# *Homotrema rubrum* taphonomy as an indicator of sedimen transport of the Bangka Island Waters, North Minahasa

**M Alam[1*], R Zuraida[2], L P Sari Yuliadi[3], W Lili[4], I Nurruhwati[5]**

[1] Marine Science Major, Faculty of Fisheries and Marine Science, University of Padjadjaran, Indonesia
[2] Marine Geological Institute, Jl. Junjunan 236, Bandung City 40174, Indonesia
[3] Marine Science Department, Faculty of Fisheries and Marine Science, University of Padjadjaran, Indonesia
[4]Aquaculture Department, Faculty of Fisheries and Marine Science, University of Padjadjaran, Indonesia
[5] MSP Department, Faculty of Fisheries and Marine Science, University of Padjadjaran, Indonesia
*e-mail: mujizat13001@mail.unpad.ac.id

**Abstract.** The determination of current direction from sedimentary deposits were based on silisiclastic deposits that behave differently than biogenic fragment-rich deposit. The objectives of this research are to determine biogenic sediment transport pathway of Bangka Island water, North Minahasa, by the taphonomy of benthic foraminifer *Homotrema rubrum* and to verify the reconstructed pathway with sea surface currents data. This study used twelve surface sediment samples that were acquired by grab sampler in 2016 and 2014-2016 annual average sea surface current data from INDESO that was generated by OPA/NEMO model. The result of this study shows that samples with higher degree of taphonomy are located closer to coral reef which forms the source of *H. rubrum* while samples with lower degree of taphonomy are located further from the source. Sediment transport pathway reconstructed from *H. rubrum* taphonomy shows inflow of water from the north and west part of the islands and West Likupang Strait to the east and flowing out of East Likupang Strait. This direction corresponds to annual sea surface current derived from INDESO. This study also shows that *H. rubrum* taphonomy can be used as sediment transport indicator in areas that are dominated by biogenic sediments.

## 1. Introduction

Bangka Island, a part of islands cluster in North Minahasa District, North Sulawesi Province, are susceptible to abrasion due to marine forcing such as ocean currents and waves (Regional Regulation of North Minahasa Regency No. 1 of 2013). Current movement will affect beach profile leading to coastal abrasion or accretion [1,2]. This longshore current transports sediment along the coast, and hence the reliable information of current patterns and sediment transport is required to develop coastal management. This information can be used to reduce the impact of coastal abrasion and accretion.

Determination of sediment transport direction can be conducted by observing sediment deposited to the updrift of a jetty or any other coastal construction [11]. Identification of past sediment transport direction from sedimentary deposits have been carried out by studying grain-size distribution. Finer grains are found deposited further from the source and vice versa. However, that method can only be applied to detrital sediment as it was developed based on experiment conducted on siliceous sediments, and cannot be applied on sediment dominated by biogenic fragments, i.e. biogenic sediments, that are found covering the seafloor in areas where coral reefs are present. Considering that Indonesia is in the center of Coral Triangle that resulted in biogenic sediments, it is imperative to find another method to identify current direction from sedimentary deposits.

One of the most recent method in establishing sediment transport direction is by using benthic foraminifera from seabed sediments [3]. The taphonomy of *Homotrema rubrum* was successfully applied to understand sediment transport in Sioba/Rio do Fogo, Brazil [4]. Taphonomy is able to reveal information on sediment source and also sedimentation process [5]. *Homotrema rubrum* (Lamarck) is benthic foraminifera that lives attached to the bottom part of corals [6].

The application of this method in Bangka Island is determined based on the position of Bangka Island within Coral Triangle Scientific Boundary that houses over 500 species of coral *zooxanthellae* [7]. To date, there is no information on benthic foraminifer from the study area. However, considering the association of *H. rubrum* with corals, it is expected tat the surface sediment might contain abundant *H. rubrum* that could be used for the study. This study aims to determine sediment transport pathway of Bangka Island water, North Minahasa, by observing *H. rubrum* taphonomy and to verify the reconstructed pathway with sea surface currents data.

## 2. Methods

A total of 3715 *H. rubrum* specimens from 12 sediment samples in the waters of Bangka Island, North Minahasa and surrounding areas (table 1). The samples were selected to represent each straits in the island cluster of which the currents flow in and out. The sediment samples were acquired in 2016 by Marine Geological Institute (MGI). The selected samples were split until it was estimated to contain approximately 300 individus of *H. rubrum.* Picking activity of *H. rubrum* was performed in Micropaleontology and Petrology Laboratory of MGI in Bandung from February to April 2017.

