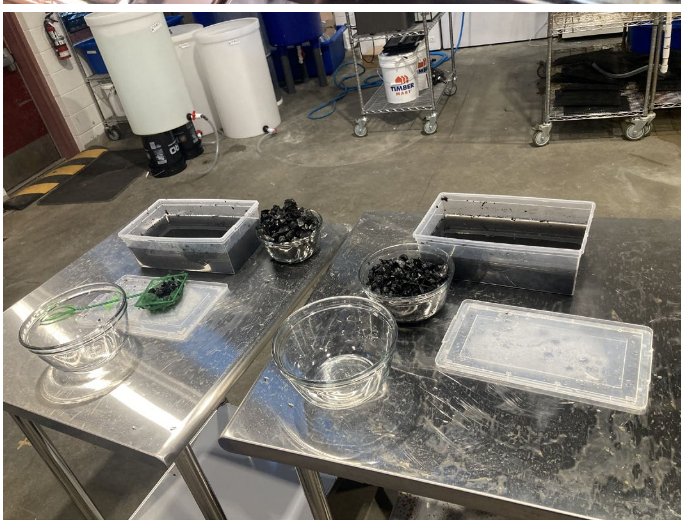
Final Draft – April 2025

Biochar Kelp Growth Report 2025

Report Prepared by North Island College for Vancouver Island Salt Co (VISC); Pacific Urchin Harvesters Association (PUHA); and Bee Sea Kelp and Seaweed (BSKS).
March 2025






Funded by an NSERC Applied Research and Technology Partnership grant with substantial contributions from all collaborators.

NORTH ISLAND COLLEGE

Natural Sciences and Engineering Research Council of Canada

Conseil de recherches en sciences naturelles et en génie du Canada

1. Executive Summary

This project - a collaboration between North Island College (NIC), Vancouver Island Salt Co (VISC), Pacific Urchin Harvesters Association (PUHA), and Bee Sea Kelp and Seaweed (BSKS) - determined that Bull Kelp (*Nereocystis luetkeana*) can be seeded on Biochar, and compared Bull Kelp growth on Biochar to the current rock "Green Gravel" seeding method. In February, 2025, four aquaria were set up in NIC's Seaweed Innovation Lab, in a paired arrangement with a chiller and pump. Each contained either Rock, Biochar, or Biochar soaked in a nutrient solution. Bull kelp gametophytes were applied to the substrate, and over the course of five weeks, growth was noted and then measured in week five.

Between all treatments, little difference was seen overall in the coverage of kelp. When comparing the non-nutrient soaked biochar and rock setup and the nutrient soaked biochar and rock pairing, the nutrient tanks had slightly higher initial growth rates; the sporophytes established quicker, and gametophytes grew to larger sizes faster. However, measurement was difficult due to the small size and there was little observable difference between the sizes in the tanks at the 5 week mark. Coverage of gametophytes and sporophytes was relatively similar, with the nutrient tanks being slightly higher in coverage (2.8 ± 0.6 per cm^2 (Gravel) and 2.5 ± 0.8 per cm^2 (Biochar) vs 2.4 ± 0.6 per cm^2 (Gravel) and 2.2 ± 0.9 per cm^2 (Biochar)), however this was not significant .Note that green algae (a hatchery contaminant) established much quicker in the nutrient tanks than in the non-nutrient tanks.

Based on these trials, biochar appears to be a suitable substrate for kelp growth. However, buoyancy is a concern with lightweight Biochar use as a green gravel; this concern is exacerbated when coupled with the positively buoyancy of Bull kelp. It would be useful to explore a more neutrally or negatively buoyant kelp or seaweed species where Biochar is the substrate.

The project was funded by a NSERC Mobilize Grant. This report summarizes work completed between January 2025 to March 2025.

2. Contents

3. Background

Kelp forests are typically found in rocky subtidal areas along semi-exposed shorelines up to 10 m deep. These habitats are often composed of multiple species that form a three-dimensional community structure, including benthic, understory, and canopy layers. Kelp provides numerous significant ecosystem benefits including refuge and nursery habitat for commercially and recreationally important species, coastline protection, and absorption of carbon dioxide and excess nutrients[1,2]. Kelp forests have declined globally, including in BC waters. This is of concern as this habitat is key to maintaining healthy coastal ecosystems. Responsible aquaculture and wild harvest of kelp may provide a way to maintain and later restore this habitat and maintain healthy coastal ecosystems.

