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in the Name of Allah the Merciful, the Compassionate

The Editorial team of Proceedings the second International Seminar on New Paradigm and Innovation on Natural Sciences and its Application in 2012 (ISNPINSA-2) expressed gratitude to God the All-Knowing and the Supreme for the successful publication of these proceedings. This book, we present to all participants of the 2nd ISNPINSA, who had participated in this regular scientific meeting held at Hotel Santika Premier, Semarang, Indonesia on October 4, 2012, and for the continuity of communication between scientists both inside and outside the country and strengthen the cooperation that already exists as well as creating a new partnership.

The publication of ISNPINSA-2 proceedings, we made in two versions which are hard copy and soft copy. The soft copy edition of the second ISNPINSA proceedings created in *.pdf, in addition the text and images in the file could not be copied because it is protected. This needs to be done in the context of protection of copyright authors and avoiding plagiarism. In these proceedings, papers are sorted by alphabetical order of the first author of each paper. This is done to facilitate the reader in searching particular paper that want to read. In the proceedings, some papers only found in abstract form only, as some authors stated does not want to publish full papers in these proceedings or because the author was too late to send full papers by the date we have set. Nevertheless, we hope this limitation does not diminish the value of the proceedings that have been published.

Regarding the implementation of the 2nd ISNPINSA and publishing these proceedings, we would like to thank and express our appreciation to the authors who have worked well accordingly the proceedings can be issued as expected, as well as all those who have supported the success of the overall activity. Also our thanks goes to all committees who have worked hard in the implementation of this great activity.

Sincerely
The Editorial team
Proceedings the second ISNPINSA
Semarang, 25 September 2012

Water and Sediments Characteristics Influencing Fish Farming Activities: Univariate and Multivariate Approaches

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ABSTRACT

Environmental variables, especially water, sediment characteristics and farming practices play important roles in influencing the degree and severity of the impacts of aquaculture. The water-sediment interface under fish farms can be influenced by organic waste in the form of feces and unconsumed feed derived from farm activities. This study focuses on the hydrographical conditions and water chemistry of the bluefin tuna farming area in the southern Spencer Gulf, especially organic carbon content, sediment grain size and current velocity. A comparative study of organic matter and sediment grain size between sites and the relationship between the silt-clay fractions of the sediments and the amount of organic matter are assessed.

Sediment samples were taken using a HAPS bottom corer equipped with a corer of 67 mm in diameter and 315 mm in length, operated from the research vessel RV Ngerin. The results suggest that hydrographical conditions and water chemistry of southern Spencer Gulf varied slightly depending on the location of the stations sampled. No accumulation in organic matter under the fallowed cages was detected, indicating that the hydrodynamic conditions at southern Spencer Gulf are considered well flushed and thus suitable for farming activities.

Keywords: *sediment characteristics, farming activities, water current, hydrodynamic conditions.*

1. INTRODUCTION

It has been suggested that environmental variables, especially sediment type [1], water current velocities [2], [3], and farming practices [4], play important roles in influencing the degree and severity of the impacts of aquaculture. Habitats characterized by coarse and clean sands are suggested to have the most rapid recovery rates following environmental disturbance, whereas habitats characterized by muddy sands have the slowest [5]. Reference [6] observed that the horizontal distance affected by farm wastes decreases with finer sediment types. Hydrodynamic forces may also influence sediment composition. For instance, strong bottom flows, horizontal flux of detritus, and low levels of organic matter are characteristics for coarse sandy sediments in high-energy environments, whereas weak flows and low horizontal but greater vertical flux of detritus are typical for silty and muddy sediments in low-energy environments [7]. Sediment composition and organic matter are suggested as pivotal elements in structuring macrobenthic infauna [8], [9]. Furthermore, [10] observed that the deposition of less dense organic particles was enhanced at areas where current velocities were low and thus increased the proportion of organic material in the sediments.

In the region where fish farming activities occur, water currents are believed to be essential in order to reduce waste accumulation, increase the oxygen supply by water movement, which thus increase decomposition of organic waste [11]. Reference [12] observed that the rate of accumulation of particulate waste on sediments, including resuspension, was mainly controlled by current speeds. Low current speeds may result in high accumulation of organic waste, while high current speeds may generate larger spatial distribution of organic enrichment, but reduce accumulation beneath the farms [3]. Current velocity has been used as an essential physical factor in modeling the deposition and dispersion of particulate waste from marine cage farms [13].