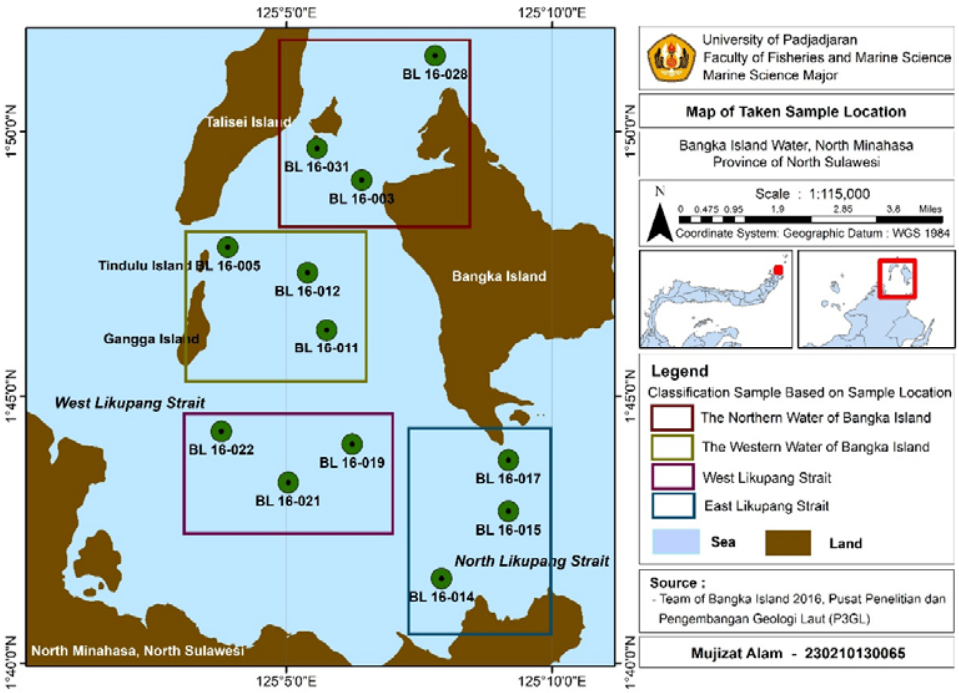


**Figure 1.** Location map of samples collection.

The observation of *H. rubrum* taphonomy was conducted by using Nikon SMZ 800 binocular microscope. Parameters observed in this study included color, shape and chamber structure [8] that determined the degree of preservation of *H. rubrum*. Plotting those data into a map developed sediment transport pathway. The developed pathway was then compared to surface current pattern of Bangka Island waters [9]

This study used five levels of *H. rubrum* degree of of preservation instead of seven groups [8]. The modification was conducted due to different characteristics of *H. rubrum* that were observed in Bangka Island waters: white, angular with intact chamber structure (table 2 and figure 2). Those characteristics are assigned as *well to moderately preserved.*

**Table 1.** Sample locations.

| Sample | Longitude (°) | Latitude (°) |
|---|---|---|
| BL 16-031 | 125.093 | 1.828 |
| BL 16-003 | 125.107 | 1.818 |
| BL 16-005 | 125.065 | 1.797 |
| BL 16-022 | 125.063 | 1.739 |
| BL 16-017 | 125.153 | 1.730 |
| BL 16-015 | 125.153 | 1.714 |
| BL 16-028 | 125.130 | 1.857 |
| BL 16-021 | 125.084 | 1.723 |
| BL 16-019 | 125.104 | 1.735 |
| BL 16-011 | 125.096 | 1.771 |
| BL 16-014 | 125.132 | 1.693 |
| BL 16-012 | 125.090 | 1.789 |

**Table 2.** Degree of preservation *Homotrema rubrum* (modified from [8]).

| Degree of Taphonomy Preservation | Test Colour | Fragment Angularity | Chamber Structure |
|---|---|---|---|
| Exceptionally Preserved (EP) | Red | Angular | Intact |
| Well Preserved (WP) | Pink | Angular | Hollowed |
| Well to Moderately Preserved (WMP) | White | Angular | Hollowed |
| Moderately Preserved (MP) | Pink | Rounded | Hollowed |
| High Altered (HA) | Light Pink to White | Highly Rounded | Hollowed |

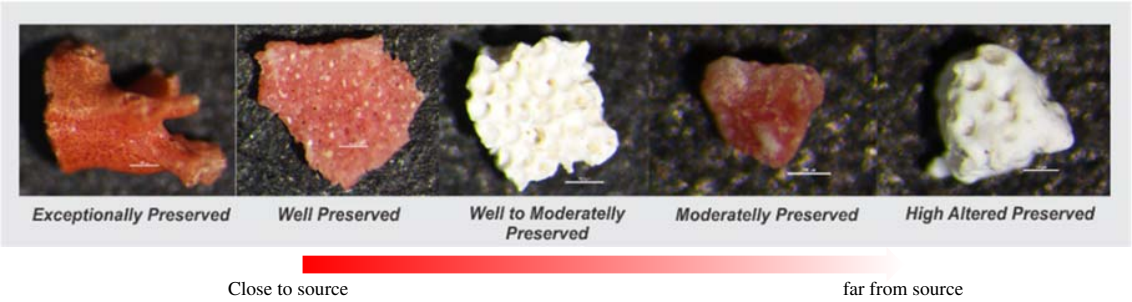


**Figure 2**. *H. rubrum* taphonomy indicated by color, angularity and chamber structure (modified from [8]).

## 3. Results

### *3.1. Taphonomy Homotrema rubrum*

*3.1.1 The Northern Bangka Island.* Taphonomy observations on BL 16-003, BL 16-028 and BL 16-031 samples shows that higher preservation was found in BL 16-028 (figure 2). *H. rubrum* BL 16-028 is characterized by red colour (3%), pink (73%), and light pink to white (24%). The degree of angularity in this location ranges from angular and sub-angular (89%) and sub-angular and sub-rounded and rounded (11%). The sample exhibit intact chamber structure (3%) and hollowed chamber (97%).

*H. rubrum* in BL 16-003 shows lower preservation than BL 16-028 but higher compared to BL 16-031 (figure 2). *H. rubrum* in BL 16-003 is characterized by red colour (2%), pink colour (43%), and light pink to white (56%). The majority of observed specimens (97%) are angular and sub-angular while 3% are sub-rounded to rounded. Only 1% of observed specimens have intact chamber while 99% show hollowed chamber.

The degree of preservation of *H. rubrum* observed in sample BL 16-031 is lower compared to that in BL 16-003 and BL-16-028 (figure 2). *H. rubrum* in BL 16-031 is characterized by 0% red, 23% pink, and 77% light pink to white. The shape *H rubrum* in this sample consists of 89% angular to sub-angular and 10% rounded to sub-rounded with 0% shows intact chamber structure.

