Effectiveness of small-scale marine ornamental fish rearing and community-based coral transplantation technique in Tanjung Tiram, Tondonggeu and Mekar village, Indonesia

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Abstract. Indonesia is the second largest exporter of ornamental fish in the world, with the value more than USD 20.5 million in the first semester of 2023. Ornamental corals are also being traded under strict supervision since several coral species are listed in Appendix II of the CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora). To harvest these high-value commodities in sustainable manner, we designed a small scale of marine ornamental fish rearing and community-based coral transplantation techniques in coastal waters of Tanjung Tiram village, Tondonggeu village and Mekar village by utilizing its suitable natural habitat and involving coastal communities. A study then carried out to analyse the growth rate of 480 fragments of transplanted ornamental coral and survival rate of 200 reared Banggai cardinalfish (*Pterapogon kauderni*) using fixed net cage in each site. This study reveals that the growth rate of ornamental corals in Mekar Village is better than in other sites. The survival rate (SR) of ornamental corals in Mekar Village is also higher than in Tanjung Tiram Village. This result indicates that the water quality conditions in Mekar Village are better for ornamental coral transplantation, then transplantation activities should be focused surround this island. This initiative looks promising and can also be developed further as marine tourism site that generate additional income for coastal communities.
Keywords: ornamental fish, ornamental corals, coral transplantation, coastal communities

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1 Introduction

Marine ornamental fish has been traded since almost a century ago (around 1930's) [1], while ornamental corals seem to be traded since 1990's after the advancement of aquarium technology [2]. Around 140 species of stony corals and 1,471 species of ornamental fish are being traded globally [3]. It is estimated that Indonesia became marine ornamental fish exporter country since early 1970s [2] and now become second largest exporter of ornamental fish in the world, with the value more than USD 20.5 million in the first semester of 2023 [4]. This figure could potentially increase in the future, considering that Indonesia has a high diversity of coral reefs and marine ornamental fish. The most notable gateway for marine ornamental export from Indonesia is Bali, followed by 17 other provinces [5]. And new suppliers continue to emerge across the nation since the government provides support and facilitation for business actors to improve their capabilities thus will raise country's export value, while remain to implement strict supervision in accordance with international conventions.

The high diversity of coral reefs in Indonesia is reflected by approximately 569 species from 83 stony coral genera that have been identified, including four endemic coral species such as *Acropora suharsonoi* in Lombok, *Euphyllia baliensis* in Bali, *Indophyllia macassarensis* in Makassar, and *Isopora togianensis* in Togean island [6]. Based on recent observation, only 6.42% of Indonesian coral coverage is in excellent condition, while 22.38 % in good condition, 37.38% in fair condition, and 33.82% in poor condition [7]. The coral reefs condition around the globe tends to degrade, which influenced by various global threats (e.g.: ocean warming and acidification) and local threats (e.g.: physical destruction due to human activities, land-based pollution, destructive fishing practices), including increasing trade of ornamental corals [8][9]. Most of coral being traded worldwide are sourced from Indonesia, and due to high market demand, hard corals trade is strictly regulated by CITES (Convention on the International Trade in Endangered Species of Wild Fauna and Flora), to impede the acceleration of coral degradation rate [5][10][11][12].

The existence of coral reefs is important for fish, including marine ornamental fish [13]. There are about 700 species of marine ornamental fish can be found in Indonesia, where about 480 species have been identified and 200 of them are being traded, including the famous clown fish and endemic ornamental fish from Indonesia namely Banggai cardinalfish (*Pterapogon kauderni*) [14]. Banggai cardinalfish is originally found in Banggai waters of Central Sulawesi Province [15]. This species lives in marine neritic habitat, a shallow marine with the depths less than 200 meters which has rich nutrients and biological activities [16]. High levels of captive and origin habitat destruction are considered as the main cause of the depletion of Banggai cardinal fish stocks in nature [17][18]. Therefore, the Banggai cardinal fish has been listed on the IUCN red list since 2007 (https://www.iucnredlist.org/species/63572/12692964) and its trading is strictly monitored and regulated accordingly [19][20][21], as well as conservation effort [22][23][24].

