Restoration of nursery functions under floating solar plant

Intermediary ecological report – 2020 **–** 2021 **–** 2022 - **2023**

BOMHOFSPLAS

Restauration écologique - Elevage raisonné - Engins de pêche et d'élevage - Diagnostic
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Key figures

- **20 Biohut nurseries installed May 2020**
- **3 monitoring campaigns**
- **3 fish species**
- **2 species of mobile invertebrates**
- **1951 mobile invertebrates observed**
- **431 fish observed**

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1. INTRODUCTION

1.1. STAKES

The implementation of Biohut artificial habitats is a possible solution to recreate a habitat with some of the ecological functions provided by natural river or lake banks.

Ecocean, a leader in marine ecological engineering, has demonstrated that the use of artificial substrates adapted in shape and material can significantly improve nursery functions for coastal fish in highly anthropized environments (*Bouchoucha et al., 2016; Mercader et al., 2017a; Mercader et al., 2017b*) and can also be beneficial for many invertebrates (*Richardson et al, in prep*).

Ecocean has also initiated various tests of its solutions in continental freshwater that have notably provided very encouraging initial information on how Biohut works in terms of spawning and nursery areas restoration. This year, the first publication on the topic has been published by Ecocean on the role of floating ecosystems to compensate habitat loss for benthic invertebrates (Salmon et al. 2022).

Indeed since 2018, the UROS research project conducted with the French Office of Biodiversity and INRAE aims to assess the ability of floating vegetated structures, composed of Biohut, to restore shoreline functionalities on Alpine lakes subject to high tidal range (study site: Lake Serre-Ponçon). Through this study, different components are studied between the raft and control areas: macroinvertebrate communities are compared as well as their dynamics, spawning and nursery functionalities are also monitored for phytophilic or lithophilic species.

In terms of preliminary results (pending publications), the UROS rafts were used 4 years in a row by pike (*Esox lucius*) as a spawning area, and pike juveniles were able to develop on the rafts.

Regarding macroinvertebrate communities, studies have shown that the rafts compensate for the loss of diversity and abundance of macroinvertebrates during water level variations. In fact, with the sudden variations of water level, the populations of banks are strongly impacted by the lack of habitat. On the other hand, the communities living on the raft are not subject to this treatment, they are abundant at all times and therefore allow fish to have an available food resource regardless of level variations.

In 2016, 4 Biohut were installed under a floating raft within the city of Rotterdam (The Netherlands), monitoring was performed by independent experts (Bureau Waardenburg). The monitoring report of the whole structure showed that the Biohut add complexity and habitat to the root system of the raft plants. It is also within the framework of this project that common perch spawns have been identified on the Biohut mesh.

In addition to research projects, the Biohut installed in freshwater are systematically checked during ecological monitoring, in order to acquire data on the species present in the habitats. This monitoring has allowed the observation of common perch spawning on the Biohut grids, the presence of juveniles of different freshwater fish species (eel, pike, common perch, stickleback, tench, roach, bleak, sculpin, gobies, etc.).

Within a reservoir in France equipped with photovoltaic platforms and Biohut, we have been able to identify significant abundances of juvenile fish (up to 16 / unit) and very high abundances and diversity of macroinvertebrates (up to 1000 individuals per Biohut).

1.2. THE BIOHUT PROCESS

Biohut is a patented artificial habitat (European Patent Number 3003019; expiration date 06/06/2034) that allows to rehabilitate essential ecological functions of aquatic ecosystems impacted by the construction of facilities (harbors, outfalls, canals, etc.) and to provide these same functions to new infrastructures (pontoons, canals, photovoltaic platforms...).

The process thus aims to restore ecosystem services:

- **Nursery** by protecting young individuals from predation, thus allowing them to reach the "refuge size" and effectively contribute to the growth of adult fish populations.

- **Spawning ground** by providing substrates that mimic the spawning habitats of certain fish. Newly hatched juvenile fish quickly find protective areas within the nearby Biohut.

This artificial habitat is composed of a central steel cage filled with natural habitat substrate (oyster shells, driftwood, etc.) and one or two empty steel cages to provide a refuge area for young fish stages from larger predators. The substrates can be adapted to locally available materials.
Thanks to the different types of Biohut offered by Ecocean, lakes, canals, pontoons, docks or any other facilities (e.g., photovoltaic platform), become once again refuges of biodiversity for many aquatic species.
The Biohut Pontoon, which can be installed under photovoltaic parks, weighs approximately 20 kg and is made up of 3 CRAPAL steel compartments that can be easily disassembled (patent):

- The part called "substrate" is usually made of oyster shells, it corresponds to a "pantry" for the juvenile fish and young stages. It is in this "cage" that the micro-organisms (algae, small crustaceans...) that make up the beginning of the food chain are growing. This compartment is never taken out of the water; it is fixed to the lines.

- The two empty cages that surround the substrate cage. These are the two parts that must be cleaned to maintain the nursery function.

In other words, Biohut, regardless of the model, are biodiversity huts offering shelter to very young fish and crustaceans in search of a nursery or for fertile adults in search of a spawning ground. On these modules, an abundant fixed fauna and flora as well as a vagile fauna develops.

Biohut are installed closest to the surface, where young fish stages are concentrated. In freshwater, Biohut can be installed horizontally or vertically.

We have also developed different solutions of fixation depending on the hydrological conditions of the location and the constraints of the client (concrete, sheet piles, pontoon).