The water-sediment interface under fish farms can be influenced by organic waste in the form of faeces and unconsumed feed derived from farm activities [14]. Reduction in sediment quality beneath fish cages has also been reported, which eventually lead to anaerobic conditions caused by oxygen consumption when organic matter decompose [15].

The southern bluefin tuna sea-ranching in southern Spencer Gulf is located in relatively oligotrophic waters off Boston and Rabbit Islands. The sediment composition of this region is generally dominated by coarse sandy sediments owing to relatively strong tidal currents. Due to substantial tuna mortalities caused by tropical cyclone “Olivia” in 1996 [16], the operation of southern bluefin tuna farms have been relocated to areas outside Boston Bay, where better flushing and dispersal of accumulated organic waste owing to stronger current velocities are likely to occur.

This study focuses on the hydrographical conditions and water chemistry of the bluefin tuna farming area in the southern Spencer Gulf, especially organic carbon content, sediment grain size and current velocity. A comparative study of organic matter and sediment grain size between control and fallowed pontoon sites, between Boston Island and Rabbit Island zones, and the relationship between the silt-clay fractions of the sediments and the amount of organic matter are discussed.

2. MATERIALS AND METHODS

2.1. The Study Sites

The sampling sites were located between 135^o 58.25' to 135^o 59.82' E and 34^o 35.41' to 34^o 42.43' S, in southern Spencer Gulf, South Australia, where farming of southern bluefin tuna (*Thunnus maccoyii*) takes place. The farms consist of a series of pontoons 40-50 m in diameter, with a 15 m deep net. Pontoons are stocked at rates of 1.5 – 2.5 kg/m^3 [17]. They are situated in areas with relatively strong microtidal (<2 m) currents with an average current velocity of 5-10 cm/s [18]. The seawater temperatures fluctuate from 14^{o}C in winter to 25^{o}C in summer [19]. The first sampling 2002 were sampled in October 2002 when farming season started. Fallowed sites were sampled after all fish and pontoons were removed and their coordinates were recorded. Control sites were at least 1 km from any leased site.

2.2. Sampling Procedures

Sediment samples were taken using a HAPS bottom corer equipped with a corer of 67 mm in diameter and 315 mm in length, operated from the research vessel RV Ngerin. The corer has been primarily used by researchers for benthic studies in soft sediment environment. It has been suggested as a more effective sampler compared to the Petersen sampler, especially for polychaetes and crustaceans [20], with a better sampling efficiency than using the Van Veen grab. Using a smaller diameter cores than used for soft sediment and more weight, the HAPS corer was found to be an efficient method of sampling coarse sandy sediments.

From the two zones of sampling located adjacent to Boston Island and Rabbit Island, 160 cores were collected for each sampling time for benthic animals. At each fallowed pontoon site, eight replicated cores were collected within a fallowed pontoon area. At each of two sampling stations, 4 replicate cores were collected (64 cores in total). The same sampling strategy was used for each control site (64 cores in total). Sediment core was taken at each station for sediment composition. In total, thirty two cores were collected for each sampling time for sediment grain size analysis. Sediment organic matter was analysed only for the first set of samples.

Samples were subsequently collected five times during the period of sampling. The depth of sediment collected varied between 25 – 75 mm (mean = 40.9 mm) at control sites and between 22 – 85 mm (mean = 44.9 mm) at fallowed sites. It was anticipated that the degree of consistency in providing similar lengths of sediment sampled would depend on sediment types, although a corer such as the HAPS has a more high digging performance compared to other sampling gears (dredge and grab samplers). Cores were collected at eight fallowed pontoon and control sites within the Rabbit Island aquaculture zone and the Boston Island aquaculture zone.

2.3 Laboratory procedures

2.3.1. Water quality measurements

From the two zones of sampling located adjacent to Boston Island and Rabbit Island, water quality measurements were carried out using a Horiba multi-probe and a Conductivity-Temperature-Depth (CTD) profiler. The parameters recorded for water quality were depth, pH, dissolved oxygen, temperature and turbidity measured just near the seafloor and at the surface (~ 5m) at each sampling site. The data of current velocities using Doppler Current Sensor (accuracy: ± 0.15 cm s^{-1}) and salinity were provided from other related study by Reference [18]. Current velocity was determined as the average of the surface current to the current near the seafloor taken from a depth of between 3 and 24 m.

