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Abstract

The aim of this thesis was to evaluate the welfare of the lumpfish (*Cyclopterus lumpus*) by studying fish behaviour in different habitats, consisting of artificial and natural seaweed hides. Substrates and hides are essential for lumpfish to maintain a good welfare, as well as that the environmental parameters are met. To the knowledge of the author there is currently no published research of lumpfish health conditions and natural seaweed hides. A few articles have focused on different types of artificial hides, such as PVC hides, plastic hides, car tyres, concrete tubes and stones, looking at fish preferences. Here, an experiment was carried out exposing lumpfish to different habitats: natural seaweed hides (*Saccharina latissima* and *Laminaria hyperborea*) and artificial hide (artificial seaweed made from PVC). The condition factor, the behavior and the external damages were assessed during the study, which was carried out from December 2020 to March 2021.

No significant differences were found in the condition factor of the different groups, indicating that the different hide conditions did not impact nutritional status of the fish. The monitoring of the fish behaviour was carried out using cameras and showed no significant differences among the groups. The only differences were found in fish after two months (T2) between the group with the *Saccharina* hide and *Laminaria* hide, and in fish after three months (T3) between the *Saccharina* and the artificial hide groups. Results varied between periods, thus differences in habitat can not be concluded. What the camera monitoring clearly shows, is that the fish utilizes the hides provided to rest and hide in. Significant difference in total injuries was found between the *Saccharina* hide and the *Laminaria* hide groups after three months (T3), indicating less damages in the *Laminaria* group. There were no significant differences on total injuries after one (T1) and two months (T2). The injury assessment represent a first attempt to give a qualitative support information and more data would need to be collected in order to provide solid conclusions using this information. This study cannot conclude that there were any correlations between type of hide, fish condition and external damages, and more studies need to be conducted order to conclude if there is any impact on behaviour and welfare to the selected groups of hide.

Preliminary trials of *Saccharina latissima* were seeded indoors, in order to test the possibility of cultivation of natural shelters. The seaweed showed good growth, especially in trial 2, and could be a good option to utilize as a hide along with fish in fish farms. The seaweed cultivation

could further be used in integration with fish, adding oxygen to the seawater and removing nutrient waste from fish, while giving the seaweed nutrient source.

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I. Introduction

1. Lumpfish biology and distribution

The lumpfish, *Cyclopterus lumpus* L., is easily recognized by its unusual morphology with a lumpy body with a high dorsal crest and short head (Figure 1). It is a marine teleost from the order Scorpaeniformes, belonging to the family Cyclopteridae, and has received its Latin name from the Cyclops, the one-eyed giants in Greek mythology. It is the only species from the genus *Cyclopterus.* The body is thight and round, covered in scale-less skin, with spiked bone plates in the thick skin. It has two dorsal fins, where the thick skin very often covers the first dorsal fin. As the fish grows older, dorsal fins grow in height (J. Davenport, 1985; B. S.-J. Jonsson, Arne, 1992, pp. 175-178).

Due to the small tail, lumpfish is a weak swimmer (Hjertager & Ekeli, 2013, pp. 164-165; Hvas, Folkedal, Imsland, & Oppedal, 2018). As a result of the lumpfish not having a swim bladder, the suction disc may be an essential strategy for resting and saving energy (Hvas et al., 2018; Powell, Treasurer, et al., 2018). The well-developed suction disc under the abdomen consist of modified pelvic fins, allowing the fish to attach and rest on surfaces, such as rocks and seaweeds (Hvas et al., 2018). Seaweed, including *Saccharina latissima* along with other *Laminariales*, have a key ecological role in coastal environments, providing resting surface, shelter and nutrients for a wide diversity of marine organisms (Bartsch et al., 2008).

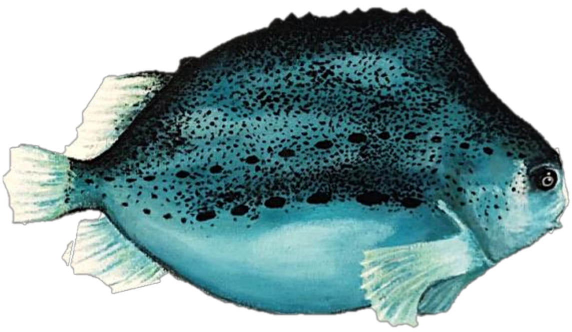

Figure 1. Illustration of the Cyclopterus lumpus.
Photo: Sunniva Vedvik

The lumpfish is distributed along both sides of the North Atlantic, where it is found in coastal regions and pelagic waters. It mainly lives in cold temperate and polar regions and in the deep sea (B. Jonsson & Semb-Johansson, 1992, pp. 175-178), feeding on planktonic organisms and benthic invertebrates (Hvas et al., 2018). During the spring, fish swims to the shore to spawn near-shore in the shallow water. The female produce up to 200000 eggs that are laid in large clumps between rocks and algae. After about 60 days, the eggs hatch, and the spawn swims around in the kelp forest and sometimes pelagically above it. After just four days, the spawn can attach to the seaweed, as the suction disc has already been developed. In the first two years, juveniles remain mainly in the coastline. Thereafter they disappear, only to return when they are sexually mature (Pethon, 2005, pp. 304-306).

2. Lumpfish in aquaculture

Lumpfish and Ballan wrasse, *Labrus bergylta,* are used as the biological alternative for controlling the sea lice, mainly the salmon louse, *Lepeoptheiris salmonis,* and the sea louse, *Caligus elongatus*. This ectoparasite has been a significant problem for many years in the salmon industry (Costello, 2006; A. K. Imsland, Reynolds, Eliassen, Hangstad, Foss, et al., 2014). The ballan wrasse have been used for several years as a cleaner fish (A. K. Imsland, Reynolds, Eliassen, Hangstad, Foss, et al., 2014; J. W. Treasurer, 2002). Although the potential for delousing is great, the low tolerance for low temperatures makes it unfit for temperatures lower than 6 °C (Sayer & Reader, 1996). In northern parts of Norway, low temperatures are a challenge, limiting its use as a cleaner fish. As a cold-water alternative, the salmon farmers have started using lumpfish, which are better adapted to cold temperatures (A. K. Imsland, Reynolds, Eliassen, Hangstad, Foss, et al., 2014; A. K. D. Imsland et al., 2018). Due to its broad temperature range, varying from 0 °C to 20 °C, lumpfish can feed at temperatures as low as 4 °C (J. Davenport, 1985). Studies have shown that the juvenile lumpfish eats the pre-adult and adult stages of lice attached to salmon (Staven et al., 2019) and the number of lice on salmon is significantly lower in cages with lumpfish (A. K. Imsland, Reynolds, Eliassen, Hangstad, Nytrø, et al., 2014).

3. Lumpfish welfare and health challenges

Over the past few years, the use of lumpfish as a cleaner fish has increased exponentially (Powell, Pooley, Scolamacchia, & Garcia de Leaniz, 2018), which has led to concerns regarding the health and welfare management of this species (Brooker et al., 2018). Causes, such as infectious diseases, starvation, too high or too low water temperatures, low oxygen, strong currents, poor husbandry, and injuries caused by rough handling, lead to compromised health of the fish and, in the worst case mortality (Chris Noble et al., 2019; Stien, Størkersen, & Gåsnes, 2020). Fish health is complex and can therefore be a challenge to understand. It is therefore important to use specific indicators such as condition index, injuries and behaviour to monitor the welfare of the fish health status (Brooker et al., 2018).

3.1. Stress

Stress is the physiological response for fish experiencing a threatening situation, leading to a homeostatic overload. It can be defined as a state where series of adaptive responses are re-establishing homeostasis after being exposed to a stressor (Chrousos, 1998, pp. 2-3; Schreck & Tort, 2016). Lumpfish can be affected negative by chronical stress, resulting in reduced growth and increased fin injuries (Espmark et al., 2019). The stress response can be grouped as: The primary stress response, the secondary stress response and the tertiary response. Primary stress response includes the initial neuroendocrine responses, releasing catecholamines (CA) and corticosteroids. Secondary responses include changes in plasma and tissue, and metabolite levels. The tertiary response are aspects of the whole performance of the animal, such as growth, behaviour and survival (Bruce A. Barton, 2002; Carragher & Rees, 1994; C. Noble et al., 2018; Wendelaar Bonga, 1997). The tertiary stress response can be used as welfare indicators, by looking at the performance of the animal, for instance the behaviour, growth and external damages (J. Treasurer, Noble, Puvanendran, Planellas, & Iversen, 2018, p. 294).

3.2. Assessing tertiary stress responses

Deformities, external injuries, and fin damages can be a result of poor fish welfare and can therefore be used as indicators to assess the fish welfare. Damages can have several causes, such as fin nipping, handling, water quality and stocking density (Hoyle, 2007; Chris Noble et al., 2012).

3.2.1. Fin damages

Fin damages are common in lumpfish hatcheries. When a fish is stressed, it may lead to aggression, further resulting in increased external damages to the fish. Fin damages are a result of interactions triggered by their aggressive behavior in the wild, under captive conditions or stress related events (Rey, Treasurer, Pattillo, & McAdam, 2021). Such injuries can cause harmful effects on the growth and survival, and due to being a direct injury to living tissue, it can make the fish more vulnerable to infections. Additionally, it may reduce the swimming ability of the fish (Brooker et al., 2018; Chris Noble et al., 2012; Chris Noble et al., 2019). Furthermore, lumpfish with damaged fins might have challenges with swimming efficiency, and they will have poor growth and an increased risk of starvation (Gutierrez Rabadan, Spreadbury, Consuegra, & Garcia de Leaniz, 2020). Fin damages may be reduced in lumpfish by frequently grading, provide the fish with shelters, improve the diet, and in general, husbandry practices that reduce stress and aggression (Gutierrez Rabadan et al., 2020).

3.2.2. Epidermal damage

The skin is the first barrier to infections, and even a slight injury or damage can result in bacterial infections and be a risk for fish welfare. Epidermal damage can result in significant wounds/ulcers and even compromise osmoregulation. Together with epidermal injuries, the pathogens present in the environment impact the welfare of the fish (C. Noble et al., 2018). Lumpfish are susceptible for different bacterial infections and can be chronically infected, with external ulcers, granulomas on internal organs, and fluid in the abdominal cavity (Brooker et al., 2018).

3.2.3. Mouth damage

Mouth damages and deformities may inhibit the fish ability to eat and ingest food due to the inability to open and close their mouths properly. This leads to adverse effects in the growth rate and reduced survival rates. Another issue with mouth damage is the reduced ability to use the buccal and opercular cavities to pump water across and ventilate their gills (Ballintijn, 1969; Chris Noble et al., 2012).

3.2.4. Eye damage/cataracts

The lumpfish is depending on an unimpaired vision to be able to feed normal, and it is, therefore, essential to maintain healthy eyes. Eye damage, cataracts and exophthalmia increase the risk of starvation. Cataracts are opaqueness or clouding of the eye lens, and it is one of the common forms of eye damage. These injuries can therefore reduce the feeding growth of the fish, and can be an indicator of when the fish is experiencing malnutrition (T. Jonassen, Hamadi, Remø, & Waagbø, 2017). Wounds in the fish eye may lead to secondary bacterial infections and also parasite infections (Chris Noble et al., 2012). Several factors can induce cataracts, for instance nutritional deficiencies, toxic agents, parasites, exposure to ultraviolet light, hereditary factors, variation in water temperature and rapid growth (Reviewed in Björnsson, 2004). The fish are dependent on a normal eyesight for a normal feed uptake, but may not be affected with minor lens opacities. Furthermore, the partly clouded sight can cause welfare implications, and can have a harmful effect on health by increasing behavioral and physiological stress. While severe cataracts can result in reduced feeding and growth, which makes cataracts a good indicator of malnutrition or over feeding. Cataracts are more usual among the growers and broodstock, compared to the lumpfish larvae and juveniles. In the hatcheries, the growth is more rapid in higher temperatures compared to the wild (T. Jonassen et al., 2017; Chris Noble et al., 2012; Powell, Treasurer, et al., 2018).

3.2.5. Suction disc deformities

It is unclear what can cause suction disc deformities, but nutritional, environmental, and genetic factors may be involved in deformities in other species (Reviewed in Berillis, 2015). Since the lumpfish require some type of substrate to attach, deformities of the suction disc can represent an acute problem (A. K. Imsland et al., 2015; Johannesen, Joensen, & Magnussen, 2018). A deformed, nonfunctional suction disc will therefore likely increase stress and energy expenditure, since to the lumpfish's primary response to threat is to cling and hide rather than to escape. This behavior might be a response due to the lack of Mauthner neurons which are involved in the fast startle response (Hale, 2000).

4. Habitats and shelters

During the first year of their life, juvenile lumpfish are found among seaweed, either attached or floating around the seaweed (Ingólfsson & Kristjánsson, 2002). Adult lumpfish are generally pelagic and can also be observed around floating seaweed (A. K. Imsland et al., 2015). Lumpfish are using the shelters to hide in or under them, as an anti-predator behavior, and to adhere on to them in order to rest (Figure 2). (A. K. Imsland, Reynolds, Eliassen, Hangstad, Nytrø, et al., 2014; A. K. Imsland et al., 2015). The use of lumpfish in the salmon cages has led to the need of shelters for this species to ensure that requirements for a natural environment is met. Such substrates and shelters can improve the health by providing shelters to hide in, and resting place during periods of inactivity or different environmental probations (A. K. Imsland, Reynolds, Eliassen, Hangstad, Nytrø, et al., 2014; A. K. Imsland et al., 2015).

Shelters used are designed to mimic the lumpfish's natural environment, and the artificial shelters and substrates that are used vary in design, material and thickness. Shelters such as PVC hides, plastic hides, car tires, concrete tubes and stones have been used (A. Imsland et al., 2018; A. K. Imsland et al., 2015).

Figure 2. C. lumpus utilizes its suction disc to attach to the smooth tank wall. Photo: Sunniva Vedvik

4.1. Environmental parameters

Habitat includes the area where the animal lives, and includes physical, like shelters, and chemical components which affects the organism (Halleraker, 2020). And alterations in the animals habitat, such as abiotic factors can influence the welfare of fish in different ways (J. Treasurer et al., 2018, p. 295). Abiotic factors are related to water quality and includes temperature, dissolved oxygen, salinity, pH, the presence of pathogens (Tort, 2011), predators and handling by people (Schreck & Tort, 2016). Environmental parameters can also include factors such as light (Espmark et al., 2019), or rearing density (J. Treasurer et al., 2018, p. 295).

The temperature is a significant parameter, affecting poikilothermic fish (a poikilotherm is an animal where the internal temperature varies considerably (Guschina & Harwood, 2006)) in several ways (Jobling, 1997). As an eurythermal fish (can function at a wide range of ambient temperatures (Giomi & Pörtner, 2013)), lumpfish can tolerate low temperatures ranging from 0-20 ºC (J. Davenport, 1985). Fish experiencing non optimal temperatures, for example too high temperatures (>18 ºC), might result in unpredictable behaviour, and in worst case death (Hvas et al., 2018). It is stated that optimal temperatures range from 8 ºC to 16 ºC (J. Treasurer et al., 2018, p. 297). Oxygen level is a critical water parameter, level and for example too low levels (<80%) can cause welfare problems, such as reduced growth and physiological stress in lumpfish (Jørgensen, Haatuft, Puvanendran, & Mortensen, 2017). Some experience-based observation shows that salinities below 32 ppt can increase the risk of cataracts. In the wild, lumpfish is found in low salinity waters (J. Davenport, 1985). It has been reported that most hatcheries operate with salinities in the range of 31-34 ppt (J. Treasurer et al., 2018, p. 297). Elevated levels of CO_2, and too low or high levels of pH can be a welfare challenge for several fish species (Chris Noble et al., 2019). Treasurer (2018, p. 297) have recommended pH of 7.3 to 7.8. Light is an environmental factor that contributes to affecting the behavior of the lumpfish. Besides, the color of the tank will also affect the light. The light can affect the casting of shadows and thus the perception of disturbances connected with activity outside the tanks. The light intensity and wavelength may also affect the behaviour and growth (Espmark et al., 2019; T. M. Jonassen, Lein, & Nytrø, 2018).

4.2. The use of natural seaweed as shelter

The use of natural seaweed as shelters can have beneficial effects both commercially and on fish health. Commercially, natural seaweed can be beneficial for the environment compared to artificial hides, first by contributing to adding oxygen to the seawater, while removing nutrient wastes from the seawater in integration with nearby fish farms (Neori, 2008). The waste product from protein metabolism in fish, ammonium, can represent a significant nitrogen source for macroalgae (Handå et al., 2013). Second, the use of seaweed are in addition to being an biological solution to lumpfish habitats, low costs and no pollution of plastic (Haward, 2018).

Seaweed shelters might provide a better habitat for cleaner fish than artificial shelters for several reasons. Seaweed is known to produce metabolites aiding in the protection against different environmental stresses. These compounds have antiviral, antifungal, and antibacterial properties (Pérez, Falqué, & Domínguez, 2016; Singh, Kumari, & Reddy, 2015). *Saccharina latissima* is one of the fastest growing species of kelp (Forbord, Steinhovden, Rød, Handå, & Skjermo, 2018, p. 38) and with its broad morphology, it is well suited for lumpfish to rest on. Other species with similar characteristics can also be used, such as *Laminaria hyperborea,* which have been associated with lumpfish (Schultze, Janke, Krüß, & Weidemann, 1990).

5. Aim of study

Currently, there are few published research articles studying lumpfish habitat preferences. Different types of artificial hides (Described in section 4 p. 5) have been assessed, but there are to the knowledge of the author no research of natural seaweeds as a shelter. Shelters are essential for the lumpfish to maintain a good welfare. The aim of this study is to evaluate different habitats for the lumpfish in order to improve fishwelfare. Two types of natural seaweed and one artificial cover will be used by assessing fish weight, condtition factor, external damages, and monitoring the behavior with camera pictures.

The scientific questions are:
Do natural seaweed provide a better hide for the lumpfish compared to the artificial seaweed by looking at:

- Are there correlations between type of hide, fish condition and external damages?
- Is the fish behavior different according to the selected groups of hide?

II. Material and methods

1. Material

1.1. Instruments and devices

The instruments and devices used in this work are shown below in Table 1.

Table 1. Overview of instrument, devices and material used for the experiment

Devices/material	**Description**	**Fabricator**
Camera	V200	VOSKER, Canada
Counting plate	0.100 mm depth, 0.0025m^2	Thoma, Germany
Feeding machine	Shyfish – Smart automatic fish feeder. Model O2	Shyfish, China
Fish net	Fine mesh fish net	TRIXIE Heimtierbedarf GmbH & Co. KG, Germany
Light meter	LI-189	LI-COR, USA
Microscope	Leica M80	Leica, Germany
Microscope	Leica Dmls 020-518.500	Leica, Germany
Oxygen, pH, salinity and temperature logger	Pacific C11PB	OxyGuard ®, Denmark
Paint brush	Size 14	Coop Byggmix, Norway
Pellets	Clean Assist CF 1.8 mm pellets	Skretting, Norway
pH-meter	Seven Compact pH meter S210	Mettler Toledo, USA
Pipette	2-20 µl	Thermo Scientific, USA
Plastic plate	PLASTGLASS 1200X800X4 1200 x 800 x 4 mm	Biltema, Norway
PVC Coils	6.7 in diameter and approximately 50 cm in lenght	Ashell, Norway
PVC plastic sheet	2 x 3 m PVC 0,5 mm 1331165	Ubbink Garden B.V, The Netherlands
Salinity and temperature device	Conductivity meter, LF 330	WTW, Germany
Scale	CS 200 Portable scale	OHAUS, USA
Seaweed	Wild *Laminaria hyperborea* collected at Kvitsøy	Kvitsøy, Norway
Tanks	Blue 650 L tanks	Sæplast, Norway
Temperature logger	Tynytag Aquatic TG-4100	Tinytag, Norway
Twine thread	1.8/2.0 mm twine	Hortimare, The Netherlands

All seaweed species, lumpfish, and seaweed spores used are shown in Table 2.

Table 2. Overview of seaweed and fish used

Species	Description	Fabricator
Saccharina latissima spores	Spores used for cultivation	Hortimare, The Netherlands
Laminaria hyperborea	Seaweed collected at Kvitsøy	Kvitsøy, Norway
Saccharina latissima	Seaweed collected at Kvitsøy	Kvitsøy, Norway
Cyclopterus lumpus	Lumpfish with mean weight of 19.8 g	Ryfylke rensefisk, Norway

Chemicals used are shown in Table 3.

1.2. Chemicals

Table 3. Overview of chemicals used

Chemical	Description	Fabricator
Chlorine	Chlorine	Lilleborg AS, Norway
Strong soap	Vaske og avfettningsmiddel, IQ 200	Würth, Norway

2. Methods

2.1. Lumpfish experimental design

The experimental design consisted of three groups with two replicates each, with approximately same amount of fish (Table 4). Setup of the tanks are shown in Figure 3 below. Six 650 L tanks; two replicates of seaweed hide *Saccharina latissima*, two replicates of seaweed hide *Laminaria hyperborea*, two replicates of artificial cover made from PVC sheet (named in this thesis artificial hide). The different hides are shown in Figure 4. Before initiating the experiment, ten fish was assessed as control fish (T0). Assessment of ten randomly picked fish from every replicate was done once every month (T1, T2 and T3). After fish was assessed, they were not placed back in its belonging tank, but in a different tank (decreasing amount of fish by ten fish every month).

Table 4. Overview of the amount of fish in each replicate for the different groups at experiment start. Amount of fish decreased with 10 fish every month.

REPLICATE	SACCHARINA	ARTIFICIAL	LAMINARIA
1	n = 41	n = 40	n = 39
2	n = 40	n = 45	n = 39

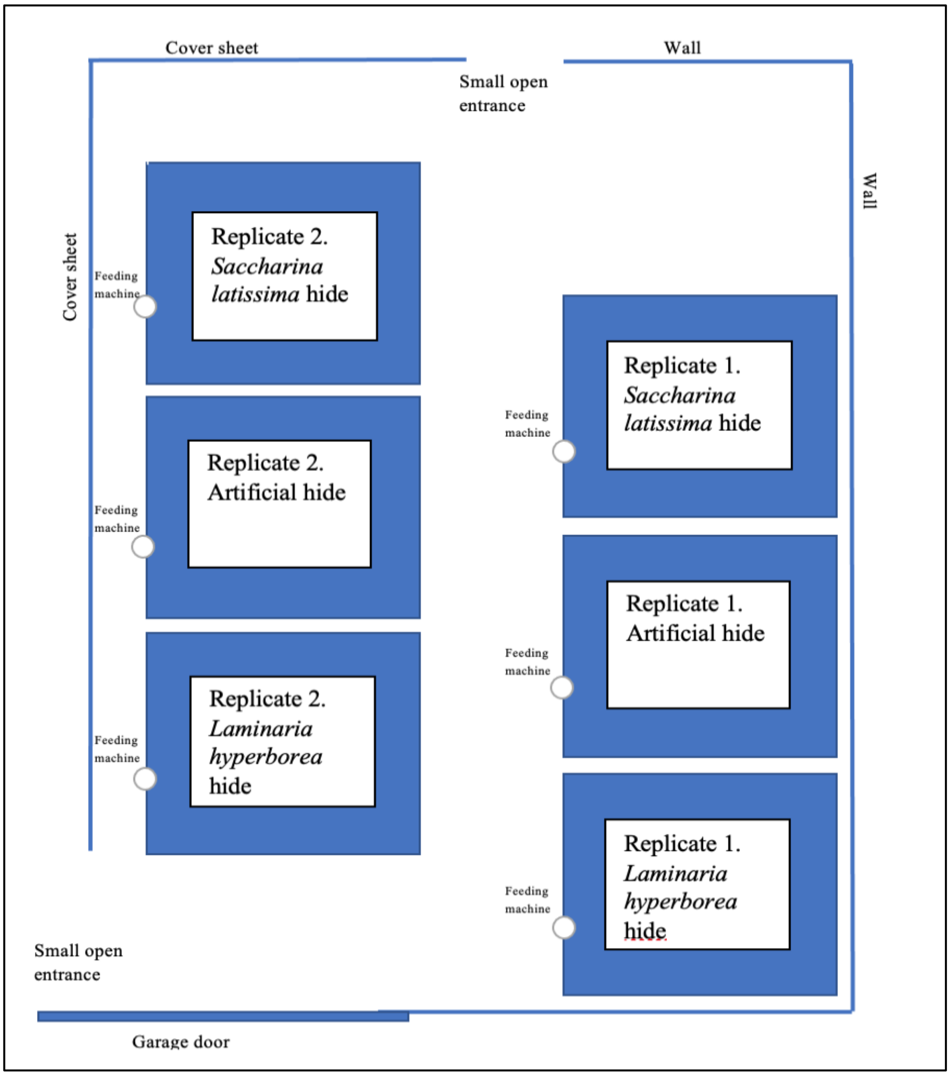

Figure 3. Experimental setup of lumpfish experiment. Showing where the different groups with its replicates are placed in the room. Feeding machines was mounted the same place in each group. Two small entrances, walls and cover sheets to block some of the intense light in the room. A camera mounted in the roof above each group.

Figure 4. From left: Saccharina hide, artificial hide and Laminaria hide placed out in experimental tanks

A camera (VOSKER Camera V200) was mounted on the roof above each tank, to be able to take pictures of fish each day to monitor where they spent most of their time. Pictures were taken every 30 min between 08.00 to 15.30,. After placing a plastic wall (Figure 5), the camera was able to take pictures of the entire tank.

