Phyco Farming

Growing Giant Kelp in Schools

A Natural Sciences Project

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Introduction

Our project was developed in response to a number of concerns raised in our local community related to climate change. Due to climate change and the warming of our oceans, there has been a steady decline in the giant kelp (*Macrocystis pyrifera*) in local waters. These kelp forests are important organisms in supporting local biodiversity and act as a hatchery ground for many important commercial fishing industries. The culture of seaweed in aquaculture is a rapidly expanding activity. As a part of our aquaculture class, we decided to investigate the possibility of growing giant kelp in a school setting for both conservation and commercial purposes.

Giant Kelp Culture for Conservation

Tasmanian waters have seen a 90% decline in its giant kelp forests (Layton *et al*, 2020). This is alarming for a number of reasons. Aside from the kelp itself now listed as an endangered species, the kelp forests of Tasmania are a stunning and hugely valuable ecosystem supporting a myriad of marine life and fisheries. Local scientists are currently conducting research into how they can save the kelp and repopulate local beds. We believe that this is extremely urgent, important and exciting research and realised that we could contribute.

Giant Kelp for Climate Care

The enhanced greenhouse effect is a result of increased carbon dioxide and other greenhouse gases being released into the atmosphere. This build up leads to more heat from the sun being trapped in our atmosphere. Luckily the world's oceans have the capacity to absorb one third of the carbon dioxide in the atmosphere but that is limited to the surface layers of the water .

Seaweed can grow very fast – at rates more than 30 times those of land-based plants. Specifically, giant kelp can grow up to 60cm a day, given the right conditions. As it grows, kelp takes carbon dioxide (CO_2) out of the water in much the same way that a land plant takes CO_2 out of the air.

By drawing significant amounts of CO_2 out of oceanic waters (thereby allowing the oceans to absorb more CO_2 from the atmosphere) they can help fight climate change. We believe that there is a real and feasible opportunity for communities to grow kelp for climate care and we wanted to see how easy it was to get this started.(source: https://theconversation.com/how-farming-giant-seaweed-can-feed-fish-and-fix-the-climate-81761)

Giant Kelp for Sustainable Commercial Purposes

Sustainable and reliable food supply for an ever growing population is also of concern. Seaweed has been shown to be fast growing, nutritious and can absorb large amounts of carbon dioxide from the surrounding environment as they grow. Currently seaweed can be eaten as a whole product but there is also a steady increase in the demand for the active ingredients contained in seaweed (Lucas *et.al.*, 2019) One example is the extraction of alginates which are widely used in manufacturing products as diverse as ice cream, skin cream, beer and medicine. Other active ingredients extracted from seaweed like fucoidans can be used to improve gut health, immune function and is anti-viral (source: https://www.marinova.com.au/product-portfolio/) Our team believes that if people can grow enough kelp, not only can we produce enough to fight extinction and care for climate, we can contribute to the production of a sustainable and nutritious food source.

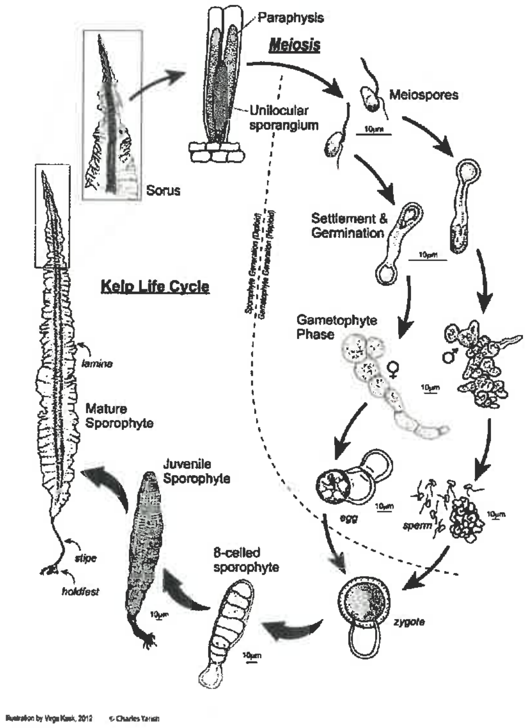
The Biology of Kelp

Instead of roots like a tree, kelp has things called holdfasts that attach the kelp onto rocky substrates. From the holdfasts, kelp plants grow toward the water's surface.

Giant kelp is a perennial (i.e. it lives for several years) and has a two-stage life cycle. They exist in their earliest life stages as gametophytes, released with millions of others from the parent kelp, called the sporophyte. The spores grow into a tiny male or female plant called a gametophyte, which produces either sperm or eggs . After fertilization occurs, the embryos may grow into mature plants (sporophytes), completing the life cycle (see image on next page).

