The growth of *Acropora loripes* (Brook 1892) using spider frame module transplantation method and its effect on the presence of fish reef in Les Village, Buleleng, Bali

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Abstract. The condition of coral reefs in Bali waters has a bad impact on the community, especially ornamental fish fishermen, so that rehabilitation is needed to restore the function of the coral reef ecosystem. This study aims to determine the growth of *Acropora loripes* using the spider frame module transplantation method at two depths and the effect of transplantation on the presence of fish. The method used in this study is an experimental method with direct observation. Transplanted corals described 88 fragments with treatment 6 and 10 meters of depths to observe the growth, survival of corals, and the presence of fish. Results showed the growth for one month, 0.59 and 0.85 cm at stations 1 and 2, respectively. The growth rate at the end of the study with the highest rates is 0.14 and 0.21 cm/week at stations 1 and 2, respectively. There are 10 species of fish found at both stations with a total number of 41 and 36 individuals and stable and unstable condition categories at stations 1 and 2, respectively. The growth of *A. loripes* showed well at the end of the study where the presence of reef fish showed a positive correlation with coral survival rates.

Keywords: *Acropora loripes*; Bali; coral reef; fish; transplantation

1. Introduction
Les Village Administratively is part of Tejakula District, has an area of 769 hectares with a coastal area of 135 hectares and a beach that stretches from west to east along two kilometers. Some of the people of Les Village have a livelihood as fishermen, one of which is as traditional ornamental fish fishermen and ornamental coral exporters. Overexploitation and unsustainable fishing such as using poison and explosives have destroyed natural coral reefs around the waters of Les Village [1]. According to Giyanto *et al.* [2], from 19 observation stations, only one station is categorized as very good, 12 stations are categorized as poor, while 7 broadcast stations are categorized as sufficient. The condition of poor coral cover is influenced by various things from human activities to climate change [2].

The bad condition of coral reefs in Bali waters has a bad impact on the community, especially ornamental fish fishermen, so that rehabilitation is needed to restore the function of the coral reef ecosystem. Activities carried out to restore coral reefs in the waters of Bali are using the coral
transplantation method. The new coral planting technique uses the fragmentation method with coral seeds taken from certain coral colony broodstock [3]. The Les Village community together with the LINI Foundation has committed to protecting the waters by rehabilitating coral reefs with transplants using concrete and following environmentally friendly fishermen certification [1].

The transplantation of coral reefs has undergone many developments and innovations. One of the efforts to rehabilitate coral reefs that have been carried out in Indonesia includes using a spider frame model. According to Rani et al. [4], the spider frame method is effective in rehabilitating coral reefs of the genus Acropora, Porites, and Pocillopora at a depth of 3-4 meters and is considered easier to do. Also, a variety of transplanted coral species have developed, not only hard corals but several types of soft corals have started to be transplanted [5]. The development of coral transplantation is influenced by the increase in the ornamental fish industry. The type of coral used as ornamental fish by fishermen and exporters is A. loripes. This species is an ornamental reef that is traded because it has high aesthetic value as an aquarium decoration, so it is exploited by fishermen and ornamental fish exporters [6].

Rehabilitation of coral reefs in the waters of the village of Les has been carried out but there is no data on coral reef transplantation using A. loripes spider frame modules. Rehabilitation is a way to help restore an ecosystem that has been damaged. The restoration of coral ecosystems will have a good impact on coral fish populations and will improve the economic and ecological functions of the waters [7]. Research on coral transplantation using a spider frame module has been carried out on Liukan Loe Island, Bulukumba Regency [4], while in the waters of Les village it has not been carried out. The research objective was to determine the growth of Acropora loripes transplanted using spider frame modules and its relationship with the presence of reef fish. This research is expected to be a preliminary study on coral growth and its impact on the presence of fish in the waters of Les Village as well as a reference by fishing community groups in Les Village as well as for the wider community as an alternative coral reef transplantation method.

2. Materials and methods

2.1. Time and study site
This research was conducted for one month from June to July 2019 in the waters of the Les Village Research Area LINI Foundation Aquaculture Training Center (LATC) Les Village, Tejakula District, Buleleng Regency, Bali Province (figure 1). Data on the length of coral fragments were taken every week for 1 month, while data for coral fish were taken at week 4.

