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# DESIGN AND IMPLEMENTATION OF PIEZOELECTRIC TRANSDUCER TO IMPROVE FISHING EFFICIENCY ON BAGAN BOAT

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## ABSTRACT

*The decline in fish catches among bagan boats in Labuhan Jambu, Sumbawa District, is caused by overfishing, illegal fishing, and climate change. To address this issue, technological innovations such as sonar systems that emit acoustic signals to attract fish are necessary. This study aims to design piezoelectric transducers and transmitter drivers capable of emitting acoustic frequencies that effectively attract fish around bagan boats, thereby increasing catch yields. The methodology included system design, fabrication, and testing. The developed transducer operates across a frequency range of 1–75 kHz, and field tests were carried out by installing the transducer beneath the bagan boat. Results indicated that fish responded quickly to frequencies between 500–800 Hz, as evidenced by the appearance of bubbles on the water surface, suggesting fish presence. The main species caught included pelagic fish, skipjack, and squid. Fish catches increased by approximately 2–3 times compared to conventional methods. The transducer and transmitter driver using piezoelectric materials were successfully developed and functioned effectively. The final prototype was capable of emitting acoustic frequencies from 1 Hz to 100 kHz. This innovation demonstrates the potential of piezoelectric transducer technology to significantly enhance fish catches in bagan boat operations in Labuhan Jambu.*

***Keywords:*** *Driver transmitter, bagan boat, piezoelectric, transducer*

## INTRODUCTION

Teluk Saleh is located in the Sumbawa district of West Nusa Tenggara Province, Indonesia. The waters of Teluk Saleh are directly connected to the Flores Sea and are semi-enclosed (Yulius *et al.* 2017). The economy of Teluk Saleh depends on the fisheries sector, which attracts local fishers (Efendi *et al.* 2021). Bagan boats are one kinds of fishing gears that are widely used to catch fish in the waters of Teluk Saleh. The largest number of fishing vessels in Teluk Saleh waters is operated in Labuhan Jambu, which is located in the Teluk Saleh area. The bagan itself uses lights as attractors to attract schools of fish, and nets that are lowered vertically to the bottom of the waters or in other words the lift net system. Over time, problems have arisen in the bagan fishery in the waters of Teluk Saleh, where the catch has decreased significantly. Therefore, an improvement is needed in fishing using this bagan boat. The low productivity of fishermen is generally caused by low skills and knowledge as well as the use of fishing gear and boats that are still simple, so that the effectiveness and efficiency of fishing gear and boats are not optimal. One solution is to continue to develop tools to lure fish that are clustered to approach the bagan boat. An innovative tool can be developed by utilizing the frequency signal from an active sonar transducer to lure schooling fish to approach the boat. Active sonar transducers emit acoustic signals, or in other words sound waves, that match the frequency of the fish to be caught.

This fishing tool can make fishing effective in addition to the use of lights. Frequency transducer-based tools can produce specific sound frequencies to attract fish to gather at the sound source. The use of this tool will help increase the catch of bagan boat fishers, and the benefits that can be obtained are the ability to determine the fishing area and the type of fish that will be caught Sugiyanto *et al.* 2019. Piezoelectric materials have long been used as transducers in sonar systems because of their ability to convert electrical energy into mechanical energy and vice versa Mowaviq *et al.* 2018. Acoustic energy generation with piezoelectric materials has several advantages, including resistance to water pressure, a working frequency range from Hz to MHz, easily adjustable transducer dimensions, and more precise and stable vibrations Carter and Kensley 2022. Therefore, piezoelectric materials are suitable for use in transducer fabrication.

The manufacture of active sonar with piezoelectric transducers requires several considerations, such as material selection, assembly techniques, and precise and complex controls. With the development of advanced technology, the selection of very small materials such as semiconductor materials is very useful as technological advances in active sonar manufacturing can help improve the accuracy and efficiency of the system. Semiconductor technology has revolutionized the design and performance of active sonar transducers in recent years. The use of semiconductor components such as transistors, capacitors, resistors, diodes, ICs, and MOSFETs by researchers and developers allows for the creation of transducers that are more complex, small, sensitive, and accurate.