Giant kelp can live up to seven years. Factors such as the severity of winter storms and seawater temperature can affect its life span (Mabin, et al , 2019). Its average growth in Spring) is 27 cm/day, but it may grow up to 61 cm/day (source: https://sanctuaries.noaa.gov/visit/ecosystems). Our team believes that research done can contribute to our understanding of the biology of giant help and help that can be used to support its potentially large scale production (starting in an aquaculture facility like ours).

Life Cycle of *Macrocystis pyrifera*



(Image from Redman, S. et al (2013) New England Seaweed Culture Handbook: Nursery Systems.)

Background Research for Project

We are Year 11 students at Newtown High school enrolled in a subject called Agricultural Enterprise (2) (Aquaculture). As part of our studies we have to research and develop an aquaculture enterprise. We were curious about the possibility of growing kelp at our school and decided as a group to explore this as a project. As well as conducting our own research, we contacted scientists at the Institute of Marine and Antarctic Studies at the University of Tasmania looking for information, guidance and mentoring. Luckily for us, Dr Cayne Layton was keen to help and provided us with invaluable support and materials – especially the baby kelp gametophytes that he and other researchers had carefully isolated and cultured.

Aim of Project

The first thing we have set out to answer is whether it possible for kelp (*Macrocystis pyrifera*) to be grown for conservation, restoration and aquaculture purposes in a school environment successfully. To do this, split the project up into 2 parts. Firstly we wanted to see what the optimum amount of nutrients (if any) that are required to grow the kelp in a school setting would be. The second was to see what kind of easily available substrates could be used to grow kelp on to and then successfully transfer out in open water and coastal conditions.

Part 1

Aim: To determine optimum amount of nutrients required to grow kelp in a school lab.

Independent Variable (what we will be changing): Quantity of F2 Seawater Nutrients supplied to kelp in culture (0% F@, 50% F@, 100% F2).

Note: F2 Nutrients is an important aspect to the growth of our algal species as it enables us to promote as much growth as possible. Water currents stimulated by the air flow allows the nutrients to be dispersed onto all algal species. F2 Nutrients is a commercial product that contains nitrate, Iron, Phosphate, citrate, and essential vitamins. It is commonly used in professional and academic algal growth trials and experiments.

Dependent variable (what we will be measuring): Observable development/growth of healthy kelp.

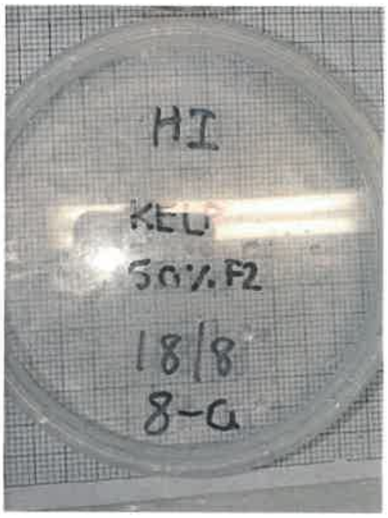
Control (what makes it a fair test): we will be using the same stock source of *Macrocystis pyrifera* gametophytes (supplied by IMAS), same supply of filtered seawater and F2 nutrients. The kelp will also be kept at the same temperature and be exposed to the same light cycle).

Equipment:

- 1 liter cylindrical containers for kelp to grow in
- *Macrocystis pyrifera* gametophytes (provided by IMAS)
- Hydroponic grow lighting
- Sterile technique equipment:
    - Glass beakers
    - Glass pipette
    - Kettle for sterile practices to reduce cross contamination.
- Stasis Chamber (Red LED Light - to maintain baby kelp in gametophyte stage)
- Growth Chamber (Blue LED light - to stimulate transformation of baby kelp from gametophyte to sporophyte stage of life cycle)
- Filtered Sea Water (provided by IMAS)
- F2 liquid Nutrients (provided by IMAS)
- Sterile flasks.

Method:

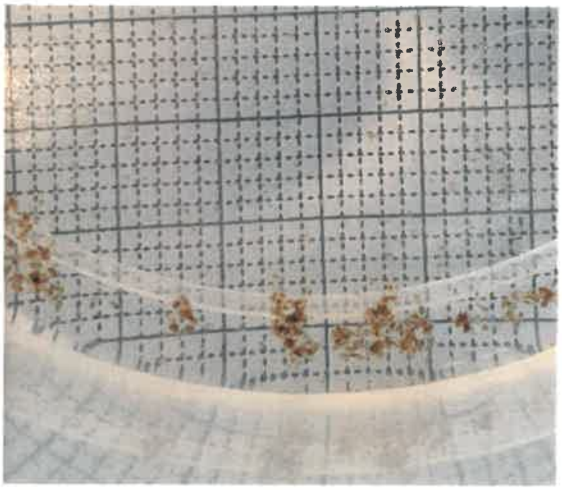
1. Set up basic laboratory facility with required equipment for salt-water algal growth.
2. Obtain sterile gametophytes from IMAS laboratory (keep in complete darkness until ready to transfer to red LED light chamber)
3. Transfer gametophytes sterile conical flasks filled with 50% sterile seawater and 50% F2 liquid nutrients and seal.
4. Keep cultivated gametophyte under red LED lighting to sustain plant life.
5. Once ready to conduct the growth trial, decanter the gametophytes evenly into three containers with 0% F2 nutrients and 100% filtered seawater, additional 3 containers of 50% F2 and 50% sea water, additional 3 containers of 100% F2 nutrients.
6. Place containers under direct hydroponic grow lighting to continue growth cycle (placed on a timer system of 12 hours lights, 12 hours dark).
7. Collect qualitative data for the growth trial – measuring through photographic evidence and commenting on observed weekly growth.



Example of growth container

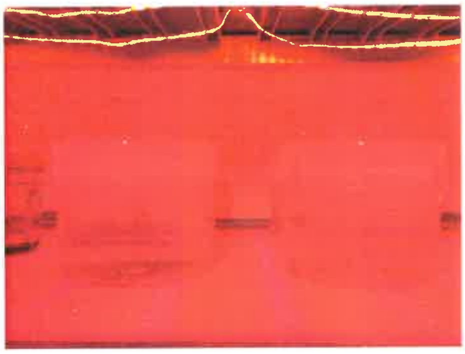
(above and below)

Samples of baby kelp growth trials



Example of growth and coverage observation

Growth chambers built by team to manage sensitive gametophyte phase of kelp life cycle



Inside red LED "stasis" chamber

Inside blue LED stimulation chamber

Part 2: Investigation of ideal substrate to be used for kelp attachment and growth.

Aim: To determine which type of easily available substrate string is most suitable for the attachment and on growing of Giant Kelp (*Macrocystis pyrifera*)

Independent Variable: Substrate string type (cotton polyester thread, acrylic wool, twine, clear stretchy jewelry string, and hemp)

Dependent Variable: Success of attachment of developing sporophytes and subsequent growth in culture (measured via qualitative observation).

Control (what makes it a fair test): we will be using the same stock source of *Macrocystis pyrifera* gametophytes (supplied by IMAS), same supply of filtered seawater and F2 nutrients. The kelp will also be kept at the same temperature and be exposed to the same light cycle).

Equipment Required:

- Containers for algal to grow in
- *Macrocystis pyrifera* gametophytes (provided by IMAS)
- Hydroponic Grow lighting
- Sterile technique equipment:
  - Glass beakers
  - Glass pipette
  - Kettle for sterile practices
- Stasis Chamber (completely sealed with Red LED Lighting)
- Growth Chamber (completely sealed with Blue LED lighting)
- Filtered Sea Water (provided by IMAS)
- F2 Nutrients (provided by IMAS)
- Hemp Cord
- Adhesive elastic jewelry string
- Cotton polyester thread
- Acrylic Wool
- Hessian Twine
- Corflute (cut into small strips)

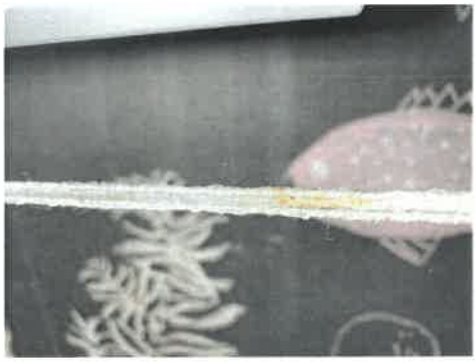
Method:

1. Wrap various substrate string around thin strips of corflute and place in tub of sea water, pour in the *Macrocystis pyrifera* gametophyte and let it settle and attach briefly to the string that is wrapped around the pipe and continued growth for five weeks under the hydroponic growth light (12 hours light, 12 hours dark timed cycle).
2. After 5 weeks, gently unravel string and set each strand up horizontally in the fish tank to simulate the oceanic conditions.

3. This experiment is ongoing and observation processes are still underway.

Ocean Simulation Grow out Tank with various substrate (and kelp) attached

Example of Hydroponics grow light



Polyester Wool Substrate

Hessian Twine Substrate

-Hemp String substrate

Cotton Polyester thread substrate wrapped

around corflute

First stage kelp sporophyte growth, and attachment to all substrate types

Gametophytes settling on to substrates

OBSERVATIONS AND RESULTS

Part 1:

Results for testing optimum amount of nutrients required to grow kelp in a school lab (without substrate).

