ENHANCING SMALL-SCALE FISHERS' CAPACITY THROUGH THE ADAPTATION OF UNDERWATER LED LIGHTING TECHNOLOGY IN WAKATOBI

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***Abstract*:** Strengthening the technological capacity of small-scale fishers remains an important strategy for improving the productivity and sustainability of island fisheries. In Wandoka Utara Village, Wakatobi Regency, a community engagement program was implemented to enhance the fishing efficiency of fishers operating floating fish aggregating devices (FADs). The program reconstructed local fishing support practices through the introduction of an underwater fishing lamp, locally known as Lampu Celup Bawah Air (LACUBA), which functions as a submerged light attractor for small pelagic fish. Prior to the intervention, partner fishers relied on surface lamps that were highly susceptible to wind disturbances, unstable sea conditions, and light reflection at the air–water interface, reducing their effectiveness in attracting fish. Program activities included a preliminary needs assessment, dissemination of light-based fishing principles, hands-on assembly training, field mentoring, and an initial performance evaluation. These activities enhanced both the technical knowledge and practical skills of fishers in assembling, operating, and maintaining the LACUBA system. Preliminary field observations demonstrated notable improvements in fishing performance. Fish aggregation time decreased from 60–300 minutes to 30–60 minutes, catch volume increased from 30–100 fish to 60–180 fish per fishing trip, lamp requirements were reduced from two units to one unit, lamp durability exceeded 12 months, and battery endurance increased from three trips to approximately five to seven trips. The outcomes suggest that affordable, appropriate, and locally adaptable fishing technologies can significantly improve the efficiency and productivity of small-scale fisheries while fostering community-based technological self-reliance in island coastal communities.

Keywords: Underwater *Fishing* Lamp, LACUBA, Floating Fish Aggregating Device, Small-Scale Fisheries

INTRODUCTION

Wakatobi Regency is widely recognized as an island district whose social and economic life is closely connected to marine resources. The dominance of marine waters within its territory makes capture fisheries one of the most important livelihood foundations for coastal households. Nevertheless, fishing practices in the area continue to face ecological and operational pressures. Earlier observations indicated that reef-related fisheries experienced signs of declining catch performance, including farther fishing locations, smaller fish size, and reduced catch volume. These conditions require complementary fishing strategies that are not merely extractive but also technically efficient, economically feasible, and compatible with the capacity of small-scale fishers.

One resource group that can support this transition is small pelagic fish. In Wandoka Utara Village, Wangi-Wangi District, fishers operate simple floating bagan or raft-based fish aggregating devices to concentrate scads, mackerels, trevallies, squid, and other pelagic organisms. The local term bagan in this program refers to a raft-like structure used as a fish aggregation platform and combined with a surface gillnet. Its operating logic depends on the tendency of several fish species to approach light, a biological response commonly described as positive phototaxis. Therefore, the quality, position, and stability of the light source become decisive factors in the success of night fishing operations.

The main operational weakness identified among partner fishers was the dependence on surface lighting. Petromax lamps, incandescent bulbs, and ordinary commercial lamps installed above the water surface tend to produce unstable illumination when the wind is strong or when sea conditions are rough. A considerable amount of light is also reflected at the air-water boundary before reaching the desired depth. As a consequence, the fishing platform becomes less effective, especially outside the main fishing season. During favorable months, fishers can receive more than IDR 1,000,000 from one trip, but in less productive periods the catch value may fall to only IDR 50,000-100,000 per trip and may not cover operational costs.

Lampu Celup Bawah Air (LACUBA), or underwater fishing lamp, provides a practical alternative because the light source is placed directly in the water column. This configuration can reduce light reflection, provide more stable illumination, and concentrate fish closer to the fishing gear. Studies on light-based fisheries have shown that submerged lamps and LED-based systems can improve catch performance compared with surface lamps, petromax lamps, or fluorescent lamps in several fishing contexts (Brown et al., 2013; Thenu, 2014; Taufiq, 2015; Li et al., 2025; Maidin et al., 2026). In addition, low-cost light fishing technology has also been discussed as a relevant innovation for fishers when adoption is supported by practical training and local adaptation (Mgana et al., 2019).

Based on these considerations, the community engagement program was designed not only to distribute a technological device but also to develop fishers' ability to understand, assemble, use, and evaluate LACUBA. The program addressed three interrelated needs: increasing knowledge of light-based fishing, improving practical skill in assembling an underwater lamp, and introducing field application on floating fish aggregating devices. This article presents a complete reconstruction of the program in scientific article format, with emphasis on appropriate technology transfer, fisher empowerment, and the efficiency of small-scale island fisheries.

