

Forest Biochar as an innovative Cultch/Substrate for Shellfish Restoration

Functional Activation of Forestry Biochar as a Shellfish Cultch: A Pilot Field Study

Introduction

Ocean warming and acidification are placing increasing pressure on natural shellfish habitat. The loss and degradation of kelp forests may further compound these pressures because kelp ecosystems can influence water quality and provide habitat and food resources for co-occurring marine organisms.

Forestry biochar is a potentially useful resource for marine habitat applications. Its physical structure, derived in part from the high lignin content of woody feedstocks, produces an extensive network of pores and capillaries. Depending on production conditions and feedstock, biochar can have a very high internal surface area, providing habitat for microorganisms and surfaces capable of adsorbing and retaining dissolved compounds. The negative surface charge that develops as biochar ages can contribute to its capacity to interact with positively charged ions, including ammonium (NH_4^+), sodium (Na^+), potassium (K^+), magnesium (Mg^{2+}), and calcium (Ca^{2+}) (Do et al., 2023).

Research in other biological systems suggests that biochar can influence microbial activity, pH, nutrient availability, and electron-transfer processes. In dark fermentation, for example, biochar addition has been associated with increases in hydrogen production rate and yield, with reported increases of approximately 26% and 41%, respectively (Lou et al., 2024). Proposed mechanisms include pH moderation, stimulation of functional microorganisms, mitigation of biotic and abiotic limitations, and facilitation of electron transfer.

These mechanisms may have relevance to marine aquaculture and restoration. Biochar may provide not only a physical substrate but also a developing microbial habitat and a surface capable of concentrating nutrients and organic compounds.



Functional Activation

In this study, functional activation refers to the addition of specific materials to biochar before deployment in order to provide particular biological or chemical functions.