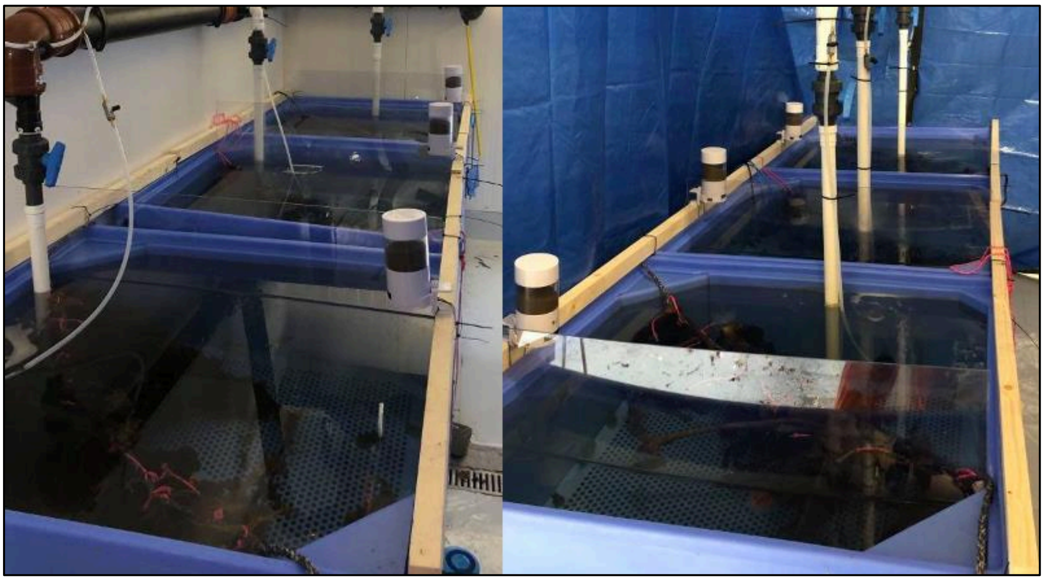

Figure 5. Experimental setup. Showing mounted plastic wall in each tank, and feeding machine are placed in the same place in every group. Left picture: from left: replicate 1 of Saccharina, artificial and Laminaria hide groups. Right picture: from left: replicate 2 of Laminaria, Saccharina and artificial hide groups.

2.2. Condition factor

Ten randomly picked lumpfishes from each replicate of the groups was netted monthly (T1, T2 and T3) and assessed for health condtions (condition factor, K), where weight, total length, fork length, and body height were recorded.

Fulton's Condition factor (K) (Nash, Valencia, & Geffen, 2006) are defined as:

$$K = 100 * W/L^3$$

Where W are wet weight (g) of the fish, L is fork length in cm (calculations of condition factor are shown in Appendix Table 1, Table 2 and Table 3). The condition factor was evaluated according to the K factor values from Imsland et al., (2020), which have conducted a different range suitable for this species (Table 5).

Table 5. Condition factor, health assessment for lumpfish.

SCORE		
0	4.5 to 5.5:	Good condition
1	3.5 to 4.5:	Moderate condition
2	3.0 to 3.5:	Poor condition
3	Under 3.0:	Fish emaciated

2.3. Lumpfish behaviour

2.3.1. Behaviour measurement

Pictures were taken every 30 min between 08.00 to 15.30. This resulted in 16 pictures from each group each day. Giving 112 pictures of each tank every week to be observed. The pictures were observed from 17.12.20 to 17.03.21. It was noted how many fish in each tank, that were on the floor, on the wall, or swimming "non-sheltered". The rest of the fishes not observed in the picture, was assumed to be resting or hiding in the seaweed hides "sheltered".

The feeding times, and the 30 min after feeding times (Table 6) are not included when conducting the tests for normality, homogeneity between variance, and ANOVA and post hoc tests. This is because the percentage “sheltered” fish and “non-sheltered” fish are very different and will not show normally distributed groups. Therefore, to achieve normal distributed groups and homogeneity between variance, they are not included when checking for significant difference.

Table 6. Overview of the times included for statistical analyses, and times excluded for statistical analyses.

TIMES INCLUDED	TIMES EXCLUDED
08.00	08.30
09.30	09.00
11.00	10.00
11.30	10.30
12.00	13.00
12.30	13.30
14.00	15.00
14.30	15.30

2.3.2. General observation

Every Monday and Friday (Between 09.00-09.30) a manual observation of fish was performed. Each group was observed for 5 min, noting down where fish spent their time, i.e. on the wall, on the floor, swimming, or hiding/resting in the seaweed, trying to look for any different or aggressive behavior, which the camera could not show from the pictures. These observation days were also used to refill the automated feeders and to check that everything worked as it was supposed to.

2.4. External damages

Fish was observed for external damages every month (T1, T2 and T3) (Table 7) according to Grøntvedt et al., (2019), and modified slightly by adding cataracts and other fin injuries in the scoring system from Imsland et al., (2020). Gill bleeding, degradation of spikes, snout injuries and eye damages was further not observed when assessing fish, and is not included in results.

Table 7. Overview of the different parameters which is categorized for possible external damages.

SCORE	**0**	**1**	**2**	**3**	
CAUDAL FIN	No visible damage	Some biting or fin splitting	Major fin ray loss	Severe injury on fin. Complete removal of fin	
OTHER FINS	No visible damage	Some biting or fin splitting	Major fin loss	Severe injury on fin. Complete removal of fin	
EPIDERMAL INJURIES	Intact/no injuries	Minimal localized damage to body	More widespread injuries	Damages areas. Compromised health status	
DEGRADATION OF SPIKES	Normal/no damage	< 5% of spikes are affected	5-20% of spikes are affected	20% < of spikes are affected	
GILL BLEEDING	Normal/no damage	Small	Moderate bleeding	Significant bleeding	
SNOUT/MOUTH DAMAGES	Normal/ No damage	Small damages/scratch in the snout	Major damages/and rifts	Signifcant severe damages	
SUCTION DISC DEFORMITIES	No deformities	Minimal deformation	More obvious deformities	Severe malformations	
EYE DAMAGE	Normal/no damage	Small bleeding/ damages	Major/ moderate bleeding/ damages	Severe damages	
SCORE	**0**	**1**	**2**	**3**	**4**
CATARACTS	No cataracts	< 10%	Between 10 and 50 %	Between 50 and 75 %	Over 75 %

2.5. Technical settings and conditions

Lumpfishes were provided by Ryfylke Rensefisk. 246 fishes were received the 18.11.20, with an initial mean weight of 19,8 g. They were acclimated for about a month in a 650 L tank with stocking density of 7.5 kg/m^3. Tanks had flow-through seawater of 24 L/min. Dissolved oxygen, pH and salinity were recorded every 10 min with OxyGuard® Pacific Monitoring System. The water temperature was measured every hour with Tinytag Aquatic 2 - TG-4100 temperature logger. The values recorded were measured from the water outlet for all groups. The average water temperature over the experimental period was 9.82 ºC ± 1.14. The mean pH and dissolved oxygen values were 7.69 ± 0.14 and 90.14 % ± 15.10. The mean salinity was 35.34 ppt ± 1.54. Light regime was 16 h dark and 8 h light. Amount of light was 5 $\mu mol/m^{-2}/sec^{-1}$. Fish were fed four times a day with an automated feeder (Shyfish) at 08.30, 10.00, 13.00, and 15.00, 10 g for each portion (Clean Assist CF 1.8 mm pellets, Skretting). After experiment start, stocking density in each replicate of every group was around 3 kg/m^3. Lumpfish tanks were cleaned every 10 day.

2.5.1. Preparation of seaweed hides

Artificial seaweed hides were made from an PVC sheet, they were rinsed with "Vaske- og avfettningsmiddel, IQ 2000" for 20 min, then rinsed thoroughly with freshwater. Thereafter they were rinsed in chlorine for 20 min. They were rinsed thoroughly with freshwater and thereafter seawater before they were placed out in the two replicates for artificial hide (Figure 4 p. 12). *Saccharina latissima* and *Laminaria hyperborea* seaweed were collected from Kvitsøy, rinsed with seawater to eliminate living organisms before being placed into the different groups (Figure 4 p. 12). This procedure was later performed when old seaweed needed to be removed. Seaweeds were changed out with new seaweed once a month.

2.6. Statistical analyses

Statistical work was performed with Microsoft ® Excel (Version 2021), with the Real Statistics Resource Pack software (Release 7.6). Copyright (2013 – 2021) Charles Zaiontz. www.real-statistics.com (Downloaded the 10.05.21). Statistical calculations performed are shown in Appendix from Table 12 p. 68 to Table 23 p. 78.

The Shapiro-Wilk-test was performed on the data to test for normality of distributions. A Levene's test was performed to check for homogeneity of variance between the groups. One-way ANOVA was used and followed by a Tukey's post hoc test to determine which groups that were significant different. For samples not normally distributed a Kruskal-Wallis test followed up with a Pairwise Mann-Whitney Test was conducted. All statistical test applied had a significance level of $\alpha = 0.05$. Differences were considered significant different if $p < 0.05$.

2.7. Cultivation of *Saccharina latissima*

The cultivated *S. latissima* seaweed was performed as preliminary trials, for the purpose for future studies to serve as seaweed hide for the lumpfish. In addition for future studies of nutrient recycling and increased growth of macroalgae in integration with fish.

2.7.1. Cultivation trial 1

Trial 1 was performed from 09.08.20 to 03.12.20. Before seeding the *Saccharina latissima* spores, tanks were cleaned. A thin rope (twine thread) was thread around the coils. For this experiment, 13.5 coils were used. 350 ml filtered and cool (10-12 °C) seawater was added to the jerrycan containing the *S. latissima* spores, and the content was mixed. 100 ml of the content was painted on the rope on the coils and placed vertically into the prepared tanks (Figure 6). The light setting was set to 12 h light and 12 h dark from the start of the trial. Light settings was later changed to 16 h light and 8 h dark 5 weeks later. Average light intensity in tank 1 and tank 2 was 50 µmol/m^{-2}/s^{-1}.

After four weeks, tanks with the seeded coils were cleaned, and then at week nine they were cleaned again and assembled in tank 2, leaving tank 1 empty and clean. The last monitoring of the seaweed was the 03.12.20.

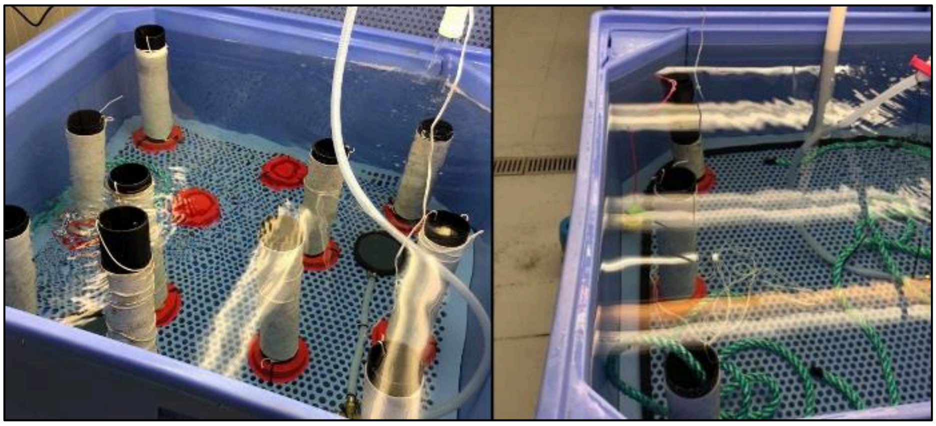

Figure 6. Experimental setup of the coils in trial 1. After seeding of *S. latissima* and placed out in tank 1 (left), and tank 2 (right).

The growth of the seaweed was monitored for 19 weeks. The temperature, salinity, and pH were checked two days a week, on Mondays and Thursdays at 09.00. Temperature and salinity were measured with WTW Conductivity meter, LF 330. Water samples of each of the two tanks containing seaweed were collected in clean and empty flasks, and pH was measured with Seven Compact pH meter S210, Mettler Toledo.

After 8 days, when the spores had grown and settled on the rope, a little piece of the rope from tanks with seaweed spores was sampled to monitor the growth. A singular measurement of the growth of one spore was monitored twice a week in the microscope. No parallels were taken during the trial, and the spores were randomly collected.

Thoma counting chamber (depth 0.100 mm and squares $0.0025 mm^2$) was used to measure the length of the spores under the microscope. The length of the spore was calculated by counting how many 0.025 mm the spore was covering. And then add 0.025 mm with amount of counted lines (0.025 mm + n).

2.7.2. Cultivation trial 2

A second trial of the *Saccharina latissima* seeding was performed the 13.01.21 to 12.04.2021. Trial 2 was performed because of clumping of spores and poor growth in trial 1. For this experiment, 10 coils were used. 300 ml filtered and cool (10-12 °C) seawater was added to the container containing the seaweed spores, and the content was mixed. Approximately 100 ml of the content was painted on the rope on the coils and placed into the prepared tank. The coils were placed in a horizontal way, closer to the surface (Figure 7) and not vertical like the coils in trial 1. This was to provide the spores with sufficient light. Light was turned on two weeks after the seeding and set to 8 h light and 16 h dark. Average light amount in the tank was 50 $\mu mol\ m^{-2}\ s^{-1}$.

Figure 7. Showing the experimental setup of the coils. After seeding of S. *latissima* and placed out in the tank.

After 3 weeks, the growth of the length was monitored in the microscope until big enough to be measured without a microscope. The growth of the seaweed was monitored for 13 weeks as described in section 2.7.1 p. 17 in methods. Spore growth was calculated as decribed in section 2.7.1 p. 17 in methods.

III. Results

1. Condition factor

The one-way ANOVA test revealed no significant difference between the replicates in every groups' condition factors in T1, T2, and T3. After conducting this test, the *Saccharina* replicates were merged as *Saccharina* hide, the artificial replicates were merged as artificial hide, and the *Laminaria* replicates were merged as *Laminaria* hide. These three groups are further defined as *Saccharina* hide, artificial hide, and *Laminaria* hide.

Table 8. The mean condition factor and mean weight for the different groups for the different periods.

PARAMETER	TRIAL PERIOD	*SACCHARINA*	ARTIFICIAL	*LAMINARIA*	CONTROL
Condition factor (K)	T0				6.78 ± 0.78
	T1	6.40 ± 0.83	6.69 ± 0.92	6.59 ± 0.78	
	T2	6.17 ± 0.66	6.62 ± 0.68	6.64 ± 0.54	
	T3	5.78 ± 0.48	5.97 ± 0.49	6.10 ± 0.42	
WEIGHT (G)	T0				27.22 ± 7.23
	T1	51.74 ± 14.78	46.22 ± 13.0	46.69 ± 9.76	
	T2	71.95 ± 16.09	72.14 ± 13.89	75.49 ± 21.21	
	T3	113.89 ± 33.68	106.49 ± 28.20	110.41 ± 20.09	

Mean condition factor of every group (Table 8) indicated a good nutritional condition of the fish when assessed for health condition (Section 2.2 methods Table 5 p. 13). Conducting a one-way ANOVA showed no significant difference of the condition factor between the three groups *Saccharina* hide, artificial hide, and *Laminaria* hide of the different months (T1, T2 and T3). Results indicates all fish had the same nutritional condition during the experimental period.

The method from Rey et al., (2021), was used to see how assessed fish in percent are bigger or smaller compared to the mean. The individual weight relative to tank mean expressed as a proportion of the mean weight of fish in every group. Looking at the differences in weight compared to the mean weight (100%), there are some fish being above 100% compared to the mean value, and some significantly lower than the mean (calculations and difference compared to mean shown in Appendix Table 4, Table 5 and Table 6). Some few fishes in each group had grown more significant than the rest of the fishes.

2. Lumpfish behaviour

2.1. Lumpfish behaviour

Average percentage of "sheltered" fish and "non-sheltered" fish for *Saccharina* hide, artificial hide and *Laminaria* hide groups between T0-T1, T1-T2 and T2-T3 are shown in Table 9. The table shows that the average percentage of "sheltered" fish during the experimental period, are the highest percentage compared to the average percentage of "non-sheltered" fish. This is shown in every group, and every month.

Table 9. Overview of the mean percentage "sheltered" fish and "non-sheltered" fish without feeding times and the 30 min after feeding time.

TRIAL PERIOD	***SACCHARINA***	**ARTIFICIAL**	***LAMINARIA***
SHELTERED			
T0-T1	72.95 % ± 2.70	71.23 % ± 5.60	75.90 % ± 4.95
T1-T2	74.38 % ± 2.22	73.15 % ± 2.11	69.17 % ± 4.77
T2-T3	64.34 % ± 4.25	68.31 % ± 1.35	65.16 % ± 2.15
NON-SHELTERED			
T0-T1	27.05 % ± 2.70	28.77 % ± 5.60	24.10 % ± 4.95
T1-T2	25.62 % ± 2.22	26.85 % ± 2.11	30.83 % ± 4.77
T2-T3	35.66 % ± 4.25	31.69 % ± 1.35	30.83 % ± 4.77

The percentage "sheltered" fish and "non-sheltered" fish for *Saccharina* hide group in the three periods T0-T1, T1-T2 and T2-T3 are shown in Figure 8 (p. 22), Figure 9 (p. 22) and Figure 10 (p. 23), respectively. The figures shows highest percentage of "sheltered" fish during the day for all three periods, and a slightly decrease in "sheltered" fish during the feeding times. The period T2-T3 shows a decrease in the percentage of "sheltered" fish (Figure 10 p. 23).

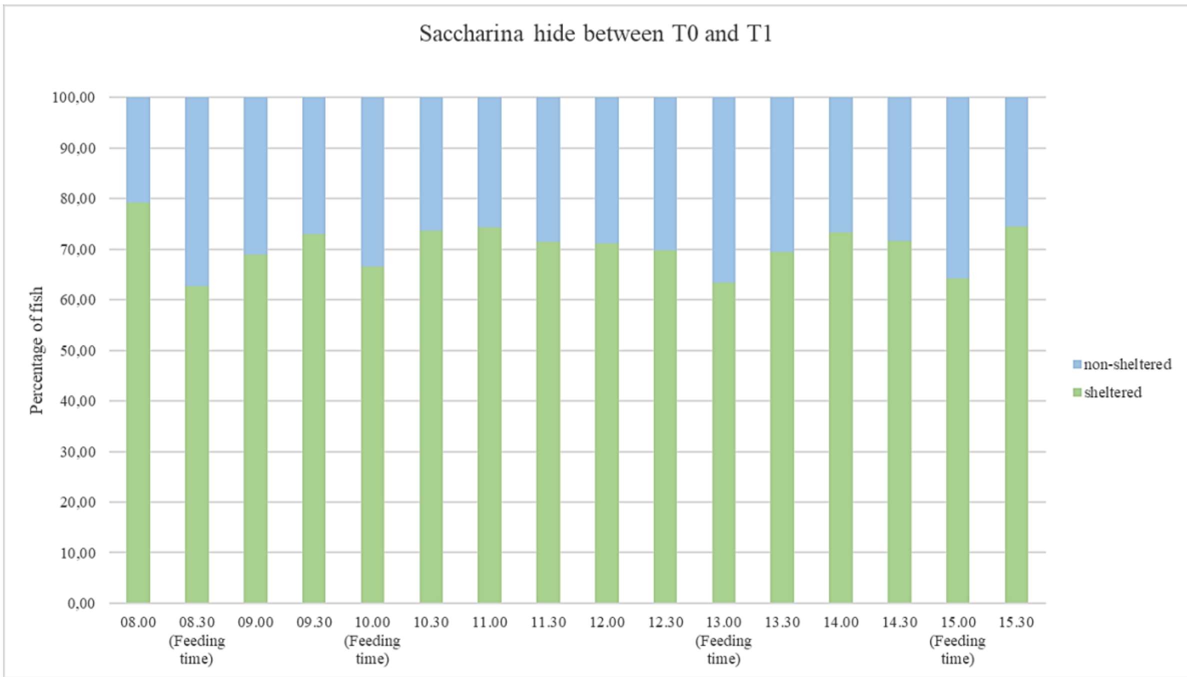

Figure 8. Showing percentage of "sheltered" fish and "non-sheltered" fish for the Saccharina hide between 08.00 to 15.30 between T0 and T1. N = 19 days monitored for this period.

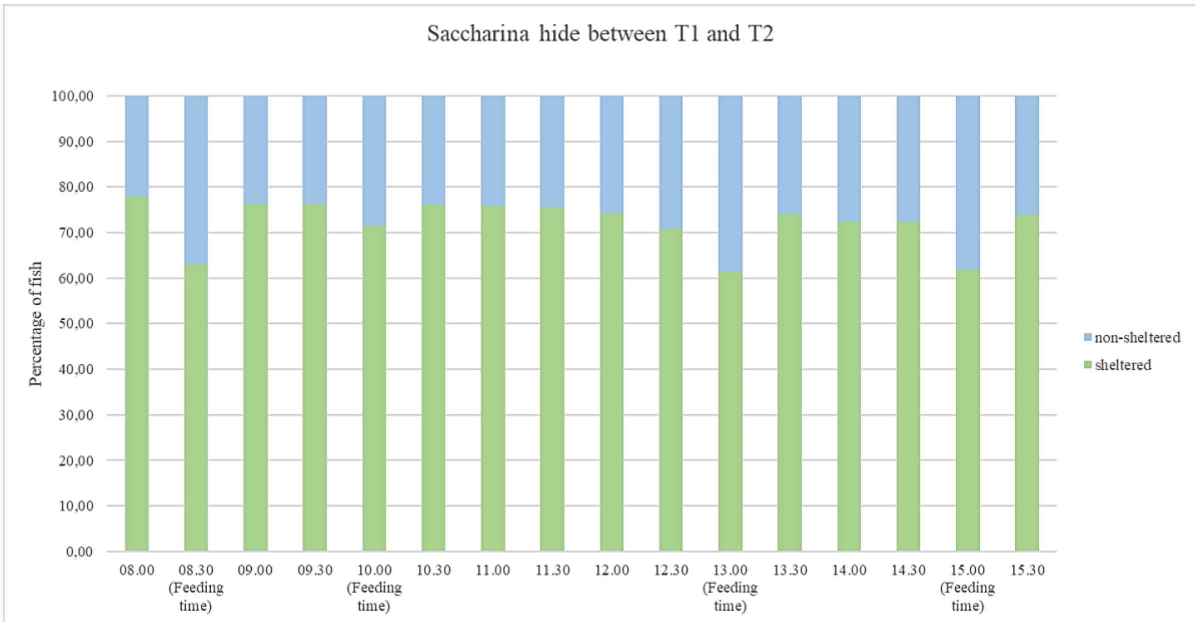

Figure 9. Showing percentage of "sheltered" fish and "non-sheltered" fish for the Saccharina hide between 08.00 to 15.30 between T1 and T2. N = 21 days monitored for this period.

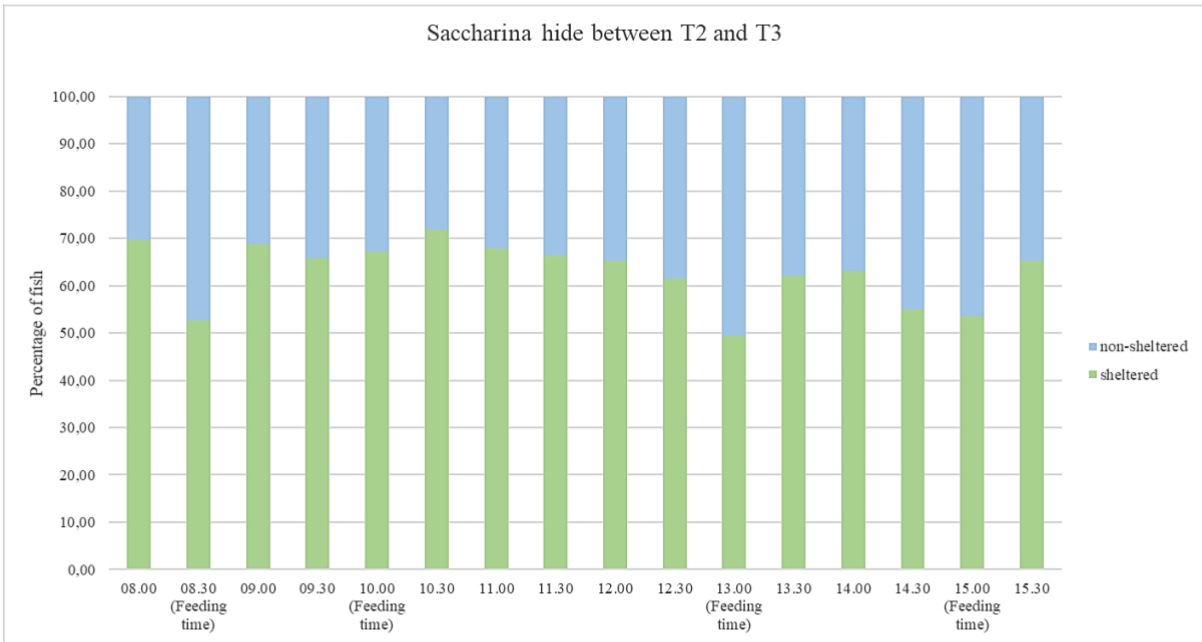

Figure 10. Showing percentage of "sheltered" fish and "non-sheltered"fish for the Saccharina hide between 08.00 to 15.30 between T2 and T3. N = 11 days monitored for this period.

The percentage "sheltered" fish and "non-sheltered" fish for artificial hide group in the three periods T0-T1, T1-T2 and T2-T3 are shown in Figure 11 (p. 23), Figure 12 (p. 24) and Figure 13 p. 24). Results show highest percentage of "sheltered" fish during the day in all periods, with a decrease in "sheltered" fish during feeding times. The period T2-T3, shows that the percentage of "sheltered" fish have decreased slightly (Figure 13 p. 24).

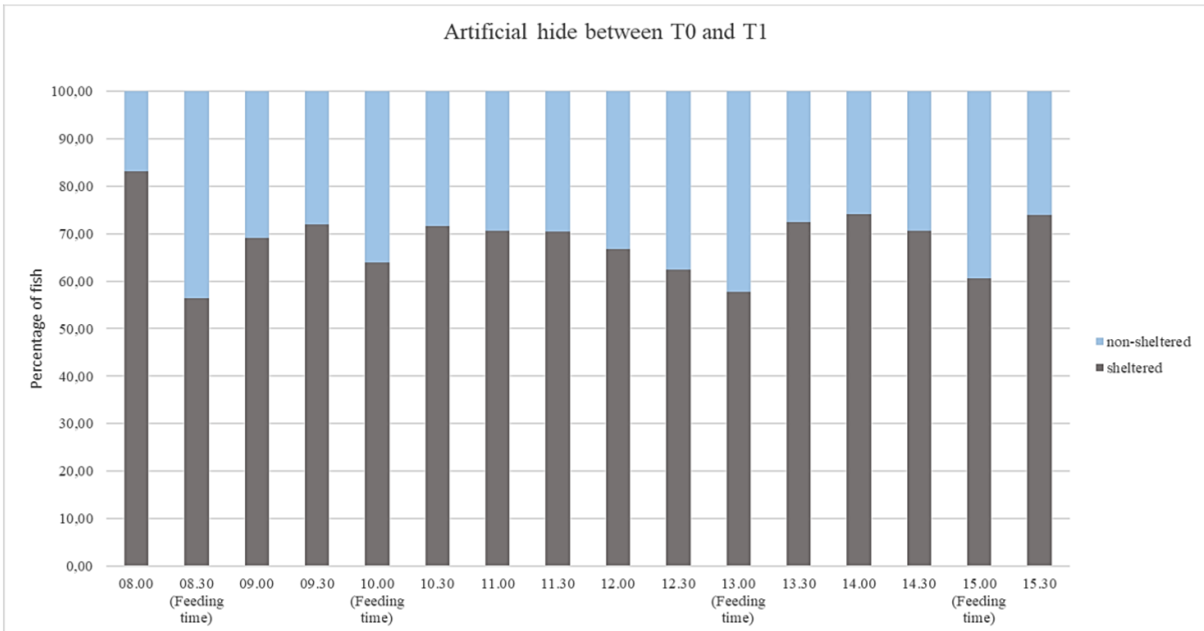

Figure 11. Showing percentage of "sheltered" fish and "non-sheltered" fish for the artificial hide between 08.00 to 15.30 between T0 and T1. N = 27 days monitored this period.