*H. rubrum* in study area can be classified into 5 degree of preservation (table 2, figure 3). The degree of preservation in BL 16-028 sample is 3% exceptionally preserved (EP), 63% well preserved (WP), 24% well to moderately preserved (WMP), 11% moderately preserved (MP), and 0% high altered (HA). BL 16-003 shows the following degree of preservation: 2% EP, 39% WP, 56% WMP, 3% MP, and 0% HA. BL 16-031 shows the following preservation levels: 0% EP, 12.7% WP, 76.6% WMP, 10.4% MP, and 0.3% HA.

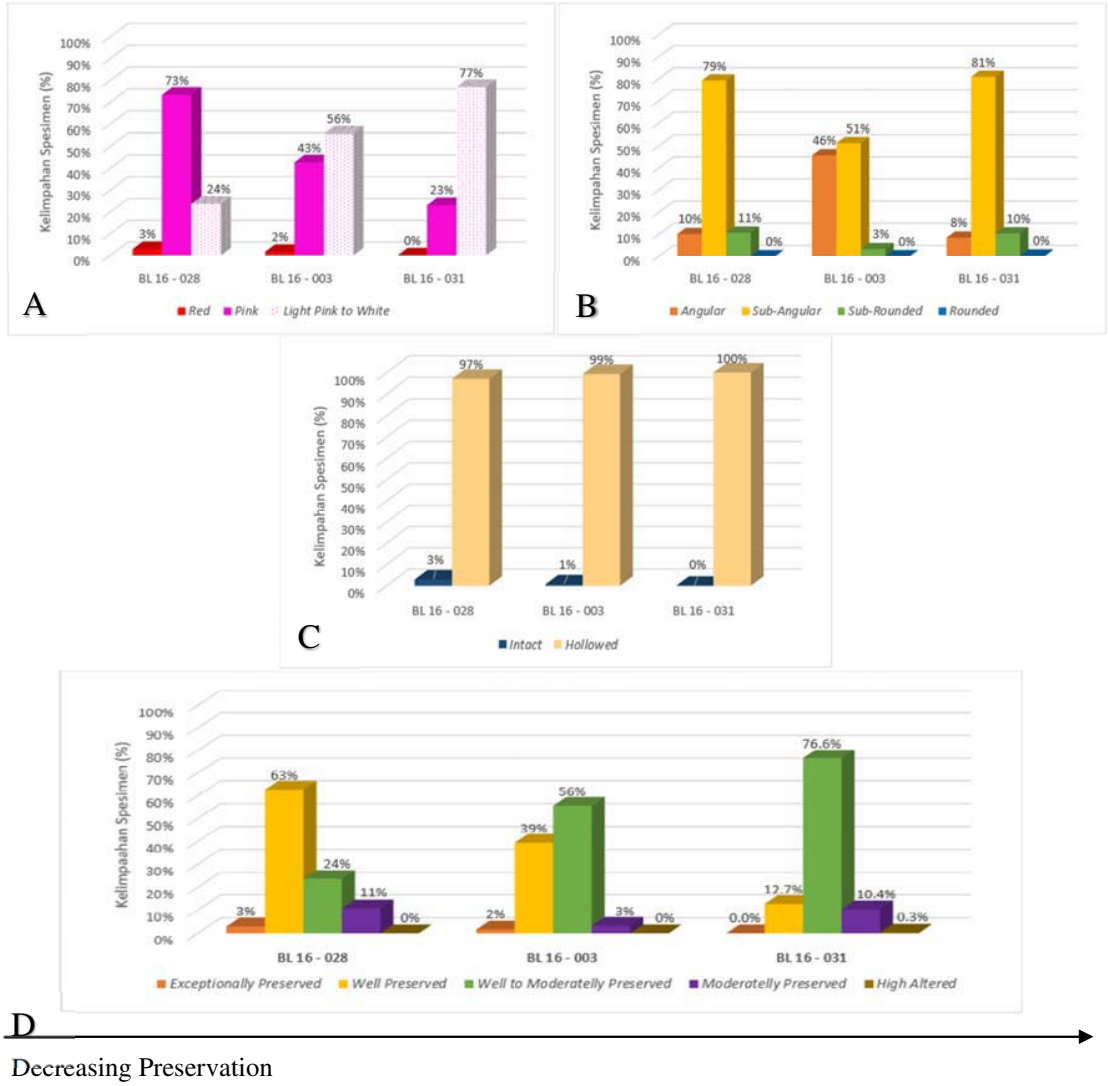


**Figure 3.** *H rubrum* taphonomy of the study area; (A) test color (%), (B) angularity (%), (C) chamber structure (%), (D) preservation degree (%).

The best level of preservation in sample is characterized by red colour, angular shape and intact chamber structure and has been used as proximity indicator to coral reef as the source of *H. rubrum* [4]. Degree of *H. rubrum* preservation shows decreasing trend from BL 16-028 that is located in the entrance of the strait, to BL 16-003 that is located near Bangka Island and BL 16-031 that is located off Talisei Island. Higher degree of preservation indicates nearest site to coral reef. Thus, BL 16-028 is closest to the reef, followed by BL 16-003 and BL 16-031. Therefore, it can be inferred that sediment transport in this area is from BL 16-028 to BL 16-003 to BL 16-031.

*3.1.2 The Western Bangka Island.* The highest preservation sample from western Bangka Island is BL 16-005 (figure 4). The sample is characterized by 0% red, 88% pink, and 12% light to pink white in colour; 77% angular to sub-angular and 22% rounded to sub-rounded in shape; and 0% intact chamber.

The degree of preservation of sample BL 16-012 is lower than BL 16-005 but higher than BL 16-011 (figure 4). BL 16-012 sample is characterized by 0% red, 84% pink, and 16% light to pink white in colour; 59% angular to sub-angular and 41% sub-rounded to rounded in shape; and shows 0% intact chamber structure. *H. rubrum* observed in BL 16-011 has lowest degree of preservation (figure 4) and characterized by 0% red, 14% pink, and 86% light pink to white; 89% angular to sub-angular and 11% of rounded to sub-rounded in shape; and 0% intact chamber.

