South Korea – WWF Industry Exchange Visit to Seaweed Industry

00 Executive Summary

South Korea is a fully modern and highly technical, developed country. It also has the one of the largest seaweed aquaculture industries, with a domestic and export market worth nearly $1b per year. The seaweed farming, although operationally and technically simple is on a massive scale (1.71 million tonnes annually). Seaweed is used to feed high value abalone and as a raw material for a modern processing industry. Seaweed is an intrinsic part of the South Korean culture and diet.

Close government and academic support allow processors to receive the best plants for their products and give the farmers the strongest cultivars to combat environmental challenges such as climate change. Co-operatives (Co-ops) allow farmers to operate in close proximity to well supported harbours. Their close knit working allows information and equipment sharing as well as market logistics. The farms are hereditary traditions within families, but foreign labour is replacing local recruitment.

The large brown kelps account for 2/3 of the volume farmed with 60% being used as food for farmed abalone. The residual harvest goes to lower value seaweed food products. The red, green and smaller brown seaweeds make up roughly 1/3 of the volume farmed but account for 73% of the value of the seaweed aquaculture industry in South Korea.

Challenges face the South Korean seaweed industry from climate change effects on rising water temperature and longer, more powerful late monsoon typhoons. This presents issues with feed security for abalone and continuity of supply for processing industry.

Changes to population demographics from lower birth rates sees an increasingly ageing population struggle to recruit to the physically demanding industry. Recruitment of foreign workers, mainly from other Asian countries bring cultural changes to this traditional industry.

Future challenges also arise from saturated home markets, competition from neighbouring countries also with similar industrial production and products and a barrier to entry into developing new markets in North America and Europe from resistance to seaweed products.

The developing seaweed industries of UK/Europe and USA/Canada are working to find a foothold in a seemingly infinite market, but regulatory, technical and market barriers stand in the way. We can learn from the South Korean industry, with its many successes, but some of our needs are significantly different and will require inspirational innovation to conquer.

One thing is clear, the value of this trip to the individuals that participated and the enduring change in mindset it brought is a testament to the need for each country, who desire to grow a functioning seaweed cultivation industry, to fund similar robust network building and knowledge exchange trips such as this, to South Korea and other leading seaweed nations.

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From left to right – Project Organisers - Mollie Gupta from WWF UK, Professor Jang K. Kim of *Incheon National University* – Dept. of Marine Science & Bailey Moritz from WWF San Diego.

South Korea – WWF Industry Exchange Visit to Seaweed Industry

The WWF exchange tour group disembarking from a seaweed farm boat in Wando District.

The WWF exchange tour group at the National Assembly of South Korea, Seaweed Symposium in Seoul.

01 Our Thanks

Stevie Jarron, of *Argyll Aquaculture* also a Director of the *Scottish Seaweed Industry Association* (*SSIA*), Owen Haines of *Cȃr-Y- Môr*, Tim van Berkel of *Cornish Seaweed Company* along with Henry Alexander, Senior Policy Adviser, No 10 Policy Unit from UK government, were honoured and privileged to be chosen to take up the offer from *World Wildlife Foundation USA* (WWF) made possible by Laura Rodrigues of *Builders Initiative*, of a place on an Industry Exchange Tour to South Korea to explore the seaweed industry there.

The tour was funded, managed and overseen by Bailey Moritz from the WWF San Diego office and Mollie Gupta from the UK office. Bailey and Mollie's management and organisation was excellent throughout. However, we believe the most influential factor creating the right culture was Professor Jang K. Kim of *Incheon National University* – Department of Marine Science. He is an extraordinary gifted individual and chaired the tour throughout with continual fun and 100% commitment. His comprehensive knowledge and network of all aspects of the South Korean seaweed sector, the international seaweed industry and research. A remarkable individual with amazing recall. Oh, and the karaoke helped a little too!

We would like to express our gratitude for inviting us to participate in the trip, it was truly a privilege to attend. The report below is a summary of our collective invaluable knowledge and insights we all gained. However, possibly the most significant value of this experience lies in the collaborative network of individuals that has been established. We are hopeful, that this network can continue to collectively work towards achieving the compelling benefits that we are all deeply passionate about.

The other participants in the tour consisted of farmers and processors from Alaska, Oregon, Washington, Maine and Canada. As well as the representation from Scotland, Wales and England. Interesting and revealing conversations were held between the participating group. Our own views and experiences were compared and measured against the experiences gained in South Korea. It is hoped that the connections made and the discussions begun on our tour continue far beyond and prove useful to all our colleagues and members. We miss you all!

Companies and individuals represented on the tour;

- Aurora Burgess - Atlantic Sea Farms
- Bailey Moritz – WWF-USA
- Brianna Warner – Atlantic Sea Farms
- Henry Alexander – UK Gov
- Hugh Cowperthwaite - Coastal Enterprises Inc
- Prof Jang K. Kim – Incheon National University
- Mollie Gupta – WWF-UK
- Stevie Jarron - Argyll Aquaculture/SSIA
- Julie Decker - Alaska Fisheries Development Foundation
- Justin Papkee – Atlantic Sea Farms
- Laura Rodriguez - Builders Initiative
- Markus Scheer - Seagrove Kelp Co
- Mat Obee - Cascadia Seaweed
- Nick Mangini - Kodiak Island Sustainable Seaweed
- Owen Haines - Car-y-Mor
- Tim van Berkel - Cornish Seaweed Company

