Potential coral implementation area for Indonesia Coral Reef Garden in Nusa Dua, Bali

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Abstract. The Indonesia Coral Reef Garden (ICRG) program is announced as a coral reef restoration program which can support the marine tourism sector since the Covid-19 pandemic hit Indonesia, particularly in Bali. A comprehensive survey and preliminary study are necessary to be conducted to decide a suitable point or to avoid a premature choice for the restoration location. Field survey in Nusa Dua, Bali was carried out on November-December 2020 to determine physical and chemical characteristics of seawater which appropriate for coral life. The bathymetry result at Nusa Dua, Bali varied from shallow to middle water depth. Area covered with coral, soft coral, coral and sand, sand, and seaweed on the seabed are found over study area. In the depth close to the seabed, the sea condition of temperature, salinity, pH, turbidity, and DO is 26.04 - 28.48 °C, 33.95 - 34.29 PSU, 7.933 - 7.982, 0.81 - 2.44 FTU, and 4.40 - 4.93 mg/L, respectively. Based on the conformity of water quality, the middle depth region has sufficient condition for coral growth. Simple Addition Weighting method is used for determining potential location. The potential coral implementation is located 3-5 km from Tanjung Benoa and in south of Nusa Dua around 1-3 km from coast.

1. Introduction

Indonesian water as one part of Coral Triangle is abundant for its coral reefs and aquatic biodiversity. The region has the most diverse marine life lies compare to the neighbouring countries in Southeast Asia. The total of 15.8% of the world’s coral reef is stored in this archipelagic nation. As a result, the economy and food security are tightly linked to marine and coastal resources. More than one third of the Indonesian population living in coastal areas depends on nearshore fisheries for livelihood [1,2,3]. Coastal habitats in Coral Triangle region are often being exploited beyond their recovery due to overfishing and coral reef destruction. In response to a noticeable loss of marine ecosystem, Marine Protected Areas were initialised and developed [2,3]. Indonesia has 108 Marine Protected Areas covering 157,841 km² and aim to expand 20 million ha by 2020. Several spots are located in Bali [4,5,6] where the area of coral reefs reaches 88,000 ha according to data obtained in the journal Status of Indonesia’s Coral Reef 2017. However, only 55% of coral are in good quality, meanwhile 30% are in
poor condition, and rest is in worrying state. Therefore, Bali has been the topmost priority by the Indonesian Government and marine activist in order to save marine habitat in the long term [7].

SARS-Cov-2 virus pandemic known as the covid-19 had been spread over countries on global scale starting from Wuhan, China in December 2019 [8]. The virus has been detected in Indonesia on early March 2020 [9]. The covid-19 hit several major cities in Indonesia, including Bali. Balinese suffer economical sector since they rely more on tourism activities. At the first announcement by local government, tourist visit rate almost 50% down [10]. A significant decline in marine industry, including marine and diving activities, was untouched from March to September 2020. Marine activist believed it is the time to lets marine biota and coral reefs grow without any human disturbances. However, a reduce in marine activities did not stop the decrease of coral quality since the bleaching phenomenon due to rising sea water temperature becomes the main culprit. Conservation should be continued, but in contradict continuous observation, maintenance and monitoring faced difficulties in the execution within this pandemic situation.

The Indonesia Coral Reef Garden (ICRG) program is a coral reef restoration program through a labour-intensive mechanism launched by the government to restore the marine tourism sector which was paralyzed by the impact of the Covid-19 pandemic. The ICRG program is targeted to absorb a workforce of around 11,000 people in 5 locations, while at the same time carrying out other objectives, namely coral reef restoration and research. This program is implemented starting in 2020 at five locations in Bali Province, namely in Nusa Dua, Serangan, Sanur, Pandawa Beach, and Buleleng [11]. The estimated potential area to be restored are around 1,606 Ha. In addition to coral reefs transplantation, determining the sinking point of ship that will be used as dive tourism sites is included in the ICRG program. Various stakeholders are involved in this project including government institution, educational institution, private, entrepreneurs, local people, researchers, and students.

