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CAN OPEN WATER BIO-FILTERS BE USED FOR THE REDUCTION OF THE ENVIRONMENTAL IMPACT OF FINFISH NET CAGE AQUACULTURE IN THE COASTAL WATERS OF ISRAEL?

Ehud SPANIER, Anat TSEMEL, Hadas LUBINEVSKI, Ayalon ROITEMBERG, Amir YURMAN & Stephen BREITSTEIN
The Leon Recanati Institute for Maritime Studies and Department of Maritime Civilizations, University of Haifa, IL-Haifa 31905, Mount Carmel
E-mail: spanier@research.haifa.ac.il

Dror ANGEL, Noa EDEN & Timor KATZ
National Centre for Mariculture, Israel Oceanographic and Limnological research, IL-Eilat 88112, POB 1212, North Beach

ABSTRACT

The use of open water artificial substrates, "bio-filters" (BFs), "Mussel lines" and bivalves in perforated plastic boxes, to reduce the organic output of pen fish farms, was examined in the coastal waters of Israel, the Red Sea and the Mediterranean. The most substantial finding was that species richness and diversity, coverage and biomass of sessile invertebrates and macroalgae were significantly greater on BFs near the fish farm compared to those from a reference site. This indicates that the food used by the fouling organisms on the BFs derived from fish cages.

Key words: aquaculture, northern Red Sea, south-eastern Mediterranean, organic loading, particulate and dissolved organic matter, bio-filtration

È POSSIBILE USARE BIO-FILTRI IN MARE APERTO ALLO SCOPO DI RIDURRE L'IMPATTO AMBIENTALE CAUSATO DA PISCICOLTURA IN GABBIE IN ACQUE COSTIERE ISRAELIANE?

SINTESI

L'uso di substrati artificiali, ossia "bio-filtri" (BFs), "linee di mitili" e bivalvi in scatole di plastica perforate in mare aperto, allo scopo di ridurre l'output organico di piscicoltura in gabbie, è stato esaminato in acque costiere israeliane, sia in Mar Rosso che Mediterraneo. La scoperta più notevole riguarda la ricchezza e diversità di specie, la copertura e la biomassa di invertebrati sessili e macroalghe, che si sono rivelate e maggiori su bio-filtri prossimi all'allevamento ittico che su quelli nei siti. Tale risultato indica che il nutrimento usato da organismi del fouling su bio-filtri deriva dalle gabbie di pesci.

Parole chiave: acquacoltura, Mar Rosso settentrionale, Mediterraneo sud-orientale, carico organico, materia organica disciolta e particellata, bio-filtrazione

INTRODUCTION

Two pen fish farms in Eilat, northern Gulf of Aqaba, Red Sea, produce ~2500 metric tons of fish, mainly gilthead sea-bream, *Sparus aurata*, annually. The remains of the fish food and secretions are released to the naturally oligotrophic marine environment. These loadings can cause algal blooms, sediment anoxia and reduce benthic biodiversity. There are disputed claims that the deterioration of the coral reef reserve (the only one in Israel) ~7 km south-west of the farm should be blamed, at least partially, on the fish farms (Atkinson *et al.*, 2001). Another farm is located in the opening of the port of Ashdod, the southern Mediterranean coast of Israel and produces 600 metric tons of *S. aurata*, annually. The present study is an attempt to reduce these environmental impacts by using sessile biota, natural settlement on open water artificial substrates ("bio-filters", "Mussel lines" and perforated plastic boxes). The attached fauna that filter the water surrounding the cages are assumed to utilize the organic output of the cages for their own growth and are subsequently removed.

MATERIALS AND METHODS

Open water bio-filters

In June 2001, four experimental arrays of bio-filters (BFs) consisting of 11 plastic (NETLON) vertical 25 mm mesh cylinders, 25 x 50 cm each, were deployed at two sites, at depths of 5-14 m. One, the fish farm site (FF), was adjacent to ARDAG fish farm (34°58'40"E, 29°32'45"N) and the other, a reference site (R), was located 300 m west of it.