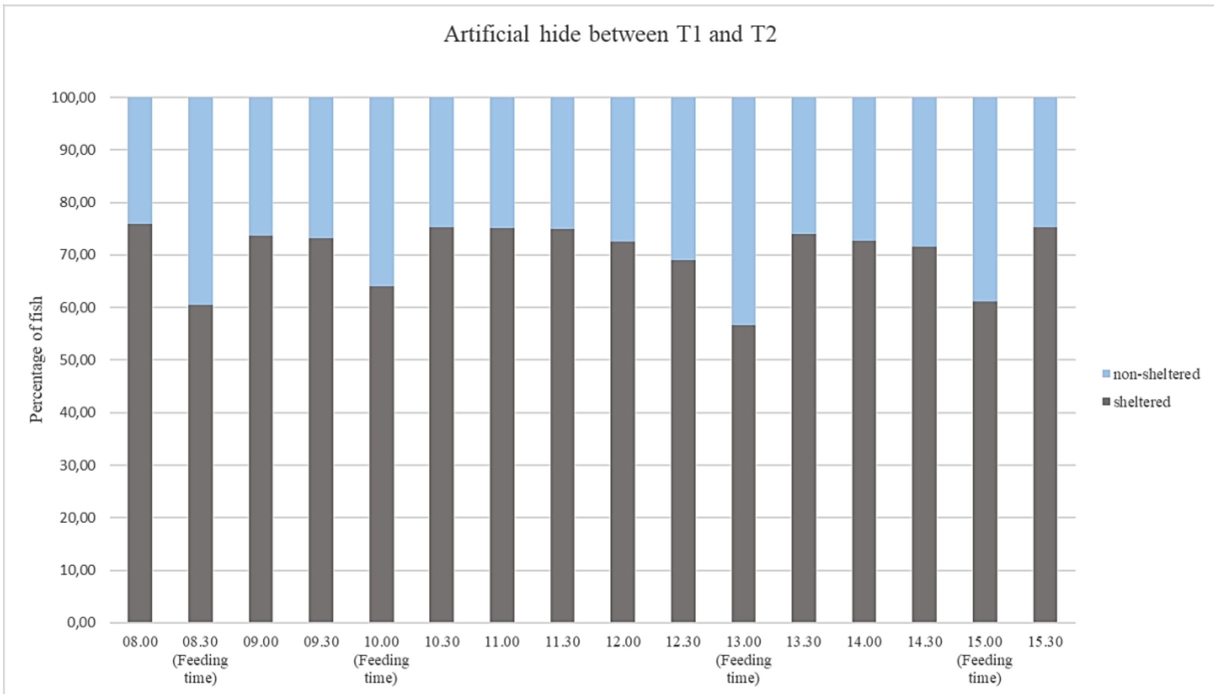

Figure 12. Showing percentage of "sheltered" fish and "non-sheltered" fish for the artificial hide between 08.00 to 15.30 between T1 and T2. N = 23 days monitored this period.

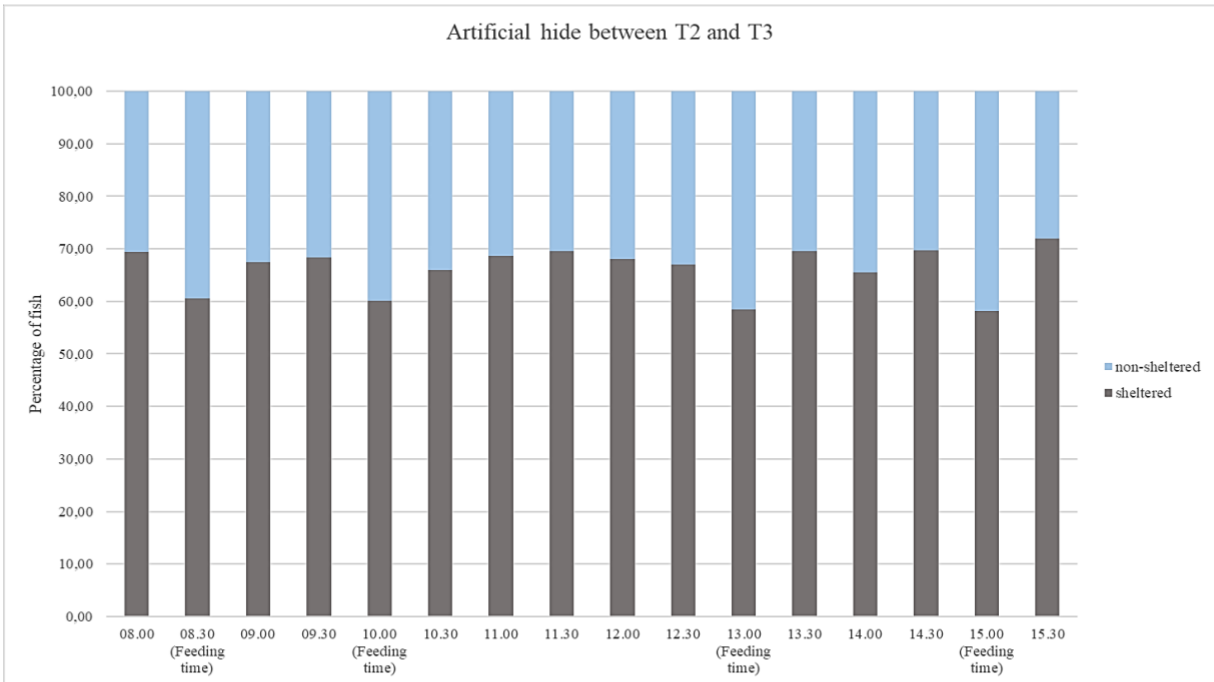

Figure 13. Showing percentage of "sheltered" fish and "non-sheltered" fish for the artificial hide between 08.00 to 15.30 between T2 and T3. N = 15 days monitored this period.

The percentage of "sheltered" fish and "non-sheltered fish" for the *Laminaria* hide group in the three periods T0-T1, T1-T2 and T2-T3 are shown in Figure 14 (p. 25), Figure 15 (p. 25) and Figure 16 (p. 26). Results shows the highest percentage of "sheltered" fish during the day in all periods, with a decrese in “sheltered” fish during feeding times. The period T2-T3 shows a decrease in the percentage of “sheltered” fish (Figure 16 p. 26).

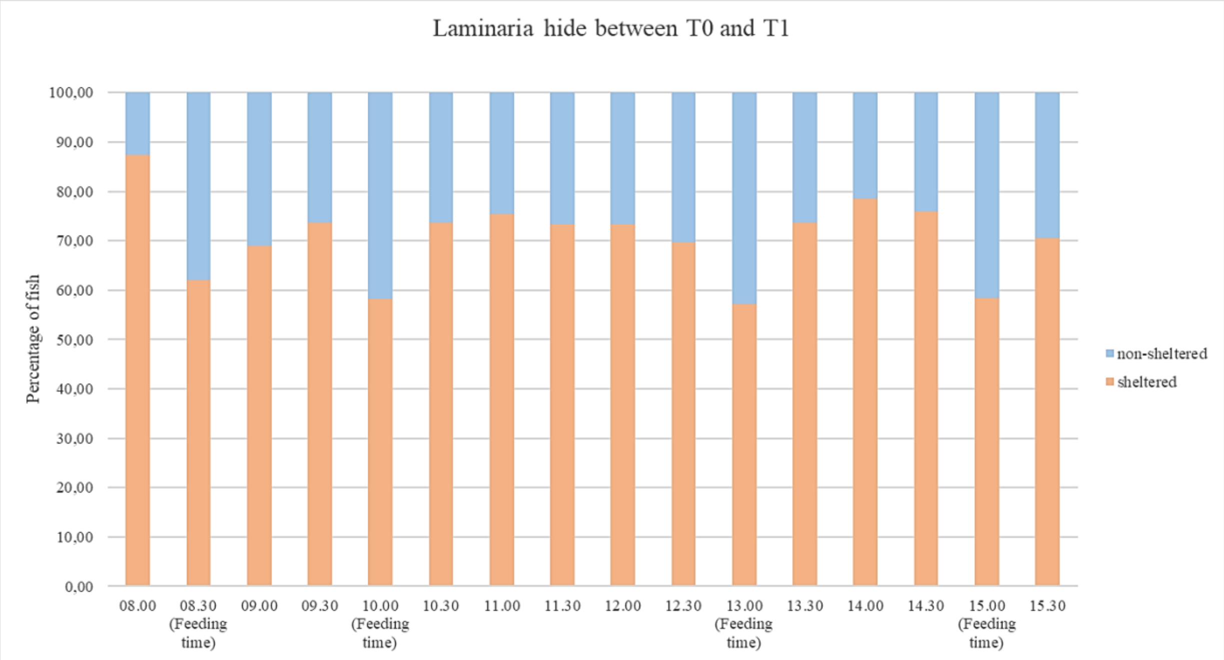

Figure 14. Showing the percentage of “sheltered” fish and “non-sheltered” fish for the Laminaria hide between 08.00 to 15.30 between T0 and T1. N = 5 days monitored this period.

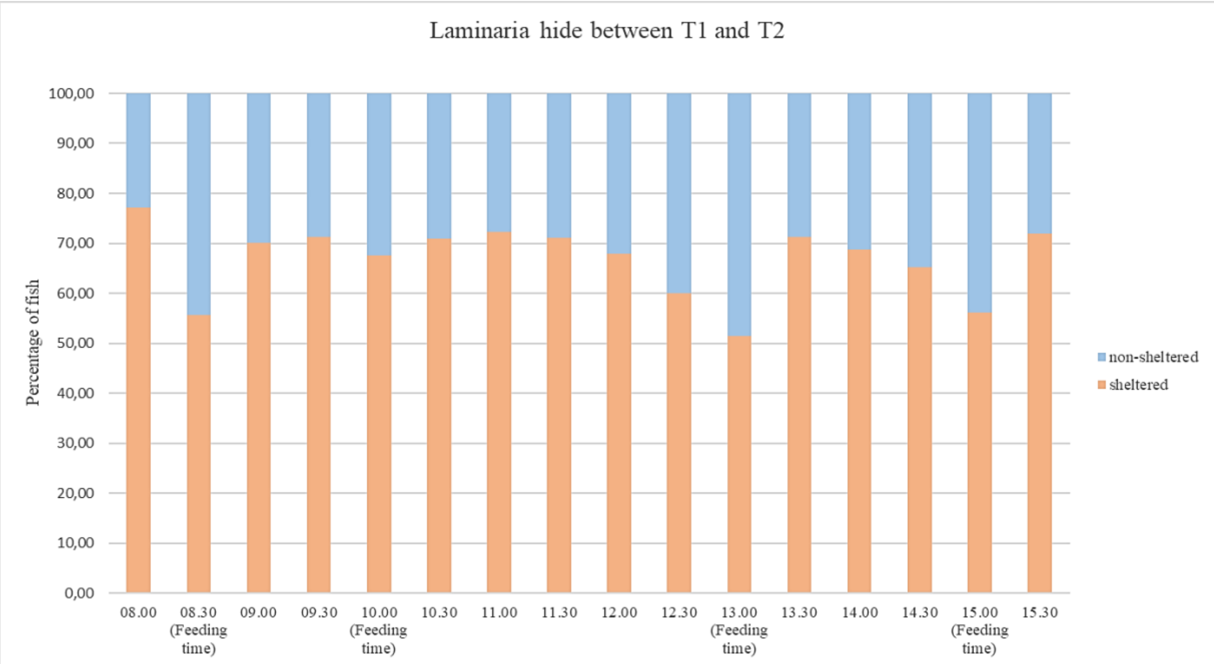

Figure 15. Showing the percentage of “sheltered” fish and “non-sheltered” fish for the Laminaria hide between 08.00 to 15.30 between T1 and T2. N = 20 days monitored this period.

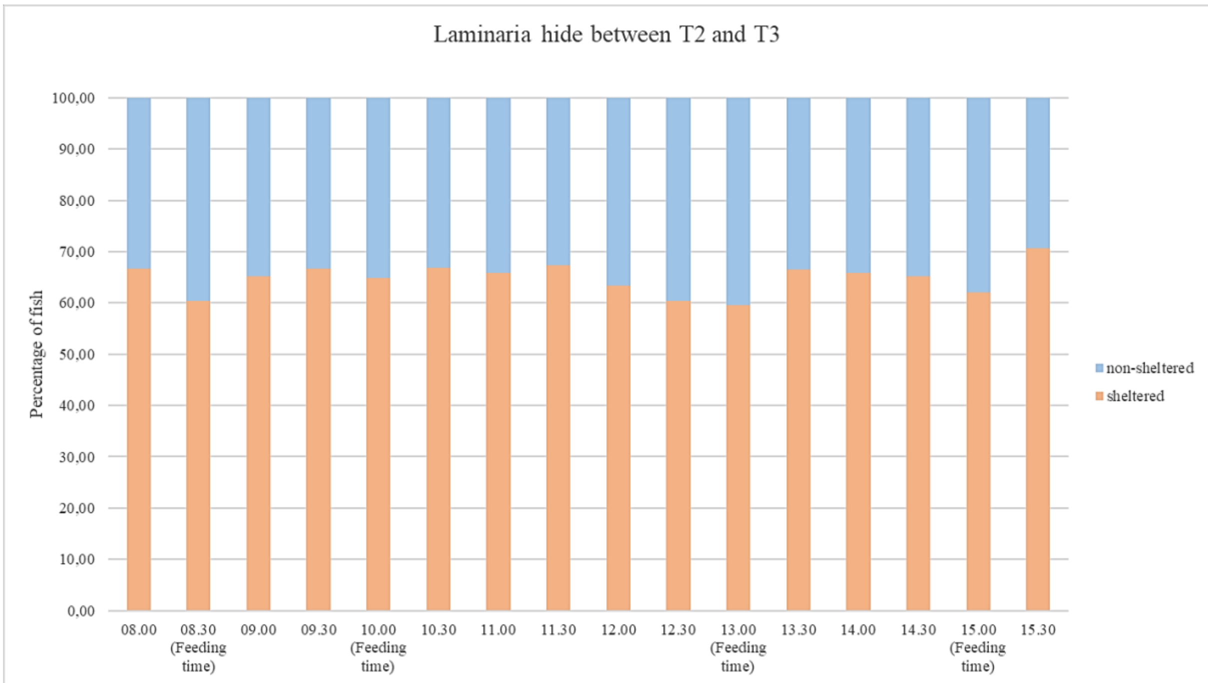

Figure 16. Showing the percentage "sheltered" fish and "non-sheltered" fish for the Laminaria hide between 08.00 to 15.30 between T2 and T3. N = 14 days monitored this period.

One-way ANOVA test conducted with included time (Table 6 in section 2.3) followed by a Tukeys test showed a significant difference between *Saccharina* hide and *Laminaria* hide after 2 months. While after 3 months one-way ANOVA test followed by a Tukeys test showed a significant difference between the *Saccharina* hide and the artificial hide.

Regardless any difference, results show clearly in every period that fish preferred to utilize the provided hide, which is indicated by the high percentage of "sheltered" fish during T0-T1, T1-T2 and T2-T3 shown from Figure 8 (p. 22) to Figure 15 (p. 25). The high percentage of "sheltered" fish seems to spend most time resting and hiding in the provided hide, while waiting for feed, indicated by the increase in "non-sheltered" fish during feeding times.

2.2. General observations

During the acclimatization, it was observed one dead fish. This fish lacked the entire caudal fin and most of the second dorsal fin. One fish from the *Laminaria* hide group was found dead the day after initiating the experiment. Further, it was no mortalities within the groups during the experiment.

After initiating the experiment, it was observed at day one (personal observations), between two to four fish in each group missing the caudal fin. It was once during the acclimatization, observed by eye, one fish biting another fish in the caudal fin.

The general observations of fish were done according to section 2.3.2 in methods. No lumpfish were observed behaving aggressively against each other. When assessing external damages for each month, the personal observation during the acclimatization was considered, when assessing the fish for external damages in T1, T2 and T3.

3. External damages

3.1. Caudal fin

Caudal fin score was assessed after one, two and three months and are referred as T1, T2 and T3 as shown in Figure 18 (p. 28), Figure 19 (p. 29) and Figure 20 (p. 29) respectively. The control measure that was performed before experiment start (T0) are shown in Figure 17. T0 shows that caudal fin damages were already present in the fish, measured by the score 2 around 20 % and score 3 around 20 %. 65 % of fish had score of 0, which means no damages.

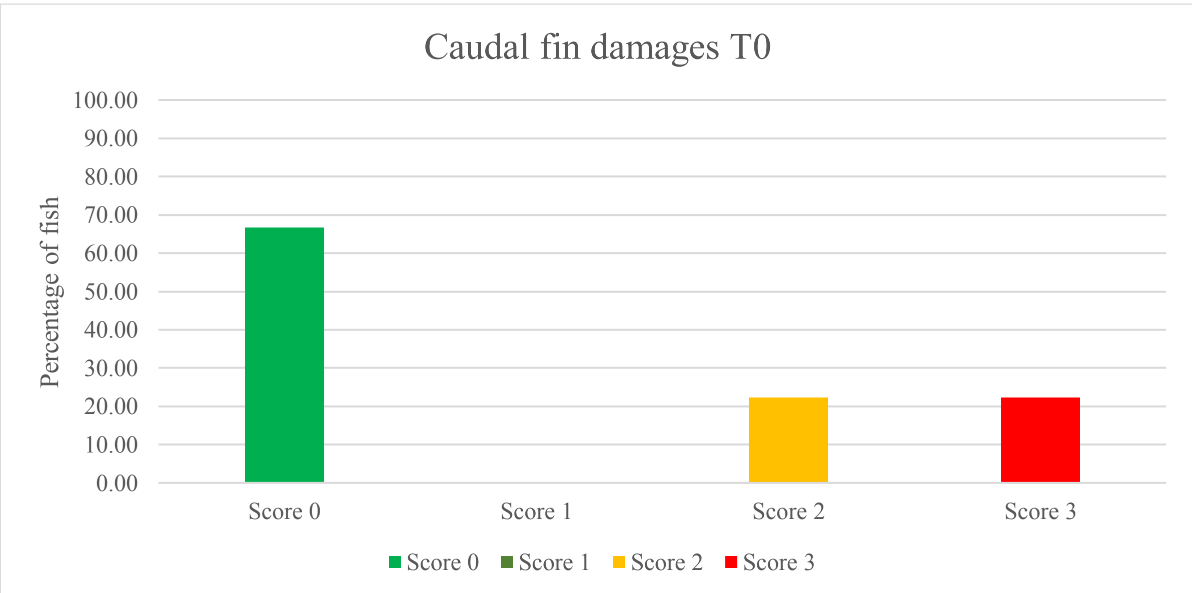

Figure 17. Showing percentage of caudal fin damages in T0. N = 9 fish. From score 0 (no injuries) to 3 (severe injuries).

The different percentages between the groups of the score of caudal fins in T1, are presented in Figure 18. *Saccharina* hide group showed 75 % fish had a score of 0, 10 % fish with score 2, and 5 % fish with score 3. The artificial hide showed a score of 0 in 70 % fish, 45 % fish with score 2 and 5 % fish with score 3. The high percentage of score 2 in artificial hide can indicate that this group had the worst condition of the caudal fin in T1. *Laminaria* hide had 70 % fish with score 0, 20 % fish with score 2 and 5 % fish with score 3. *Saccharina* hide group had the lowest amount of fin damage, while the artificial hide group had the highest amount of caudal fin damage in T1.

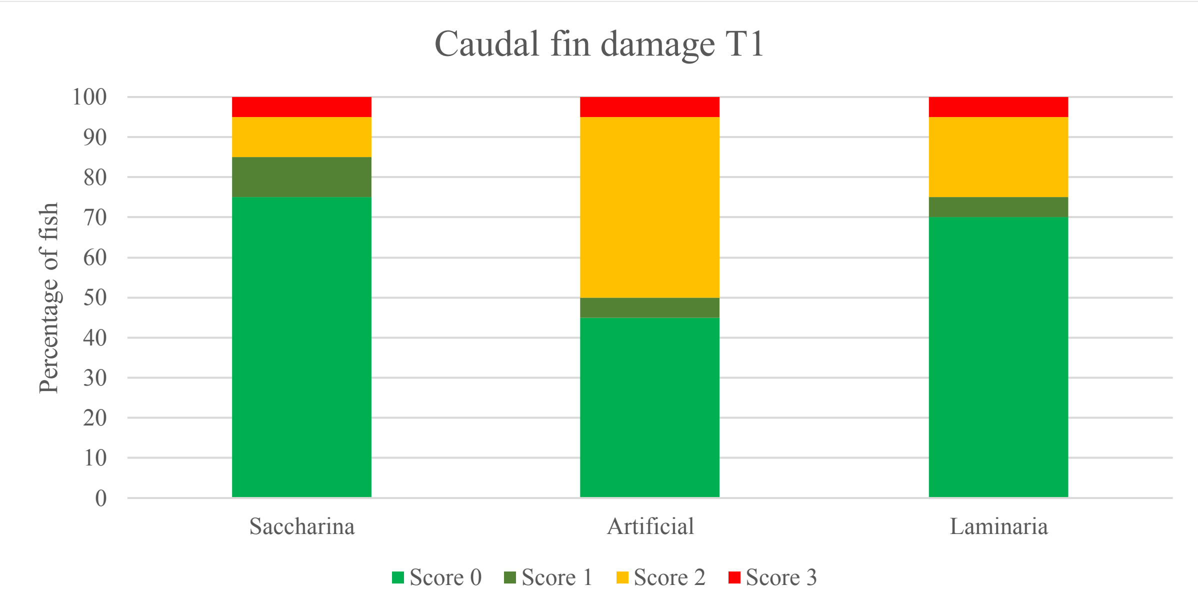

Figure 18. Showing percentage of caudal fin damages in T1 for Saccharina hide, artificial hide, and Laminaria hide groups. From score 0 (no injuries) to 3 (severe injuries).

The percentage of the caudal fin damages in T2 are presented in Figure 19. *Laminaria* hide group showed 65 % fish with score 0 and 35 % fish with score 1, no higher score was observed for this group, indicating that this group had the lowest amount of damage in T2. Artificial hide group showed 40 % fish with score of 0, 45 % fish with a score of 1, 5 % fish with score 2 and a score of 3 in 10 % fish. While *Saccharina* hide group showed 45 % fish with score 0, 40 % fish with a score of 1, 5 % fish with a score of 2, and a score of 3 in 10 % fish. *Saccharina* hide group, and artificial hide had a similar percentage of the different scores in T2 and indicated fish with most damages for this period.

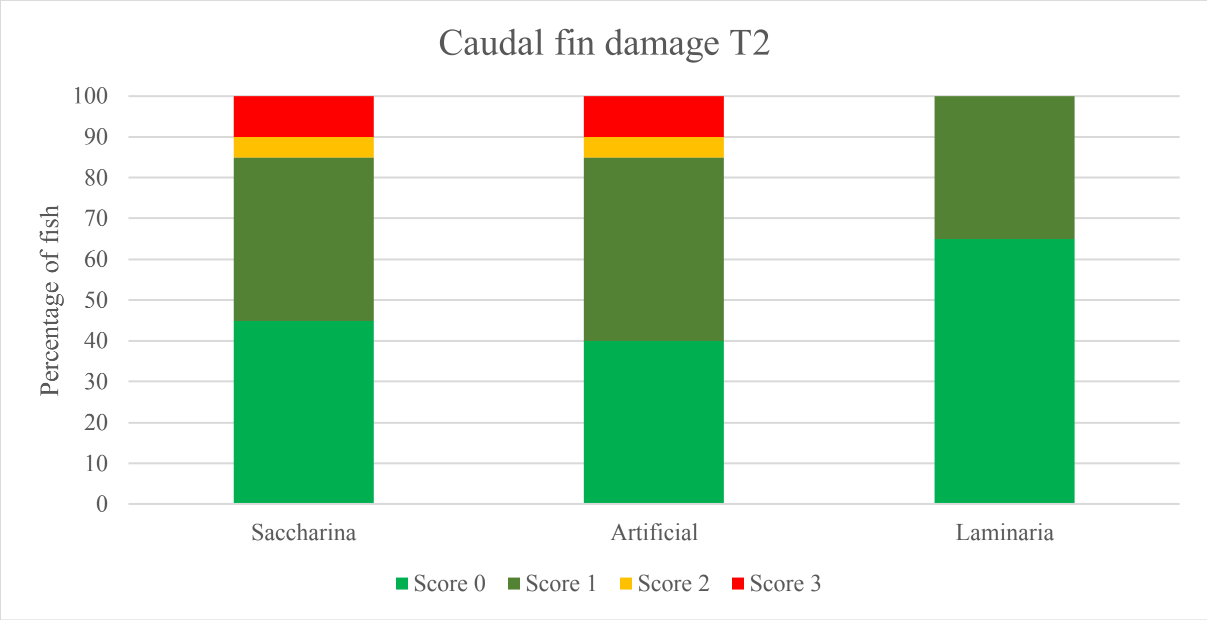

Figure 19. Showing percentage of caudal fin damages in T2 for Saccharina hide, artificial hide, Laminaria hide groups. From score 0 (no injuries) to 3 (severe injuries).