2.3.2. Sediment grain size analyses

Individual cores were thawed, oven-dried overnight at 105 ^{o}C and homogenized. A 50 g aliquot of each core was muffled for 12 h at 350 °C to remove organic matter and allowed to cool. This sample was stirred with a dispersing agent (40 g L^{-1} sodium hexametaphosphate in MilliQ water) for 15 minutes and left to soak overnight. Blank hydrometer (Calton Glass Marketing) readings were recorded for the dispersing solution. The sample was stirred for 10 minutes, transferred into a 1L-measuring cylinder and the volume made up to 1L using MilliQ water. The cylinder was then inverted until the sediment was evenly suspended throughout the water column and placed on a level surface. A hydrometer and temperature reading were taken exactly 2 hours after this placement to determine clay content (<4 µm). The contents of the cylinder was then wet sieved through a 63 µm sieve and the retained fraction was dried at 100°C. A stacked series of graded sieves comprising 2000, 1000, 500, 250, 125 and 63 µm mesh size were used to obtain sand fractions. The sample was dry sieved using an automatic sieve (Endecotts EFL2000) set at 5 min. The silt content (4-63 µm) was calculated as the difference between the muffled weight of the sample and the sand and clay fractions. Other sediment analyses, which were organic carbon, total nitrogen and carbonate contents, are provided by [21].

A three-way analysis of variance (ANOVA) was used to compare the difference sediment grain size between sites, zones and sampling times, whereas two-way analysis of variance was carried out to assess the effect of site and zone on sediment chemistry. Firstly, data of proportions was transformed using arcsine transformation, which is $\theta = \text{arcsine} \sqrt{p}$, where p is a proportion [22]. The data was then tested using Komogorov-Smirnov's test for normal distribution of the data and Levene's test for homogeneity of variances. Further test using Tukey's HSD post hoc for multiple comparisons were carried out if results revealed significant differences between treatments ($p < 0.05$). The mean values of current velocities between control and fallowed sites were compared using Student *t*-test. Pearson correlation analysis was also used to assess the relationship between silt-clay fraction and percent organic carbon [23] Univariate analyses were carried out using the SPSS 11.5 software packages

Principal Component Analysis (PCA) of Euclidean distance was performed to assess the difference in environmental variability between zones. Firstly, draftsman plot of normalized data was performed to see the symmetrical distribution across the range of each variable and relationship between some pairs of variables. Based on the assessment of this plot, transformations of specific or group of similar variables were chosen. Logarithmic and square root transformations were applied on some variables before the operation of PCA using the PRIMER 6.1.5 software packages [24].

3. RESULTS AND DISCUSSION

3.1. Hydrography, sediment structures and water chemistry

The hydrographical conditions and water chemistry of southern Spencer Gulf varied depending on the location of the stations sampled. Water temperatures of the surface and bottom varied between 13.9 – 21.2 ^{o}C and 13.8 – 21.2 ^{o}C, respectively. Dissolved oxygen levels at control and fallowed sites were relatively similar, ranging from 6.8 to 9.7 mg/l and from 6.5 to 10.4 mg/l. These values at both sites are considered suitable for the farms, as it has been suggested that the levels for salmonid and crustacean cultures should not be below 5 mg/l for more than a few hours [25].

The ranges of pH levels were 7.9-8.3 at control sites and 8.0-8.3 at fallowed sites, which are in a desirable range for fish production (6.5-9.0) recommended by Reference [25]. Mean salinity at the water surface was 36.853 psu, near seafloor (bottom) was 36.850 psu, respectively. Salinity during the winter time was 36.08 – 36.11 psu, and 36.73 – 37.13 psu in summer. The depth of sampling sites varied between 18 and 23 m, and pH between 7.88 and 8.35. The average current velocities at all sites recorded in Mach 2003 varied between 7.19 and 21.41 cm/s, as shown in Figure 3.1. Generally, records from the control sites (both Boston and Rabbit Island) were slightly higher than at the fallowed sites.