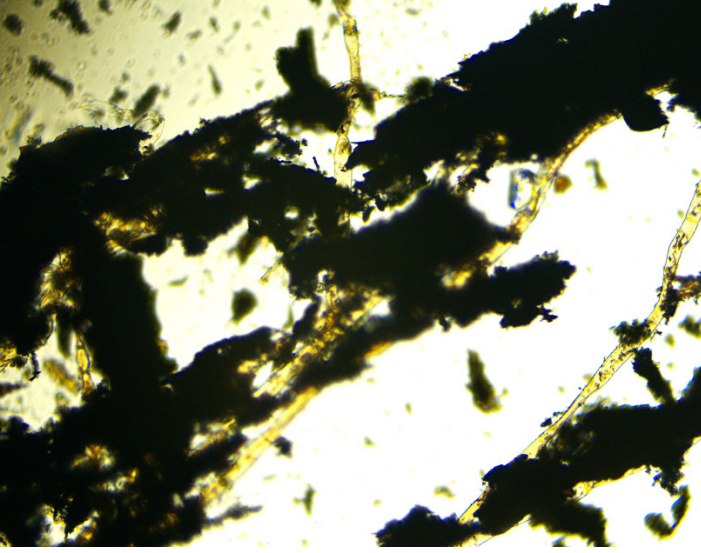
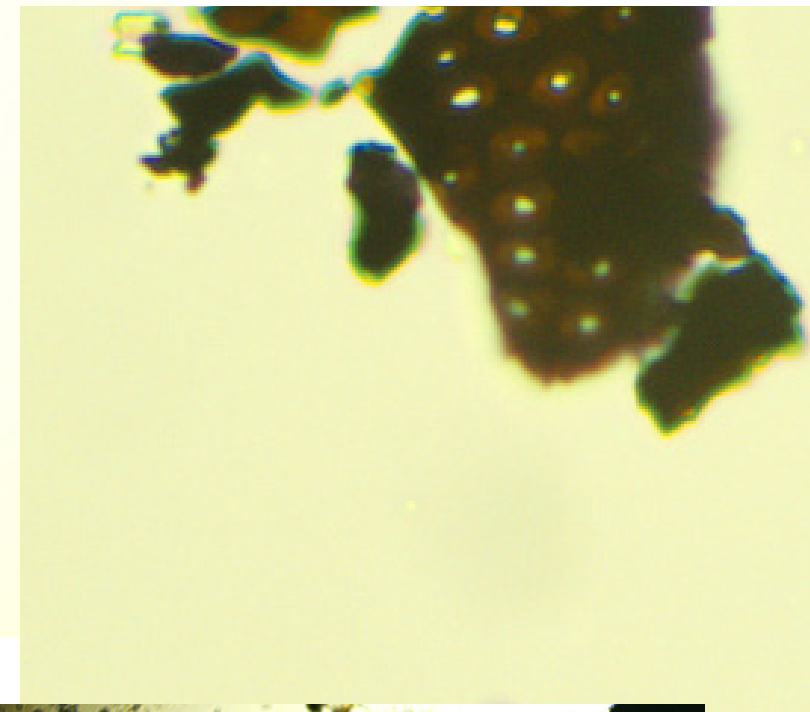
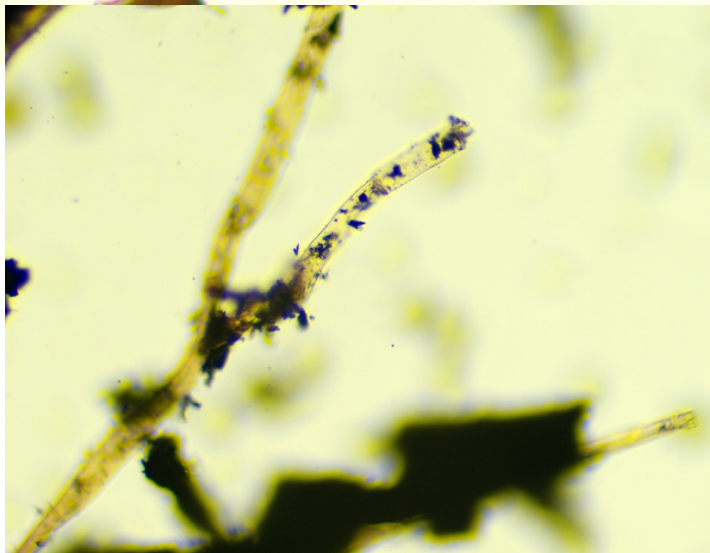
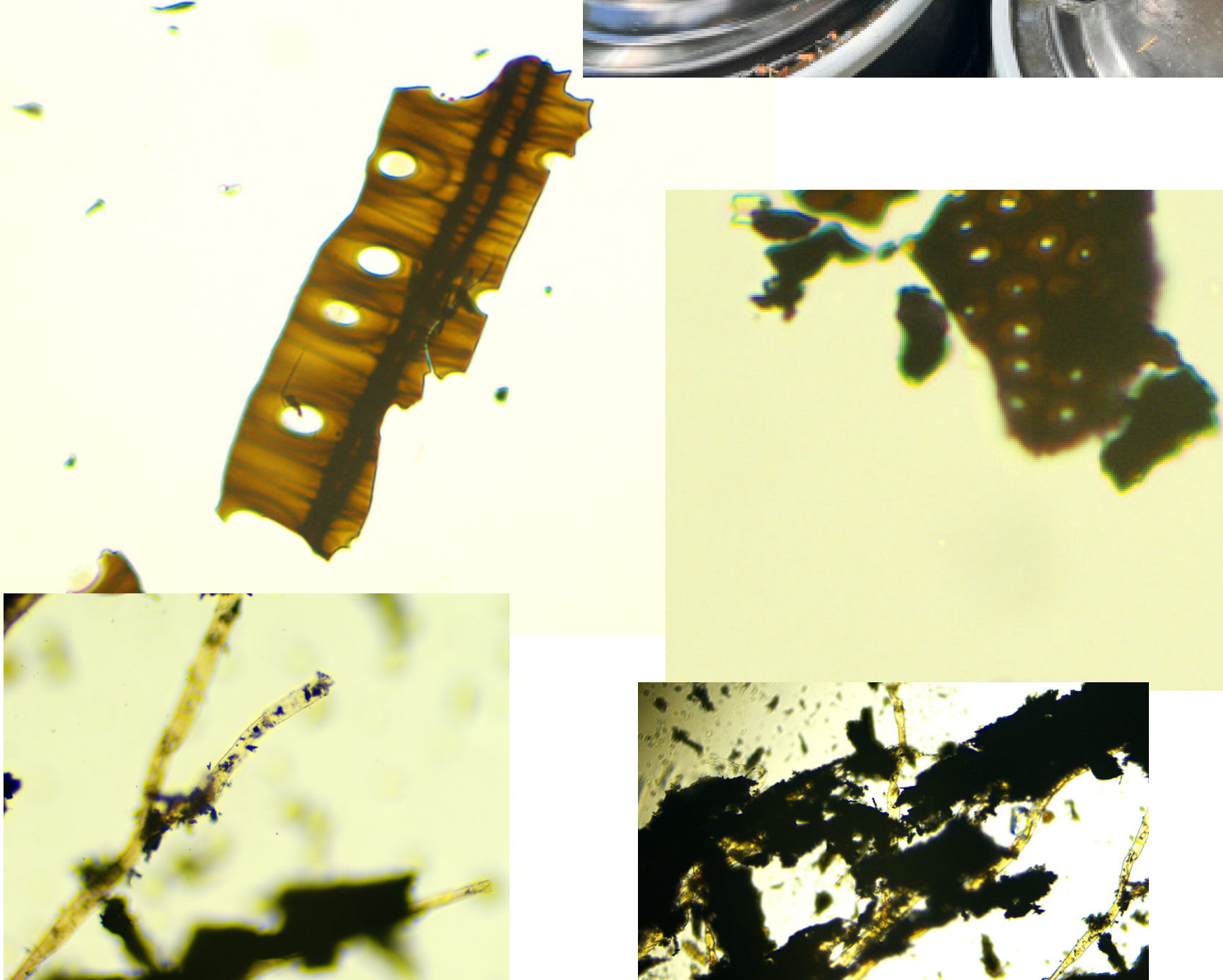
A study of *P. hecatensis* (Pacific red seaweed) found that treatment with *Sargassum horneri* extract enhanced thermal tolerance, growth, and biochemical resilience under elevated temperatures (Kim et al., 2024). Separately, a study of bull kelp grown on biochar functionally activated with seaweed extract reported rapid growth, earlier gametophyte establishment, and larger gametophytes compared with empty biochar and rock controls (Zienhart et al., 2025).