02 South Korea

South Korea in figures (2022)

- Population 51,309,705 (compares to UK 67,026,000)
- Size 100,210 km² (compares to UK 243,610 km²)
- GDP per capita $48,653.1 (compares to UK $46,510.28).
- GDP growth rate 2.6% (compares to UK 4.1%)
- Average salary per month $2,592 (compares to UK $3,440) (Nov 2022)

The climate of the country sees near or below freezing temperatures and dry conditions over winter with a strong monsoon season in June to August with temperatures reaching the high 20's C and 80% of the annual rainfall. Discussion on weather patterns raised concerns over climate change. Milder winters, longer dry periods in spring and autumn, with stronger more destructive typhoons over the monsoon season and into September. Climate change is also bringing warmer sea temperature, raising fears around cultivation species survival in aquaculture for both abalone farming and the seaweed grown to feed the shellfish.

02.1 Seoul and Incheon

The north of the country is dominated by the capital city Seoul (Fig 1 & 2), which has a population of over 10 million with the connected surrounding cities such as Incheon (Fig 3) forming a megatropolis consisting of nearly half the country's population, making Seoul one of the world's largest cities. Few buildings in the area are older than 40 years old and many less than 10 years old. The country is at the cutting edge of urban planning and technology integration. This has come at a price, with Seoul suffering some of the world's worst air pollution with South Korea ranked 173rd of 180 countries in terms of air quality (2016). More than 50 percent of the population in South Korea are exposed to dangerous levels of fine dust, mostly from car exhaust fumes trapped in lower atmospheric air over the city's microclimate.

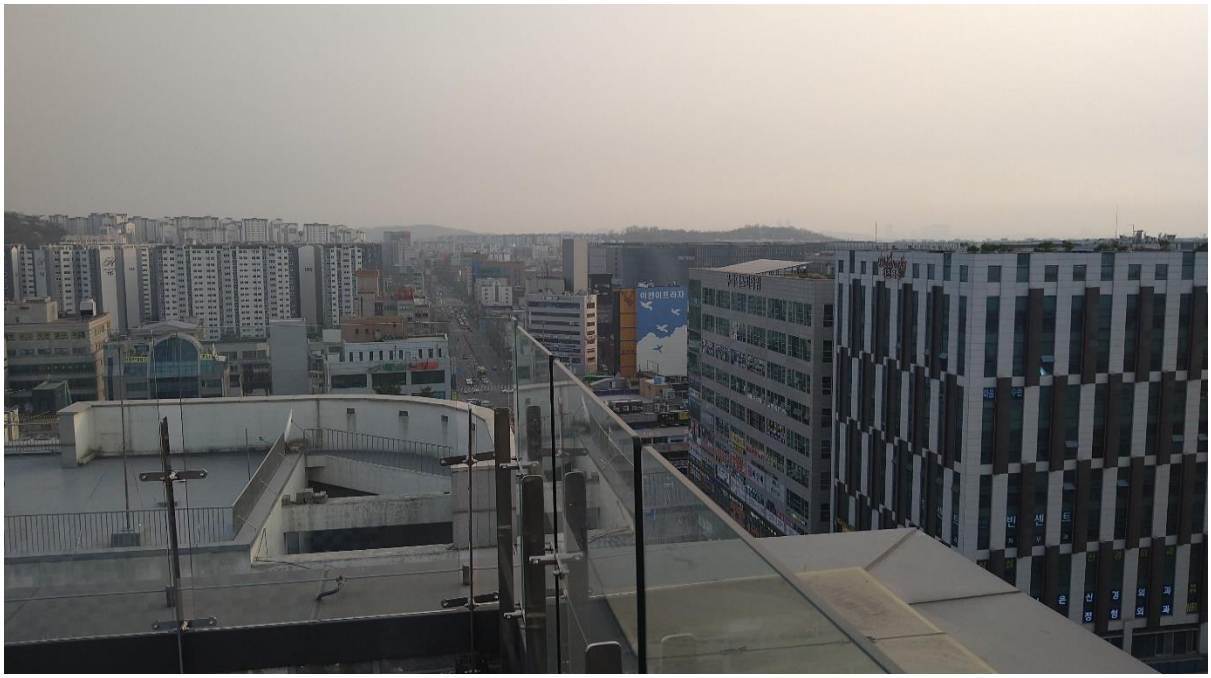

Fig 1 - Downtown Seoul.

Fig 2 - Seoul's grand scale modern infrastructure.

Fig 3 - Incheon – remarkable skylines and open grand parks.

With futuristic buildings and infrastructure, South Korea's north has a highly technical and connected society, very much in the fast lane of life. But this has brought issues with sustainability of growth and a legacy of urban pollution.

02.2 Wando

The southern end of the South Korean peninsula opens out in river valleys, housing terraced fields and limited farming between forested hills. The far south coast consists of sheltered bays and islands which is the setting for the South Korean aquaculture industry. The south east of the peninsula focusses on fish farming (mostly flounder and halibut) and the south west of the peninsula on seaweed and abalone farming. Several species of seaweeds are farmed and harvested, with one of them, sacharina japonica being mainly farmed as a feedstock for the abalone farms.

