South African Kelp Farming Project
(Phase 2 - Project number: 300708-201)

Funded through UK aid by the UK government.

Project Quarterly Report

	Quarter 1 (Apr – Jun 2023)
	Quarter 2 (Jul – Sept 2023)
	Quarter 3 (Oct – Dec 2023)
√	**Quarter 4 (Jan - March 2024)**

Compiled by: Dr Lizeth Botes

On behalf of:

Bivalve Shellfish Farmers Association of South Africa (BSASA)

Declaration of the Project Manager

I hereby declare as Project Manager (on behalf of BSASA) and as per FCDO Accountable Grant Arrangement with BSASA that (please encircle):

1. All FCDO funding has, to the best of my knowledge, been used on the project's deliverables and assets as outlined in the Grant Arrangement

(YES)/NO (If no, please provide explanation)

2. All assets bought with FCDO funding to date are, to the best of my knowledge, being recorded and can confirm that I have verified the assets, that they are in good working condition and being used for the purposes of the project.

(YES)/NO (If no, please provide explanation)

3. All progress of project deliverables are satisfactory and still within the FCDO Grant Arrangement time frames & budget, and that I have timeously reported on delays due to unforeseen circumstances.

(YES)/NO (If no, please provide explanation)

5. To the best of my knowledge, am not aware of suspicions or complaints of any incidences of sexual exploitation, abuse and sexual harassment (SEAH).

(Confirm)/Unable to confirm (If unable to confirm, please provide explanation)

Project Manager

15/5/2024

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Glossary of Terms

ADZ	Aquaculture Development Zone
AMC	Aquaculture Management Committee
BOM	Blue Ocean Mussels
BSASA	Bivalve Shellfish Farmers Association of South Africa
CTD data	Conductivity, Temperature and Depth data
DFFE	Department of Forestry, Fisheries and Environment
DSI	Department of Science and Innovation
EA	Environmental Authorisation
EMPr	Environmental Monitoring Programme
FCDO	Foreign, Commonwealth & Development Office
FAO	Food and Agricultural Organisation
UNDP	United Nations Development Programme of the United Nations
GeO_2	Germanium dioxide
POC	Paternoster Oyster Company
PM	Project Manager
RAs	Research Assistants
RED	Research and Evidence Directorate within the FCDO
SA	South Africa
SABS	South African Bureau of Standards
SOP	Standard Operating Procedures
TOR	Terms of Reference
UCT	University of Cape Town
UK	United Kingdom

1. Introduction

The Government of the United Kingdom (UK) of Great Britain and Northern Ireland acting through the Research and Evidence Directorate (RED) at the Foreign, Commonwealth & Development Office (FCDO), deliver science and technology partnerships to maximise the UK's development impact internationally.

In 2021-2022 the FCDO commissioned the non-profit Bivalve Shellfish Farmers Association of South Africa (BSASA), in collaboration with the Department of Forestry, Fisheries and Environment (DFFE), to conduct a short three-month pre-feasibility study (Phase 1) to assess the potential for the commercial cultivation of African kelp along South Africa's West Coast. The final output report concluded/recommended that a Phase 2 Feasibility Study be conducted.

In 2022-2023, the FCDO commissioned BSASA to proceed to Phase 2 of the project with the Accountable Grant Agreement signed at the end of July 2022. Phase 2 only gained momentum toward the end of 2022 when two Research Assistants (RAs) and a Project Manager (PM) were appointed in late Nov 2022 as part of the implementation team. The Saldanha Bay Aquaculture Development Zone (ADZ) was identified as the study area for grow-out trials to be conducted in/on already existing industry infrastructure & structures. Phase 2 is planned to be conducted over a 30-month period and will focus on the following activities:

- Refining kelp hatchery/nursery technologies
- Testing and refining kelp grow-out technologies in Saldanha Bay
- Conducting food safety analyses to inform future food safety standards and certification
- Monitoring environmental parameters and assessing environmental benefits/risks as decision support for the DFFE's Environmental Management Programme (EMPr)
- Conduct stakeholder engagements to disseminate information and gain insights into the Kelp Value Chain and associated employment opportunities
- Investigate the financial feasibility of kelp farming in South Africa (SA)

The overall goal of the project is to disseminate information and research results available to a broad stakeholder base, including the existing kelp industry and new potential entrants in order to build a sustainable Kelp Aquaculture Industry in SA.

1.1 Phase 2: Year 1 (2022-2023):

While the project only gained momentum around November 2022, efforts to successfully establish the project by the FCDO's financial year end in March 2023 were ongoing. Progress during those months were captured in the 2022- 2023 Project Year-end Report.

1.2 Phase 2: Year 2 (2023-2024) Quarter 1 (Apr-Jun 2023):

Much of the 1st quarter (Q1) was spent on repositioning the project to accommodate a grow-out site change and accounting for assets, a change in the Project Implementation team, drafting and updating a Project Plan, considering the request from the RAs to use the data generated from their respective components toward MSc degrees and, implementing tasks that were planned for Q1 (progress of which were captured in the Phase 2: Yr2-Q1 report)

1.3 Phase 2: Year 2 (2023-2024) Quarter 2 (Jul-Sep 2023):

Similar to Q1, quarter two (Q2) focused on strengthening the project by furthering progress at the new grow-out site at Blue Ocean Mussels (BOM), setting up an industry-based hatchery at Paternoster Oyster Company (POC), restoring the kelp hatchery based at DFFE Sea Point Research Aquarium and implementing the tasks that were planned for Q2 (progress of which were captured in the Phase 2: Yr2-Q2 report).

1.4 Phase 2: Year 2 (2023-2024) Quarter 3 (Oct-Dec 2023):

Most of quarter 3 (Q3) was focused on gathering data to complete the picture of the first year's progress at the grow-out site of the kelps out-planted during winter, and to set-up hatchery spools in order to be ready in the new year for a summer out-plant. The first harvesting for food safety and nutritional analyses of *M. pyrifera* took place in Nov'23, data of which attached to the quarter 4 (Q4) report. Moreover, the Kelp Value Chain Analysis, Market Assessment and roadmap for the development of a kelp farming industry was completed and will be presented to stakeholders along with the rest of the study components at the annual Kelp Farming Information Session during Q4.

1.5 Phase 2: Year 2 (2023-2024) Quarter 4 (Jan-Mar 2024):

Although not without its challenges, Q4 was marked with several highlights which included a visit to KelpBlue (based in Lüderitz, Namibia), a successful summer out-plant which included the third target species *Ecklonia maxima*, and a very constructive Kelp farming Information Session on 18/3/2024 with attendance from the Food and Agricultural Organisation (FAO), United Nations Development Programme (UNDP), government, academia, industry and civil society.