2. THE PROJECT IN BOMHOFSPLAS

2.1. DESCRIPTION OF THE PROJECT

In May 2020, 20 Biohut have been installed on the edges of the floating photovoltaic platform of energy company GroenLeven, in Bomhofsplas, close to Zwolle in the Netherlands.
This project, developed for 4 years, aims to enhance habitat functions under the floating photovoltaic platform installed in a sandpit, and to assess the ecological gain of the Biohut for the parc in this environment. The Biohut have been installed in 3 groups (8, 6 and 6 units) in 3 different parts of the parc (Fig. 1). They will be monitored and checked 3 times by Ecocean, in order to document the species taking benefit from the functions provided by the Biohut. The monitoring is done yearly, in end of spring/ beginning of summer, in order to maximize the chances of observation of early juvenile fish.
In addition to the monitoring performed by Ecocean, the Bureau Bakker is leading ecological surveys of the whole project.

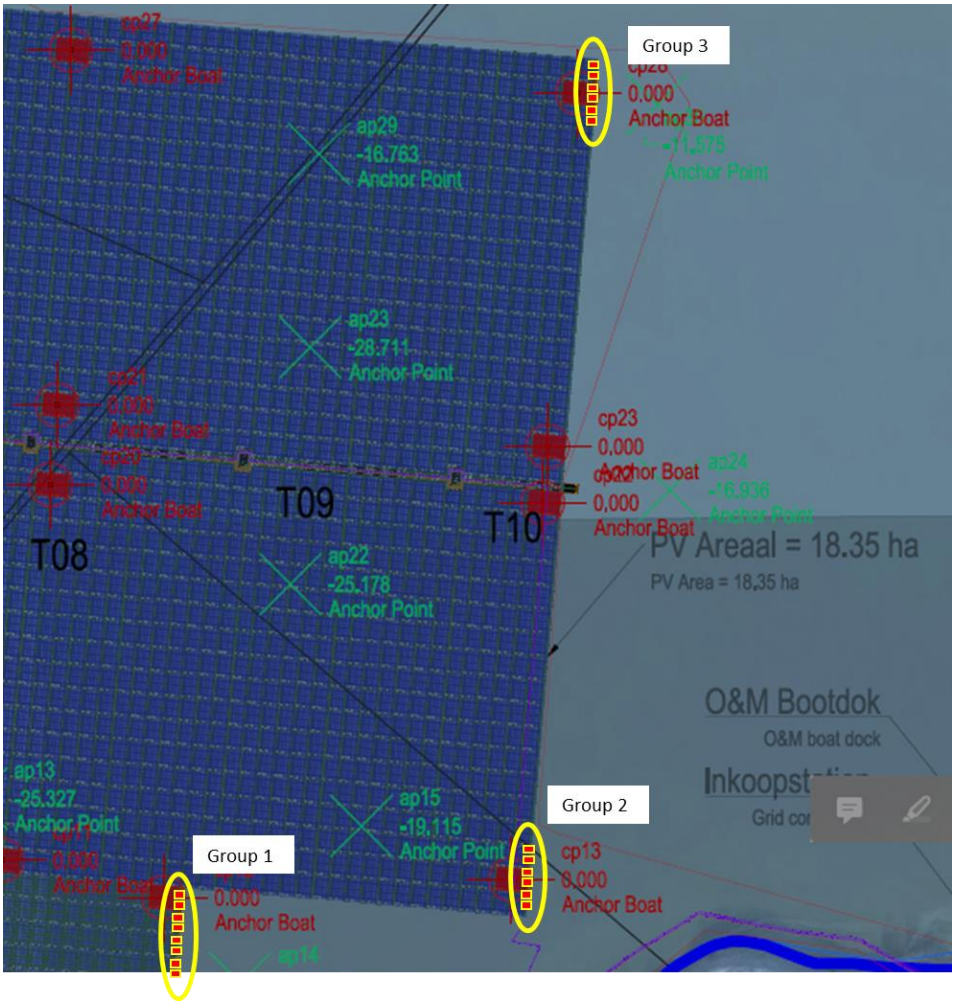

Figure 1: Map of the Biohut installation on the floating photovoltaic farm of Bomhofsplas.

2.2. ECOLOGICAL MONITORING

PROTOCOLS AND GROUP OF SPECIES MONITORED

In order to improve the knowledge of biodiversity and in particular the settlement and development of juvenile fish, an ecological monitoring expertise has been proposed after years of data acquisition. It allows to assess different groups of species:

- Fish, and mainly post-larvae and juveniles,
- The vagile fauna (cryptic fish, invertebrates) present inside the Biohut substrate

The fishes are surveyed in snorkeling and the monitoring can easily be done by a trained naturalist diver. This monitoring process is quite dependent on the weather conditions and visibility underwater. All fish present in a radius of 1m around the Biohut are counted, during 3 minutes by the naturalist, their specie and size are recorded and inserted into a database.

The monitoring of the vagile fauna requires to take the Biohut out of the water, in order to inventory the fauna hidden inside. Before that, in order not to lose any organisms, the Biohut is wrapped into a PVC net. The whole substrate is then sorted, and all the organisms are counted, measured and recorded. This monitoring being more complex, and intrusive for the Biohut, it is done only once a year, during the most favorable period.