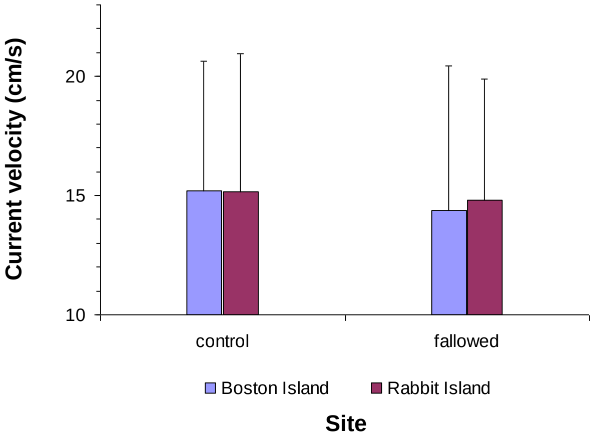

Figure 3.1. Current velocities (± 95% C.I.) between Boston Island (a) and Rabbit Island (b), and at control and fallowed sites (c).

The mean values (± 95% C.I.) of the current velocity at site BC7 and RC1 were 8.54±2.16 cm/s and 7.19±2.14 cm/s, respectively, and were recorded the slowest for Boston-control and Rabbit-control. The slowest current speed recorded at Boston-fallowed and Rabbit-fallowed were 8.54±2.16 cm/s (P08) and 10.06±1.64 cm/s (P04). Meanwhile, current speed was recorded fastest at site RC5 for the control sites, and site P03 for the fallowed sites. The averages of current velocity were slightly greater at control sites than at fallowed sites. Overall, the mean values between control ($\overline{X}$= 15.426, SD= 7.374) and fallowed sites ($\overline{X}$ = 14.055, SD= 6.876) were not significantly different ($t_{(62)}$= 0.769, *p*= 0.45). Figure 2.5 shows the average proportion of silt, clay, fine sand, and coarse sand at control and fallowed sites at each sampling time. A three-way ANOVA was carried out to explore the effect of site, zone and time on the four sediment types, which are coarse sand, fine sand, clay, and silt.

