The Food Security Research Institute (FSRI)

Yellowtail Kingfish

Atlantic salmon (*Salmo salar*)

West coast Rock Lobster (*Jasus lalandii*)

Bivalve molluscs: oysters, clams, scallops, mussels [IMTA options]

Abalone (Perlemoen) [IMTA options]

Shrimp species [IMTA options]

Silver kob, Dusky kob, White stumpnose and other marine finfish

Sea cucumber species [IMTA options]

Rainbow trout *Oncorhynchus mykiss*

Marron (freshwater crayfish), *Cherax tenuimanus*

Harders [*Chelon richardsonii*] (Southern mullet) [IMTA options]

Mozambique tilapia (marine culture)

Nile tilapia (freshwater culture)

Ulva spp. Sea lettuce [IMTA options]

Atlantic dulse *Palmaria palmata* [IMTA options]

Glasswort *Salicornia spp.* [IMTA options]

Lemna spp. Duckweed [IMTA options]

West Cape Coast, South Africa

v1.1

FSRI

FSRI

The Food Security Research Institute (FSRI)

What We Do

The Food Security Research Institute (FSRI), a Non-Profit Company (NPC), bridges the missing gap between fundamental research and the need to demonstrate technical and commercial viability of marine and freshwater aquaculture opportunities in the oceans economy space, or applied research.

This is accomplished through innovative design, engineering and careful project concept design packaging followed by project prototyping, and either pilot scale or semi-commercial scale implementation [and sometimes prior experimental scale] and finally the auditing of outcomes paving the way for private sector commercialization to follow. The FSRI bridges the impossible divide by overcoming sub-optimal scale economies in semi-commercial and pilot plant operations often viewed as both as both too high risk, marginal, or yielding unattractive returns, which typify proof-of-concept start-up aquaculture projects. The FSRI's high-impact outcomes then aim to lure private sector investment into the oceans economy space breaking new ground by ushering in new sustainably cultivated marine product offerings such as seawater farmed tilapia to replace unaffordable Cape hake, and both Atlantic salmon and marine shrimp for import replacement in South African markets, Rock lobster, and several marine line-fish species, inland saline zero-discharge Integrated Multi Trophic Aquaculture (IMTA) and more.

In addition, the other major objectives of the FSRI are to advance commercial aquaculture growth in South Africa through several initiatives;

I. Technology demonstration on a smaller commercial scale;
II. Practical hands-on teaching and technology dissemination;
III. The provision of early seeding and catalytic industry inputs;
IV. Wild seed quarantining and disease purging to create Specific Pathogen Free (SPF) breeding colonies and;
V. Genetic development of wild germplasm for the aquaculture industry.

Then, the FSRI is your oceans or blue economy food security partner. The FSRI will host a skills transfer and capacity building Human Resource Development Centre (HRDC) specifically to provide a pipeline of skilled manpower for the aquaculture industry in South Africa.

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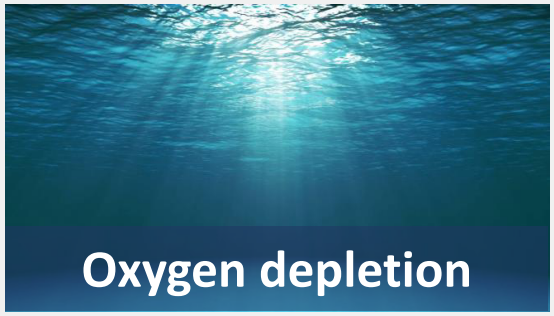
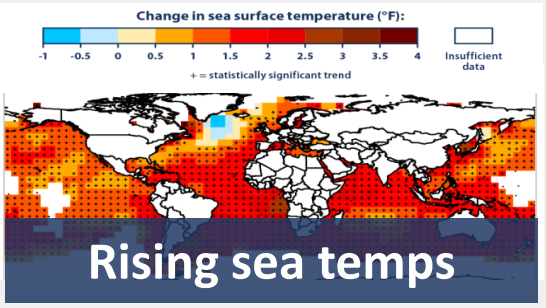
Who cares?





