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Original Paper

RESPONSE OF TROPHIC GROUPS OF MACROBENTHIC FAUNA TO ENVIRONMENTAL DISTURBANCE CAUSED BY FISH FARMING

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ABSTRACT

Sediment dynamics and the hydrodynamics of the environment cause the complexity and variability in animal-sediment relationship, both in spatial and temporal. This study is focused on the response of macrobenthic fauna to environmental disturbance caused by fish farming using their trophic structure. Their changes in trophic structure can be used as an indicator of disturbance. Eight control sites and eight farm pontoon sites were samped in a full year period. Two stations at each site were sampled five times throughout the year with four replicates. Macrobenthic abundance was categorised based on six major trophic groups: carnivores (CAR), herbivores (HER), omnivores (OMN), suspension feeders (SF), surface deposit feeders (SDF), and subsurface deposit feeders (SSDF). The Infaunal Trophic Index (ITI) and Shanon-Wiener diversity index (H') were used to assess the degree of environmental disturbance caused by fish farming based on trophic structure. The relationship between ITI and H' was assessed using Spearman's rank order correlation (rho). The result showed that the abundance of deposit feeders was significantly higher at the farm sites than at the control sites, suggesting that food availability is more varied and abundant at farm sites than those at control sites. The results of the ITI indicate that the entire sampling sites have been moderately disturbed over the sampling period, with the exception for site BC8. Variability of Shanon-Wiener diversity index (H') spatially and temporally seems co-vary with ITI, owing to the influence of taxa richness and evenness.

Keywords: trophic structure, deposit feeders, Infaunal Trophic Index (ITI), Shanon-Wiener diversity index (H'), and environmental disturbance**.**

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INTRODUCTION

Animal-sediment relationship is complex and variable both spatially and temporally as a result of sediment dynamics and the hydrodynamics of the environment, and the complexity in the patterns of food availability (Snelgrove & Butman, 1994). The complexity of the relationships may be even greater as many species are associated with more than just a single type of sediment, while others show little affinity with any particular sediment type (Mancinelli *et al.*, 1998; Snelgrove & Butman, 1994). Overlapping in

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food selection can also occur by changing their feeding patterns during a life span influenced by environmental factors (Roth & Wilson, 1998, Snelgrove & Butman, 1994).

It has been suggested that the ability of macrobenthic animals to establish themselves is generally influenced by feeding patterns and food availability (Roth & Wilson, 1998). Physico-chemical factors, such as water stability, salinity, sediment characteristics, organic content, dissolved oxygen, particle size and microbiomass, are considered as significant factors influencing trophic composition of benthic assemblages (Gaston, 1998). Grizzle (1989) emphasized the significant role of tidal currents in food availability for benthic suspension feeders through turbulent diffusion, allowing pelagic production to be available for benthic suspension/filter feeders. Food quality and quantity can thus be a limiting factor for suspension-feeders .

Among macrobenthic animals, polychaetes are considered more sensitive organisms to organic enrichment by changing rapidly in diversity and abundance (Tomassetti & Porello, 2005). They have been recognized as good indicators of environmental disturbance, owing to their trophic flexibility and life history traits as a pre-adaptation to the condition of disturbed habitats (Tomassetti & Porello, 2005), and their high tolerance to stress associated with organic loading and low oxygen levels (Levin & Gage, 1998). Single species, such as *Capitella capitata* (Capitellidae), *Polydora ciliata* (Spionidae) and *Hydrobia ulvae* (Bivalvia), have previously been used as indicators of organic enrichment. However, these species can also be found in areas with low organic content. Thus, the relative spatial and temporal abundance of groups of species are considered to be more useful to assess the level of organic enrichment than individual species.