Week 1

0%F2, 100% filtered seawater	50% F2, 50% filtered seawater	100% F2, 0% filtered seawater
a. Small amount present	a. Small amount of kelp visible	a. Small amount of kelp visible
b. Small amount present	b. Small amount of kelp visible	b. Small amount of kelp visible
c. Small amount present	c. Small amount of kelp visible	c. Small amount of kelp visible

Week 2

0%F2, 100% filtered seawater	50% F2, 50% filtered seawater	100% F2, 0% filtered seawater
a. Size and amount of kelp has increased slightly	a. Size and amount of kelp has increased	a. Kelp has increased in size but there appears to be some form of contamination in the container
b. Size and amount of kelp has increased slightly	b. Size and amount of kelp has increased	b. This container also showing signs of growth and contamination
c. Size and amount of kelp coverage has increased slightly	c. Size and amount of kelp has increased	c. Kelp has grown and deepened in colour but this containers has less contamination than others

Week 3

0%F2, 100% filtered seawater	50% F2, 50% filtered seawater	100% F2, 0% filtered seawater
a. Growing and developing well	a. Growing and developing well	a. Appears to be darker in colour to the others
b. Growing well – pale in colour	b. Growing well but darker in colour	b. Growing well along with everything else – contaminated growth though
c. Growing and developing well – pale colour	c. Growing and developing well - darker	c. Appears to be getting darker in colour to the others along with contamination

Week 4

0%F2, 100% filtered seawater	50% F2, 50% filtered seawater	100% F2, 0% filtered seawater
a. Growing and developing well – leaves are larger and less in number	a. Growth visible – leaves smaller but greater in number	a. Appears to be darker in colour to the others and growing alongside contamination.
b. Growing well – pale in colour but longer leaves	b. Darker growth but appears smaller	b. Difficult to determine growth due to contamination
c. Growing and developing well – pale colour and more noticeable leaves	c. Small dark leaves – growing ok	c. Kelp darkening up but too much contamination

Week 5

0%F2, 100% filtered seawater	50% F2, 50% filtered seawater	100% F2, 0% filtered seawater
a. Leaves are noticeably paler in colour but larger than the others	a. Leaves more detailed and darker – doesn't appear to be getting bigger in size	a. Kelp appears to have died
b. Good growth but pale in colour	b. Coverage increasing but plants don't seem to be getting bigger	b. Whole container looks pale – kelp appears to have died
c. Growth good – fewer leaves but bigger	c. Kelp growing in thickness but not size	c. Container contents very pale

Image gallery of our kelp growth under microscope:

Summary of results: Based on initial observations, it appears that 100% F2 nutrient is not good for growing kelp in culture. Despite initial good results and growth the increased amount of nutrients available support both the growth of the kelp and contaminants Both 0% F2 and 50% F2 showed good growth but we will need to conduct further research to determine the long term effects of the difference between pale large growth and small dense growth of leaves.

Part 2:

Results for Investigation of ideal substrate to be used for kelp attachment and growth.

Week 1 0% F2 Nutrients			
	Growth (mm)	Coverage (%)	Observations
Cotton-Polyester Thread	<1mm	<1%	Small amount of attachment to thread
Hessian Twine	<1mm	<1%	Difficult to observe due to colour, small amount of attachment
Jewellery String	<1mm	<1%	Unsure if attachment is on string or on plastic
Hemp String	<1mm	<1%	Small amount of attachment to string
Acrylic Wool	<1mm	<1%	Most visible amount of attachment
Corflute Plastic	<1mm	<1%	Unsure if it is attached

Week 1 50% F2 Nutrients			
	Growth (mm)	Coverage (%)	Observations
Cotton-Polyester Thread	<1mm	<1%	Small amount of attachment to thread
Hessian Twine	<1mm	<1%	Difficult to observe due to colour, small amount of attachment
Jewellery String	<1mm	<1%	Unsure if attachment is on string or on plastic, not much attachment
Hemp String	<1mm	<1%	Small amount of attachment to string
Acrylic Wool	<1mm	<1%	Not much attachment
Corflute Plastic	<1mm?	<1%?	Maybe attachment or just settled on plastic