1.6 Project team & Project Delivery Chain Map:

The project team's roles and responsibilities are briefly outlined below:

The Project Sponsor/Funder representatives:
Ms Leanne Jones (Team Leader, Southern Africa Research and Innovation Hub [SARIH], FCDO).
Ms Kristin Klose (FCDO Technical Advisor - Science, Technology and Innovation)
Ms Nyameka Mbete// Mr Jaco Louw (FCDO Global Science Lead: Programmes and Finance)

The Implementation team:
Industry:
Mr V Pienaar (Chairperson of BSASA as lead implementation and host organisation, Imbaza Mussels)
Mr M Tarrant (BSASA Secretary & Boland Financial Services)

BSASA member representatives and project participants:
Mr S Visser (COO of Blue Ocean Mussels [BOM])
Mr T Maswanganye (Assistant Farm Manager at BOM)
Mr J Louw/M Smith (Manager at Paternoster Oyster Company [POC])

BSASA appointed:
Dr L Botes (Project Manager)
Ms F Hill (Research Assistant)
Ms N Xulu (Research Assistant)
Scientific Advisor: Emeritus Prof JJ Bolton (Associated with University of Cape Town [UCT])

Government:
Department of Forestry, Fisheries and Environment (DFFE) Representatives:
Ms A Bernatzeder (Director of Aquaculture Research & Development– strategic support)
Dr B Macey (Specialist Scientist: Aquaculture Research – scientific input)

Andre du Randt (Scientific Technician: Aquaculture Research – environmental monitoring)
Dr Mark Rothman (Specialist Scientist: Fisheries Research – seaweed research)
Mr John Foord (Food safety officer)

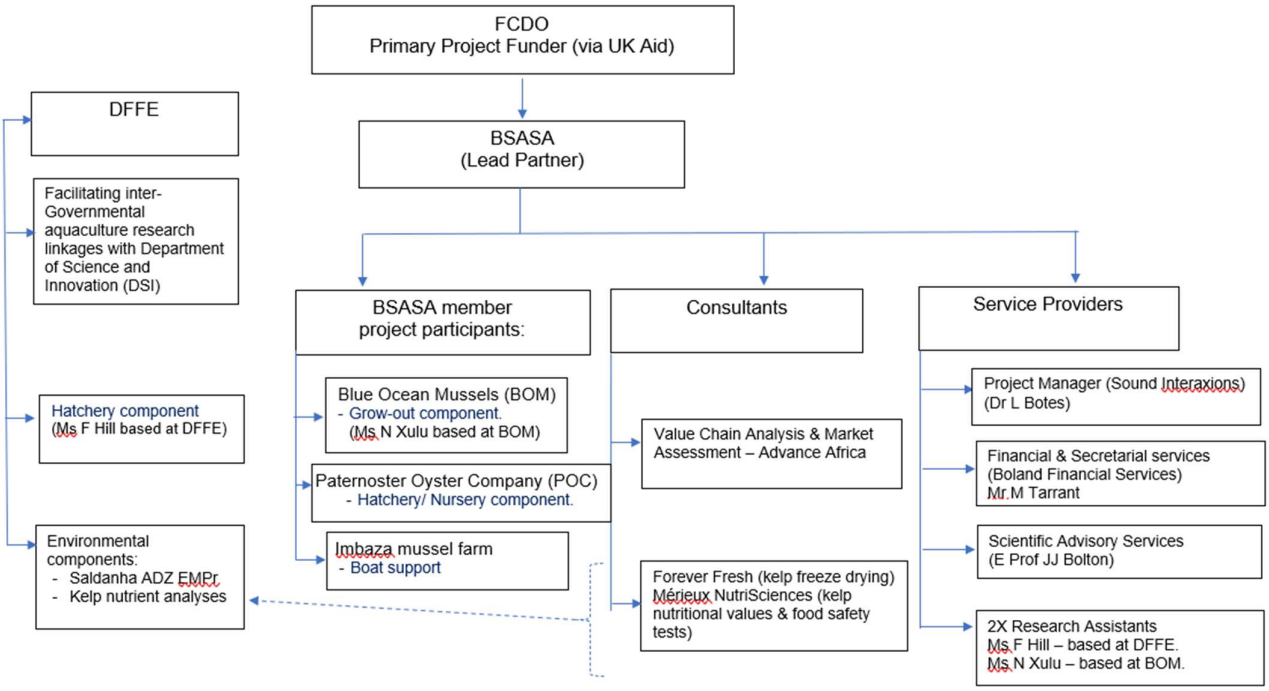


Figure 1. Diagrammatic summary of the Project Delivery Chain Map.

2. Summary of milestones achieved to date

The milestones achieved during Q1-Q4 are outlined below:

~ All three target species (namely *Laminaria pallida*, *Ecklonia maxima* and *Macrocytis pyrifera*) were successfully out-planted on the grow-out structures within the first year of this project. Measuring of growth rates is on-going.

~ In addition, *M. pyrifera* was also grown from wild collected holdfast fragments and out-planted on mussel rafts and long-lines.

~ *M. pyrifera* was sent for the food safety and nutritional analyses as well as for microbial tests. We aim to test *L. pallida* and *E. maxima* in the upcoming months which will mark the second season for grow-out in this project.

~ Environmental parameters were collected, and we will soon have a full year's worth of data which is crucial for understanding the site-specific environmental trends that influence the growth of the kelps in the bay.

~ The Value Chain Analysis, Market Assessment and roadmap for the development of a kelp farming industry was successfully completed and well received at our annual Kelp Farming Information Session in Mar'24.

~ A partnership with the UNDP has been established which will look at unpacking how best to involve coastal communities in the seaweed value chain.

Q1 of the new financial year (2024-2025) will be utilised to prepare the farming structures for the upcoming out-planting season during which all 3 target species will again be out-planted to improve on and compare with data captured during 2023-2024. This data will hopefully be sufficient to enable us to commence with the last deliverable namely to investigate the financial feasibility of kelp farming in South Africa (SA).

3. Visit to Kelp Blue (Lüderitz, Namibia)

The visit to Kelp Blue from 15-19 Jan'24, kindly hosted by Mr Michael Fleishman (see figure 2), highlighted the differences between our efforts with Kelp Blue being a private company entering its commercial stage and focusing on farming *Macrocystis pyrifera* only which is non-indigenous to Lüderitz while our project is a collaborative effort aimed at establishing a sustainable kelp farming industry in SA. They have access to over 40 hectares of water space with an in-shore experimental pilot farm in Shearwater Bay (where they are experimenting with various *Macrocystis* strains from California, Cape Town and Falkland islands) and an off-shore site further north where they hope to expand their efforts based on results obtained from their research at the on-shore pilot farm. Kelp Blue's Lüderitz staff component is close to 100 persons, and they are also busy expanding to Alaska and New Zealand (and looking into possibly expanding into South Africa).

They have adopted their hatchery and nursery methods from a company named Hortimare based in the Netherlands (www.hortimare.com), who also provides them with gametophyte stock which is then kept at Kelp Blue's hatchery facility in a red-light cabinet within the temperature controlled room until such time they wish to inoculate spools according to the grow-out department's out-planting schedule. During our visit we were fortunate to interact with many of the Kelp Blue staff in particular the Hatchery/Nursery team who took us through all their processes and procedures. The knowledge exchange was very fruitful, and since they wish to learn more about our techniques of collecting, processing and sporulating directly onto hatchery spools, the PM has invited them to visit our project on their next visit to SA to further the knowledge exchange. Please see Ms F. Hill's Jan'24 report attached in Annexure A for more information on the differences between the hatchery components of the two projects.

During our visit, most days were dominated by strong winds and we only went out to their grow-out site in Shearwater Bay on one day when the wind subsided where the RAs had the privilege to swim amongst the Californian *Macrocystis* strain which grows significantly faster than the strain from Cape Town (both strains were out-planted the same time and the Californian strain grew to 15m whereas the Cape Town strain only grew to 5m in length). Please see Ms N. Xulu's Jan'24 report attached in Annexure C for more information on the differences between the grow-out components of the two projects.

We also visited their small processing facility where they aim to have zero waste. Apart from their biostimulant product (Stimplus+) which is the extracted liquid component, they are investigating how to make bio-plastics and vegan leather products from the remaining pulp which was particularly interesting to see.

Figure 2: (a) The PM and two RAs at the Kelp Blue premises (b) From left to right: Mr M Fleishman, Ms F Hill and Ms N Xulu with *Macrocystis* growing in the background.

4. Progress on project objectives & deliverables

The sections below will build on the findings of the previous quarters in order to summarise the different project components and provide an overview of progress for the 2023-2024 financial year. The monthly progress reports, attached as Annexures, provide more detail.