Monitoring of juvenile fish

Monitoring of mobile fauna

AGENDA OF MONITORING AND AREAS MONITORED

Between 2020 and 2023, three ecological monitoring will be done on the Biohut of Bomhofsplas. The different monitoring will allow to have a good understanding of the role of the Biohut, their colonization by invertebrates and juvenile fish in the environment of this sandpit. The compilation of the monitoring will help to reduce the influence of abiotic conditions the day of monitoring (weather, water temperature, turbidity).

Table 1 shows the dates of these campaigns. The first monitoring was performed in May, and in order to spot different species at juvenile stage, the second monitoring was done in June 2022, to have a bit warmer water, and the third was done in June 2023.

Table 1: Agenda of ecological monitoring in Bomhofsplas

	2021	2022	2023
Fish monitoring	16/05	22/06	09/06
Vagile monitoring	16/05	22/06	09/06

MONITORING OF JUVENILE FISH

In May 2021, the team of Ecocean performed juvenile fish monitoring. Due to the degraded weather conditions (heavy rain, hail), the temperature of the water dropped in surface and the visibility was critical around the Biohut (about 30-50 cm). Because of such difficult conditions, the juvenile fish monitoring did not allow to properly observe juvenile fish inside and around the Biohut.

The diver had to approach too much to the structures in order to distinguish the animal, and they were then likely to leave the structures. In freshwater, this monitoring is used to bring additional information, but the assessment of the Biohut relies mainly on the monitoring of mobile fauna.

In June 2022 weather conditions were harsh as well on the day of the underwater visual census (UVC) monitoring, however the underwater visibility was better than the previous year. In total, two species of fish have been recorded during the underwater visual census monitoring, and the still poor visibility may have led to miss observation of individuals.

On the first group of Biohut, we have been able to observe 18 juveniles of *Cyprinidae* (probably *Rutilus rutilus* or *Scardinius erythrophtalmus*) of around 30 mm long, feeding and hiding on the modules.

In June 2023, the weather conditions were ideal for good visibility during visual monitoring. In total, we observed three species of fish, including a high abundance of cyprinid larvae.

In the third Biohut group, we observed 300 of around 10 mm long larvae of *Cyprinidae* (figure 2), as well as an individual identified as the *Protherorhinus semilunaris* species (figure 3). During the observations, the individuals used the modules as a nursery, seeking refuge inside them to protect themselves from predators and to find a source of food.

Figure 2: Juveniles of cyprinids feeding on a Biohut in Bomhofsplas

On the two other groups of Biohut (group 1 and 2), we had no opportunity to observe juvenile Cyprinids fish there, but we observed one individual of the species *Perca fluviatilis* per group. Each individual measured around 100 mm.

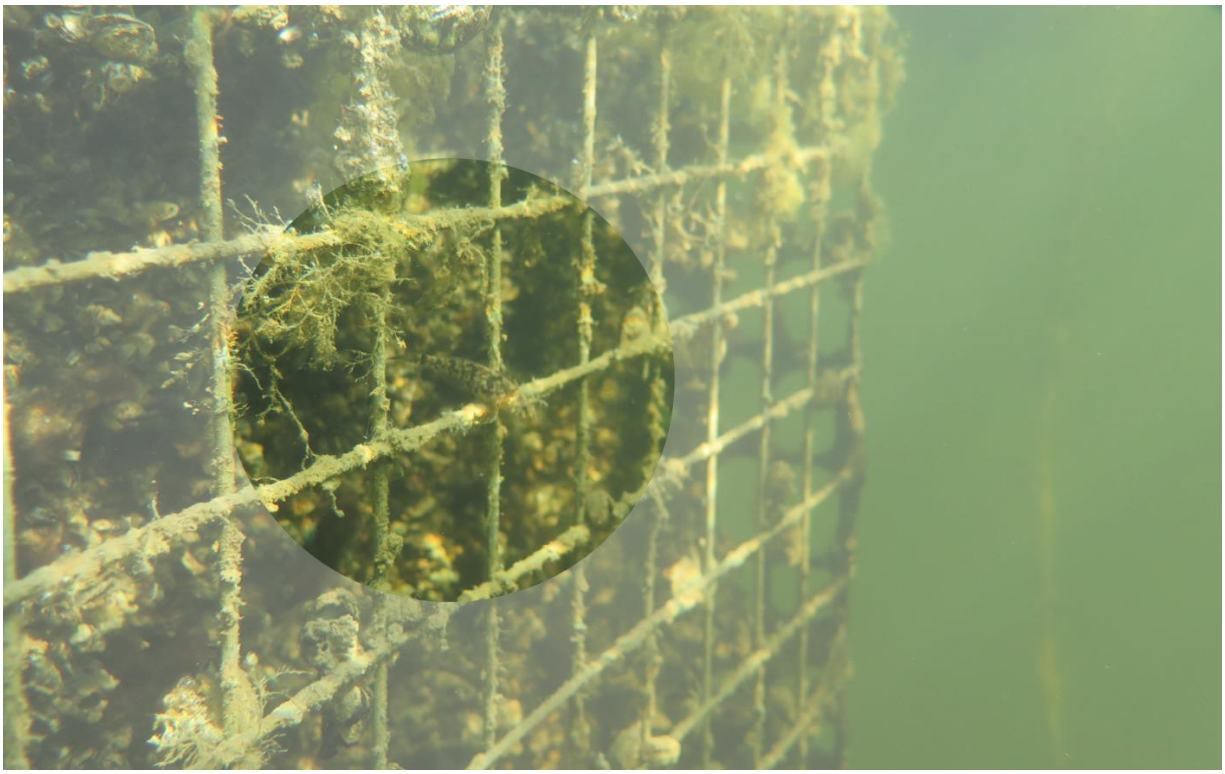

Figure 3: Juvenile of Proterorhinus semilunaris *(40mm) resting on a sponge fixed on a Biohut in Bomhosfplas*

It is important to note that in all the Biohut groups that we observed, we observed the presence of many *Daphnia* sp. (planktonic arthropods). This finding is of significant interest, as *Daphnia* sp. are at the base of the trophic chain as a food base. They are an essential food source for many species of fish (figure 4).