To prevent further depletion of ornamental fish stock in the wild, marine aquaculture is regarded as the most sustainable solution [25][26][27][28]. By shifting to marine aquaculture practice, overfishing of marine ornamental species can be reduced, also offering alternative livelihoods for coastal communities and artisanal fishers in small islands in Indonesia [29]. Banggai cardinalfish began to be cultivated in several places around the 1980-1990s. It is suspected that some reared individuals of Banggai cardinalfish are escaped into the wild then breeding in new places, thus spread to other waters in Indonesia, such as in Lembeh strait of North Sulawesi Province [30], Bali strait (between east Java and Bali Province) [31] and Maluku Province [32].

Meanwhile, coral farming through coral transplantation technique can be implemented not for market orientation only, but also aims to rehabilitate the damaged coral reefs

ecosystem [33][34][35][36][37][38]. There are many success stories on coral transplantation, which offer best practices that can be transferred to coastal communities to accelerate coral rehabilitation program [39][40][41][42][43][44][45][46][47][48][49][50][51]. Coral farming activities also have great potential to be developed as marine ecotourism that can provide additional income for community-based economies in coastal areas and small islands [52].

As part of coral reef ecosystems preservation effort and sustainable use of marine resources, we conducted a study to test whether these coral farming and ornamental fish rearing activities can be applied on a small scale in Southeast Sulawesi by involving coastal communities. This research aims to examine the effectiveness of this program which indicated by the growth rate and survival rate of transplanted corals, as well as the survival rate of reared Banggai Cardinalfish in Southeast Sulawesi Province. Through this study, the knowledge of these applied techniques can be transferred directly to the coastal communities. In the future, it is expected that they can apply this knowledge to improve their welfare while preserving their natural resources simultaneously.

2 Material and methods

There are four stations for this study, located in Southeast Sulawesi Province, Indonesia. The first station (**ST 1**) is the hatchery facility in Kendari city; a private company which provide us with transplanted coral seeds. The cultivation of these transplanted coral is conducted in station 2 (**ST2**) and station 3 (**ST3**). ST2 is in the waters of Bokori island (Mekar village, Konawe Regency), while ST3 is in the waters of Tanjung Tiram, North Moramo (South Konawe Regency). The last station (**ST 4**) is the site for ornamental fish rearing using fixed net cage, in the waters of Bokori island (Figure 1).

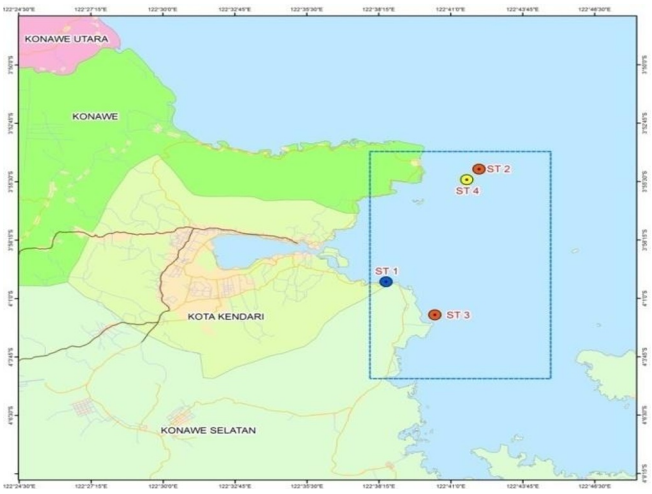

Figure 1. Study sites

This study is implemented through series of activities from March to September 2017, including:

1. Characterization of the study site to seek the water condition and existence of natural coral cover fish at the research location, through: (i) water quality measurement, i.e.: sea surface temperature (SST), salinity, ocean current, dissolved oxygen (DO), acidity (pH), and brightness; (ii) visual census natural live coral cover and diversity using Line

Intercept Transect (LIT). The existence of natural live coral can be measured with the percentage of each coral live form coverage:

$$PC = \frac{TLE}{TTL} X\ 100\% \quad (1)$$

where:

PC = Percentage Cover for each category
TLE = Total Length of Each category (cm)
TTL = Total Transect Length (cm)

The percentage of live coral cover or the status of natural live coral coverage surround the studied sites can be determined with the following formula:

$$PLC = \frac{TLE_H}{TTL_H} X\ 100\% \quad (2)$$

where:

PLC = Percentage of Live Coral cover
TLE_H = Total Length of Each category of live coral (cm)
TTL_H = Total Transect Length (cm)

The status of natural coral coverage surround study sites can be determined based on the percentage of live coral, as follows:

- Low, if PLC < 24,9%,
- Moderate, if 25% < PLC < 49,9%,
- High, if 50% < PLC < 74,9%,
- Very high, if PLC > 75%.

The ornamental coral diversity index is used to measure the diversity of coral lifeforms or genera at each research station:

$$H' = -\sum_{i=1}^{S}(Pi\ ln\ Pi) \quad (3)$$

$$Pi = \frac{ni}{N}, \quad i = 1,2,3 \ldots \ldots S$$

where:

S = Number of genus or coral lifeform
Pi = Abundance of specific genus
ni = Total number of genus colony
N = Total number of individuals for all genus or coral lifeform

2. Preparation of rearing media for transplanted coral and ornamental fish, including:
   - Rack assembly and moulding of planting substrate. Racks for transplanted ornamental coral is made from 1 inch diameter of PVC pipe with dimension of 100 cm x 100 cm x 25 cm. Each rack can hold 16 transplanted corals. PVC material is selected due to its durability, corrosion-resistant nature, cheap, easy to get, cut and assembly. While the round shape planting substrates sized 10 cm diameter with a thickness of 3 cm, are made from sand and cement. Each substrate is equipped with cable and pipe, casted in its centre as place to tie coral seeds substrate with the rack.
   - Restocking transplanted seeds. Live coral seeds are stocked from local hatchery in Kendari (ST1) and prepared for a month prior the transplantation process, as well as to reduce stress level of live coral during transfer from hatchery to cultivation sites (ST2 and ST3).

- These transplanted coral racks then placed in ST2 and ST3 on dead coral spot which has relative flat seabed to facilitate coral growth monitoring. Also, at the depth around 3-8 meters where the sunlight still able to penetrate the waters.
- Assembling the 16 m^2 (4 m x 4 m) of fixed net cage for ornamental fish rearing on ST4. The net then filled with several sea urchins prior to fish stocking, to control algae growth in the net, and as a shelter for the fish larva that have just been released from male brood's mouth.

3. Preparation of samples (transplanted coral fish stocks and ornamental fish) until placed on determined sites, including:
   - 480 fragments of ornamental live coral from five different species, i.e. *Acropora sp., Alueopora sp., Caulastrea sp., Pocillopora sp.,* and *Isis Hippuris.* Size of transplanted live coral are varied, between 50 mm and 76.90 mm.
   - 200 individuals of Banggai Cardinalfish (*Pterapogon kauderni*) are captured from waters of Bokori Island by local fishermen then placed in a tank temporarily for fish sample selection purpose using these criteria: (i) bright, smooth, and flawless skin, and (ii) active motion of fish. Afterward, acclimatization is conducted before being released into the fixed net cage.