The tour group spent 5 days in the city of Wando, where we were extended every courtesy by the Mayor of Wando and his officials. The Mayor has a PhD in phycology, underscoring the level of integration seaweed has in the coastal and arguably national culture. During an audience with the Mayor and representatives of the local Seaweed Farming Co-ops, he pointed out a few key points:

1. the role seaweed could have in blue carbon and as a result of this South Korea has recently been subject of a NASA article showcasing seaweed industry.
2. climate change is a concern and something we need to adapt to.
3. South Korea is open to collaboration including tech transfer and joint research.
4. Farming and product development in UK/European and USA/Canadian seaweed industry, could be greatly enhanced by South Korean involvement and investment.

We were able to sample the culture and cuisine of the area and meet with local representatives of the farming and processing companies and visit the harbours, farms and factories in the area. An experience all of us will never forget and cannot be more thankful for experiencing.

Fig 4 - Wando - beautiful bay city at the centre of the aquaculture industry.

03 Farm Visit

The South Korean Seaweed farming industry is mainly focussed around local farming Co-operatives (Co-ops) in the south west of the South Korean Peninsula near the city of Wando (Fig 4). Wando's large port supports fishing vessels and ferry terminals and adjacent to the city are multiple sea areas set out for seaweed farming, organised into local Co-ops. These are locally run and self regulating, with generations of farmers having held farm spaces set up exclusively for the culturing of seaweed and abalone.

- Single species seaweed farming licenses: 2,185, covering 90,547 Ha cultivation area.
- Multiple species licenses: 1,205, covering 13,368 Ha cultivation area.
- Employees: 14,449 in 2020 (this does include part time employees).

From discussing directly with the farmers (through translators) it was revealed that the seaweed industry is struggling with youth recruitment. Seaweed farming is labour intensive and the farmers' viewpoint was that perhaps Seaweed farming simply no longer offers younger generation the kind of work they're looking for. They do see that is a more complicated story, in that South Korea's population demographics are generally changing to smaller families, therefore fewer young people available for work, and as a highly modern, educated and technologically advanced country, there are many opportunities for young people to study and achieve more dynamic roles at home and abroad. So, although still locally owned and managed, with an ever ageing workforce across the country, many of the farms now employ migrant workers to fill many of the roles in both the farming and beyond into processing.

The individual farm areas are organised into Co-ops. These take an annual fee from farmers to cover port and administration costs. There are no joining fees, but from various comments, it seems that membership is local and family held and unlikely that outside individuals or organisations would be able to join easily. The Co-op areas (fig 5) are laid out with abalone farms near to the ports and the generally more sheltered bays, while the seaweed is farmed further offshore, in places exposed to the open seas. On the day of our farm visit the winds quickly veered to seaward and freshened and a rolling sea swell built very quickly.