These observations raise a related question: if a kelp holobiont can access nutrients or other resources associated with activated biochar, might shellfish larvae and other marine organisms similarly respond to the substrate?

Shellfish larvae are known to respond to environmental cues associated with biofilms, calcium availability, and suitable settlement surfaces. This pilot experiment therefore examined whether forestry biochar functionally activated with seaweed extract, calcium derived from seawater, and magnesium-rich bitters could improve biochar as a shellfish cultch.

Empty forestry biochar may also become biologically activated after deployment in seawater. Its pores can provide microbial habitat, while aging can alter its surface chemistry. Over time, biofilms and sorbed organic compounds may develop on and within the material (Mukherjee et al., 2014; Joseph et al., 2021). Pre-activation is intended to reduce this initial lag by introducing biological and chemical cues before spawning occurs. This pilot study does not distinguish between these two pathways: pre-activation before deployment and natural activation after deployment.

Biofilm from Biochar soaked in diluted seaweed extract...



Methods

Seven scallop lanterns were used as field-deployment structures.

A Control lantern contained socks filled with:

- PVC pipe;
- drain rock; and
- aged oyster shells.

Two lanterns contained socks full of empty Biochar

Four additional lanterns contained socks filled with forestry biochar that had been functionally activated using:

- seaweed extract;
- calcium derived from seawater; and
- magnesium-rich bitters.