![Figure 1. Map of study site.](image)

2.2. Research design
The transplanted coral fragments came from the parent coral A. loripes which is a branching coral found throughout Indonesian waters, especially the edge area. Parent coral colonies of A. loripes were
obtained from the cultivation of the Gilimanuk ornamental coral reef. The parent coral colony was then cut using pliers into sections with a size of 4-13 cm. The study used an experimental method with direct observation by transplanting coral fragments of *A. loripes* to a spider skeleton module that had been coated with sand at two different depths in the waters of Les Village. The spider frame module containing the fragments is placed at a depth of 6 (station 1) and 10 meters (station 2) with 22 modules each. Each spider frame module contained 2 coral fragments observed with a total of 44 fragments at each station (a total of 88 fragments).

2.3. Data collected
Data collection includes measurement and survival rates of fragments is carried out by monitoring coral fragments once a week in a month to take photos of corals at scale and to see the survival of coral fragments. Fish presence data was also taken at the end of the study using fish stationery plot surveys to see the effect of transplants on fish presence. Data collection was done quantitatively by collecting scale variables using digital measurement methods. The software used, namely CPCe 4.1 [8] was used to measure coral fragments that had been photographed with a scale, then digitizing the length of the corals. Also, the physical and chemical parameters of the waters that are taken include temperature, salinity, ammonia, brightness, turbidity, current velocity, and depth by equipment were measure in situ.

2.4. Data analysis
2.4.1. Fish community and transplantation. The structure of the reef fish community was analyzed based on the diversity, evenness, and dominance index [9]. Observation data of fragment length and survival rate were processed using Microsoft Excel software and analyzed descriptively. The calculation of the attainment of the transplanted coral growth is calculated mathematically using the formula that refers to [10] as follows:

$$\beta = \frac{L_t - L_o}{L_o}$$

where:
$$\beta$$ = Increase in length / height of coral fragments
$$L_t$$ = Average length / height of coral fragments after t-observation
$$L_o$$ = Average length/height of initial coral fragments

The transplanted coral growth rate, the formula used is as follows [10]:

$$\alpha = \frac{L_{i+1} - L_i}{t_{i+1} - t_i}$$

where:
$$\alpha$$ = The rate of increase in length or width of the transplanted coral fragment
$$L_{i+1}$$ = Average length or height of fragments at time i + 1
$$L_i$$ = Average length or height of fragments at the time i
$$t_{i+1}$$ = time i + 1
$$t_i$$ = time i

The survival rate for the transplanted corals was calculated using the formula referring to [10] as follows:

$$SR = \frac{N_t}{N_o} \times 100\%$$

where:
$$SR$$ = Survival Rate
$$N_t$$ = Number of individuals at the end of the research
$$N_o$$ = Number of individuals at the start of the research
2.4.2. **Statistic analysis.** The physical chemistry of the waters was analyzed descriptively and used the standard [11]. Differences in coral fragment growth achievement values between depths were analyzed using the paired-sample T-Test which was processed using IBM SPSS version 16.0 software. The correlation between the presence of reef fish and live coral was analyzed using linear regression. Linear regression analysis was processed using Microsoft Excel software.

3. Results

3.1. **Aquatic physical chemistry**

Physical-chemical parameters measured temperature, pH, ammonia (NH$_3$-N), salinity, brightness, and current are presented in table 1. Water temperature ranges from 26-28 °C at station 1 and 26-27 °C at station 2, pH values at both stations range 8-8.3, ammonia 0.15 mg/L, salinity 34 ‰, brightness values ranging from 178-694 cm at station 1 and 213-1040 cm at station 2. Current velocity ranges from 0.09-0.28 m/s$^{-1}$ at station 1 and 0.05-0.36 m/s$^{-1}$ at station 2.

3.2. **Survival rate**

The survival of *A. loripes* from the start of the observation to the end of the study had decreased (figure 2). The first week of observation of the survival of *A. loripes*, which was 91% at station 1 and 98% at station 2, with the number of living samples as many as 40 fragments at station 1 and 43 fragments at station 2. The survival of *A. loripes* at week 4 was 82% at station 1 and 91% at station 2 with 36 fragments at station 1 and 40 fragments at station 2.