The trophic structure analysis on macrobenthic assemblages has been widely used as a method to determine energy flow in marine sediments owing to their sensitivity to multiple factors, including environmental disturbance. In most macrobenthic studies of soft-bottom sediments, relationships between sediment types and trophic structure are usually typical in that fine grained, muddy-sediments with high organic content are dominated by deposit-feeder organisms, whereas coarse-sandy sediments with low organic content and high energy environments are dominated by suspension feeders and carnivores (Diaz & Rosenberg, 1995; Gaston *et al.* 1998; Rakocinski *et al*., 2000)

Because a significant relationship between benthic trophic structure, sediment contaminants and environmental variables have been observed (Gaston *et al*., 1998), changes in trophic structure can be used as an indicator of disturbance. Reduction in trophic complexity in organically-enriched and chemically-contaminated sediments, in which the benthic assemblages were dominated by opportunistic species, has been observed by several authors (Weston, 1990; Diaz & Rosenberg, 1995; Gaston *et al.* 1998; Rakocinski *et al*., 2000). It has been reported that sub-surface deposit feeders dominated sediments at high accumulation of organic matter, whereas carnivores, filter feeders, and surface deposit feeders decreased (Rosenberg, 1995; Rakocinski *et al*., 2000). The use of patterns of distribution and abundance of suspension feeders to detect environmental disturbance has also been suggested (Carballo & Naranjo, 2002). On the basis of invertebrate feeding patterns, the Infaunal Trophic Index (ITI) was used by several authors to assess the response of feeding groups to sources of organic matter and as a regulatory tool in management decisions for marine environmental monitoring (Cromey *et al.* 1998; Maurer *et al*., 1999; Cromey *et al.* 2002). The ITI includes four feeding groups of marine organisms and classified on their response to source of organic matter.

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MATERIALS AND METHODS

Sampling

The sampling sites were located in the vicinity of southern bluefin tuna (*Thunnus maccoyii*) farms, southern Spencer Gulf, South Australia. The areas are relatively strong microtidal (<2 m) currents with an average current velocity of 5-10 cm s^{-1}. The seawater temperatures fluctuate from 14^{o}C in winter to 25^{o}C in summer.

Samples were subsequently collected five times during the period from October 2002 to October 2003. 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 farm sites. Cores were collected at eight farm pontoon and control sites.

Macrobenthic abundance

Because of the complexity of functionally grouping of benthic fauna, which ideally involves the assessment of motility and feeding patterns, macrobenthic abundance was categorised based on six major trophic groups: carnivores (CAR), herbivores (HER), omnivores (OMN), suspension feeders (SF), surface deposit feeders (SDF), and subsurface deposit feeders (SSDF) using literature descriptions of feeding behavior (Jones & Morgan, 2002; Pardo & Dauer, 2003; Rouse & Pleijel, 2001). The proportion of each trophic group was then calculated for each sampling site and time. Changes of the composition of trophic groups over the study period and the response of the trophic groups to organic enrichment are discussed.

Relative contribution of trophic groups

The relative contribution of each trophic group over time is shown as area-blocks charts. The proportions of abundance and biomass of the trophic groups are related to the relative organic carbon content in sediments. Differences in number of individuals for deposit feeders (SDF and SSDF) and SF between site and time were assessed using a two-way analysis of variance (ANOVA). The data was tested using Komogorov-Smirnov's test for normal distribution and Levene's test for homogeneity of variances. Further test using Tukey's HSD post hoc for multiple comparisons was done if the results revealed significant differences between sampling times ($p<0.05$). Pearson correlation coefficient was used to assess the relationship SF and SDF. Preliminary analyses were carried out to avoid violation of the statistical assumptions of normality, linearity, and homoscedasticity (Palant, 2005). Relative distribution of dominant trophic groups and taxa in relation to sediment characteristics and hydrodynamical conditions was presented as a table.