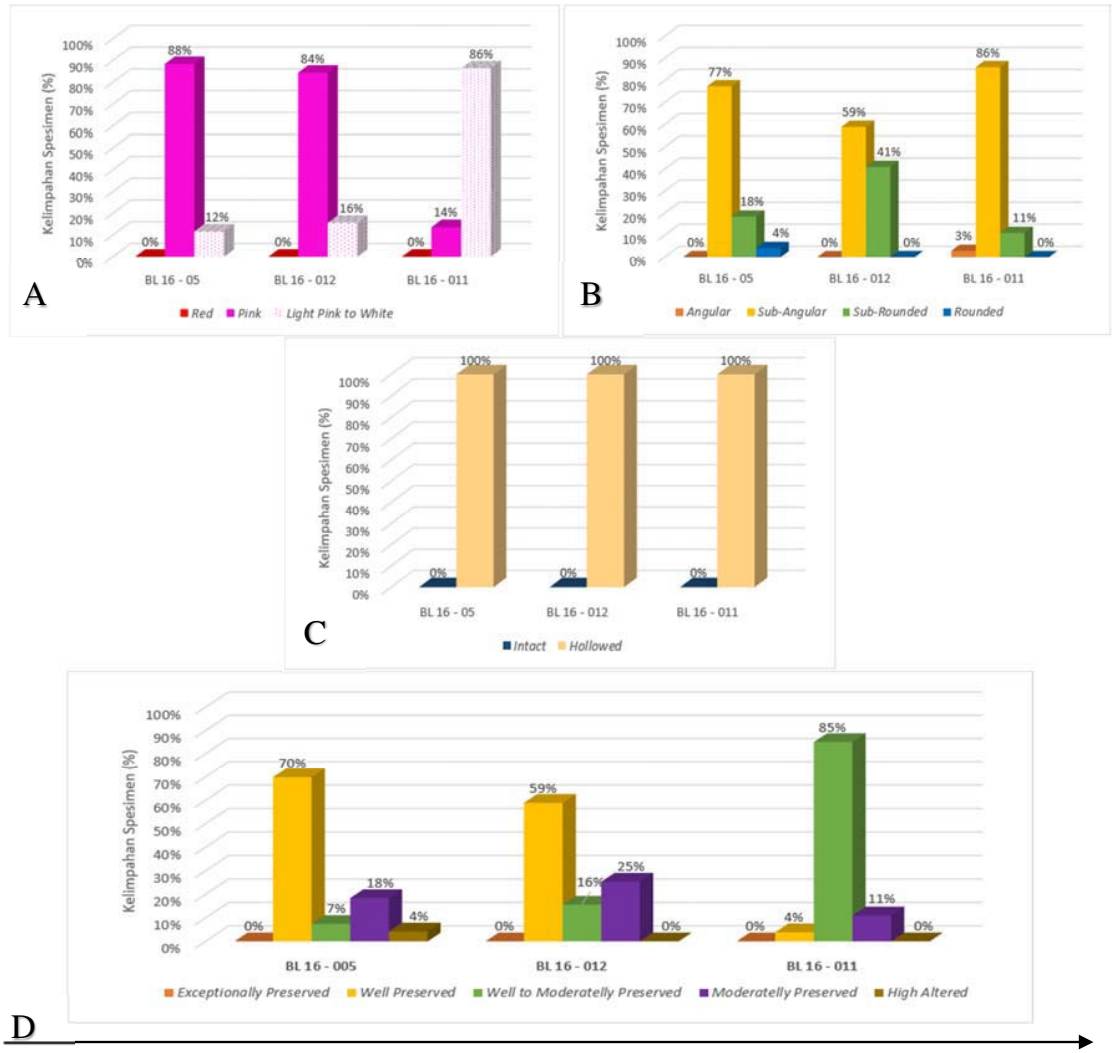


**Figure 4.** *H. rubrum* taphonomy in Western Bangka Island*;* (A) test color (%), (B) angularity (%), (C) chamber structure (%), (D) preservation degree (%).

The three samples show considerable amount of angular to sub-angular shape (>50%), but also exhibit 100% hollowed chamber structure. The abundance of pink *H. rubrum* in these samples indicates that *H rubrum* were deposited near or in the proximity of the source. The degree of *H. rubrum* preservation in these samples indicate that BL 16-005 and BL 16-012 are located near coral reefs, while BL 16-011 lies furthermost of the coral reefs. The shape and chamber structure that were observed in BL 16-005 and BL 16-022 reveal the possibility of shell abrasion during sediment transport. The abrasion might involve scouring of *H. rubrum* shells by other sediment particles during transport

Combination of observed parameters yields 5 levels of *H. rubrum* preservation (figure 4). Sample in BL 16-005 exhibits 0% EP, 70% WP, 7% WMP, 18% MP, and 4% HA. Sample BL 16-012 consists of 0% EP, 59% WP, 16% WMP, 25% MP, and 0% HA. The lowest level of *H. rubrum*'s preservation is observed in BL 16-011 with 0% EP, 4% WP, 85% WMP, 11% MP, and 0% HA.

Decreasing preservation is shown from BL 16-05 to BL 16-012 to BL 16-011 indicating that BL 16-05 is closest to the reef followed by BL 16-012 and BL 16-011. Thus, the direction of sediment transport in western Bangka Island is from BL 16-005 to BL 16-012 to BL 16-011.

This area shows different preservation degree compared to Northern Bangka that shows higher percentage of WP and WMP compared to this area that shows a mixture of WP and MP. The distinction might be related to bathymetry of Bangka waters that is deeper in the central part of the islands (figure 5). This central part forms a depositional basin for sediments that are transported into the central part of the islands from the west or the north. Because the cental part of the islands are further from coral reef, *H, rubrum* that is accumulated in site BL 16-011 is mostly less preserved (MP) compared to BL 16-05 and BL 16-012.