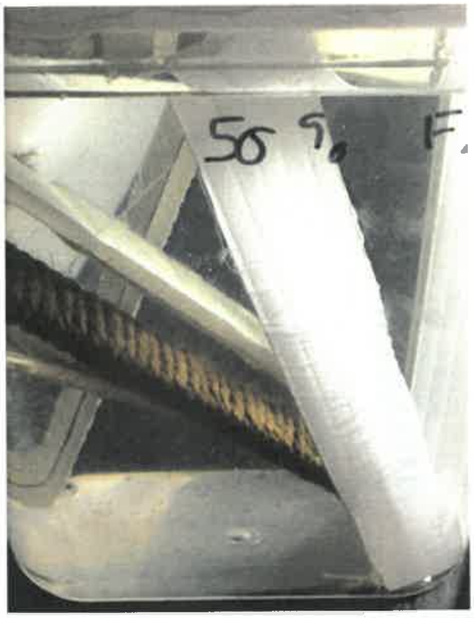
Week 2 0% F2 Nutrients			
	Growth (mm)	Coverage (%)	Observations
Cotton-Polyester Thread	<1mm	<1%-1%	More attachment to string, still small amount/size
Hessian Twine	<1mm	1%	Difficult to tell, more attachment
Jewellery String	<1mm	<1%	No change, still unsure if on string or on plastic
Hemp String	<1mm	<1%	Very small amount/size
Acrylic Wool	<1mm-1mm	2%	Wider range of growth sizes, best growth/coverage
Corflute Plastic	<1mm-1mm	<1%-1%	Wider range of growth sizes, better coverage

Week 2 0% F2 Nutrients

Week 2 0% F2 Nutrients

Week 2 50% F2 Nutrients			
	Growth (mm)	Coverage (%)	Observations
Cotton-Polyester Thread	<1mm	<1%	Not much growth or coverage
Hessian Twine	<1mm	<1%	Very difficult to tell
Jewellery String	<1mm	<1%	Unsure if there is any attachment
Hemp String	<1mm	<1%	Small amount of growth and coverage
Acrylic Wool	<1mm-1mm	<1%	Biggest of all
Corflute Plastic	<1mm-1mm	<1%	Little amount, big size

Week 2 50% F2 Nutrients



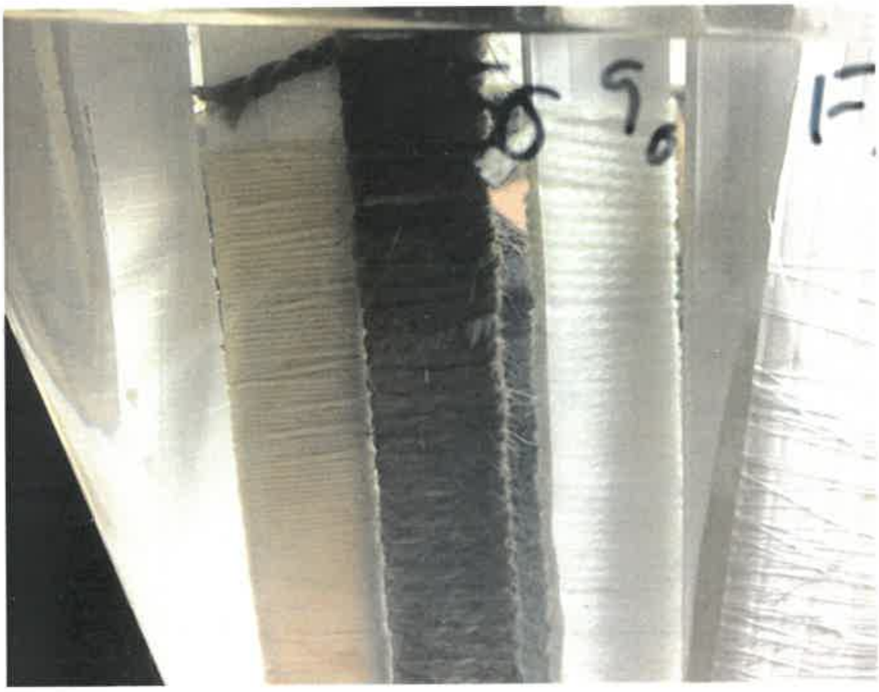
Week 2 50% F2 Nutrients

Week 3 0% F2 Nutrients			
	Growth (mm)	Coverage (%)	Observations
Cotton-Polyester Thread	<1mm-1mm	1%	Bigger growth
Hessian Twine	<1mm-1mm	2%	More attachment, bigger growth
Jewellery String	<1mm-1mm	2%	Unsure if on string or on plastic
Hemp String	<1mm-1mm	1%	Not much attachment
Acrylic Wool	<1mm-1mm	3%	Going very well, more attachment, wider range of growth sizes
Corflute Plastic	<1mm-1mm	2%	Going well