Assessment of environmental disturbance

The Infaunal Trophic Index (ITI) was used to identify the degree of environmental disturbance or potential organic enrichment caused by fish farming based on trophic structure. This approach is based on the distribution of taxa to one of the four main trophic groups (Cromey *et al.*, 1998, 2002). The index is calculated by the following formula:

$$ITI = 100 - \left\{ 33.33 \left[\frac{(0n_1 + n_2 + 2n_3 + 3n_4)}{(n_1 + n_2 + n_3 + n_4)} \right] \right\}$$

where n_i is the number of individuals in trophic group i. Values of the ITI range between 0 (dominated by subsurface deposit-

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feeding invertebrates) and 100 (dominated by suspension-feeding invertebrates). The interpretation of the values is based on three categories: values of 100–60 generally indicate normal/unaffected conditions, 60–30 indicate modified/changed conditions, and 30–0 indicate degraded/polluted conditions. The four trophic groups used for assessing the ITI values according to Cromey *et al.* (2002) are: *Group 1*: animals feeding on detritus from the water column and usually lack sediment grains in their gut contents; most of them are suspension feeders; *Group 2*: animals feeding on the same types of food as suspension feeders, but usually from the upper 0.5 cm of the sediment as interface/surface-detritus feeders (a combination of suspension feeders and surface-detritus feeders); *Group 3:* animals feeding from the top few centimeters of the sediment and contain encrusted mineral aggregates, deposit particles or biological remains in their gut. These include surface deposit feeders and carnivores; *Group 4*: animals feeding on deposited organic material as mobile burrowers, sub-surface deposit or ‘‘specialised environment’’ feeders, which are all adapted to live in highly anaerobic sediments.

Ditrophic taxa, which have two different feeding patterns, or multiple feeding patterns were categorized into a single trophic group (Word, 1979). Because members (species) of a family can have more than one feeding pattern, the results of this study may thus constitute the general tendency of ITI numerical values of the main four trophic groups. The variances of transformed data of ITI were heterogeneous; therefore, non-parametric tests were employed to asses the difference of ITI between site and time. The Mann-Whitney U test was used to compare ITI between control and farm sites, whereas the difference of ITI in time was assessed using Kruskal-Wallis test. It was hypothesized that the ITI values at control sites would be more than 60 and at farm sites would be less than 60, or at least less than the scores for the control sites. As both indices indicate the quality of environment based on the structure of assemblages, the relationship between ITI and Shanon-Wiener diversity index was assessed using Spearman’s rank order correlation (rho).

RESULTS AND DISCUSSION

The structure of trophic groups at control and farm sites

Surface deposit feeders (SDF) followed by carnivores dominated in abundance at both control and farm sites over the study period (**Fig 1**). The proportion of SDF abundance increased from 42% in October 2002 to 59% in October 2003 at control sites, and at farm pontoon sites from 37% to 64%. However, the proportion of sub-surface deposit feeders (SSDF) abundance was relatively low at both control and farm sites ranging between 5 and 6% at control sites and 5 and 12% at farm sites.

A two-way ANOVA showed that the abundance of deposit feeders was significantly higher at the farm sites than at the control sites ($F_{(1, 158)} = 6.817$, $p = 0.01$); however the effect size was small (partial eta squared = 0.044). The difference between times was also significant, with a large effect size (partial eta squared = 0.208). ($F_{(4, 158)} = 9.767$, $p < 0.001$), showing that only 4.4 % of the variance can be contributed to “site” while 20.8% can be contributed to “time”. Post hoc comparisons, using the Tukey HSD test, indicated that the mean abundance of deposit feeders in October 2003 ($\overline{X}$ = 39.94, SD= 22.32) was significantly different from October 2002 ($\overline{X}$ = 19.25, SD= 11.022), January 2003 ($\overline{X}$ = 24.53, SD= 8.80), or May 2003($\overline{X}$ = 23.72, SD= 11.79) and in October 2002 from July 2003 ($\overline{X}$ = 32.19, SD= 20.37).