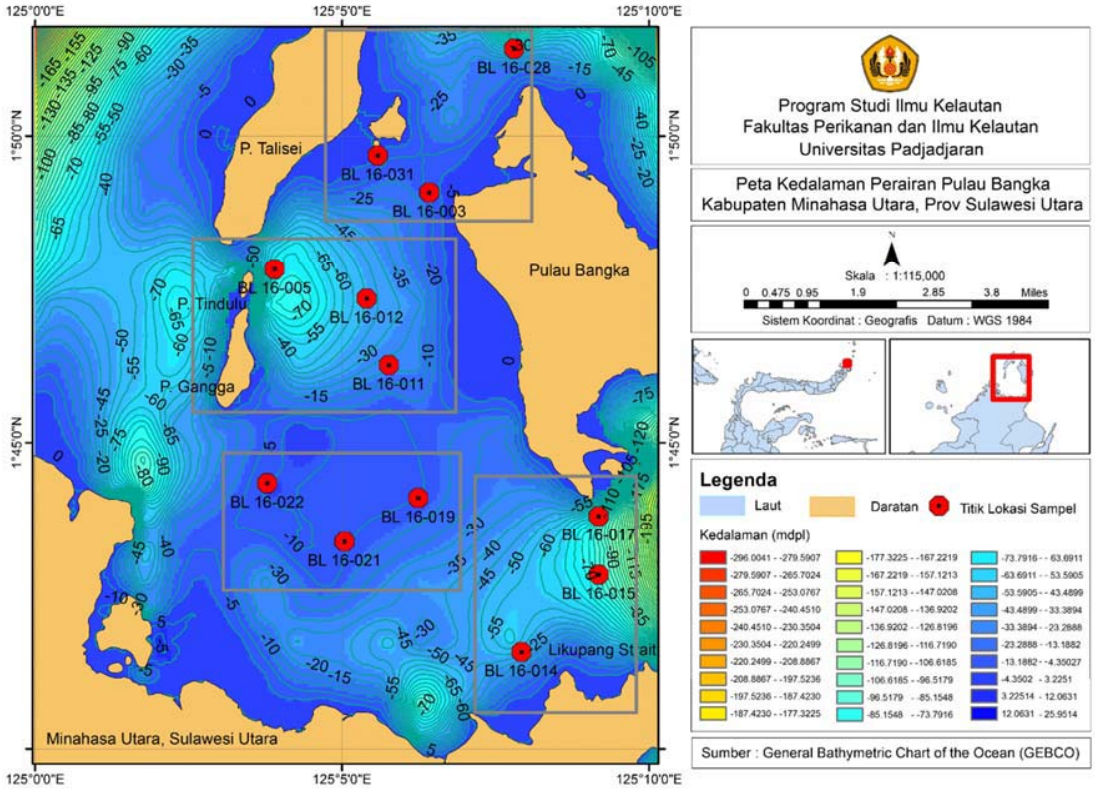


**Figure 5.** Bathymetry map of Bangka Island water and surrounding islands.

*3.1.3 West Likupang Strait.* The taphonomy of *H. rubrum* from samples acquired from West Likupang Strait shows highest preservation in BL 16-022 (figure 6). *H. rubrum* in BL 16-022 sediment is characterized by 0% red, 25% pink and 55% light pink to white in colour; 56% angular to sub-angular and 44% rounded to sub-rounded in shape; and 19% have intact chamber structure while 81% have hollowed chamber.

*H. rubrum* observed in BL 16-021 have lower preservation than those in BL 16-022 but higher than BL 16-019 (figure 6). *H. rubrum* in BL 16-021 is characterized by 1% red, 34% pink and 65% light pink to white in colour; 22% angular to sub-angular and 78% rounded to sub-rounded in shape; and 1% with intact chamber and 99% with hollowed chamber. The lowest preservation degree, BL 16-019, shows 0% red, 2% pink, and 98% light pink to white *H. rubrum*; 7% angular to sub-angular and 93% rounded to sub-rounded in shape; with 0% intact chamber.

The degree of *H. rubrum* preservation in West Likupang Strait are as follows (figure 6). Preservation level of sample BL 16-022 consists of 20% EP, 33% WP, 12% WMP, 24% MP, and 12% HA. Sample BL 16-021 comprises of 1% EP, 21% WP, 55% WMP, 13% WP, and 10% HA. BL 16-019 shows the following level of preservation: 0.3% EP, 1.3% WP, 6% WMP, 28.9% MP, and 63.5% HA.

