Marine Pollution Bulletin 79 (2014) 164–174

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Influence of tuna penning activities on soft bottom macrobenthic assemblages

Marija Mangion [a,*], Joseph A. Borg [a], Richard Thompson [b], Patrick J. Schembri [a]

[a] Department of Biology, Faculty of Science, University of Malta, Msida MSD 2080, Malta
[b] School of Marine Science and Engineering, Faculty of Science and Technology, University of Plymouth, Drake Circus, Plymouth PL4 8AA, Devon, United Kingdom

ARTICLE INFO

Keywords:
Mediterranean Sea
Tuna penning
Aquaculture impact
Benthic assemblages
Sediment quality

ABSTRACT

The influence of tuna penning on soft bottom habitat present in the vicinity of tuna pens and at distances 200 m and 1.5 km away, was assessed by comparing attributes of macroinvertebrate assemblages and sediment quality before (November 2000, March 2001) and after (November 2001, April 2002) initiation of the activity. Results from November 2001 indicated a significant increase in sediment organic carbon and organic nitrogen, and a non-significant increase in the abundance of Capitellidae in the vicinity of the cages. Similar results were obtained 200 m from the cages but not 1.5 km away, where the only change was a significant increase in organic nitrogen in sediment. Results from April 2002 indicated no significant change in sediment organic carbon and organic nitrogen, however, mean sediment grain size decreased significantly in the immediate vicinity of the cages. Changes in attributes of the benthic assemblages and sediment resulted from accumulation of uneaten feed-fish on the seabed.

1. Introduction

Aquaculture is an important and rapidly expanding food-producing sector (FAO, 2010; IUCN, 2010) but the activity has been often criticised (WWF, 2003; Greenpeace, 2008) because of its potential adverse impacts on the environment, including deterioration of water quality and changes to the biotic assemblages in the vicinity of fish farms (GESAMP, 1990; Wu, 1995; Hargrave et al., 1997). As a result, the reduction or possibly elimination of the undesirable environmental effects of aquaculture to make it more sustainable are being strongly advocated (IUCN, 2009a, 2009b, 2009c, 2010; FAO, 2010). Measures to promote this include site selection and management (IUCN, 2009a, 2009b), identification of suitable indicators (Giles, 2008; IUCN, 2010) and adoption of effective monitoring programmes (Fernandes et al., 2001). However, successful implementation of such measures is highly dependent on availability of information concerning interactions between aquaculture and the environment that is essential for coastal planners and managers to make informed decisions and formulate appropriate management plans.

A lucrative sector of the aquaculture industry is the ranching of Atlantic Bluefin Tuna (ABT) *Thunnus thynnus thynnus* Linnaeus 1758. ABT has a very high commercial value and constituted 8% of the total global fish exports in 2010 (FAO, 2012). Tuna penning is considered by many as not being 'true' aquaculture but a capture-based variant of the activity, since the stock is harvested from the wild. The general history and development of this industry have been well documented by Miyake (2005, 2007). Large-scale ABT ranching started in Canada in the 1980s, and in the 1990s was taken up in Spain and other parts of the Mediterranean (Miyake et al., 2010). It now constitutes a large sector within the fish aquaculture industry (FAO, 2004), with the main producers in the Mediterranean being Italy, Malta and Spain (ICCAT, 2011). Other tuna farms are found in Turkey, Croatia, Cyprus, Greece, Tunisia and Libya (ICCAT, 2011). The number of tuna farms in each Mediterranean country and their total capacity must be registered with the International Commission for the Conservation of Atlantic Tunas (ICCAT). According to the latest statistics, there are 62 Mediterranean farms having a total capacity of 60,809 t currently registered with ICCAT (ICCAT, 2011). Of these, eight installations with a total capacity of 12,300 t are located around the Maltese Islands (ICCAT, 2011), although they are not operated at maximum capacity. In 2011, Malta produced 1759 t of tuna with a value of 38.594 million Euro (NSO, 2012).

A general review of the issues related to the ranching of ABT in the Mediterranean is available in FAO (2005); the fish are caught in May–July by purse-seine vessels and transferred to offshore floating cages for fattening until October/January, when they are harvested for export, mainly to Japan (FAO, 2005–2011). Ranched ABT are mainly fed fresh fish and molluscs, including sardine, mackerel and squid (Aguado et al., 2004; Vita and Marin, 2007). Uneaten fish are the main source of pollution of the seabed at tuna farms. The uneaten fish accumulate under the tuna-pens (Aguado

* Corresponding author. Tel.: +356 79869262.
E-mail address: marija.mangion.06@um.edu.mt (M. Mangion).

0025-326X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.marpolbul.2013.12.021

et al., 2004; Vita et al., 2004a; Borg and Schembri, 2005; Aguado-Gimenez et al., 2006; Vita and Marin, 2007) and may lead to potential adverse effects on the composition and structure of benthic assemblages in the vicinity of a farm (Vita et al., 2004a; Borg and Schembri, 2005; Vita and Marin, 2007; Vezzulli et al., 2008). Potential adverse effects may be reduced or eliminated when the tuna pens are located well offshore in high energy environments (Maldonado et al., 2005). There are also concerns regarding the potential for tuna cages to break loose from their moorings during adverse sea conditions and eventually breaking up, resulting in large amounts of marine litter (Macfadyen et al., 2009). Although ABT is kept in high stocking densities that entail high feed input, the number of stocked tuna varies amongst different farms and even between different cages within the same farm. As a result, one would expect large differences in the level of impact, if any. Furthermore, because of the particular characteristics of the activity, namely use of feed fish instead of processed feed and the large size of the fish, the potential impacts of tuna penning are expected to differ from those of other intensive fish farming activities, such as salmon, sea bream and sea bass farming.