The purpose of this study was to design and develop a sonar system that utilizes acoustic sound frequencies as a fish attractant on a bagan boat. This study aimed to determine the most effective sound frequency range for attracting fish around the bagan boat and to test the performance of piezoelectric transducers and transmitter drivers in emitting acoustic signals that can increase the fish catch. Thus, this study is expected to provide an innovative solution for improving the efficiency of fishing on bagan boats through the proper utilization of sonar technology.

## METHODS

This research is an experimental study that includes the manufacture of piezoelectric transducers and sonar transmitters. Testing of the equipment was carried out on a bagan boat and then observations were made of the fish response to the emitted acoustic waves. The study was conducted in the waters of Teluk Saleh, Sumbawa Regency, Labuhan Jambu village from May to July 2024.

### 1. Piezoelectric Transducer

Piezoelectric transducers have been widely used as sound-producing materials for various types of acoustic applications, such as fish markers, sonar, position detection, medical imaging, and micro-mixing Kalimuldina *et al.* 2020. Much previous research has focused on improving the performance of transducers in terms of sensitivity, bandwidth, and durability. The use of composite materials and beamforming techniques has been a trend in the development of transducers for fish detection in recent years. The challenges of varying channels have been overcome using MSK modulation and adaptive equalization techniques in underwater communications. Future research should focus on creating multifunctional transducers that can be used for both detection and communication, and integrating transducers with autonomous systems.

The beam pattern function significantly affects the ability of an acoustic signal to emit sound frequencies. The beam pattern is the beam pattern produced by a transducer composed of several elements when an acoustic signal is sent. Most transducers and acoustic arrays have beam patterns that are frequency-dependent. If the wavelength ratio exceeds the array length, the beam pattern expands, Huang 2017. The beam angle obtained from the piezoelectric array can be determined using the following equation:

$$\theta = \frac{\lambda}{L} \quad (1)$$

With:
$\lambda$ = Wavelength
$L$ = diameter of the piezoelectric *array*

$$\lambda = \frac{c}{f} \quad (2)$$

With:
$c$ = The speed of sound propagating in the water column
$f$ = frequency used.

Determining the range or signal propagation in the water column, as described by Manik *et al*. (2017), can be performed using the following equation:

$$B(\theta) = 20\log\left[\frac{2j1(\pi\frac{D}{\lambda})}{\pi\frac{D}{\lambda}\sin\theta}\right] \quad (3)$$

With:

($\theta$) = The width of the angle produced by the sound wave emission from the transducer perpendicular away from the transducer

$D$ = total width of the transducer,

$\lambda$ = wavelength of the emitted sound

$J_1$ = first-order *Bessel* function

The fabrication process begins with the creation of a beamforming design for the transducer. Equation 3 was used to design the beam pattern, where *B(θ)* is the beam width, D is the overall diameter of the transducer, λ is the wavelength, and Bessel function *j1*. All types of arrays can now be used for specific applications due to improvements in electronic device technology. After the beamforming design is made, the piezoelectric transducers are designed according to their function and purpose as acoustic signal generators.

The parameter data were created using *Matlab software*, especially in determining the distance between elements, which is half λ or 1 cm in the design. The transducer design uses one set of arrays consisting of nine ceramic-type piezoelectric elements, each element made in parallel, and a total of nine ceramic piezoelectric pieces are used. The arrangement of the piezoelectric is assumed to be LEDs arranged in parallel so that each piezoelectric pole is supplied with voltage and ground (Negara *et al.* 2022). Figure 1 shows the piezoelectric material and the arrangement of the array of piezoelectric.

## 2. Transmitter Design

The manufacturing of sonar transducer transmitters is crucial in the development of advanced sonar technology. Transducer transmitters are key components of sonar systems that generate sound waves that are transmitted into water. Therefore, the quality and performance of the transducer transmitter directly affect the sonar system's ability to detect, map, and understand the underwater environment.


