Coral transplantation on a multilevel substrate of Artificial Patch Reefs: effect of fixing methods on the growth rate of two Acropora species

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Coral transplantation on a multilevel substrate of Artificial Patch Reefs: effect of fixing methods on the growth rate of two *Acropora* species

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Abstract. *Munasik, Sabdono A, Assyfa AN, Wijayanti DP, Sugiyanto, Irwani, Pribadi R. 2020. Coral transplantation on a multilevel substrate of Artificial Patch Reefs: effect of fixing methods on the growth rate of two* Acropora *species. Biodiversitas 21: 1816-1822.* Branching *Acropora* is generally used in coral transplantation to rehabilitate coral reefs. However, these corals are sensitive to environmental changes. Artificial Patch Reef (APR) is an artificial structure that provides a multilevel hard substrate. The purpose of the study was to investigate the effectiveness of the APR structure to facilitate the growth and survival of Acropora branching. Two species *Acropora aspera* and *Acropora copiosa* were transplanted vertically and horizontally on a modular concrete block in different levels of APR situated in the shallow reef of Panjang Island, Central Java. The results showed that the coral growth rate varied from 96.7 to 346.9 cm^3/month, while survival ranged from 30 to 100% after 8 months. Lower survival rate mostly was found in the upper level of APR. The statistical analyses showed that the growth rate of *A. copiosa* fragment was significantly higher than that of *A. aspera* ($p<0.05$). Moreover, there were also significant differences in the treatments of transplantation method ($p<0.05$) to enhance coral growth. However, multilevel substrates were not significantly influenced by coral growth. This study suggested that *A. copiosa* which has high-level complexity in branching pattern will be selected to apply in shallow reef rehabilitation with transplanted vertically.

Keywords: *Acropora aspera*, *Acropora copiosa*, artificial patch reef, coral transplant, Panjang Island

INTRODUCTION

Coral reef is one of an important ecosystem on earth, it is most complex and biodiverse ecosystem that provides the ecological services for humankind. Recently, coral reefs worldwide have been degrading by natural and man-made stress (Wilkinson 2000; Burke et al. 2011). Reef health has been declining apparently by limiting space for natural recruitment and change in physical environmental conditions ([illegible]ne et al. 2010). Thus, coral reef rehabilitation is considered one of the major reef management strategies that coral reefs may not be able to recover naturally without human intervention.

To rehabilitate damage of natural reefs, artificial reefs and coral transplantation has been applied regardless of environmental condition, cause of decline, or goals. Coral transplantation generally applied by transplanted coral fragments on table cages in shallow water in order to cultivate coral fragments due to transferred and transplanted to rehabilitation reef areas (Heeger and Sotto 2000; Ammar 2013). It seems to be the most widely implemented for coral reef rehabilitation. Many studies dealing with reef rehabilitation by applied coral transplantation (Yap 2000, 2004; Epstein et al. 2001, 2003; Sabater and Yap 2002). Coral transplantation may contribute to enhance the coral population in the reef areas, although natural recovery indicated by coral recruitment (Edwards and Clark 1998; Ng et al. 2015). Coral transplantation method potentially has an impact on reef health by losing colonies from the donor area, reducing the growth of transplanted corals, reducing fecundity of transplant due to stress. Alternatively, artificial reefs are considered an efficient rehabilitation tool, it is a suitable method for protection of existing natural reefs, environmental, mitigation for damaged reef areas and shoreline protections (Meester et al. 2015; Ng et al. 2016). Artificial reefs are expected to increase in available substrates for reef organisms, provide structural complexity and natural recruitment. However, the application of these methods in Indonesia waters was apparently not successful, indicated by high mortality of coral fragments in coral transplantation and many artificial reefs that applied damage to natural reefs (Munasik 2009). In order to optimize reef rehabilitation, combining artificial reefs and coral transplantation is recommended (Abelson 2006; Ammar et al. 2013; Cummings et al. 2015).