The percentage of caudal fin damage score in T3, are shown in Figure 20. *Laminaria* hide group had the highest score of 0 in 95 % fish, and only 5 % fish with score 3. *Saccharina* hide group was the group with the lowest percentage of score 0 in 35 % fish, 15 % fish with score 2, and a score 1 in 50 % fish. Artificial hide group showed 65 % fish with score 0, 30 % fish with score 1 and 5 % fish with score 3. *Laminaria* hide group was the group with the lowest injuries on the caudal fin, while *Saccharina* hide had the highest amount of fish with injuries in T3.

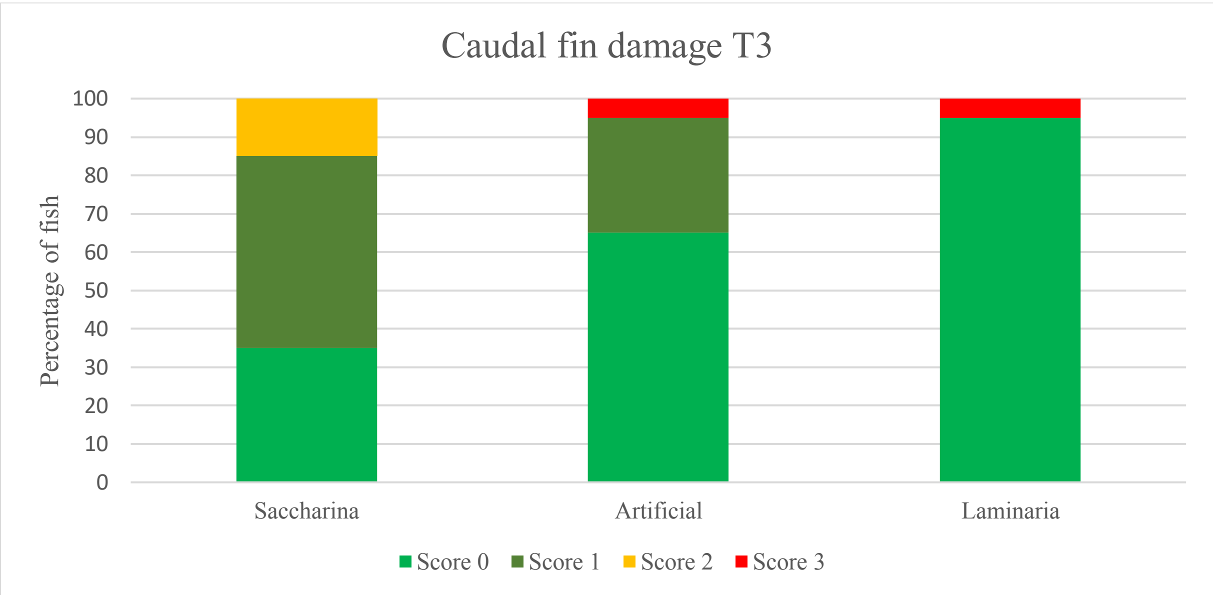

Figure 20. Showing percentage of caudal fin damages in T2 for Saccharina hide, artificial hide, Laminaria hide groups. From score 0 (no injuries) to 3 (severe injuries).

3.2. Other fins

Other fin damage assessed in T1, T2 and T3 are shown in Figure 22 (p.31), Figure 23 (p. 31) and Figure 24 (p. 32) respectively.
The control measure that was performed before experiment start (T0) are shown in Figure 21. T0 shows no damages in other fins (second dorsal, anal, pectoral and pelvic fin). 100 % fish shows a score of 0.

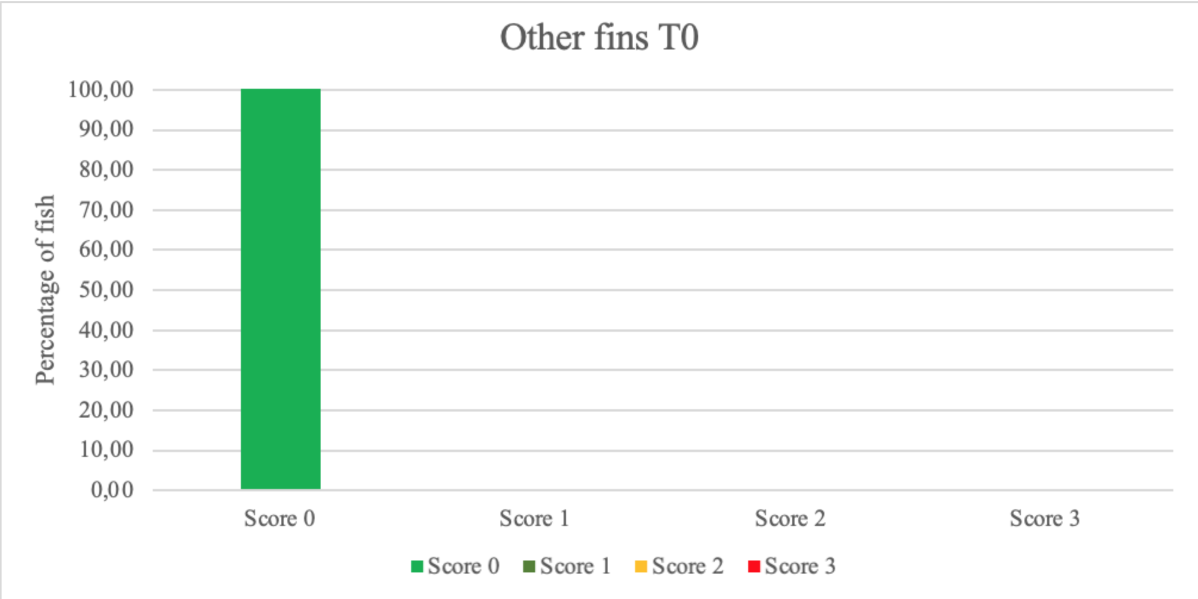

Figure 21. Showing percentage of other fin damages in T0. From score 0 (no injuries) to 3 (severe injuries).

No injuries were observed in T1 for all the three groups (Figure 22). All groups had 100 % fish with score 0.

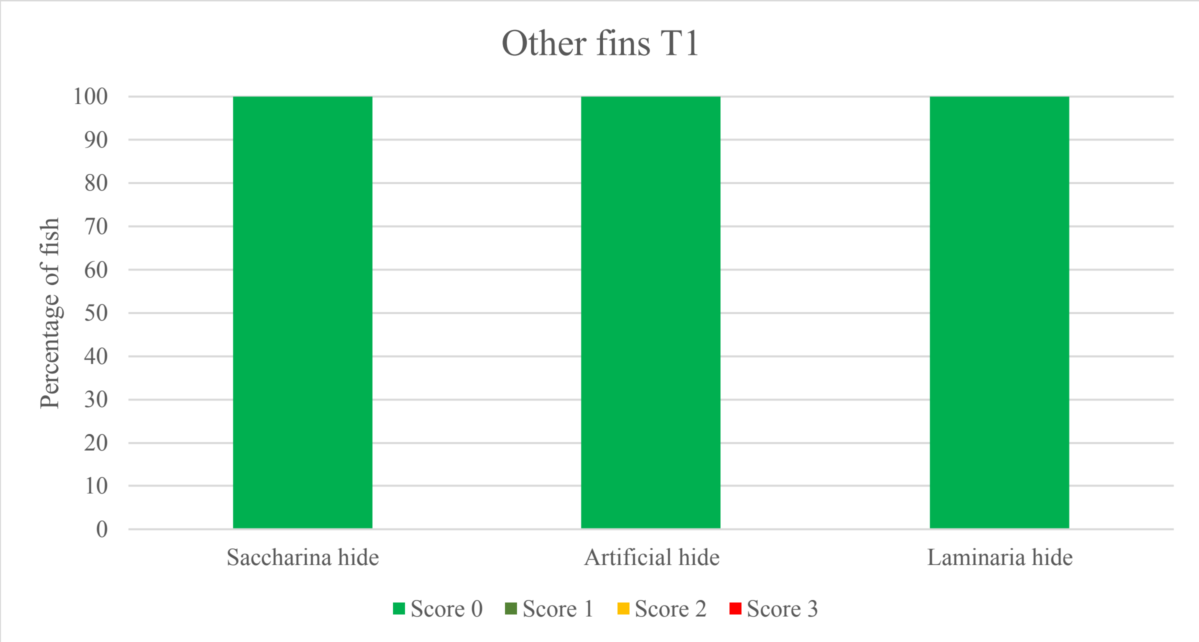

Figure 22. Showing percentage of other fin damages in T1 of Saccharina hide, artificial hide, Laminaria hide groups. From score 0 (no injuries) to 3 (severe injuries).

Figure 23 shows injuries on other fins in T2. *Saccharina* hide group had fish with most injuries with 5% fishwith score 3, 5% fish with score 2, and 10% fish with score 1. Fish in artificial hide group had 5% fish with score 3, and 10% fish with score 1. Fish in L*aminaria* hide group had 5 % fish with injury of score 1 and the rest of the fish had no injuries.

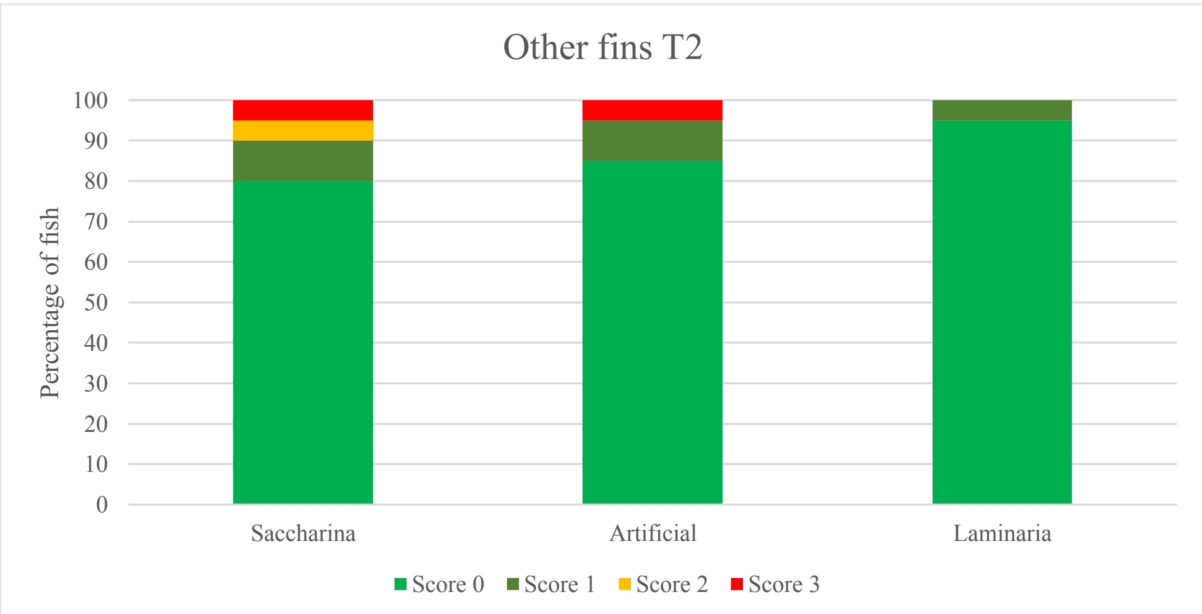

Figure 23. Showing percentage of other fin damages in T2 of Saccharina hide, artificial hide, Laminaria hide groups. From score 0 (no injuries) to 3 (severe injuries).

Figure 24 shows other fin damages observed in T3. It was observed 5% of score 3, and 5% of score 2 in fish from *Saccharina* hide group. Fish in artificial hide had 5% injuries of score 2, while it was not observed any injuries in fish in *Laminaria* hide group.

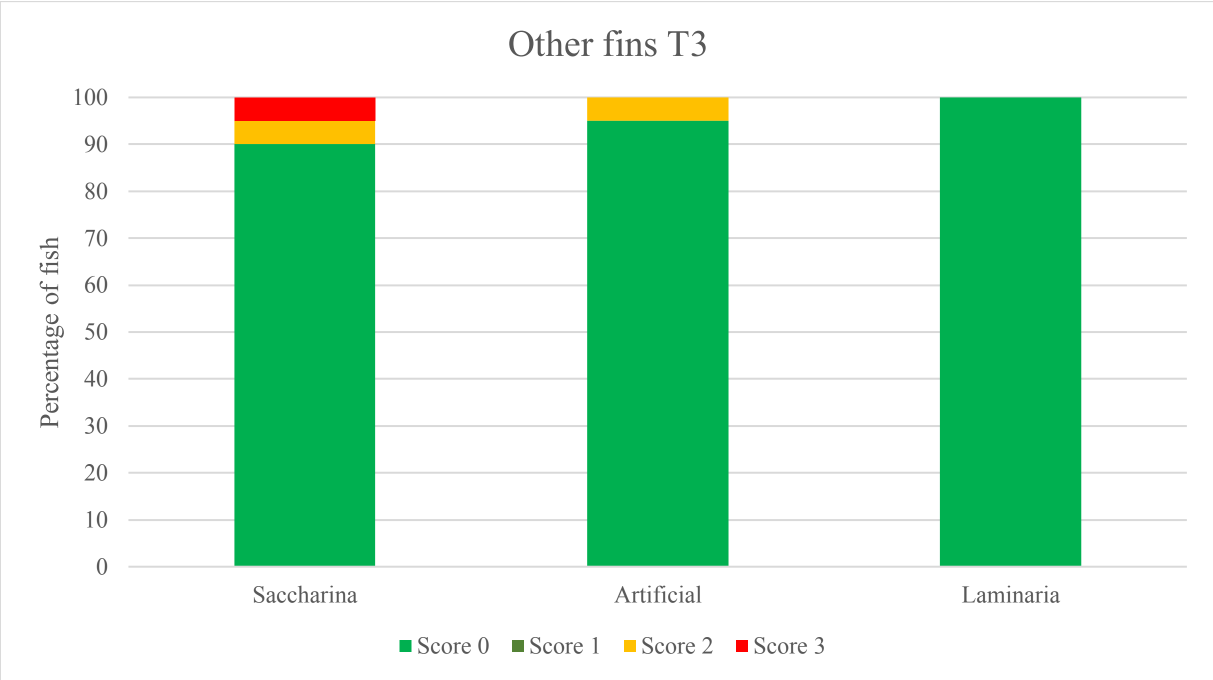

Figure 24. Showing percentage of other fin damages in T3 of Saccharina hide, artificial hide and Laminaria hide groups. From score 0 (no injuries) to 3 (severe injuries).

3.3. Epidermal injuries

Epidermal injuries for T1, T2 and T3 are shown in Figure 26 (p. 33), Figure 27 (p. 34) and Figure 28 (p. 34).

Figure 25 shows epidermal injuries observed in T0. No fish had score between 1-3 and hence 100 % of the fish were grouped in score 0, showing that there were no epidermal injuries on the fish from T0.

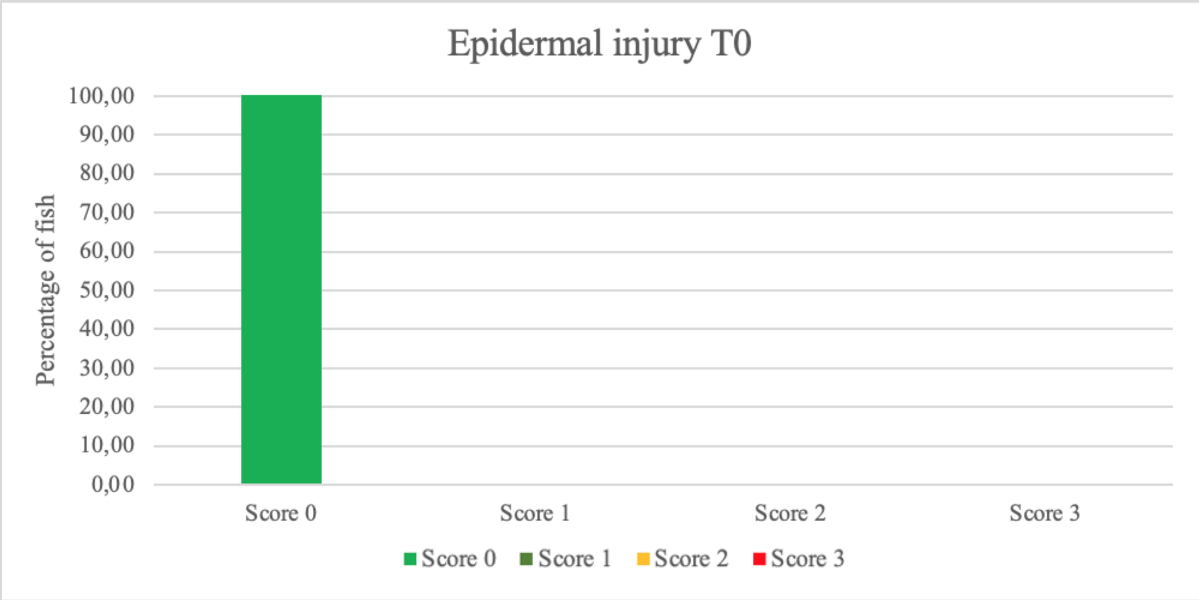

Figure 25. Showing percentage of epidermal injury in T0. N = 9. From score 0 (no injuries) to 3 (severe injuries).

Figure 26 shows 5% of fish in artificial hide have epidermal injury of score 3, while fish in *Saccharina* hide and *Laminaria* hide show 100 % fish with score 0, indicating no injury in epidermal in *Saccharina* hide and *Laminaria* hide group from T1.

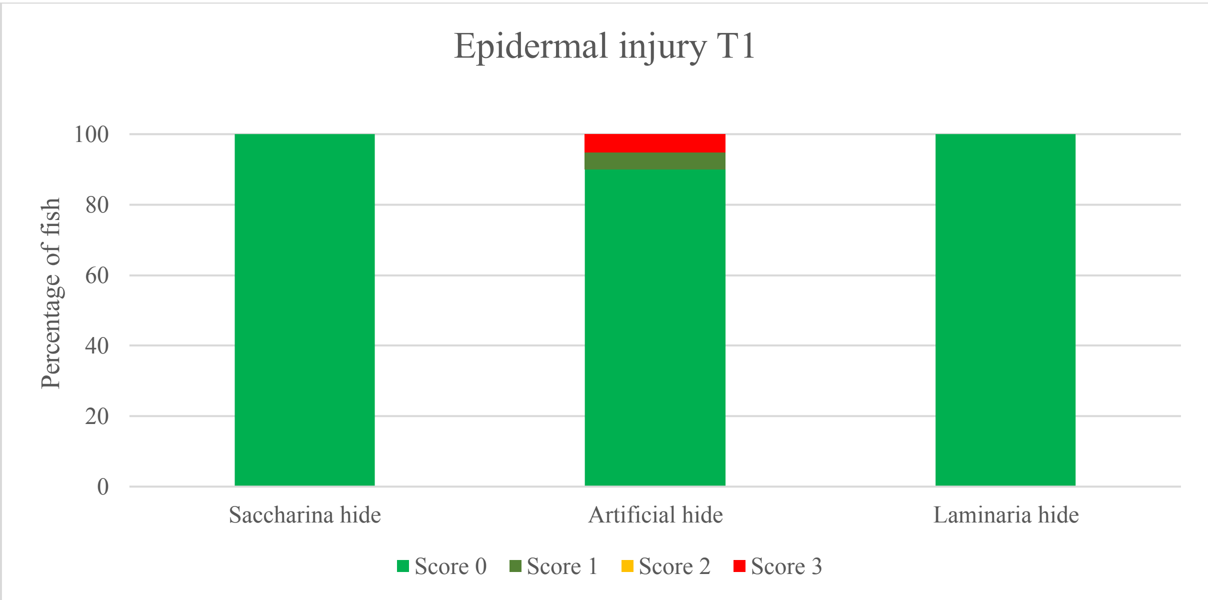

Figure 26. Showing percentage of epidermal injuries in T1 of Saccharina hide, artificial hide and Laminaria hide groups. From score 0 (no injuries) to 3 (severe injuries).

Epidermal injuries are shown in Figure 27. It was only observed 10 % fish in *Saccharina* hide group having a score of 1. The artificial hide and *Laminaria* hide groups showed no injuries with 100 % fish with a score of 0.

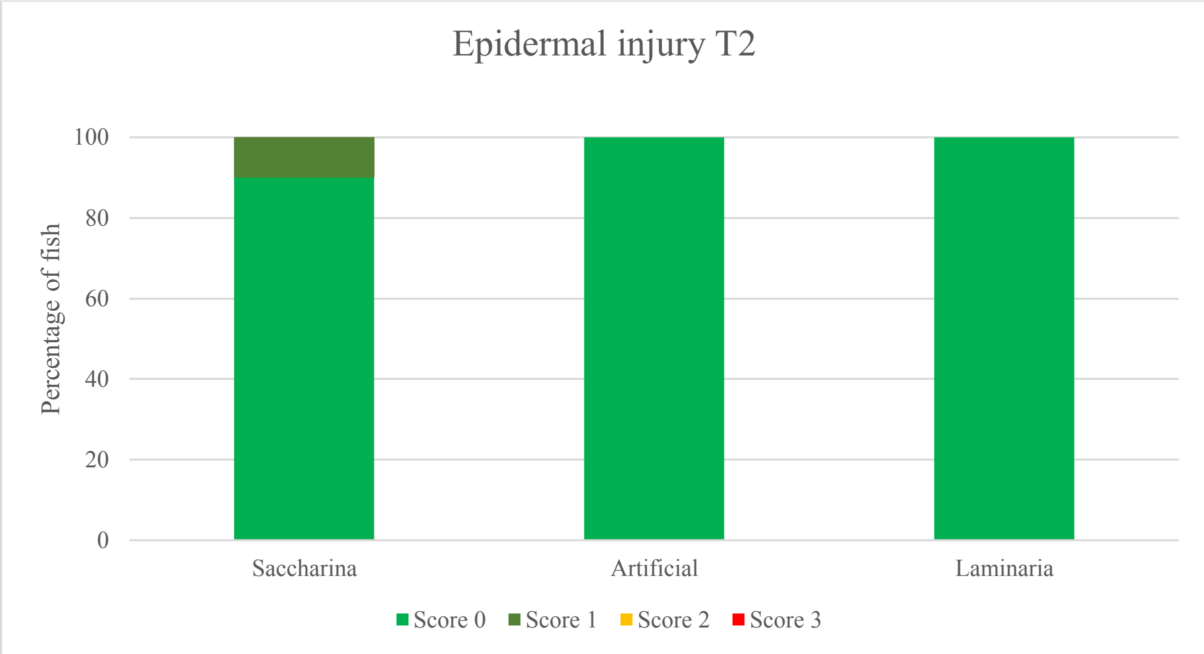

Figure 27. Showing percentage of epidermal injuries score T2, Saccharina hide, Artificial hide and Laminaria hide groups. From score 0 (no injuries) to 3 (severe injuries).

Figure 28 shows all groups in T3 had no score between 1-3 and hence 100 % fish were grouped in score 0, showing no epidermal injuries on the fish from T3..

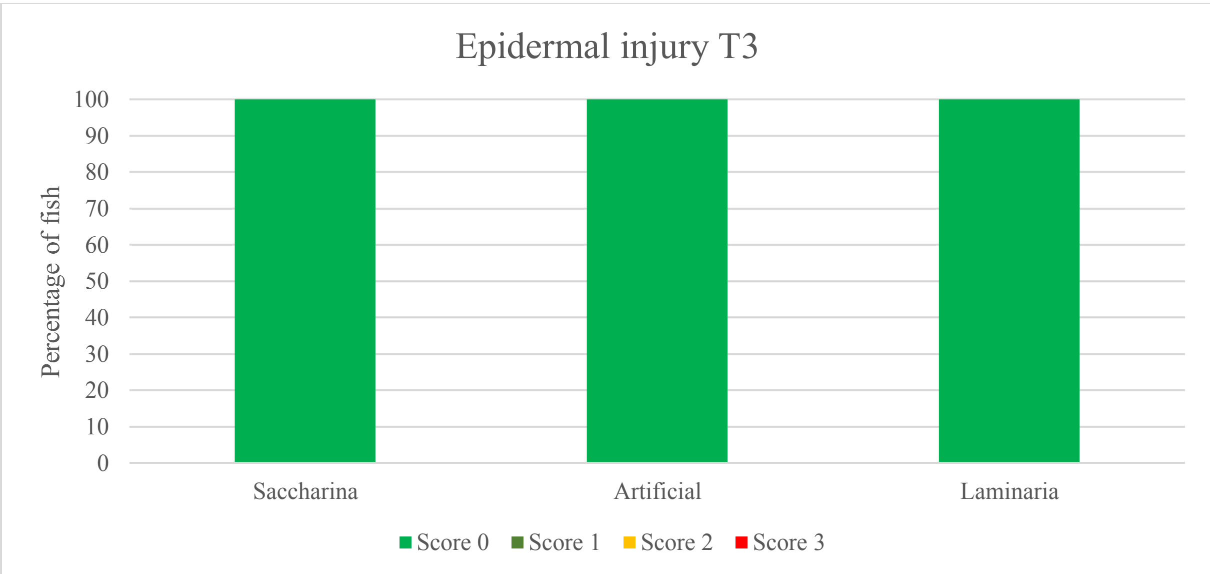

Figure 28. Showing percentage of epidermal injuries score T3, Saccharina hide, Artificial hide and Laminaria hide groups. From score 0 (no injuries) to 3 (severe injuries).

3.4. Cataracts

Cataract formation in fish in T1, T2 and T3 are shown in Figure 30 (p. 36), Figure 31 (p. 36) and Figure 32 (p. 37).

Figure 29 shows 100 % fish with score 0, indicating no cataracts in fish in T0.

