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The plate collector, a new option for *Pinctada margaritifera* spat collection in French Polynesia

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A R T I C L E I N F O

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A B S T R A C T

The aquaculture industry can constitute an important source of waste in the environment. In atoll lagoons of French Polynesia, among the materials used by pearl farmers, shade-mesh collectors can release toxic substances and are responsible of microplastics production. With the aim of providing a less polluting alternative, we performed *in situ* tests comparing reusable plate collectors and shade-mesh collectors during 16 months. Plate collectors were significantly more efficient for spat collection, especially after the first 6 months of immersion ($P < 0.0001$). These results confirmed that this device can be a suitable and more sustainable alternative for the pearl industry.

1. Introduction

The production and accumulation of waste (especially plastic) have a negative impact on the environment and marine ecosystems are particularly impacted (Gregory and Andrady, 2004; Katsanevakis et al., 2007; Le Bihanic et al., 2020; Shomura and Yoshida, 1985). Around 268, 940 tons of plastic are floating at sea, 92% of it being microplastics (MP) *i.e.* particles smaller than 5 mm (Eriksen et al., 2014). Aquaculture industries as major users of plastic (due to its cost and properties) can contribute significantly to this environmental pollution (Hinojosa and Thiel, 2009; Lebreton et al., 2018).

In French Polynesia, the pearl-farming industry, the country's second most important economic resource (IEOM, 2018), is no exception. This activity is performed in remote islands, where there is to date no real waste management or recycling system (Murzilli et al., 2012). Aquaculture materials (buoys, ropes, *etc.*), mainly made from plastic, are imported from abroad. When the material is no longer usable it becomes waste, dumped at sea, on shores or even in landfills in the remote islands (Andréfouët et al., 2014). A first characterization of pearl-farming plastic wastes notably highlighted the very important contribution of the spat-collection stage, a mandatory step in Polynesian pearl-farming (Gaertner-Mazouni et al., 2018). This stage consists in immersing supports (*i.e.* spat collectors) made from black polypropylene (PP) shade-mesh strip on a polyethylene rope (referred to as 'shade-mesh') during 12–24 months, to collect *Pinctada margaritifera* spat (Gardon et al., 2020). Despite being inexpensive with a price of 0.59 € (tax incl.) per unit, the poor quality of this plastic material results in a short life span of around three years, and makes it particularly brittle and subject to fragmentation, resulting in MP production. Indeed some of the MP produced might be directly linked to the high MP contamination recorded in a pearl-farming lagoon (surface water: 2.4 ± 2.3 MP.m^{-3}; water column: 100.3 ± 24.3 MP.m^{-3}), since the FTIR characterization of the latter revealed that their color and composition were mostly similar to ropes and shade-mesh collector plastics (Gardon et al., 2021). Furthermore, recent laboratory experiments have shown that shade-mesh collectors and plastic ropes leachates contain chemical compounds that are poisonous to oyster larvae (Gardon et al., 2020). Thus, it has become essential for the sake of the pearl-farming industry's sustainability to explore a more resistant and eco-friendly solution to replace the shade-mesh collector.

For this purpose, we assessed in a preliminary study whether a reusable plastic spat collector referred to as 'plates' could be an alternative (Crusot et al., 2021). These collectors are made from semi-rigid high-density polyethylene (HDPE) grooved plastic plates making them more resistant to mechanical erosion and UV exposure than shade-mesh implying lower MP production while in-use. Indeed, HDPE are known to oxidize less under UV exposition and to degrade slower than PP of equivalent thickness in marine environment (Arias Villamizar and

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Vázquez Morillas, 2018; Chamas et al., 2020; Gijsman et al., 1999). Plates collector also have a longer life span of 3–6 years under direct UV and tide exposure conditions (Ferra, 2008; Lescroart, 2017). In Polynesian pearl farming lagoon, this life span is likely to be extended as collectors are currently immersed at 5–6 m depth during the whole collection period (Crusot et al., 2021). Finally, these collectors can currently be found in French Polynesia at a price of 18.96 € (tax incl.) per collector of 50 plates. *In situ* experiments were designed to compare plates spat collection efficiency with that of shade-mesh in Takapoto lagoon. Our results showed that plates could collect around twelve times more *P. margaritifera* spat.cm^{-2} than shade-mesh. However, the duration of this experiment (4.5 months) was short as the collection stage in French Polynesia usually lasts between 12 and 24 months. To confirm this result, the present study was performed with a comparable experimental design but over a longer period (16 months).