Biggest concern is ocean pH by 2036 some 12 years away

Since the 1950's some 50% of all marine life has been lost (Dryden and Duncan, 2022). Many fish species in South African coastal waters are Red Data Book listed and may no longer be traded e.g. White stumpnose, Red stumpnose, White steenbras, Galjoen etc.

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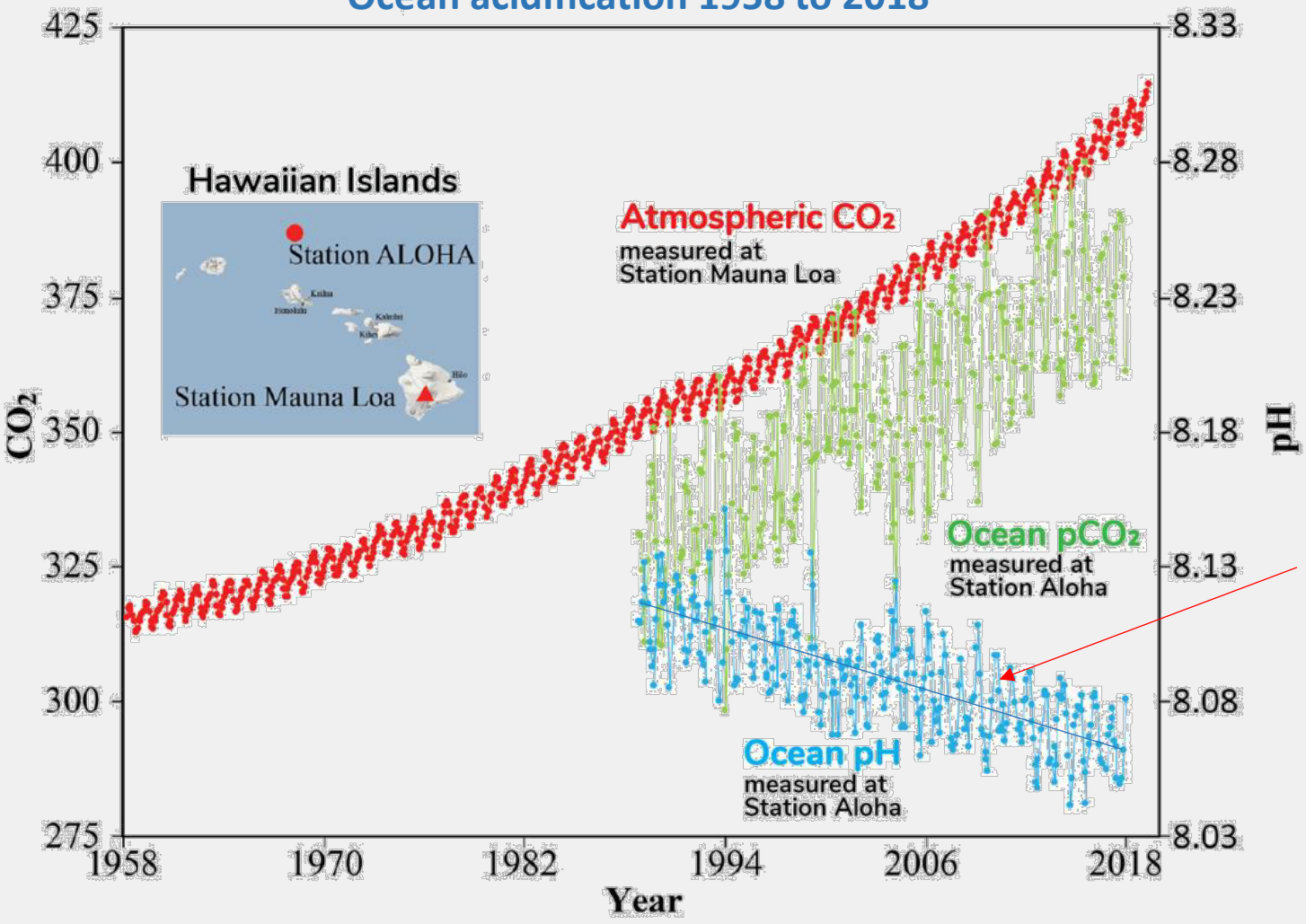
The FSRI cares about the food security in South Africa and access to affordable seafood