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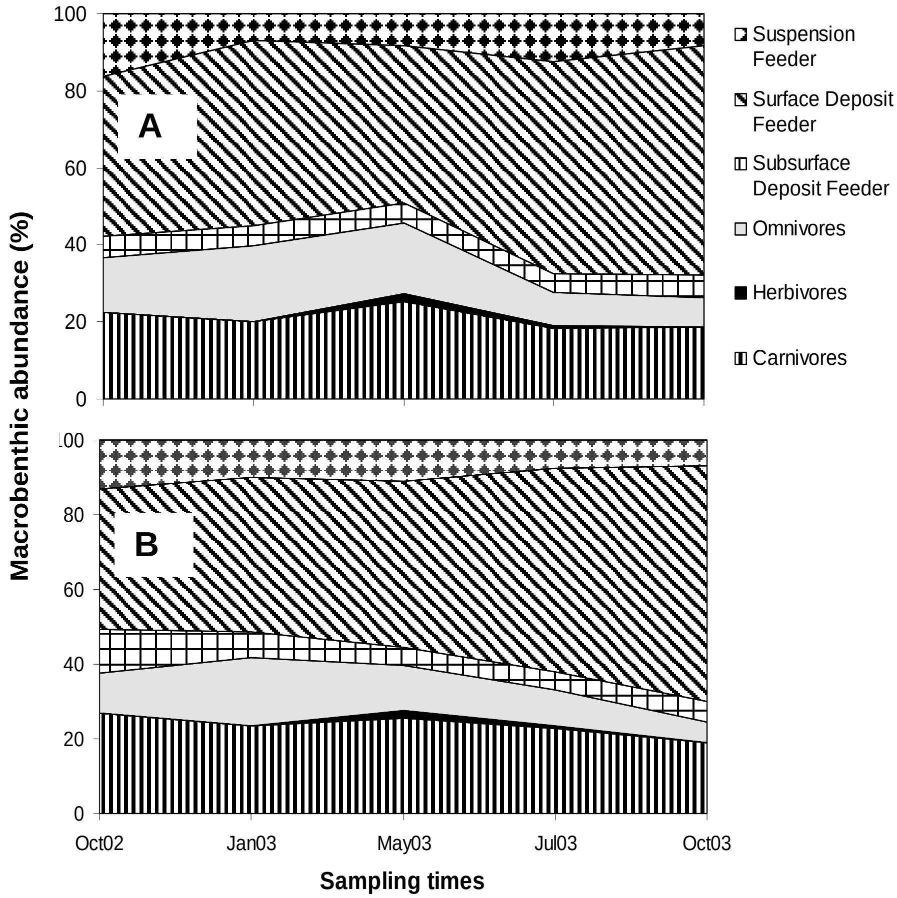

Fig 1. The proportion of trophic groups of the fauna at control (A) and fallowed (B) sites over the sampling period.

However, no significant difference between sites ($F_{(1, 158)}$ = 1.527, p>0.05) and times ($F_{(4, 158)}$ = 0.716, p>0.05) were observed for the abundance of suspension feeders.

Most macrobenthic species are relatively unselective in their food requirements and rely on spatial partitioning of the habitat (Dernie *et al*., 2003); however, species may still be functionally grouped based on their feeding patterns. Fauchald & Jumars (1979) categorized polychaete families based on their motility and feeding patterns into several major feeding guilds and grouped polychaete families as surface deposit feeders (19 families), carnivores (19 families), subsurface deposit feeders (13 families), herbivores (10 families), filter feeders (8 families), and a few families as omnivores. Nevertheless, assessing trophic groups of macrobenthic assemblages can be complicated, because overlapping in food selection can occur, especially suspension feeders (Roth, 1998). They can also switch feeding patterns during their life span depending on environmental factors (Snelgrove and Butman, 1994). In this study, the classification of all taxa (mostly at the family level) of the assemblages into the main

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trophic groups is based on a general trend of most members of a family categorized by the literature (Jones & Morgan, 2002; Pardo & Dauer, 2003; Rouse & Pleijel, 2001; Shepherd & Thomas, 1997).