Coral reef restoration, i.e., artificial reefs or man-made ecosystem, takes long-term processes until some coral fragments mature and develop complex symbiosis between marine organism. Many restorations program has been implemented, but the success rate depends on the treatment and environment itself. A premature choice of the restoration point leads to the zero-coral growth. Therefore, ocean survey activities and researches are necessary to mapping the potential location and increase the certainty in the location decision. Coral growth depends on several factors, such as temperature, salinity, light penetration, sedimentation, current, and waves [12].

A comprehensive survey and preliminary study are necessary to be conducted to support coral reef rehabilitation program. The field survey, involving bathymetric survey, oceanographic studies, water quality measurement, and sediment sample, aims to determine the physical characteristics of seawater in Nusa Dua, Bali. The collected information therefore can be used as the basis for determining potential coral implementation area.

2. Material and Methods

2.1. Study site

The field survey was located in eastern coast of Nusa Dua, Bali. The survey was conducted within 26 November - 2 December 2020 in Nusa Dua, Bali.
2.2. Data Collection

2.2.1. Sea bottom morphology. Kongsberg’s MultiBeam Echosounder (MBES) GeoSwath 4 and Single Beam Echosounder (SBES) EA440 Kongsberg were used to measure the water depth at the measurement point through several routes and are supported by the satellite navigation system by Seapath 130 GNSS which covers the entire survey area. Correction of the position and tilt of the ship due to sea elevation is carried out in the GeoSwath 4 program by entering the details of the position of the instrument in order to obtain the correction of heave, pitch, yaw, roll movements through the Kongsberg Seatex MRU-H instrument installed in the MBES. Valeport miniSVS also installed in MBES for sound correction velocity in the water. The survey is focused on the coastal area from the coast to the area which has a contour of 50 m depth with the total length of the route is 174.4 km. The distance between each survey line is 200 m. During the survey, the maximum speed of the boat was around 6 knots or 3 m/s. This speed is still within the maximum speed range of the boat to obtain good quality data [13,14]. Water depth, position, and measurement time are recorded at the same time using the Hypack Max navigation and Geoswath 4 software.

2.2.2. Tidal observation. Tidal measurement had been started from 26 November 2020 to 3 December 2020 (8 days) using Valeport Tidemaster tide gauge and conventional tide staff. Both of the tide instruments were installed at Benoa Marina Harbor (8.74482056°S and 115.21162571°E). Tidal gauge
and tidal staff were put in the inner side of Tanjung Benoa (Figure 1) to avoid short-term elevations such as wind and waves during observation [15].

2.2.3. Bottom sediment sample. Sediment sampling was done using a Ponar grab sampler from 29 points. Grab sampler was dropped overboard until it reached the bottom. The sediment which was lifted by boat’s pulley then stored in 250cc bottle sample.

2.2.4. Sea characteristics. The water quality survey was conducted at 29 points in line with bathymetry survey route (Figure 1). It was conducted using the CTD Valeport Midas+ to determine the parameters of conductivity, temperature, salinity, dissolved oxygen (DO), pH, turbidity and density. Data collection was carried out on 1-2 December 2020. The CTD instrument was pulled down until 0.8 of total depth or around 5-10 m above the seabed for safety. Sediment sample obtained at each point was observed qualitatively. Then the measurement result is compared with standard quality to see its conformity.

2.2.5. Data Analysis. Sea morphology data processing was handled by Geoswath 4. Certain noises alongside survey track line were reduced with the help of the software. Tide corrections for depth data are made with ranges per minute. Sea bottom map generated from this survey was plotted using mapping software after correcting its water depth. Tidal data also analyzed its harmonic constituent to classified the tidal type in this area [16]. Sea characteristics was analyzed vertically and spatially and compared with standard quality to see its conformity. Bottom sediment sample result observed qualitatively and classified spatially into sand and coral. Then, the suitable location for potential coral implementation determined based on the survey analysis.