This study will refer only to the 8 BFs deployed at 8m depth (Plate I: Figs. 5a, b). In addition to bimonthly visual and video censuses of all the BFs, divers censused the number of sea urchins in each BF.

Four BFs from each site were randomly sampled between September 2001 to June 2002 and subsamples, constituting 20% of the surface area of each mesh, were cut and photographed. Sub-samples were analyzed for species composition, coverage and weight.

Sessile biota was identified to the lowest taxonomic level possible and species richness was determined. Species-specific cover was determined (following Foster *et al.*, 1991) by counting the number of mesh cross points covered by each taxa, divided by the total number of mesh cross points examined (144).

Mussel lines

In June 2002, eight 1 m pieces of mussel line (loosely woven rope used by professional mussel fishermen in Scotland), were deployed at 8 m depth on each of the above BFs arrays, on both sites (FF and R) in an attempt to recruit natural bivalves. Each mussel line was weighed down using a small lead weight, attached to its edge. Four mussel lines were randomly sampled bimonthly. Sessile biota was identified to the lowest taxonomic level possible and the biota was weighed.

Mono-species bio-filters

Two species of bivalves, the pearl oyster, *Pinctada radiata*, and the spiny oyster, *Spondylus spinosus*, both Lessepsian migrants from the Red Sea (Spanier & Galil, 1991), were collected in the Mediterranean coastal waters of Israel. They were deployed, in groups of 25 specimens each, in separate 60x40x40 cm perforated plastic boxes, 2-4 m under the water surface beside the cages of the fish farm in the opening of the Port of Ashdod (FA), at a reference site inside this port (RA) and at a control site located in a ship wreck (CSW) off southern Haifa (140 km north of Ashdod) where these bivalves grow naturally. Survival and growth were monitored periodically.

RESULTS AND DISCUSSION

Open water bio-filters

A variety of sessile organisms rapidly colonized BFs at both sites (Plate II). Red algae (especially *Jania adhaerens*), sponges (especially *Mycale fistulifera*, see Plate II: Fig. 7), sea anemones, serpulids, polychaets and bivalves were the dominant taxa on the FF substrata. Sponges, tunicates, bryozoans, and bivalves were the dominant sessile taxa at R site. Stony corals appeared on BFs at both sites (Plate II: Fig. 8). The succession process differed at the two sites. Species richness and diversity, coverage and biomass were significantly greater on BFs from site FF compared to those from site R at all times (Fig. 1) (Plate I: Figs. 5a, b). The ash free dry weight, representing living tissue, continued to accumulate throughout the research period (11 months). *M. fistulifera*, known from laboratory experiments to be a very efficient dead particulate organic feeder (Reiswig, 1974), was the main contributor. The increase of bio-fouling on the BFs at site FF compared to those from site R may indicate that these organisms can potentially utilize the organic output from fish cages, directly or via the food web.

Grazing, by wild fish and mobile macroinvertebrates (such as sea urchins, e.g. Plate II: Fig. 7), may supply an alternative explanation: in site FF, wild mobile organisms have an alternative food source – the organic output from the cages. This artificial nutrition is lacking at site R and may cause greater grazing of the bio-fouling on the BFs there. This seemingly greater grazing of the bio-fouling may result in less biomass on BFs at site R than at FF. However, the finding that the number of sea

urchins censused (between December 2002 and May 2003) was considerably higher on BFs at site FF (mean 0.25 – 0.5 sea urchin / BF / census) than on those from site R (mean 0.0 – 0.1 sea urchin / BF / census) supports the rejection of the grazing hypothesis. Moreover, the study by Lojen *et al.* (2002) of stable isotopes (^{13}C, ^{15}N) in the food of cultured fish, particulate organic matter (POM) and organisms sampled on the BFs, indicated that organisms from the BF were enriched with ^{15}N compared to POM. Lojen *et al.* (2002) estimated that 61% of the food used by fouling organisms on the BFs derived from the cages.