RESEARCH METHODS

The activity was implemented in Wandoka Utara Village, Wangi-Wangi District, Wakatobi Regency, Southeast Sulawesi Province, Indonesia. The program partners were small-scale fishers who operate floating bagan or raft-based fish aggregating devices for catching small pelagic fish. The engagement design used an educational and participatory model. This model was selected because the expected outcome was not limited to the delivery of equipment but included changes in knowledge, skill, and confidence in adopting fishing support technology.

The first stage was a preliminary survey and coordination with the fisher group and village stakeholders. This stage was used to observe the existing fishing platform, identify the type of lamps used by fishers, map operational constraints, and prepare materials for training. The needs assessment showed that partner fishers required a light source that was more stable, more resistant to weather disturbance, and capable of operating under the water surface.

The second stage was dissemination of LACUBA and light-based fishing principles. The dissemination session was attended by 20 fishers and covered the function of light as an attractor, the limitation of surface lighting, the difference between surface and underwater illumination, and the potential of LACUBA to improve fishing efficiency. The session emphasized practical understanding so that participants could relate the technology to their daily fishing experience.

The third stage was technical training in LACUBA assembly. Sixteen participants joined this hands-on session. The training combined explanation, demonstration, and direct practice. Participants were introduced to the main components, including LED lamps, cables, pipes, protective tubes, adhesives, connectors, and battery or power supply systems. The use of relatively accessible materials was emphasized to make the device easier to repair and replicate locally.

The fourth stage was field mentoring during fishing operations. The implementing team assisted partner fishers in transporting the device, positioning the lamp within the bagan structure, lowering it into the water column, and observing the fish aggregation process. The fifth stage involved early evaluation using selected technical and economic indicators, namely catch per trip, sales value, aggregation time, number of lamps, lamp durability, lamp purchase price, and battery endurance. The before-after comparison was used as a preliminary measure of program performance.

RESULTS AND DISCUSSION

Program Implementation and Fisher Participation

The program was implemented through all planned stages, beginning with field observation and ending with preliminary evaluation. The preliminary survey confirmed that the local bagan structure was simple, raft-based, and operated with surface lighting. This condition became the practical foundation for adapting the LACUBA prototype to local fishing needs rather than introducing a device that was detached from the fishers' existing work system.

The dissemination activity received a positive response because the material addressed problems that fishers encountered directly in their nightly operations. Participants did not only receive information about the device but also discussed why underwater placement could improve the performance of light attraction. The training session further transformed this understanding into practical skill. Fishers practiced assembling the main components and learned basic safety considerations related to cables, waterproofing, lamp protection, and power supply management.

Table 1. Preliminary performance of floating bagan operations before and after the LACUBA program

No.	Indicator	Unit	Before program	After program
1	Catch per trip	fish	30-100 (5-20 kg)	60-180 (12-36 kg)
2	Catch sales value	IDR/trip	100,000	150,000-200,000
3	Fish aggregation time after lamp deployment	minutes	60-300	30-60

4	Number of lamps used	unit	2	1
5	Lamp durability	months	4-5	>12
6	Purchase price	IDR/unit	90,000	300,000
7	Battery endurance	trip/night	3	5-7

Field mentoring demonstrated that the device could be integrated into the existing bagan operation without requiring a major redesign of the fishing platform. The team and partner fishers prepared the unit on land, brought it to the fishing ground, lowered the lamp into the water, and observed the fish response. This direct mentoring stage was essential because technology adoption in small-scale fisheries is often shaped by practical evidence, peer observation, and immediate relevance to daily work.

Technical Performance of LACUBA in Bagan Operations

The most visible technical change was the increase in catch volume. Before the program, partner fishers generally obtained 30-100 fish per trip, equivalent to approximately 5-20 kg. After LACUBA was applied, catch volume increased to 60-180 fish per trip, or approximately 12-36 kg. This improvement suggests that placing the light source below the water surface helped concentrate fish within a more accessible area of the fishing platform. The result is consistent with the principle that submerged light can illuminate the water column more directly than surface light, which is partly lost through reflection and scattering.