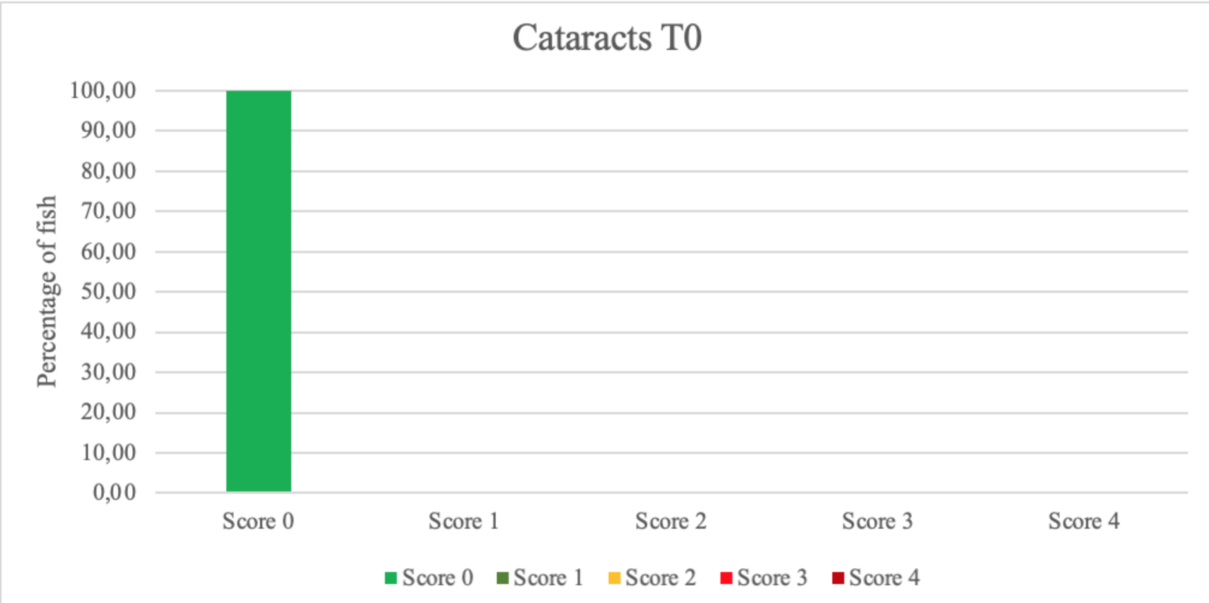

Figure 29. Percentage of cataracts in T0. N = 9. From score 0 (no injuries) to 3 (severe injuries).

Figure 30 shows cataract formation with 5 % fish of with score 1 from the *Saccharina* hide group. Artificial hide and *Laminaria* hide groups shows 100 % fish with 0 score, indicated no cataracts in T1.

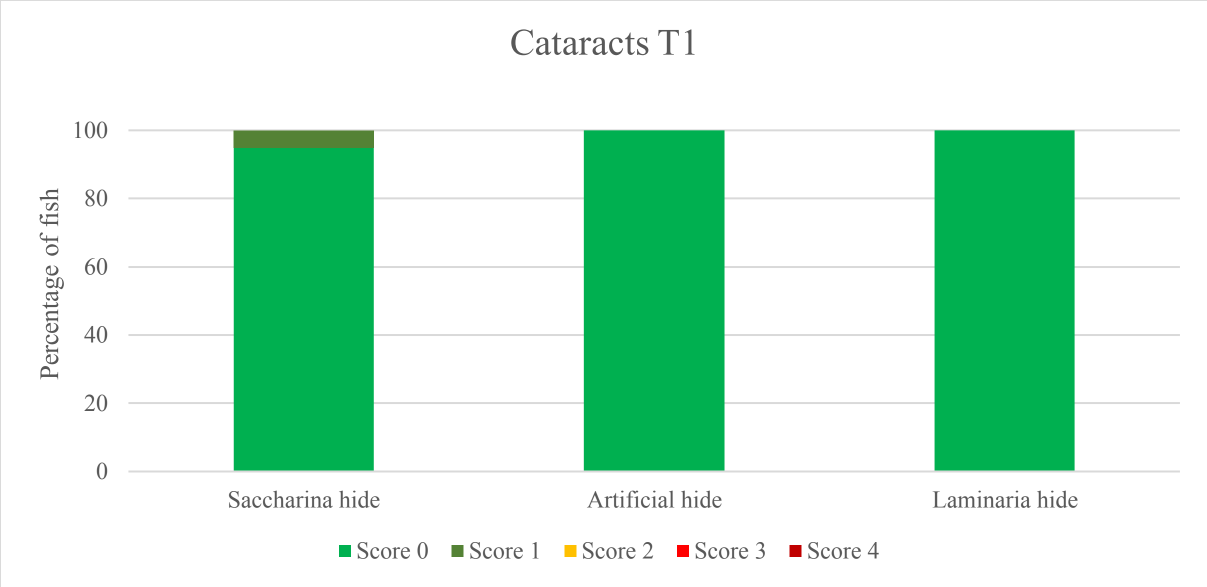

Figure 30. Showing percentage of cataracts in T1 of Saccharina hide, artificial hide and Laminaria hide groups. From score 0 to score 4..

Figure 31 shows that the *Saccharina* hide, artificial hide and *Laminaria* hide groups had 100 % fish with score 0, indicating no cataracts in the three different groups in T2.

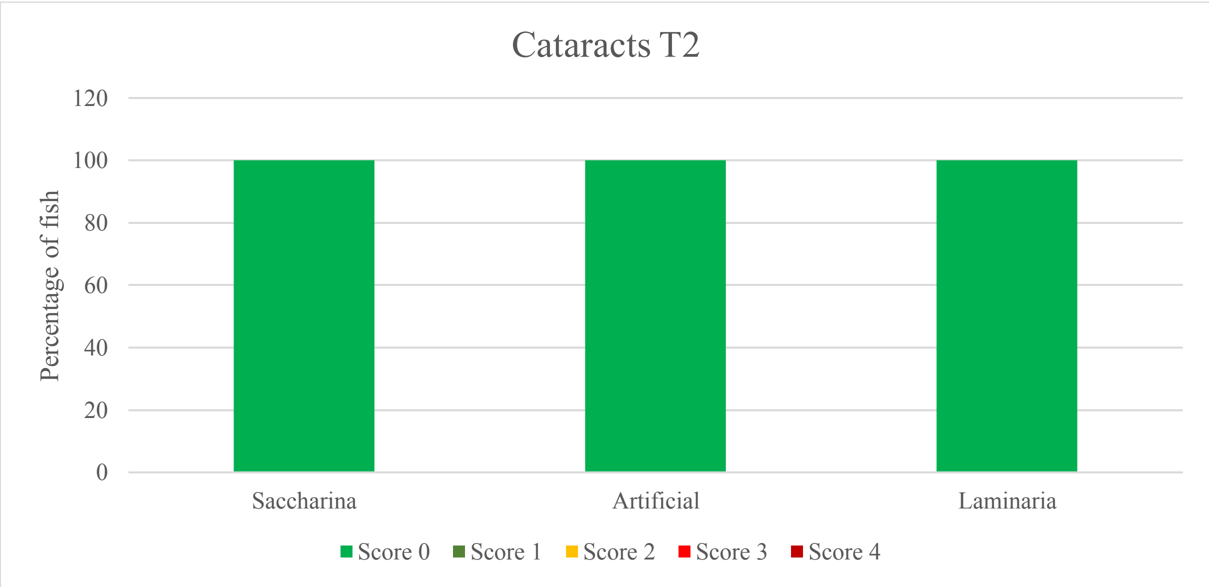

Figure 31. Showing percentage of cataracts in T2 of Saccharina hide, artificial hide and Laminaria hide groups. From score 0 to score 4.

Figure 32 shows that it was observed 5% fish with score 3, and 5% fish with score 1 in *Saccharina* hide group in T3. It was observed cataracts of score 2 in 5% fish in the artificial hide group, and no cataracts in *Laminaria* hide group in T3.

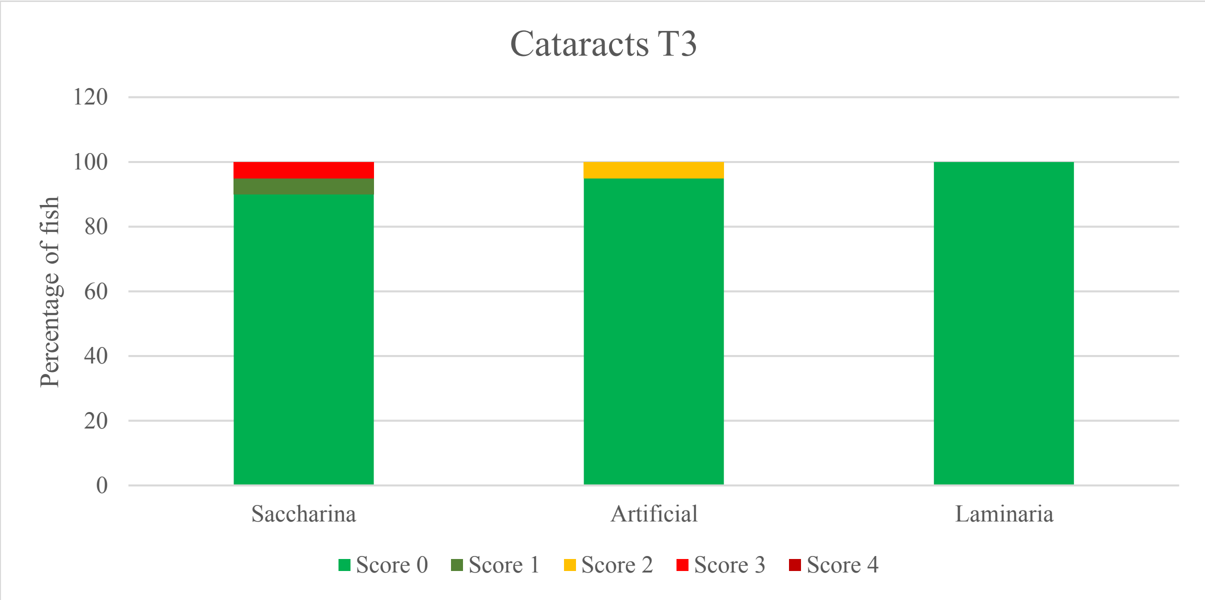

Figure 32. Showing percentage of cataracts in T3 of, Saccharina hide, Artificial hide and Laminaria hide groups. From score 0 to score 4.

3.5. Suction disc deformities

Suction disc deformities in T1, T2 and T3 are shown in Figure 34 (p. 38), Figure 35 (p. 38) and Figure 36 (p. 39).

Figure 33 shows 100 % fish with score 0, meaning no suction disc deformities in fish in T0.

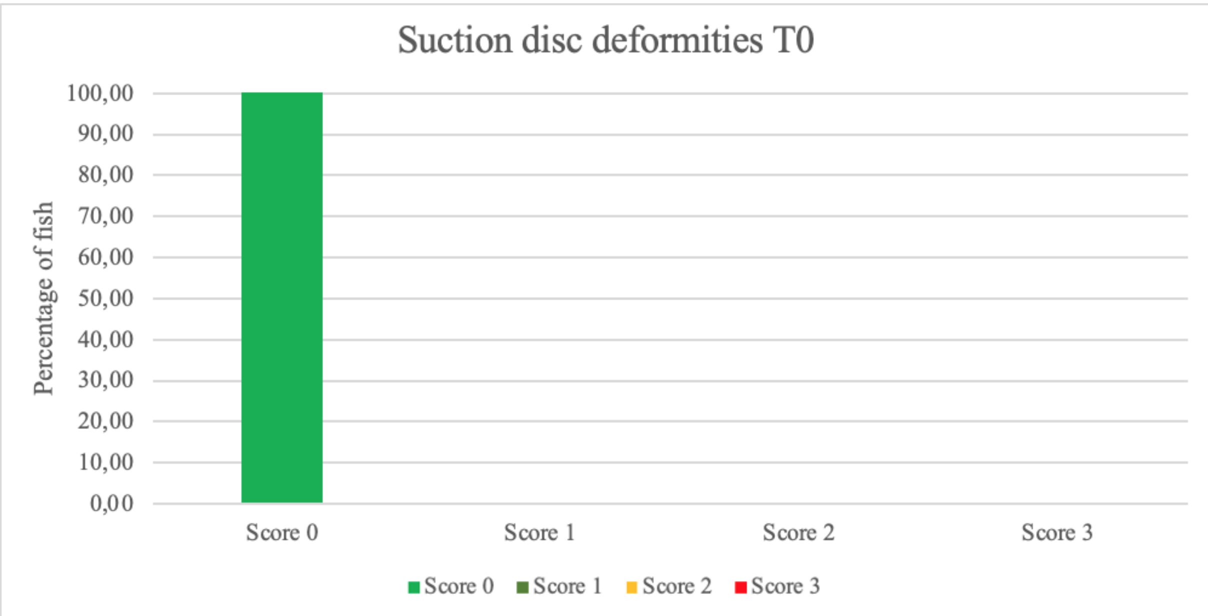

Figure 33. Percentage of score in suction dic deformities in T0. N = 9. From score 0 (no injuries) to 3 (severe injuries).

Figure 34 shows 5% fish with score 1 in *Saccharina* hide, and 5% fish with score 2 in artificial hide. *Laminaria* hide show 100 % fish with score 0, and no suction disc deformities were observed in *Laminaria* hide group (Figure 34).

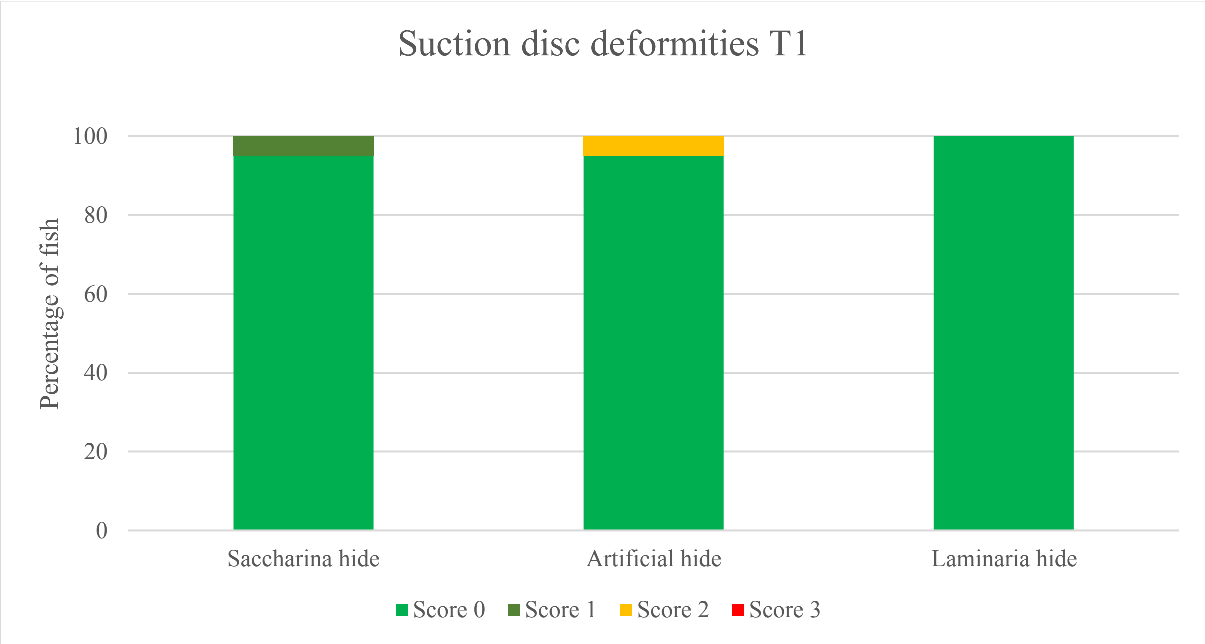

Figure 34. Showing percentage of suction disc score in T1 of Saccharina hide, artificial hide and Laminaria hide groups.From score 0 to score 3.

Figure 35 shows all groups had 100 % fish with score 0, indicating no fish in T2 had suction disc deformities.

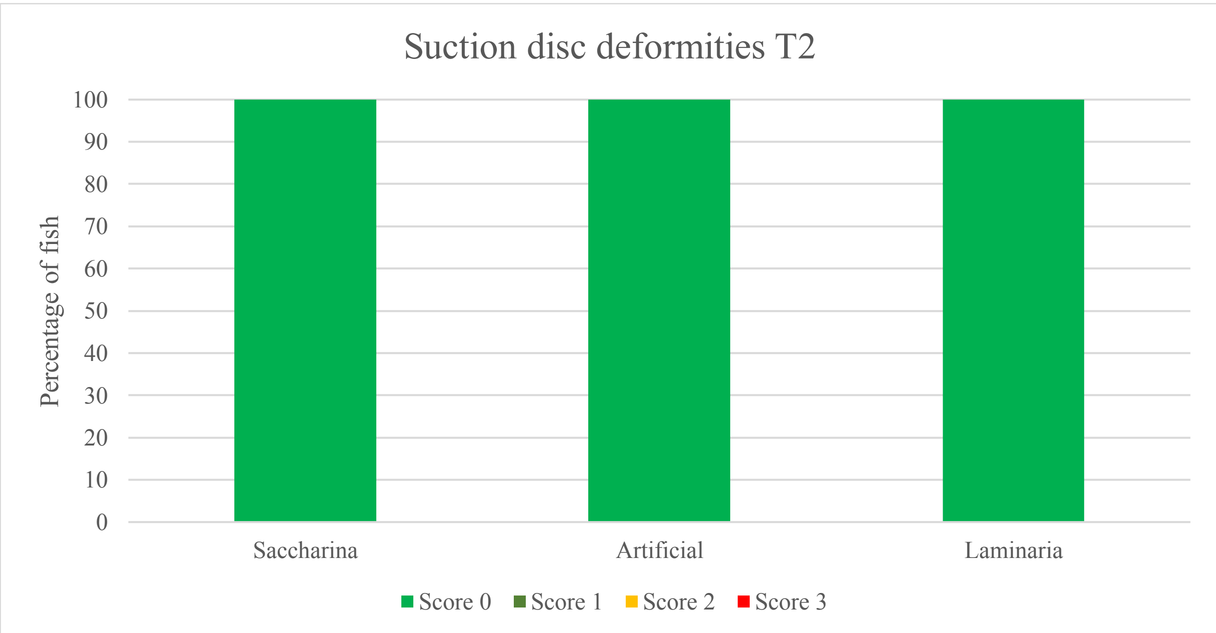

Figure 35. Showing percentage of suction disc in T2 of Saccharina hide, artificial hide and Laminaria hide groups. From score 0 to score 3.

Figure 36 shows 5% fish with score 1 in *Laminaria* hide, while *Saccharina* hide and artificial hide had 100 % fish with score 0.

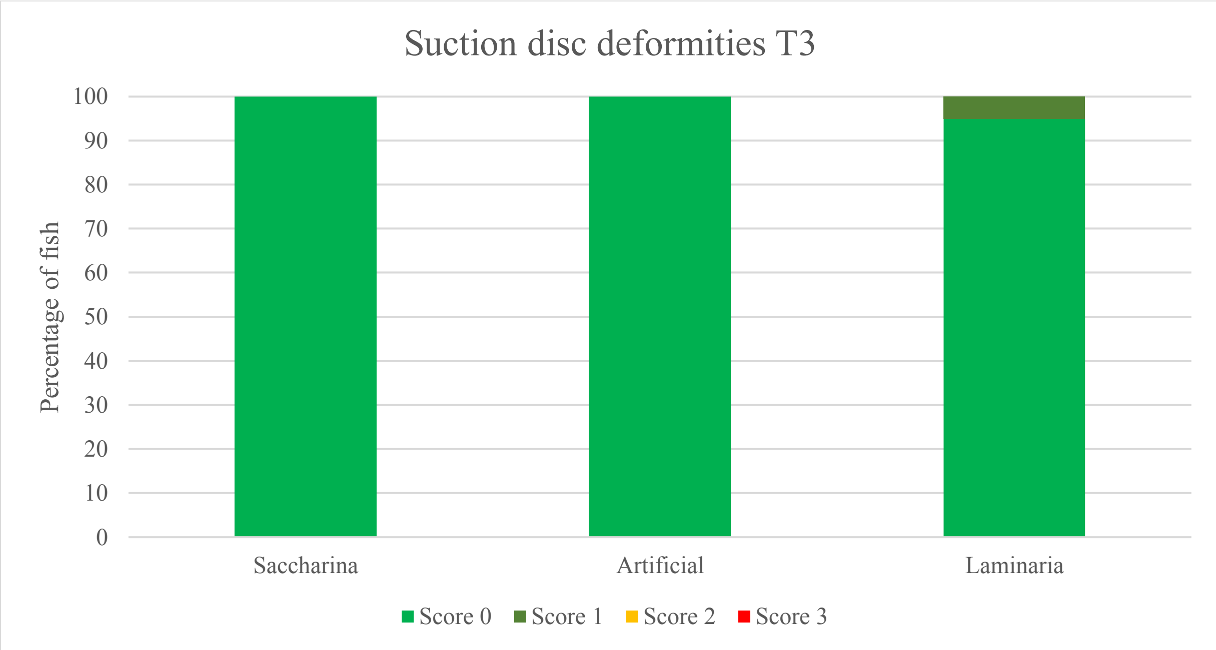

Figure 36. Showing percentage of suction disc score T3, Saccharina hide, artificial hide and Laminaria hide. Score 0 to score 3.

A Kruskal-Wallis test followed by a Mann Whitney test was performed on the total injuries and deformities observed and revealed significant difference between the *Saccharina* hide and the *Laminaria* hide in T3. There were no significant differences on total injuries in T1 and T2

4. Environmental parameters

Eleven weeks with data of dissolved oxygen saturation, salinity and pH values were missing when exporting the data from the Pacific data log. The average dissolved oxygen, pH and salinity are reported in methods section 2.5 p. 15. The data log is only showing data log for the last five weeks when exported out. Water temperature measured with temperature recorder Tinytag Aquatic 2 - TG-4100 temperature logger did record data every day from acclimatization and experimental period. In this experiment, the amount of withe light was adjusted to a sufficiently low level, average of 5 µmol/m^{-2}/s^{-1}, to achieve optimal camera pictures. Environmental parameters in this experiment indicates that the experiment went well, and these factors are not considered to be a problem for the welfare of the fish.

5. *Saccharina latissima*

The cultivated *S. latissima* were preliminary trials along with the lumpfish experiment. The cultivation was performed with the idea of using cultivated *S. latissima* as seaweed hides along with lumpfish. In addition for future work, to contribute with nutrient recycling of fish waste and increased growth of macroalgae in integration with the fish.

5.1. *S. latissima* Trial 1.

The mean temperatures, salinities and pH for trial 1 are shown in Appendix Table 7, Table 8, Table 9 and 10. Average light measured right above the surface of the experimental tank was 50 µmole m^{-2} s^{-1}. Because of overgrowth of other algae/epiphytes on the seeded spores, and an attempt to increase the concentration of the *S. latissima*, the coils from tank 1 and tank 2 were assembled in tank 2 (Figure 37).

Figure 37. S. latissima trial 1, tank 1 and 2 assembled at day 63. Attempt to increase concentration of S. latissima, due to overgrowth of other algaes/epiphytes.

The spores in trial 1 stayed under 1 cm for the whole monitoring, with an exception after the trial ended, shown in (Figure 38). On day 87 of the monitoring, it was decided to stop the trial of the seaweed due to too much contamination, making it impossible for the spores to grow. Two weeks later, it was noticed that the spores had grown past the contamination and developed leaves, and they had grown a few cm. One of the leaves that were brought back to the lab had grown 5.5 cm (Figure 38). The monitoring of water parameters was followed once a week, checking salinity and temperature (Appendix Table 10).

Figure 38. Left picture: S. latissima at day 102 (Week 14). Showing small leaves grown after ended trial. Right picture: S. latissima at day 102 (Week 14). One of the leaves were collected to measure the length. Showing 5.5 cm long.

Figure 39 hows the growth trend of the spores monitored twice a week. The trend is not showing any specific exponential increase in growth. One day, the spore could be larger than the next monitoring, collecting a smaller spore. The size varied, and furthermore, the trend is therefore not exponential. This trial was in the end terminated and was not placed out in the sea.

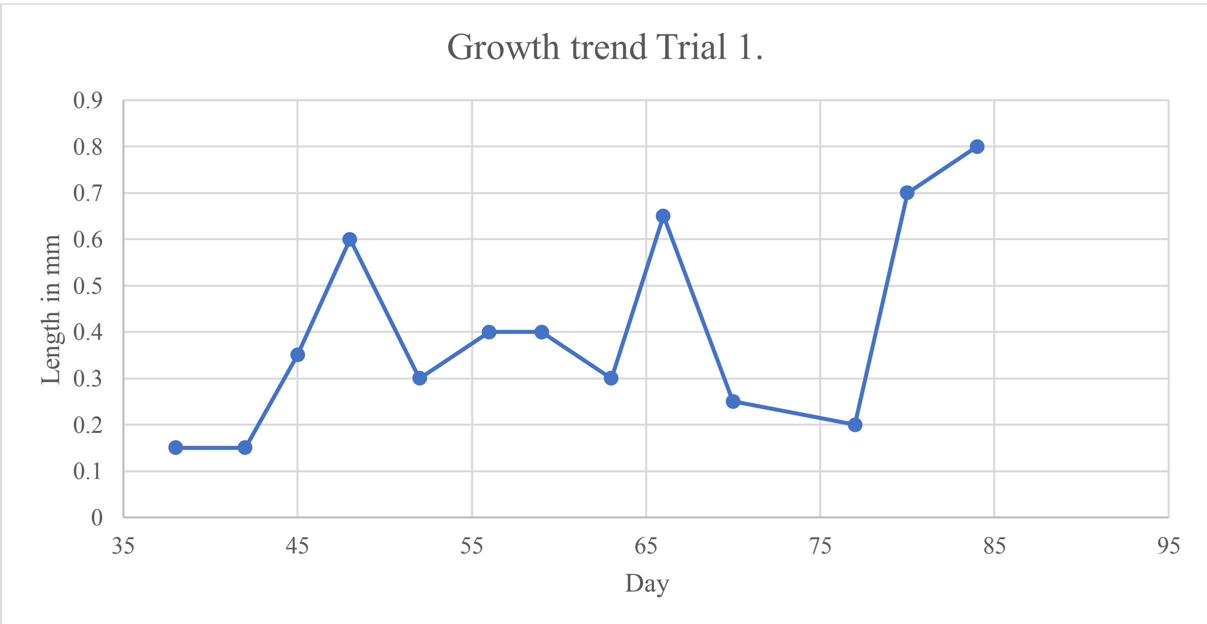

Figure 39. Randomly collected spores of S. latissima every week. Following a growth trend of the seaweed.

5.2. *S. latissima* Trail 2.

The mean temperature, salinity, and pH are shown in Appendix Table 11. Average light measured right above the surface of the experimental tank was 50 µmol m^{-2} s^{-1}. Figure 40. Shows the growth of *S. latissima* after seven weeks.