4.1 Hatchery technologies of targeted species:

- **Kelp hatchery facility based at the DFFE Sea Point Research Aquarium:**
  The project spools that were seeded during Q3 at the end of Nov/beginning of Dec'23 of all 3 target species (collected from Jacobsbaai and Kommetjie) and maintained in the temperature-control rooms in the DFFE kelp hatchery are still growing well, albeit very slowly. This is likely due to the fact that this particular batch is now entering its 4th month **in jars** at DFFE to minimise contamination which may have caused the sporophytes to **stagnate** but at least **the cultures remain relatively free from contamination** as can be seen in Ms F. Hill's monthly reports attached hereto as Annexure A. These spools are due for out-planting in Apr'24.

- **Kelp Hatchery/Nursery Facility based at Paternoster Oyster Company (POC)**
  In the Q3 report, the recommendation was made for Ms F Hill to assist Ms I Meyer at POC while at the same time moving the incubators to POC to conduct the hatchery optimisation experiments at Paternoster. However, during February Ms I. Meyer accepted a position overseas with Mar'24 being her last month at POC. Thus, the attached monthly reports for POC (see Annexure B) were compiled as follows:
  POC Jan'24 Hatchery report – compiled by Ms Meyer and Ms Hill
  POC Feb'24 Hatchery report - compiled by Ms Meyer and Ms Hill
  POC & DFFE March'24 Hatchery reports were combined - compiled by Ms Hill
  Going forward, a combined Hatchery report for the two sites will be compiled by Ms Hill.

  Despite the human resource challenges that the project experienced over the Festive Season, and although we lost the *Laminaria* sporophytes, sporophytes of the *Ecklonia* and *Macrocystis* (which were seeded at the end Oct'23) were between 1-2cm in length when out-planted the week immediately after the Kelp Blue visit on 26 Jan'24 (albeit it slightly later than originally planned due to Kelp Blue visit). The out-plant of both species were successful as a summer out-plant and we look forward to track the growth which will be elaborated upon in Ms N Xulu's section below.

  In contrast to the spools maintained at the DFFE based hatchery, it is worth noting that Ms Meyer's spools at POC had an initial **hatchery stage** of 3 weeks with no water movement. When the sporophytes reached 2-3mm, the PM requested Ms Meyer to add the filter pumps that she had bought for POC to serve as a **nursery stage** to create movement of water, oxygen and nutrients. Although contamination started appearing toward Jan'24, the sporophytes reached ~1-2cm at which point they were out-planted on 26 Jan'24. The spools containing the best looking sporophytes were out-planted immediately onto ladders while those looking a bit pale were hung at 6m (in reach of the colder water deeper down considering that it was summer) to strengthen for approximately a month to serve as a **weaning stage** (at which point they reached ~4-5cm) and then subsequently unwound from the hatchery spools onto grow-out rope structures as part of the **grow-out stage.**

  Please note, more will be elaborated upon between the differences in approach between the two hatcheries in the Lessons learnt – Production cycle section (Section 6).

4.2 Grow-out trials & Monitoring of environmental parameters:

- **Blue Ocean Mussels' (BOM) grow-out facility.**

  At the BOM grow-out study site, kelps are out-planted on ladder structures onto mussel rafts and long-lines at two positions, one closer to the mouth (marked in red, see figure 3) and the other further away from the mouth (marked in blue, see figure 3). The ladder structures were 5m wide on the mussel rafts and are 2m wide on the long-lines. All ladders are a little over 6m long/deep with ladder rungs at 2m, 4m, and 6m depth. The intention with the ladder structures is to determine if the target species have a specific preference for a specific depth and if indeed the case, which depth that would be. This however provides a very one-dimensional view (ie horizontal), and the PM proposed to add vertical droppers to obtain a two dimensional (ie horizontal and vertical) view to determine if the target species have a range (ie summer range between 2-4m, and a winter range between 4-6m) which can be utilised as opposed to a specific depth.

Figure 3. Blue Ocean Mussels (BOM) study site in Saldanha Bay (SB)

As such, one vertical dropper of *M. pyrifera* was added to both long-lines (LL1 & LL2) during the 26 Jan'24 out-plant of *E. maxima* and *M. pyrifera* (apart from the usual ladders structures as described above). A vertical dropper consists of an 8m long rope that is tied to the main long-line containing a small float at the top and a weight at the bottom. The outcome, although still being monitored, was rather surprising and presented in table format (see Table 1).

While the horizontal ladder rope structure presented an expected outcome in-line with what we saw in the months prior (ie significant biofouling and kelps growing only at 6m as water temperatures at 6m are colder with presumably better access to nutrients as well as lower light intensity), the vertical dropper structure presented kelps from the top all the way down to 8m with very little and very different biofouling. At this stage an attempt to explain this will very much be speculative, thus we will keep monitoring this to better understand why there is such a difference. It is encouraging though that, while horizontal long-line kelp culture is common, vertical droppers are seemingly being used by companies such as Ocean Rainforest in the Faroe Islands. More recently in 2023, results from a research group in New Zealand also indicated that kelps grew better on vertical droppers with less biofouling than on their horizontal line structures so this is certainly worth investigating further.

Table 1.
Summary of *M. pyrifera* growing on vertical droppers (8m deep) as opposed to horizontal ladder structures (at 2, 4, & 6m).
(Photo credits Dr L Botes)

	Macrocystis	
	Dropper	Ladder
Spool outplant date	25-26/1/2024	25-26/1/2024
Sporophyte condition (Jan'24)	pale colour, 1cm and below	good colour, btwn 1-2cm
Unwinding date	29/2/2024	---------
Sporophyte condition (Feb'24)	Sporphytes good colour, grew to 4-5cm 	Sporophytes good colour, grew to 4-5cm 
Sporophyte condition (Mar'24)	sporophytes from top to bottom of dropper, slightly bigger than on ladder, very little competition by competitors, healthy looking blades, epiphytes starting to appear on blade tips 	sporophytes only on 6m, being squeezed by competitors, healthy blades with epiphytes starting to appear at blade tips 
Rope condition & fouling	Dropper line less fouled possibly due to later "outplanting" in Feb'24 Only red algae species across the entire dropper  	Huge amounts of fouling (outplanted in Jan) Jan - ladder rung at 2m and 4m totally covered with skeleton shrimps totally smothering sporophytes, actual rope not visible. At 6m MUCH LESS skeleton shrimps  Feb - Ulva on 2 & 4m ladder rung, small mussel spat and skeleton shrimp on 6m  March - Even though mussel spat and tunicates covering all ladder rungs (extreme competition for space), kelps seem to grow fast enough to cope with competition at this stage 

Together with the ongoing environmental monitoring, Ms Xulu's monthly reports (attached as Annexure C) present more details on the progress of the *E. maxima* and *M. pyrifera* out-planted in Jan'24 of which some of the main points of interest are highlighted below.

(a) Progress on monitoring of the kelp growth:

In 2023-2024 the growth of *M. pyrifera* far outpaced that of *L. pallida*. While *L. pallida* appeared to increase in size as we had hoped over the warmer summer months, the biofouling had completely deteriorated the quality of the blades to the extent that we were not able to do any food safety analyses on the remaining blades. We had noticed, similar to observations of Dr B Macey and E Prof JJ Bolton with the wild collected *Laminaria* nearby, that a plant grew into one very large blade (to just under ~1m) but never took on the characteristic fan/hand shaped appearance while becoming very brittle and lost its leathery texture.