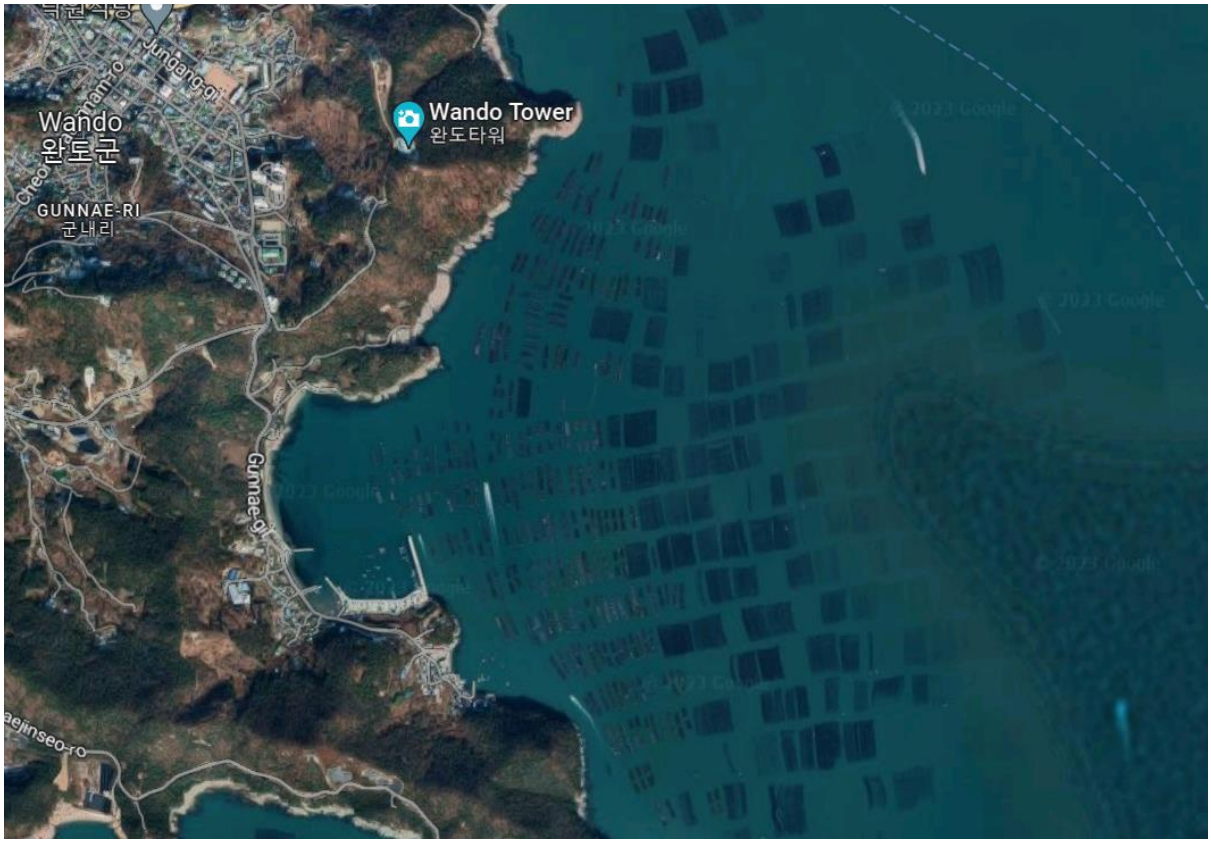

Fig 5 - Ariel photo of a Co-op. the near shore quarter are abalone farms, the rest are seaweed. For scale, the long pier in the harbour is 250m long.

The Co-op provides the farm anchors and maintains their integrity. This forms part of the payment made to the Co-op by farmers. The system of farming did not appear to be technically complex nor over engineered. There are no obvious barriers to joining a Co-op and spare space may either be allocated to existing farmers or be the route in which new farmers join. But the allocation of space was held by local family hereditary lineage.

Co-op farm sites rotate between members to ensure that people take turns on the best sites. The farmers take on a 3Ha minimum "unit" of farm for a minimum of 3 years. More can be requested if required. One farmer we spoke with had 6Ha of seaweed to feed his 540 frames of abalone. He managed most of the work himself but at busy periods employed up to 10 people, mostly foreign workers (seaweed and abalone seeding and harvesting periods). There were 53 members in the Wando Co-op. In one 3 hour boat tour we visited 4 different Co-ops.

The vessels used at the farms were mainly 5m x 18m open deck aluminium workboats, with raked bows and very low freeboard (Fig 6). They all had a long reach multi knuckle hydraulic crane run from a Beta diesel generator, while the main propulsion was twin 250 horsepower Honda outboards. Smaller aluminium dory style boats also ran between farm and shore. All the boats were hull shaped for impressive speeds, possibly in the high teens of knots or higher even for the larger craft (empty). A few larger bulk harvesting vessels were seen moored in Wando, but they seemed the exception to the style of vessel employed at the farming Co-ops.

Fig 6 - Co-op harbour facilities with farm boats.

There were no heavy fixtures or fittings on any of the vessels that would indicate a complex structure of additional frames or machinery would be fitted at any point and discussion of this led to the thinking that the hydraulic crane was used very effectively for multiple roles in the deployment, maintenance and harvesting, including holding a roller block high over the deck around midships to run line right over the ship for the purposes of clear harvesting larger kelps. Videos we were shown also pointed to a small, simple harvesting machine to be set upon the deck space as net grids of smaller red seaweeds were coppice harvested.

Fig 7 – Wando seaweed farming Co-op harbour. Pontoon, moorings and wharf areas.
Co-op harbour facilities (fig 7) consisted of hard standing along wharfs and piers that held several large cargo cranes, slipways and pontoons as well as moorings. Line seeding machines, light harvesting machines, abalone pontoon frames and nets and other equipment were stored on the hard standing with easy access to and from the vessels. Offices buildings and weigh bridges were also on the quayside. Easy access was available for large vehicles to access the queys and onto the connecting roadways of Wando.

The farm systems that lay beyond the Co-op harbour breakwaters were hybrid longlines (Fig 8) where surface or very shallow growing lines were held afloat by regular floats (some as close as every 4m while lateral lines (also at 4m spacing crossed at 90° to prevent interaction of the lines. Some of the large kelps' lines were wider apart, perhaps to cater for their larger size.

Fig 8 – versatile farm vessels alongside hybrid grid/longline farm structures. Buoys stretching out into the distance gives an indication of the scale of the Co-op limits.

The ropes used at the various seaweed farms were simple 12mm to 14mm polypropylene/polyurethane 3 strand twist used for creel fishing etc. At the harbour, various pieces of equipment were stored as well as growing ropes, cleaned ready for re-use (Fig 7). They did not appear to be particularly new ropes, so perhaps had been used for several years of cultivation.

We travelled across through other Co-ops to see other species being farmed for products other than as abalone feed. It was very poignant that we were repeatedly told that the abalone market was saturated and that the price had collapsed. Also, that the kelps grown for their feed had little value beyond that use. And that the farm areas (the Co-ops) were fixed, and

that now new farms could develop beyond the present allocated areas. There seems to be no market for that expansion at present, but it does point to future expansion as being a problem. Typical water depth at the farm sites are 14m-28m. The structures are loose grid/longline hybrids with 120m growing lines, held 2m apart with cross ropes every 20m and anchors at the end of each line. There are no structural headlines, with floats every 10m attached to weighted seaweed lines 2m-3m below.

03.1 Abalone (*Haliotis discus hannai)*

Abalone faming dominates the near shore area of the Co-op we visited (Fig 9). These are arranged in rafts of square 2.4m x 2.4m floating frames arranged 2 x 20 to 40 long (Fig 10 & 11). Fine meshed nets are hung within the frame structures. Plastic corrugated forms provide a habitat for juvenile abalone and farmed kelp is dropped into the frames weekly to feed them. After 18 to 20 months, the abalone are harvested for market. There are 1,500 abalone in each frame.