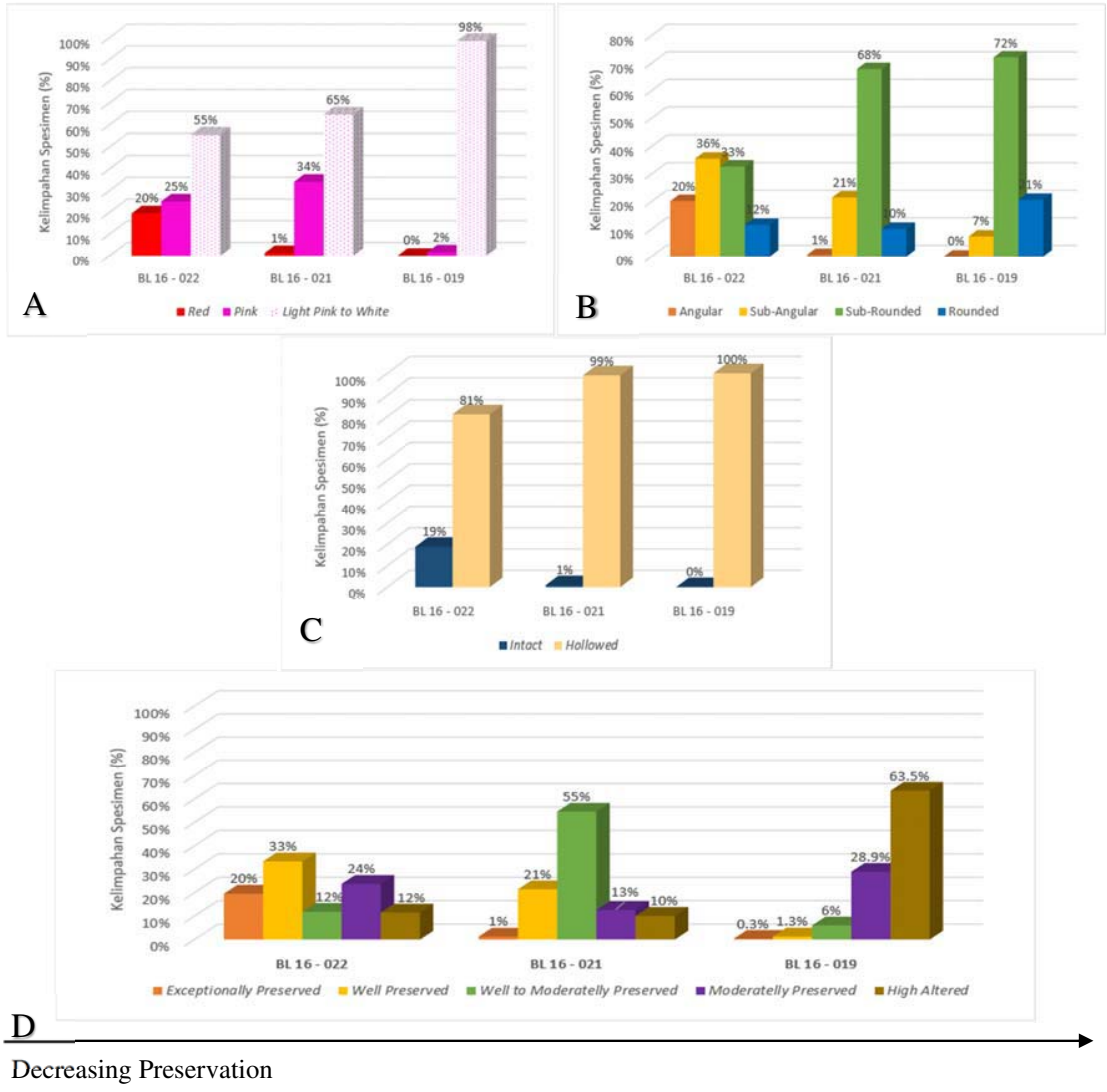


**Figure 6.** *H. rubrum* taphonomyin West Likupang Strait; (A) test color (%), (B) angularity (%), (C) chamber structure (%), (D) preservation degree (%).

Red colour and angular *H. rubrum* can be used as indicator of source (coral reef) proximity [4]. Those characteristics were observed in BL 16-022 suggesting that this sample has not been transported far from or deposited near the coral reefs. Declining preservation trend from BL 16-022 to BL 16-021 to BL 16-019 points to the direction of sediment transport from BL 16-022 to BL 16-021 to BL 16-019.

High percentage of HA in BL 16-019 might be related to its position in the central part of the islands. As was discussed in pervious section, the central part of the islands is deeper than the rest forming depositional basin for sediments flowing through. Moreover, site BL 16-019 is further from coral reef that will lead to less preserved H. rubrum compared to BL 16-022 and BL 16-021. Thus, sediments that are accumulated in this site will be less preserved than the others.

*3.1.4 East Likupang Strait. H. rubrum* observed in BL 16-014 have higher preservation than those in BL 16-015 and BL 16-017 (figure 7). The characteristics of *H. rubrum* in BL 16-014 are 5% red, 27% pink, and 67% light pink to white in colour; 35% are angular and sub-angular and 65% rounded and sub-rounded in shape; with 3% have intact chamber and 97% have hollowed chamber.

*H. rubrum* in BL 16-015 has lower preservation than those in BL 16-014, but higher than those in BL 16-017 (figure 7). The taphonomy of *H. rubrum* in BL 16-015 is as follows: 2% red, 52% pink and 46% of light pink in colour; 89% are angular and sub-angular and 11% are rounded and sub-rounded in shape; with 0% show intact chamber structure. Sample BL 16-017 has lowest preservation and is characterized by 0% red, 65% pink, and 35% light pink to white in colour; 89% are angular and sub-angular and 11% are rounded and sub-rounded in shape; with 0% shows intact chamber structure.