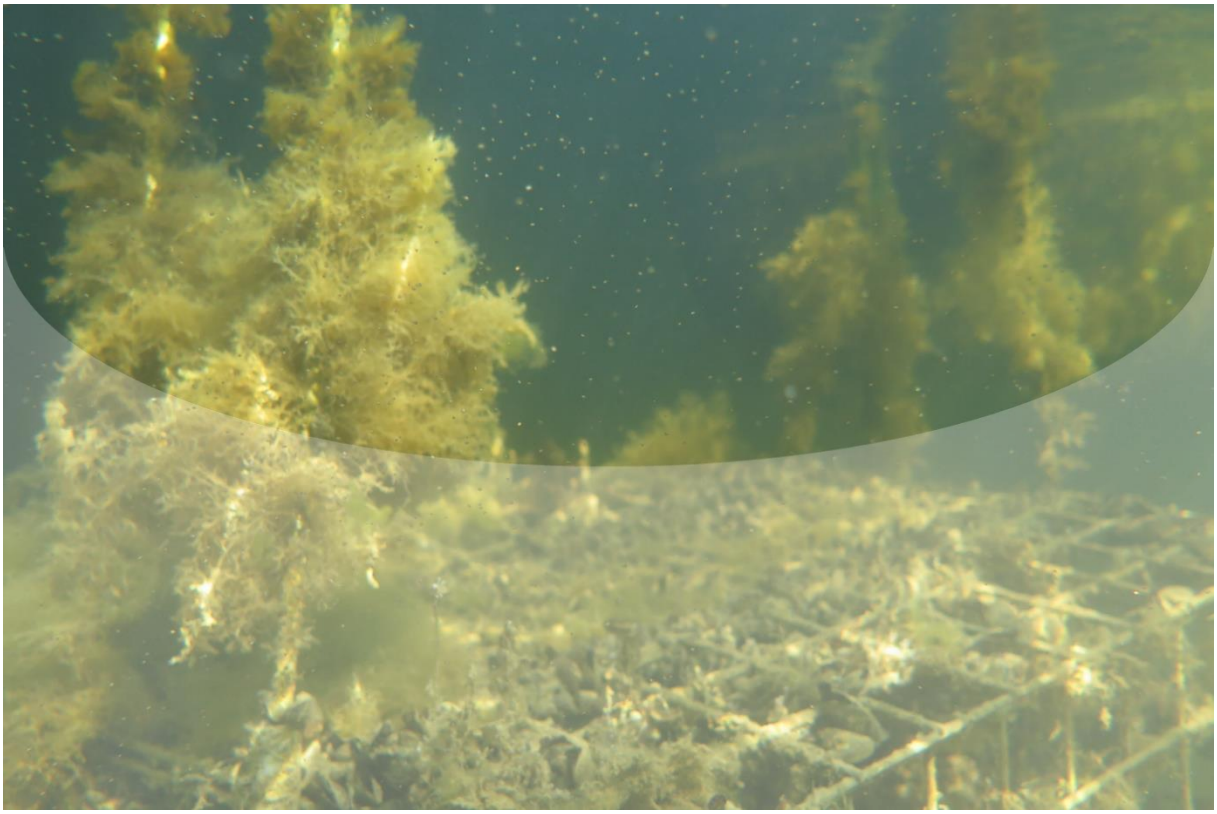

Figure 4: High density of Daphnia sp. (zooplankton) on a Biohut in Bomhofsplas

The first Biohut group seems to be the most functional in terms of habitat for fish larvae. This can be explained by its proximity to the shoreline, as well as its position further away from the dredging zone compared to the other groups.

MONITORING OF MOBILE FAUNA

This monitoring process is complementary to the UVC fish protocol. In 2021, no fish were observed during the visual census monitoring, and this protocol allowed to sample several individuals of fish and invertebrates inside the Biohut. The year after, for species like *Proterorhinus semilunaris*, this protocol allowed to sample about 10 times more individuals than with the UVC monitoring. However, it was not possible to observe cyprinids fish, it's thus very important to combine the two technics when possible.

In 2021, one Biohut was sampled in each of the 3 Biohut groups, it was brough up to the surface inside a net, and emptied, all the macro-organisms present inside the substrate were collected, results are presented in the figure 5.

During the first year, the abundance of fish observed per Biohut is not very high (1.3/Biohut on average, which is correct for freshwater), but juveniles of common perch (*Perca fluviatilis, Fig. 10*) and tubenose goby (*Proterorhinus semilunaris*) were present inside 2 of 3 of the Biohut investigated, despite the weather conditions. Some invertebrates, like gammarids shrimps, have been observed and they are known to be kick starters of trophic network by degrading organic matter and serving as prey for bigger organisms.