### Table 1. Physical and chemical conditions of the waters.

| Parameter          | Station 1 | Station 2 | Quality Standards |
|--------------------|-----------|-----------|-------------------|
|                    | Weeks     |           |                   |
| Temp (°C)          | 27 28 26 27 0.71 27 27 26 26 0.50 | 28 - 32 |
| pH                 | 8.3 8.3 8 8.3 0.13 8.3 8.3 8.3 8.3 0.3 8.5 |
| Ammonia (mg/L)     | 0.15 0.15 0.15 0.15 0 | 0.3 |
| Salinity (%)       | 34 34 34 34 0 34 34 34 0 | 33 - 34 |
| Brightness (cm)    | 178 226 284 694 204.68 213 356 438 1040 315.43 | >500 |
| Current (m/s$^{-1}$)| 0.09 0.13 0.23 0.28 0.08 0.24 0.27 0.36 0.36 0.05 | - |

Note: Quality Standards based on Ministry of Environment and Forestry 51/2004.

![Figure 2. Survival rate for *A. loripes* (Blue: station 1 and orange: station 2).](image-url)
3.3. Total growth
The average total growth of *A. loripes* corals at station 1 was 0.59 cm while at station 2 was 0.85 cm (figure 3). The results showed that the total height growth rate of *A. loripes* at station 2 was greater than the total height growth of the corals at station 1. Based on the results of the Paired-Samples T-Test analysis at the 95% confidence level (*P* <0.05) significance of 0.015 for height increase between stations. Based on these results it can be concluded that station 1 and station 2 are significantly different or there is a significant difference between the two stations.

3.4. Growth rate
The coral growth rate began to increase at week 2, with 0.09 cm/week at station 1 and 0.14 at station 2. At week 4, the growth rate of *A. loripes* was at the highest growth rate during the study, with 0.14 cm/week and 0.21 cm/week (figure 4). The coral growth rate in the two stations had a significant difference based on the results of the Paired-Samples T-Test analysis at the 95% confidence level (*P* <0.05) with a significance value of 0.04.

3.5. Coral fish by transplant
The results (table 2) showed that there were 8 species found at station 1 and 5 species at station 2 with 3 species found at both stations. The most common fish group found is Pomacentridae with a total of 6 species at both stations. The species with the most number of individuals at station 1 was the *Chromis margaritifer* with 18 individuals, while at station 2 the *Neoglyphidodon melas* were found the most with 21 individuals. The types of fish found generally live in groups such as *Chromis ternatensis, C. margaritifer, Neoglyphidodon melas*, and *Pomacentrus pavo*.

Table 2. Types of fish found at the research station.

| Family           | Species                | Station 1 | Station 2 |
|------------------|------------------------|-----------|-----------|
| Pomacentridae    | *Abudedefu vaigiensis* | 6         | 0         |
|                  | *Chromis margaritifer* | 18        | 11        |
|                  | *Chromis ternatensis*  | 10        | 0         |
|                  | *Lethrinus sp*         | 0         | 2         |
|                  | *Neoglyphidodon melas* | 5         | 21        |
|                  | *Pomacentrus pavo*     | 7         | 0         |
| Chaetodontidae   | *Chaetodon kleinii*    | 1         | 0         |
|                  | *Chaetodon triangulum* | 1         | 0         |
| Nemipteridae     | *Scolopsis bilineatus* | 0         | 1         |
| Acanthuridae     | *Zebrasoma scopas*     | 1         | 1         |
| **Total**        |                        | 49        | 36        |
The condition of the reef fish community structure in the study area can be seen using the ecological index, namely the diversity index (H'), the uniformity index (S), and the dominance index (D) which are available in table 3. Based on the research results, the value of fish diversity in the two stations has a category low, namely 1.70 at station 1 and 1.04 at station 2. The uniformity value of fish at station 1 was included in the high category, namely 0.82 and included in the medium category at station 2, namely 0.60. The dominance index value (D) at station 1 is included in the low category, namely 0.22, while at station 2 it is in the high category with a value of 1.

| Indices | Stations |
|---------|----------|
| H'      | 1.70     |
|         | 1.04     |
| E       | 0.82     |
|         | 0.60     |
| D       | 0.22     |
|         | 1.00     |

The number of individual fish species found and the number of fragments of *A. loripes* that are alive are the results of the linear regression equation (figure 5). The linear regression graphs for stations 1 and 2 each show positive results in the linear regression equation, namely $y = 0.2429x + 4.8678$, $R^2 = 76\%$ at station 1 and $y = 0.309x + 5.5755$, $R^2 = 92\%$ at station 2.