Figure 1 Piezoelectric materials and array arrangement

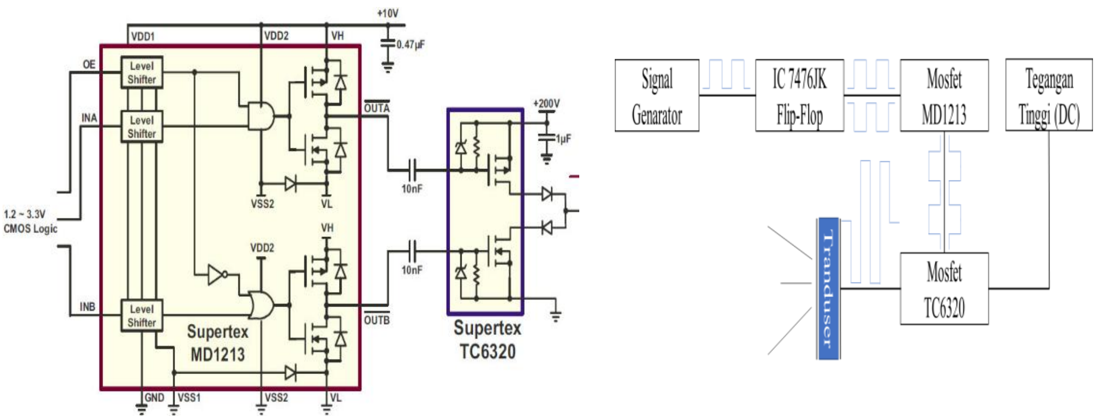


Figure 2 Transmitter Driver Circuit and Output Signal of Each Mosfet

Table 1 Tools and Materials

| No. | Tools and Materials | Usability |
|---|---|---|
| 1 | Piezoelectric | As the main material for making transducers |
| 2 | Cable | To connect between components |
| 4 | Arduino | As a microcontroller in this research |
| 5 | Multimeter | As voltage and current testing of each component |
| 6 | Oscilloscope | For testing and viewing wave frequencies |
| 7 | GPS | As coordinate instructions |
| 8 | Box | As a container for equipment |
| 9 | Battery | As a Voltage power source |
| 10 | Easy EDA Software | As a test of the overall design |
| 11 | Arduino IDE software | Microcontroller Programme Software |
| 12 | IC 7476JK | Frequency signal converter into two channels |
| | Mosfet MD1213, and TC6320 | Connection or gate in sending acoustic signals from the module |
| 16 | USB Cable | Arduino connector with laptop |
| 17 | Matlab Software | As a transducer simulation |

Through continuous research and development in the manufacturing of sonar transducer transmitters, we can enhance the capabilities of sonar systems for a wide range of applications, from underwater surveying to ship navigation, marine environment monitoring, underwater object detection, and using the emitted frequencies to lure shoaling fish, among others. Thus, a deep understanding of the background of sonar transducer *transmitter* manufacturing is key to developing innovative and effective sonar technologies.

The selection of the MD1213 MOSFET and TC6320 MOSFET pair is one of the best and most appropriate solutions for transmitter assembly. The ability of this MOSFET is very good for development in advancing in the field of sonar, the ability of this MOSFET is due to the input and output logic of this MOSFET is very easy to program using any microcontroller, MOSFET MD1213 has three inputs, namely INA, INB, and OE where two inputs will be entered into the desired frequency signal up to Mhz frequency while the OE input is used to adjust the desired signal output. The output of the MD1213 MOSFET was the input of the TC6320 MOSFET pair to increase the signal amplitude through other channels. In addition, the connections between the components are integrated, as shown in Figure 2.

The transducer transmitter must be able to generate sound waves with a frequency, amplitude, and radiation pattern that suit the needs of a particular sonar application, such as transmitting acoustic waves with the frequency of a shoaling fish. Therefore, the manufacturing process of the transducer transmitter involves proper material selection, careful acoustic design, and precise manufacturing. Figure 3 shows the signal output of each MOSFET.

## RESULTS

The manufacture of transducers and *transmitters* has been successfully made in luring fish to increase catches on bagan boats, and the following design was obtained.