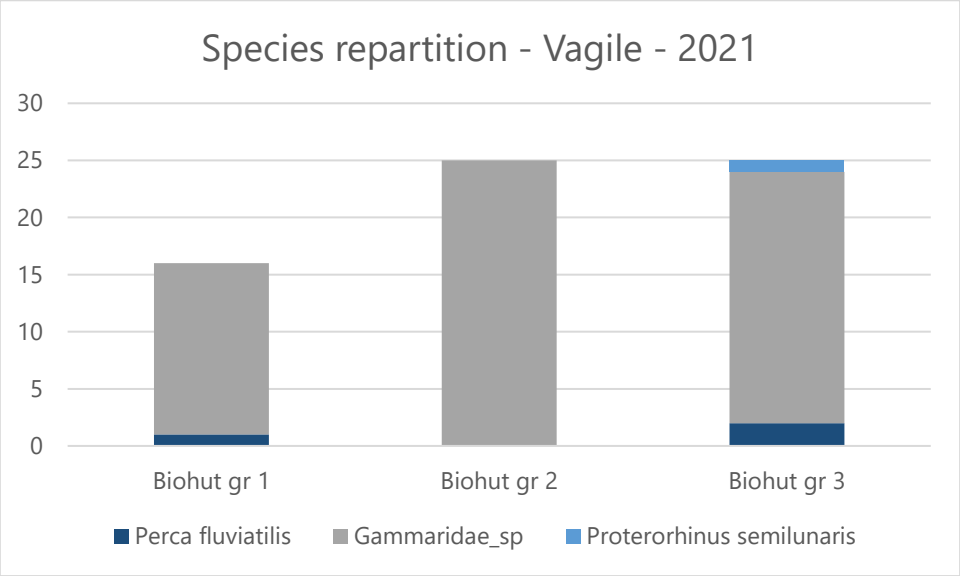

Figure 5: Abundance of fish and invertebrates observed during the vagile fauna monitoring in 2021

In 2022, weather conditions and time only allowed to pull out Biohut in the groups 3 and 2 with the same protocol, and the results are presented in the figure 6.

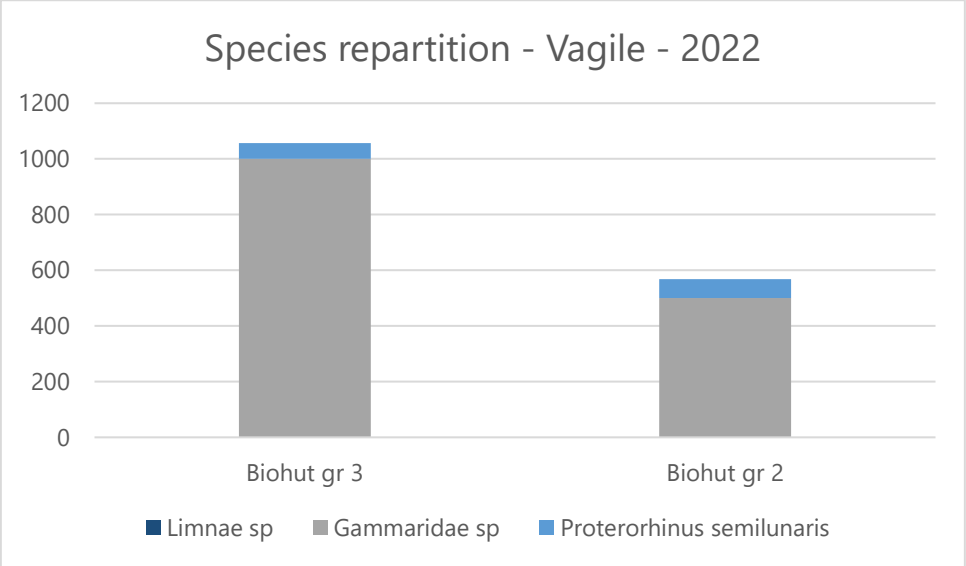

Figure 6: Abundance of fish and invertebrates observed during the vagile fauna monitoring in 2022

Only two Biohut were sampled, but the recorded abundancies were much higher than the first year. In the Biohut of the group 3, about 1000 gammarids shrimps were observed with 56 tube nose gobies (figure 6). In the Biohut of the group 2, we observed 500 gammarids shrimps with 68 tube nose gobies. On average, we observed 62 individuals of fish per Biohut, which is more than 45 times more than in 2021. In the two sampled Biohut, we observed nests with spawn and fry of tube nose gobies inside the shell substrate. This behavior is regularly observed as well in marine environment for the peacock blenny (*Salaria pavo*).

In terms of richness, 3 species have been observed, a freshwater snail (*Limnae sp*), gammarids shrimps and tube nose gobies (*Proterorhinus semilunaris*). This time, we did not observe juveniles

of common perch (*Perca fluviatilis*), possibly because it was a bit late in the year. The purpose of having the two monitoring at two slightly different periods (May and July) was to be able to spot species that need nursery areas at different moments in the spring.

In 2023, to obtain reliable comparisons, we sampled Biohut in the same areas as the previous year, specifically Biohut from groups 3 and 2, and the species observed are presented in the figure 7.