Artificial Patch Reefs (APR) is an artificial structure which is applied to rehabilitate coral reef in order to develop shallow water habitat (Munasik et al. 2018). APR is a rehabilitation tool that is designed by multilevel substrates and applied the combination both of coral transplantation and artificial reefs. *Acropora* spp. is generally considered as a good for candidates for use in coral transplantation or population enhancement project due to their high growth rate and high survivorship of fragments (Lirman et al. 2010; Boch and Morse 2012; Mercado-Molina 2016; Schopmeyer et al. 2017). The application of APR with *Acropora* transplanted on their substrates is considered contributing to the local conservation of the small island reefs in the near future. In this study, two *Acropora* species were selected and applied to investigate the suitable method and species selection for reef rehabilitation. Multilevel substrates of APR may provide the hard substrate to facilitate fragment of coral grows in shallow turbid water. However, the information about the effect of multilevel substrates on survival and growth of transplanted corals is limited. This study aims to address the effectiveness of the APR structure to provide the multilevel substrate to facilitate the growth rate and survival of coral fragment.

MATERIALS AND METHODS

Study area

Acroporid corals are significantly important in the shallow reef of Panjang Island, Central Java however the population decline slightly due to the anthropogenic stressor (Munasik et al. 2012). Two species *Acropora* i.e. *Acropora aspera* and *A. copiosa* were known as limiting local population on the island. Colonies of *A. aspera* is common in the inner lagoon and the species was defined as a corymbose clump with short thick branches. Population of *A. copiosa* is generally found in front of the reef flat and colony was characterized as arborescent clumps of upright branches. Comparing to the previous species, *Acropora copiosa* have more complexity in branching patterns. Rehabilitation of coral reefs program was carried out in shallow reefs of Panjang Island Central Java by deployed 12 (twelve) artificial patch reefs (APR) from 2015 to 2018 at 3 m depth. In order to conduct a coral transplantation experiment, a unit of Artificial Patch Reef (APR) No. 12 was selected to perform the study of the effect of species and coral transplantation method in multilevel of substrates on growth of *Acropora* (Figure 1).

Procedures

Coral fragments were collected from donor site of two *Acropora* species in the inner lagoon and in front of the reef flat of Panjang Island. Fragments of *A. aspera* were collected by broken off small branches at random mother colonies while *A. copiosa* fragments were chisel off main branches of adult colonies randomly. The small branches of two species (average size was 12.57 cm^3) were transferred into basket and then were transplanted on multilevel substrates of Artificial Patch Reefs (APR) which deployed in the eastern site of Panjang Island.