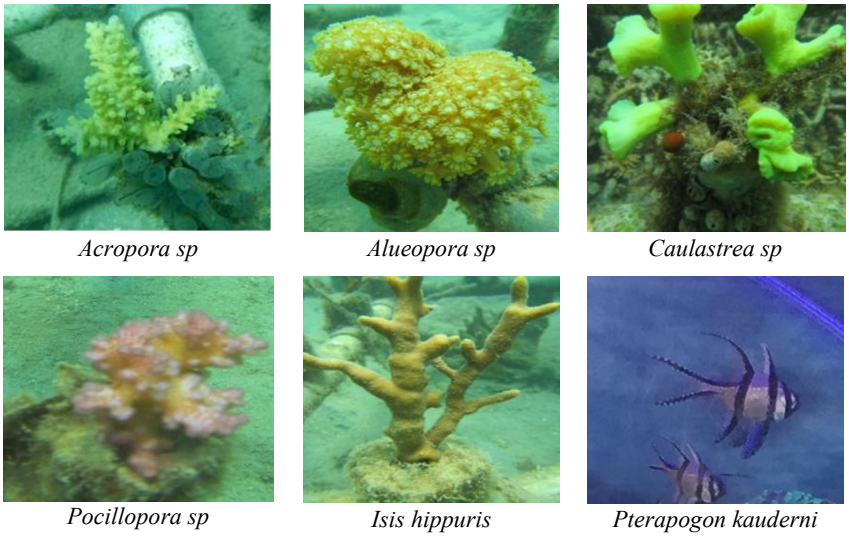

Figure 2. Species of transplanted corals and ornamental fish cultivated in this study.

4. Maintenance and monitoring (live coral growth and survival rate of ornamental fish). Series of monitoring activities are carried out every month during observation period; to maintain or clean cultivation media from algae which can possibly inhibit coral growth, as well as to record the growth and survival rate of transplanted live corals and Banggai cardinalfish.

Figure 3. Transplanted rack maintenance and live corals growth monitoring.

The effectiveness of transplanted live corals is indicated by the absolute growth of transplanted live coral fragments (βL), live corals growth rate (AGR), and survival rate (SR), using the modest formulas. The absolute growth of transplanted live coral fragments is measured using the following formula:

$$\beta L = L_t - L_0 \quad (4)$$

where:
βL = Absolute growth of transplanted live corals during observation period (mm),
L_t = Average of transplanted live corals height at the end of observation period (mm),
L_0 = Average of transplanted live corals height at the beginning of observation period (mm).

While the average growth rate of the transplanted corals is measured with the following formula:

$$AGR = \frac{\beta_L}{t} \quad (5)$$

where:
AGR = average growth rate of the transplanted corals (mm per month),
βL = Absolute growth of transplanted live corals during observation period (mm),
t = Observation period (month).

The survival rate of transplanted coral fragments and reared Banggai cardinalfish in the fixed net cage during observation period, are measured using the following formula:

$$SR = \frac{N_t}{N_0} X\ 100\% \quad (6)$$

where:
SR = Survival rate of fish or coral fragments (%),
N_t = Number of live individuals or coral fragments at the end of observation period,
N_0 = Number of live individuals or coral fragments at the beginning of observation period.

3 Result and discussion

3.1. Water quality and the existence of natural coral reefs coverage in study sites

Water quality measurement of all studied sites is presented in Table 1, while existence of natural live corals is presented in Figure 4 below. This measurement is important to determine how well the water conditions support the coral transplantation and ornamental fish rearing activities. Otherwise, poor water quality conditions can inhibit coral growth, or worse, can cause coral bleaching [53][54] and decreasing survival rate of reared ornamental fish.

Table 1. Average value of water quality parameters of each location.

Location	SST (ºC)	Salinity (‰)	Current (m/s)	DO (mg/l)	pH	Brightness (m)
TanjungTiram	26-29	29-30	0.23-0.51	6.8-7.1	8.1-8.4	5-8
Tondonggeu	28-29	31-32	0.12-0.15	7.5-7.9	7.2-76	0.5-1
Mekar village (Bokori island)	28-31	30-33	0.31-0.59	8.0-8.5	7.6-8.1	5-10