2021	2022	2023	Latin names	Common names
	X	X	*Cyprinidae sp*	Unspecified cyprinids
X	X	X	*Proterorhinus semilunaris*	Tube nose gobies
X		X	*Perca fluviatilis*	Common perch

Figure 7: Species of fish recorded during the three years of fish monitoring

As observed in previous years, the sampling results show a marked difference between Group 3 and Group 2. Group 3 stands out with a higher abundance compared to Group 2.

In the Biohut of Group 3, we witnessed a significant presence of species. Approximately 200 gammarids shrimps were observed, which form the basis of the food chain for many fish. Additionally, we recorded 12 tube nose gobies in the same habitat, indicating that these fish also find favorable conditions there. We observed a common perch, which, although in limited numbers, is an interesting addition to the diversity of this Biohut (Figure 9).

On the other hand, the Biohut of Group 2 shows a slightly lower but still significant abundance. Approximately 170 gammarids shrimps were counted, and we also observed 4 tube nose gobies in this Biohut, suggesting that although fewer than in Group 3, they are still attracted to this habitat. A common perch was spotted in the Biohut of Group 2, indicating some attractiveness of the habitat for this species as well. An interesting and consistent fact with previous years is the observation of nests containing eggs and fry of tube nose gobies within the shell substrate in both sampled Biohut (Figure 10). These observations are crucial for our understanding of the local ecosystem and the evolution of biodiversity in the region. Comparing with previous years allows us to track trends and variations in the populations of key species in these artificial habitats.

By comparing the data from the three successive years for mobile organisms monitoring (Figure 8), we notice a significant increase in overall abundances in 2022, approximately 20 times higher than in 2021, mainly due to the strong presence of gammarid shrimp. In 2023, we observe a slight decrease in the number of individuals compared to 2022, but we still see a continuous presence of species of interest, such as the common perch. After three years, it appears that the modules are colonized, and a stable diversity is developing. This observation suggests that artificial modules provide a suitable habitat for colonization and proliferation of certain species that seem to thrive in this environment. These findings are crucial for our understanding of the impact of artificial structures on biodiversity and the ecology of aquatic ecosystems.

Our several years of experience in monitoring freshwater environment globally showed that the colonization dynamic of the Biohut is slower here than in marine environment in terms of diversity and abundance.

After three years of careful monitoring, we have begun to observe a growing interest from the aquatic biodiversity of Bomhofsplas sand pit in settling within the Biohut. The initial colonization of this infrastructure by pioneer species, notably the gammarid shrimps, played a crucial role in initiating the food supply function of the Biohut. From 2021 to 2022, we witnessed a remarkable increase in the population of these shrimps, multiplying their numbers by approximately 30.

However, what is equally interesting and encouraging is that this rapid growth stabilized during the last year of monitoring. This stability demonstrates the ecosystem's ability to adapt to the arrival of new species and the establishment of their populations. For an artificial ecosystem like the Biohut, achieving a dynamic balance where different species interact harmoniously is essential, thus promoting sustainable biodiversity.

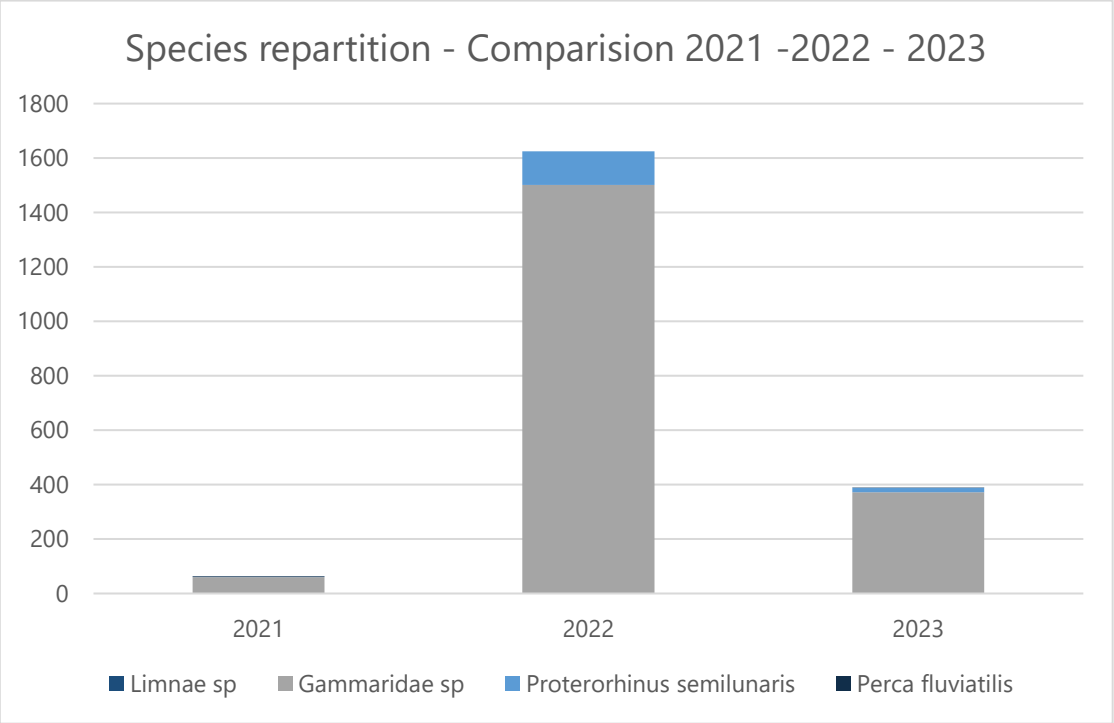

Figure 8: Comparison of the abundance of mobile fauna in the Biohut between 2021 - 2022 - 2023.