Figure 40. Left picture: S. Latissima at day 49 (Week 7). Showing growth on all coils placed out in the tank. Right picture: showing S. Latissima at day 49 (Week 7) closer look at the growth of leaves on the rope.

The light, which was turned on two weeks after seeding the spores, was by mistake set to 23 h light and 1 h dark. This was noticed and changed to 8 h light and 16 h dark one month later.

Examination of the graph trend shows an increase in the growth of the spores, growing exponentially (Figure 41). This is only a growth trend, and the graph may appear different if parallels were taken.

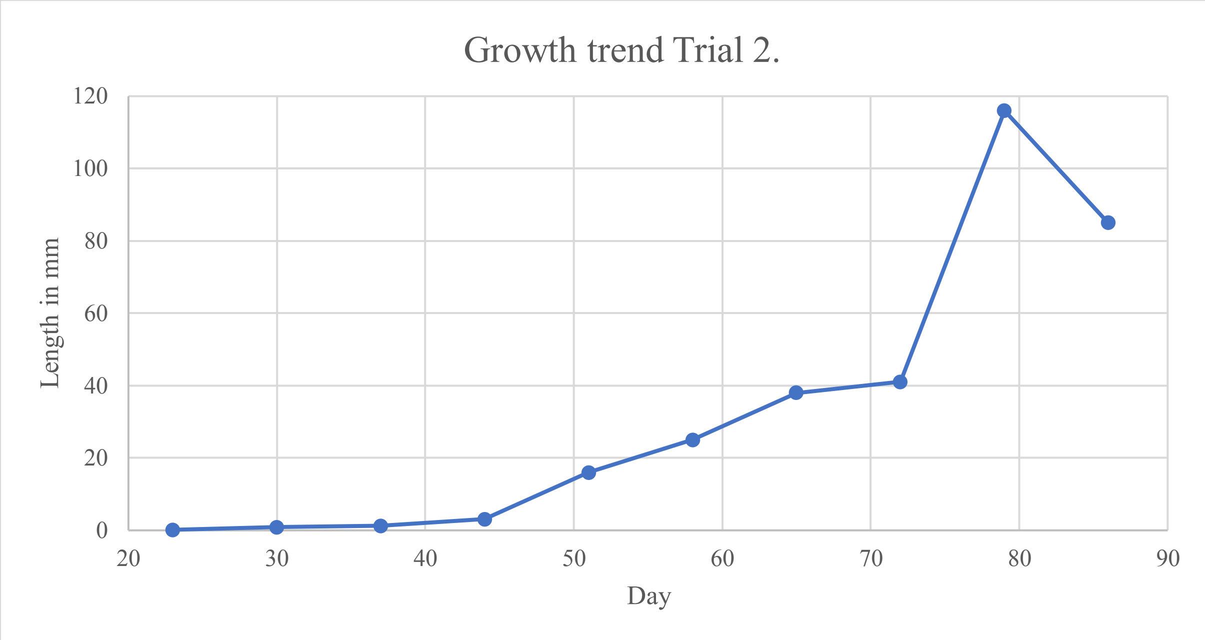

Figure 41. Random collected spores/leaves of S. latissima every week. Following a growth trend of the seaweed.

After monitoring of the cultivated seaweed was finished. The *S. latissima* from trial 2 was placed out in the ocean at Kvitsøy for future monitoring of growth. Figure 42 shows how the cultivated seaweed are being thread around a bigger rope and placed out in the sea.

Figure 42. S. latissima trial 2. Placed out in the ocean at Kvitsøy, Norway after day 89 of monitoring the growth. Cultivated seaweed are thread around a bigger rope, before placed out in the sea. Photo: Sunniva Vedvik

IV. Discussion

To the authors knowledge, there are few papers regarding lumpfish substrate preference, and no studies of natural seaweed. It have been studies of material types and different artificial hides (Section 4 in introduction p. 5). In this study the tertiary responses to stress; body condition, behaviour and external damages was assesed in order to draw a conclusion if there is any differences in fish welfare living along with seaweed.

1. Condition factor

The condition factor of fish in every group was insignificant different for every months (T1, T2 and T3) assessed. All groups included control group were concluded to be in a good nutritional condition (Table 8 p. 20), and could be compared to the condition factor of Imsland et al., (2018) of 2.6 to 4.2 reported earlier. Brooker et al., (2018) have stated that given the different body form, the typical ranges recorded for lumpfish (4-4.5) are much higher than in most teleost

It was observed size differences in every group, when comparing the individuals to tank mean. Differences showed fish being bigger than the rest, and fish being smaller (Appendix Table 4, Table 5 and Table 6). It has been suggested that the difference might contribute to hierarchies related to feeding and space availability, caused from bigger fish swimming freely around in the tank, dominating feeding stations (T. M. Jonassen et al., 2018, p. 130). Here, experiments showed that a possible hierarchy did not affect the condition factor in the fish since all fish were in a good nutritional condition, indicated by the values from 6.10 to 6.78 the whole experimental period. Thus, it could still have an impact on the external damages observed.

2. Lumpfish behaviour

2.1. Lumpfish behaviour

The highest percentage of fish observed in every group for every period was the "sheltered" fish with mean percentage values shown in Table 9 p. 21, indicating that all groups utilized the hide provided during the day. Treasurer et al., (2018) have reported that if lumpfish can choose, they prefer to hide inside or under pipes or hides rather than to be in open spaces. Here, there were significant difference in percentage of fish “sheltered” between *Saccharina* hide and *Laminaria* hide after two months. While after three months, there were significant difference between the *Saccharina* hide and the artificial hide. Results varied between periods, thus different behavior and fish observed “sheltered” could not be concluded for each habitat. Further studies need to be conducted in order to conclude difference between natural and artificial seaweed.

The percentage of fish observed “non-sheltered” includes fish who are swimming and resting on the tank wall or on the floor. Some fish did rest on the tank wall or on the floor instead of in the hide, and could have different surface preferences. Imsland et al., (2015) studied different substrate types (concrete tube, car tyre, stone substrate, and two size of plastic plates), and concluded that lumpfish easily adhered to smooth, plastic surfaces, instead of the natural surfaces, for instance stone substrates and seaweed. Although the authors did not provide natural seaweed, these findings could explain the fish observed on the smooth, plastic wall or floor in the tank, not utilizing the hide provided. The percentage of “sheltered” fish (Table 9 p. 21) decreased slightly after three months (316 days old) compared to one and two months. This result can indicate that as the fish that are growing bigger, it might have other preferences for surfaces. Lusedata (2017) have observed larger lumpfish (60 g +) that prefered to adhere to more rigid surfaces to rest on. The observations could be comparable with the decrease in percentage of “sheltered” fish after three months, assuming that larger fish might prefer the walls or the floor for better support when resting. Another assumption for the decrease in percentage of “sheltered” fish after three months could be because the fish are getting older, and are becoming more pelagic. Litteratures states that juvenile lumpfish are found attached and floating among seaweed during their first year, and around one year after hatching, as they are getting older, they are becoming more pelagic (Ingólfsson & Kristjánsson, 2002).

The data of “sheltered” versus the “non-sheltered” fish, from Figure 8 (p. 22) to Figure 15 (p. 25) shows an increase in the percentage of ”non-sheltered” fish in every group during feeding times, which could be assumed to be a type of foraging mode of the fish. Killen et al., (2007) have suggested that juvenile lumpfish forage in a manner that reduces activity and conserves space in their limited aerobic scope. The author noted that this behaviour is beneficial for this species, as it allows the young individuals to use its energy towards growth as opposed to activity. Furthermore, Killen et al., (2007) suggested that lumpfish adopt a passive cling foraging mode when food is abundant, and switches to an active swim mode when there is a lack of food. Their suggestions of the sit and wait for prey foraging mode, might explain the increase in “non-sheltered” fish group during feeding times, assuming that fish in this experiment are saving its energy by resting, and will only swim when feed is delivered. Imsland et al., (2014) studied the behavior of lumpfish in sea pens with and without salmon, with underwater technology. There were no artificial shelter provided, but only seaweed floating on the surface. Their results indicated that most of the daylight time was spent foraging for food. When not foraging for food, the fish were found either resting within the floating seaweed in the cage or hovering under the seaweed. Furthermore, Imsland et al., (2014) observed that fish spent more time resting in absence of Atlantic salmon. Theire findings of fish without salmon can indicate that most fish in this experiment prefer to spend most of its time resting in the hidewhen allowed

Johannesen et al., (2018) have studied the availability of shelter and the way feed is delivered, and concluded that these factors can have consequences for growth and fish condition. The authors suggested that if fish closest to the feed delivery point could eat to satiation first, it was likely that there was competition for the spot in the shelter that was closest to where feed was delivered. Their findings can support the fish observed resting close to the feeding machine, indicating that fish in this experiment might have preferred resting areas while waiting for feed. It is a low possibility that the shelter and place of feeding machine in this study have affected the condition of the fish, as K values was found to be good (Table 8 p. 20). It can still be speculated that fish would compete for the “best” resting space, closest to the feeding machine. In this study, sufficient shelter area was provided, but there could also be fish a with preferred resting area, being territorial against other fish approaching this area.

The behaviour observation of lumpfish with camera pictures showed where fish preferred to spend their time during the day, mainly in the hides provided (Figure 8 p. 22 to Figure 15 p. 25). Furthermore, the camera pictures could not conclude the behavior of fish, and it can only be speculated if fish behaved dominant and aggressively against each other during the experimental period. Since the possible dominant behavior of the bigger fish cannot be proven during the experimental period, it is only speculations and possibilities that can indicate the weight difference and behaviour. Imsland et al., (2016) assessed the behaviour between lumpfish and goldsinny at specific time intervals three to four times per week during feeding time, with direct observations and assist by underwater cameras. Their results showed larger lumpfish chasing goldsinny away, preventing it from food and in some instances the lumpfish was observed biting the caudal fin of goldsinny. The method from Imsland et al., (2016) using video recordings, could be used as a further method in order to standardize the behaviour monitoring of fish. Also by observing individual tagged fish, behavior and possible aggression that could be related to individual fish, and further to monitor hierarchy establishments.

2.2. General observations

The method from Imsland et al., (2016) mentioned in section 2.1 above could be a good combination with video recordings and direct observations in order to improve general observations and get significant data. Still, the general observation was an good way to assess fish before initiating the experiment. It was helpful to discover possible deaths, such as the dead fish observed. Furthermore, to get a quick overview, estimate and note down how many fish already had significant injuries, which were easily shown just by assessing and making a quick count of fish in the different groups.

When removing and adding new seaweed, and cleaning the tank, it was observed that fish would either try to stick to the ground with their suction disc or swim rapidly away. This was especially observed when trying to catch them with the net, when cleaning the tank. Some fish used the suction disc to cling and hide rather than to escape. They would not move at all, even when the net was approaching them. Litterature states that this behavior could be due to the lack of Mauthner neurons, which are involved in the fast startle response (Hale, 2000). The Mauthner cells are found in most teleost (Bierman, Zottoli, & Hale, 2009), but have not been observed in lumpfish (Hale, 2000). The rapid swimming observed, when approached by the net have been observed by Davenport and Thorsteinsson (1990), who observed how lumpfish quickly detached from the substrate and fled when a predator approached. Hale (2000) have observed this response in larval lumpfish, and suggested that this rapid escape behavior could be explained by the presence of a homologous physiological structure with similar functions as the Mauthner cells.

3. External damages

Significant difference in total injuries was found between the *Saccharina* hide group and the *Laminaria* hide group in T3, indicating less total damages in the *Laminaria* group. These findings could still not indicate differences in the different habitat as they only was observed to be different once. Caudal fin damages was present during the whole experimental period, an could be caused by different reasons. The control fish (T0) which showed external damages on the caudal fin indicated that the damages might have appeared during acclimatization or could already be present before receiving the fish from the hatchery. Treasurer et al., (2018, p. 285) have suggested that caudal fin erosion may be life stage specific, and further reported observations of the early phase of rearing first two to three months. Their observations suggested that lumpfish were aggressive to each other, resulting in high prevalence of caudal fin nipping. After this stage, Treasurer et al., (2018, p. 285) reported that this behaviour ceased, and when lumpfish reached 10 g, the fin nipping disappeared. The authors findings could support the speculations of external damages being present before receiving the fish from the hatchery. Furthermore, litterature have stated that aggression can increase when stocking density is low (Brown, Brown, & Srivastava, 1992; Jørgensen, Christiansen, & Jobling, 1993). In this experiment, the stocking density was very low (3 kg/m^3), compared to stocking densities normally used (10-20 kg/m^3) (J. Treasurer et al., 2018, p. 285). In comparison, the low biomass used in this experiment might have resulted in aggressive interactions among the fish during the experiment period. Furthermore, the stocking density was slightly higher during acclimatization, with a stocking density of 7.5 kg/m^3, that might have affected the amount of external damages. Espmark et al., (2019) studied different stocking densities of lumpfish (7.5-15 kg/m^3, 15-30 kg/m^3 and 30-60 kg/m^3). Authors found that caudal fin damages was highest in the lowest stocking density, while caudal fin damages was found to be significant lower in fish at the highest stocking density. Espmark et al., (2019) did have a different setup with sylindrical tanks, and no shelters for the fish, which could have affected the amount of damages observed. Still, their findings could support the assumptions of fin nipping during acclimatization, and why it was observed damages in T0. Further, it could be speculated that even the lower stocking density during the experiment period could have affected the fish even more. It seems that the stocking density can affect fish in different ways, Espmark et al., (2019) findings, could suggest that too low densities might increase the dominant behaviour of bigger fish having its preferred resting area, leading to aggression and increase in tail nippingas. Treasurer et al., (2018, p. 289) have reported that insufficient surface area can cause increased aggression, and tail nipping, suggesting too high density may decrease the resting space available and possibly making the fish more stressed (Espmark et al., 2019). Here, it was not observed any aggressive behaviour among the different groups, and with the pre-exisitng damages found in control fish (T0), made it difficult to assume if external damages appeared during the experiment, during acclimatization or before received from hatchery. Further, no hides were provided for the fish during the acclimatization, which could have affected the behaviour of fish in a negative way.

As mentioned, hierarchies could be a possibility in the groups, due to observed size difference in the tank. Although the correlation between size difference and damages were not monitored, injuries found when assessing fish in T1, T2 and T3 could possibly have appeared from the size difference. Imsland et al., (2016) studied lumpfish and goldsinny together, and observed aggression from lumpfish (110 g) towards the goldsinny species (30 g). Moreover, their results showed that bigger lumpfish were chasing the goldsinny and preventing them from having access to food, and it was also observed that lumpfish were biting their caudal fins. Imsland et al., (2016) concluded that it was size-dependent aggression by lumpfish towards the small fish, as this was less observed by the smaller lumpfish (32 g) living along with goldsinny (30 g). Accordingly, since it is shown size dependent hierachies in the findings from Imsland et al., (2016), their assumptions of hierarchies in this experiment can be possible, due to the observed size difference in the fish. Even if aggression among fish was not monitored during the experiment, it can still be speculated that this can be a cause of the injuries observed.

Furthermore the caudal fin was the most observed damage in the groups, but it was still observed some few fish with cataracts and suction disc deformities. Results show after three months, 5% fish from *Saccharina* hide group was observed with a severe cataract formation of score 3. The number of fish observed with cataracts was either not observed or very low in the groups. Litterature states that severe cataracts could result in reduced feeding and growth and can be used as an indicator for overfeeding or malnutrition (T. Jonassen et al., 2017). Common aquaculture husbandry and management practices such as handling and netting fish during vaccination, grading and bathing procedures can cause injuries (Björnsson, 2004). Here, environmental parameters indicated good water quality during the experiment (Section 2.5 in methods p. 15) and it is possible that the cataracts rather have appeared from the handling with the net. It is unclear how fish in this experiment have developed cataracts and why only a few of the ones assessed was observed with it. Litterature states that suboptimal values of CO_2 and O_2 saturation can cause chronic stress as density increases, which can result in cataracts in lumpfish (T. M. Jonassen et al., 2018, p. 133). In this case, the mean dissolved oxygen saturations was optimal for fish, thus not indicating to be the cause. Still, there are some months missing, and it could be possible that the dissolved oxygen saturations dropped under 80% in this period although a high waterflow was maintained in the tanks during the entire experiment to ensure sufficient oxygen supply. During general observations, all water parameters was observed and it is therefor a low chance this could have happened. To maintain a normal feed uptake, the fish are dependent on normal eyesight (T. Jonassen et al., 2017; Chris Noble et al., 2012; Powell, Treasurer, et al., 2018).

Powell et al., (2018) have stated that a non-functional suction disc can make lumpfish vulnerable to exhaustion. The few fish observed with some small deformities might have experienced stress if not being able to attach and rest to a surface. Most likely these deformities might be hereditary and not environmental, and possible pre-existing, and not from the environmental parameters. Litterature states that it is unclear what can cause suction disc deformities, but nutritional, environmental, and genetic factors may be involved in deformities in other species (Gutierrez Rabadan et al., 2020; A. K. Imsland et al., 2015; Johannesen et al., 2018). Further experiments would be required in order to study the non-functional suction disc possible effect on external damages or measure such as low weight.

4. Saccharina latissima

The cultivated *S. latissima* from trial 1 and trial 2 were preliminary trials along with the lumpfish experiment. The cultivations was performed with the idea of using cultivated *S. latissima* as seaweed hides along with lumpfish. Handå et al., (2013) have reported that landbased studies have showed nutrient recycling and increased growth of macroalgae in integration with fish aquaculture. Handå et al., (2013) did also study cultivated *S. latissima* integrated in salmon farming cages, and found that the *S. latissima* in the salmon farm had a faster growth compared to its reference station.

Forbord et al., (2012) studied cultivated *S. latissima*, and incubated the ropes on horizontal plates. When spores had reached a length of 5-10 mm after 8 weeks incubation they were placed out in the sea. Here, the cultivation trial can indicate that trial 1 did not grow as well as trial 2. Trial 2 showed a more rapid growth compared to trial 1. Because parallels were not taken, the graph cannot be compared properly with trial 1. The different growth shown, can indicate a better growth of the spores in trial 2. The trial 1 and trial 2 is only a growth trend, and length of spores may vary in size. The good growth in trial 2 might be because of the light provided were closer, as the coils was placed vertically, getting closer to the surface. Forbord et al., (2012) found that the low levels of light during the winter months reduce the growth of the spores out in the sea. Forbords study report that the spores need sufficient light to grow well. Their findings can indicate that since trial 2 had a lot of light it would grow more rapid, compared to trial 1. In addition the timer in trial 2 was set to 23 h light and 1 h dark when spores had settled after 2 weeks. This light regime of 23 h light and 1 h dark could have affected the growth of trial 2. It can also be speculated that the different growth of the trials is because of clumping of the spores in trial 1, not giving the same fundamental start as trial 2. When seeding the spores in trial 1, it was observed that the spores looked more clumped together than in trial 2. In trial 2 spores were observed to look much smaller and fine when seeded on the coils. This clumping of the spores in trial 1 may inhibit the spores to attach properly on the rope, and not having the same fundamental start as trial 2.

V. Conclusion

In this thesis, lumpfish in three different habitats, two natural seaweed hides and a artificial cover were monitored from December 2020 to March 2021. No significant differences were found in the condition factor of the different groups, indicating that the different hide conditions did not impact the fish nutritional status. From the camera monitoring, significant differences were found in fish after two months (T2) between the group with the *Saccharina* hide and *Laminaria* hide, and in fish after three months (T3) between the *Saccharina* and the artificial hide groups. Results varied between periods, thus differenences in habitat can not be concluded. What the camera monitoring clearly shows, is that the fish utilizes the hides provided to rest and hide in. Caudal fin damage was the most common injury observed when assessing and grading the fish for external damages. Significant difference was found between the *Saccharina* hide group and the *Laminaria* hide group after three months (T3). There were no significant differences on total injuries after one (T1) and two months (T2). Overall the groups varied in which group had different injuries, such as cataracts, suction disc deformities, other fin injuries, and epidermal injuries. The injury assessment represent a first attempt to give a qualitative support information and more data would need to be collected in order to provide solid conclusions using this information. This study cannot conclude that there were any correlations between type of hide, fish condition and external damages, and more studies need to be conducted in order to conclude if there is any impact on behaviour and welfare related to the selected groups of hide.

Preliminary trials of *Saccharina latissima* cultivated indoors, showed good growth, especially in trial 2, and could be a good option to utilize as a hide along with fish in fish farms or tanks inside. The seaweed cultivation could further be used in integration with fish, adding oxygen to the seawater and removing nutrient waste from fish, while giving the seaweed nutrient source.

VI. Future work

Future work on monitoring the behaviour of lumpfish could be performed with video recordings for some minutes several times of the day. This would be interesting to improve, to get a closer indication on how the fish behave against each other, and during the feeding times. This could also be a good method to prove aggressive behavior and tail nipping.

The external damages assessed was based on assumptions from where they had appeared, due to pre-existing damages. For further work, it should be done assessment and grading of every individual fish when receiving them from the hatchery and before experiment start. Furthermore, assessing the fish before, could be important to make sure there are similar size in the same tank to avoid hierarchies.

For future studies it would be interesting to assess the primary stress response by measuring cortisol in blood along with the assessment of external damages and behavior. Cortisol is commonly used to indicate the degree of stress experienced by fish (B. A. Barton & Iwama, 1991). When fish are exposed to a stressor, cortisol is released as part of the primary stress response (Schreck & Tort, 2016). Measuring the cortisol in blood plasma would be a good indicator to conclude if fish in this experiment experienced stress. Another interesting thing to study for future work is the microbiome and the bacteria found. Stress is well known to disrupt the microbiome, which is associated with health effects in the host. In addition elevated plasma cortisol is associated with alterations in the structure of the mammalian microbiome (Uren Webster, Rodriguez-Barreto, Consuegra, & Garcia de Leaniz, 2020).

The preliminary trials of growing *S. latissima* showed a good growth, and was a success, when not clumping together. For future work, it would be interesting to use the cultivated seaweed as seaweed hide along with the lumpfish. The cultivated seaweed would provide a more sterile and standardized substrate compared to the wild harvested seaweed. And if future analyzing of cortisol in blood, and sampling of gut for microbiome samples, it could be better to consider cultivated seaweed.

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Appendix

Table 1. Overview of induvidual fish assessed for weight, fork length, and total length. Calculations of condition factor for individual fish are included for T1.

	T1 *Saccharina* hide				T1 artificial hide				T1 *Laminaria* hide			
Sample	Wet weight (g)	Fork (cm)	Total (cm)	Condition factor (weight/fork^3)*100	Wet weight (g)	Fork (cm)	Total (cm)	Condition factor (weight/fork^3)*100	Wet weight (g)	Fork (cm)	Total (cm)	Condition factor (weight/fork^3)*100
1	40	8.1	9.6	7.53	58.7	9.49	11.3	6.87	41.5	8.1	8.1	7.81
2	44	8.53	9.33	7.09	37.7	8.55	9.5	6.03	48.4	9.1	10.02	6.42
3	41.7	9.14	9.78	5.46	77.8	10.44	12.2	6.84	50.5	8.8	10.45	7.41
4	22	6.84	6.84	6.87	31.6	7.31	8.01	8.09	44.5	8.84	10.11	6.44
5	48.5	9.29	10.42	6.05	36.2	7.75	8.75	7.78	36.6	8.3	8.7	6.4
6	38.2	8.09	8.99	7.21	39.5	8.71	9.31	5.98	44.8	8.67	9.33	6.87
7	41.8	8.4	9.11	7.05	42.3	8.55	9.4	6.77	74.7	10.55	12.13	6.36
8	66.6	9.82	11.09	7.03	40.9	8.4	8.4	6.9	43.4	8.44	9	7.22
9	42.8	8.65	9.5	6.61	36.27	7.55	8.4	8.43	33	8.15	8.69	6.1
10	55.1	9.57	10.4	6.29	48.5	9.34	10.53	5.95	29.7	8.1	8.34	5.59
11	50.2	9.49	11.1	5.87	45.8	8.72	9.71	6.91	54.5	8.6	9.5	8.57
12	48.3	9.09	9.91	6.43	33.9	7.82	8.48	7.09	47.6	9.24	9.84	6.03
13	33.6	7.75	8.86	7.22	37	8.9	9.72	5.25	58.3	10.04	11.18	5.76
14	63.5	9.82	11.27	6.71	61.5	10.6	9.3	5.16	43.8	8.59	9.08	6.91
15	51.3	9.04	10.6	6.94	71.2	10.1	11.45	6.91	50	8.72	9.94	7.54
16	75.9	11.55	12.25	4.93	31.6	7.9	9.45	6.41	47.6	9.04	9.63	6.44
17	78.8	11	11.5	5.92	37.6	8.75	9.66	5.61	36.8	8.6	9.12	5.79
18	75.2	11.92	12.2	4.44	52.3	9.27	10.75	6.57	50.8	9.79	10.95	5.41
19	66.9	10.8	11.86	5.31	41.8	8.89	10	5.95	40.2	8.58	9.1	6.36
20	50.4	8.97	10.12	6.98	62.2	9.08	9.61	8.31	57	9.6	10.5	6.44
Mean	**51.74**			**6.37**			**46.22**	**6.69**	**46.68**			**6.59**
SD	**14.78**			**0.83**			**13.43**	**0.92**	**10.02**			**0.78**

Table 2. Overview of induvidual fish assessed for weight, fork length, and total length. Calculations of condition factor for individual fish are included for T2.