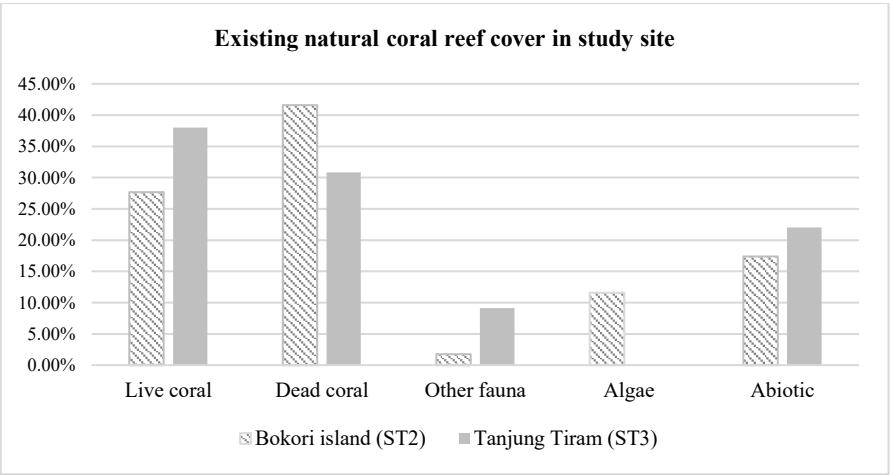

Figure 4. Existing coverage of natural coral reef surround experiment sites.

Based on these observation, coral coverage in the waters of Mekar village (Bokori island) is 27.68%. About 15.11% of live coral cover in the form of Acropora branching with a coverage percentage of 15.11%. For the dead coral category, the highest percent cover is occupied by dead coral with a coverage value of 24.41%. The algae category is occupied by Turf Algae with a value of 9.84%. While 9% of abiotic coverage in the form of rubble or fragments of dead coral due to unsustainable fishing practices or from ship anchorage.

The cover of live coral at the observation site is classified as moderate to damaged condition. The low live coral cover is also a result of unsustainable fishing activities that have occurred at the observation site. Based on the monitoring results of coral transplant in Tanjung Tiram Village, the percentage of live coral cover is 38.00%. The highest live coral cover is Acropora branching life form with a cover percentage of 18.82%. The dead coral category with the highest percentage cover is dead coral with algae with a cover value of 25.74%. Meanwhile, for the abiotic category, the highest value is occupied by sand with a

value of 9%. The coverage of live coral at the observation site is classified as moderate to medium criteria, with high cover of dead coral (30.84%) due to coral bleaching that previously occurred at the observation site. Corals that experienced bleaching in previous observations were overgrown with algae as seen from the high value of dead coral with algae cover (25.74%).

3.2. Growth and survival rate of transplanted live corals and Banggai cardinalfish

Absolute growth (β) of transplanted corals in Bokori island (ST2) during five-month observation period ranging from 10.5 mm to 39.91 mm, while in Tanjung Tiram waters (ST3) ranges between 8.17 mm and 28.17 mm (Figure 5). Thus, the average growth rate of transplanted corals per month in each station can be estimated as shown in Figure 6 below:

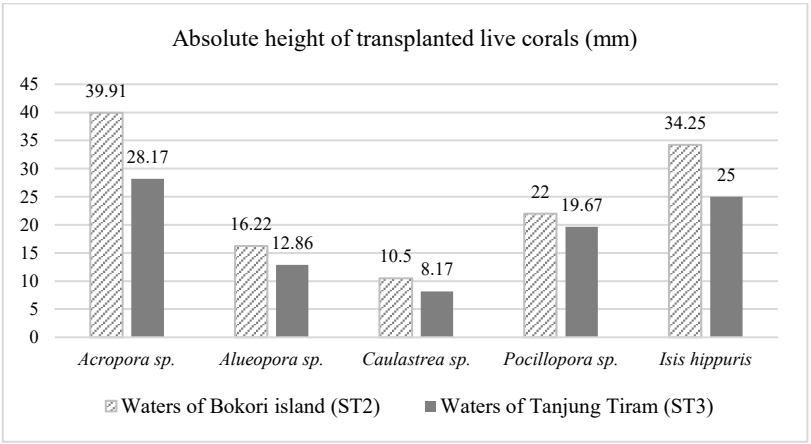

Figure 5. Comparison of absolute height of transplanted live corals in different stations.