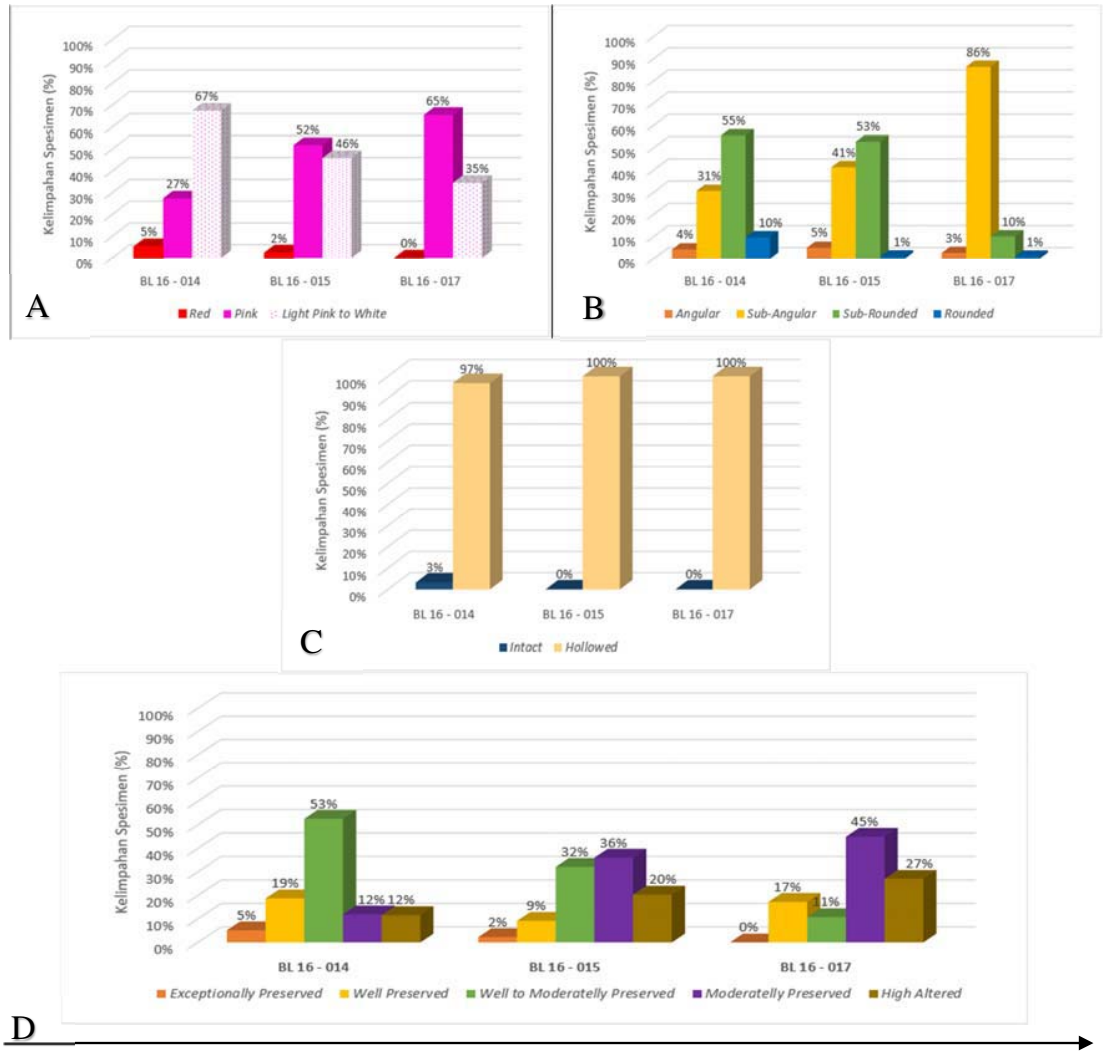


**Figure 7**. *H. rubrum* taphonomy in East Likupang Strait. (A) Test Color (%), (B) Angularity (%), (C) Chamber Structure (%), (D) Preservation Degree (%).

The observed parameters of the taphonomy then used to categorize *H. rubrum* in samples from East Likupang Strait into 5 levels of preservation (figure 7). Sample of BL 16-014 shows the following preservation level: 5% EP, 19% WP, 53% WMP, 12% MP and 12% HA. The preservation level of BL 16-015 is as follows: 2% EP, 9% WP, 32% WMP, 36% MP and 20% HA. BL 16-017 comprises of 0% EP, 17% WP, 11% WMP, 45% MP and 27% HA.

In general, preservation level decrease from BL 16-014 to BL 16-015 to BL 16-017. It indicates that sediments in Eastern Likupang Strait are transported from BL 16-014 to BL 16-015 to BL 16-017. This area shows distinc trend compared to the rest due to relatively higher percentage of MP and HA. The presence of MP and HA might be the result of the accummulation of H. rubrum that is transported from Northern and Western Bangka Island as well as West Likupang Strait to East Likupang Strait that forms the outlet of the water flowing through Bangka Islands.

*3.2 Reconstruction of sediment transport based on H. rubrum taphonomy*

As demonstrated in Brazil, *H. rubrum* with red color and sharp points were mostly deposited near the source while white and rounded specimens were found further from the source [4]. A study from Wallis Island, Polynesia, show that *H. rubrum* taphonomy can be used to identify sediment transport trends in tropical island [8]. Sediment reddish and angular specimens of *H. rubrum* indicates that the sample location is close to source [4]. The further from source, the dominant taphonomy of *H, rubrum* woud decrease from EP to WP to WMP to MP and HA indicates location furthest from the source [9]. The modification of H, rubrum taphonomy (color, angularity and chamber structure) is the result of sediment transport and/or energetic hydrological conditions [4]. Surface current in study area is estimated to be between 0 t 0.35 m/s that can be classified as low to medium current velocity [12], therefore the taphonomy the taphonomy is mostly caused by sediment transport.

Plot of *H. rubrum* preservation degrees demonstrate that the higher degree of preservation is observed in samples located in the inflow areas (figure 9) where most coral reefs in this area are located (figure 8) while H, rubrum with lower preservation degree is observed in samples from the outflow area (figure 9). The lowest preservation degree is observed in the central part of study area (BL 16-019) that is interpreted as the preferential site for sediment accummulation.

