around 3–5 m, depending on the tides. The placement of the fish-calling atrator was placed in the center, which was immersed in the water column. Field experiment was divided into one measurement category in the afternoon and evening. In this study, first the attractor was placed under the lift net, then the measurement of the distance of fish

attraction from the attractor was carried out horizontally. In this case, the zone of interest was determined in advance, namely in areas with a distance of 0–5 m, 5–10 m, 10–15 m, and > 15 m from the attractor with a transect model.

Measurement of sound frequency using a sound meter free android application while the intensity of the light emitted by the attractor was measured with a using a lux meter with specifications: AS803 Item, weight: 85 g, measuring Range: 1 to 200,000 Lx, sampling rate: 1.5 times/s, Accuracy: $\pm 4\% + 10$, and temperature change: $0.1\%/^{\circ}\text{C}$ with ten measurements per group ($N = 10$). Monitoring the behavior of fish in the sea used one unit of underwater fishing camera 50 m/360 degrees Eyoyo (Guangdong, China) brand fish finder type cr110-7b. Two units of Garmin (Olathe, KS, USA) brand fish finder, Type: GPSMAP 585, with frequency specifications: 50/200 kHz, Output power: 500 W (RMS), 4,000 W (peak to peak), Voltage: 10–36 VDC and maximum depth: 1,500 feet by installing a transducer under the sea that could be directed vertically and horizontally. The stages are illustrated in Fig. 3.

Analysis results of fish behavior data related to movement patterns and distribution of fish movement areas were presented in the form of images, graphs and then discussed descriptively in order to find models of fish patterns and distributions due to sound waves. In addition, an analysis of the volume of fish caught using an attractor without light and an attractor with a combination of sound and lighting was also carried out.

Results and Discussions

Designing and building a fish attractor

The results of making an attractor based on field experiment can be seen in Table 1.

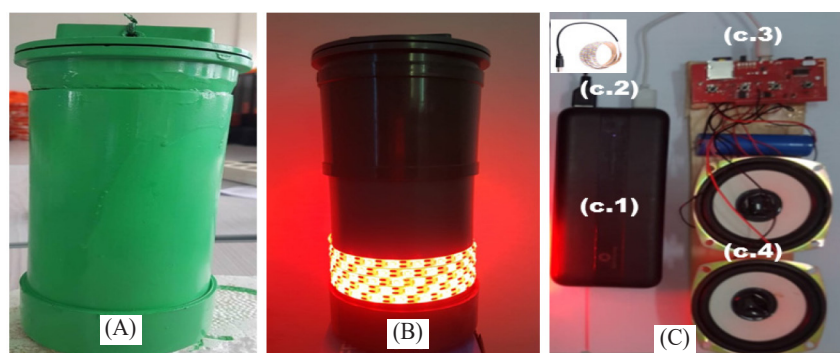


Fig. 2. Title. (A) Sound Attractor, (B) combination of sound Attractor and red light, (C) electrical components inside the attractor, including representative conditions: (1) Power source/Power bank, (2) LED Strip DC 5 Volt USB, (3) Mainboard sound, (4) Speaker.

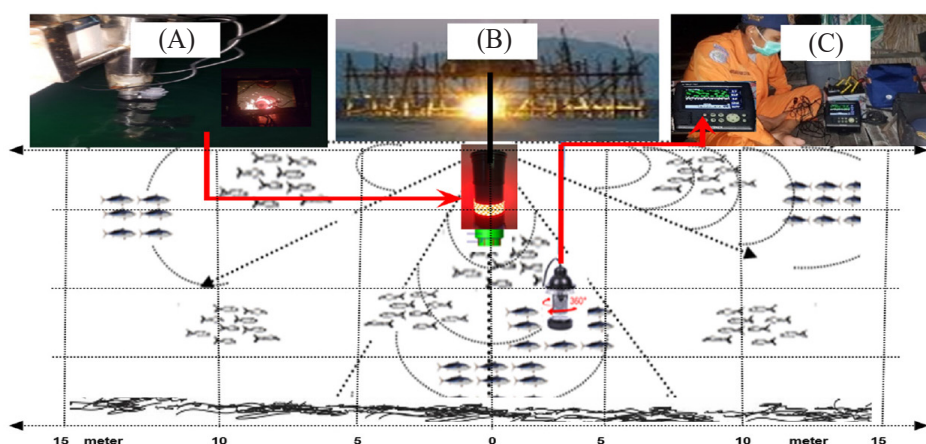


Fig. 3. Depiction and Phases of the Sound Attractor Installation Location within the construction sector of the pole-and-line bagan. (A) Phases of installing attractor components, (B) Activating the attractor, (C) Observing the locomotion of fish beneath the lift net.