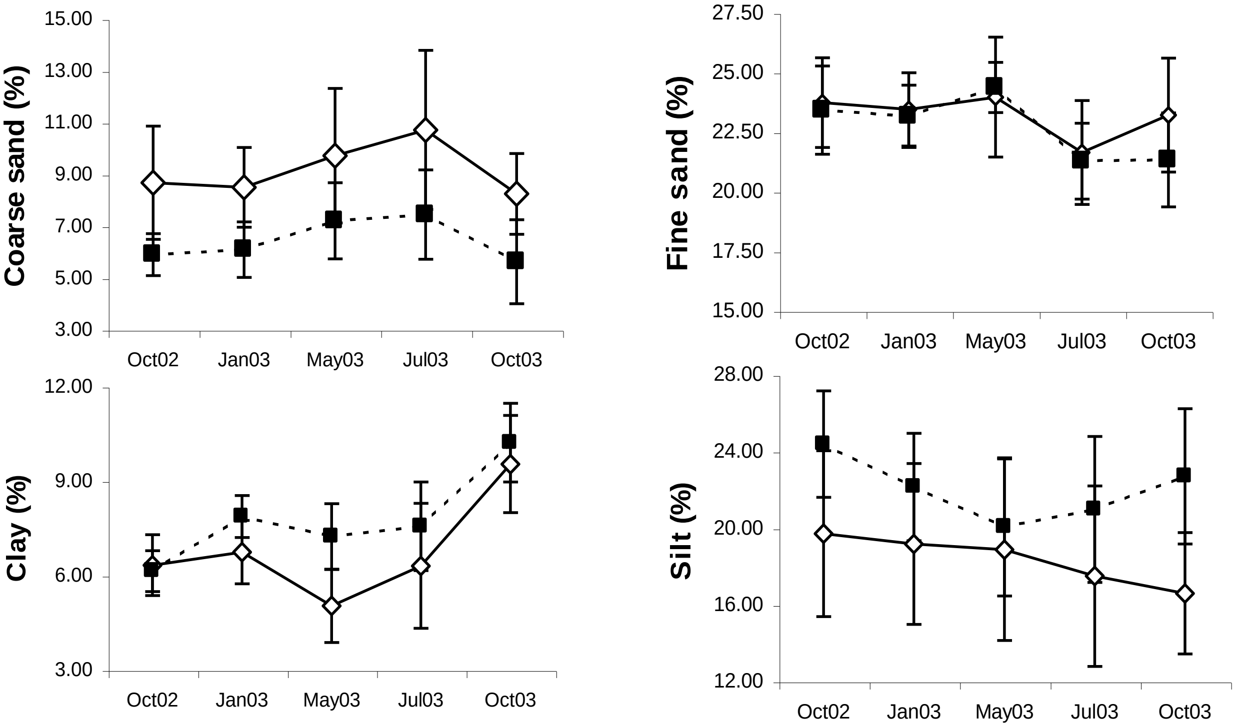

Figure 3.2. Sediment grain size at control and fallowed pontoon sites over the study period (error bars are 95% CI). Continued lines represent control sites and dashed lines represent fallowed sites.

The result showed that coarse sand content was significantly different between sites ($F_{(1, 160)}$= 24.153, p<0.001) and zones $F_{(1, 160)}$= 11.253, p=0.001), but not for time ($F_{(4, 160)}$= 1.628, p>0.05). A significant interaction between site and zone was also observed ($F_{(1, 160)}$= 22.291, p<0.001), indicating that the effect of site (control and fallowed

sites) on the content of coarse sand for zone (Boston and Rabbit Island) was inconsistent (Figure 2.5). No significant effects for site, zone and time were evident for fine sand. However, interactions between site and zone was significant ($F_{(1, 160)}$= 19.228, p<0.001) caused by interference (Figure 2.5). Fine sand contributed 21.28 % to 24.37 % of the total sediment composition at both sites.
The proportion of clay at fallowed sites was significantly higher ($F_{(1, 160)}$= 10.587, p=0.001) compared to the control sites, with a significant effect of time ($F_{(4, 160)}$= 11.645, p<0.001).However, the effect of site (control and fallowed sites) on clay for Boston and Rabbit Island was also significantly different ($F_{(1, 160)}$= 14.396, p<0.001). Post hoc comparisons, using the Tukey HSD test, indicated that the mean proportion of clay in October 2003 ($\bar{x}$= 0.099, SD= 0.028) was significantly different from October 2002 ($\bar{x}$= 0.062, SD= 0.017), January 2003($\bar{x}$ = 0.073, SD= 0.018), May 2003($\bar{x}$ = 0.061, SD= 0.025), or July 2003($\bar{x}$ = 0.069, SD= 0.035). The mean proportion of silt was recorded higher significantly at fallowed sites than at control sites over the study period ($F_{(1, 160)}$= 12.827, p<0.001). Although the effect size was moderate (partial eta squared= .05), there was a statistically significant effect of zone ($F_{(1, 160)}$= 7.331, p<0.001). Nevertheless, there was also a significant effect of interaction between site and zone site ($F_{(1, 160)}$= 22.291, p<0.001) (Figure 2.5).

In general, the results showed that the sediments at control sites adjacent to Rabbit Island were dominated by fine, medium, and coarse sands while sediment grain size composition at the control sites adjacent to Boston Island appeared somewhat finer. The dominant fractions at Boston Island were silt and fine sands. Compared to control sites, sediments at fallowed pontoon sites had less coarse sand, but more silts and clays. The proportion of silt at control sites decreased gradually from 19.72% in October 2002 to 16.60 % at the end of the study, while the values at fallowed sites were fluctuated between 20.07 and 24.38 %. High seasonal variability was observed in the clay fraction at both sites over the study period. The proportion of organic carbon at control sites adjacent to Rabbit Island was generally lower than any other zones. A two-way analysis of variance was employed to explore the effect of site (control and fallowed sites) and zone (Boston Island and Rabbit Island) on the proportions of carbonate, organic carbon, and total nitrogen in sediments. No effect of time was included, because the analysis of sediment chemistry was available only for the first samples.