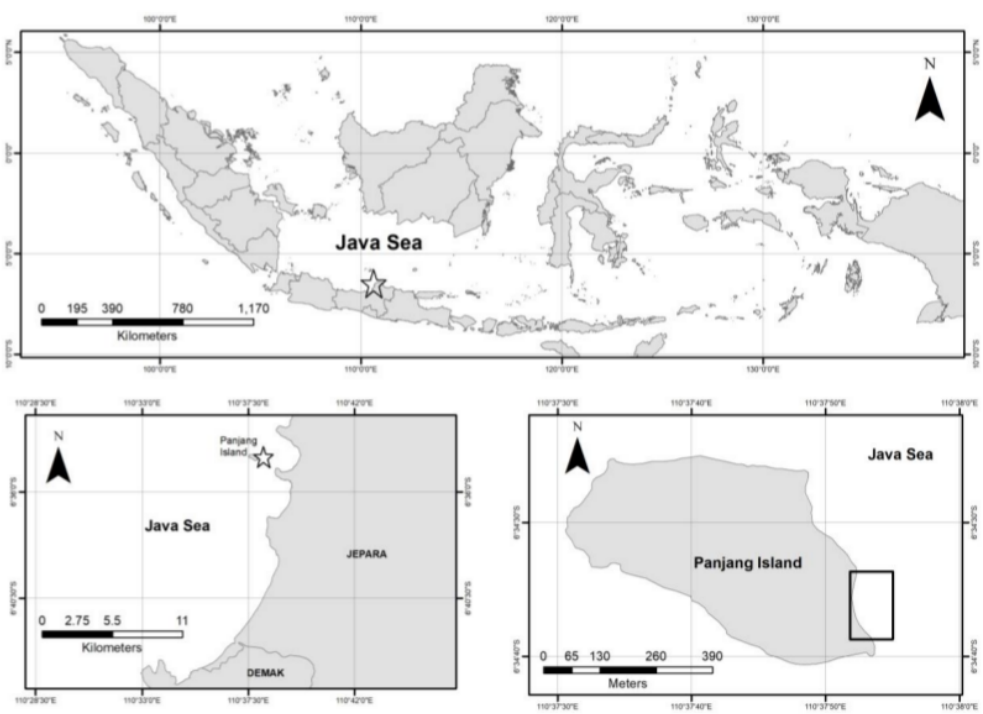

Figure 1. Study site of coral transplantation on Artificial Patch Reef at Panjang Island, Central Java, Indonesia (6º34'30" S; 110º37'44" E)

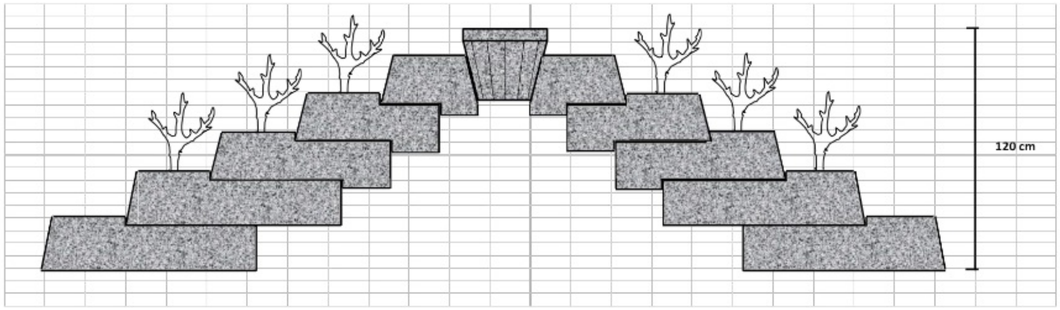

Figure 2. Layout of coral transplantation experiment, *Acropora* fragment transplanted on the multilevel: in upper, middle and lower of Artificial Patch Reef (APR)

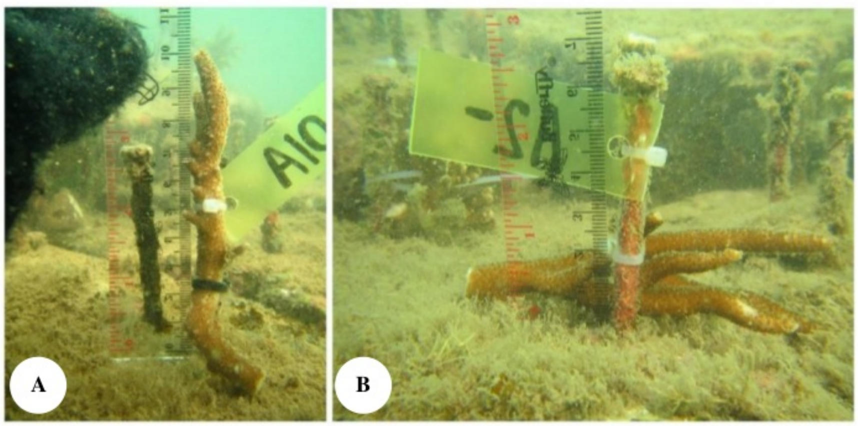

Figure 3. Fixing methods of coral fragments tied to nail by cable ties. A. vertically fixing method, B. horizontally fixing method

Artificial Patch Reefs (APR) is artificial reefs made by concrete blocks composed as modular circular structure in shape, constructed 5 (five) levels of substrates were deployed from small boats by SCUBA divers, and are suitable near natural reefs in shallow water. The total height of the multilevel APR structure is about 120 cm from the bottom of the sea, and the height of each level is 20 cm. In this experiment, coral fragments were transplanted in the upper, middle, and lower level. Coral transplantation experiments were not applied at the top level to prevent physical damage in coral fragments. The experiments were also not implemented in the coral transplantation in the base of APR (level 5) since the surface of the substrate usually covering sediment due to resuspension (Figure 2). At the beginning of November 2018, 120 coral fragments were transplanted on three levels of APR by two fixation methods: vertically and horizontally orientation of the fragments fixing on the surface of substrates and tied to a paired of the nail using cable ties (Figure 3). Cable ties method of coral transplantation has been widely applied and effective technique for attaching *Acropora* fragments to artificial substrate (William and Miller 2010; Young et al. 2012). Coral fragment stabilization using cable ties was similarly effective to epoxy or cement methods (William and Miller 2010).