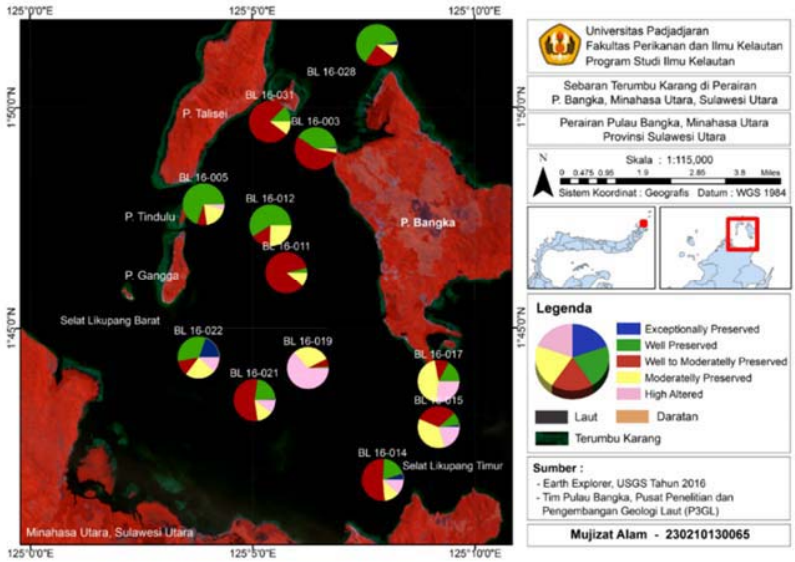


**Figure 8**. Distribution of Coral Reefs in Bangka Island, North Minahasa.

Identification of current direction can be reconstructed by following the taphonomy of H, rubrum in the study area. Tracing of the degree of preservation from EP to HA points to the direction of sediment transport that indicates current direction. Figure 9 shows that sediments are transported from the north and west into the central part of the island cluster and then flow out from the East Likupang Strait. The predominant sediment transport direction is Bangka Island water is eastward.

Because sediments reflect net transport flux as was demonstrate in Fly River, Papua New Guinea, we can infer that net transport direction in study area is eastward [10]. To validate the reconstructed sediment transport pathway, we use annual annual average surface current data. The annual average sea surface current is obtained from Infrastructure Development and Space Oceanography (INDESO) within the period of 2014-2016 and has been discussed in detail [9]

In general, the reconstructed sediment transport pattern shows similar direction with 2014 - 2016 annual average sea surface current from INDESO (figure 10) detailed sediment transport within Bangka Island waters is not visible in the INDESO map (figure 10). The discrepancy is caused by the size of study area (18x11 km$^2$) that is smaller to INDESO resolution (1/12°)[9]. Thus, *H. rubrum* taphonomy can be used to reconstruct detail net sediment transport in areas that are dominated by coral reefs [9].

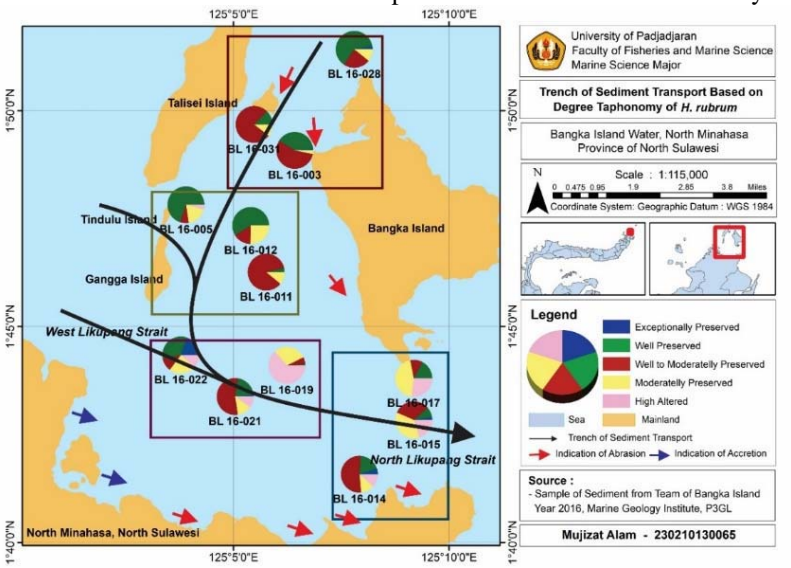


**Figure 9**. Direction of sedimen transport in Bangka Island waters constructed from *Homotrema rubrum* taphonomy.

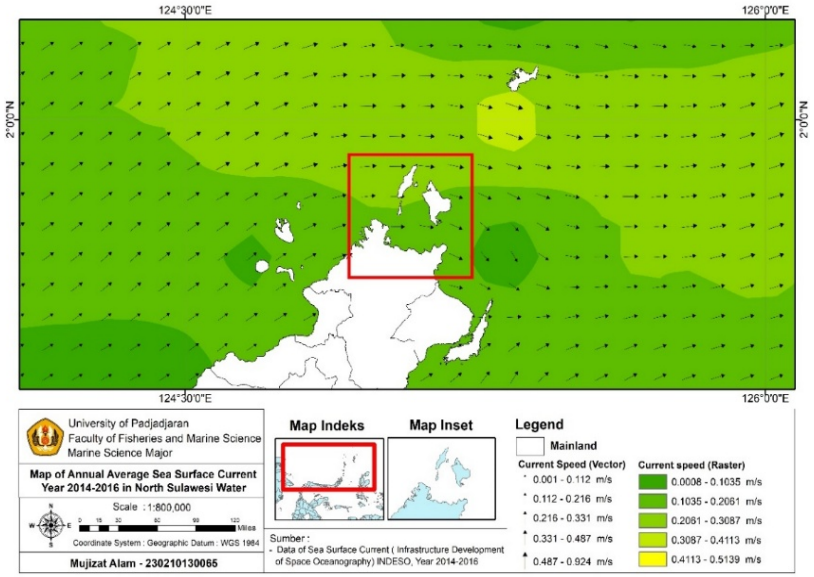


**Figure 10**. Map of annual sea surface current 2014-2016 from INDESO In North Bangka Island water [9].

## 4. Conclusions

Reconstruction of sediment transport pathway based on preservation degree of *H. rubrum* in Bangka Island waters reveal predominant eastward transport. Water from the open sea flows into study area through the straits between islands and flows out through East Likupang Strait. The eastward movement corresponds with annual average sea surface current for 2014-2016 period from INDESO. Our result shows that *Homotrema rubrum* taphonomy can be used to reconstruct sediment transport pathway in coral reef region.

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