The reduction in aggregation time further supports the effectiveness of underwater illumination. Prior to the intervention, fishers waited 60-300 minutes after lamp deployment before fish gathered around the platform. After the use of LACUBA, the waiting period decreased to 30-60 minutes. For small-scale fishers, this time saving is important because night fishing is strongly affected by uncertainty, weather, and labor fatigue. Faster aggregation allows fishers to organize operations more predictably and reduces the amount of idle time spent waiting for fish to approach the gear.

Figure 1. Initial condition of floating bagan or raft-based fish aggregating devices used by partner fishers in northern Wandoka, Wakatobi

Operational efficiency was also observed in the number of lamps and energy use. Previously, fishers used two surface lamps, while the LACUBA system enabled operation with one underwater lamp. Battery endurance increased from about three trips to five to seven trips. Although the purchase price of the underwater lamp was higher than the surface lamp, the longer durability and lower energy demand indicate that the device may be more efficient over repeated use. The lamp durability increased from four to five months to more than 12 months, suggesting a stronger potential for long-term application when maintenance is properly conducted.

From a fisheries technology perspective, these results align with earlier findings that underwater lamps and LED-based lighting can improve the effectiveness of light fishing systems (Brown et al., 2013; Thenu, 2014; Taufiq, 2015). More recent studies also highlight that lamp configuration, light position, and illumination performance influence the response of target fish and the efficiency of fishing operations (Li et al., 2025; Maidin et al., 2026). In Wandoka Utara, the relevance of LACUBA lies not only in its technical function but also in its compatibility with a simple fishing platform operated by small-scale fishers.

Figure 2. Dissemination and practical training on the assembly of underwater fishing lamps with the fisher group.

Community Empowerment and Technology Adoption

The program had an empowerment dimension because fishers were positioned as learners, practitioners, and evaluators of the technology. They were not treated as passive recipients of equipment. Through explanation and hands-on practice, fishers learned how each component functions and how the device should be protected from water intrusion. This learning process is important because a technology that cannot be repaired or understood by users often fails after the initial project period.

The LACUBA training also strengthened collective learning among the fisher group. Participants observed each other during assembly and field trials, which encouraged discussion about possible modifications. Such peer-based learning is relevant for small island communities where technology diffusion frequently depends on trust, repeated observation, and evidence from fellow fishers. Therefore, the program can be interpreted as a practical technology-transfer process that combines scientific knowledge with local operational experience.

The economic implication of the program should be read carefully. The increase in catch and the reduction in waiting time indicate potential benefits, but the effect on household income depends on market access, price stability, post-harvest handling, and seasonal conditions. The program initially introduced market-network strengthening through digital business and e-commerce applications, but this component was still at an early stage. Therefore, future intervention should link the technical improvement in fishing operations with stronger marketing arrangements so that higher production can be converted into better income.