The result showed that deposit feeders dominated both control and farm sites over time. Despite a significant higher abundance of deposit feeders at the farm sites than at the control sites, the result showed that the abundance of SDF increased at both sites over the study period. Because the high presence of this trophic group is an indication of a disturbed environment, there appears not to be any sign of a major recovery of the infauna after a twelve-month period of fallowing.

It is likely that food abundance and variety regulate the organization of deposit-feeding assemblages. The various particle types found in the sediments at the sampling sites were considered potential food particles for deposit feeding organisms. These particles are organic-mineral aggregates, organic-encrusted mineral grains (bacterial films and diatoms), fecal pellets and fragments, living diatoms (pinnate, centric, and pleurosigmoid-like), angiosperm plant fragments, meiofauna (nematodes, copepods, ostracods, turbellarians, naupli), chitinous molts and fragments, protozoans (ciliates, foraminiferas, amoebas), and pollen or spores. Similar results have been reported by Pardo & Dauer (2003) showing that deposit feeders obtain their nutritional requirements from the organic fraction of ingested sediments, which constitutes a wide variety and large number of food particles including mineral grains, detritus, diatoms, protozoans and metazoans. Thus, the higher abundance of deposit feeders at the farm sites in this study may indicate a wider variety of food particles or organic matter at these sites.

Although the proportions of SF decreased and SDF increased at both control and farm sites throughout the sampling period, the presence of SDF does not seem to influence the presence of SF. A weak negative correlation between density of deposit feeders and suspension feeders has also been reported, suggesting that the species utilizing different trophic groups can co-occur in large numbers and that distributions of suspension and deposit feeders are not mutually exclusive (Snelgrove & Butman, 1994). It has been reported that suspension feeders trap particles that are transported horizontally close to the bottom, and thus collect particles before they settle on the bottom (Loo & Rosenberg, 1996), whereas deposit feeders rely on particles that have settled on to the bottom (Snelgrove & Butman, 1994; Snelgrove, 1999). Deposit feeders utilize organic materials deposited on the sediment surface (Hansen & Josefson, 2004), while suspension feeders catch suspended particles from near-bottom water (Snelgrove, 1999). Thus, the difference in feeding patterns and subsequently difference in food resources may be the main explanation for the co-occurrence of the two trophic groups.

Trophic structure related to environmental variables

The proportion of carnivores at control sites fluctuated between 18 and 25%, while at farm pontoon sites it decreased from 27% in October 2002 to 19% in October 2003. The highest percentages of omnivores occurred in January 2003 at both sites. Suspension feeders (SF) decreased at both control and farm sites by 8% and 6%, respectively, throughout the sampling period. The smallest trophic group was herbivores with 0.1% represented by Asselota (Isopoda).

The distribution of dominant trophic groups and taxa at control and farm sites, with additional information on environmental variables are shown in **Table 1**. Changes in the proportion of trophic groups and the abundance of dominant taxa were observed

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over the study period. However, the relative composition of the trophic groups were similar, in which surface deposit feeders (SDF) dominated the assemblages at all sites/zones, followed by carnivores (CAR), suspension feeders (SF), and sub-surface deposit feeders (SSDF). This was expressed by the domination of Spionidae (SDF), which was the most dominant taxon at all sites/zones. Although the proportion of organic carbon was somewhat higher and current velocities slower at farm sites than at control sites, there were no significant differences between sites, as well as between zones for the two variables. However, sediment composition was significantly different between sites, especially for coarse sand, clay and silt, suggesting that sediments at farm pontoon sites had less coarse sand, but more silt and clay compared to control sites. Given that the proportions of SF decreased and SDF increased at both control and farm sites throughout the sampling period, attempts were made to assess the relationship between two trophic groups using Pearson correlation coefficient. The result showed that there was no significant correlation between the two trophic groups ($r = 0.05$, $n = 626$, $p>0.05$), suggesting that the presence of suspension feeders is unlikely to be influenced by surface deposit feeders in the sediments. Correlations between the other trophic groups also revealed similar results, in which none of the correlation between any of two trophic groups (within SF, SDF, SSDF, OMN, and CAR) were significant.