2. Material and methods

The experiment took place in Takapoto lagoon (145″20′W, 14′70′S) between May 2019 and September 2020. The collectors used were the same as described in our previous study (Crusot et al., 2021). Because of the variability of shade-mesh characteristics, the collecting surface was estimated through direct measurements of the total length of unfolded shade-mesh strip (10 m long x 8 cm width for 1-m collector). Then, we measured the effective collecting weaving surface on a piece of 10 cm as reported on Fig. S1, considering that settlement could occur on both sides. Collection surface of plates collector was also determined through measurements of the area of one plate including the exposed part of the spacer as spat can be collected on it as well and then multiplied by the plate number. Thus, collection surface of 1-m shade-mesh collector was of 1.5 m^2 and the one of plates collector was of 1.25 m^2. In total, 80 collectors of each type (*e.g.* shade-mesh and black horizontal 50-plates collectors) were alternately arranged every 40 cm on a main rope immersed at 6 m depth during the whole experiment. After 6 months, half of the collectors were retrieved and the rest were retrieved after 16 months. For each collector, *Pinctada margaritifera* and *Pinctada maculata* spat were removed, counted and weighed. Size of *P. margaritifera* spat was also measured individually. Spat density, mean size and mean weight per collector were calculated (Crusot et al., 2021).

The influence of the collector type and collection duration on mean spat density (for both species) and weight and individual size of *P. margaritifera* was analyzed. All data were first tested for their variances homoscedasticity (Levene's test) and normality (Shapiro's test). As interaction was found between the two factors ($P < 0.05$), either Student t-test or Kruskal Wallis test were performed independently at a confidence level of 0.05. Moreover, a Pearson correlation test was conducted between weight and size of *P. margaritifera* and showed a significantly high correlation of 0.9345 ($P < 0.0001$). Accordingly, only individual size data will be presented here.

3. Results

Regardless the duration of the experiment, plates collected significantly more spat than shade-mesh with respectively $9.19 \pm 2.75\times10^{-4}$ spat.cm^{-2} and $4.90 \pm 2.86\times10^{-4}$ spat.cm^{-2} ($P < 0.0001$) after 6 months and $6.75 \pm 2.13\times10^{-4}$ spat.cm^{-2} and $4.55 \pm 2.64\times10^{-4}$ spat.cm^{-2} ($P = 0.0208$) after 16 months (Fig. 1 and Fig. 2A). However, plates results also showed a significant decrease of spat density when the collection period was 16 months compared to 6 months ($P = 0.0002$).

Furthermore, mean size of *P. margaritifera* spat was significantly different between the two devices at 6 months with plates collecting the biggest spat with 2.790 ± 0.979 cm against 1.749 ± 0.806 cm for shade-mesh ($P = 0002$). However, after 16 months shade-mesh presented spat of 7.692 ± 1.098 cm on average compared to 7.022 ± 1.433 cm for Plates ($P < 0.0001$; Fig. 2B).

Results for *Pinctada maculata* spat density showed a higher recruitment on plates than on shade-mesh without influence of collection duration with $3.75 \pm 0.83\times10^{-2}$ spat.cm^{-2} and $5.36 \pm 7.84\times10^{-4}$ spat.cm^{-2} respectively ($P < 0.0001$).

Fig. 1. Shade-mesh (left) and Plates (right) collectors after 16 months of immersion.

4. Discussion

Our results showed that plates can collect from 1.9 (16 months) to 1.5 (6 months) times more *P. margaritifera* spat than shade-mesh, highlighting a better collection efficiency regardless of the duration of the experiment. This efficiency is also confirmed for *P. maculata* spat collection. These results (*i.e.* better efficiency of plates) are in accordance with our previous findings. However, the magnitude is lower as we found previously 11 times more *P. margaritifera* spat on plates than on shade-mesh (Crusot et al., 2021). *Pinctada margaritifera* has been described as a species capable of spawning throughout the year but with varying intensity, this intensity being greater during the off-season periods (Pouvreau et al., 2000; Southgate and Lucas, 2008). Moreover, collectors are known to be most effective shortly after their immersion (Crossland, 1956; Yigitkurt et al., 2020). As a result, they must be deployed at the right time to optimize spat recruitment. In our previous study, the experiment was launched during an important reproduction period (November) whereas, in this study, it was the reverse (Crusot et al., 2021). Thus, seasonal spawning variability could explain the observed difference. Nevertheless, plates still showed greater collection efficiency in both periods.