Fig 9 - from Wando tower – we can clearly see the Abalone farm frames in rafts, anchored near the Co-op harbour. The Abalone farms gain some shelter from the open sea, but the seaweed farms further out to sea, hidden below the surface in the above photo, are exposed to the full might of the seasonal monsoons. These are increasing in strength and duration due to Climate Crisis changes in water temperature.

Fig 10 - Abalone frames being harvested and abalone graded by size. Up to 3 tonnes per day.

Fig 11 - The primary source of food for the abalone farming is kelp grown near the abalone farms. An abalone farmer will manage his own kelp stock and the seaweed is dropped into the netted squares to feed the shellfish.

03.2 Seaweed species farmed

Across South Korea, over 85% of the seaweed farming is done within Co-ops.

The large kelps

- *miyeok* or wakame = *Undaria pinnatifida*
- *dasima* or kombu = *Saccharina japonica*

The smaller browns and reds

- *mojaban* = *Sargassum fusiforme*
- *kim* or Nori = *Neopyropia yezoensis, Neopyropia tenera, Neopyropia dentata, Neoporphyra seriata*
- *kkosiraegi* or bootlace seaweed = *Gracilariopsis lemaneiformis*

The different species have differing propagation styles.

- The large kelps *miyeok* (fig 12 & 13) and *dasima* (fig 14 & 15) are propagated from short lengths (10cm) of seaweed impregnated string that are woven into ropes, spaced every 30cm.
- *Mojaban* (fig 16 & 17) is grown on long ropes to which continuous seeded string is stitched.
- *Kim* (fig 18 & 19) is grown on continuous infused nets and grown and coppiced 2 or 3 times a year.
- *Kkosiraegi* (fig 20 & 21) is grown vegetatively from a small bunch (10 strands 10cm to 15cm long) of naturally settled plant, which is woven into the twist of a rope, this is then repeated over and over to increase biomass across a farm site.

Production and value of farmed seaweed species in South Korea in 2018

Species	Production (MT, wet weight)	Value (US$ 1,000s)
dasima or kombu = *Saccharina japonica*	572,595 (33.5%)	90,608 (10.8%)
kim or Nori = *Neopyropia yezoensis, Neopyropia tenera, Neopyropia dentata, Neoporphyra seriata*	567,827 (33.2%)	572,864 (68.2%)
miyeok or wakame = *Undaria pinnatifida*	515,666 (30.1%)	135,923 (16.2%)
mojaban = *Sargassum fusiforme*	36,170 (2.1%)	17,833 (2.1%)
Others	18,226 (1.12%)	22,700 (2.74%)
Sum	1,710,484	839,928

Data from Ministry of Oceans and Fisheries South Korea –
Hwang *et al*, Botanica Marina 2020; 63(4): 395–405.

Fig 12 - *miyeok* or wakame = *Undaria pinnatifida*.

Fig 13 - *miyeok* or wakame = *Undaria pinnatifida*.

Fig 14 - *dasima* or kombu = *Saccharina japonica*.

Fig 15 - *dasima* or kombu = *Saccharina japonica*. The general farmer attitude towards seaweed farming, their dedication and their pride to their cultural vocation shined through in every meeting and conversation we had with them.