Data analysis

In order to investigate the growth rate of *Acropora* fragments, we used a measurement of corallum size in volume dimension (Buddemeier and Kinzie III 1976). The final measurement of volume (length, wide, and height) of the coral fragments were evaluated in late July 2019. The size of the fragments was measured by taking a picture using an underwater camera and putting the scale beside each the fragment (Mercado-Molina et al. 2016). The size measurement of the fragments was analyzed using image analyses of computer software, Image J. Volume of the fragment was determined by ecological volume (EV; de la Cruz et al. 2015), and its calculated following the cylindrical volume formula (Levy et al. 2010) as define, in equation (1)

$$EV = \pi r^2 h, \text{ where } \quad r = \frac{(l+W)}{4} \qquad (1)$$

Growth rate (***GR***) of the corals (Ecological Volume per month) was calculated using the formula (2)

$$Gr = [EVf - EVi]/m \qquad (2)$$

Where: Gr is the standardized growth rate, EVf and EVi are final and initial Ecological Volume and m is number of months elapsed.

Only the tagged coral fragments alive at 8 (eight) months post-transplantation were included in the growth rate determination.

In order to test the effect of different levels of transplant position, and different fixing methods of coral transplantation to the growth of two *Acropora* species, data growth rate of the fragments were analyzed using two-way of variance (ANOVA, at 95% confidence level, $p<0.05$).

RESULTS AND DISCUSSION

Survival rate

The survival rate of two *Acropora* species which transplanted on multilevel substrate was varied from 30 to 100%, the average of the survival rate was 80%. Both *Acropora* species which transplanted horizontally possess higher survivorship (average of survival rate was 95%) than the fragments which transplanted vertically (average of survival rate was 85%). The lower survival rate of the fragments was found in the upper level of substrates (varied from 30 to 50%; Figure 4) which located on the top of APR, about 1 m from the bottom of the sea during low tide. Coral fragment of *A. copiosa* was more survive than *A. aspera,* indicated the lower survival rate coral fragment was found in *A. aspera* which transplanted vertically.

Growth rate

The growth rate of two *Acropora* species which transplanted on multilevel substrate of APR varied from 96.7 to 346.9 cm^3/month. The growth rate of *Acropora* fragments was significantly different among species, substrate levels and fixing method of transplantation ($p<0.05$) after 8 months. The growth rate of two *Acropora* species on multilevel substrate of APR after 8 months demonstrated that there were no significant differences in species *A aspera*. Whereas, there were significantly different on the *A. copiosa* growth that transplanted either in the upper and the middle levels or in the lower and in the middle levels ($p<0.05$). However, there were no significantly different on the coral growth transplanted in the upper and in the lower levels (Table 1).

The growth rate of two Acropora species transplanted in different fixing methods (vertical vs. horizontal) demonstrated significantly different ($p<0.05$; Figure 5). Growth rate of the fragments which transplanted in vertical fixing method was higher than the horizontal method. The lowest growth rate was found in *A. aspera* which transplanted in horizontal fixing method, while the highest growth rate occurred in *A. copiosa* which transplanted in vertical fixing methods. Fragments of coral *A. copiosa* can grow optimally on all levels by both vertical and horizontal fixing methods of coral transplantation. Comparing the species, the growth of transplanted *A. copiosa* was higher than that of *A. aspera* due to the different branching patterns ($p<0.05$; Figure 6).