British Columbia and the Pacific Northwest coast has more than 600 species of marine aquatic plants including the greatest diversity of kelps found anywhere in the world. Canopy kelps are large seaweeds that form the canopies of dense marine kelp forests along British Columbia's coastline. Canopy kelps are a great indicator species due to their ecological value and sensitivity to shifts in oceanographic conditions and human pressures. Bull kelp (Nereocystis luetkeana) is a seaweed that can reach over 20 m in length. Each plant is composed of a holdfast anchoring the plant to the seafloor, a long flexible stipe, a single gas-filled bulb, and long narrow blades that form the surface canopy. Reproduction in bull kelp occurs when patches of spores (sori) are released from reproductive blades, settling on nearby rocky substrate. Giant kelp (Macrocystis pyrifera) is a seaweed that can reach over 30 m in length. Each plant is comprised of a holdfast, multiple fronds reaching the surface, along which there are multiple gas filled pneumatocysts from which extend the blades of kelp.

A novel kelp outplanting method called 'green gravel' uses natural rock as the substrate, thus avoiding artificial/disposable cultivation materials[3]. Green gravel is placed on the ocean floor, and the neutrally or positively buoyant kelp grows upwards, creating a 3D habitat. There are many advantages to green gravel over standard (rope-based) kelp outplanting methods, including the absence of plastics and other infrastructure introduced into the environment. Green gravel is in the early field-testing stage in BC[4] and fundamental questions remain about

---

[1] Smale, D.A., Burrows, M.T., Moore, P., O'Connor, N. and Hawkins, S.J., 2013. Threats and knowledge gaps for ecosystem services provided by kelp forests: a northeast Atlantic perspective. *Ecology and Evolution*. 3(11), 4016-4038.

[2] Steneck, R.S., Graham, M.H., Bourque, B.J., Corbett, D., Erlandson, J.M., Estes, J.A. and Tegner, M.J., 2002. Kelp forest ecosystems: biodiversity, stability, resilience and future. *Environmental conservation*. 29(4), 436-459.

[3] S. Fredriksen et al., "Green gravel: a novel restoration tool to combat kelp forest decline," *Sci Rep*, vol. 10, no. 1, p. 3983, 2020.

[4] A. Lang-Wong, C. Robinson, A. Warner, R. Glover, and C. Drews, Monitoring biodiversity returns of kelp restoration using environmental DNA (e-DNA): Report of phase 1, 2023.

the optimal rock size, outplant timing, species and substrate selection to maximize the outplant success rate and long-term viability of these kelp habitats.

Biochar is a carbon-rich material produced through the pyrolysis of biomass in an oxygen-limited environment[5]. This process transforms organic matter, such as wood chips, plant residues, and manure, into a stable form of carbon that can be used for various applications. The primary use of biochar is as a soil amendment though further research is needed to confirm the benefits of its application[6]. Beyond agriculture, biochar can be used in water filtration, waste management, and even as an additive in construction materials. This project focuses on biochar as a green gravel substrate, due to the porous nature being able to hold a nutrient solution which may boost kelp growth in early stages, and the promise of using what otherwise may be waste material as a substrate in the restoration of kelp beds.

We designed an experiment to challenge three questions, determining in part the suitability of biochar as a substrate for kelp growth and use in restoration:

1. Does Bull Kelp successfully grow on biochar in a hatchery environment?
2. If successful, how does this compare to current "Green Gravel" results in a hatchery?
3. How does biochar soaked with a nutrient compare in growth to a non-nutrient soaked biochar?

---

[5] Wu, P., Fu, Y., Vancov, T. *et al.* Analyzing the trends and hotspots of biochar's applications in agriculture, environment, and energy: a bibliometrics study for 2022 and 2023. *Biochar* 6, 78 (2024). https://doi.org/10.1007/s42773-024-00370-x

[6] Spokas KA, Cantrell KB, Novak JM, Archer DW, Ippolito JA, Collins HP, Boateng AA, Lima IM, Lamb MC, McAloon AJ, Lentz RD, Nichols KA. Biochar: a synthesis of its agronomic impact beyond carbon sequestration. *J Environ Qual*. 2012 Jul-Aug;41(4):973-89. doi: 10.2134/jeq2011.0069. PMID: 22751040.