Thus the use of open water BFs of this nature to reduce organic load in the marine environment should be considered. Yet the large numbers of surfaces needed may limit the applicability of this method.

Mussel lines

Algae (mainly *J. adhaerens)* were detected first at site FF and continued to dominate the BFs at this site during the whole study period (12 months). At Site R, they appeared only 6 months later. At this site, *M. fistulifera* (Plate II: Fig. 9) was the dominant species for most of the year. Serpulids appeared at both sites, occasionally in high concentrations. It is interesting to note that there was a negative correlation between the appearance of algae and serpulids, possibly indicating competition in the space between them. Bryozoans, other sponges, tunicates (solitary and colonial), hydrozoans (Plate II: Fig. 9) were also detected on mussel lines at both sites, although in smaller amounts than the taxa discussed above, without significant differences between sites.

Only a small amount of bivalves settled on the mussel ropes. The effect of recruitment from the adjacent fouled BFs should be considered as well as competition for space (taken by earlier and more "aggressive" settlers such as algae, sponges and serpulids) that might have limited the development of bivalves on the mussel lines.

Relatively low levels of bivalves' larvae in the water column in this area may be an alternative/additional explanation for the relatively low recruitment of bivalves to the mussel lines.

Mono-species bio-filters

Since the depth of the bottom of the cages in the opening of Ashdod port is only 1 m above the muddy bottom, preliminary deployment of the perforated plastic boxes at 6 m depth resulted in a very heavy siltation of the bivalves. Thus a shallower depth was selected for the positioning of the bivalves' boxes.