Sample	T2 *Saccharina* hide				T2 artificial hide				T2 *Laminaria* hide			
	Wet weight (g)	Fork (cm)	Total (cm)	Condition factor (weight/fork^3)*100	Wet weight (g)	Fork (cm)	Total (cm)	Condition factor (weight/fork^3)*100	Wet weight (g)	Fork (cm)	Total (cm)	Condition factor (weight/fork^3)*100
1	60.3	9.6	10.5	6.82	64.5	9.9	11.6	6.65	61.4	10.2	11.4	5.79
2	75.2	11.1	12.6	5.50	98.5	11.2	13.3	7.01	107.6	11.5	12.9	7.07
3	83.2	11.5	13	5.47	73.2	10	11.9	7.31	42.9	8.4	9.4	7.24
4	90	11.4	12.7	6.07	52.9	9.1	11.5	7.02	84.4	10.9	12.2	6.52
5	80.5	10.9	11.9	6.22	83.4	10.6	10.6	7.0	115.5	11.5	13.3	7.59
6	74.9	11.1	12.4	5.48	53	9.6	10.6	5.99	56.7	9.5	10.6	6.61
7	51	9.7	9.7	5.59	79.3	10.5	12.7	6.85	57.4	9.4	10.7	6.91
8	98	12.5	12.7	5.02	77.9	10.9	12.7	6.02	58.6	9.8	12.8	6.23
9	116.5	12.2	14	6.42	42	8.1	9.3	7.90	89.3	11.4	12.4	6.03
10	63.4	9.9	11.1	6.53	85.2	10.9	12.9	6.58	75.8	11	12.4	5.69
11	68.4	9.9	11.1	7.05	61.5	9.7	9.7	6.74	57.7	9.8	10.8	6.13
12	49.5	9.8	10.5	5.26	68.7	10.7	11.8	5.61	80.5	10.7	12	6.57
13	65.8	9.9	11.4	6.78	75.4	10.5	11.1	6.51	100	11.3	13.3	6.93
14	65.4	9.7	10.8	7.17	91.4	10.6	12.1	7.67	76	10	12.2	7.60
15	63.7	10.6	11.6	5.35	53.7	9.5	11.2	6.26	70.5	10.4	12.1	6.27
16	59.7	9.9	11.5	6.15	74.1	10.3	11.9	6.78	109	12	15.5	6.31
17	61.5	9.7	11.1	6.74	79.5	10.3	12.6	7.28	47.5	9.1	10	6.30
18	55	9.2	10.4	7.06	85.3	11.9	12.9	5.06	55.4	9.4	10.6	6.67
19	74.8	10.5	11.5	6.46	70.9	10.6	11.9	5.95	65.7	9.7	11.7	7.20
20	82.1	10.9	12.9	6.34	72.4	10.5	12	6.25	97.8	11.1	12.7	7.15
Mean	**71.94**			**6.44**	**72.14**			**6.62**	**46.68**			**6.64**
SD	**16.09**			**0.65**	**13.89**			**0.68**	**10.02**			**0.54**

Table 3. Overview of induvidual fish assessed for weight, fork length, and total length. Calculations of condition factor for individual fish are included for T3. Fish no. 17 in artificial hide are a outlier, and are not included in statistical analyses.

	T3 *Saccharina* hide				**T3 artificial hide**				**T3 Lam*inaria* hide**			
Sample	Wet weight (g)	Fork (cm)	Total (cm)	Condition factor (weight/fork^3) *100	Wet weight (g)	Fork (cm)	Total (cm)	Condition factor (weight/fork^3) *100	Wet weight (g)	Fork (cm)	Total (cm)	Condition factor (weight/fork^3) *100
1	112.3	12.53	14	5.71	208.6	15.35	17.45	5.77	107.3	11.7	13	6.70
2	163.3	14	14.9	5.95	111.9	12.75	15	5.40	86.7	11.8	13.1	5.28
3	69.6	11.1	12.9	5.09	90.2	11.8	13.3	5.49	134.3	12.8	14	6.40
4	106.8	12	13.7	6.18	95.7	11.9	13.4	5.68	142.7	13.2	14.8	6.20
5	137	13.4	15.1	5.69	98.6	11.5	13	6.48	154.9	13.8	16.6	5.89
6	83.5	11.4	12.6	5.64	110.8	12.3	13.6	5.95	138.3	12.6	14.1	6.91
7	120.3	12.5	13.9	6.16	82.9	11.2	12	5.90	104.6	11.8	13	6.37
8	95.1	12	12	5.50	91.6	11.3	12.4	6.35	94.5	11.2	12.5	6.73
9	59.7	10.3	11.4	5.46	75.4	10.2	11.6	7.11	95.9	11.7	14.6	5.99
10	126.6	13.3	13.9	5.38	94.9	11.8	13.4	5.78	106.3	12.4	13.7	5.58
11	99.2	12.4	13.8	5.20	121.4	12.4	13.9	6.37	130	12.8	14.4	6.20
12	150.1	13.8	14.6	5.71	111.3	12.6	15.1	5.56	123.7	13	14.3	5.63
13	128.4	13.1	14.3	5.71	118.1	12.6	14.3	5.90	90.4	11.1	11.1	6.61
14	195.2	14.8	16.5	6.02	137.1	13.4	15.6	5.70	98.7	12.1	13.6	5.57
15	158.3	13.8	15.3	6.02	97.2	11.7	12.8	6.07	88.7	11.5	12.7	5.83
16	98	11.4	13	6.61	113.4	12.8	13	5.41	89.8	11.6	12.9	5.75
17	84.3	10.8	11.7	6.69	117.8	10.5	10.5	10.18	119	12.4	13.7	6.24
18	77.3	10.8	12.1	6.14	88	11.9	12.7	5.22	101.7	11.9	13.5	6.04
19	92.6	12.6	13.3	4.63	79.2	10.6	11.7	6.65	111.8	12.3	14.4	6.01
20	120.1	12.6	14.8	6.00	85.6	10.9	12.7	6.61	88.8	11.3	13.4	6.15
MEAN	**113.88**			**5.76**	**106.48**			**6.18**	**110.40**			**6.10**
SD	**33.68**			**0.48**	**28.20**			**1.03**	**20.09**			**0.42**

*Table 4. Overview of the fish in each group compared to mean weight in T1. Percentage over mean weight and percentage under mean weight. Indicating which fish are bigger than the rest. (individual weight/mean weight)*100*

T1	**SACCHARINA**		**ARTIFICIAL**		**LAMINARIA**	
SAMPLE	Wet weight (g)	% over or under mean weight	Wet weight (g)	% over or under mean weight	Wet weight (g)	% over or under mean weight
1	40	77.31 %	58.7	127.0 %	41.5	88.89 %
2	44	85.04 %	37.7	81.57 %	48.4	103.67 %
3	41.7	80.60 %	77.8	168.33 %	50.5	108.17 %
4	22	42.52 %	31.6	68.37 %	44.5	95.32 %
5	48.5	93.74 %	36.2	78.32 %	36.6	78.40 %
6	38.2	73.83 %	39.5	85.46 %	44.8	95.96 %
7	41.8	80.79 %	42.3	91.52 %	74.7	160.01 %
8	66.6	128.72 %	40.9	88.49 %	43.4	92.96 %
9	42.8	82.72 %	36.3	78.54 %	33	70.69 %
10	55.1	106.49 %	48.5	104.93 %	29.7	63.62 %
11	50.2	97.02 %	45.8	99.09 %	54.5	116.74 %
12	48.3	93.35 %	33.9	73.34 %	47.6	101.96 %
13	33.6	64.94 %	37	80.05 %	58.3	124.88 %
14	63.5	122.73 %	61.5	133.06 %	43.8	93.82 %
15	51.3	99.15 %	71.2	154.05 %	50	107.10 %
16	75.9	146.70 %	31.6	68.37 %	47.6	101.96 %
17	78.8	152.30 %	37.6	81.35 %	36.8	78.83 %
18	75.2	145.34 %	52.3	113.15 %	50.8	108.81 %
19	66.9	129.30 %	41.8	90.44 %	40.2	86.11 %
20	50.4	97.42 %	62.2	143.57 %	57	122.09 %
MEAN	51.74 ± 15.16		46.22 ± 13.43		46.69 ± 10.02	

*Table 5. Overview of the fishesin each group compared to mean weight in T2. Percentage over mean weight and percentage under mean weight. Indicating which fish are bigger than the rest. (individual weight/mean weight)*100*

T2	**SACCAHRINA**		**ARTIFICIAL**		**LAMINARIA**	
SAMPLE	Wet weight (g)	% over or under mean weight	Wet weight (g)	% over or under mean weight	Wet weight (g)	% over or under mean weight
1	60.3	83.81 %	64.5	89.41 %	61.4	81.34 %
2	75.2	104.52 %	98.5	136.54 %	107.6	142.54 %
3	83.2	115.64 %	73.2	101.47 %	42.9	56.83 %
4	90	125.10 %	52.9	73.33 %	84.4	111.81 %
5	80.5	111.89 %	83.4	115.61 %	115.5	153.01 %
6	74.9	104.11 %	5	73.47 %	56.7	75.11 %
7	51	70.89 %	79.3	109.93 %	57.4	76.04 %
8	98	136.22 %	77.9	107.98 %	58.6	77.63 %
9	116.5	161.93 %	42	58.22 %	89.3	118.30 %
10	63.4	88.12 %	85.2	118.10 %	75.8	100.42 %
11	68.4	95.07 %	61.5	85.25 %	57.7	76.44 %
12	49.5	68.80 %	68.7	95.23 %	80.5	106.64 %
13	65.8	91.46 %	75.4	104.52 %	100	132.48 %
14	65.4	90.90 %	91.4	126.70 %	76	100.68 %
15	63.7	88.54 %	53.7	74.44 %	70.5	93.40 %
16	59.7	82.98 %	74.1	102.72 %	109	144.40 %
17	61.5	85.48 %	79.5	110.20 %	47.5	62.93 %
18	55	76.45 %	85.3	118.24 %	55.4	73.39 %
19	74.8	103.97 %	70.9	98.28 %	65.7	87.04 %
20	82.1	114.11 %	72.4	100.36 %	97.8	129.56 %
MEAN	71.95 ± 16.51		72.14 ± 14.25		75.49 ± 21.76	

*Table 6. Overview of the fishesin each group compared to mean weight in T3. Percentage over mean weight and percentage under mean weight. Indicating which fish are bigger than the rest. Sample no. 17 in artificial hide is not included, due to being counted out. (individual weight/mean weight)*100*

T3	**SACCHARINA**		**ARTIFICIAL**		**LAMINARIA**	
SAMPLE	Wet weight (g)	% over or under mean weight	Wet weight (g)	% over or under mean weight	Wet weight (g)	% over or under mean weight
1	112.3	98.61 %	208.6	197 %	107.3	97.19 %
2	163.3	143.39 %	111.9	105.68 %	86.7	78.53 %
3	69.6	61.11 %	90.2	85.18 %	134.3	121.64 %
4	106.8	93.78 %	95.7	90.38 %	142.7	129.25 %
5	137	120.30 %	98.6	93.12 %	154.9	140.30 %
6	83.5	73.32 %	110.8	104.64 %	138.3	125.27 %
7	120.3	105.63 %	82.9	78.29 %	104.6	94.74 %
8	95.1	83.51 %	91.6	86.51 %	94.5	85.59 %
9	59.7	52.42 %	75.4	71.21 %	95.9	86.86 %
10	126.6	111.16 %	94.9	89.62 %	106.3	96.28 %
11	99.2	87.11 %	121.4	114.65 %	130	117.75 %
12	150.1	131.80 %	111.3	105.11 %	123.7	112.04 %
13	128.4	112.75 %	118.1	111.53 %	90.4	81.88 %
14	195.2	171.40 %	137.1	129.47 %	98.7	89.40 %
15	158.3	139.00 %	97.2	91.79 %	88.7	80.34 %
16	98	86.05 %	113.4	107.09 %	89.8	81.34 %
17	84.3	74.02 %	~~117.8~~	~~110.63 %~~	119	107.78 %
18	77.3	67.88 %	88	83.11 %	101.7	92.12 %
19	92.6	81.31 %	79.2	74.79 %	111.8	101.26 %
20	120.1	105.46 %	85.6	80.84 %	88.8	80.43 %
MEAN	113.89 ± 33.68		105.89 ± 28.20		110.41 ± 20.09	

Table 7. S. latissima trial 1. Tank 1 temperature, salinity, and pH monitored twice a week (Monday and Thursday at 09.00). Salinity shows different decimals over this period. Intrument was optimized the 15.10.20.

Tank 1	Day/Date	Temperature ºC	Salinity (psu/ppt)	pH
Start	09.09.2020	9.1	0.3	x
Day 3	11.09.2020	10.9	0.3	7.86
Day 6	14.09.2020	9.4	0.3	7.88
Day 9	17.09.2020	9.7	0.3	7.95
Day 13	21.09.2020	10.7	0.3	7.94
Day 16	24.09.2020	11.2	0.3	7.96
Day 20	28.09.2020	12.0	0.3	8.04
Day 24	01.10.2020	12.6	0.3	8.06
Day 28	05.10.2020	12.9	0.3	8.05
Day 31	08.10.2020	13.9	0.3	8.03
Day 35	12.10.2020	11.5	0.3	8.0
Day 38	15.10.2020	11.2	34.3	7.92
Day 42	19.10.2020	12.0	33.8	7.91
Day 45	22.10.2020	11.4	34.1	7.98
Day 48	26.10.2020	11.8	33.9	8.0
Day 52	29.10.2020	11.9	33.4	8.0
Day 56	02.11.2020	11.1	32.7	7.99
Day 59	05.11.2020	12.6	33.4	8.02
Day 63	09.11.2020	11.8	34.1	7.99
Mean		11.73 ± 0.45	33.71 ± 0.49	7.98 ± 0.04

Table 8. S. latissima trial 1. Tank 2, temperature, salinity, and pH. Salinity shows different decimals over this period. Instrument was optimized the 15.10.20. At day 63 the seaweed were assembled in Tank 2.

Tank 2	Day/Date	Temperature	Salinity (ppt)	pH
Start	09.09.2020	9.2	0.3	x
Day 3	11.09.2020	10.6	0.3	7.78
Day 6	14.09.2020	9.6	0.3	7.92
Day 9	17.09.2020	10.0	0.3	7.86
Day 13	21.09.2020	10.9	0.3	7.88
Day 16	24.09.2020	11.4	0.3	7.87
Day 20	28.09.2020	12.1	0.3	8.02
Day 24	01.10.2020	12.7	0.3	8.01
Day 28	05.10.2020	13.0	0.3	8.04
Day 31	08.10.2020	14.0	0.3	8.01
Day 35	12.10.2020	11.6	0.3	8.03
Day 38	15.10.2020	11.3	34.3	7.95
Day 42	19.10.2020	12.1	33.8	7.93
Day 45	22.10.2020	11.6	34.1	7.96
Day 48	26.10.2020	12.0	33.9	8.0
Day 52	29.10.2020	11.9	33.3	8.01

Day 56	02.11.2020	11.5	32.7	8.01
Day 59	05.11.2020	12.6	33.4	8.02
Day 63	09.11.2020	12.0	34.1	8.01
Mean		11.88 ± 0.38	33.70 ± 0.50	7.99 ± 0.03

Table 9. S. laissima trial 1. Temperature, salinity an pH of S. latissima from Tank 1 and Tank 2 assembled tgether in Tank 2.

Tank 2	Day/Date	Temperature	Salinity ppt)	pH
Day 66	12.11.2020	12.2	33.9	7.98
Day 67	16.11.2020	12.1	33.6	7.99
Day 73	18.11.2020	12.1	33.5	8.1
Day 77	23.11.2020	11.4	34.0	8.1
Day 80	26.11.2020	11.5	34.2	7.92
Day 84	30.11.2020	11.5	33.9	7.90
Day 87 – End of monitoring	03.12.2020	11.6	33.9	7.93
Mean		11.77 ± 0.32	33.86 ± 0.22	7.99 ± 0.08

Table 10. S. latissima trial 1. Tank 2. New monitoring of temperature and salinity, after observing growing seaweed.

Tank 2	Date	Temperature	Salinity (ppt)
Day 102	18.12.2020	11,5	33,5
Day 103	23.12.2020	11,8	33,6
Day 104	02.01.2021	11,8	33,6
Day 105	05.01.2021	11,6	34,1
Day 106	13.01.2021	10,6	34
Mean		11.46 ± 0.45	33.76 ± 0.24

Table 11. S. latissima trial 2. Temperature, salinity and pH.

Tank 1	Day/date	Temperature	Salinity (ppt)	pH
Day 3	16.01.2021	9.5	34.6	8.0
Day 5	18.01.2021	9.6	34.0	7.99
Day 9	22.01.2021	8.7	33.5	7.98
Day 12	25.01.2021	9.3	33.6	7.99
Day 16	29.01.2021	9.5	34.5	8.03
Day 19	01.02.2021	9.6	34.0	8.02
Day 23	05.02.2021	9.3	34.1	7.95
Day 26	08.02.2021	8.1	33.3	8.04
Day 30	12.02.2021	8.8	33.2	7.95
Day 33	15.02.2021	9.2	34.0	7.93
Day 37	19.02.2021	9.4	33.8	7.99
Day 40	22.02.2021	9.3	33.3	8.03
Day 44	26.02.2021	9.2	33.9	7.96
Day 47	01.03.2021	10.2	33.9	7.98

Day 51	05.03.2021	9.1	34.5	8.03
Day 54	08.03.2021	9.1	34.5	8.01
Day 58	12.03.2021	9.2	34.3	7.98
Day 61	15.03.2021	8.8	34.2	7.95
Day 65	19.03.2021	9.0	34.4	7.97
Day 68	22.03.2021	9.0	34.3	8.0
Day 72	26.03.2021	9.1	34.1	7.84
Day 75	29.03.2021	8.9	34.4	7.98
Day 79	02.04.2021	9.1	34.3	8.01
Day 82	05.04.2021	9.0	34.3	7.7
Day 86	09.04.2021	8.5	34.6	7.99
Day 89	12.04.2021	8.6	34.6	7.7
Mean		9.12 ± 0.39	34.08 ± 0.40	7.97 ± 0.07

Table 12. Statistics on condition factor of the fish in each replicate for T1. Shapiro-Wilk Test to check that groups are normally distributed, and Levene's test to check for homogeneity between the variance. Statistics show normally distributed groups and homogeneity between variance, and parametric test was performed. Parametric test ANOVA followed by Tukey test to check for significant difference between the different replicates in order to group them as Saccharina hide, artificial hide and Laminaria hide for T1. Following replicates were grouped with its replicate in one group as Saccharina hide, artificial hide and Laminaria hide. (p-value < 0.05 indicate significant difference).

Shapiro-Wilk Test							Levene's Tests	
	Saccharina replicate 1	*Artificial replicate 1*	*Laminaria replicate 1*	*Saccharina replicate 2*	*Artificial replicate 2*	*Laminaria replicate 2*		
W-stat	0,92703231	0,89706573	0,95733715	0,93456237	0,9482704	0,90422059	type	p-value
p-value	0,41934446	0,20336841	0,75513559	0,49423436	0,6480827	0,24360215	means	0,72883707
alpha	0,05	0,05	0,05	0,05	0,05	0,05	medians	0,71933751
normal	yes	yes	yes	yes	yes	yes	trimmed	0,72883707

ANOVA: Single Factor

DESCRIPTION					Alpha	0,05		
Group	*Count*	*Sum*	*Mean*	*Variance*	*SS*	*Std Err*	*Lower*	*Upper*
Saccharina replicate 1	10	67,20	6,72	0,38865728	3,4979155	0,26826404	6,18225082	7,25792484
Artificial replicate 1	10	69,63	6,96	0,77809501	7,00285509	0,26826404	6,42515969	7,50083372
Laminaria replicate 1	10	66,62	6,66	0,44082805	3,96745244	0,26826404	6,12455067	7,2002247
Saccharina replicate 2	10	60,75	6,08	0,89478407	8,05305663	0,26826404	5,5374205	6,61309452
Artificial replicate 2	10	64,16	6,42	0,92647976	8,33831782	0,26826404	5,87859895	6,95427298
Laminaria replicate 2	10	65,26	6,53	0,88909147	8,0018232	0,26826404	5,98854941	7,06422344

ANOVA

Sources	*SS*	*df*	*MS*	*F*	*P value*	*Eta-sq*	*RMSSE*	*Omega Sq*
Between Grou	4,55231378	5	0,91046276	1,26513617	0,29239553	0,10485884	0,35568753	0,02161706
Within Groups	38,8614207	54	0,71965594					
Total	43,4137345	59	0,73582601					

TUKEY HSD/KRAMER			alpha	0,05	
group	*mean*	*n*	*ss*	*df*	*q-crit*
Saccharina re	6,72	10	3,4979155		
Artificial repli	6,96	10	7,00285509		
Laminaria rep	6,66	10	3,96745244		
Saccharina re	6,08	10	8,05305663		
Artificial repli	6,42	10	8,33831782		
Laminaria rep	6,53	10	8,0018232		
		60	38,8614207	54	4,17811111

Q TEST

group 1	*group 2*	*mean*	*std err*	*q-stat*	*lower*	*upper*	*p-value*	*mean-crit*	*Cohen d*
Saccharina replicate 1	Artificial replicate 1	0,24290887	0,26826404	0,9054843	-0,8779281	1,36374583	0,98736538	1,12083696	0,28633928
Saccharina replicate 1	Laminaria replicate 1	0,05770014	0,26826404	0,21508714	-1,0631368	1,1785371	0,99998798	1,12083696	0,06801653
Saccharina replicate 1	Saccharina replicate 2	0,64483032	0,26826404	2,40371511	-0,4760066	1,76566728	0,53799452	1,12083696	0,76012146
Saccharina replicate 1	Artificial replicate 2	0,30365187	0,26826404	1,13191417	-0,8171851	1,42448882	0,96623301	1,12083696	0,35794269
Saccharina replicate 1	Laminaria replicate 2	0,19370141	0,26826404	0,72205507	-0,9271355	1,31453836	0,99555291	1,12083696	0,22833386
Artificial replicate 1	Laminaria replicate 1	0,30060902	0,26826404	1,12057144	-0,8202279	1,42144597	0,9676566	1,12083696	0,3543558
Artificial replicate 1	Saccharina replicate 2	0,88773919	0,26826404	3,3091994	-0,2330978	2,00857615	0,19638214	1,12083696	1,04646073
Artificial replicate 1	Artificial replicate 2	0,54656074	0,26826404	2,03739847	-0,5742762	1,6673977	0,70239133	1,12083696	0,64428197
Artificial replicate 1	Laminaria replicate 2	0,43661028	0,26826404	1,62753936	-0,6842267	1,55744724	0,85762491	1,12083696	0,51467314
Laminaria replicate 1	Saccharina replicate 2	0,58713017	0,26826404	2,18862797	-0,5337068	1,70796713	0,63565475	1,12083696	0,69210493
Laminaria replicate 1	Artificial replicate 2	0,24595172	0,26826404	0,91682703	-0,8748852	1,36678868	0,98663467	1,12083696	0,28992616
Laminaria replicate 1	Laminaria replicate 2	0,13600126	0,26826404	0,50696793	-0,9848357	1,25683822	0,99917907	1,12083696	0,16031733
Saccharina replicate 2	Artificial replicate 2	0,34117845	0,26826404	1,27180094	-0,7796585	1,46201541	0,94501301	1,12083696	0,40217877
Saccharina replicate 2	Laminaria replicate 2	0,45112891	0,26826404	1,68166004	-0,669708	1,57196587	0,84010285	1,12083696	0,5317876
Artificial replicate 2	Laminaria replicate 2	0,10995046	0,26826404	0,4098591	-1,0108865	1,23078741	0,9997088	1,12083696	0,12960883

Table 13. Statistics on condition factor of the fish in each replicate for T2. Shapiro-Wilk Test to check that groups are normally distributed, and Levene's test to check for homogeneity between the variance. Statistics show normally distributed groups and homogeneity between variance, and parametric test was performed. Parametric test ANOVA followed by Tukey test to check for significant difference between the different replicates in order to group them as Saccharina hide, artificial hide and Laminaria hide for. Following replicates were grouped with its replicate in one group as Saccharina hide, artificial hide and Laminaria hide. (p-value < 0.05 indicate significant difference).

Shapiro-Wilk Test							Levene's Tests	
	Saccharina replicate 1	*Artificial replicate 1*	*Laminaria replicate 1*	*Saccharina replicate 2*	*Artificial replicate 2*	*Laminaria replicate 2*		
W-stat	0,94096344	0,94567874	0,96438293	0,87968643	0,9896481	0,92517325	type	p-value
p-value	0,56378298	0,61774114	0,83445092	0,12941585	0,99637001	0,40212625	means	0,85662463
alpha	0,05	0,05	0,05	0,05	0,05	0,05	medians	0,86351479
normal	yes	yes	yes	yes	yes	yes	trimmed	0,85662463

ANOVA: Single Factor

DESCRIPTION					Alpha	0,05		
Group	*Count*	*Sum*	*Mean*	*Variance*	*SS*	*Std Err*	*Lower*	*Upper*
Saccharina replicate 1	10	59,11	5,91	0,33738299	3,03644687	0,1986005	5,51258157	6,30892164
Artificial replicate 1	10	68,34	6,83	0,32835289	2,95517602	0,1986005	6,43571779	7,23205785
Laminaria replicate 1	10	65,68	6,57	0,40713685	3,66423161	0,1986005	6,17012069	6,96646076
Saccharina replicate 2	10	64,36	6,44	0,46340614	4,17065527	0,1986005	6,03780011	6,83414017
replicate 2	10	64,12	6,41	0,59096779	5,31871015	0,1986005	6,01409717	6,81043724
replicate 2	10	67,13	6,71	0,2392829	2,15354609	0,1986005	6,31488315	7,11122321

ANOVA

Sources	*SS*	*df*	*MS*	*F*	*P value*	*Eta-sq*	*RMSSE*	*Omega Sq*
Between Grc	5,17910152	5	1,0358203	2,62617545	0,03383065	0,19560116	0,51246224	0,11934203
Within Grou	21,298766	54	0,39442159					
Total	26,4778675	59	0,44877742					

TUKEY HSD/KRAMER		alpha	0,05		
group	*mean*	*n*	*ss*	*df*	*q-crit*
Saccharina replicate 1	5,91	10	3,03644687		
Artificial replicate 1	6,83	10	2,95517602		
Laminaria replicate 1	6,57	10	3,66423161		
Saccharina replicate 2	6,44	10	4,17065527		
Artificial replicate 2	6,41	10	5,31871015		
Laminaria replicate 2	6,71	10	2,15354609		
		60	21,298766	54	4,17811111

Q TEST

group 1	*group 2*	*mean*	*std err*	*q-stat*	*lower*	*upper*	*p-value*	*mean-crit*	*Cohen d*
Saccharina replicate 1	Artificial replicate 1	0,92313621	0,1986005	4,64820685	0,09336125	1,75291118	0,02093617	0,82977496	1,46989207
Saccharina replicate 1	Laminaria replicate 1	0,65753912	0,1986005	3,31086332	-0,1722358	1,48731408	0,19593596	0,82977496	1,04698691
Saccharina replicate 1	Saccharina replicate 2	0,52521853	0,1986005	2,64459821	-0,3045564	1,35499349	0,4313042	0,82977496	0,83629539
Saccharina replicate 1	Artificial replicate 2	0,5015156	0,1986005	2,52524839	-0,3282594	1,33129056	0,4833769	0,82977496	0,79855366
Saccharina replicate 1	Laminaria replicate 2	0,80230157	0,1986005	4,03977617	-0,0274734	1,63207654	0,06358902	0,82977496	1,27748939
Artificial replicate 1	Laminaria replicate 1	0,2655971	0,1986005	1,33734353	-0,5641779	1,09537206	0,93260072	0,82977496	0,42290516
Artificial replicate 1	Saccharina replicate 2	0,39791768	0,1986005	2,00360864	-0,4318573	1,22769264	0,71682666	0,82977496	0,63359668
replicate 1	replicate 2	0,42162062	0,1986005	2,12295846	-0,4081543	1,25139558	0,66499294	0,82977496	0,67133841
Artificial replicate 1	Laminaria replicate 2	0,12083464	0,1986005	0,60843068	-0,7089403	0,9506096	0,99802407	0,82977496	0,19240268
Laminaria replicate 1	Saccharina replicate 2	0,13232058	0,1986005	0,66626511	-0,6974544	0,96209555	0,99695612	0,82977496	0,21069153
Laminaria replicate 1	Artificial replicate 2	0,15602352	0,1986005	0,78561493	-0,6737514	0,98579848	0,99340837	0,82977496	0,24843325
Laminaria replicate 1	Laminaria replicate 2	0,14476246	0,1986005	0,72891285	-0,6850125	0,97453742	0,99535137	0,82977496	0,23050248
Artificial replicate 2	Laminaria replicate 2	0,30078598	0,1986005	1,51452778	-0,528989	1,13056094	0,8907052	0,82977496	0,47893573

Table 14. Stastistics on condition factor of each fish for each replicate for T3. Shapiro-Wilk Test to check that groups are normally distributed, and Levene's test to check for homogeneity between the variance. Statistics show normally distributed groups and homogeneity between variance, and parametric test was performed. Parametric test ANOVA followed by Tukey test to check for significant difference between the different replicates in order to group them as Saccharina hide, artificial hide and Laminaria hide for. Following replicates were grouped with its replicate in one group as Saccharina hide, artificial hide and Laminaria hide. (p-value < 0.05 indicate significant difference).