4. Methods

4.1. Biochar and Green Gravel Preparation

Biochar in two forms was delivered to the CARTI Seaweed Innovation Lab in January, 2025. One was a pure form of biochar, and the other was soaked in a kelp fertiliser/nutrient solution. These two forms were placed into two separate containers, each filled with cultivated seawater (Instant Ocean) to soak for a minimum of 3 days to absorb salt water and reduce buoyancy when added to the cultivation tanks. After the soaking time had elapsed, the remaining floating biochar pieces were removed from the container, and the sinking pieces were collected then rinsed under more cultivated seawater to remove any debris and smaller biochar pieces. Gravel was also rinsed under cultivated seawater to remove any debris and wet the rocks prior to Bull Kelp inoculation.

4.2. Aquaria Setup

Two 10 gallon aquaria were connected with basic plumbing supplies, then attached to a pump (Mag-Drive Supreme Classic 5) which supplied a chiller (Active Aqua 1/10 HP), which in turn fed a distribution block that allowed flow control into each aquaria. This was repeated for both the nutrient and non-nutrient biochar.

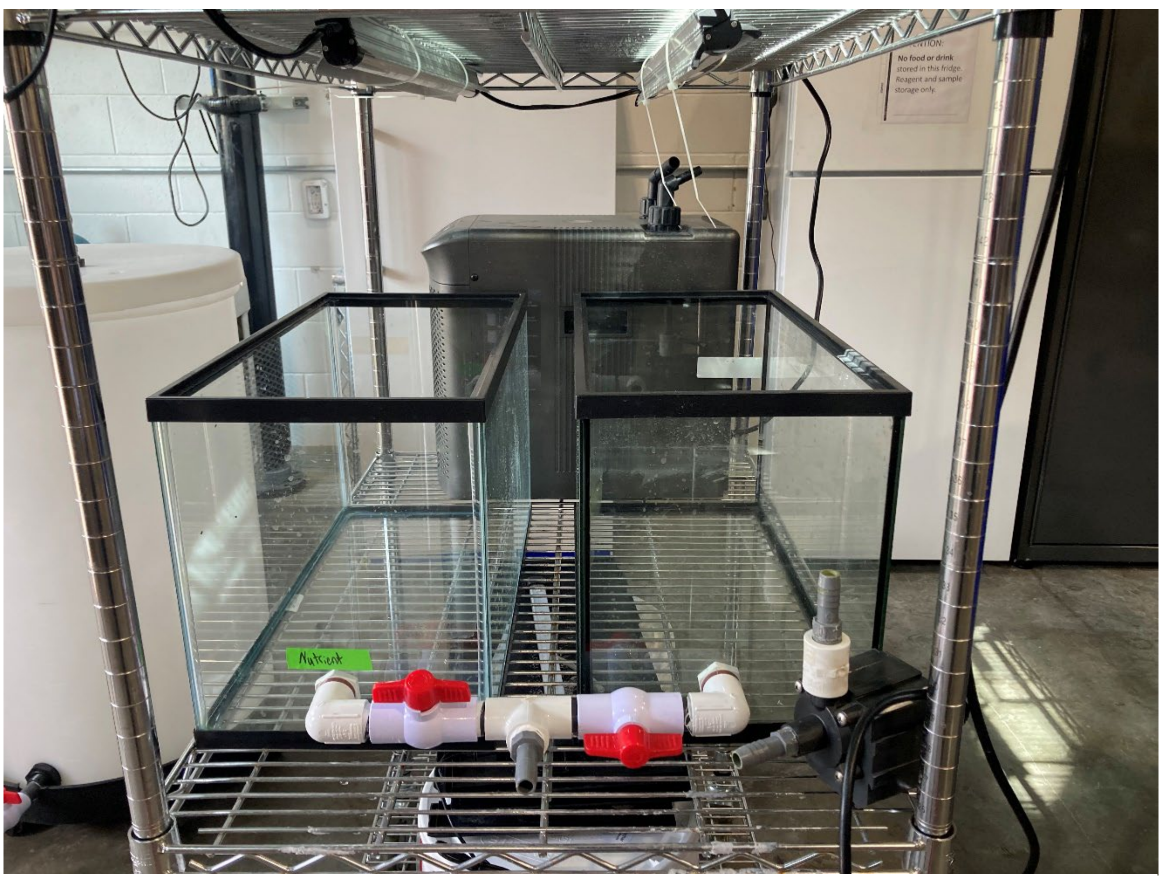


Figure 1. Setup of aquaria, pump and chiller for biochar kelp cultivation.