### 1. Transducer Design Results

The simulation results using *Matlab software* (Array Analyzer) obtained a simulation of the transducer design with a 3 × 3 *array, as shown* in Figure 1. In the simulation, the beam angle of the transducer was 38.18$^{o}$ with a frequency of 70 kHz. The angle of emission was very influential on the frequency, where the higher the frequency, the greater the angle of emission, and if the frequency of emission was small, then the angle of emission was smaller. However, even though the angle of emission was small, the power of the small frequency of emission was greater than that of the high frequency. The simulation results are shown in Figure 3.

The ability of acoustic signals to transmit signals is strongly influenced by the beam pattern function. A beam pattern is a beam pattern generated by a transducer composed of several elements at the time of transmission Zhang *et al*. 2017. If the signal inputted to the element has the same frequency and amplitude, the resulting signal will amplify each other into a main lobe and the rest into a sidelobe. One of the elements that affects the beam pattern is the wavelength Huang 2017, which is the distance between elements and frequency. Most acoustic transducers and arrays have beam patterns that are frequency-dependent.

After obtaining the simulation results, the material was printed using the simulation results. As shown in Figure 4, the piezoelectric material was arranged on a plain PCB surface that had been coated with tin and then heated to glue between the material and the piezoelectric material. After the lower surface was put together, the upper surface was connected using a cable. On the back, a metal material is added, which functions to hold the acoustic waves radiating in two directions; this material holds the direction of the acoustic wave emission to radiate backward and only radiates forward. This aims to increase the vibrational effect produced by the transducer Li *et al.* 2015. The advantage of this method, if applied to the transducer, is that it will increase the vibration effect, thereby increasing the acoustic energy owing to the addition of vibrational potential power to the transducer. In addition, all components must be covered with materials that can withstand water entering the component; therefore, the selection of materials to cover must be very concerned. Figure 4 shows a material that has been covered with waterproof material, namely with a glue gun and then coated with epoxy glue on the side of the circle to avoid the possibility of water entering through the gap from the glue gun that has covered the component.

## 2. Transmitter Design Results

In assembling the transmitter driver, the first step is to determine the components to be used, and to create the connection path between components using *EasyEDA software* to test the connection between components and print on the PCB. After the design results come out, then the printing of the design results that have been made is carried out after the PCB printout is complete, the components are soldered with the printing results of the PCB, in the unification of the components on the PCB, skill is needed because the components used use many very small SMD components.

The signal from the generator known as Pulse Width Modulation (PWM) plays an important role in sending the signal to the transducer. PWM is a signal that is set in the ‘on’ and ’off’ modes periodically at a specific frequency (Manik 2015). The signal generator can be constructed using a PWM module. The PWM signal from the module was then forwarded to IC 7476JK to be converted into two output, signalsas shown in Figure 4: the p-channel signal and n-channel signal. The two-channel signal that has been generated is forwarded to the MD1213 MOSFET. The input of the MD1213 MOSFET has three channels: the first INA is an input with a positive channel signal, the second INB is a channel with a negative signal, and the last OE is a channel that is fused to convert the output signal on the MD1213 into a continuous or discrete signal Elshafie and Ashraf 2022.

TC6320 is a MOSFET pair from MD1213, where the input of the TC6320 MOSFET is the output signal from MD1213. In addition, the TC6320 MOSFET has two other input pins that function as high-voltage inputs to increase the amplitude of the signal that will come out of the TC6320 output pin. The output of the TC6320 MOSFET was forwarded to the transducer, and before the signal entered the transducer, this output signal was paired with two diodes to protect the transducer from excessive current. The high-voltage input for the TC6320 MOSFET was used as *a drain-to-source break voltage* (BVDSS). In the high-voltage design, a *steep-up* module is used for high voltage with 4–12volt input with output of 12–100volt Sharma 2015.