Ocean acidification 1958 to 2018

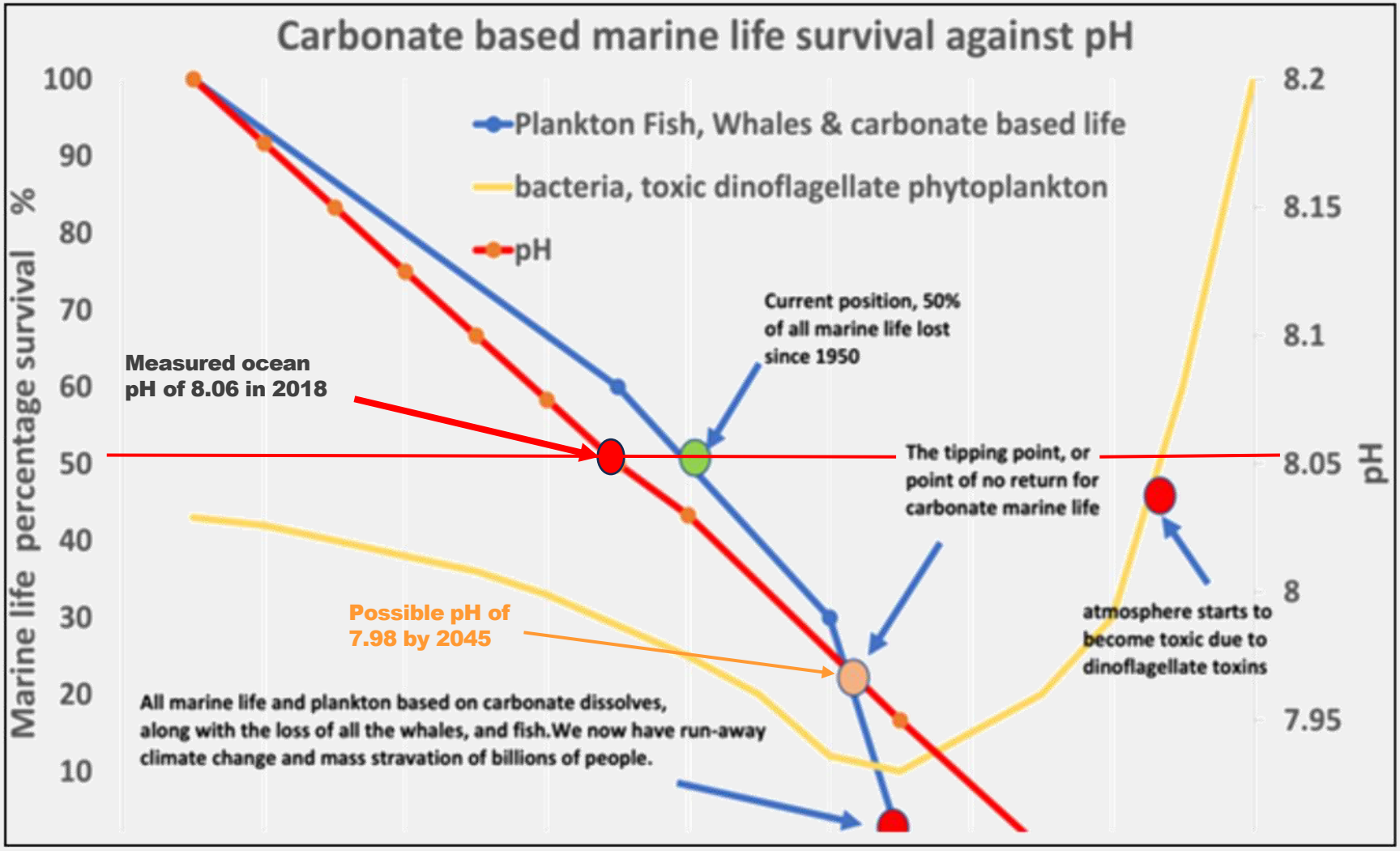


The rate of pH drop means that by 2036 we may dip below a pH of 8.03 and below 7.98 around 2045 the tipping point of no return assuming current CO_2 emissions

As human activities have increased so have CO_2 levels in our atmosphere (red line), about a third of that CO_2 has been absorbed by the ocean (green line), and ocean pH has decreased (blue line). Adapted from NOAA.

FSRI

The FSRI cares about the food security in South Africa and access to affordable seafood



Ocean acidification and loss of marine life since 1950 and future catastrophic milestones (Dryden and Duncan, 2022)

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Current and Future Projects

Yellowtail Kingfish

Atlantic salmon (*Salmo salar*)

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Mozambique tilapia (marine culture)

Nile tilapia (freshwater culture)

Ulva spp. Sea lettuce

Atlantic dulse *Palmaria palmata*

Glasswort *Salicornia spp.*

Lemna spp. Duckweed [IMTA options]

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Current Projects at the Food Security Research Institute (FSRI)

Mozambique tilapia (*Oreochromis mossambicus*) [marine culture]

The first, and flagship project, at the FSRI, is Phase 1 of the Future Fish 2035 vision (marine tilapia culture) which aims to execute early seeding and catalytic work to spawn a new marine finfish aquaculture industry targeting the white fish market to replace increasingly unaffordable Cape Hake. Marine tilapia potentially offers a more affordable and wholesome marine product targeting the least cost animal meat protein source in South Africa and the South African Development Community (SADC) in particular.

The Cape hake fishery, based upon annualized quotas, is worth more than R5Bn annually. As such, the value proposition offered by a scalable marine tilapia aquaculture industry of comparable volumes would be worth over R4.5Bn annually potentially creating over 5,000 new jobs in impoverished communities along the west Cape coast, and also new fish related jobs for fishers not awarded a quota.

Mozambique tilapia *(O. mossambicus)* = South Africa's Best Kept Secret Weapon Against National Malnutrition and Food [protein] Insecurity.