The lanterns were deployed during the spring 2026 swimming scallop spawning season. Approximately four socks from each lantern were examined and photographed in September 2026.

The examination was observational. The presence of biofouling organisms, barnacles, green biofilm, green sea urchins, and juvenile scallops was recorded. Juvenile scallop size was assessed qualitatively using the purple mesh of the socks as a relative reference.



By: Bruce Bradley
BC Timber Goats, Kelp and Biochar
info@bctimbergoat.ca
www.bctimbergoat.ca
www.bctimbergoat.ca
250-203-3534



Control Lantern



Empty Biochar Lantern



FA Biochar Lantern

The apparent size difference between juveniles on activated and empty biochar is similarly preliminary. Quantitative shell measurements and larger sample sizes would be required to determine whether activated biochar is associated with increased growth or simply earlier settlement.

An important observation requiring further investigation is the apparent difference in biofouling between biochar and the other substrates. If biochar consistently develops a biologically active surface that attracts or supports organisms associated with shellfish settlement, the material could potentially function as more than a passive physical cultch.

Conclusion

This limited field study provides preliminary observations supporting further investigation of forestry biochar as a potential shellfish cultch and marine restoration substrate.

The functionally activated biochar treatment had four observed juvenile scallops, compared with two on empty biochar and none on the examined rock, PVC, and oyster-shell control socks. Juveniles on the activated biochar also appeared somewhat larger relative to the mesh, although this observation was not quantitatively measured.

Both empty and functionally activated biochar developed visible biological films during marine deployment. This suggests that biochar may rapidly become biologically conditioned after placement in seawater and raises the possibility that its effects as a marine substrate may develop through both its initial physical and chemical properties and its subsequent colonization by microorganisms and other marine organisms.

The findings should be considered preliminary. They do not establish that functional activation caused increased scallop settlement or growth. However, they identify several testable hypotheses for future research.

Future Research

Further research should examine the benthic conditioning of biochar and its potential contribution to natural marine recovery and aquaculture systems.

Particular attention should be given to:

- comparing activated biochar, empty biochar, and conventional cultch under replicated conditions;
- measuring scallop settlement density and survival quantitatively;
- measuring juvenile growth through time;
- characterizing biofilm composition on the different substrates;
- analyzing nutrient and mineral concentrations in biochar before and after marine deployment;
- examining whether seawater conditioning changes biochar surface chemistry;
- using microscopy to determine whether biological films occur primarily on the exterior surface or extend into the pore structure; and
- testing different biochar inclusion rates in aquaculture and restoration environments.

A particularly useful experiment would compare fresh empty biochar, naturally conditioned biochar, and pre-activated biochar under the same field conditions. This would help determine whether functional activation provides a measurable advantage over the natural marine conditioning that occurs after deployment.

If subsequent replicated trials demonstrate increased settlement, survival, or growth, biochar inclusion could then be evaluated as a potential component of aquaculture and marine restoration systems.

Forestry biochar represents an abundant potential resource whose application in marine habitat restoration remains relatively unexplored. Its combination of physical structure, evolving surface chemistry, microbial habitat, and capacity for functional activation makes it a promising material for further investigation in climate-resilient aquaculture and marine restoration.