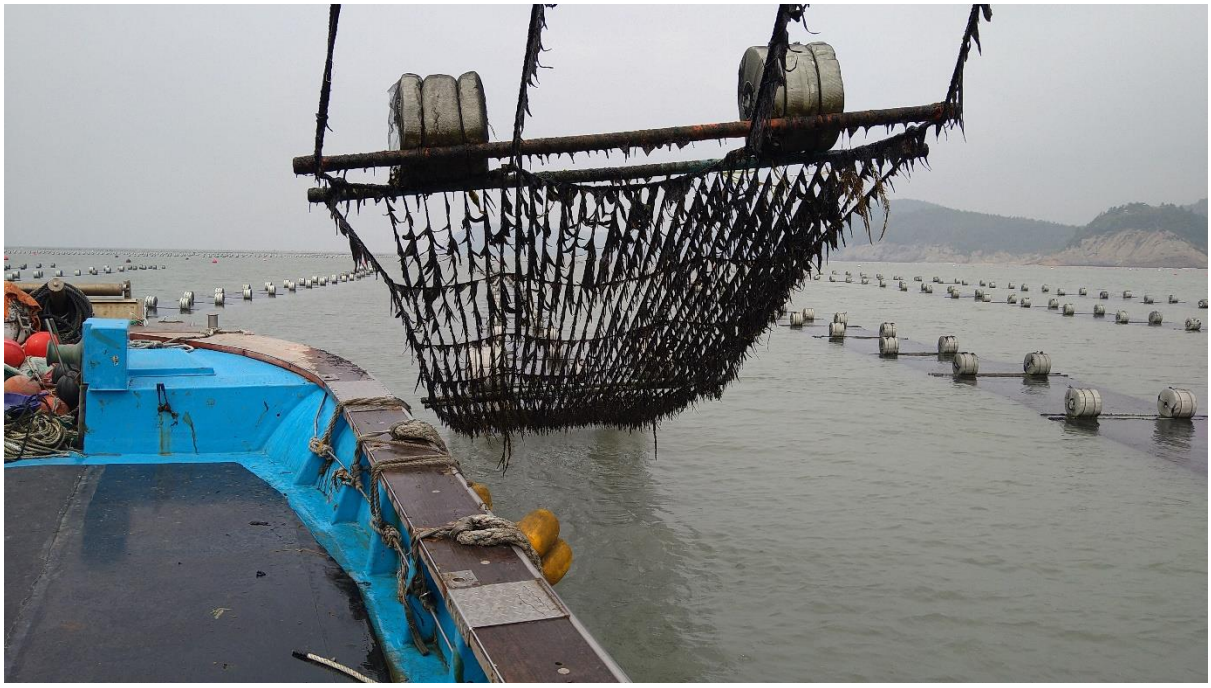

Fig 16 - *kim* or Nori = *Neopyropia yezoensis, Neopyropia tenera, Neopyropia dentata, Neoporphyra seriata*. Using a "Turnover net" system to mimic intertidal cycle. The whole surface structure can be flipped over, leaving the seaweed out of the water for few hours a day, mimicking a natural low tide. This stimulates better, stronger plant growth.

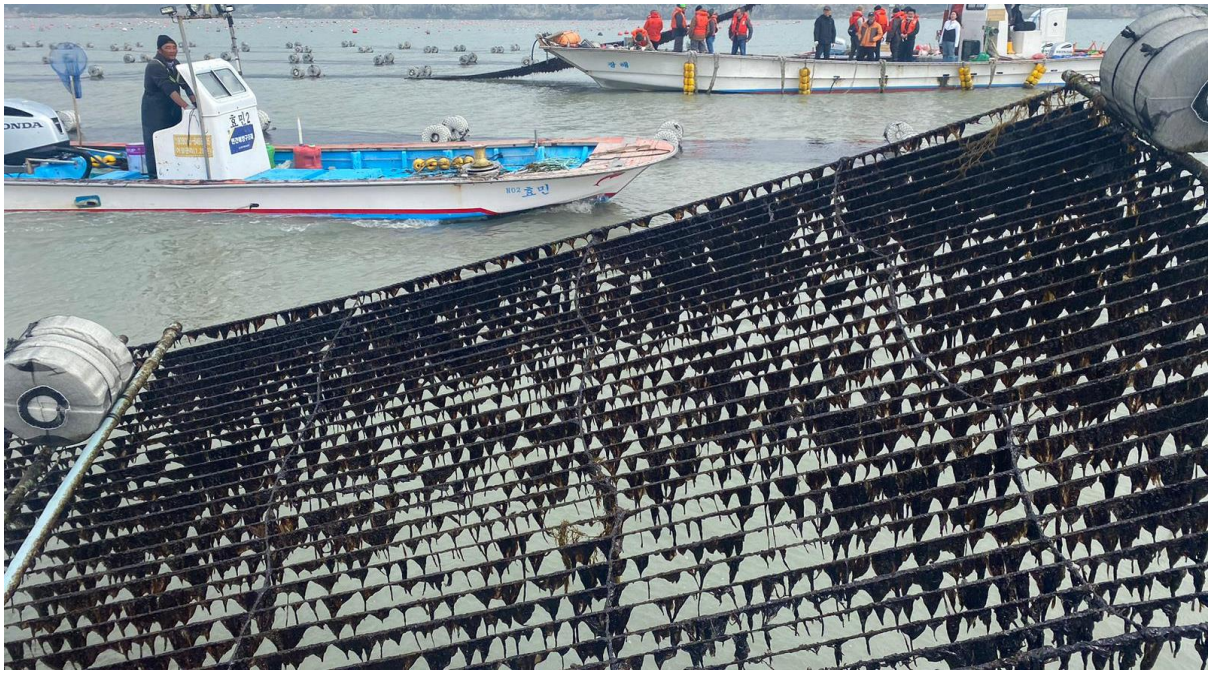

Fig 17 - The *kim* (Nori) is cut to 20mm at each coppiced harvest. A farmer will take up to 3 small harvests over the 8 month season. The plants can grow up to 15cm to 20cm between coppicing.

Fig 18 - *mojaban = Sargassum fusiforme.*

Fig 19 - *mojaban = Sargassum fusiforme.*

Fig 20 - *kkosiraegi* or bootlace seaweed = *Gracilariopsis lemaneiformis*.

Fig 21 - Grown vegetatively, not from seeded lines, wild plants are divided continuously to create biomass.

04 Technology Visits

Throughout the tour we were reminded of, and saw in place, the very close connection between Government Institutional academic support for the seeding and cultivar innovation and the processing and farming operations. The National Institute of Fishery Science (started 1921) has 15 research centres and 18 research vessels. It's aims are to prepare for the future industry's success with a significant amount of its work dedicated to technical aquaculture manuals for farmers and operators. Their work also searches for seaweed, shellfish and fish species that will be able to thrive in the predicted increase in water temperatures due to the Climate Crisis. New cultivars of seaweeds have been identified and propagated in government funded nurseries by organisations such as the Incheon and Seoul universities. These are "given" to the processors to offer to the farmers to grow. It was said that the purchase of this seeded material is free market based and competitive, but the full mechanism of the exchange between academic research, government support, nurseries at scale and processor to farmer is complex and hard to follow. One thing that was understood, is that the farmers seek to have the best cultivar seed demanded by the processors.

The work of the research institutes looks at many topics including the physical size and shape of cultivars and their nutritional qualities. A pressing need is being placed on cultivars that have increasing resilience to the changes in water temperature and other stresses from rapid climate change. As seaweeds are cultivated as feed to high value abalone, the knock-on effect of a kelp crop failure would have serious consequences for the lucrative secondary crop.