Shapiro-Wilk Test							Levene's Tests	
	Saccharina replicate 1	*Artificial replicate 1*	*Laminaria replicate 1*	*Saccharina replicate 2*	*Artificial replicate 2*	*Laminaria replicate 2*	type	p-value
W-stat	0,95847605	0,90304128	0,96388123	0,92970214	0,94341592	0,9627003	means	0,43772028
p-value	0,76836523	0,23652441	0,82905546	0,44496882	0,61828108	0,81617018	medians	0,63268733
alpha	0,05	0,05	0,05	0,05	0,05	0,05	trimmed	0,43772028
normal	yes	yes	yes	yes	yes	yes		

ANOVA: Single Factor

Group	*Count*	*Sum*	*Mean*	*Variance*	*SS*	*Std Err*	*Lower*	*Upper*
Saccharina replicate 1	10	56,77	5,68	0,11924889	1,07324005	0,15315611	5,36947386	5,98385836
Artificial replicate 1	10	59,90	5,99	0,26844352	2,41599164	0,15315611	5,68306055	6,29744506
Laminaria replicate 1	10	62,05	6,20	0,27622942	2,48606476	0,15315611	5,89761308	6,51199758
Saccharina replicate 2	10	58,75	5,87	0,37782404	3,40041633	0,15315611	5,56747539	6,18185989
Artificial replicate 2	9	53,49	5,94	0,26900783	2,1520626	0,16144071	5,61964395	6,26726208
Laminaria replicate 2	10	60,03	6,00	0,10048058	0,90432521	0,15315611	5,69626432	6,31064882

ANOVA

Sources	*SS*	*df*	*MS*	*F*	*P value*	*Eta-sq*	*RMSSE*	*Omega Sq*
Between Grc	1,49822414	5	0,29964483	1,27743302	0,28743563	0,10755127	0,35741553	0,02297119
Within Grouţ	12,4321006	53	0,23456794					
Total	13,9303247	58	0,24017801					

TUKEY HSD/KRAMER — alpha 0,05

group	*mean*	*n*	*ss*	*df*	*q-crit*
Saccharina replicate 1	5,68	10	1,07324005		
Artificial replicate 1	5,99	10	2,41599164		
Laminaria replicate 1	6,20	10	2,48606476		
Saccharina replicate 2	5,87	10	3,40041633		
Artificial replicate 2	5,94	9	2,1520626		
Laminaria replicate 2	6,00	10	0,90432521		
		59	12,4321006	53	4,18096226

Q TEST

group 1	*group 2*	*mean*	*std err*	*q-stat*	*lower*	*upper*	*p-value*	*mean-crit*	*Cohen d*
Saccharina replicate 1	Artificial replicate 1	0,31358669	0,15315611	2,04749714	-0,3267532	0,9539266	0,6980465	0,64033991	0,64747545
Saccharina replicate 1	Laminaria replicate 1	0,52813922	0,15315611	3,44837188	-0,1122007	1,16847913	0,16190143	0,64033991	1,09047094
Saccharina replicate 1	Saccharina replicate 2	0,19800153	0,15315611	1,29280857	-0,4423384	0,83834144	0,94117834	0,64033991	0,40882197
Saccharina replicate 1	Artificial replicate 2	0,2667869	0,15735294	1,69546814	-0,3910998	0,92467362	0,83542692	0,65788672	0,55084598
Saccharina replicate 1	Laminaria replicate 2	0,32679046	0,15315611	2,1337083	-0,3135495	0,96713037	0,6602522	0,64033991	0,67473781
Artificial replicate 1	Laminaria replicate 1	0,21455252	0,15315611	1,40087475	-0,4257874	0,85489243	0,91895186	0,64033991	0,44299549
Artificial replicate 1	Saccharina replicate 2	0,11558516	0,15315611	0,75468857	-0,5247547	0,75592507	0,99452594	0,64033991	0,23865348
Artificial replicate 1	Artificial replicate 2	0,04679979	0,15735294	0,29741923	-0,6110869	0,70468651	0,99993991	0,65788672	0,09662947
Artificial replicate 1	Laminaria replicate 2	0,01320377	0,15315611	0,08621116	-0,6271361	0,65354368	0,99999987	0,64033991	0,02726236
Laminaria replicate 1	Saccharina replicate 2	0,33013769	0,15315611	2,15556331	-0,3102022	0,9704776	0,65051783	0,64033991	0,68164897
Laminaria replicate 1	Artificial replicate 2	0,26135232	0,15735294	1,66093058	-0,3965344	0,91923903	0,84689828	0,65788672	0,53962496
Laminaria replicate 1	Laminaria replicate 2	0,20134876	0,15315611	1,31466358	-0,4389912	0,84168867	0,93704586	0,64033991	0,41573313
Saccharina replicate 2	Artificial replicate 2	0,06878537	0,15735294	0,43714068	-0,5891013	0,72667209	0,99960042	0,65788672	0,14202401
Saccharina replicate 2	Laminaria replicate 2	0,12878893	0,15315611	0,84089973	-0,511551	0,76912884	0,99097184	0,64033991	0,26591584
Artificial replicate 2	Laminaria replicate 2	0,06000356	0,15735294	0,38133101	-0,5978832	0,71789028	0,99979536	0,65788672	0,12389183

Table 15. Statistics on condition factor of fish in T1. Shapiro-Wilk Test to check that groups are normally distributed, and Levene's test to check for homogeneity between the variance. Statistics show normally distributed groups and homogeneity between variance, and parametric tests was performed. Parametric test ANOVA followed by Tukey test to check for significant difference between the different groups; Saccharina hide, artificial hide and Laminaria hide. (p-value < 0.05 indicate significant difference).

Shapiro-Wilk Test		Shapiro-Wilk Test		Shapiro-Wilk Test		Levene's Tests	
	Saccharina		*Artificial*		*Laminaria*		
W-stat	0,91613975	W-stat	0,94926029	W-stat	0,94126385	type	p-value
p-value	0,08352362	p-value	0,35600119	p-value	0,25331191	means	0,77665541
alpha	0,05	alpha	0,05	alpha	0,05	medians	0,70634182
normal	yes	normal	yes	normal	yes	trimmed	0,73700984

ANOVA: Single Factor

DESCRIPTION Alpha 0,05

Group	*Count*	*Sum*	*Mean*	*Variance*	*SS*	*Std Err*	*Lower*	*Upper*
Saccharina	20	127,95	6,40	0,71736857	13,6300028	0,19314247	6,01091154	6,7844338
Artificial	20	133,79	6,69	0,88604295	16,8348161	0,19314247	6,30295521	7,07647746
Laminaria	20	131,89	6,59	0,63482933	12,0617574	0,19314247	6,20762593	6,98114818

ANOVA

Sources	*SS*	*df*	*MS*	*F*	*P value*	*Eta-sq*	*RMSSE*	*Omega Sq*
Between Grc	0,88715815	2	0,44357907	0,59454603	0,55519856	0,02043497	0,17241607	-0,0137003
Within Grou	42,5265763	57	0,74608029					
Total	43,4137345	59	0,73582601					

TUKEY HSD/KRAMER alpha 0,05

group	*mean*	*n*	*ss*	*df*	*q-crit*
Saccharina	6,40	20	13,6300028		
Artificial	6,69	20	16,8348161		
Laminaria	6,59	20	12,0617574		
		60	42,5265763	57	3,40342105

Q TEST

group 1	*group 2*	*mean*	*std err*	*q-stat*	*lower*	*upper*	*p-value*	*mean-crit*	*Cohen d*
Saccharina	Artificial	0,29204366	0,19314247	1,51206341	-0,3653015	0,94938882	0,53691933	0,65734515	0,33810766
Saccharina	Laminaria	0,19671438	0,19314247	1,01849367	-0,4606308	0,85405954	0,75260563	0,65734515	0,22774211
Artificial	Laminaria	0,09532928	0,19314247	0,49356974	-0,5620159	0,75267443	0,93514083	0,65734515	0,11036555

Table 16. Statistics on condition factor of fish in T2. Shapiro-Wilk Test to check that groups are normally distributed, and Levene's test to check for homogeneity between the variance. Statistics show normally distributed groups and homogeneity between variance, and parametric tests was performed. Parametric test ANOVA followed by Tukey test to check for significant difference between the different groups; Saccharina hide, artificial hide and Laminaria hide. (p-value < 0.05 indicate significant difference).

Shapiro-Wilk Test	*Saccharina*	Shapiro-Wilk Test	*Artificial*	Shapiro-Wilk Test	*Laminaria*	Levene's Tests	
W-stat	0,93566262	W-stat	0,98633128	W-stat	0,96699204	type	p-value
p-value	0,19831071	p-value	0,98852096	p-value	0,69052588	means	0,62079675
alpha	0,05	alpha	0,05	alpha	0,05	medians	0,64831468
normal	yes	normal	yes	normal	yes	trimmed	0,62912741

ANOVA: Single Factor

DESCRIPTION — Alpha 0,05

Group	*Count*	*Sum*	*Mean*	*Variance*	*SS*	*Std Err*	*Lower*	*Upper*
Saccharina	20	123,47	6,17	0,45191446	8,58637467	0,14409926	5,88480709	6,46191466
Artificial	20	132,46	6,62	0,48224768	9,16270589	0,14409926	6,33452373	6,9116313
Laminaria	20	132,81	6,64	0,31171361	5,92255854	0,14409926	6,35211817	6,92922574

ANOVA

Sources	*SS*	*df*	*MS*	*F*	*P value*	*Eta-sq*	*RMSSE*	*Omega Sq*
Between Grc	2,80622843	2	1,40311421	3,37862156	0,04105271	0,10598393	0,41101226	0,07346272
Within Grou	23,6716391	57	0,41529191					
Total	26,4778675	59	0,44877742					

TUKEY HSD/KRAMER — alpha 0,05

group	*mean*	*n*	*ss*	*df*	*q-crit*
Saccharina	6,17	20	8,58637467		
Artificial	6,62	20	9,16270589		
Laminaria	6,64	20	5,92255854		
		60	23,6716391	57	3,40342105

Q TEST

group 1	*group 2*	*mean*	*std err*	*q-stat*	*lower*	*upper*	*p-value*	*mean-crit*	*Cohen d*
Saccharina	Artificial	0,44971664	0,14409926	3,12088105	-0,0407138	0,94014708	0,07859681	0,49043044	0,69785022
Saccharina	Laminaria	0,46731108	0,14409926	3,2429805	-0,0231194	0,95774152	0,06487729	0,49043044	0,72515249
Artificial	Laminaria	0,01759444	0,14409926	0,12209945	-0,472836	0,50802488	0,99589911	0,49043044	0,02730227

Table 17. Statistics on condition factor of fish in T3. Shapiro-Wilk Test to check that groups are normally distributed, and Levene's test to check for homogeneity between the variance. Statistics show normally distributed groups and homogeneity between variance, and parametric tests was performed. Parametric test ANOVA followed by Tukey test to check for significant difference between the different groups; Saccharina hide, artificial hide and Laminaria hide. (p-value < 0.05 indicate significant difference).

Shapiro-Wilk Test		Shapiro-Wilk Test		Shapiro-Wilk Test		Levene's Tests	
	Saccharina		*Artificial*		*Laminaria*		
W-stat	0,97504653	W-stat	0,95285539	W-stat	0,98309453	type	p-value
p-value	0,85567796	p-value	0,44130503	p-value	0,96754083	means	0,81050748
alpha	0,05	alpha	0,05	alpha	0,05	medians	0,88547934
normal	yes	normal	yes	normal	yes	trimmed	0,80905639

ANOVA: Single Factor

DESCRIPTION					Alpha	0,05		
Group	*Count*	*Sum*	*Mean*	*Variance*	*SS*	*Std Err*	*Lower*	*Upper*
Saccharina	20	115,51	5,78	0,2457726	4,66967941	0,10707643	5,56116701	5,99016674
Artificial	19	113,39	5,97	0,25435717	4,57842897	0,1098581	5,74801227	6,1881567
Laminaria	20	122,08	6,10	0,18911035	3,59309658	0,10707643	5,88963109	6,31863081

ANOVA

Sources	*SS*	*df*	*MS*	*F*	*P value*	*Eta-sq*	*RMSSE*	*Omega Sq*
Between Grc	1,08911977	2	0,54455988	2,37480467	0,10234039	0,07818337	0,34464385	0,04452837
Within Grouį	12,841205	56	0,22930723					
Total	13,9303247	58	0,24017801					

TUKEY HSD/KRAMER		alpha		0,05	
group	*mean*	*n*	*ss*	*df*	*q-crit*
Saccharina	5,78	20	4,66967941		
Artificial	5,97	19	4,57842897		
Laminaria	6,10	20	3,59309658		
		59	12,841205	56	3,405

Q TEST

group 1	*group 2*	*mean*	*std err*	*q-stat*	*lower*	*upper*	*p-value*	*mean-crit*	*Cohen d*
Saccharina	Artificial	0,19241761	0,10847618	1,77382359	-0,1769438	0,561779	0,42679631	0,36936139	0,40182406
Saccharina	Laminaria	0,32846407	0,10707643	3,06756658	-0,0361312	0,69305931	0,08546149	0,36459524	0,68592874
Artificial	Laminaria	0,13604647	0,10847618	1,25415983	-0,2333149	0,50540786	0,65079675	0,36936139	0,28410468

Table 18. Statistics on the percentage of "sheltered" fish in T0-T1. Feeding times and the 30 min after are excluded. Shapiro-Wilk Test to check that groups are normally distributed, and Levene's test to check for homogeneity between the variance. Statistics show normally distributed groups and homogeneity between variance, and parametric tests was performed. Parametric test ANOVA followed by Tukey test to check for significant difference between the different groups; Saccharina hide, artificial hide and Laminaria hide. (p-value < 0.05 indicate significant difference).

Shapiro-Wilk Test		Shapiro-Wilk Test		Shapiro-Wilk Test		Levene's Tests	
	Saccharina hide		*Artificial hide*		*Laminaria hide*		
W-stat	0,8708623	W-stat	0,914780664	W-stat	0,844683028	type	p-value
p-value	0,153681987	p-value	0,38895996	p-value	0,084116576	means	0,52780485
alpha	0,05	alpha	0,05	alpha	0,05	medians	0,62585502
normal	yes	normal	yes	normal	yes	trimmed	0,52780485

ANOVA: Single Factor

DESCRIPTION					Alpha	0,05		
Group	*Count*	*Sum*	*Mean*	*Variance*	*SS*	*Std Err*	*Lower*	*Upper*
Saccharina hic	8	583,63	72,95	8,30385593	58,12699149	1,73445918	69,346211	76,5602217
Artificial hide	8	569,80	71,23	35,8510531	250,9573716	1,73445918	67,6184849	74,8324955
Laminaria hid	8	607,18	75,90	28,0454588	196,3182117	1,73445918	72,2904306	79,5044412

ANOVA

Sources	*SS*	*df*	*MS*	*F*	*P value*	*Eta-sq*	*RMSSE*	*Omega Sq*
Between Grou	89,28144796	2	44,64072398	1,85486828	0,18121218	0,15013258	0,48151691	0,06650152
Within Group	505,4025748	21	24,06678927					
Total	594,6840227	23	25,85582707					

TUKEY HSD/KRAMER			alpha	0,05	
group	*mean*	*n*	*ss*	*df*	*q-crit*
Saccharina hic	72,95	8	58,12699149		
Artificial hide	71,23	8	250,9573716		
Laminaria hid	75,90	8	196,3182117		
		24	505,4025748	21	3,565

Q TEST

group 1	*group 2*	*mean*	*std err*	*q-stat*	*lower*	*upper*	*p-value*	*mean-crit*	*Cohen d*
Saccharina hic	Artificial hide	1,72772618	1,734459184	0,9961181	-4,455620811	7,91107317	0,76358556	6,18334699	0,35218093
Saccharina hic	Laminaria hide	2,94421952	1,734459184	1,69748562	-3,239127466	9,12756651	0,46605091	6,18334699	0,6001518
Artificial hide	Laminaria hide	4,6719457	1,734459184	2,69360372	-1,511401288	10,8552927	0,1621143	6,18334699	0,95233273

Table 19. Statistics on the percentage of "sheltered" fish in T1-T2. Feeding times and the 30 min after are excluded. Shapiro-Wilk Test to check that groups are normally distributed, and Levene's test to check for homogeneity between the variance. Statistics show normally distributed groups and homogeneity between variance, and parametric tests was performed. Parametric test ANOVA followed by Tukey test to check for significant difference between the different groups; Saccharina hide, artificial hide and Laminaria hide. (p-value < 0.05 indicate significant difference).

Shapiro-Wilk Test		Shapiro-Wilk Test		Shapiro-Wilk Test		Levene's Tests	
	Saccharina hide		*Artificial hide*		*Laminaria hide*		
W-stat	0,958461311	W-stat	0,946845778	W-stat	0,973398717	type	p-value
p-value	0,795321274	p-value	0,679413315	p-value	0,923261837	means	0,12707322
alpha	0,05	alpha	0,05	alpha	0,05	medians	0,1424102
normal	yes	normal	yes	normal	yes	trimmed	0,12707322

ANOVA: Single Factor								
DESCRIPTION					Alpha	0,05		
Group	*Count*	*Sum*	*Mean*	*Variance*	*SS*	*Std Err*	*Lower*	*Upper*
Saccharina hic	8	595,08	74,38	5,60763149	39,25342041	1,23682187	71,8124725	76,9566962
Artificial hide	8	585,23	73,15	5,10164959	35,7115471	1,23682187	70,5817874	75,7260111
Laminaria hid	8	553,36	69,17	26,0041989	182,0293921	1,23682187	66,5981467	71,7423705
ANOVA								
Sources	*SS*	*df*	*MS*	*F*	*P value*	*Eta-sq*	*RMSSE*	*Omega Sq*
Between Grou	118,8617897	2	59,43089485	4,85632756	0,018470144	0,31624277	0,77912832	0,24320433
Within Group	256,9943596	21	12,23782665					
Total	375,8561493	23	16,34157171					

TUKEY HSD/KRAMER		alpha		0,05	
group	*mean*	*n*	*ss*	*df*	*q-crit*
Saccharina hic	74,38	8	39,25342041		
Artificial hide	73,15	8	35,7115471		
Laminaria hid	69,17	8	182,0293921		
		24	256,9943596	21	3,565

Q TEST									
group 1	*group 2*	*mean*	*std err*	*q-stat*	*lower*	*upper*	*p-value*	*mean-crit*	*Cohen d*
Saccharina hic	Artificial hide	1,2306851	1,236821867	0,99503828	-3,178584855	5,63995506	0,76402584	4,40926996	0,35179916
Saccharina hic	Laminaria hide	5,21432572	1,236821867	4,2159068	0,805055765	9,62359568	0,01871678	4,40926996	1,49054814
Artificial hide	Laminaria hide	3,98364062	1,236821867	3,22086852	-0,425629336	8,39291058	0,08133523	4,40926996	1,13874899

Table 20. Statistics on the percentage of "sheltered" fish in T2-T3. Feeding times and the 30 min after are excluded. Shapiro-Wilk Test to check that groups are normally distributed, and Levene's test to check for homogeneity between the variance. Statistics show normally distributed groups and homogeneity between variance, and parametric tests was performed. Parametric test ANOVA followed by Tukey test to check for significant difference between the different groups; Saccharina hide, artificial hide and Laminaria hide. (p-value < 0.05 indicate significant difference).

Shapiro-Wilk Test		Shapiro-Wilk Test		Shapiro-Wilk Test		Levene's Tests	
	Saccharina hide		*Laminaria hide*		*Artificial hide*		
W-stat	0,912256902	W-stat	0,834230141	W-stat	0,90396296	type	p-value
p-value	0,370230581	p-value	0,065679631	p-value	0,313500432	means	0,07204573
alpha	0,05	alpha	0,05	alpha	0,05	medians	0,19168434
normal	yes	normal	yes	normal	yes	trimmed	0,07204573

ANOVA: Single Factor

DESCRIPTION — Alpha 0,05

Group	*Count*	*Sum*	*Mean*	*Variance*	*SS*	*Std Err*	*Lower*	*Upper*
Saccharina hid	8	514,69	64,34	20,6165241	144,3156688	1,07927264	62,091194	66,5801347
Laminaria hid	8	521,24	65,16	5,25889273	36,81224914	1,07927264	62,9106049	67,3995455
Artificial hide	8	546,51	68,31	2,08048967	14,56342768	1,07927264	66,0694832	70,5584238

ANOVA

Sources	*SS*	*df*	*MS*	*F*	*P value*	*Eta-sq*	*RMSSE*	*Omega Sq*
Between Grou	70,60461558	2	35,30230779	3,7883559	0,039370771	0,26513589	0,68814569	0,18855077
Within Group	195,6913456	21	9,318635505					
Total	266,2959612	23	11,57808527					

TUKEY HSD/KRAMER — alpha 0,05

group	*mean*	*n*	*ss*	*df*	*q-crit*
Saccharina hid	64,34	8	144,3156688		
Laminaria hid	65,16	8	36,81224914		
Artificial hide	68,31	8	14,56342768		
		24	195,6913456	21	3,565

Q TEST

group 1	*group 2*	*mean*	*std err*	*q-stat*	*lower*	*upper*	*p-value*	*mean-crit*	*Cohen d*
Saccharina hid	Laminaria hide	0,81941085	1,079272643	0,75922507	-3,02819612	4,66701782	0,85418586	3,84760697	0,2684266
Saccharina hid	Artificial hide	3,97828915	1,079272643	3,68608357	0,13068218	7,82589613	0,04185718	3,84760697	1,30322734
Laminaria hid	Artificial hide	3,1588783	1,079272643	2,92685849	-0,688728672	7,00648527	0,12060558	3,84760697	1,03480074

Table 21. Total injuries for T1. Non-parametric test: Kruskal-Wallis Test to check for difference between the groups, followed by Pairwise Mann-Whitney test

Kruskal-Wallis Test				
	Saccharina	Artificial	Laminaria	
median	5	7	5	
rank sum	557,5	736,5	536	
count	20	20	20	60
r^2/n	15540,3125	27121,6125	14364,8	57026,725
H-stat				3,97286885
H-ties				5,03995594
df				2
p-value				0,08046138
alpha				0,05
sig				no

Pairwise Mann-Whitney exact tests

group 1	*group 2*	*p-value*	*U-stat*	*mean*
Saccharina	Artificial	0,10216095	139,5	0,75
Saccharina	Laminaria	0,84101273	192	0,1
Artificial	Laminaria	0,07626619	134	0,85

Table 22. Total injuries for T2. Non-parametric test: Kruskal-Wallis Test to check for difference between the groups, followed by Pairwise Mann-Whitney test

Kruskal-Wallis Test				
	Saccharina	Artificial	Laminaria	
median	6	6	5	
rank sum	673	675	482	
count	20	20	20	60
r^2/n	22646,45	22781,25	11616,2	57043,9
H-stat				4,02918033
H-ties				4,84967727
df				2
p-value				0,0884924
alpha				0,05
sig				no

Pairwise Mann-Whitney exact tests

group 1	*group 2*	*p-value*	*U-stat*	*mean*
Saccharina	Artificial	0,98933163	199	0
Saccharina	Laminaria	0,08591402	136	0,75
Artificial	Laminaria	0,08591402	136	0,75

Table 23. Total injuries for T3. Non-parametric test: Kruskal-Wallis Test to check for difference between the groups, followed by Pairwise Mann-Whitney test

Kruskal-Wallis Test				
	Saccharina	Artificial	Laminaria	
median	6	5	5	
rank sum	798,5	587	444,5	
count	20	20	20	60
r^2/n	31880,1125	17228,45	9879,0125	58987,575
H-stat				10,4018852
H-ties				13,875606
df				2
p-value				0,0009704
alpha				0,05
sig				yes

Pairwise Mann-Whitney exact tests

group 1	*group 2*	*p-value*	*U-stat*	*mean*
Saccharina	Artificial	0,05239952	128,5	0,55
Saccharina	Laminaria	0,00116007	83	0,9
Artificial	Laminaria	0,19175132	151,5	0,35