Simple Additive Weighting (SAW) method was used to define the potential location for coral implementation over study area. SAW is one popular method because of its simplicity [17]. It is widely used in making decision that have many attributes, so the potential decision can be calculated quickly. The method aims to find a weighted sum of the performance on each parameter/criterion. SAW requires a normalizing process in the decision matrix to a scale that can be compared with all the ratings of existing criteria [18]. In this study, 9 parameters were used as basic criteria for determine the location. Additional criteria namely wave breaking location, depth, and vessel traffic are included beside all CTD parameters and sediment sampling. Each criterion divided into 3-4 rating with range based on several references (Table 1). The determination of this ratings and weights have been made through modifications based on various references obtained which explained briefly in the next section.

| Temperature | Range | Rating | Salinity | Range | Rating | pH | Range | Rating |
|-------------|-------|--------|----------|-------|--------|-----|-------|--------|
| Suitable    | 28-30 °C | 4      | Suitable  | 33-34 PSU | 4       | Suitable | 8.0-8.5 | 4     |
| Acceptable | 23-28 °C | 3      | Acceptable | 31-33 PSU | 3       | Acceptable | 7.6-8.0 | 3     |
| Susceptible | 30-31 °C | 2      | Susceptible | 34-42 PSU | 2       | Susceptible | 8.5-8.6 |       |
| Not suitable | 31-35 °C | 1      | Not suitable | <25 PSU | 1       | Not suitable | 7.0-7.6 | 2     |
|             | <18 °C | 1      |           | >35 °C | 1       |           | <7.0  | 1     |

| Turbidity | Range | Rating | DO | Range | Rating | Bed sediment | criteria | Rating |
|-----------|-------|--------|----|-------|--------|-------------|---------|--------|
| Suitable  | 0-3 NTU | 4      | Suitable | 5-8 mg/L | 4       | Suitable | Coral  | 4     |
| Acceptable | 3-4 NTU | 3      | Acceptable | 4-5 mg/L | 3       | Acceptable | Soft coral |       |
| Susceptible | 4-5 NTU | 2      | Susceptible | 8-15 mg/L | 2       | Susceptible | Sand+coral | 3     |
| Not suitable | >5 NTU | 1      | Not suitable | < 3.5 mg/L | 1       | Not suitable | Sand | 2     |

Table 1. Rating for each parameter
Wave breaking criteria | Rating
--- | ---
Suitable | Less
Acceptable | Moderate
Susceptible | Potential

Depth Range | Rating
--- | ---
Accessible (a) 2-10 m | 4
Moderate a. 10-20 m | 3
Less a. 20-30 m | 2
Difficult a. >30 m | 1

Vessel traffic criteria | Rating
--- | ---
Suitable | Low traffic
Acceptable | Moderate
Susceptible | High traffic

Based on the Minister of Environment and Forestry (MOEF), suitable temperature for coral is around 28-30°C [19]. Many corals grow optimally in water temperatures between 23 – 30 °C, some can tolerate in higher temperature but only for short period [20,21]. However, reef-building corals cannot tolerate temperature below 18°C. Most of reef-building corals also require very saline water ranging from 32 to 42 PSU [21,22]. For the tropical area such as Indonesia region, the salinity of 33-34 is suitable [19]. The water must also be clear so the maximum amount of light penetrates which is necessary for photosynthesis. As mentioned in Table 2, the turbidity should be lower than 5 NTU. However, for optimal growth it should be suggested to have turbidity below 0-3 NTU. There is a possibility to have higher turbidity in wet season and when the extreme event occurred. However, the biological response of coral is varying depends on its depth and species as well as the duration of exposure to turbidity [23].