4.3. Inoculation

Bull Kelp (*Nereocystis leutkeana*) gametophytes were removed from the Industrial Plankton Seaweed Bioreactors and blended to reduce the size of the gametophytes. A subsample was then taken and placed onto a haemocytometer slide to determine the density of the blended gametophytes. This was then scaled to 200 gametophytes per ml, and added to a spray bottle. This was placed into the refrigerator to stay cool (12 °C) while any final checks were occurring.

Biochar was placed in a single layer into one of the two aquaria in the setup (in Figure 1, the side labelled nutrient), while gravel was placed into the adjacent aquaria in the setup, also in one layer. A glass slide was added to each aquaria to monitor growth. The gametophyte solution was then sprayed onto the biochar and gravel to evenly coat the surface of the substrate and left for 30 minutes to settle and ensure adherence. Cultivated seawater with 50% F/2 solution was then gently added to the tanks at a rate of around 1 L/min to prevent disturbance of the gametophytes from the substate, and when tanks were full the pumps were turned on and flow rates were adjusted. Chillers were set to 12 ± 1 °C. This was repeated for both the biochar containing the kelp nutrient, and the pure biochar.

4.4. Monitoring of Growth

Weekly, both the biochar and gravel were monitored for kelp growth. This included checking for contamination and observing growth and comparison between all cultures. Growth of gametophytes and sporophytes were observed under the microscope to ensure that expected trends were occurring. After gametophytes developed on the substrate lighting was increased from 60 µMol of light to 100 µMol of light.

5. Results, Discussions and Conclusions

5.1. Kelp Growth

In general, kelp followed expected growth patterns, emerging as gametophytes after 2 - 3 weeks, and then as sporophytes after 4 - 5 weeks when light was increased. Overall, there were insignificant differences between the biochar and the gravel in each trial. Between trials, it was noted that the biochar and rock in the system with nutrient grew had a slightly higher initial growth rate, however after week 5 the size of the sporophytes were the same size. Due to the fragility of the sporophytes at this stage these were visual observations and were not measured. Coverage between each of the 4 aquaria was relatively similar. They were compared using sporophytes per cm^2 due to the smaller size of the biochar substrate compared to the gravel (~2 cm^2 vs ~85 cm^2 horizontal surface area)

5.2. Other Notes

Biochar was significantly lighter than the gravel, appeared slightly more at risk of losing gametophytes than the gravel during initial inoculation and addition of water to the tanks. However, this did not appear to have any effect on growth. What was apparent, however, was the water flow directly under the distribution block. While this flow was not high (~1.5 L/Min), the turbulent water shifted all biochar away from this area to show the glass below. This also created some movement of the biochar throughout the tank and shifted all pieces from their initial positions. Further, even after being filtered for sinking pieces, some biochar was so close to neutral buoyancy that the turbulent flow brought it to the surface, whilst others were caught in the outflow and a small mesh had to be added to prevent blockages.

Green algae was observed as contamination and established much quicker in the nutrient tanks than in the non-nutrient tanks. Thus, although the nutrient levels in both the tanks and the inoculated biochar did not appear to have an effect of the rate of early kelp growth, there appeared to be some effect in the establishment of the green algae. However, establishment and growth of green algae was not measured in this trial.

Figure 2. Growth of the Bull Kelp gametophytes after 2 weeks: A, Non-Nutrient Biochar; B, Nutrient Biochar; C, Green Gravel in Non-Nutrient Biochar system; D, Green Gravel in Nutrient Biochar system.