At the same time, while a few newly formed blades at the tip of the *M. pyrifera* plants did appear during Jan'24, the overall quality of plants and blades entirely deteriorated with no new stipes observed at the holdfast as we had hoped because the holdfast areas of all the plants were completely taken over by mussels (see figure 4).

Figure 4 Holdfast of *M. pyrifera* covered with mussels. (Photo credit. Dr L Botes)

As mentioned previously, *E. maxima* and *M. pyrifera* were out-planted in Jan'24 (unfortunately we lost our *L. pallida* spools at POC during the Festive Season) to test the theory that kelp farming in Saldanha Bay would likely be limited between April to October annually and see how these species would fare during a summer out-plant. Initially, after a month, both species were very healthy and similar in size (~5cm) in the early stages, but by 20 Mar'24, although individuals of both species were reaching <20cm, *M. pyrifera* were much denser and appeared to be coping better with the competition (in particular from mussels and tunicates) than *E. maxima* that declined in numbers likely due to it not being as able to compete for space as *M. pyrifera* (see figure 5). In terms of biofouling, a January out-plant may not be the best due to biofouling establishing itself on the ropes as late in the biofouling season as January (see also diagram 2).

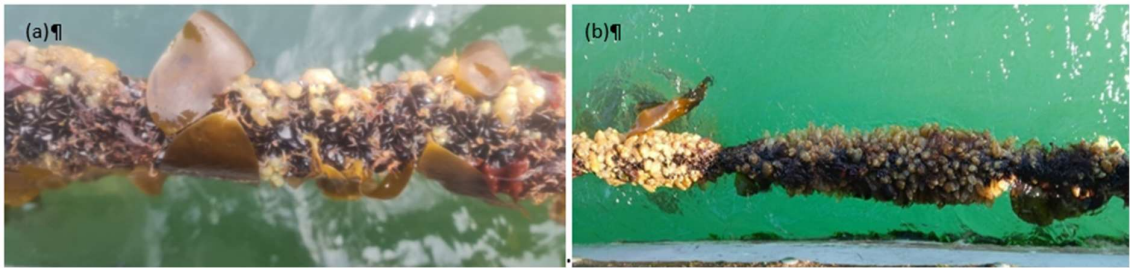


Figure 5 (a) *M. pyrifera* and (b) *E. maxima* competing with mussels & tunicates at 6m (Photo credits: Dr L Botes & Ms N Xulu)

(b) Progress on monitoring of environmental parameters:

During July – Sep 2023, water temperature across the three depths (2, 4 and 6m) increased gradually to approximately 16°C with a narrow range of fluctuation between the three depths. However, from Oct'23 onward the range of fluctuation in temperature across all three depths increases with the biggest fluctuations in temperatures taking place in Dec'23, Jan'24 and Feb'24. From Mar'24, the range in fluctuation gets smaller as we move back into the winter months. It is during the period from October to March when upwelling events occur, and it is also during this period that productivity increases resulting in the biofouling season referred to in diagram 2. Several low oxygen events happened over this time notably in Nov'23, Dec'23 and Mar'24. It was also interesting to see how the pH varied during this period especially over December and January.

During this period, all the nutrients (with the exception of phosphates) dropped to near zero between October and November. This is crucial and may well explain the quick deterioration of the kelps between October and November (therefore also the reason why diagram 2 was updated to include this as a risk factor). From December onward, nutrients appear higher at 6m (though not always the case) which may also explains why the kelps at 6m survived longer although quality of the blades were badly affected by the increase in biofouling over the same time period.

(d) Skills transfer to the Imbaza and POC workers assisting in project activities:

The Imbaza Mussel farm boat crew members have been a constant support to the project in every out-plant to date, assisting us with installing and cleaning rope structures for out-planting, and monitoring the growth of the kelps as well as taking part in the environmental monitoring activities.

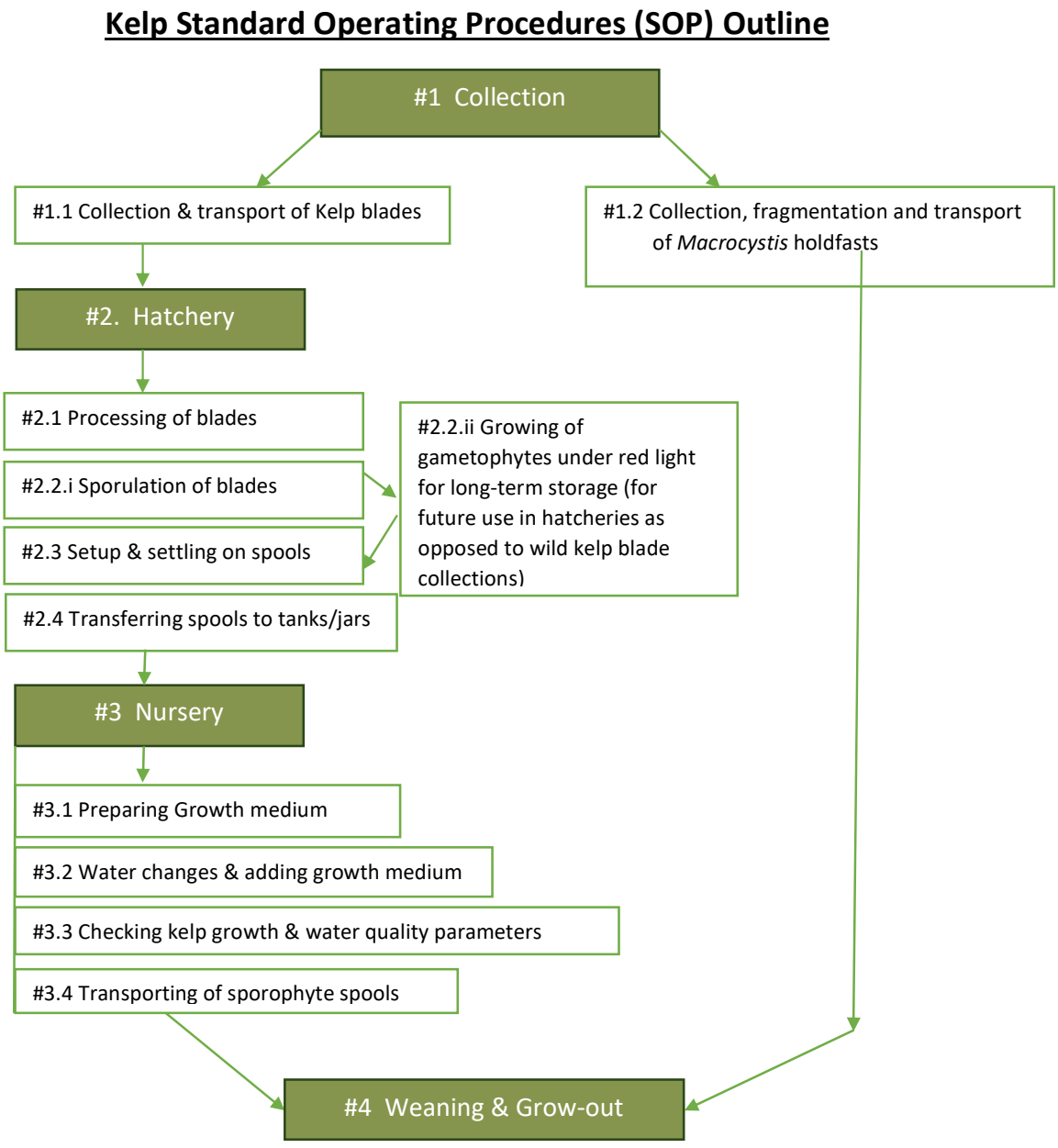
Figure 6. Kelp out-planting team:
Back row left to right:
Mr Cobi Adams, Mr Luntu Magopeni, Mr Elvis Ngwenze, Mr Benny Sikolweni
Front row left to right:
Ms Nonto Xulu, Dr Lizeth Botes, Ms Frances hill
(Photo credit: Ms I Meyer)