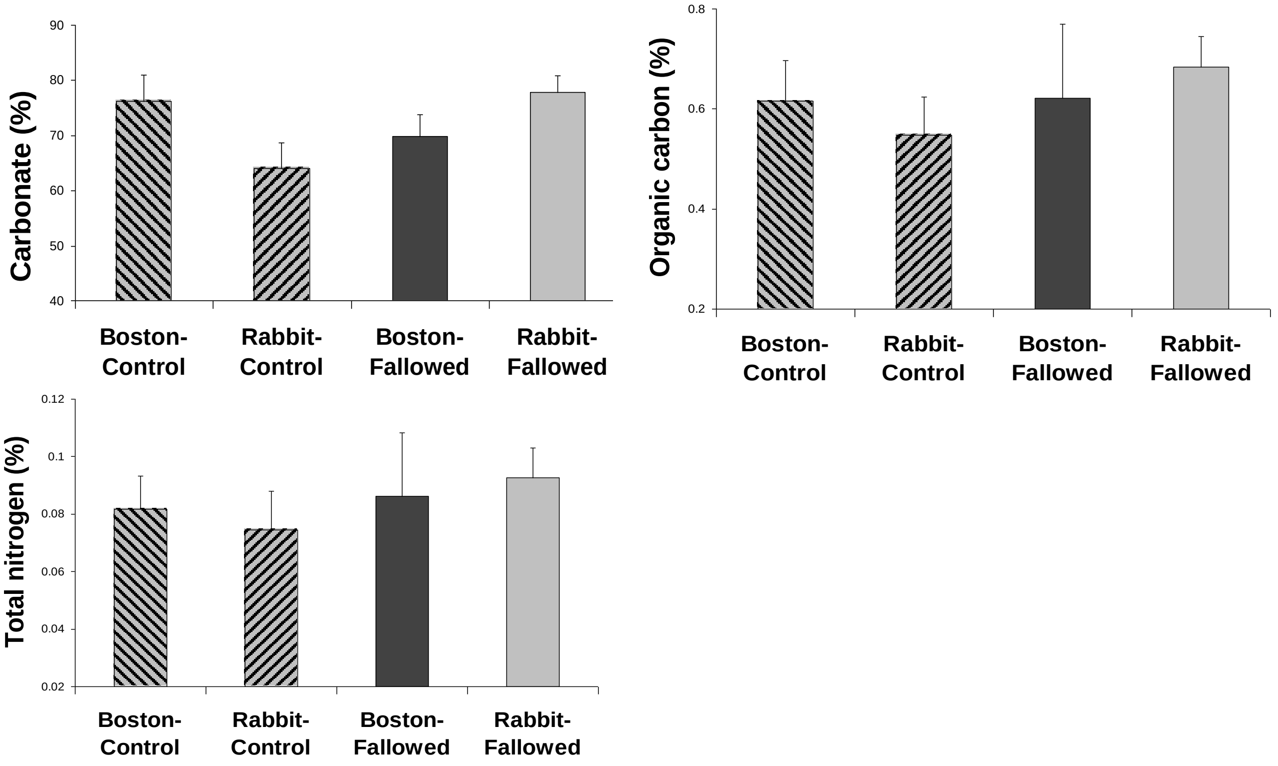

Figure 3.3. The proportion of sediment chemistry (carbonate, organic carbon and total nitrogen) at Boston-control zone, Rabbit-control zone, Boston-fallowed zone, and Rabbit-fallowed zone.

The result of two-way ANOVA showed no significant difference effect of organic carbon between sites ($F_{(1,\ 128)}$= 2.097, p>0.05) or zones ($F_{(1,\ 128)}$= 1.228, p>0.05). The result for total nitrogen also showed no significant effect of site ($F_{(1,\ 128)}$= 2.267, p>0.05) and zone ($F_{(1,\ 128)}$= 0.543, p>0.05). Although the trends for the proportions of carbonate were relatively similar to organic carbon and total nitrogen, the result showed a significant effect of zone ($F_{(1,\ 128)}$= 23.981, p<0.001), with also showed a large effect size (partial eta squared= 0.162). No significant effect of interaction between site and zone was observed for organic carbon ($F_{(1,\ 128)}$= 0.222, p=0.639), carbonate($F_{(1,\ 128)}$= 0.658, p=0.419) and total nitrogen($F_{(1,\ 128)}$= 0.226, p=0.635). Given that the trends of the proportion of organic carbon and silt-clay fraction exhibited similar in that both variables exhibited higher at fallowed than at control sites, attempt was made to assess the relationship between these variables. However, Pearson correlation analysis showed that the silt-clay fraction was not significantly correlated with percent organic carbon in the sediments (r= 0.134, p>0.05).