The condition around the seabed can influence the coral growth. The location surrounding by coral and soft coral is obviously suitable for coral implementation. Area dominated by sand categorized as susceptible for coral since it correlates with turbidity. Seagrass were found but since seagrass and coral has their own habitat, it is rated as not suitable. Also in those area, the sand is much and close to breaking zone. Commonly, coral grow in environment with pH 8.0-8.5 [24]. The environment should not be acidic (<7), even the area is vulnerable if the pH below 7.6 where the coral reefs begin to collapse due to lack of calcium carbonate [25]. Many tropical saltwater fish require high level of DO, such as in surrounding coral reefs. Higher DO are generally found around coral due to photosynthesis and aeration from eddies and breaking waves [26]. The DO levels usually around 5-8 mg/L, though they can fluctuate from 4-15 mg/L, cycling between day photosynthesis production and night respiration [27]. The Indonesian government through MOEF consider the DO should be above 5 mg/L for coral [19]. Most of fish organism avoid area below 3.7 mg/L with more specific species abandoning an area completely when level falls below 3.5 mg/L [28].

The potential location for coral plantation should consider marine tourism value and safety consideration so it could support social and economic for local people. In this study we only involve depth area, wave breaking, and vessel traffic as one of the parameters. Undoubtedly, tourist and diver would like to have more accessible in enjoying the coral site. Shallower area is preferable since deeper area needs more requirement and preparation for diver. Based on Professional Association of Diving Instructor (PADI), the common depth for recreational tourism is between 10 – 30 m [29]. The location should also be safe from any wave breaking and channel where marine traffic is usually crowded. Wave breaking location was observed qualitatively when the survey held and the potential wave breaking location was found in some location. Vessel traffic is observed through marine traffic platform over two years period (2019-2020) [30]. Crowded area found in area close to channel in the north of Tanjung Benoa.

After each survey point have been rated and turned into matrix, the normalization of this matrix is calculated and compared to find the best alternative for potential location. The equation for carrying out the normalization is as follows:

\[ r_{ij} = \frac{x_{ij}}{\text{Max}(x_{ij})} \]  
\[ r_{ij} = \frac{\text{Min}(x_{ij})}{x_{ij}} \]
where $r_{ij}$ and $x_{ij}$ is a normalized performance rating and the attribute value of each criterion, respectively. Each observation point is indicated by $i = 1, 2, \ldots, m$ and criteria is indicated by $j = 1, 2, \ldots, n$. Equation (1) is used for criteria which have increasing value as well as the increasing of rating, known as benefit attribute. On the other hand, if the criteria have increasing value while the rating is decreasing it will use equation (2) namely the cost attribute. Simply, benefit attribute which has the greatest value is the best but vice versa for the cost attribute. Then, calculating preference value for each alternative ($V_i$) as given formula [18]:

$$w = \frac{C_i}{C_1 + \ldots + C_n} \times 100\%$$

(3)

$$V_i = \sum_{j=1}^{n} w_j r_{ij}$$

(4)

where $V_i$ is the ranking for each alternative, while $w_j$ is the weighted value of each criterion ($C_n$). Weighting criteria in SAW method are determined by the decision makers, in other words, policy makers must decide the weight preference in advance. In this study, the identification of criteria for weighting were faced. Mousavi et al. surveyed similar studies about coastal and marine constructions to elicit important criteria from 53 studies [31]. Therefore, we adapt those references into our weighting calculation. Based on many references, we decided to put criteria for some important parameter than other parameter. The value of $C_n$ for temperature, salinity, pH, turbidity, DO, bed sediment, wave breaking, depth, and vessel traffic is 2, 2, 1, 2, 1, 3, 2, 3, and 2, respectively. The final result is obtained from the ranking process, namely the addition and multiplication of the normalized matrix $r_{ij}$ with the weight vector so that the largest value of $V_i$ is chosen as the best alternative as a solution.