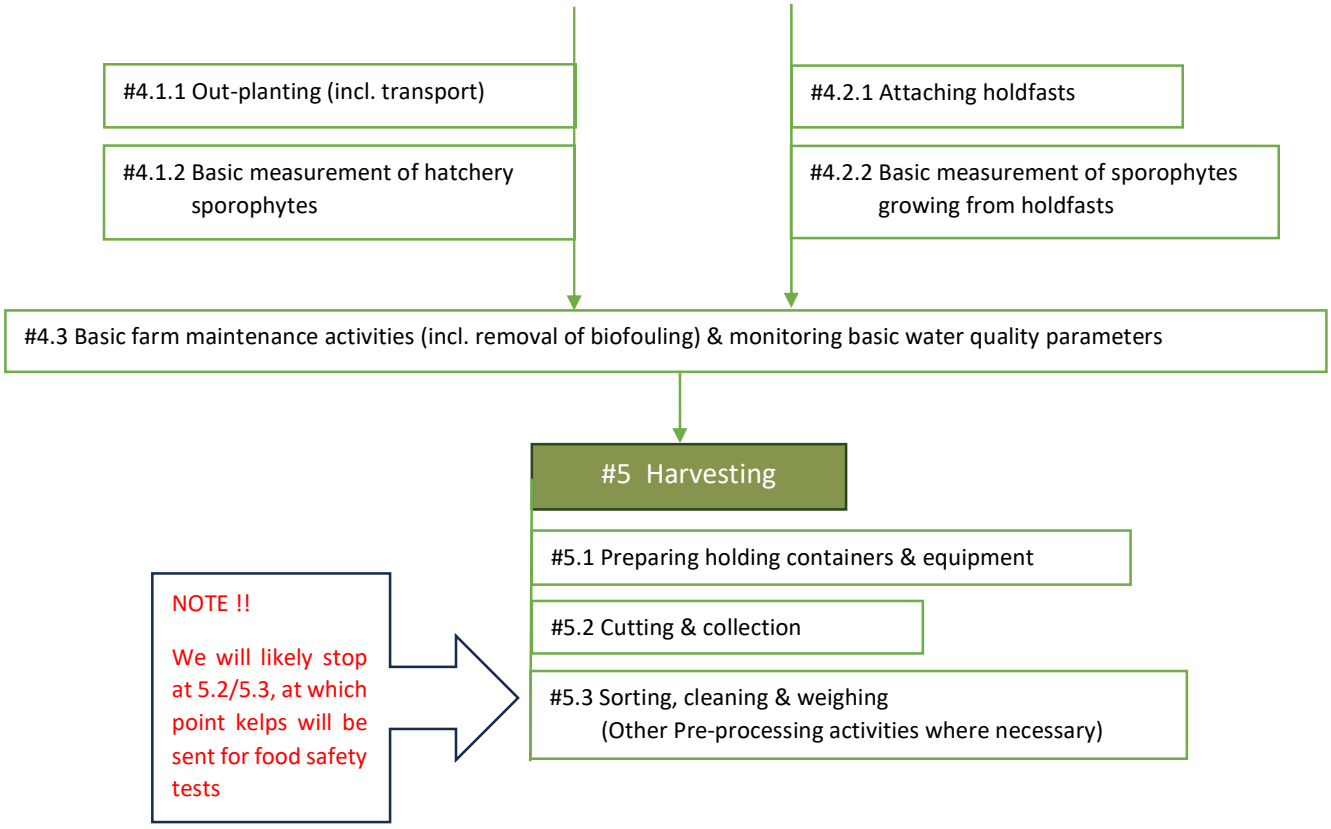
Similarly, Ms I Meyer and her colleague Mr P Sithole at POC have been learning and taking part in hatchery preparation tasks, monitoring of kelps and hatchery conditions.

4.3 Updating of Project Plan (containing Research protocols & SOPs):

The purpose of this document is to summarise the overarching project plan and associated research protocols. It is a living document that is continuously being updated to reflect the research developments, with particular reference to the Standard Operating Procedures (SOPs). As the Research Assistants (RAs) trial the protocols under the guidance of the project team, the SOPs will be updated to eventually be released with the rest of the deliverables of this project in the hope of establishing a sustainable kelp farming industry in South Africa.

The draft diagram below outlines the SOPs which will likely be relevant to the industry. Draft copies of SOP 1.1, 1.2, 2.1 and 2.2i are attached as Annexure D. The rest of the SOPs will be added as the project progresses and thus will remain open for inputs/comments until the point that it will be signed off when the project draws to a close at the end of March 2025.





4.4 Food safety testing and nutritional analyses of kelp:

The aim of the investigation is to study the nutritional value and potential food safety risks of wild kelp vs farmed kelp. The data will eventually be used toward the drafting of food safety standards for the kelp industry and serve as a comprehensive overview of the potential for kelp use in human and animal nutrition.

Initial data from the three wild candidate species collected in the Kommetjie region (as part of Phase 1) showed that all three kelp species have a high mineral content. The essential minerals were within the range recorded for other seaweed species, with the exception of Fe, Mn, and Zn, which were notably higher. Furthermore, all heavy metals fell within the range of values reported for other brown seaweed species, except for *M. pyrifera* that showed the highest Al, Pb, and Cd contents of the three kelp species collected from the same geographical area.

For Phase 2 of the project, fronds/blades of two species of wild kelp (*E. maxima* and *L. pallida*) were collected from three sites in Saldanha Bay and freeze-dried by Forever Fresh (Somerset West, Western Cape) and subsequently sent to Mérieux NutriSciences laboratories in Cape Town for food safety analysis. Since *M. pyrifera* does not occur naturally in Saldanha Bay it was not included for testing. A full report on the food safety analysis of the two kelps was attached to the Q1 report as Annexure E.

Fronds from *M. pyrifera* that was grown at BOM, were collected on 17 Nov 2023 from the mussel rafts (where the kelps were grown from hatchery spools as well as holdfast fragments) and from the long-lines (where kelps were grown from holdfast fragments). Dr. B Macey and Emeritus Prof. JJ Bolton are also involved with OceanGrown Aquaculture's (previously WCOG) *M. pyrifera* farming project where kelps are grown on long-lines, and from where kelp blades were also collected on the same day. Similar to the wild kelps collected

earlier in the year, the material was sent to Forever Fresh for freeze drying after which it was sent to Mérieux NutriSciences laboratories in Cape Town for food safety and nutritional analyses as well as microbial testing. The report on the food safety and nutritional analyses on *M. pyrifera* (attached as Annexure E) provides results and discussions on the mineral content, heavy metal content, fatty acid content, proximate composition, elements such as pesticides as well as microbiological hazards.

As mentioned in the previous report, Dr B Macey assisted with the drafting of a project proposal to the South African Bureau of Standards (SABS) to request the development of standards for seaweed for human consumption. The proposal was submitted on the 12th of June 2023, and following minor amendments has been submitted (on 3 Aug 2023) to the technical committee to start the process of developing the standard.

4.5 Kelp Farming Information session (18/3/2024):

The progress that was achieved during 2023-2024 was presented in a hybrid fashion (40 in-person attendees and approximately 60 online attendees) at Blue Bay Lodge, Saldanha Bay on 18 March 2024. Eight presentations covering all the project aspects/deliverables were presented to a wide audience which included members from the FAO, UNDP, Conservation South Africa, government, academia, industry and civil society. The event was recorded (Kelp Farming Information session 18-3-2024.mp4) and the programme with starting time stamps for the respective presentations can be found attached as Annexure F.