Week 3 0%F2 Nutrients

Week 3 50% F2 Nutrients			
	Growth (mm)	Coverage (%)	Observations
Cotton-Polyester Thread	1mm	<1%	Not much coverage but bigger size
Hessian Twine	1mm	<1%	Not much coverage but bigger size
Jewellery String	<1mm	<1%	Not much coverage or size
Hemp String	<1mm-1mm	<1%	Not much coverage but bigger size
Acrylic Wool	1mm	<1%	Not much coverage but bigger size
Corflute Plastic	<1mm	<1%	Not much coverage or size

Week 3 50% F2 Nutrients



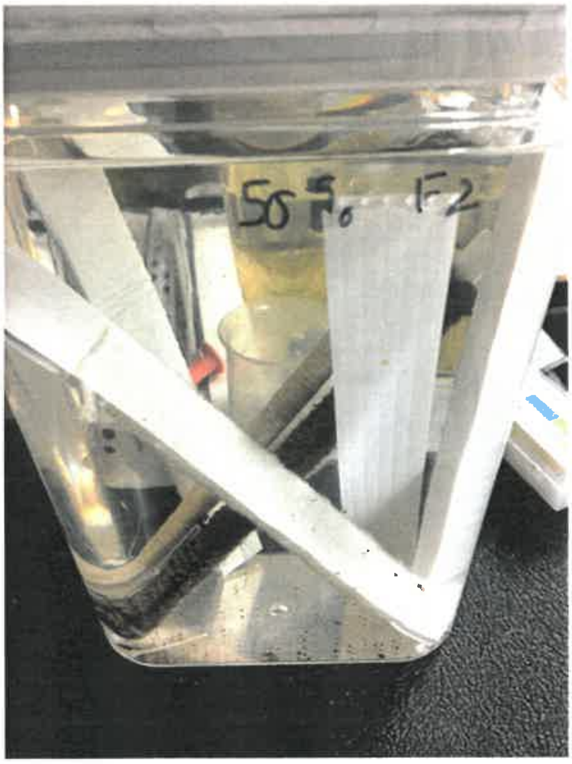
Week 4 0% F2 Nutrients			
	Growth (mm)	Coverage (%)	Observations
Cotton-Polyester Thread	<1mm-2mm	10%	Going well, increase in growth and coverage
Hessian Twine	<1mm-2mm	15%	Going well, increase in growth and coverage
Jewellery String	<1mm-1mm	10%	Going OK, increase in coverage, not much growth
Hemp String	<1mm-2mm	10%	Going well, easy to see, increase in growth and coverage
Acrylic Wool	<1mm-2mm	20-25%	Going very well, great coverage, big sizes
Corflute Plastic	<1mm-2mm	5-10%	Small coverage

Week 4 0%F2 Nutrients

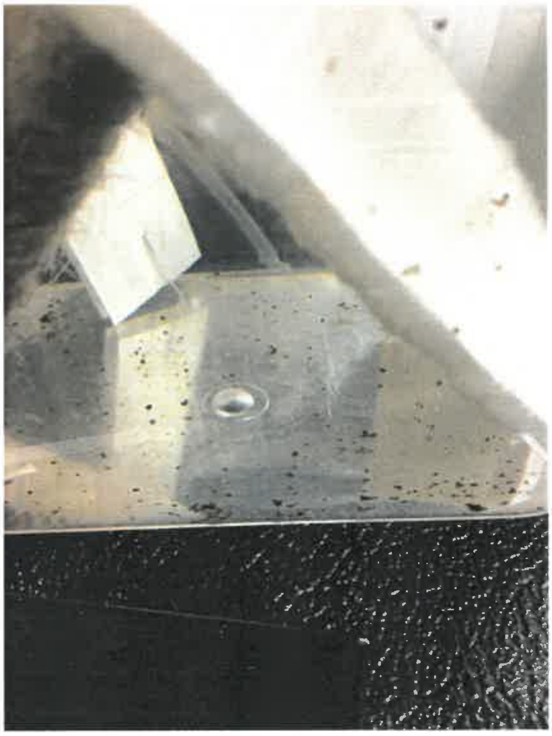
Week 4 0% F2 Nutrients

Week 4 50% F2 Nutrients			
	Growth (mm)	Coverage (%)	Observations
Cotton-Polyester Thread	<1mm-1mm	5%	Not much growth or coverage, very dark colour
Hessian Twine	<1mm-1mm	5%	Not much growth or coverage, very dark colour
Jewellery String	<1mm	<1%	Basically nothing
Hemp String	<1mm-1mm	5%	Not much growth or coverage, very dark colour
Acrylic Wool	<1mm-2mm	5%	Not much growth or coverage, very dark colour
Corflute Plastic	<1mm	<1%	Basically nothing