It was interesting to hear that the cultivation of seaweeds in South Korea does not involve the use of direct seeding methods as is being pursued in Europe. Seaweed impregnated string and vegetive regrowth are the methods used. In the former method, string is wrapped around frames, not onto spools and seaweed is stitched into ropes (in whole or in parts) rather than wound around the ropes (Fig 22). Seaweed string is produced at scale and sold on to farmers at less that 10p per metre (approx. $15 per frame with 160meters/frame).

Fig 22 - String wound round frames being seeded – then being brought on in large batches.

05 Processing Visit

We were given tours of multiple experimental and scale processing facilities across the Wando region. Some of the equipment and processes are business sensitive so we were prevented from photographing in some areas and details of some processes and equipment were kept private, but many useful answers were given freely and openly.

First impressions of the processing factories are their absolute cleanliness, efficiency and modernity. Product quality, food hygiene and staff safety were foremost at all times. The level of automation and the volume of production speaks of how highly seaweed is prized as a food in South Korea (and wider Asia). Some facilities were owned by municipal research facilities and repurposed for different supply chains depending on seasonal and local needs.

05.1 Primary Processing

Seaweed is harvested within a 120 day period for kelps (that are not used for abalone feed) and a similar but out of sync window for the smaller red species. Some seaweed is processed immediately into products, but the processors attempt to ensure they have seaweed available to process all year long by a combination, depending on final product of blanching, salting (brining) and low temp chill (-18° C, not freezing as salted products can't freeze). Products are also part processed and then frozen so to keep quality and extend shelf life beyond final processing stage.

Seaweed is brought in bulk bags or dump trucks to large processing facilities where the seaweed is "parked" for up to 2 or 3 days by being washed in seawater by slow spinning propellors in huge tanks (Fig 23).

Fig 23 – huge tanks to wash and store harvested seaweed.

When required, the seaweed is then pumped into a dicing system to create a fine slurry. This can be sprayed into rectangular moulds and quickly toasted dry (Fig 24). The dried sheets can then be further processed and packaged or stored in bulk cardboard boxes in chillers until required for final processing (Fig 25 & 26).

Fig 24 – large scale spray and roasting of seaweed sheets

Fig 25 – sheets are packaged for immediate processing or chilled storage.

Fig 26 – chilled storage preserves sheet quality and allows longer shelf life after final processing.

05.2 Secondary Processing

At a surprisingly small, compact factory in Wando, the large boxes of *kim* or Nori sheets are opened and fed into automated lines. These roast, toats and flavour, then cut the sheets and seal them into small packages for distribution directly to retail outlets (Fig 27 & 28). A simple bar coding system is used to keep track of batches, offering traceability to source of materials.

At another site in Wando, *dasima* or kombu whole leaf fronds of large seaweed kelps are laid out and dried in huge outdoor clean areas. These dried bundles of seaweed are transported to facilities where they are diced down to cracker sized pieces for eventual rehydration as an ingredient in seaweed broths or soups, commonly served with tofu and seafoods for all meals of the day (Fig 29 & 30).

Broken pieces of the seaweed are collected and ground down into very fine powder which will then be further processed into other products such as seaweed noodles at separate processing factories (Fig 32).

Fig 27 - In a separate factory the stored sheets come in from chill storage.

Fig 28 – sprayed with sesame oil, roasted, cut and packaged in one production line.

Fig 29 - Huge pallet bundles of dried *dasima* or kombu kelp. The first step is for the huge kelp blades to be visually inspected and manually brushed to remove epiphytes and other fouling.

Fig 30 – diced and repackaged for further processing and packaging. Offcuts are powdered for alternative uses in seaweed noodle production.

05.3 Biorefining

To expand the uses of seaweed, government facilities are set up in the Wando region to trial new techniques of processing and the extraction of constituent chemicals (Fig 31 & 32). These can be used for a massive range of products including dissolving soft capsules for pharmaceuticals.

Fig 31 – experimental biorefinery was looking to extract novel chemical from different species.

Fig 32 – showcasing the various elements from new cultivars and species.

06 Takeaways and Conclusions

06.1 Different starting points

1. The South Korean seaweed industry is very well established, but this means that few new players are entering the market, and few new ideas are pressuring the *status quo*. There appears to be relatively few new uses for seaweed in South Korea, with almost all taken up for direct consumption as food for humans or to feed high value abalone.
2. This is direct contrast to the UK/European and USA/Canadian industries where seaweed is new and upcoming and many new startups offering new ideas and uses are being developed. This makes seaweed here a very dynamic space, with a lot of potential.
3. However, the problem we have in the UK/European and USA/Canadian is the cost of seaweed cultivation (and also processing) and therefore the wet or dry, raw primary product cost is high. To use seaweed for anything else but food or high value extracts, the underlying wet tonnage biomass cost needs to come down significantly.