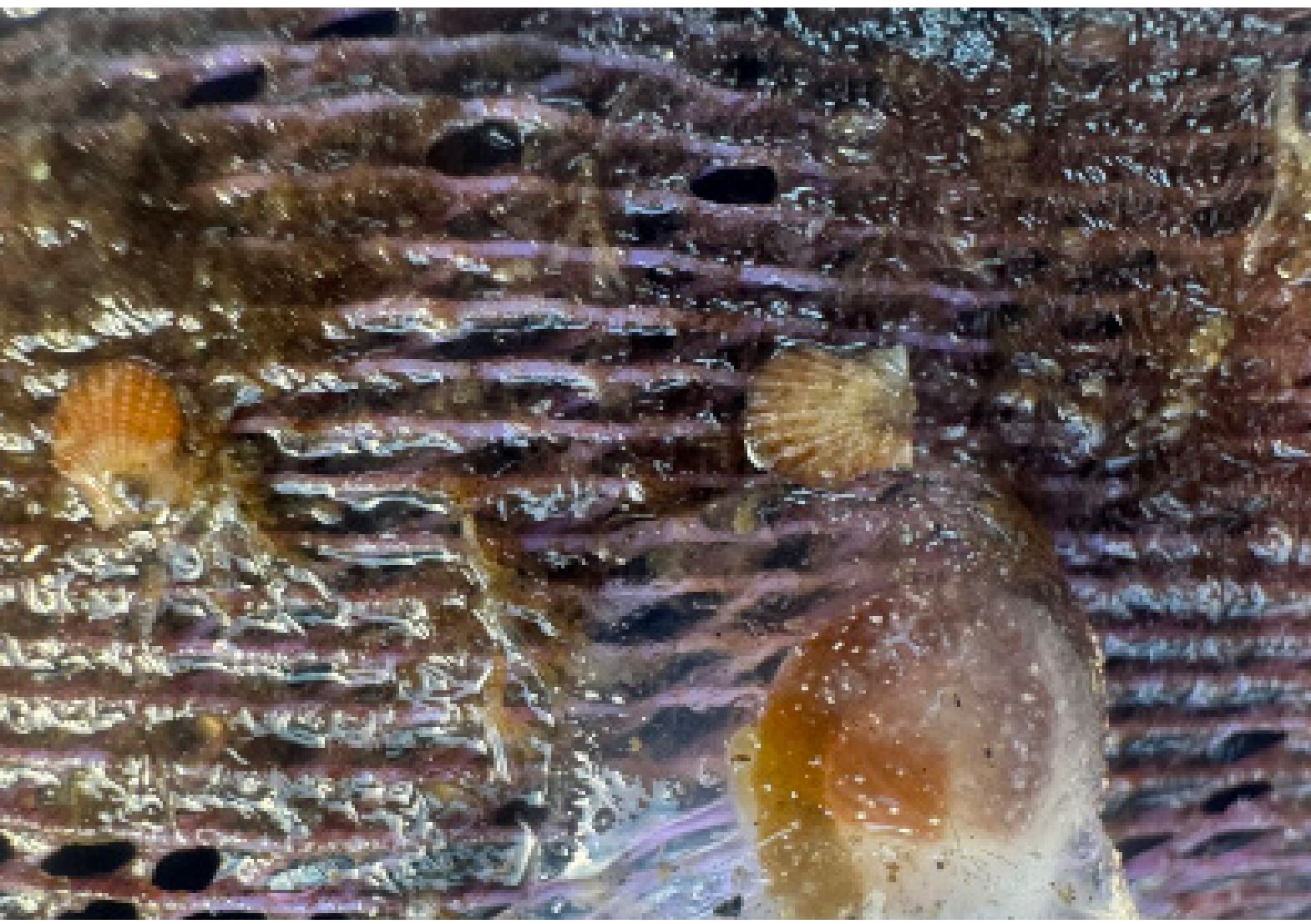
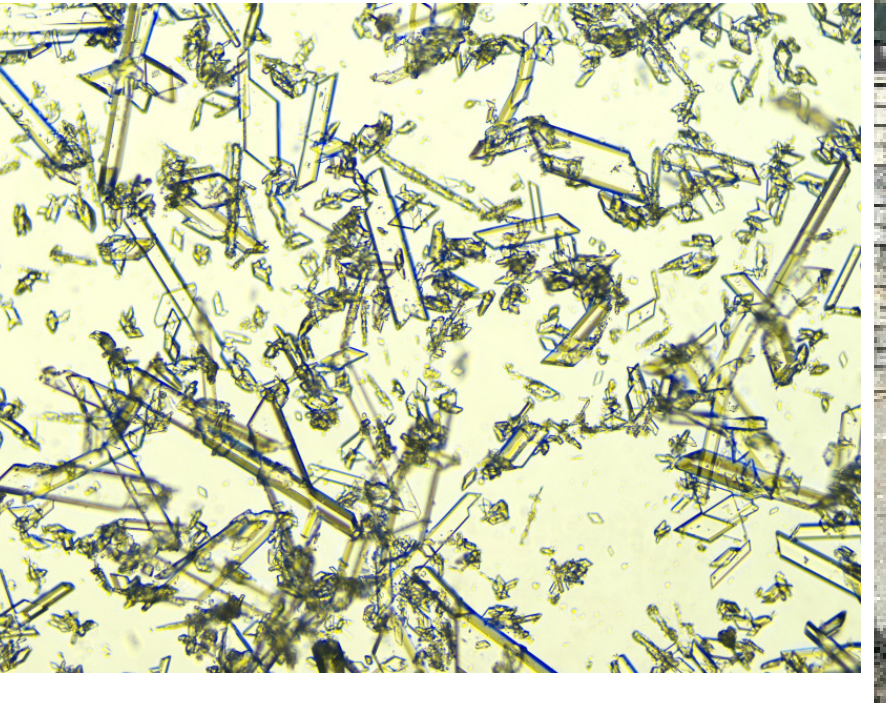
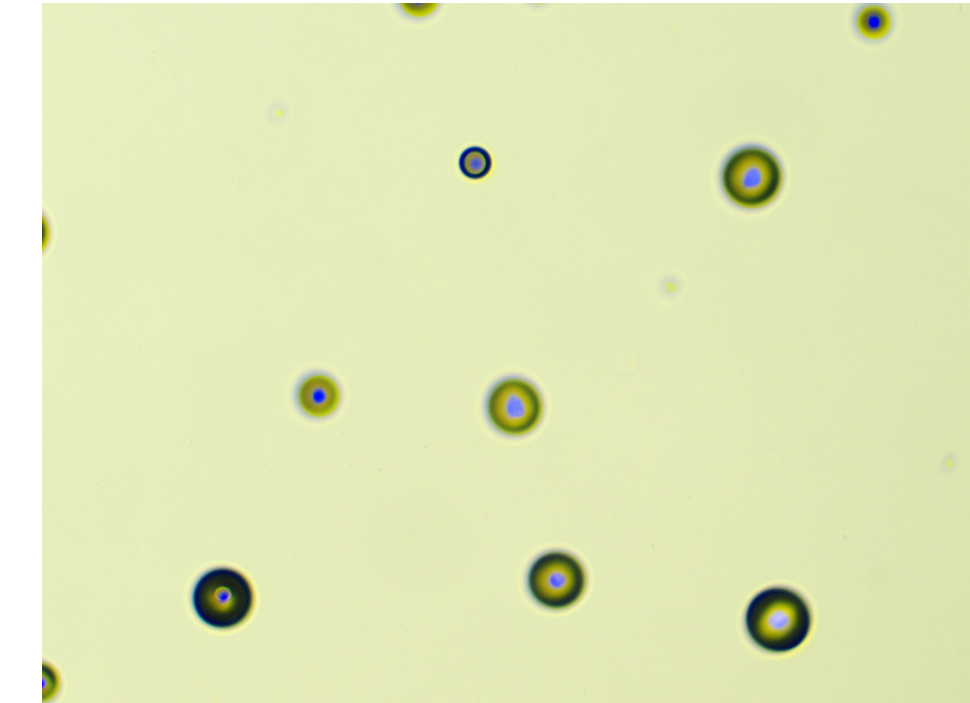


Figure 2. Growth of the Bull Kelp gametophytes after 2 weeks: A, Non-Nutrient Biochar; B, Nutrient Biochar; C, Green Gravel in Non-Nutrient Biochar system; D, Green Gravel in Nutrient Biochar system.



Top Left: Calcium rendered from Salt Water. Top Right: Functional Activation Station. Bottom Left: Magnesium Bitter under microscope. Bottom Right: Sea Calcium under the microscope