The presentation of E. Prof. T Hecht on the Value Chain Analysis, Market Assessment and roadmap for the development of a sustainable kelp farming industry was well received (see figure 7). Ms S. Smit provided background to the UNDP's activities to date and indicated that the collaboration with the Kelp Farming Project to unpack the involvement of coastal communities in the seaweed value chain is crucial and will involve a further three workshops over the coming months.

Figure 7 Emeritus Professor Tom Hecht presenting (on behalf of Advance Africa) the Value Chain Analysis, Market Assessment and roadmap for the development of a sustainable Kelp Farming Industry in South Africa (Photo credit: Dr L Botes)

The Information Session allowed for very constructive discussions between in-person and on-line attendees during the Q & A sessions as well as during lunch. We were particularly pleased with the feedback from the community members which is also attached as Annexure F

4.6 DFFE Environmental Management Programme (EMPr) update:

The desktop study to investigate the Environmental Impacts and Risks/Benefits associated with Kelp Farming (commissioned by this project and compiled by Ecosense) was sent to the Saldanha Bay ADZs Aquaculture Management Committee (AMC) for inputs after which the go-ahead was given for the DFFE to proceed with a Part 1 amendment (minor) in order to include Kelp into the Environmental Authorisation.

Currently, DFFE is busy with the application process for a Part 1 amendment. More information on this will be provided as information becomes available.

4.7 Financial feasibility study for kelp farming in South Africa:

This component has not yet been addressed. Discussions around this need to take place to ensure a common understanding of what this component requires in order to circumvent expectations that might lead to an undesirable outcome. It is important to determine if the data that are currently being generated are sufficiently aligned with the data that is required for a Kelp Financial Feasibility Study (KFFS). Topics of discussion should include for example:

~ should the KFFS be site-specific or a general study that will later be refined to be site-specific?
~ on which kelp species will it be based and will we have enough data on all three species to feed into a study such as this?
~ will it be based on a specific end product in mind as different end products may provide a different answer to a study such as this?
~ or will it focus on the farming component only (which is dangerous as we then make the mistake of taking a production-driven approach instead of a demand-driven approach)?
~ or could it be modelled similar to other studies (ie as was done in Chile)?

Based on the outcomes of the above, a clear Terms of Reference (TOR) should be drafted that will ensure that the message flowing from a study such as this will not mislead investors and potential farmers and result in unnecessary financial losses.

5. Challenges & Recommendations

5.1. Challenges experienced in each project component with accompanying recommendations

5.1.1 Hatchery technologies of targeted species:

In the Q3 report, the recommendation that Ms F Hill temporarily commute between POC and DFFE to assist Ms Meyer while also conducting her hatchery optimisation experiments in the incubators at POC took effect in Mar'24 but almost a week or so later we learnt that Ms Meyer has accepted a job with a company growing seaweeds in the Netherlands. Though we are happy for Ms Meyer, this has left a huge void in the project where we are now seriously understaffed having to juggle two hatcheries. The PM has committed to spending significantly more time at POC to assist where possible while Ms Hill continues with the arrangement of commuting between the two hatchery sites. This is however not ideal as the PM can only afford so much time to assist Ms Hill as she is also having to assist Ms Xulu where we are also understaffed (see section 5.1.2 below).

Recommendation:
The matter will have to be discussed with the partners in the project as this is putting immense strain on our ability to achieve our deliverables.

5.1.2 Grow-out trials & Monitoring of environmental parameters:

- **Grow-out facility at BOM's site**
  In Q3, we have indicated that it will likely become near impossible for Ms Xulu to manage all the grow-out tasks and environmental monitoring on her own if we were to out-plant all three target species on both mussel rafts and long-lines. We have subsequently decided to focus this year on long-lines (since last year we focused mostly on the mussel rafts). The constraint of not having enough staff to deal with all the grow-out tasks does not allow us to do as much as we would have liked and it is not possible to put more pressure on Imbaza's staff either as we currently only have access to the boat in the afternoons.
  Recommendation:
  The matter will have to be discussed with the partners in the project as this is putting immense strain on our ability to achieve our deliverables.

5.2. General recommendations:

The following matters need to be addressed during the next quarter to further progress:

- In the next financial year (2024-2025) we hope to obtain enough data that could feed into the last deliverable namely the Financial Feasibility Study for kelp farming in South Africa. The PM would like to recommend that one of the Kelp Team meetings perhaps be dedicated to discussing if the data that we are currently generating are sufficiently aligned with the data that a KFFS requires.
- Considering the fact that the project is understaffed, the PM would like to recommend that the partners meet to discuss a co-funding model to support the continuation of the project but with more hands/farms involved to address the site challenges and also the fact that the data that are currently generated may end up being site-specific (and possibly not enough to feed into a KFFS).
- We hope to also follow up with the recently established United Nations Development Programme (UNDP) collaboration to find out when the follow-up workshops with communities will take place to unpack how best to integrate communities into the kelp value chain.
- We have also started engaging with the Phycological Society of Southern Africa (PSSA)'s President to see if the PSSA website can be utilised as a portal for the dissemination of information as suggested in Section 6.3 of this report.

6. Lessons learnt, closing remarks & thinking ahead

6.1 Lessons learnt and observations relevant to industry

Despite some operational challenges and set-backs, data has been generated from which valuable lessons were learned. Many of which were already outlined in the Q3 report, but additional components have been added here while others have been expanded upon.

- <u>Production cycle</u>
  In land-based aquaculture farm facilities the Production Cycle is well known to include the following production stages ie Hatchery (where parent stock are maintained indoors to produce offspring), Nursery

(where offspring are reared indoors until big enough to be introduced to a semi-outdoors area), Weaning (where offspring are being transitioned to better equip them to being grown outdoors), Grow-out (where offspring are maintained outdoors until market size is reached).
[Note Processing related activities are not being discussed here as it has not yet been our focus].

Initially we have taken the approach to move kelp sporophytes which are barely visible with the eye from the hatchery directly to grow-out and immediately out-planting and exposing them to the outside environmental elements without intermediary stages. While this approach may well work elsewhere (in calmer waters with less biofouling), we have found that having all the stages as explained above and in Section 4.1 (under the POC hatchery component) were more successful with Saldanha Bay as the out-planting site. The inclusion of the intermediary stages ie nursery (where sporophytes were grown to ~1cm even though we eventually end up having to accept some degree of green algae contaminants) and weaning (where spools were hung for ~3 weeks before being unwound) have allowed the kelps from the nursery with a better chance to compete with siltation and biofouling when out-planted in Saldanha Bay while the weaning stage has repeatedly proven to be successful providing the kelp sporophytes approximately 2-3 weeks to acclimatize especially if the travel distance between the hatchery site and the grow-out site is far. However, the other school of thought to outplant the hatchery spools as soon as possible before hatchery contamination sets in, is equally valid thus each potential kelp farmer will have to assess the two options and see which will work the best depending on the distance between the hatchery and grow-out as well the conditions at the grow-out site.

Hatchery/Nursery component

Although we are still in the process to research the developmental stages of the three target species and hoping to obtain detailed hatchery optimisation results for the development of future kelp hatcheries, diagram 1 aims to provide a general timeline that will be useful to a future kelp farmer in terms of planning bearing in mind that this time-line may or may not be different for each of the target species. In the case of this project, we have also seen that the time-line between the two hatchery sites is different and we hope to streamline the set-ups in the coming months to see if we can get similar outcomes at the two sites.