3. Results and Discussion

Based on the results of tide observations (Figure 2), it can be seen that the tidal pattern in Nusa Dua waters has two tides in one day or commonly called as mixed tides tend to be semidiurnal. The highest tide occurs around 22:00 and the lowest low tide occurs around 05:00 with tidal range around 1–2 m. The data from tide gauge also compared with BIG (Indonesia Geospatial Information Agency) tide station located in Benoa. The comparison between the tide gauge and the BIG tide station has almost the same pattern and values with correlation close to 1 (almost fit) and root mean square error of ~10 cm. The blank data occurred on 28 November due to system error, but it can be covered by BIG’s data for bathymetry correction.
ship routes for entering the inner area of Tanjung Benoa or Benoa Port. This area has seabed with a depth lower than 20 m. Nusa Dua coastal area were unable to be surveyed due to wave breaking zone area which is not safe for boat navigation. Although no data in those areas was taken, it is believed that the area has a slope bathymetry with a depth shallower than 4 m. Simple interpolation can be done by connecting the coastal data with the nearest depth data that has been obtained. Study in the past shown the typical cross-section of the beach at Nusa Dua. The beaches consist of white coarse sand (0.5<\text{d_m} < 2 \text{ mm}) which slope of 1:5 up till 1:9. In front of Nusa Dua, there is shallow flat with constant depth of 1 m or more with width 400 m – 600 m. This flat is bounded by coral reef (dead coral). The depth increases suddenly to 7 m and more with more living coral are to be found. Since decades ago, the waves attacking the shores are losing most their energy at this coral reef and completely lost in the breaking zone near the sandy beach [32].

![Bathymetry contours at Nusa Dua, Bali (left) and sediment sampling at each station (right).](image)

The results of the grab sampling (Figure 3) are assumed to represent the surface conditions under water at the point of observation. Figure 4 shows several samples obtained in the observation points. In general, there are two kinds of materials taken by the grab sampler, namely sand and coral. Sand is generally found in shallow areas near the coast. Coral was still found until sampling was at a depth of 83 m (st. 25-6). The sample could not be obtained in point 20-3, though repeating procedure had been taken. It was assumed that the device hit hard seabed layer and could not take any samples. Coral distributed almost 1 km (or more) from the Tanjung Benoa and Nusa Dua coastline. Based on Ministry of Energy and Mineral Resources (MEMR) gravity core map [33], seabed in front of Nusa Dua consist of silty sand, muddy sand, and gravelly sand. Although the information is not detailed and the point distributed sparsely, our survey data show similar type of sediment (mostly sand) in the seabed close to the shore as provided by MEMR. There are not many studies focused on the seabed in local area, particularly in Nusa Dua.
Figure 4. Sediment sample from grab sampler classified by (a) sand+coral, (b) sand, (c) coral, (d) soft coral, (e) seaweed

In the CTD measurement, each parameter affects other parameters through empirical correction of the instrument. Based on data from 29 stations, a temperature-salinity diagram was made to determine the mass of water in the waters of Nusa Dua, Bali. The density in the survey area ranges from 1021.1 - 1022.8 kg / m³ with salinity ranging from 33.7 - 34.45 PSU (Practical Salinity Unit) and potential temperature ranging from 24.5 – 29°C. Other parameter namely pH, DO, and turbidity has a variation value around 7.932-8.0, 4.40-4.93 mg/L and 0.7 – 3.417 FTU, respectively.

In several point, particularly closest point to the shore, mixed layer area characterized by temperature and salinity that tends to be uniform from surface to bottom with a narrow density range, namely 1021.3 - 1021.8 kg/m³. Although the points are close to the land, there is no river that empties around the study area so that there is no clear influence of fresh water. On the other points which has deeper depth, temperature is decreasing while salinity is increasing after passing the mixed layer line. In Hao et al. [34], the thermocline layer in waters with a depth below 200 m is characterized by a temperature change gradient of -0.2°C/m. Based on our measurement, the gradient is found at a depth of more than 40 meters at points 25-4, 25-5, and 25-6. It is suspected that the depth of the mixed layer in Nusa Dua waters is up to 40 m. Dissolved oxygen and pH decrease with increasing depth. Meanwhile, the vertical distribution of turbidity has a different trend at each point with spikes that are clearly visible at several depths.