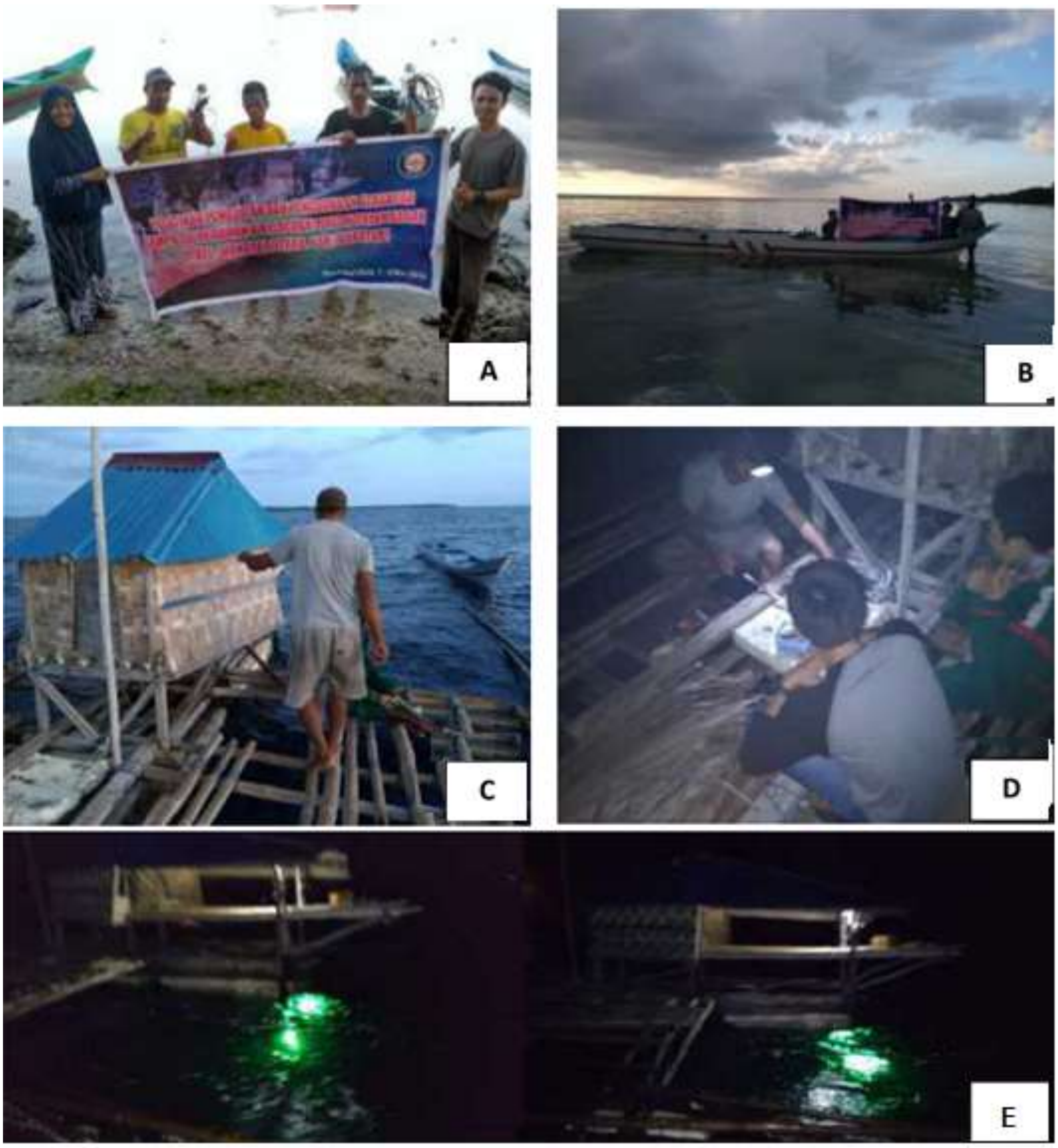

Figure 3. Field testing of the underwater fishing lamp on bagan: (A-B) preparation and travel to the fishing ground; (C) arrival at the fishing ground; (D) preparation for lowering the underwater lamp; (E) underwater lamp positioned within the bagan structure.

The program also contributes to the discussion of appropriate technology in fisheries. An appropriate fishing innovation should be affordable, understandable, locally repairable, and relevant to the ecological behavior of target fish. LACUBA meets these criteria because it uses a simple principle, can be assembled from accessible materials, and responds to a specific operational problem faced by the partner group. This makes the technology different from externally imposed innovations that are technically sophisticated but difficult to maintain in small-scale fishing communities.

Limitations and Follow-up Needs

Several limitations should be acknowledged. First, the evaluation was preliminary and could not represent all seasonal conditions. Bagan operations in Wakatobi are affected by wind, currents, waves, moon phase, and seasonal fish movement. Therefore, multi-season monitoring is required before the long-term performance of LACUBA can be generalized. Second, the program evaluation used a simple before-after comparison and did not yet include detailed cost-benefit analysis, catch composition analysis, or statistical testing.

Third, digital marketing support was not yet fully evaluated. The creation or introduction of online marketing channels may help fishers in the future, but its impact depends on product handling, cold storage, buyer networks, and collective marketing capacity. Consequently, future programs should combine LACUBA adoption with systematic catch recording, maintenance schedules, operational cost documentation, and market-network development. These follow-up activities will make it possible to evaluate the technology not only as a fishing aid but also as a component of a more efficient small-scale fisheries value chain.

CONCLUSION

The community engagement program in Wandoka Utara demonstrated that the introduction of underwater fishing lamp technology can strengthen the capacity of floating bagan fishers in both technical and operational aspects. The program improved fishers' understanding of light-based fishing, increased their ability to assemble and apply LACUBA, and provided direct field experience in using submerged illumination as a fish attractor.

Preliminary evaluation showed positive changes in catch volume, aggregation time, lamp use, lamp durability, and battery endurance. These improvements indicate that underwater lighting can serve as an appropriate technology for small-scale island fisheries when it is introduced through participatory training and field mentoring. To sustain the benefits, future programs should conduct multi-season monitoring, maintain regular catch and cost records, improve equipment maintenance, and strengthen market linkages so that technical gains can contribute to improved fisher welfare.

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