Table 1. Design of Fish Attractor

Item Variable	Observed Data	Testing Result
Electric Component	• Power bank 10,000 mAh and 20 Mah with output 5 V. • Mainboard durability. • Speaker power/sound output wave. • Light intensity.	• 34 h/60 h by supplying current to the lights and sound speakers. • Untested (Trial Stage). • -40 to -60 dB at a distance of 1–5 m, with sound output was on mode in the air. • 2 Lx at 1 m in the air.
Case attractor design	• Tool weight and dimension. • Durability of the attractor coating/watertightness. • Battery usage/replacement.	• 2 kg. • Very resistant and waterproof by using Paralon Pipes. • Practical and easy to use.

Determination and measurement of pitch and sound waves (seawater bubble tone) on fish attraction

Tone and sound wave measurements were performed under controlled settings in the fish pond laboratory, while the assessment of tone and frequency to evaluate the attractiveness of fish species to tones and sound waves was undertaken in the lift net area.

Test under controlled condition (Laboratory)

The tested tones and sound waves were those produced by seawater bubbles. The recording procedure utilizes a device linked to a hydrophone, with the output stored in audio format (wav). Moreover, the processing is conducted using audio software. Fig. 4 illustrates the average readings recorded by the sound meter application for Android.

Further details regarding the measurement of tone and frequency of sound waves (Laboratory Scale) are presented in Table 2.

Field experiment (lift net fishing gear)

Following the laboratory-scale assessment of tones and frequencies, field-scale trials are conducted in the baited bagan region to evaluate the attractiveness of fish species to these tones and sound waves.

Attractor experiment without lighting in lift net area

The initial stage of observation was carried out to see the presence of schooling fish reaction attracted and associated with the “APILBAG “ attractor vertically under the lift net. Illustrated in Fig. 5.

Further data regarding the measurement of tone and frequency of sound waves (Laboratory Scale) are presented in Tables 3 and 4.

The frequency of the sound generated by sea water bubbles was multi-frequency, where the frequency of the sound produced ranged from 30 to 1,800 Hz, with the average range of dominant sound values occurring at frequencies of 43, 473,

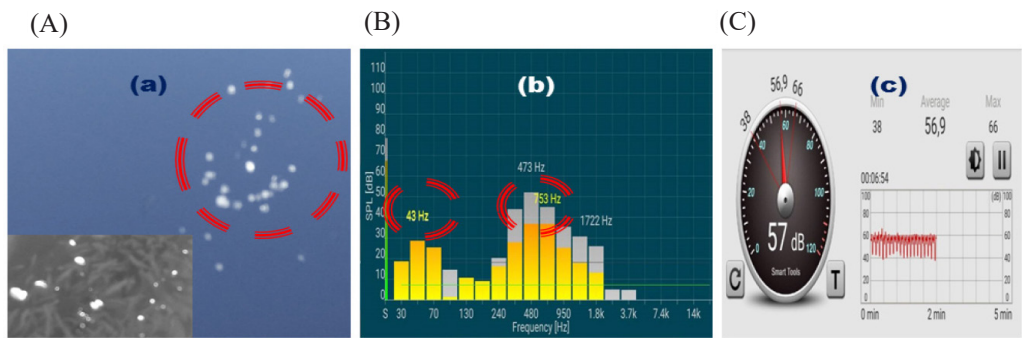


Fig. 4. (A) Model of Seawater Bubble Appearance, (B) frequency of sound produced by seawater bubbles, (C) sound pressure produced at a distance of 1 m from the seawater bubble.