Table 1. Distribution of dominant trophic groups and taxa in related to sediment characteristics and hydrodynamical conditions at control and fallowed sites represented by Rabbit Island and Boston Island zones.

SITE	DOMINANT TROPHIC GROUPS (% of total)	DOMINANT TAXA (Number of inividuals/m^2)	SEDIMENT COMPOSITION (% ± 95% CI)	ORGANIC CARBON*) (mg/g ± 95% CI)	CURRENT VELOCITIES (cm/s ± 95% CI)
A. Control sites					
1. Rabbit Island	SDF (52.60) CAR (18.14) SF (9.65) SSDF (5.45)	Spionidae (4909) Nephtyidae (3828) Lumbrineridae (3403)	Coarse sand (11.5 ± 2.82) Fine sand (24.8 ± 1.00) Clay (6.0± 1.10) Silt (14.2 ± 3.74)	5.47 ± 0.08	15.2 ± 5.78
2. Boston Island	SDF (47.62) CAR (23.55) SF (9.94) SSDF (5.23)	Spionidae (4697) Nephtyidae (4324) Lumbrineridae (2658)	Coarse sand (6.9 ± 1.62) Fine sand (21.6 ± 3.19) Clay (7.6 ± 1.41) Silt (22.6 ± 5.37)	6.14 ± 0.08	15.2 ± 5.45
B. Fallowed sites					
1. Rabbit Island	SDF (53.49) CAR (22.73) SF (8.16) SSDF (6.06)	Spionidae (12549) Lumbrineridae (5424) Capitellidae (2587)	Coarse sand (6.9 ± 1.51) Fine sand (23.6 ± 2.08) Clay (7.1 ± 0.72) Silt (21.2 ± 4.69)	6.85 ± 0.06	14.8 ± 5.10
2. Boston Island	SDF (44.27) CAR (23.64) SF (11.11) SSDF (7.21)	Spionidae (4697) Lumbrineridae (4112) Nephtyidae (3882)	Coarse sand (5.97 ± 0.70) Fine sand (21.8 ± 0.60) Clay (8.6 ± 0.63) Silt (22.9 ± 1.25)	6.22 ± 0.15	14.4 ± 6.06

Notes:
*) Only data from the first samples (October 2002).
SDF = Surface deposit feeders; CAR = Carnivores; SF = Suspension feeders; SSDF = Sub-surface deposit feeders.

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The distribution of abundance and biomass of the trophic groups as a function of organic carbon content in sediments is shown in **Fig 2**. At low levels of organic carbon, SDF (mostly sipunculans, terebellids, and sabellids) dominated macrobenthic abundance (52.4%), and SSDF had the lowest proportion (4.8%) while carnivores (mostly eunicids, lumbrinerids, and nemerteans) and SF (mostly bivalve molluscs) were recorded as having the highest (47.0%) and the lowest (14.3%) biomass, respectively. At high levels of organic carbon recorded, however, three detritivore feeding groups (SF, SDF, and SSDF) dominated numerically, contributing about 67% of total abundance. At the same level of organic carbon, the biomass was dominated by nearly equal proportion of SF (31.8%) and omnivores (32%), while SSDF (mostly capitellid polychaetes) showed the lowest proportion of the total biomass. The abundance of SSDF increased gradually as a function of organic carbon content, but decreased markedly in biomass proportion owing to the elimination of some large body taxa and the dominance of small body size-opportunistic taxa, such as echinoids (the largest omnivore group collected). Other large animals recorded over the sampling period were mytilids for suspension feeders and holothuroids for surface deposit feeders.