Table 1. Growth rate (cm^3/month) of transplanted two species of Acropora on multilevel substrate of APR after 8 months (November 2018-July 2019)

Level	*A. aspera*	*A. copiosa*
Upper	130.05±47.16[a]	293.00±76.23[a]
Middle	178.75±34.17[a]	152.05±95.11[a]
Lower	202.75±44.74[a]	333.30±64.21[a]

Note: All results are expressed as mean ± SD. Values in each column which have the same letters are no significant different ($p<0.05$)

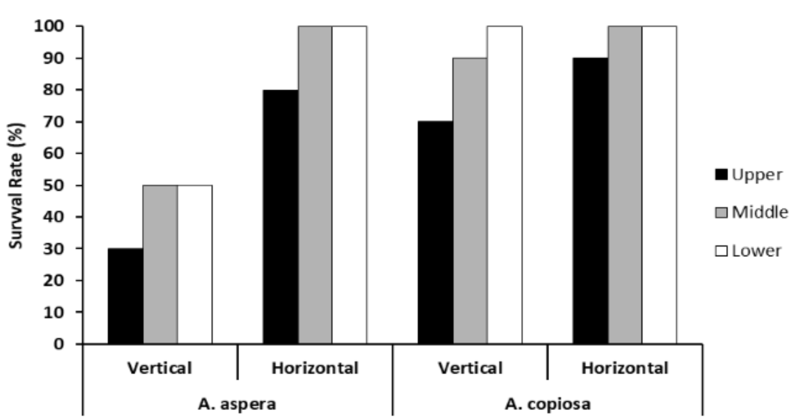

Figure 4. Survival rate (%) of transplanted two Acropora species on multilevel substrate of APR after 8 months (November 2018-July 2019)

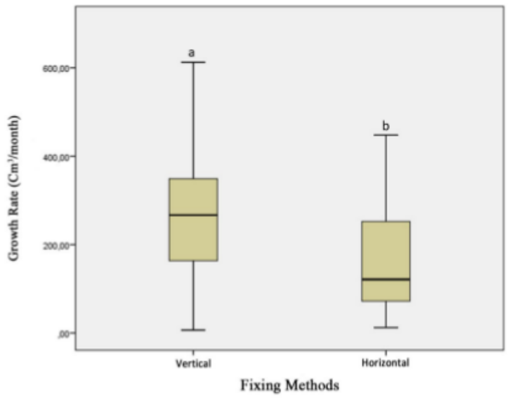

Figure 5. Growth rate (cm³/month) of transplanted two *Acropora* species on multilevel substrate of APR in different fixing method after 8 months (November 2018-July 2019 (Note: Letter in each bar which has different letters are significantly different, $p<0.05$)

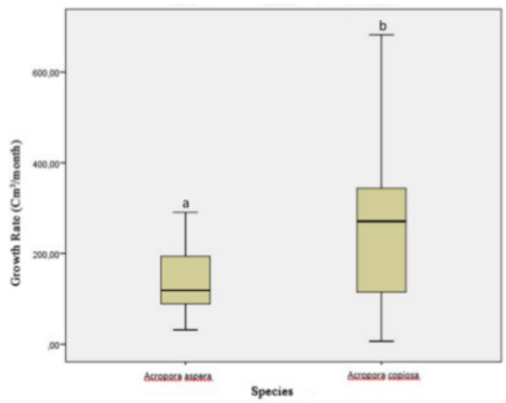

Figure 6. Comparison of growth rate (cm³/month) transplanted *A. aspera* and *A. copiosa* on multilevel substrate of APR after 8 months, November 2018-July 2019 (Note: Letter in each bar which has different letters are significantly different, $p<0.05$)

Discussion

Lower survival rate during the experiment was revealed by *A. aspera* in all levels of substrate particularly in coral transplanted in fixing vertically. Coral fragments mortality was found in *A. aspera* which fixed in vertical orientation during the experiment. Lower survival rate of the coral fragments in vertically fixing method due to minimize of fragment surface attaching to the substrate may affecting the coral expend more energy in repairing the damage (Yap et al. 1992), consequently, the coral fragments died and then detached from the substrates. Additionally, lower survival rate of the coral fragments in the upper level may be caused by some of them lost by wave actions that occurred at the beginning of experiment, after fixed the coral fragments. Disadvantage of coral transplantation using directly fragment transplantation method on the substrates in shallow water is generally affected by algae competition, sediment accumulation and wave exposure (Young et al. 2012).