Studies have assessed the amounts of organic nitrogen and phosphorus waste generated by ABT farming (Vita et al., 2004a; Aguado et al., 2004; Aguado-Gimenez et al., 2006), and the impact of this waste on nutrient levels in the water column and sediments (Matijević et al., 2006, 2008; Marin et al., 2007; Vita and Marin, 2007; Aksu et al., 2010), and on water column microbial levels (Kapetanović et al., 2013). Vezzulli et al. (2008) assessed the organic waste impact of ABT farming on a variety of water column and benthic habitat attributes, while a study by Šegvić Bubić et al. (2011) assessed the influence of a tuna farm on the associated wild fish assemblages. Other studies assessed the food-web effects of tuna farming on trophic linkages (Forrestal et al., 2012) and the emissions that result from the tuna penning industrial activities (Hospido and Tyedmers, 2005) However, few studies have addressed the influence of ABT ranching on the benthic macroinvertebrate assemblages in the vicinity of tuna pens (Marin et al., 2007; Vita and Marin, 2007; Vezzulli et al., 2008; Moraitis et al., 2013). In particular, studies comparing attributes of benthic assemblages before initiation of tuna penning to after, are lacking.

The present study was aimed at assessing the influence of a large tuna farm, located off the northeastern coast of the Maltese Islands, on the soft bottom macroinvertebrate assemblages present in its vicinity. The farming practice included a fallow period during winter of each year when the pens did not hold any tuna. Samples of soft sediment for biological and physico-chemical studies were collected in autumn and spring before initiation of the tuna penning activities and after during the same seasons. The following null hypothesis was tested: tuna penning activities do not have an influence on (a) sediment physico-chemical attributes and (b) number of taxa, abundance of selected macroinvertebrate taxa, and assemblage composition of the macroinvertebrates associated with the soft sediment habitat in the vicinity of tuna pens.

2. Materials and methods

2.1. Study area and sampling

The tuna farm studied is located 1 km off the northeastern coast of the Maltese Islands (Fig. 1), where the seabed consists of soft sediment and the water depth is between 45 m and 50 m. The farm has a total annual capacity of around 3000 t and utilises cages of 50 m diameter and 25 m height.

The sampling design incorporated three sampling areas at incremental distances from the tuna pens, all of which had a similar bottom type: (i) 'Cage' area, i.e. the seabed area directly beneath the tuna cages; (ii) 'Influence' area, some 200 m from the cages; and (iii) 'Control' area, some 1.5 km from the cages. Four replicate sampling sites were allotted to each area, such that a total of twelve samples were collected on each sampling occasion. Sampling was carried out in November (hence autumn) 2000 and in March (hence spring) 2001 before initiation of any tuna penning activities, and one year later in November 2001 and in April 2002 following commencement of the tuna penning activities. The cages did not hold any tuna during the fallow period in winter.

Samples were collected using a 0.1 m^2 van Veen grab. Three replicate grab samples for benthic macrofaunal studies and one grab sample for sediment studies were collected from each of the twelve sampling sites in November 2000, March 2001, November 2001 and April 2002 (Fig. 1). As the exact place where the cages would be located was not yet known at the time when the 'Before' samples were collected, sampling in November 2000 and March 2001 was made in the general area of influence of the farm, rather than from the specific locations indicated in Fig. 1 in the area where the cages are found. Samples for sediment analyses were collected in March 2001, November 2001 and April 2002 but not in November 2000.

In the laboratory, samples for faunal studies were sorted for macroinvertebrates after washing on a 0.5 mm mesh. Macroinvertebrates were identified to family level and enumerated to obtain estimates of number of taxa and abundance per grab sample. For sediment physico-chemical studies, sub-samples for the determination of percent organic nitrogen content (PONC), percent organic carbon content (POCC) and weight/weight percentage feed-fish bone content (PFBC) were frozen at −20 °C for later analysis, while another sub-sample was oven-dried for determination of mean sediment grain size (MSGS).

Analysis of the sediment to determine the PFBC was carried out by sorting fish bones from the sediment using forceps under a dissecting microscope. PONC in the sediment was determined using the Kjeldhal method (see Holme and McIntyre, 1984), while POCC in the sediment was determined using acid digestion (see Walkley and Black, 1934). MSGS was determined according to Buchanan (1984).

2.2. Data analysis

Separate three-factor analysis of variance (ANOVA) was carried out on the number of taxa and abundance of selected indicator taxa Paraonidae (Polychaeta), Phoxocephalidae (Amphipoda), Apseudidae (Tanaidacea) and Arcidae (Bivalvia) using a model with two orthogonal factors 'Before/After' (BA; 2 levels, before and after, fixed) and 'Area' (Ar; 3 levels, Cage, Influence and Control, fixed), and the factor 'Site' (Si; 4 levels, a–d, random) nested within 'BA x Ar', using data collected in (i) November 2000 and November 2001, and (ii) March 2001 and April 2002. The four indicator taxa at family level were selected on the basis of being the four most abundant macroinvertebrate families in the data collected before the tuna penning activities were initiated. Separate two-factor ANOVA, based on a model with the two orthogonal factors 'Before/After' and 'Area' where levels of 'Site' were treated as replicates, was carried out using sediment data for MSGS, POCC and PONC, collected in (i) March 2001 and November 2001, and (ii) March 2001 and April 2002. Missing data on physico-chemical sediment attributes for November 2000 was replaced with that collected in March 2001, with the assumption that natural seasonal factors did not influence sediment attributes.

All ANOVA were carried out using GMAV 5 (Underwood et al., 1998), with α set at 0.05. Prior to analysis, data were checked for homogeneity of variances using Cochran's test and, where necessary, data were transformed as appropriate. When the data retained heterogeneous variance following transformation,