**Figure 5.** Linear regression of coral transplantation to the fish presence (stations 1 and 2).

### 4. Discussion

#### 4.1. Aquatic physical chemistry

Marine biota has to limit factors, were the physical chemistry of water including temperature, pH, and current which are influenced by season, depth, and geographic location [11]. Sudden temperature changes around 4–6 °C below or above the threshold can reduce coral growth, and can even cause death [12]. The temperature at the research location is at the optimal temperature for coral growth, ranging from 25-28 °C [13]. According to Nybakken [14] in June the temperature of the southern waters of Indonesia has decreased with an average temperature of 27 °C, while in the northern waters the average temperature is around 29 °C. Also, the pH of the waters of Les village is still in the normal category because the pH value at the research location is still included in the raw value based on sea water quality standards for marine biota [11]. Normal coral metabolism generally works in an alkaline environment (pH 8.2) which is an environment where symbiotic algae live coral [15].
The temperature and pH values at the research location are influenced by the seasonal upwelling process, namely in the east monsoon (May - September). The movement of rising seawater mass from the bottom to the surface in the upwelling process brings with it water with cooler temperatures, high salinity, carbon, and nutrients to the surface [16]. Bali waters experience a decrease in temperature that occurs in June, this indicates an upwelling phenomenon [17]. Starting in June, indications of upwelling began to appear along the southern part of Java-Bali-Sumbawa [18].

The ammonia level in the waters of Les village is still in the range of quality standards based on State Minister for the Environment [11]. Ammonia in water is a source of pollutants that are harmful to marine life [19]. Aquatic ammonia comes from nitrogen compounds which are influenced by the oxygen content in water, if ammonia in the water is present in large amounts (> 1.1 mg/L), it can be concluded that pollution has occurred [20]. Different results were obtained in the waters of Malacca, Sulawesi, which have the same substrate and have high ammonia levels ranging from 0.02-0.39 mg/L [21].

The salinity of Les village is classified as stable at a value of 34‰. This value is still in the standard range of Baku Mutu, which is 33-34‰ based on sea water quality standards for marine biota [11]. Bali waters have good annual salinity, especially in the waters of east Bali (30-35‰) and Nusa Penida (33-34‰) so that they have water quality suitable for marine biota [22]. The stability of the salinity value at the research location is influenced by low rainfall and the supply of freshwater from the land because in June the Bali region is at the peak of the dry season [16]. According to Rachmawati [23], several factors affect the salinity of the waters, namely the intake of freshwater, storms, and rain. In general, coral reefs can grow well in coastal areas with a salinity of 30-35‰, although coral reefs can survive at salinity outside this range, their growth is inhibited.

The brightness at the study site in the first week is low compared to the fourth week, which is thought to be influenced by the season. In contrast to the southern part of Bali which has an average water brightness of up to 90% in July because it has strong currents so that substrate particles are easily exposed to currents [24]. The eastern monsoon brings the substrate from the bottom of the water and causes the brightness value to be low [21]. The water conditions at the research location consist of volcanic boulders and black sand and gray sand from volcanic eruptions [1] which are easily swept away by currents and waves so that they can affect the brightness of the waters. Based on sea water quality standards for marine biota [11], the brightness is good for coral reef growth, namely >500 cm so that coral reefs get sufficient sunlight for the photosynthesis process.

The current velocity at the study site is classified as low and moderate because it is below 0.5 m/s which is an indicator of strong currents [25]. The condition of current velocity at station 1 with an average of 0.18 is due to the location of station 1 being close to natural coral reefs so that the current received has slowed down because it has been split by the surrounding coral reefs, while at station 2 is on an empty stretch of sand so that the current speed at station 2 is classified as moderate (0.3 m/s). A good current for coral reef growth is >0.2 m/s. Strong currents can help lift sediment on corals and carry sediment to other locations so that these waters become clearer [26]. The South Bali region has slightly better current speeds with a range of 0.3-0.8 m/s [21].