The horizontal distribution pattern of each parameter is related to the bathymetric pattern. Each ocean parameter on 80% original depth (0.8h) at each point is displayed spatially with interpolation approach (Figure 5). Those depth is the deepest CTD measurement did in the survey. We avoided the direct contact between the instrument and seabed for safety reason. To analyze it simpler in this spatial distribution map, we divide the area into depth 1 (depth below 50 m) and depth 2 (depth above 50 m). The depth 1 has temperature 27.6-28.4 °C and it keep decreasing in the eastern part of measurement area. The temperature can reach 26.4 °C which is one or two degrees lower than in the shallower area. The turbidity is quite similar in most area with 0.7-1.1 FTU. There is a surge in the turbidity value near the base at point 20-5, 20-6, 25-5, and 25-6 with value up to 2.4 FTU. On the other hand, the turbidity value become higher where the location closer to the shore due to the effect of mixing. It is suspected that a significant change in bathymetry affects the current at the bottom, causing stirring and increasing turbidity. Turbidity is impacted by the presence of suspended and dissolved material (clay, silt, organic matter, and plankton) [35,36]. Suspended sediment distribution in Nusa Dua surround in some source point (i.e., Serangan reclamation island) and varying during tidal level [37].
There are small differences in pH parameter value over study area. The pH is around 7.9 where the deeper depth has more alkaline than the shallow one. However, previous study shows pH near the south coast of Nusa Dua is 8.04-8.1 where the location is dominated by seagrass [38]. Salinity in depth 1 is around 33.94-34.09 PSU while the depth 2 in increase up to 34.29 PSU. Similar pattern found in DO where mostly the area has DO around 4.65-4.8 mg/L; meanwhile in deeper depth, the DO decreasing to 4.4 mg/L. In the seagrass area (south of Nusa Dua) the average DO is 7.3 mg/L [38] while close to beach resort (north of Nusa Dua) is 5.5 mg/L [39]. The difference with our result is caused by different location and the measurement depth since we did not measure until the seabed (only 80% of original depth).
Based on the quality standards in the third attachment of Decree of the Minister of Environment and Forestry (MOEF) Number: 51 of 2004 [19], there are 5 main parameters that influence coral growth, namely temperature, salinity, pH, dissolved oxygen, and turbidity. Referring to Table 2, it can be seen that the pH and turbidity values meet the quality standards at all observation points. The temperature and salinity values at the observation point with a depth of more than 50 meters (the eastern part of the study) do not meet quality standards because they are too cold and salty. Meanwhile, the DO values at all observation points did not meet the specified quality standards which it should be more than 5 mg/L. Even so, the DO value in these waters has almost reached the lower limit of the quality standard, which is between 4.4 - 4.93 mg/L.

**Table 2.** Measurement of water quality in Nusa Dua, Bali compared with MOEF quality standard

| No | Parameter      | measurement | Quality standard | Conformity          |
|----|----------------|-------------|------------------|---------------------|
| 1  | pH             | 7.933 - 7.982 | 7 - 8.5          | Meets at all points |
| 2  | Turbidity      | 0.81 - 2.44 FTU’ | < 5 NTU         | Meets at all points |
| 3  | Temperature    | 26.04 - 28.48 °C | 28 - 30 °C     | Meets at some points|
| 4  | Salinity       | 33.95 - 34.29 PSU | 33 - 34 PSU   | Meets at some points|
| 5  | Dissolved Oxygen| 4.40 - 4.93 mg/L | > 5 mg/L       | Not fulfilling at all points |