Acropora is one of the important coral in the shallow water and usually applied to coral transplantation (Heeger and Sotto 2000; Edwards 2010; Young et al. 2012). The coral was competent to grow fast, inversely they are also sensitive responding to the environment (Yap et al. 1992). Survival of the corals which have transplanted varied in different location and various in rehabilitation technic. The survival rate of *Acropora* in nubbin fix to the nursery table was 46% (Nithyanandan et al. 2018), while the high survival rate of the coral was found in *Acropora hyacinthus*, 83.3% (Bongiorni et al. 2011). In the present study, the survival rate of the *Acropora* is high due to the fragment stabilization using cable ties method and removing sediment accumulation caused by applying the multilevel designed of substrate. Thus, application of Artificial Patch Reef (APR) in shallow reef rehabilitation can contribute to enhance the survival of *Acropora* fragments.

Some previous studies of coral transplantation revealed that the growth rate of *Acropora* was higher than that of other hermatypic corals. Bongiorni et al. (2011) reported that *Acropora* possesses relative growth ranged 66.9 to 83.3%, while growth rate of *Acropora* which transplanted on the artificial reef dome-shaped was 1.07 cm/month (Muzaki et al. 2019), Acropora fragments fixed to the dead coral was 7.8 cm/year (Nithyanandan et al. 2018). This result showed that the growth rate of both Acropora which transplanted on multilevel substrate possesses a high growth rate. Presumably, the construction of multilevel APR can optimize coral growth by increasing light and preventing sediment coverage. The different branching pattern of the Acropora may affect to the growth of the corals, two Acropora shows a different level of complexity (Mercado-Monila et al. 2016) *A. copiosa* was more complex than *A. aspera* (Figure 7). Veron and Stafford-Smith (2000) identified that *A. copiosa* was clumps of prostrate or upright branches irregular branching patterns with frequent sub-branches, while *A. aspera* which is defined as a corymbose clump with thick branches (Veron and Stafford-Smith 2000). The higher growth rate of vertically fixing method in *Acropora copiosa* indicated that vertical fixing of the fragments was suitable orientation of the natural growth form of the donor colony of *Acropora* (Okubo et al. 2005). This study suggests that multilevel APR using vertical fixation method of selected *Acropora* which has high-level complexity should be applied in future coral rehabilitation projects.

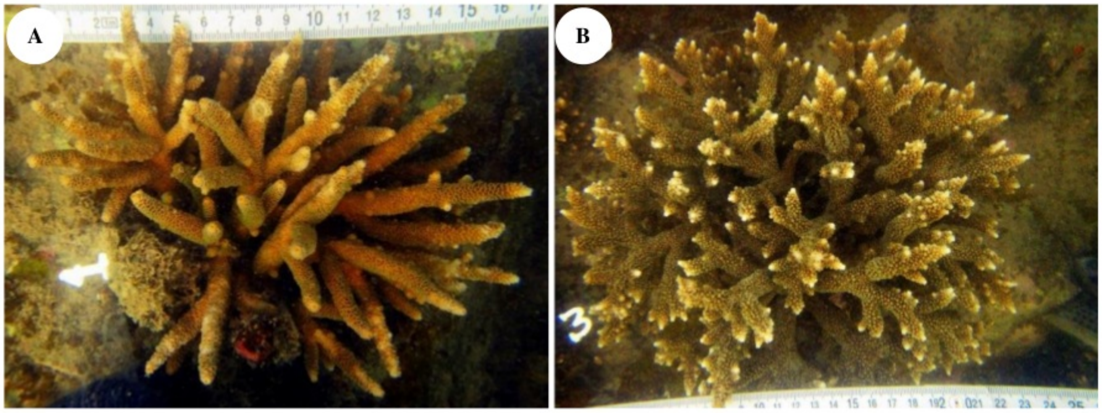

Figure 7. Transplanted of two species Acropora on multilevel substrate of APR after 8 months (A. horizontal fixing method of transplanted *Acropora aspera*; B. vertical fixing method of transplanted *Acropora copiosa*)

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Include relevant facts, definitions, and examples to back up the claim.