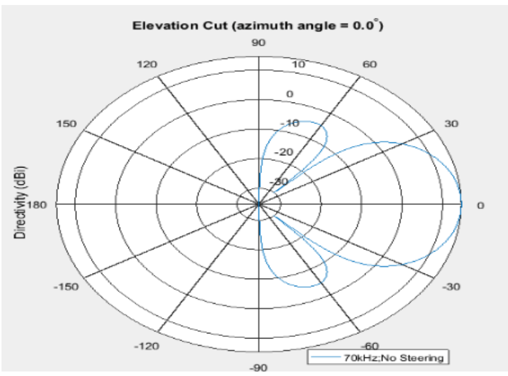


Figure 3 Simulation Using *Matlab Software*

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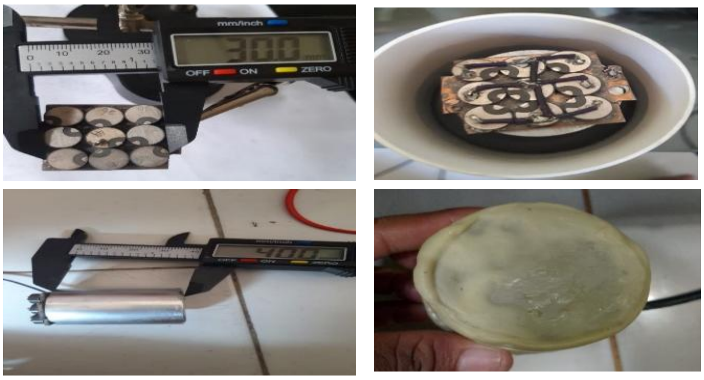