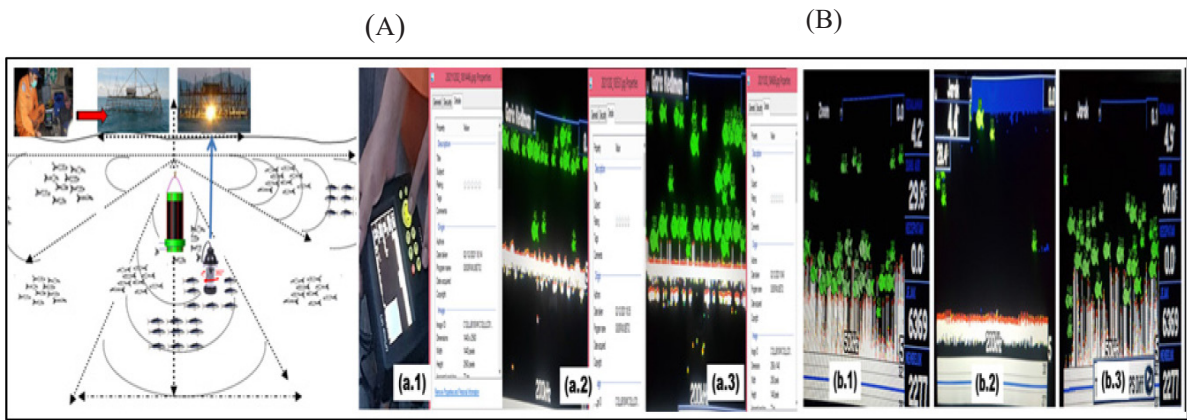


Fig. 5. Observations. (A) Reaction and arrival time of fish, (B) fish response to the elevation and descent of the attractor within the water beneath the lift-net.

Table 3. Measurement of tone and frequency of sound (Fig. 3A)

Observation (Fig. 3A.1)	Observation (Fig. 3A.2)	Observation (Fig. 3A.3)
• Early Drop at 18.00, Fish were under lift net (fish not detected/zero).	• At 18.30, the average fish started to react to the attractor with moderate the sound waves .	• At 19.45, the average fish started to react to the attractor with high sound waves .

Table 4. Measurement of sound tone and frequency on the up and down condition of the attractor (Fig. 3B)

Observation (Fig. 3B.1)	Observation (Fig. 3B.2)	Observation (Fig. 3B.3)
• Attractor lowering to the water (fish were detected approaching the attractor in large numbers).	• Attractor raising from the water (fish were detected to disappear /away from the attractor).	• Attractor lowering again (fish were detected approaching the attractor in large numbers).

753, and 1,722 Hz, which could attract a wide variety of species existing in the cathabel area fixed lift net. These frequencies are in accordance with the research conducted by (Yulianto et al., 2018). The sound spectrum in leaftail croaker fishing was the initial study of making FADs. In this case, there was a relationship between the frequency (Hz) and the relative amplitude of the sound. The frequency of the sound of the

bubbles that attracted the fish's attention was at 37.83 to 1,795 Hz, while the recorded sound amplitude was -54.97 dB.

The results of this study are similar to those of (Rosana & Suryadhi, 2017). In his research, in the range of sound waves ranging from 500 to 1,000 Hz, fish responded to sound by approaching the PIKNET tool. This is confirmed by research of (Fay & Popper, 2000; Kasumyan, 2008), who state that the

Table 5. Measurement of fish reaction to tone and sound waves

Observation (Fig. 3A)	Observation (Fig. 3B)
• At night, fish approaching the attractor in moderate numbers. • Fish came in and went out of the lift net cathable area in moderate numbers per individual and sometimes in groups.	• At night, fish approaching the attractor in large numbers. • Fish came in and went out of the lift net cathable area in moderate numbers per individual and sometimes in groups.

maximum hearing sensitivity frequency range for most fish is between 100 and 1,000 Hz, with an upper limit of frequency at 2,000 Hz. Amorim et al. (2003) revealed that fish species emit sound frequencies below KHz, the majority of fish species are known to detect sounds below 50 to 500 Hz or even 1,500 Hz. A small number of fish detects sounds up to more than 3,000 Hz. The reality in the field shows that the frequency issued by the attractor is also in the average range of 43 and 473 Hz. The difference in the results of these studies may be due to the different species of fish studied. This is in line with the finding of (Adamska et al., 2000), that each fish species had a different sound frequency, amplitude, duration, number of pulses per signal, and the average number of pulse repetitions emitted. This study also showed that the dominant and highest frequency that appeared in the sound of sea water bubbles was around 753 Hz. This is not much different from the sound frequency emitted by the yellow croaker (*Pseudosciaena crocea*), where the peak frequency of the fish was 800 Hz. In contrast to these findings, (Yulianto et al., 2018) said that leaftail croaker fish had a peak frequency of around 732.13 Hz.

The response of the fish being attracted and approaching the “APILBAG” attractor was probably due to exposure to sound waves that were favored by fish species in the fishing gear area. Thus, the spectrum data above can be used as a reference for the development of fish calling tools. This is in line with (Brierley et al., 1998) statement that sound is very important to behavior when communicating. Some types of fish can emit various sound amplitudes to communicate in the exchange of information. Information carried from sound signals describes a state of threatening danger, an aggressive state to scare the enemy. Some fish species use sound as a medium for underwater communication. The use of sound waves as a means of communication for fish has several advantages, namely: it can propagate long distances without being affected by the presence of coral reefs or coral reefs; and it is not affected by the brightness of the waters, so certain fish species are able to communicate using sound in the dark.