Transporting from Hatchery/Nursery facility to Weaning/Grow-out facility

When transporting the kelp sporophytes to the grow-out site, it is important to be acutely aware of the fact that this very activity, if not done carefully, could potentially be the cause of obliterating 2-3month's worth of nurturing one's kelps. Therefore, when planning to transport one's kelp sporophytes from the hatchery to the grow-out site (and depending on the distance to be travelled) it is important to choose a cool overcast day especially if one does not have access to a vehicle with air conditioning. Care should be taken to maintain the appropriate temperature (which is dependent on the species that are being transported) in the transporting canisters and cooler containers, and to note the sea temperatures where the kelps will be out-planted to as far as possible prevent the kelps from getting a temperature shock either from heating up in the vehicle and then out-planted in cold water or from putting it into canisters and coolers where it is too cold and then being out-planted in water that is much warmer.

Out-planting

When considering a day to out-plant, it is important to select a day (www.windguru.cz) that is cool with little to no wind for ease of working on the boat. If the boat has a cabin, put the coolers with canisters containing the spools with sporophytes in the cabin until you reach the out-planting rope structures. It would be advantageous to look at the days prior to the out-plant day and consider which winds were

blowing and what the prevailing sea surface temperatures are (and even to obtain a vague idea of which winds may have resulted in a nutrient influx). If possible, overcast days during April with water temperatures between 12-15°C would be ideal. When the coolers with canisters (containing the hatchery spools) arrive, it is worth recording the air temperature inside the cooler, as well as the water temperature inside the canister for record keeping purposes. If possible, all should be between 12-15°C and as closely matched to the sea surface temperature where the unwinding of spools onto the grow-out rope structures will take place if one chooses to unwind the spools immediately. Alternatively, if it is preferred to attached the spools at a certain depth (see weaning paragraph below) for the sporophytes to acclimatise then it would be better to consider the water temperature at the preferred depth to avoid giving the sporophytes a temperature shock.

Weaning/Grow-out component

We have repeatedly had success with the method of hanging spools at the preferred depth for 3-4 weeks (depending on the size of the sporophytes when out-planted) without unwinding the spools, serving as a weaning stage. As soon as sporophytes reached 2-4cm, the spools were removed and unwound on the desired out-planting rope structures, serving as the grow-out stage and at which point kelps can be monitored for growth on a monthly basis.

- General time-line

Diagram 1 & 2 below provides a general timeline (based mostly on *M. pyrifera*) that will be useful to a future kelp farmer in terms of planning.

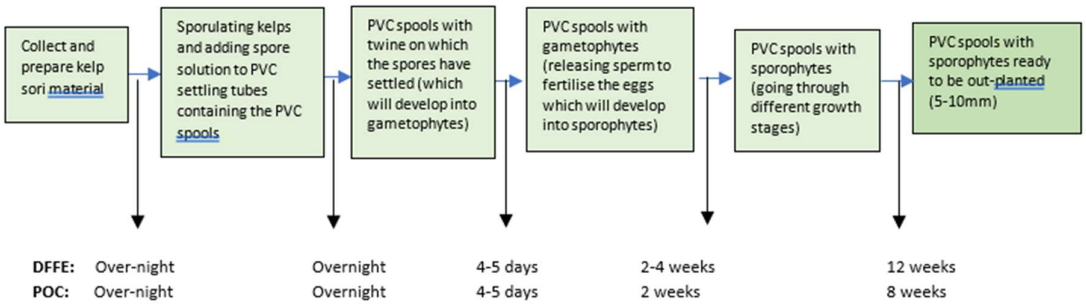


Diagram1: Time-line of all 3 species from collection of kelp sori to sporophytes ready for out-planting (~ 2 months at POC and ~3 months at the Sea Point based hatchery).

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Kelp cycle	1. Collecting kelp to stock up hatchery spools 2. Kelp spool care & maintenance (see together with diagram 1)			3. Out-planting of hatchery spools (Temps preferably ≤15 °C)		4. Monitoring-kelp growth &-biofouling 5. Inspections & infrastructure maintenance (especially after storms)				6. Harvesting	7. Removal & cleaning of infrastructure/structures 8. Pre-processing & Processing activities	
Possible risks										Extremely low Nitrogen based nutrient conc's		
	Biofouling & siltation season									Biofouling & siltation season		
	Phytoplankton blooms & low O2 events											
Benefit	Decreasing temperatures with ad hoc upwelling events			Cooler water temperatures						Increasing water temperatures with ad hoc upwelling events		

Diagram 2: Kelp farming cycle time-line (from hatchery spool out-planting to harvesting takes approximately 6 months (TBC/spp)

This timeline may or may not be entirely different for each of the target species and we hope to update it in the coming months once the hatcheries have been stabilised and if/when more species-specific data becomes available.

~ In terms of sori collection:

Although it may be the case that collection of sori material for different kelp species are more successful during certain months of the year, to date we have been collecting sorus material of all three species throughout the year and have had successful sporulation.

~ In terms of the production stages:

For hatchery grown sporophytes that will be grown in Saldanha Bay, it is important to establish the time necessary for each of the 3 target species in the hatchery and the time available to grow the target species out in the bay. While one must be mindful that the risk for contamination increase if sporophytes are left too long in the hatchery, one also must be mindful of the fact the high level of siltation and biofouling in Saldanha Bay may prevent the sporophytes from photosynthesizing if out-planted too small even if the sporophytes have self-cleaning mechanisms. It may well be necessary to out-plant the sporophytes at around 1cm in length to ensure that they are able to photosynthesize and not be covered with siltation before having a chance to grow. For kelp farming at a site other that in Saldanha Bay, this may be different.

We trialled two different techniques:

- At the DFFE based hatchery; we kept sporophytes of all three species for as long as possible in jars to minimise contamination and to see how big the sporophytes would get. Here we found that the sporophytes eventually stagnated around a few millimetres and struggled to reach the desired size of 1cm while contamination was generally kept to a minimum but eventually crept in after 3months.
- At the POC based hatchery; we kept the spools in jars for ~3weeks (with no water movement and/or aeration) serving as the hatchery stage. After ~ 3 weeks we moved the spools into tanks (with no water movement and/or aeration) but when the sporophytes reached 2-3mm, we introduced a filter pump to add air and water movement to circulate the nutrient containing water until the sporophytes reached approximately 1cm (serving as the nursery stage and taking ~2-3 months) and at which point they could be out-planted. The trade-off here is that if any contaminants are present at this stage, that these too would start to make its appearance and start to grow. At this point it is important to assess the sporophyte sizes and contamination present in the tanks vs the biofouling present at the grow-out site and make a judgement call as to where the sporophytes would cope the best in order to determine the best time for out-planting. In our case at our Saldanha bay site at BOM, we found that out-planting ~1cm sporophytes had a better chance of survival.

~ In terms of out-planting:

Based on observations on our out-plantings at BOM in Small bay (Saldanha Bay), which have taken place between May and August during 2023 and January 2024, from an industry point of view it may be preferable to out-plant after February or as soon as biofouling and siltation subsides (possibly even after March) and water temperatures drop below 15 °C. This has proven to work well for *M. pyrifera* in Saldanha Bay, which grew well over the winter months through to spring (Oct) as it is likely to be more cold tolerant than *L. pallida*. The time frame may also work well for *E. maxima* (in wild populations the secondary blades develop between late winter until November) but may be problematic with *L. pallida* (in wild population blades grow faster between Nov -Apr). See Phase 1 pre-feasibility study for more details on kelps in their natural environments.

However, the above may be different if these three species were out-planted in areas outside of Saldanha bay. In areas more exposed to the open ocean such as Kommetjie and St Helena Bay, mean water temperatures are in fact cooler in summer than in winter due to upwelling events during the summer months.