Figure 4 Piezoelectric Transducer Assembly

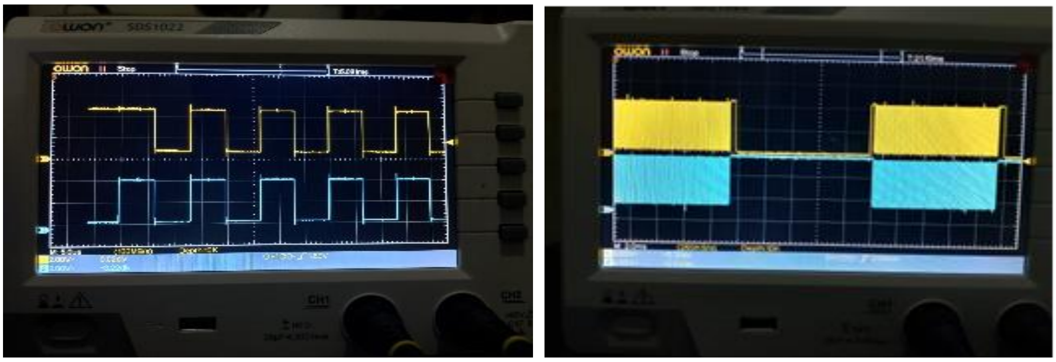

Figure 5 Output Signal of IC 7476JK and Mosfet MD1213

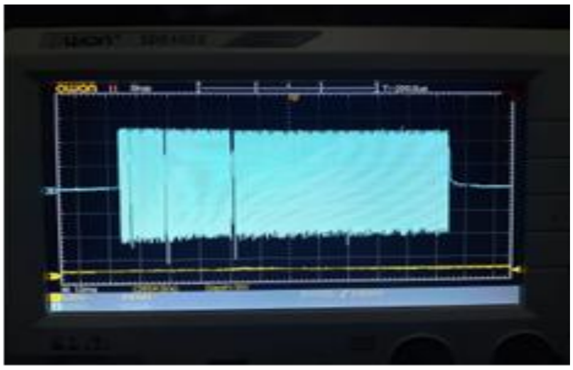

Figure 6 TC6320 mosfet output signal to transducer

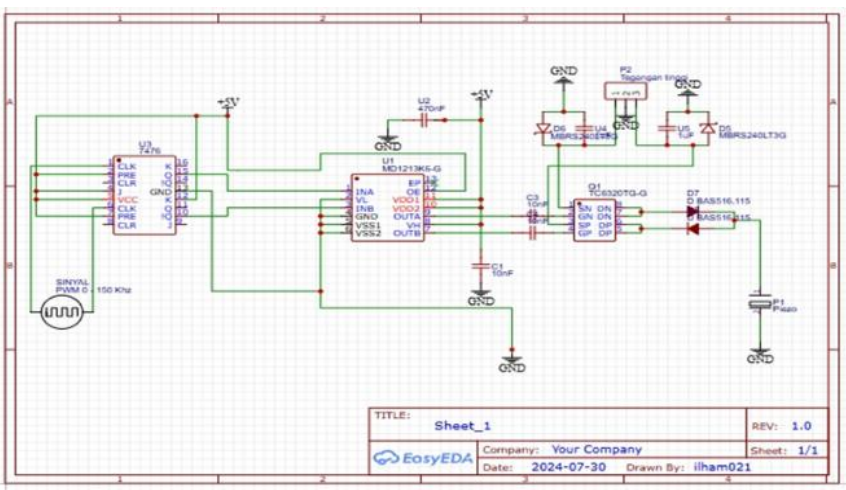


Figure 7 Transmitter *Driver* Schematic

## DISCUSSION

After completing the assembly of the transducer and *transmitter* driver, the next step was to test the tool on the bagan boat to be used as an attractor tool to lure fish to gather in the bagan boat net, which was lowered vertically to the bottom of the water (Septiyani *et al*. 2022). The initial stage of determining the location of the bagan boat is by paying attention to several things, the first being determining the type of fish you want to catch, measuring the depth of the water, and knowing the type of water bottom.

The type of fish to be caught, namely pelagic fish such as swallow, mackerel, skipjack, and other types of pelagic fish, was tested. Furthermore, the search for locations by paying attention to the depth of the waters, usually fishing using bagan boats in the waters of Teluk Saleh, has a depth of 30 – 65 meters. The last factor is to determine the type of water bottom, which is very important because there is a bad impact if the water bottom is not suitable. The type of bottom in determining the location is usually muddy, as the net will be lowered to the bottom of the water. If the type of water bottom is rock or coral, it will cause the net to be lowered vertically to get stuck on the rock, which can damage the net.

After determining the next fishing location and making preparations for fishing on the bagan boat, the first stage of the net is lowered at 17:30, and then the generator is turned on to turn on the light bulbs as many as 68 64watt LED lights, and 6 spotlights 120 watts. After the lights were turned on, the transducer was lowered into the water, and all systems were turned on, as shown in Figure 8. The transducer and transmitter driver were turned on during the range of the net being lowered until the net was raised. This process was performed twice, at 17:30, the beginning of lowering the net, and raising it again at 00:00, then lowering it again at 01:30 and raising it for the second time at 05:30. In the vulnerable distance between the time the net is lowered until it is raised again, the transducer is activated and the frequency is set at 500-1500 Hz to observe the fish response. Figure 9 shows the process in which the frequency emitted by the transducer receives a response from the fish with the appearance of small bubbles around the transducer, indicating that the fish is swimming under the transducer.

The fish response to the frequency emitted by the transducer varied with each frequency. One noticeable response is that fish emit air bubbles from the bottom of the water. In conventional fishing methods that do not use sound to lure fish, the fish typically respond when the lights on the bagan sign are turned off and the spotlight is moved away. At this point, the fish usually released swimming bubbles. However, with the addition of sound frequencies from the transducer, the fish response became more immediate. Additionally, the rapid response of fish beneath the boat can attract larger fish, such as skipjack tuna, which prey on smaller fish, such as anchovies, under the boat.

Field testing results were obtained by catching fly fish, mackerel, anchovies, squid, cook fish, cake fish, red snapper, and skipjack. The frequency response to the acoustic waves emitted by the transducer is presented in Table 3. The types of fish that respond using air bubbles that come to the surface are swallow fish, mackerel, cake fish, and anchovies, while for other types of fish, such as squid and skipjack, the response to the frequency does not release air bubbles from the seawater but will come to the surface that can be seen directly to the surface. The frequency that is recommended to be used on the bagan boat is 600 Hz, in addition to the response of fish that quickly appear in the catch at a frequency of 600 Hz is more than at other frequencies. In addition, the types of fish caught were more than at other frequencies.