The difference in environmental variability between zones was analysed using Principal Component Analysis (PCA). This included all physical and chemical measurements of the sediments and seawater. The result is shown in Figure 3.4. The separations between Rabbit and Boston Island zones and between control and fallowed sites are not distinct. The result suggests that the environmental differences between zones and sites are overlapping and not clearly separated, indicating high variability between sites and zones.

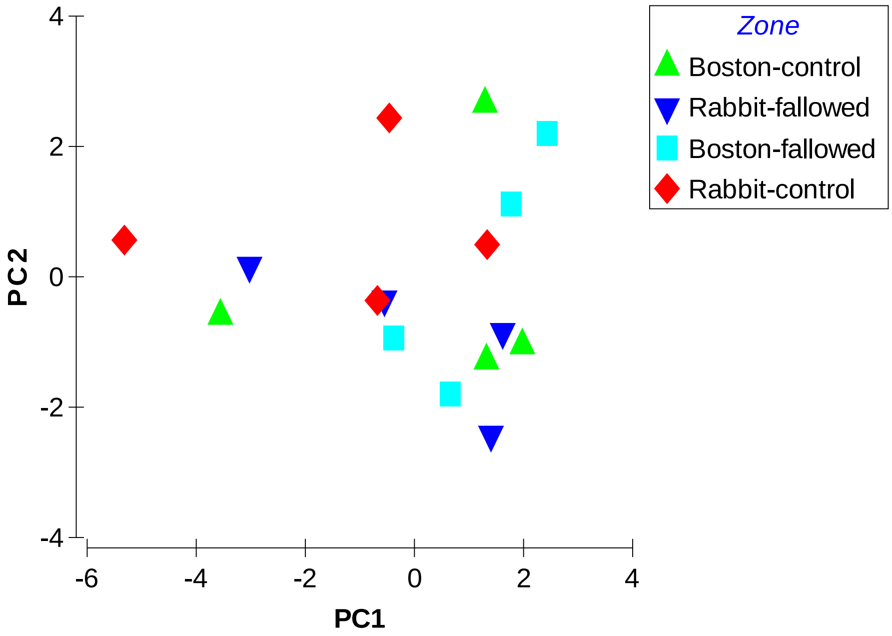

Figure 3.4. PCA ordination of Euclidian distances comparing environmental variables between zones (from the first samples).

During the sampling period, the hydrographical conditions of southern Spencer Gulf can be considered similar between control and farm sites and within the optimal ranges for fish production [25]. The water temperatures measured were relatively close to the representative mean temperature of this region, which is ~22°C [26], and within the range of fluctuation between winter and summer observed by [19]. The sampled sites adjacent to Rabbit Island were different in sediment structure to those of Boston Island. The proportion of silts and very fine sands were higher off Boston Island than off Rabbit Island. Reference [21] observed that sediments off Cape Donington close to Boston Island were finer and lighter due to a small siliciclastic component (<20%). Furthermore, the dominance of silts and very fine sands in this region may be caused by the presence of highly weathered biogenic fragments covered by a coating of fine particles. Sampling sites off Rabbit Island appear to be in a higher energy environment than those off Boston Island. High-energy environments are typically characterised by strong bottom flows, coarse sandy sediments, and low organic and microbial content. In contrast, low-energy environments are characterized by weak flows muddy, low horizontal but greater vertical flux of food, and fine muddy sediments.

It has been observed that the interactions between two factors (site and zone) for any of sediment grain size fractions were significant, indicating interference of one factor to the other factor. For control sites, the proportions of coarse sand and fine sand were higher at Rabbit Island than those at Boston Island, while for fallowed sites were higher in clay and silt fractions at Rabbit Island than at Boston Island. This implies that the sediments at fallowed sites had large silt and clay fractions and lower proportions of coarse and fine sands than at control sites over the entire sampling period, irrespective of whether the sampling sites were positioned adjacent to Rabbit Island (sandy sediments) or Boston Island (silty sediments). These differences indicate that farming practices in this region may influence sediment characteristics.