Attractor experiment while the combination of sound waves

and lighting in the lift-net area was applied

The next step was to analyze the comparison of the fish's reaction towards the sound attractor without lighting (Fig. 1A) and the combination of sound attractor and lighting (Fig. 1B). Finally, measuring the comparison of fish volume caught used two fixed lift nets that were close to each other at the same time (N = 10). Table 5 presents the measurements of fish responses to tones and sound waves.

The research conducted was still relatively simple, although fish species in the fixed lift net area were attracted to approach. In this case, the area of the fixed lift net cathable area was quite narrow and not wide enough. In addition, the experiments carried out only used tone and sound frequency attractors. Furthermore, the reaction duration of the arrival of fish and the volume of fish caught had not been optimized properly. Therefore, a combination of lighting was needed to support the ability of “APILBAG” to attract fish attention, one of which was by adding light in fixed lift net fisheries. The weakness of fixed lift net fishing gear which generally uses lighting is that there are few fish around the fishing area. Thus, the possibility of fish species that will gather when the lighting is turned on will also not be much. Therefore, additional fish collection tools around the fixed lift-net area need to be provided during the day and night, so that the volume of fish can increase. One of the steps that can be taken is to turn on the “APILBAG” attractor as a medium for attracting fish during the day. Fig. 6 illustrates the comparison between sound attractors and attractors that combine sound and light and Fig. 7 show the species and percentages of catches.

The experiment results of the combination of sound and light attractor based on the duration of fish arrival and the fish volume caught showed a shorter duration and a larger volume. This happens because of the additional light aids. According to (Nguyen & Winger, 2019), light is one of the most successful elements in attracting fish species at night to the cathabel area before fishing is carried out, because sight is the most dominant sense in feeding and other activities. According to studies by (Nuridin et al., 2007; Parmentier & Fine, 2016), light intensity is the main factor that directly affects fish behavior patterns.

The addition of a red 5 V USB DC LED Strip light with a light intensity in the range of 2 Lx at a distance of one meter could be said to be affordable. In addition to only requiring a very small electric current, fish could also be fully concentrated in the cathabel area under the fixed lift net. To concentrate fish in the catchable area, with lower light intensity using red light at the final stage of catching, it is proven that schooling fish can be optimally concentrated below the surface of the fixed lift-net.

The research of (Sulaiman et al., 2015) stated that fish species such as mackerel scad fish (*Decapterus* sp) are very sensitive to light and tend to be around 0.2–5 Lx illumination. Fish need light to gather and avoid bright light, which is in the vicinity of not too bright lighting. The design of the “APILBAG” attractor during experimental fishing was going well. This was indicated by the reaction of the fish approaching the attractor. However, further studies need to be done regarding the electrical durability of the mainboard. It is also necessary to measure the distance range based on the sound amplitude towards the fish reaction at a certain distance. In addition, more in-depth observations regarding the composition/species of fish attracted to the “APILBAG” attractor based on the frequency released also need to be carried out. By knowing the frequency and amplitude of the sound of sea bubbles, FAD attractors based on the same sound frequency and amplitude in water can also be developed. Thus, schooling fish are attracted not only pelagic fish, but also domestic fish.

Conclusion

The “APILBAG” attractor system is sufficiently efficient to reduce light fishing operational costs and effectively draws fish to congregate beneath the lift-net, operating continuously for 34 h, as evidenced by the fish's response to the attractor. In the creation of sound-fish aggregating devices, particularly for pelagic and demersal fish aggregation, the integration of attractors with light yields a superior catch composition compared to attractors used without light.

Competing interests

No potential conflict of interest relevant to this article was reported.

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Availability of data and materials

Upon reasonable request, the datasets of this study can be available from the corresponding author.

Ethics approval and consent to participate

Not applicable.

ORCID

Tamrin Tamrin	https://orcid.org/0009-0008-0064-4179
Arham Rumpa	https://orcid.org/0009-0009-5783-8182
Muhammad Masykur	https://orcid.org/0009-0004-8704-9727
Bongbongan Kusmedy	https://orcid.org/0009-0006-7557-7017
Amir Yusuf	https://orcid.org/0000-0000-0000-0000
Dika Rachmat Tamrin	https://orcid.org/0009-0001-5592-1021

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