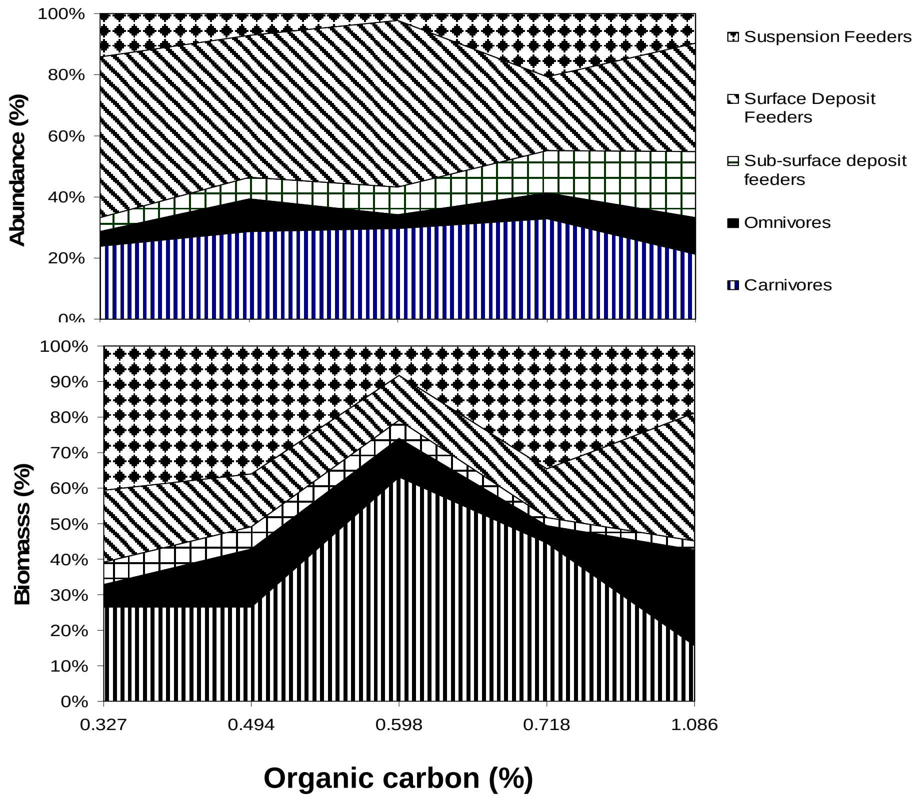

Fig 2. Abundance and biomass of macrobenthic fauna as a function of increasing amount of organic carbon.

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Attempts have been made by several authors to relate organic content and abundance of trophic groups. Rakoncinski *et al*. (2000) showed that the proportion of subsurface deposit feeders increased along an organic-chemical contamination gradient, whereas carnivores, filter feeders, and surface deposit feeders decreased. Organic carbon in the sediment surface correlated with deposit feeding species richness, whereas total and food particulate matter correlated with species diversity. The results showed that responses of benthic fauna to organic matter (assessed using % organic carbon) are likely to be in accordance with the theory of macrobenthic succession proposed by Pearson & Rosenberg (1978). The main trophic groups seem to respond the classical way to organic enrichment at the pontoon sites. As the amount of organic material on the sediment surface increases, the larger and deeper burrowing species are gradually eliminated and replaced by greater numbers of small surface deposit feeders. A simple trophic system composed of only non-selective deposit feeders and carnivores can be established in sediments where input levels of organic matter are noticeably high. Weston (1990) observed that trophic diversity was reduced with proximity to a salmon farm as a result of increasing organic matter. He found that suspension feeders constituted 10% of the assemblages at 450 m from the farms, but disappeared at 45-90 m from the farm, whereas sub-surface deposit feeders increased directly under the farm. In this study, however, the reduction of trophic diversity, as has been reported by Weston (1990), did not occur as organic carbon increased. Beside high variability during the sampling time, the low levels of organic carbon recorded may be the main reason of this. It is likely that organic loading from southern bluefin tuna farms at this region is relatively low in comparison to most situations that have been studied elsewhere.