4.2. Survival rate

The results of coral transplantation for A. loripes using spider skeleton modules in the waters of Les Village were quite successful. According to Mompala et al. [27] that coral transplantation is successful if it has a survival rate of between 50 and 100%. The coral mortality in this study was caused by being covered by algae (Dead by algae). Macroalgae that grow around the fragments and modules have the same effect as coral cover by sediment, namely reduced light supply and coral polyps unable to capture food in the waters [22]. Another cause of death is excess sedimentation caused by upwelling because it has the effect of lifting sediment to the surface [17, 28].

The condition of the coral fragments at the beginning of the study showed that the corals were secreting mucus, then in the second week of observation, there was no visible mucus on the corals. The excretion of mucus on corals is a response to coral stress due to a coral parent being broken and...
placed in a particular container [29]. The beginning of coral growth is marked by starting to close the cut wound during fragmentation, then the coral will stick to the substrate [28]. Transplantation of living coral reefs is thought to be able to survive physiologically and morphologically where Acropora corals can live under strong currents [30].

4.3. Total growth
The total growth of *A. loripes* is better at station 2 compared to station 1. It is assumed that the contours tend to be tubular-like in their natural habitat, while at station 1 the spider frame module is placed at a lower depth. Station 1 is located near natural coral which is an intertidal zone, which is a water zone that is still affected by tides. *A. loripes* in their natural habitat are scattered throughout Indonesian waters and in the outlying areas that have strong waves and currents [30]. According to Rachmawati [23], areas that have strong waves make the reef form massive coral or branched forms with very thick branches and flat ends and tend to widen.

*A. loripes* corals at both stations experienced significant growth. Transplants of corals have been carried out in the waters of Badi Island, Makassar using the iron rack method, different depths, and fragments originating from cultivation and nature. The results of this study indicate that the total growth of corals for 3 months is 0.76-0.96 cm (3 meters) and 0.85-0.93 cm (7 meters) for broodstock originating from nature and 0.82-0.87 cm (3 meters) and 0.87-1.00 cm (7 meters) of cultivation. The results showed that the total growth of *A. loripes* corals in the village of Les was better than the research by [6].

*A. loripes* corals transplanted using spider skeleton modules in this study generally experienced a length growth that was not much different from other corals of the Acroporidae family [4]. Based on the results of previous research [31] on the growth of several types of Acroporidae with natural substrates for 3 months, total growth results were between 1.5-2.47 cm for 3 months. The total growth of Acropora species is relatively fast compared to other species and other branch corals such as Pocillopora and Porites. The high growth of Acropora is due to the structure of the limestone skeleton which is more porous than other denser species [4].

4.4. Growth rate
The results of the coral growth rate of the genus Acropora in previous studies [13, 27] were greater than the growth rate of *A. loripes*. The difference in growth rate is caused by different conditions due to the conditions of the aquatic environment and the observed coral species. The coral growth rate of Acropora sp. ranged from 0.93 to 1.00 cm/month in artificial reef media and 1.00 cm/month in iron media in the waters of Kareko, North Lembah [27].

The coral growth rate at the two stations was different due to differences in the physical factors of water, current velocity, and light. The current speed at station 1 tends to be lower than station 2 as well as the light intensity at station 2 has better light penetration. According to Suharsono [30], *A. loripes* have a strong current habitat so that the corals get an adequate supply of food and oxygen. In addition, differences in growth rates are caused by predation, symbiosis, parasitism of temperature, light intensity, current, and salinity [14, 33].

*A. loripes* continues to increase every week and are expected to continue to increase because the value of the growth rate at the end of the observation has not reached the maximum value. The maximum value of coral growth takes approximately one year of observation so that it is known the maximum period in which the coral growth rate becomes stable [28]. The growth rate or velocity of corals in producing reefs is influenced by many factors, one of the most important factors being the influence of sunlight penetration which is important for zooxanthellae for photosynthesis [13].