Week 4   50% F2 Nutrients



Week 4   50% F2 Nutrients

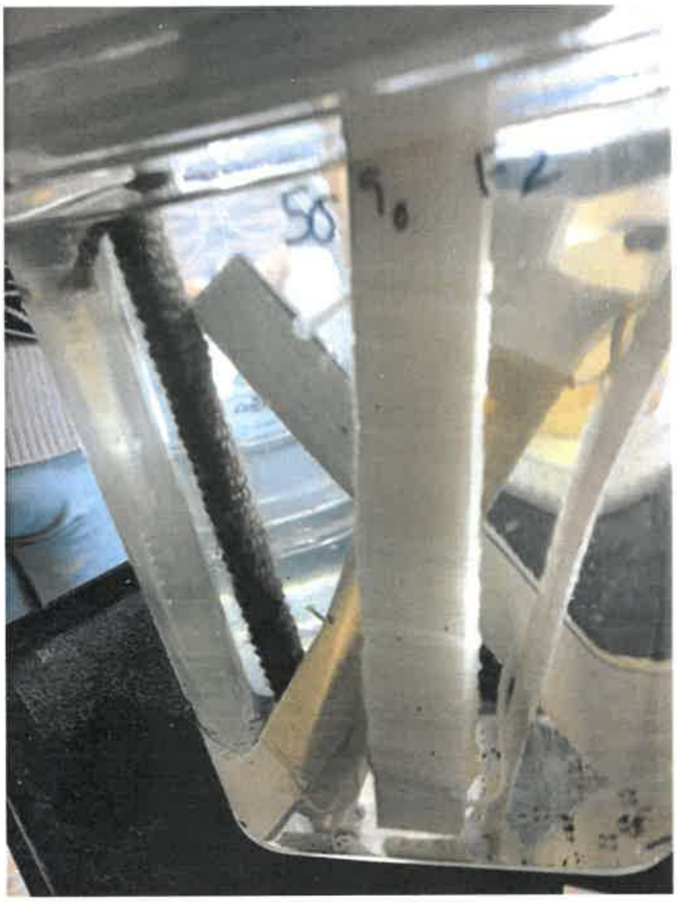


Week 5 0% F2 Nutrients			
	Growth (mm)	Coverage (%)	Observations
Cotton-Polyester Thread	<1mm-2mm	30%	Going well, better coverage
Hessian Twine	<1mm-2mm	40%	Going well, better coverage
Jewellery String	<1mm-1mm	15%	Half on string, half on plastic
Hemp String	<1mm-2mm	15%	Going OK, not much coverage
Acrylic Wool	<1mm-2mm	50%	Going well, good growth, good coverage
Corflute Plastic	<1mm-2mm	10-15%	Going OK, not much coverage

Week 5 0% F2 Nutrients

Week 5 50% F2 Nutrients			
	Growth (mm)	Coverage (%)	Observations
Cotton-Polyester Thread	<1mm-1mm	5%	Good growth, not much coverage, very dark
Hessian Twine	<1mm-2mm	10%	Good growth, more coverage, very dark
Jewellery String	<1mm	<1%	No attachment, brown patches on Corflute Plastic
Hemp String	<1mm-1mm	5%	Not much growth or coverage
Acrylic Wool	<1mm-2mm	5-10%	Good growth, not much coverage, very dark
Corflute Plastic	<1mm	<1%	No attachment, brown patches

Week 5 50% F2 Nutrients



Summary of results: After 5 weeks of observations, it appears that acrylic wool substrate in either 0%F2 or 50% yield the great attachment, coverage and growth. We will need to conduct further research to determine the impact of darkness of growth and long term health of kelp.

Images of examples of kelp attaching to polyester wool under a microscope:

Discussion

The project was set up to determine if giant kelp (*Macrosystis pyrifera*) could be grown in a school lab environment from gametophytes to adult kelp for commercial and conservational purposes. The observations from both parts of our investigation have proven that it is possible to grow *Macrocystis pyrifora* under school laboratory conditions.

The first part of the project was looking at the effect of different percentages of F2 nutrients contained in 1L plastic growth vessels (0%F2 50%F2 100%F2) on growth and development of kelp. The overall results suggest that there is little benefit in growing the kelp in 100% F2 growth media. The differences observed between the other 2 tests (0% F2 and 50% F2) were inconclusive at this stage and require further investigation. However it is possible to conclude that in the case of growing kelp, less nutrients (than 100%) would appear to be most beneficial to growth and development.

The second part of the project was investigating the effectiveness of different substrate types for kelp to attach to and grow on, (cotton polyester thread, acrylic wool, hessian twine, hemp, and clear stretchy jewellery string). From our summary of observations, it would appear that the acrylic wool is the most suitable easily accessible and cheap substrate to use.