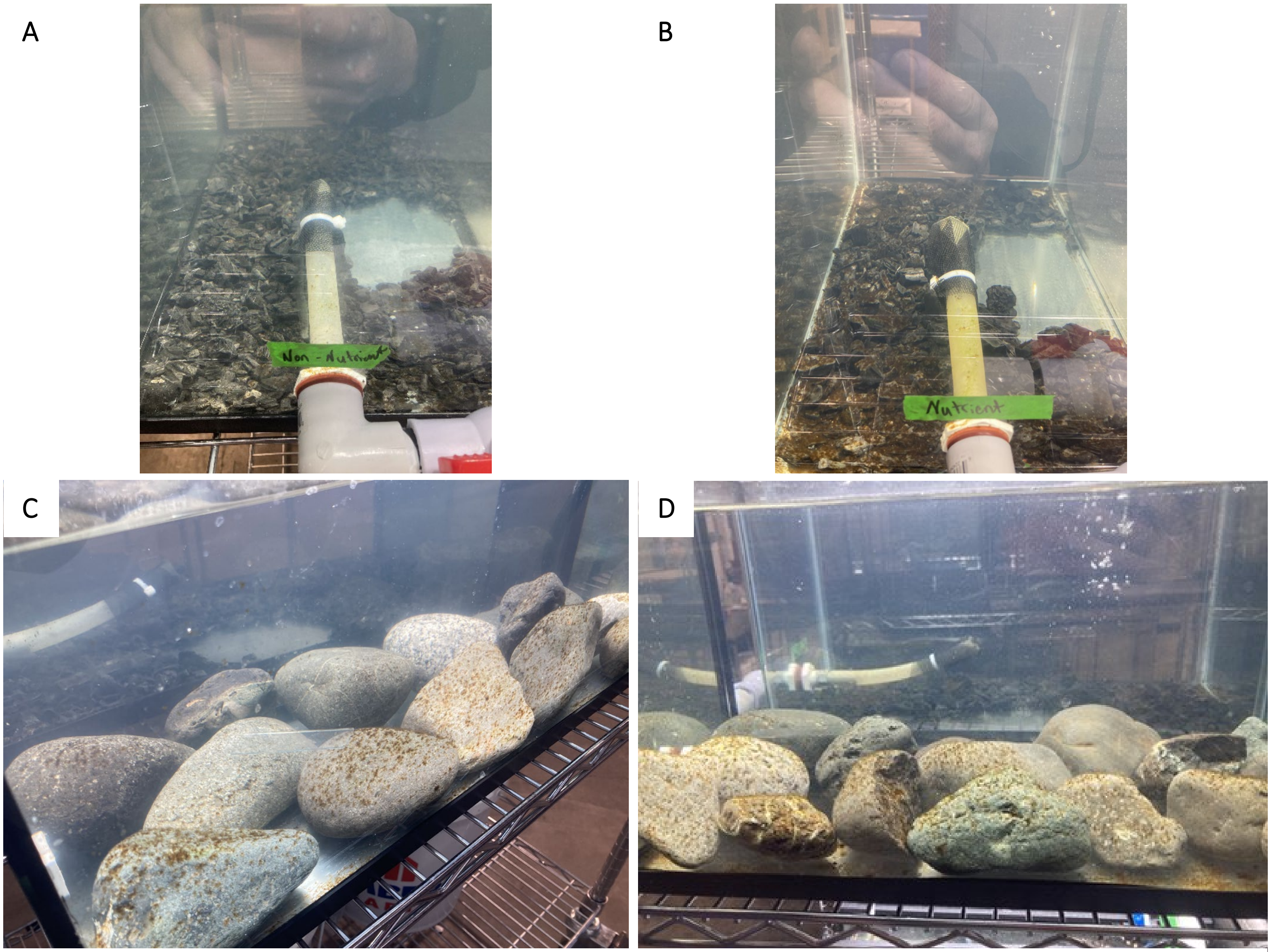


Figure 3. Growth of the Bull Kelp gametophytes and emergence of sporophytes after 3 weeks: A, Non-Nutrient Biochar; B, Nutrient Biochar; C, Green Gravel in Non-Nutrient Biochar system; D, Green Gravel in Nutrient Biochar system.