Our results also revealed a significant drop in *P. margaritifera* spat density on plates between the 6th and 16th month of collection, implying that the spat died or fell during this period, whereas no difference were found on shade-mesh. Mortalities could be due to predation or parasites during the additional time spent by the spat in the water as described by others authors (Coeroli et al., 1984; Papa et al., 2021). However, the decrease observed on plates could also be due to their

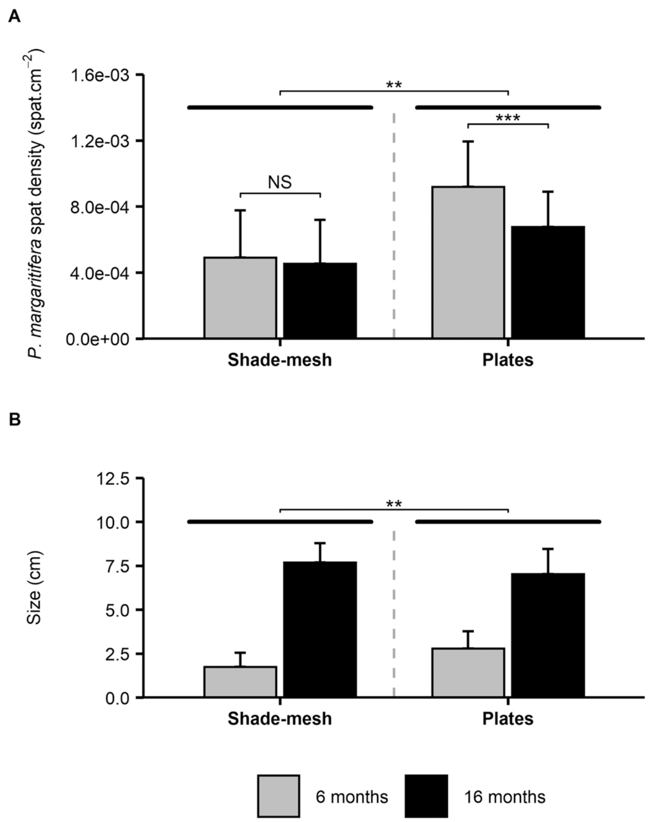

Fig. 2. Mean Pinctada margaritifera spat density (number of spat per cm^2) (A) and size (B) in function of the type of collector after 6 and 16 months of collection. Error bars denote standard deviations. Significant differences are represented as follows: *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$.

texture (*i.e.* rough *vs* filamentous). The byssal attachment may be weaker than on shade-mesh as byssus are only hung on the plate surface whereas they are entangled with the meshes of the shade-mesh collector. Thus, when *P. margaritifera* are getting heavier, they could break the byssal thread and unhook the spat, while this would not happen with *P. maculata* spat as they have a limited growth and weight over time. Therefore, spat removal from plates must take place as soon as possible in order to enhance *P. margaritifera* spat recruitment.

Furthermore, we found that body size of spat on plates was bigger at 6 months than on shade-mesh, whereas it was the contrary at 16 months of collection. In our previous study, *P. margaritifera* spat were smaller on plates than on shade-mesh after 4 months of collection but the density of spat was much higher (Crusot et al., 2021). Thus, this outcome tends to show that plates can be a favorable substrate for growth until a certain load of spat of *P. margaritifera* and *P. maculata* is reached. Growth would then decrease because of space and food limitation due to competition (Addessi, 1999; De La Roche et al., 2005; Filgueira et al., 2007; Guiñez, 2005).

In conclusion, this work confirmed that plates could be a more efficient collector for *Pinctada margaritifera* spat recruitment than shade-mesh for the studied period. Thus, on the basis of their recruitment efficiency, plates can be considered as a real alternative. Moreover, our results suggest that plate collector efficiency could be optimal if immersed in November (*e.g.* during the peak of the spawning season) and for only 6 months. However, broader cost-benefit analysis to include equipment and inputs costs, as well as spat yield, is needed to definitively validate the proposed alternative (Crusot et al., 2021). Uptake of plate-based spat collection by pearl farmers will require not only a change of equipment but also of culture practices.

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CRediT authorship contribution statement

M. Crusot: Conceptualization, Methodology, Validation, Investigation, Resources, Writing – original draft, Writing – review & editing, Visualization, Project management. **C. Lo**: Conceptualization, Methodology, Writing – review & editing, Visualization, Funding acquisition. **N. Gaertner-Mazouni**: Conceptualization, Methodology, Validation, Investigation, Resources, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.aqrep.2022.101305.

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