The proportions of sediment organic matter were spatially variable, especially between sites, ranging from 2.6 to 12.6 mg/g for the control sites and from 0.14 to 24.8 mg/g for the fallowed sites. This spatial variability may be influenced by great spatial variability in current velocities in this region. It has been reported that, in a Mediterranean oligotrophic-farm area where the mean current was 10-1 cm/s and the depth was 25 m, the influence of carbon and nitrogen from fish farm waste could be detected in both the particulate and the sediments in a wide area around the fish cages [27].

Although no significant difference was observed between control and fallowed sites, the proportion of organic carbon at the Rabbit-control zone was significantly lower than any other zone. This indicates that the difference in organic carbon between zones may be influenced by factors such as sediment composition, which is controlled by hydrodynamic forces as well as farm activities. Although the excess of organic matter in sediments can decrease species richness, abundance and biomass, the impact of organic matter depends on its concentration. According to Reference [28], total organic carbon in sediments may have low impact on species richness if its concentration less than 10 mg/g, but it has high impact at more than 35 mg/g.

In the two dimensional scales represented by the PCA plot, however, the differences in environmental variables (water chemistry, sediment composition, and organic matter contents) between zones and between site were found to be variable and less distinct. This may be due to a high spatial variability among the sampled sites, and thus result in scattering the position of the grouped sites (Boston-control, Boston-fallowed, Rabbit-control, and Rabbit-fallowed) on the ordination.

Reference [10] observed that low current velocities increase the deposition of less dense organic particles and thus increase the proportion of organic material in the sediments with an increasing proportion of silt-clay fraction. In this study, a direct relationship between the silt-clay fraction of the sediments and the amount of organic matter was not apparent. Given that only a relatively small amount of organic carbon was detected at both control and fallowed sites and the insignificant difference in the deposition of organic carbon and nitrogen between the two sites (only 0.04% and 0.01% higher respectively at fallowed sites compared to control sites), the finer sediment fraction at the fallowed sites may be caused by other factors. For instance, the pontoon nets may affect hydrodynamic forces, causing lower current velocities and thus higher rates of particle deposition[7], irrespective of inorganic or organic matter. In this study, average values of current velocity were slightly lower at the fallowed sites than at the control sites.

Current velocities in this region were relatively strong, an average of 12.21 cm/s at the water surface compared to 9.98 cm/s near the seafloor [18]. With a great variability between sites, the mean current speeds between control and fallowed sites were not different, suggesting that the reduction in water current speed caused by farming activities is negligible. These results indicate that hydrodynamic conditions at southern Spencer Gulf are suitable for farming activities, according to [29]. Reference [30] observed that serious environmental deterioration (< 1 mg/l of DO, >2.5 mg S/g of Acid Volatile Sulfide) caused by heavy accumulation of aquaculture-derived nitrogen (>3 mg/g) will occur at areas where the current velocity is less than 5 cm/s. At areas where the water depth is 18 m and the current velocity is more than 8 cm/s, excessive accumulation of organic wastes into sediments will not occur.

Nevertheless, strong currents may not just cause a reduction in organic enrichment beneath the fish farms, but also contribute to the dispersal of organic matter gradually from the farms, causing an extended zone of impact in long term period. This has to be taken into consideration for the sustainability of farming activities because a constant downstream flux of particulate organic matter. Reference [29] reported that less intensive but more widespread pollution occurred as a result of increasing dispersion of organic wastes generated by fish farms.

4. CONCLUSIONS

The hydrographical conditions and water chemistry of southern Spencer Gulf varied slightly depending on the location of the stations sampled. The sediments at control sites adjacent to Rabbit Island are dominated by fine, medium, and coarse sands, while sediment grain size composition at the control sites adjacent to Boston Island are finer. The sediments at fallowed pontoon sites had more silt and clay and a lower proportion of coarse sands than at control sites over the entire sampling period.

Because there is no significant difference in the mean proportion of organic carbon and current velocity between control and fallowed sites, and no accumulation in organic matter under the fallowed cages was detected, the results indicate that the hydrodynamic conditions at southern Spencer Gulf are considered well flushed and thus suitable for farming activities.

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