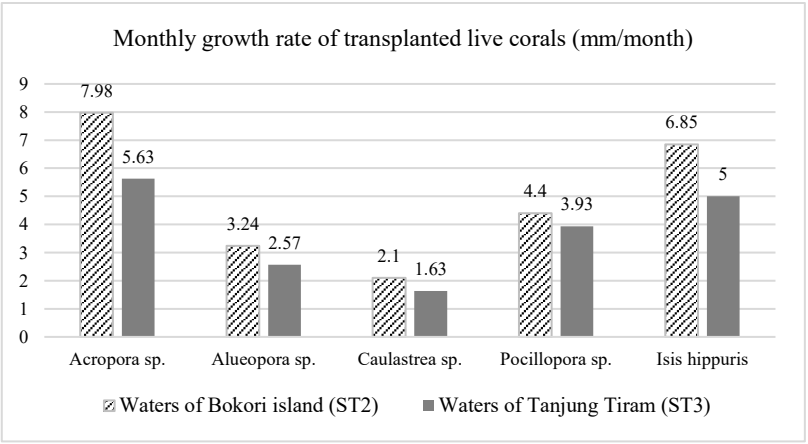

Figure 6. Comparison of monthly growth rate of transplanted live corals in different stations.

These charts shows that each transplanted coral species has a different growth rate where growth rate of transplanted coral in the waters of Bokori Island (ST2) is higher than waters of Tanjung Tiram (ST3). The difference of growth rate indicates that the environmental

characteristics of waters in Bokori Island (both water quality and level of nutrient) is better compared to waters in Tanjung Tiram. It also confirmed with survival rate (SR) data, where the survival rate of coral fragments in ST2 is 85,42%, higher than in ST3 (78,33%). This is probably due to proximity of ST3 with mainland of Sulawesi, where the influence of human activity and sedimentation is relatively higher than in Bokori island.

Figure 5 and Figure 6 also indicates that growth rate of each species is vary. In Bokori island (ST2), the average growth rate (in mm per month) of *Acropora sp.*, *Aluepora sp.*, *Claulastrea sp.*, *Pocillopora sp.*, and *Isis hippuris* are 7.98, 3.24, 2.10, 4.40, and 6.85 respectively While in Tanjung Tiram (ST3), the average growth rate (in mm per month) of *Acropora sp.*, *Aluepora sp.*, *Claulastrea sp.*, *Pocillopora sp.*, and *Isis hippuris* are 5.63, 2.57, 1.63, 3.93, and 5.00 respectively. The survival rate of reared BCF in ST4 during five month period is considering high (88.50%). Most of mortality cases are occurred in the first month of observation, then decreases in the following months, probably due to adaptation process of fish with the new micro environment. Natural habitat for Banggai cardinalfish is in shallow and calm waters (< 200m of depth) which has enough coral reefs and seagrass beds.

4 Conclusion

Cultivation of transplanted corals and red-listed ornamental fish such as Banggai Cardinalfish plays an important role to prevent species extinction and coral reef damage amid the high demand of these commodities around the globe. Site selection become a key success factor for this program. Therefore, it is important to find suitable location for coral transplantation and ornamental fish rearing that has similar characteristics to its natural habitat which indicated by water quality parameters (e.g. temperature, salinity, pH, DO, brightness, and ocean current) also the existence of natural live corals. Effectivity of this small-scale coral transplantation and Banggai Cardinalfish rearing can be measured from the growth rate of transplanted live corals and survival rate of samples. The growth rate of ornamental corals in Mekar Village (ST2) is higher than in Tanjung Tiram (ST3), while coral growth of each species are varied. The survival rate (SR) of ornamental corals in Mekar village/Bokori Island (ST2) is 85.42%, higher than ST3 in Tanjung Tiram Village (78.33%). The survival rate (SR) of Banggai Cardinalfish rearing in the waters of Bokori island (ST4) also high (88.50%), where high mortality case is only recorded on the first month due to adaptation process. These results indicate that the water quality conditions for ornamental coral cultivation activities in Mekar Village (Bokori Island) are more supportive for these programs rather than the water conditions in Tanjung Tiram. These results can be used for further research, or upscaled into a larger or industrial scale (with export oriented), particularly in Southeast Sulawesi Province. Since this activity is potentially providing benefits (in term of alternative livelihoods and/or additional income) in a sustainable manner for coastal communities in Southeast Sulawesi Province, it is recommended that local government should facilitate this initiative, also establish a core-plasma partnership link between cultivator and buyer/exporter.

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