06.2 New product development

4. Say we make the assumption that seaweed is mainly used for food in South Korea because the cost of growing seaweed is so high, prohibiting its use for other purposes. If so, then this might be a huge barrier to the UK/European and USA/Canadian industries developing as the available seaweed market for food is relatively small and already dominated with Indonesian and East Asian sourced products. But we know and we saw first hand that seaweed is accepted and in demand as a foodstuff at a far deeper cultural level than we will ever achieve.
5. So, it is worth contemplating that the UK/European and USA/Canadian seaweed industries will need to develop in a differently to way that South Korea's did.
6. It does suggest that we will struggle if we focus all our efforts on only growing seaweed as a food crop. We may need the joint/parallel approach of getting to scale for other products and to develop high quality food products as smaller offtakes from this scaled farming, allowing for a lower seaweed biomass cost for both.
7. It is possible that the UK/European and USA/Canadian have the momentum in available funding to use seaweed for different purposes, such as biopolymers, fertilizers and soil conditioners. And this may be more realistically the route to opening up the seaweed industries at scale that human food products.

06.3 Researching different species

8. Nori and wakame are by far the most widely cultivated seaweeds for human consumption in South Korea. We see that these are also the most imported species in the UK/European and USA/Canadian marketplace, because compared to other seaweeds their taste is simply superior.
9. However, both species are either challenging to cultivate here or non-native, therefore barred from production. Even though many non-native species are widely seen on our land and in our waters, their use is illegal and their propagation even more so.
10. This limited species mix (mostly large brown kelps) is a significant barrier to developing the UK seaweed industry, for human consumption and wider appreciated uses. So, the development of cultivation techniques for species such as Dulse (*palmaria palmata*) for

example. There is a need for the UK to innovate to a greater degree in the chemical and taste qualities of the hundreds of species that naturally grow here.

11. Until then, many of the routes of development that were available to the South Korean industry model will be closed to us (eg abalone feed). Could fin-fish farming have a use for cultivated seaweed as a low-trophic/low carbon feed supplement?

06.4 Climate Change mitigation

12. The impact climate change is having on seaweed cultivation in South Korea is significant. Warming waters are starting to become an equally serious issue in UK/European and USA/Canadian the UK. The Maine crab/lobster fishery as an example, as it begins to collapse due to warming sea temperatures. The fact that new strains and cultivars are being developed in Korea is encouraging as this shows a potential to mitigate higher temperatures. This is something that UK/Europe and USA/Canada should looked at also.

06.5 Zoning and Licensing

13. The South Korean seaweed farming operations are concentrated into Co-ops and the processing in and around Wando city. This has an obvious logistical and resource concentration advantage, but alternatively makes it very vulnerable to disease/invasives outbreaks, weather events and climate change. It raises the question of the wisdom in concentrating efforts into Aquaculture Zones being proposed here for shellfish/seaweed farming.
14. Zoning and Licensing are a perpetual issue raised by all the participants across UK/European and USA/Canadian seaweed industry representatives. Too restrictive, too slow and too expensive. Given the benign nature of seaweed cultivation the only real issue about seaweed cultivation is the obvious impacts on sensitive environments, which are easily avoided at the point of site choice and the impact on other marine users, especially inshore creel fisheries, which share the target areas of the developing industry (at this time).
15. Zoning into Co-op zones in South Korea does add the advantage of permanently available licensed areas and understandable and reliable resources and costs for farmers.

06.6 Vessel coding

16. One barrier to a potential mitigation for the latter that is raised (certainly in the UK case) is the frustrating situation regarding rules that govern small vessel safety coding. Small fishing vessels and small workboats are safety coded with separate certificates, but the safety equipment and sea worthiness of two coding systems produce very similar vessel safety outcomes.
17. When we approach rural communities, we are often prevented from fully including the local marine talent and existing local fishing infrastructure, both ashore and afloat as the division of the coding systems mean that no existing fishing vessels can participate in our cultivation work. Therefore, there is no incentive to work with us and we are simply another additional marine spacial squeeze on already constricted resources.

18. New entrants to the seaweed industry have to buy in workboats that are codeable as such and crew them accordingly, separate from the existing available fishery personnel and craft. An unnecessary division and dilution and competition with community resources.
19. There surely can be a simple duties that small, coded fishing vessels could perform for seaweed aquaculture without recoding as workboats?
20. Safety of any vessel, at all times is at the discretion of the vessel skipper, as in all marine operations. The skipper is fully capable of ensuring that any task undertaken is within the vessel's limits for stability, sea conditions and crew welfare.
21. Fishing vessels primarily coding and equipment would remain for fishing, with appropriate licencing and insurance. Then (either) an exemption (or) allowance for workboat activities (or) a second additional parallel coding for workboat activities. The latter being expensive.
22. This as a critical discussion point for the diversification and modernising of the existing fishing fleet. So far, all approaches to the MCGA on the matter have been ignored.

07 Products and gifts

We were given gifts of products produced at the factories we visited (Fig 33). On trial of the range, each was found be fresh, delicious and very, very moreish! It was clear from the tour of their wider industry that the final product development, including product presentation was where the value lay. That the value of the raw seaweed as a product at the pier, was almost irrelevant. It was the uptake of a stylised and recognised final product that was the key to the industry. There friendliness and generosity of our hosts was remarkable. We were treated to the finest dining and offered every courtesy to see their industry and ask questions of the highest official and the hard working farmers. We were given beautiful gifts to bring home (Fig 34) and these will stay with us forever.

Fig 33 - Gifts from the processing facilities visited. Seaweed in whole or part in each item.

Fig 34 - A beautiful and thoughtful gift pen from Incheon University given to each of the group, pen and box inlaid with abalone mother of pearl.