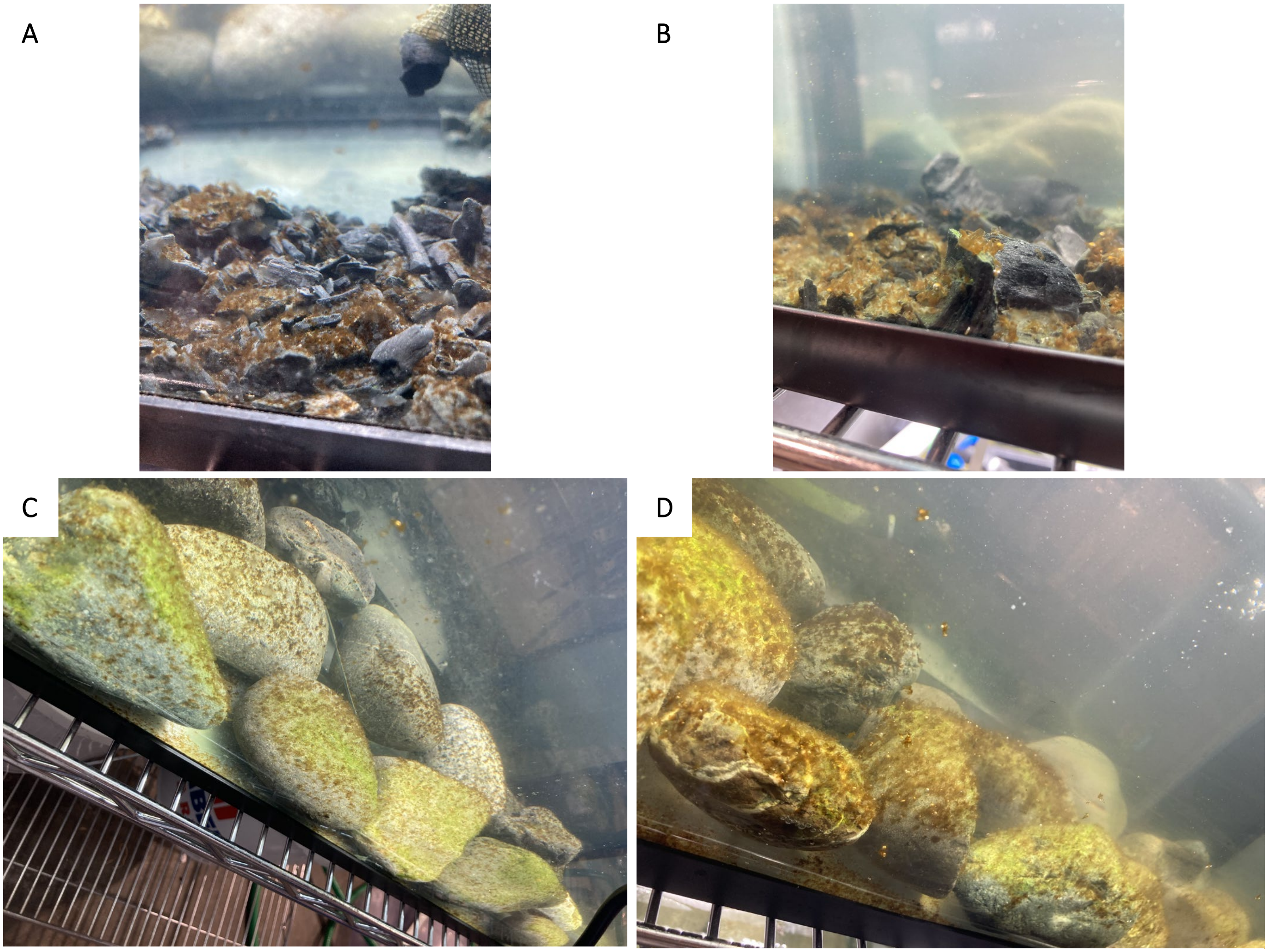


Figure 4. Growth of the Bull Kelp sporophytes after 5 weeks: A, Non-Nutrient Biochar; B, Nutrient Biochar; C, Green Gravel in Non-Nutrient Biochar system; D, Green Gravel in Nutrient Biochar system.

Table 1. Mean Number of sporophytes per centimeter^2 greater than 5 mm (± Standard Deviation) on each of the respective treatments in the aquaria after 5 weeks.

Treatment	Gravel	BioChar
Non-Nutrient	2.4 ± 0.6 per cm^2	2.2 ± 0.9 per cm^2
Nutrient	2.8 ± 0.6 per cm^2	2.5 ± 0.8 per cm^2

5.3. Conclusions

While biochar appears to be a suitable substrate for kelp growth, there are some concerns with the buoyancy of the biochar during this cultivation, and potentially during an outplanting (which did not occur in this trial). While we worked with smaller pieces of biochar, further work is needed to test the characteristics of the larger pieces. This brings into the conversation developments within the current landscape of kelp restoration, whereby practitioners in British Columbia have begun to move away from the smaller (~1 cm^3) pieces of gravel in favour of larger ones, such as those used in this experiment. This was largely due to the negative buoyancy of the rocks when growing canopy kelps, which are inherently buoyant to reach the surface. While it was theorised that the holdfasts would grow over the small pieces of gravel and attach to surrounding substate, this did not appear to occur prior to the kelp being swept away by the currents after being outplanted. However, for non canopy forming species these smaller gravel pieces, and perhaps biochar, may be more suitable. Future work may include trialling other kelp species on the biochar to test whether kelp buoyancy does indeed affect the efficacy of biochar as a green gravel alternative substrate and testing the size of individual biochar pieces and how these affect the outplanting and localized restoration success at a site.