~ In terms of growth rate:
Although our grow-out site at BOM is closely situated to the mouth of Saldanha Bay, it is important to keep in mind that it is based within Small Bay (Saldanha Bay) which is very sheltered with little water flow/circulation during summer resulting in minimal nutrient influx between October and December. In this context, of the 3 target species, *Macrocystis* (which grew well over the cooler winter months) has to date been the only species that has grown fast enough to outcompete the biofouling species and be harvested for food safety tests. *Laminaria* (although a species which we expected to cope better over the summer months) did not grow fast enough over the warm summer months to outcompete the biofouling and deal with the deteriorating water quality and low level of nutrients over the summer months. Although *Ecklonia* was successfully out-planted in Jan'24, it too was not able to outcompete the competing biofouling species and by Mar'24 very few individuals were present on the rope structures. However, it is still too early to make a final verdict on any of the 3 target species as we have had to deal with many challenges in the hatchery and grow-out components which affected our ability to out-plant healthy specimens when the timing would have been more appropriate.

~ In terms of the growth of the kelps at different depths and different grow-out rope structures:
From the data that we have collected to date (although not finalised), it appears that for future kelp farmers wanting to farm with horizontal rope structures, that their main rope-line may have to be between 2-4m during winter while dropping the depth of the main rope-line to 6m as they are heading toward late spring where kelps will be within reach of upwelling events and where there is less intense sunlight during the day. Farming on vertical dropper rope structures of ~6m long/deep may also be an option and likely more economical in terms of space, however we are still in the process of assessing/verifying this.

~ In terms of nutrients
Nutrient data from Jul'23- Mar'24 (see N. Xulu March 2024 report containing nutrient analyses conducted by UCT) shows nutrient concentrations at 2m, 4m, and 6 meters at the BOM grow-out site. Although site-specific, the data shows how nutrient concentrations decrease from Jul'23 to Oct'23 with extremely low concentrations during Oct-Nov'23 which extends in the case of Nitrate, Nitrite and Ammonium into Jan'24 likely due to the high productivity in Small Bay during this period and certainly creating a challenging environment for kelps to cope with and grow in.

~ In terms of biofouling succession:
Biofouling is the biological fouling of other organisms which degrade the quality of the kelp blades, compete for light, dissolved nutrients and space on the grow-out ropes and interfere with kelp farming infrastructure. Although investigating biofouling on kelps per se was not one of the listed deliverables of the project, it seems that it may well play a very important role (and possibly a big stumbling block in Saldanha bay particularly for *L. pallida*). Based on our observations, biofouling starts annually as early as October and only seem to dissipate during March. On our structures at BOM, over the last year we started seeing a crustose Bryozoan *Membranipora* species on the blades from Oct'23 and some *Ulva* spp. on the ropes. By Nov'23 this progressed to many filter- and particle-feeding animals (sponges, tunicates, anemones) and also short (a few cm) but dense turf of small seaweeds (particularly *Ceramium*, *Ectocarpus*, *Polysiphonia* filamentous types), and quite a bit of foliose *Ulva.* From time to time, we also experienced a slimy covering on our ladders. The ladder

anchors too, were so densely packed with biofouling (especially with the tunicate *C. intestinalis*) that the total weight of the actual ladder required two people to pull up at each side of the ladder (thus 4 workers in total). On the long-line and mussel raft closer to the mouth, the biofouling on some blades and holdfasts were severe. During Jan'24, we installed new rope structure and soon thereafter all the rope structures were completely covered with skeleton shrimps so much so that it was impossible to see any rope (see table 1 pg 10). However during Feb'24, skeleton shrimps and small mussel spat were only present on the 6m ladder rung, while the 2m and 4m rungs were mostly covered in *Ulva* species. By Mar'24 the mussels and tunicates populated the ladders rungs to the degree that it is literally squeezing out the kelps.

Although there appear to be differences between sites in biofouling, and even within sites, it is almost certain that all sites will experience some degree of siltation and biofouling annually during October - March and therefore, the biofouling season as indicated in diagram 2 is something that will have to be considered when farming with kelps in Saldanha Bay.

6.2 Closing remarks

It is pivotal that the hatchery challenges be addressed and sorted out to ensure completion of the deliverables as per the BSASA contract with the FCDO. Essentially, if the first four months of 2024 are not utilised to successfully cultivate the three target species in the hatchery, then we will not have any kelps to monitor during the remainder of the year.

6.3 Anticipated work for the 2023-2024 (and beyond)

2023-2024												
	Quarter 1			Quarter 2			Quarter 3			Quarter 4		
Project deliverable	April	May	June	July	August	September	October	November	December	January	February	March
Hatchery/Nursery trials												
Grow-out trials												
Environmental monitoring												
Food Safety Testing												
1. Analysing results obtained in March 2023												
2. Testing farmed kelp								??			??	
Value Chain Analysis & Market assessment												
1. Drafting of TOR												
2. Sourcing consultant												
3. Study commence												
Stakeholder Engagements:												
1. Drafting of TOR												
2. Mini-workshop/meeting with community members to unpack possible involvement												
3. Value-chain workshop focussed on kelp farming component												
PM physical check of assets at all sites												
PM output report & budgeting												

Considerations for 2024-2025

Over and above the on-going research on the hatchery and grow-out components to optimise farming techniques and to determine which of the 3 species will be most suitable for cultivation in Saldanha Bay, the following items may also considered if time allows (some of which is also reflected in the Kelp Value Chain and Market Assessment study):

- Portal for information dissemination

  Developing a portal of sorts where interested parties and possible new-entrants can access relevant information on the project, available kelp farming manuals and research outcomes (from our projects and elsewhere in the world), funding avenue, links to government departments providing assistance to start-ups etc. Since BSASA does not have a website, we may want to explore options to either set something up or making use of a platform already in place. The PM to explore options during Q1 of the next financial year.

- Volunteer & training programme for new-entrants

  The PM could possibly start giving some thought to explore how endeavours such as these can be implemented.

- Kelp traceability/tracker system

  As in any other food industry, tracking systems to trace products back to its origin will become important in the kelp industry. A very basic manual tagging system could be looked at as a starting point which could form the basis of more automated systems once an industry is established.

7. Acknowledgements

The PM would like to thank (on behalf of the BSASA and the implementation team) the FCDO for the continued funding support, and the entire project team as well as the external consultants for their respective contributions to the deliverables of Q4 which contributed toward the contents of this report.

8. Annexures

(Note: please contact the project manager to access the annexures)

8.1. Annexure A: Ms F Hill monthly reports

F. Hill Jan'24 Monthly Report.pdf

F. Hill Feb'24 Monthly Report.pdf

F. Hill Mar'24 Monthly Report.pdf

8.2. Annexure B: Ms I Meyer monthly reports

POC Jan'24 Monthly Report.pdf

POC Feb'24 Monthly Report.pdf

8.3. Annexure C: Ms N Xulu monthly reports

N. Xulu Jan'24 Monthly Report.pdf

N. Xulu Feb'24 Monthly Report.pdf

N. Xulu Mar'24 Monthly Report.pdf

8.4. Annexure D: Project Plan (Research Protocol & SOPs)

Please note that the SOP's are currently work in progress and thus drafts. All SOP's will be finalised toward the end of the project.


SOP BSASA-1.1.pdf


SOP BSASA-1.2.pdf


SOP BSASA-2.1.pdf


SOP BSASA-2.2i.pdf

8.5. Annexure E: Food Safety Tests & Nutritional analyses


Kelp Project_ Food Safety Reports_April 2

8.6. Annexure F: Kelp Farming Information Session

Programme with time stamps for the video link Kelp Farming Information session 18-3-2024.mp4


Programme with recording time stamp


Kelp workshop - appreciation letter.pd