*Figure 9: Juvenile of common perch (*Perca fluviatilis*) sampled in one of the Biohut of Bomhofsplas in 2023.*

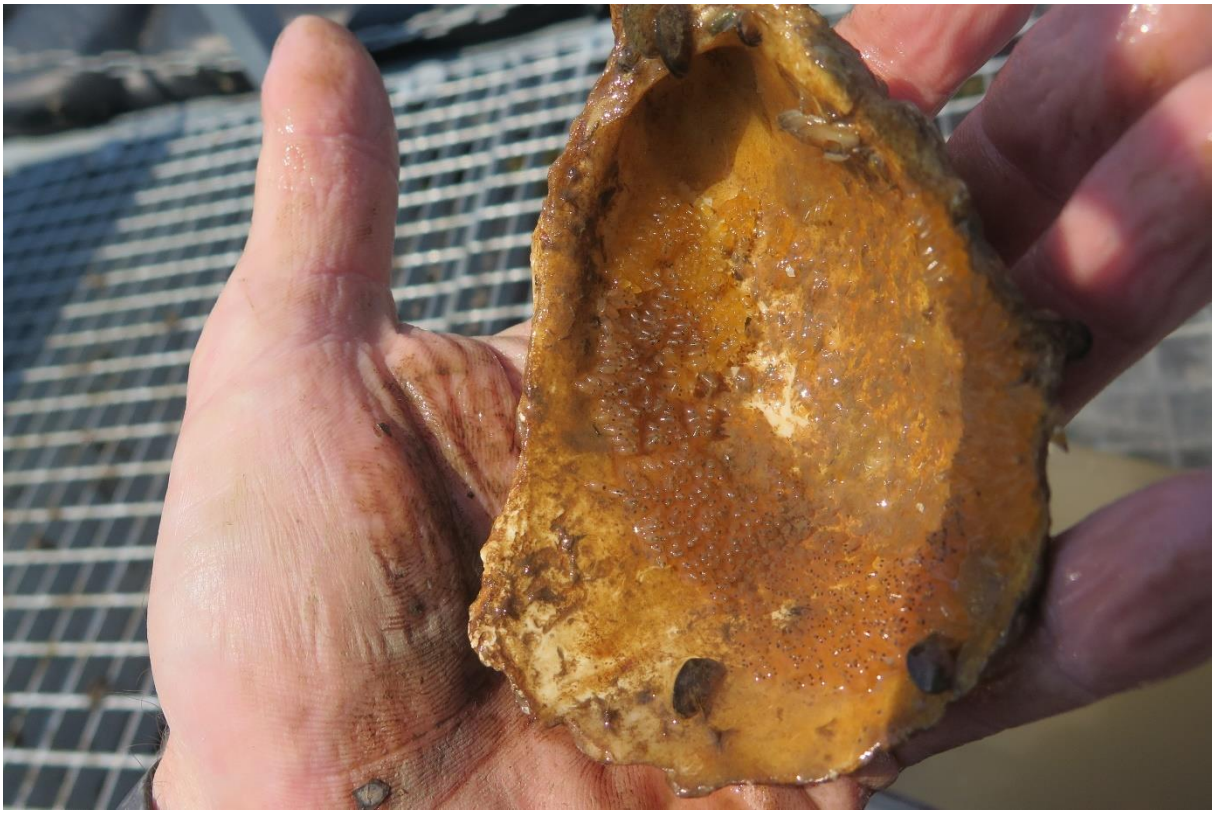

*Figure 10: Eggs of tubenose gobies (*Proterorhinus semilunaris*) inside of a shell of a Biohut in 2023*

3. TECHNICAL ASPECTS

The installation of the 20 Biohut of Bomhofsplas has been done on June 2nd of 2020. The Biohut are fixed under the platform, on the edges, thanks to stainless-steel cable and stainless-steel cable clamps.

Biohut ready to be installed

Biohut installed under the platform

Since their installation, all modules remain well in place, without any visible impact on the floating structure or on its buoyancy. The Biohut do not show any sign of corrosion, and the substrate is well in place, with the presence of sediment inside the shell. The fouling of the mesh is low, so the modules did not need to be cleaned to keep the targeted ecological functions.

During the third year of monitoring, in July 2023, the modules are still in perfect condition, while the fixation systems continue to adapt well to the ZIM Float system. The colonization of the Biohut by fixed fauna, algae, and freshwater sponges (*Spongilla lacustris*) is maintaining and further developing on the mesh of the Biohut, as observed in previous years (figure 11). This growth adds increasing complexity to the ecosystem, contributing to the formation of a rich and diversified habitat.

We also note the persistent notable development of the quagga mussel on the Biohut's mesh. Despite this growth, the individuals remain small enough not to obstruct the mesh of the modules, thus avoiding the need for maintenance operations. The introduction of fixed fauna and filter-feeding organisms such as sponges has strengthened the balance of the ecosystem while preserving the proper functioning of the Biohut.