*1 FTU = 1 NTU

**Table 3.** Measurement of water quality in Nusa Dua, Bali

| No | Parameter | $x_{ij}$ |
|----|-----------|----------|
|    |           | 10-1 10-2 10-3 10-4 10-5 10-6 10-7 15-1 15-2 15-3 15-4 15-5 15-6 15-7 15-8 |
| 1  | Temperature| 4 4 3 3 3 3 4 4 4 4 3 3 3 3 3 |
| 2  | Salinity   | 3 3 3 3 3 3 3 3 3 4 3 3 3 3 3 |
| 3  | pH         | 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 |
| 4  | Turbidity  | 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 |
| 5  | Dissolved Oxygen | 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 |
The potential coral implementation based on SAW method is shown in Figure 6. The location has higher alternative value ($V_i$) than the average of all location, namely site A and site B. Site A located in the east part of study area which ~3-5 km perpendicular to the Tanjung Benoa coast, meanwhile site B covered in south part of study area around 1-3 km from coast. The best alternative is the location with $V_i$ above 0.8, however since some of location has value close to this threshold, it can be assumed certain location with $V_i$ above 0.75 become potential also. Certainly, the $V_i$ depend on rating value and weighting used. Although we only use certain number for weighting value as mentioned before, the $V_i$ had been tested using homogenous weighting value and variation weighting value. The result of potential coral location is quite a same with is shown in Figure 6. The variation is not different since the variability of rating result is close each other, even same for all points in certain parameter.

It is found some shallower area in the middle of sea such as east part of site A. Although, it is a bit far from coast, it has potential for diving site and coral plantation. On the west of site B, seagrass is found in shallow area [38]. The deeper area within site A and site B is suitable for coral conservation. Less marine activity will make the coral growth optimally. However, the coral plantation design and submerging technique should be considered carefully. Numerous designs of coral plantation had been made by many researchers and practitioners, and one of them is adapting MARRS (Mars Assisted Reef Restoration System) method which is planted in Nusa Dua, Bali [40]. Other location which can be potential coral implementation area was investigated by observing lived coral Nusa Dua coastal area [41]. They found coral alongside Tanjung Benoa until south of Nusa Dua based on satellite imagery. Although the classification between seagrass and coral is not distinguishable and should be investigate further.
Figure 6. potential location for coral implementation, indicated by black dashed line

Chemical properties and nutrient likely influence coral growth, however in this study, there is lack in measurement of this parameter, beside pH and DO. There is a possibility in the sensitivity of the SAW if the method involves additional parameter, namely the nutrient. However, additional study and references is required for this advanced determination of coral potential location. Very low nutrient level is not necessarily optimal for coral physiological performance, however level beyond certain thresholds can have a fatal direct effect for coral [42]. The increased productivity of nutrient enriched waters might increase availability of particulate food and give benefit for corals [42,43]. On the other hand, increased phosphate not only can accelerate coral growth, but also reduce skeletal density, rendering the corals more brittle, and susceptible to mechanical damage [44]. Indirect negative effect of elevated nutrient level had been studied for recent years. Nutrient enrichment can increase the productivity coral reef macroalgae, however once established, macroalgae can lead competition in coral recruitment by shading/overtopping and reducing water exchange [45,46]. The standard quality of nutrient for coral is not specifically explained in the government regulation yet, except nutrient threshold for healthy sea water. The potential location might not be changed significantly, but the potential location for coral will be more selective from former SAW result.

The regulation and restriction should be socialized to local and tourist so the coral site can be maintained well. On other study, Nusa Penida which is not far from Nusa Dua is faced the damage of coral reefs, including coral breakage and fragmentation, due to scuba diving and snorkeling activity [47]. Elevated sea surface and temperature should be concerned for long term sustainability of coral. Many coral locations are suffered from this issue which is shown by bleaching evidence. Thus, after coral are planted, they should be checked regularly in certain period, be in once in six month or one year. Therefore, the coral growth can be monitored.
4. Conclusion

Potential location for coral conservation had been determined using SAW method with involving certain physical and chemical properties of ocean. One potential location locates in east part of survey area which is 3-5 km from Tanjung Benoa and the other is in south of Nusa Dua around 1-3 km from coast. Both of the location has sufficient range value of temperature, salinity, and pH. Also, those location have reasonable depth for tourism activity and coral conservation, less vessel traffic, and less wave breaking. Moreover, based on the water quality standards set by the ministry of environment, several areas on Nusa Dua, Bali are in sufficient condition for coral growth. Dissolved oxygen almost qualifies the standard, therefore if the conservation is going well this parameter concentration might increase.

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