Table 2 Data collection location points

| No. | Coordinates | Depth (metres) | Bottom of the Water |
|---|---|---|---|
| 1 | S 08$^0$ 42.274’<br>E 117$^0$ 53.923’ | 45 | Muddy |
| 2 | S 08$^0$ 37.988’<br>E 118$^0$ 07.034’ | 58 | Muddy |
| 3 | S 08$^0$ 31.931’<br>E 118$^0$ 00.884’ | 60 | Muddy |
| 4 | S 08$^0$ 36.217’<br>E 118$^0$ 00.331’ | 45 | Muddy |
| 5 | S 08$^0$ 32.811’<br>E 118$^0$ 00.152’ | 48 | Muddy |

Figure 8 System preparation and testing

Figure 9 Fish response to sound frequency

Table 3 Fish Response to Transducer Frequency

| No. | Frequency (Hz) | Water bubble response | Response Duration |
|---|---|---|---|
| 1 | 500 | Yes (quick response) | 3.5 hours |
| 2 | 600 | Yes (quick response) | 2 hours |
| 3 | 700 | Yes (quick response) | 2 hours |
| 4 | 800 | Yes (quick response) | 3 hours |
| 5 | 900 | There is (old response) | 4.5 hours |
| 6 | 1000 | There is (old response) | - |
| 7 | 1100-1500 | No response | - |

Overall, the use of transducers on bagan boats provides several significant benefits, including increased catch, operating efficiency, and sustainability of fishery resources. The number of fish caught using the transducer has had a very good impact on the bagan boats in Labuhan Jambu village, where fish catches without the use of active sonar transducers averaged just under 100 kg, while using the transducer has increased catches with an average catch of 125 kg per night. The difference in catch is shown in Figure 10. Table 4 shows the results of the catch using the transducer; for those who did not use the transducer, there was a significant difference. Some of the fish caught with very significant catches were mackerel scad, mackerel, cotek, and snapper fish.

Figure 10 shows the catch using the Transducer and Catch without the transducer.

Table 4 Fish Catch Results Using sound-based tools with non-voice-based tools

| Location | With Transducer | Without transducer |
|---|---|---|
| S 08$^0$42.274’ E 117$^0$53.923’ | 150 kg (mackerel scad, mackerel Fish, cotek fish, snapper fish) | 70 kg (mackerel scad, mackerel fish, cotek fish, snapper fish) |
| S 08$^0$37.988’ E 118$^0$07.034’ | 178 kg (sardine, sardinella lamuru, cotek fish, squid) | 85 kg (sardine, sardinella lamuru, cotek fish, squid) |
| S 08$^0$31.931’ E 118$^0$00.884’ | 114 kg (mackerel scad, mackerel fish, cotek fish, snapper fish) | 60 kg (mackerel scad, mackerel fish, cotek fish, snapper fish) |
| S 08$^0$36.217’ E 118$^0$00.331’ | 130 kg (mackerel scad, mackerel fish, cotek fish, snapper fish) | 50 kg (mackerel scad, mackerel fish, cotek fish, snapper fish) |
| S 08$^0$32.811’ E 118$^0$00.152’ | 160 kg (mackerel scad, mackerel fish, cotek fish, snapper fish) | 80 kg (mackerel scad, mackerel fish, cotek fish, snapper fish) |

## CONCLUSIONS

Transducers with piezoelectric materials and transmitter drivers were successfully manufactured. The transducer that has been developed can emit frequencies from 1 Hz-100Khz. System testing on transducers and transmitter drivers has been successfully conducted on mast boats with increasing catches. The acoustic frequency response emitted by the transducer has a fast response by fish that are vulnerable to frequencies of 500-800 Hz, where the fish response occurs with an interval of 2 to 4 h after the system is turned on. However, the frequency emitted above 800 Hz the fish response tends to be long and there is also no response. The nested frequency is 600 Hz. Therefore, the manufacture of piezoelectric transducers and transmitter drivers provides the latest innovation to increase catches on Bagan boats in Labuhan Jambu.

## RECOMMENDATION

It is necessary to improve the transducer's performance by adding a receiver to obtain other information, such as fish target strength, depth, and biomass. This tool is limited to emitting acoustic signals without being able to detect the signal that returns (echoes); therefore, it needs to be developed again by adding a receiver system.

## ACKNOWLEDGMENTS

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