Acropora has a small number of sprouts and have a faster growth rate than corals that have high sprouting [32]. *A. loripes* have a type of corymbose branching or resembling shrubs with shoots, many branches and tend to grow wider [28] so that they have slower growth than other Acropora species. The coral growth rate tends to get light for *Zooxanthellae* which increases the ability of photosynthesis so that the calcification rate will be faster [33].
4.5. Reef fish and transplant

The fish found indicated that coral transplants served as indicators, habitat, and foraging. According to Manembu et al. [34], the increase in the number of individuals from previously vacant locations is an indicator of improving coral ecosystems. Furthermore, the most common species found in the Pomacenthridae family, which is a resident fish species and has territorial behavior so that it rarely goes far from food sources and shelter [35]. The spider frame module is made of iron covered with beach sand so that it is easily overgrown by algae that feed herbivorous fish. A suitable habitat will determine the abundance of coral fish in the area, the species of coral fish in the Pomacenthridae family tend to gather in branching gaps [36] that coral transplants of Acropora loriipes are mostly visited by fish from the Pomacentridae family. The emergence of reef fish in the transplanted area tends to be dominated by algae-eating fish from the Pomacentridae family. The majority of reef fish are diurnal and generally have a preference for herbivorous eating [37].

The diversity index at the two stations is low. It is suspected that the transplants in this study had only reached one month, so the species of fish that gathered were still few. Previous research in the waters of Tanjung Tiram Village, South Konawe Regency, transplanted artificial coral reefs for 3 months obtained a diversity index value ranging from 2.04 to 2.45 in the moderate category [38]. Furthermore, research on Wangi-Wangi Wakatobi Island, an artificial reef 1.5 years old, obtained the value of fish diversity in the medium category [39].

According to Kwon et al. [40] stated that the high and low diversity of fish species is influenced by environmental quality. The location of station 1 which is close to natural coral reefs causes the condition of the reef fish community to be more stable than station 2. The coral fish community at station 2 is declared unstable because one fish species dominates, namely Neoglyphidodon melas, which is a family of Pomacentridae which includes pioneer fish, besides that species The transplanted coral also affects the types of fish that come [41].

The results of the uniformity index showed that the fish community at station 1 was in a stable condition while at station 2 it was in an unstable condition. A high level of uniformity shows that the ecosystem is in a stable condition [35]. The low dominance value indicates that in the study location there is no dominance by certain reef fish species and there is no pressure on the ecosystem and vice versa. The absence of dominance in the two research locations is influenced by the abundance of fish food preferences [38] and the environment of the research location which is a foster habitat for various types of fish [37].

4.6. Fragment relationship with fish

Artificial coral reefs function as a spawning ground, nursery ground, and feeding ground for reef fish so that artificial coral reefs can invite fish around them [34]. The presence of fish at station 2 has a high relationship compared to station 1 where this is thought to be influenced by the habitat. The presence of fish at both stations is influenced by the habitat where at station 2 it is in an open area with a sand substrate, while at station 1 it is surrounded by natural coral. The reef fish at station 2 tend to settle down because there are no other protected areas around it. Reef fish will settle in areas that have sufficient resources and will choose a suitable place to hide from predators. Fish gather in coral transplants due to the succession colonization process by algae (periphyton), the presence of periphyton attached to artificial reefs is a food source for small fish [39]. In addition to a food source, coral species have a function of shelter for immigrant fish (Pomacentridae family) which have a small body shape [38].

The results of linear regression at both stations showed that coral transplantation had a positive effect on fish populations at the research location, namely the more live coral fragments, the higher the number of fish present. The fish population is closely related to coral reef cover, where an increase in coral reef cover will be followed by an increase in the number of coral species and individuals [42]. The contribution of coral transplantation greatly supports the improvement of the quality of coral reef ecosystems and has direct implications for the biodiversity of reef fish [34].
5. Conclusions and suggestions
In general, the physical-chemical factors in the waters of the village of Les are suitable for the growth of *A. loriipes* corals with temperature, pH, ammonia, and salinity in good categories and sufficient brightness and flow speed. The coral growth of *A. loriipes* transplanted using spider skeleton modules in the waters of Les Village showed significant results. The growth rate showed an increase until the end of the study with the highest growth rate at station 2. Different depths and habitats affected coral growth. The presence of fish in coral transplantation shows positive results where the more corals are alive the more fish are present. The fish found at station 2 were higher than those at station 1. The condition of the reef fish community at station 1 was in the stable category, while at station 2 it was in the unstable category.

Suggestions for further research are the need for further research using corals of different species to see the effectiveness of spider skeleton modules as a transplant medium. Coral transplantation needs to be carried out periodically in order to know the stagnant phase and rate. Transplantation monitoring is carried out every day to perform maintenance on the transplant module so that it is not dirty or damaged.

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