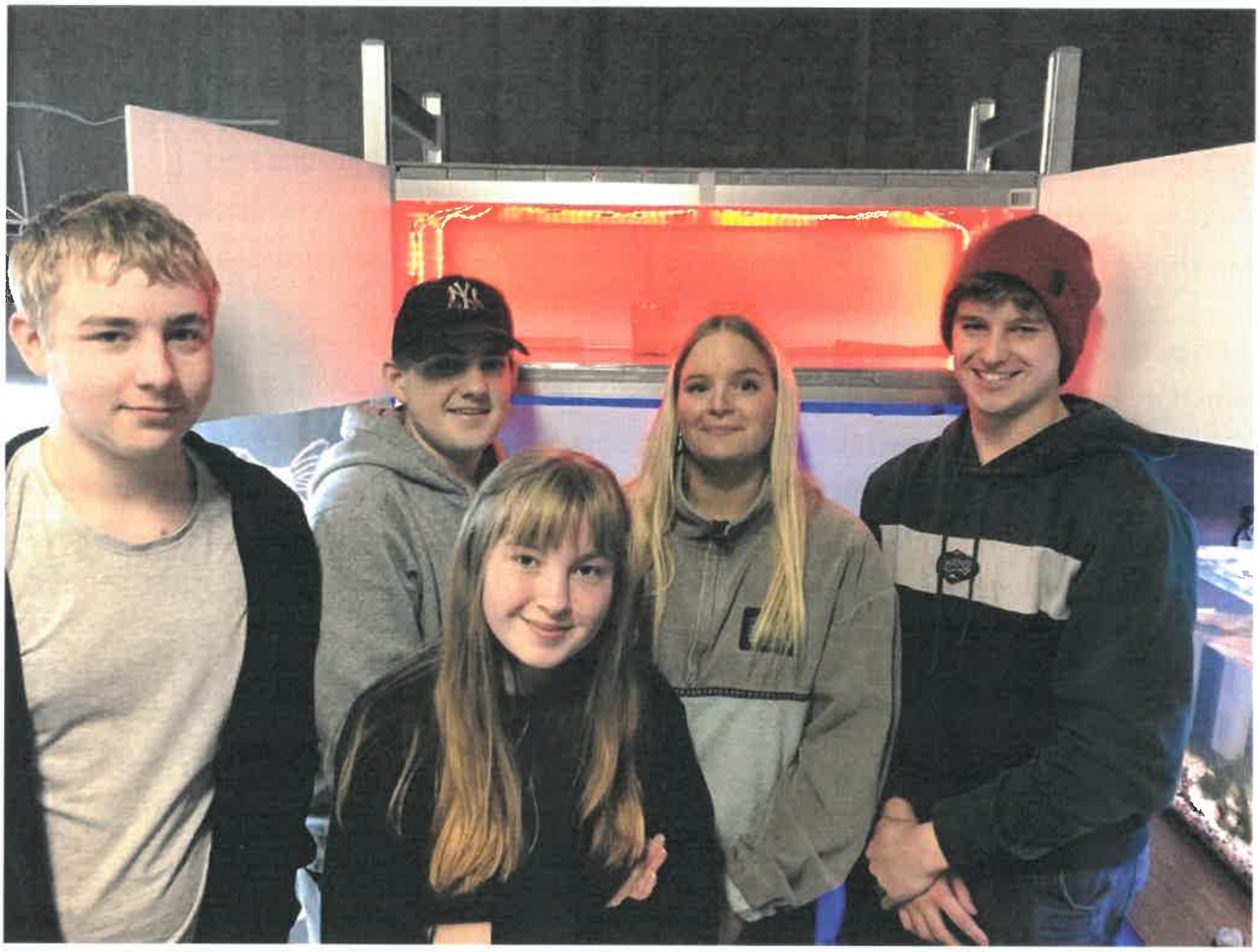
Problem Solving and Teamwork

As we progressed through our project we met many different issues that we had to sort out from a global pandemic to engineering design of growth facilities and making sure we had a regular supply of filtered seawater (homemade seawater simply does not work – but that is a whole other story!)

We believe our group have done an excellent job on producing highly promising results and working together as an efficient and top notch team.

Conclusion:

Giant kelp is an important species of plant in the marine environment. Despite natural populations going in to decline around Tasmania, we believe that through simple aquaculture in facilities as basic as ours, it is possible to grow kelp for conservation, commercial and climate care purposes. We hope that this is this beginning of an exciting journey where we can teach other interested people to growth kelp for good.



The team: (L to R) Liam Napthali, Jaden Moore, Remi Sherman-Noth, Clea Hallam and Max Watson.

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