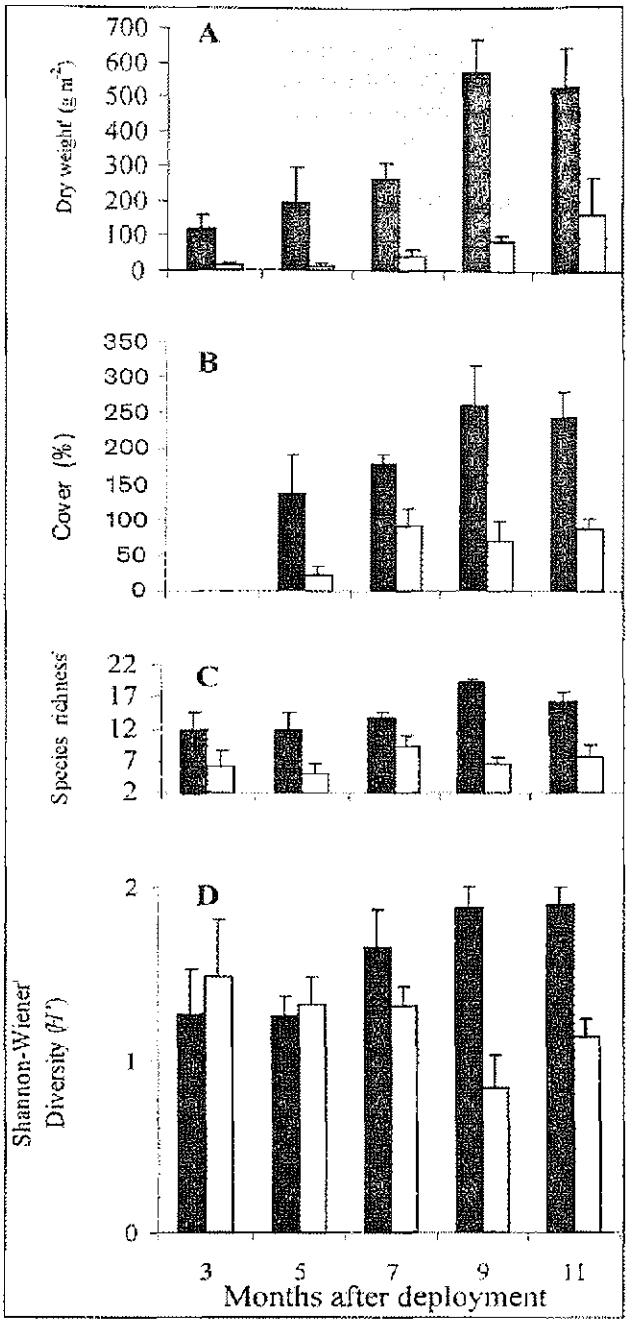

Fig. 1: Characteristics (mean ± SD) of epi-biota community on artificial substrata near the fish farm (FF - black columns) and reference site (R - white columns), 3 to 11 months after deployment. (A) Dry weight; (B) Cover percentage; (C) Species richness; (D) Shannon-Wiener diversity (H').

Sl. 1: Značilnosti (srednja vrednost ± SD) epibiotske združbe na umetnih substratih v bližini morske ribogojnice (FF - črni stolpci) in referenčnih lokalitetah (R - beli stolpci), 3 do 11 mesecev po njihovi postavitvi. (A) Suha teža; (B) Pokrovnost; (C) Vrstna pestrost; (D) Shannon-Wienerjev diverzitetni indeks (H').

In January 2003, several boxes disappeared from Ashdod port during a severe winter storm (9.7 m maximum wave height). Of the remaining *P. radiata* at FA, 65% survived after a year. The survival rates at RA, and CSW were 84% and 33% respectively. The mortality in Ashdod (FA, RA) occurred mostly during the winter, while at the control site (CSW) death occurred mainly during the summer. There was no growth in FA during the summer. During the rest of the year mean growth rates of this species in FA was 4.9 mm/month. Annual mean growth rate was 5.8 and 9.2 mm/month at CA and CSW respectively.

Mass mortality (89%) of *S. spinosus* at FA was observed in the spring and summer. It seems that fish cages located in an opening of a port are not an ideal location for mono-species BFs. The intense water movement due to ship transport, combined with shallow depth, cause intense siltation. This and the massive growth of algae, tunicates and bryozoans on the bivalves' box and the possible competition with the bivalves may explain the low growth rate and mortality of the bivalves.

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ALI JE MOGOČE UPORABITI BIOFILTRE ODPRTIH VODA ZA ZMANJŠEVANJE OKOLJSKEGA VPLIVA MARIKULTURNIH KLETK V OBREŽNIH VODAH IZRAELA?

Ehud SPANIER, Anat TSEMEL, Hadas LUBINEVSKI, Ayalon ROITEMBERG, Amir YURMAN & Stephen BREITSTEIN
The Leon Recanati Institute for Maritime Studies and Department of Maritime Civilizations, University of Haifa, IL-Haifa 31905, Mount Carmel
E-mail: spanier@research.haifa.ac.il

Dror ANGEL, Noa EDEN & Timor KATZ
National Centre for Mariculture, Israel Oceanographic and Limnological research, IL-Eilat 88112, POB 1212, North Beach

POVZETEK

V obrežnih vodah Izraela, Rdečega morja in jugovzhodnega Sredozemskega morja so avorji raziskovali, kako bi z uporabo umetnih substratov, "biofiltrov" (BFs), "školjčnih vrvic" in školjk v perforiranih plastičnih škatlah, lahko zmanjšali organski izpust iz kletk za vzgojo rib. Najpomembnejša je bila ugotovitev, da je pestrost vrst, pokrovnost in biomasa sesilnih nevretenčarjev in makroalg neprimerno večja na biofiltrih v bližini marikulturnih kletk kot na referenčnih lokalitetah, kar kaže na to, da je hrana, ki so jo uporabljali organizmi na biofiltrih, prihajala iz ribjih kletk.

Ključne besede: marikultura, severno Rdeče morje, jugovzhodno Sredozemsko morje, organska obremenitev, suspendirane in raztopljene organske snovi, bio-filtriranje

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