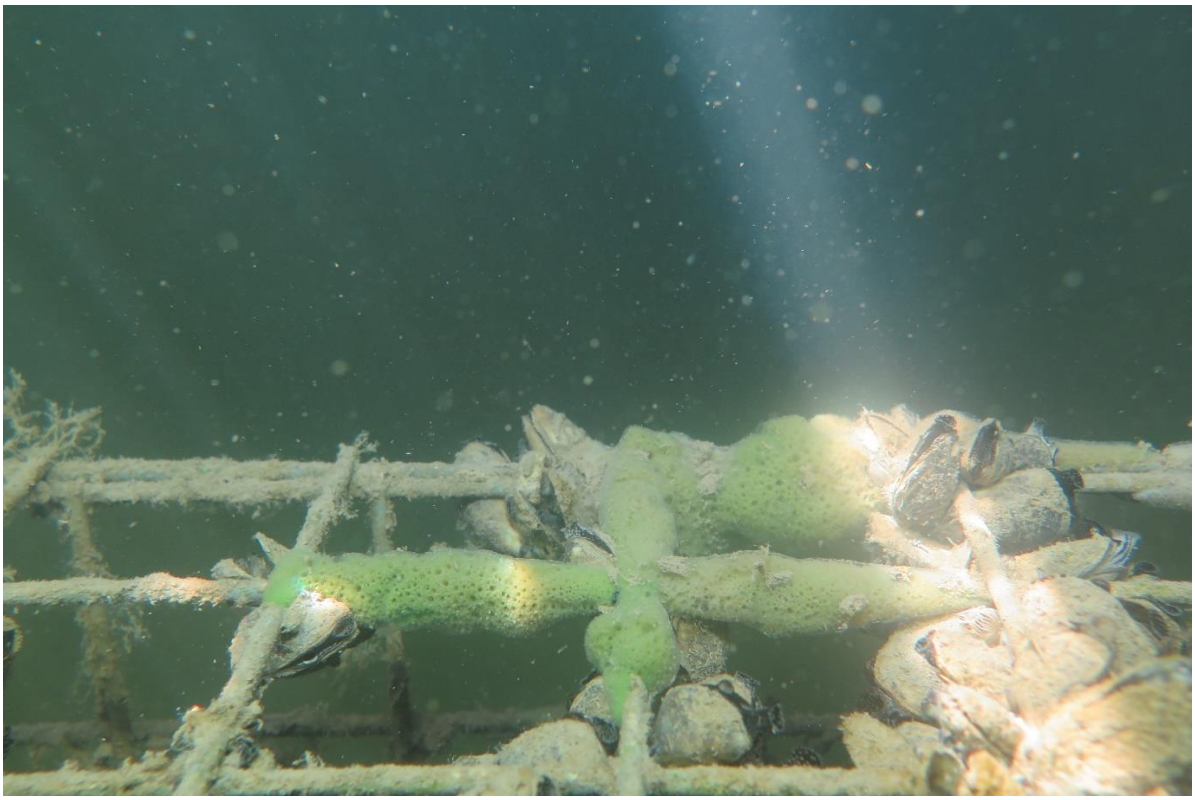

*Figure 11: Freshwater sponge (*Spongilla lacustris*) developped on the Biohut in Bomhofsplas 2023*

4. CONCLUSIONS

We are now four years after the installation of the 20 Biohut under the floating solar platform of Bomhofsplas, Zwolle, and we have been able to document the colonization of the modules by the species present in the waterbody.

The three monitoring campaigns led to the observation of 3 fish species (common perch, cyprinids and tube nose goby), and 2 species of invertebrates (*Limnae* sp and gammarids shrimps). In total we observed 2382 individuals during the three monitoring, 1951 invertebrates and 431 fish. We can also note the presence of zebra mussel and freshwater sponges (*Spongilla lacustris*) on the mesh of the Biohut, and the fact that their growth has no impact on the functions of the Biohut so far. The range of species is not as big as in other locations, but the Biohut do adapt to the species present and breeding in the waterbody.

As expected, during the last year of monitoring, we observed that the rapid growth witnessed previously has stabilized. This observation indicates that the Biohut ecosystem has successfully adapted and found a balance with the new species that have colonized the habitat. During this last year of monitoring, we particularly noted a large abundance of cyprinids, with 300 individuals observed. This abundance provides tangible evidence that the species have indeed invested in the Biohut as a preferred habitat, reinforcing the idea that the Biohut effectively fulfills its role as a nursery, providing an environment conducive to the growth and survival of juvenile fish.

The monitoring conducted in 2023 also revealed that we have potentially achieved a comprehensiveness of the species present in the Bomhofsplas photovoltaic park. The significant abundance of species at the base of the food chain, such as daphnia and gammarids, indicates the proper balance and functioning of the Biohut ecosystem to support aquatic life. The abundant presence of small arthropods is of vital importance, as these organisms play a crucial role in the food chain, serving as prey for other fish species and larger animals. Their abundance indicates a favorable environment for the proliferation of diverse fauna, which is essential for the health and stability of the overall ecosystem.

These findings are very encouraging and highlight the importance of the Biohut as a beneficial artificial structure for aquatic biodiversity. The Biohut plays a role in preserving and supporting key ecological functions of the Bomhofsplas sandpit ecosystem, contributing to the conservation of aquatic life and environmental sustainability.

Additional monitoring operations would help to assess the stability of the presence of the species observed and would give the occasion to observe other species that are present in the sand extraction pit, and that we did not have the occasion to see during the 3 monitoring campaigns.