ADVANCED	The essay supplies sufficient relevant, accurate qualitative and/or quantitative data and evidence related to the scientific topic or text(s) to support its claim and counterclaim.
PROFICIENT	The essay supplies relevant, accurate qualitative and/or quantitative data and evidence related to the scientific topic or text(s) to support its claim and counterclaim.
DEVELOPING	The essay supplies some qualitative and/or quantitative data and evidence, but it may not be closely related to the scientific topic or text(s), or the support that is offered relies mostly on summary of the source(s), thereby not effectively supporting the essay's claim and counterclaim.
EMERGING	The essay supplies very little or no data and evidence to support its claim and counterclaim, or the evidence that is provided is not clear or relevant.

REASONING

Explain how or why each piece of evidence supports the claim.

ADVANCED	The essay effectively applies scientific ideas and principles in order to explain how or why the cited evidence supports the claim. The essay demonstrates consistently logical reasoning and understanding of the scientific topic and/or text(s). The essay's explanations anticipate the audience's knowledge level and concerns about this scientific topic.

PROFICIENT	The essay applies scientific reasoning in order to explain how or why the cited evidence supports the claim. The essay demonstrates logical reasoning and understanding of the scientific topic and/or text(s). The essay's explanations attempt to anticipate the audience's knowledge level and concerns about this scientific topic.
DEVELOPING	The essay includes some reasoning and understanding of the scientific topic and/or text(s), but it does not effectively apply scientific ideas or principles to explain how or why the evidence supports the claim.
EMERGING	The essay does not demonstrate clear or relevant reasoning to support the claim or to demonstrate an understanding of the scientific topic and/or text(s).

FOCUS

Focus your writing on the prompt and task.

ADVANCED	The essay maintains strong focus on the purpose and task, using the whole essay to support and develop the claim and counterclaims evenly while thoroughly addressing the demands of the prompt.
PROFICIENT	The essay addresses the demands of the prompt and is mostly focused on the purpose and task. The essay may not acknowledge the claim and counterclaims evenly throughout.
DEVELOPING	The essay may not fully address the demands of the prompt or stay focused on the purpose and task. The writing may stray significantly off topic at times, and introduce the writer's bias occasionally, making it difficult to follow the central claim at times.
EMERGING	The essay does not maintain focus on purpose or task.

ORGANIZATION

Organize your writing in a logical sequence.

ADVANCED	The essay incorporates an organizational structure throughout that establishes clear relationships among the claim(s), counterclaims, reasons, and evidence. Effective transitional words and phrases are included to clarify the relationships between and among ideas (i.e. claim and reasons, reasons and evidence, claim and counterclaim) in a way that strengthens the argument. The essay includes an introduction and conclusion that effectively follows from and supports the argument presented.
PROFICIENT	The essay incorporates an organizational structure with clear transitional words and phrases that show the relationship between and among ideas. The essay includes a progression of ideas from beginning to end, including an introduction and concluding statement or section that follows from and supports the argument presented.
DEVELOPING	The essay uses a basic organizational structure and minimal transitional words and phrases, though relationships between and among ideas are not consistently clear. The essay moves from beginning to end; however, an introduction and/or conclusion may not be clearly evident.
EMERGING	The essay does not have an organizational structure and may simply offer a series of

ideas without any clear transitions or connections. An introduction and conclusion are not evident.

LANGUAGE

Pay close attention to your tone, style, word choice, and sentence structure when writing.

ADVANCED	The essay effectively establishes and maintains a formal style and objective tone and incorporates language that anticipates the reader's knowledge level and concerns. The essay consistently demonstrates a clear command of conventions, while also employing discipline-specific word choices and varied sentence structure.
PROFICIENT	The essay generally establishes and maintains a formal style with few possible exceptions and incorporates language that anticipates the reader's knowledge level and concerns. The essay demonstrates a general command of conventions, while also employing discipline-specific word choices and some variety in sentence structure.
DEVELOPING	The essay does not maintain a formal style consistently and incorporates language that may not show an awareness of the reader's knowledge or concerns. The essay may contain errors in conventions that interfere with meaning. Some attempts at discipline-specific word choices are made, and sentence structure may not vary often.
EMERGING	The essay employs language that is inappropriate for the audience and is not formal in style. The essay may contain pervasive errors in conventions that interfere with meaning, word choice is not discipline-specific, and sentence structures are simplistic and unvaried.