Response of trophic groups to the disturbance: Infaunal Trophic Index (ITI) vs diversity index (H')

The ITI and Shannon-Wiener diversity index are shown in **Fig 3**. The values of ITI at most sites fluctuated throughout study period. The index was smallest at site P06 (30) and highest at site BC8 (67) in October 2002. In October 2003, however, site P01 (35) and RC5 (53) have the smallest and the highest score of ITI, respectively. The ITI progressively increased at site RC5 from 38 in October 2002 to 53 in October 2003, indicating a marked recovery of the infauna from the disturbance. In contrast, ITI gradually decreased at P01 over time, from 44 in October 2002 to 35 in October 2002, suggesting a further disturbance at this site. In general, the difference of ITI between control and farm sites assessed using Mann-Whitney U test was significant ($Z = -3.318$, $n = 640$, $p = 0.01$). However, no significant difference between sample times was observed (Kruskal-Wallis test, $\chi^2 = 3.07$, $n = 640$, $p>0.05$). Most of the values at both control and farm sites range between 60-30 and categorised as modified/changed condition, except for site BC8 in October 2002. This site has the ITI values of 67; therefore, it is classified as a normal/undisturbed condition. The results indicate that the entire sampling sites have been moderately disturbed over the sampling period, with the exception for site BC8 of October 2002 sample.

The Shannon-Wiener diversity index (H') fluctuated and is likely to co-vary with the fluctuation of the infaunal trophic index, with some exceptions for site BC8 of October-02's sample and site RC5 and P05 of May-03's samples. A medium strength of the correlation between the two indices using Pearson's rank order correlation was observed ($rho = 0.408$, $n = 559$, $p <0.001$), indicating that 40.8 % of the variance can be contributed to the correlation between H' and ITI.

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At an environmental disturbance (organic enrichment, hypoxia or anoxia etc), each trophic group may respond differently. Diaz & Rosenberg (1995) observed that sediment contamination leads to greatly reduced trophic complexity in which benthic assemblages are dominated by opportunistic species such as Capitellidae and Spionidae. These groups are adapted to rapidly re-colonize disturbed areas and establish a large population within a relatively short time (Lu & Wu, 1998). Depletion of nitrogen sources of food affects population dynamics of deposit-feeder individual growth and/or reproductive output (Rossi, 2003).

Although positive correlation between H' and ITI was considered weak in this study, the variability of Shanon-Wiener diversity index (H') spatially and temporally seems co-vary with ITI. This suggests that the assessment of ITI is influenced by taxa richness and evenness. Increasing ITI will increase the Shanon-Wiener index. Cromey *et al*. (1998) observed that the relationship between ITI and Shannon-Wiener index was significantly correlated. Despite almost all sites in this study represented changed/modified condition based on ITI criteria, the result showed that ITI was significantly higher at control than at farm sites. This can be explained by a more stressed environment at farm sites than at control sites. It has been reported that ITI is significantly influenced by environmental variables, such as water depth, granulometry, and distance from the source of pollution (Maurer *et al*., 1999).

CONCLUSIONS

Five dominant taxa (Capitellidae, Cirratullidae, Lumbrineridae, Nephtyidae, and Spionidae), relatively tolerant to organic enrichment, were recorded in higher numbers at the farm sites than at control sites. In particular, spionids and lumbrinerids were found to be the responsible taxa for assessing levels of disturbance at farm sites. The responses of the main trophic groups to organic matter are in accordance with Pearson & Rosenberg (1978) in that larger and deeper burrowing species are gradually replaced by greater numbers of small suspension- and surface deposit feeders as organic matter increases. However, reduction in trophic groups did not occur, implying only moderate levels of disturbance at the studied sites.

Although the proportions of suspension feeders decreased and surface deposit feeders increased at both control and farm sites throughout the sampling period, the presence of surface deposit feeders did not seem to influence the presence of suspension feeders. The difference in feeding patterns and thus difference of food resources may be the main reason to explain co-occurrence of the two trophic groups.

In general, ITI was significantly higher than at allowed sites, implying a better condition of macrobenthic habitat at control sites. However, no significant temporal difference was observed. Most of the values at both control and farm sites range between 60-30, indicating a modified/changed condition.

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