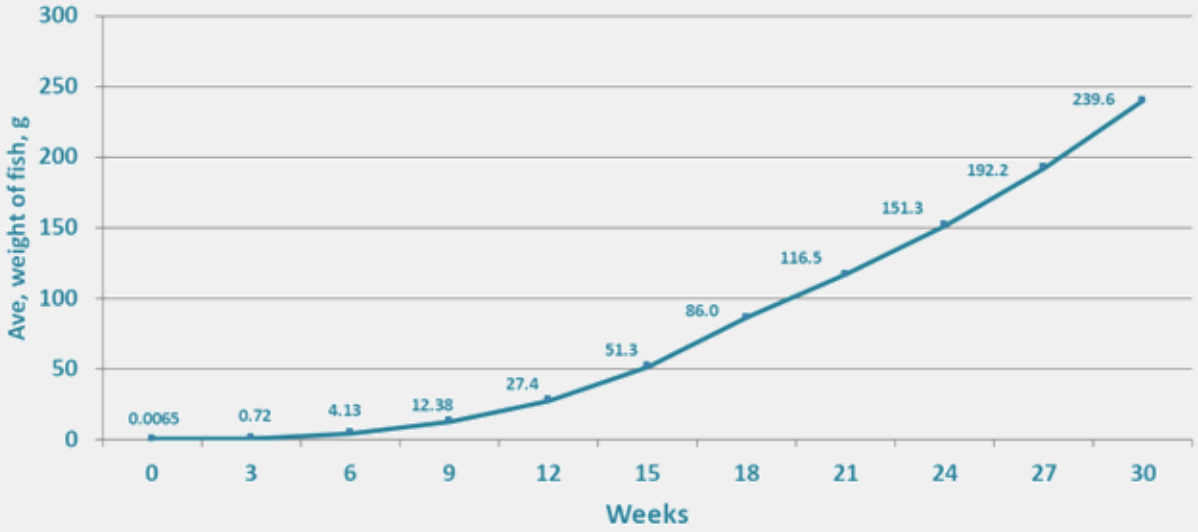
- ✓ **Indigenous to the east coast of South Africa, and widely introduced across the country → no biodiversity risks**
- ✓ **They grow 1.66 to 2 times faster in seawater** (Howerton *et al.*, 1992; Kuwaye *et al.*, 1993; Ron *et al.*, 1995; Shepard *et al.*, 1997; Sparks et al., 2002)
- ✓ **They taste better when grown in sea water, on par with the best line fish** (Head *et al.* ,1994; Infofish, 2003; Fraga *et al.*, 2015)
- ✓ **Higher marketability –** Sold as a marine fish, overcomes market biases favouring the consumption of marine fish in South Africa
- ✓ **Fetch a premium price in Japan and discerning Asian markets** – In Japan marine cultivated sushi quality, *izumidai,* Taiwanese tilapia fetch a premium of US$ 12.00/kg of fillets about 80% higher than the retail price of Cape hake (Head *et al.*, 1994; Infofish, 2003; Fraga *et al.*, 2015). Note that exports are not the objective and that higher fish quality aims to leverage market acceptance and market share as an alternative species to Cape hake rather than higher local prices.
- ✓ **Low Trophic Level species, contribute to food security; highly efficient digestive system, low cost production.** Mozambique tilapia when grown in seawater exhibit lower Feed Conversion Ratio's (FCR's) requiring less food to yield 1kg of body weight gain than when reared in freshwater, and also less than broiler chickens in a marine Biofloc Technology (BFT) system, to become potentially the least cost farmed animal protein in the country.

Current Projects at the Food Security Research Institute (FSRI)

Mozambique tilapia (marine culture)

Experimental saline 12m^3 BFT batch-production tank system at the FSRI

Achieved growth of *O. mossambicus* in experimental seawater (35‰ salinity) BFT tanks at the Food Security Research Institute (FSRI) at 27°C through the farmed life-cycle



The way forward towards a 50% scaled replica of a large-scale commercial scale system at the Marine Tilapia Industry Incubator (MTII) [synonymous with marine tilapia aquaculture]

- Current feed vendors do not mill low-protein feeds tuned to achieve a Carbon: Nitrogen ratio (C/N ratio) of 15-16:1 required for optimum and low-cost BFT tilapia production, requiring on-farm made aquafeeds using moist pressed pellet milling technology to be built into the farm.
- The use of solar greenhouses supplemented with solar water heating would be mandatory along the west Cape coast to enable year-round production and good annualized productivities from the Marine Tilapia Industry Incubator (MTII).
- A minimum scale of 125 tonnes per annum of production would be needed based upon a scale factor 50% of a full-scale 250 tonne per annum tank system for the Marine Tilapia Industry Incubator (MTII) at the Food Security Research Institute (FSRI).
- The Marine Tilapia Industry Incubator (MTII) will provide definitive roadmap for the scale-up of the commercial *Marine Tilapia 2035 Vision.* The MTII aims to support the first cluster of grow-out farms with a skills development platform for the forthcoming seawater farmed Mozambique tilapia aquaculture industry targeting 100,000 tonnes of production by 2035 from five clusters.

Current Projects at the Food Security Research Institute (FSRI)

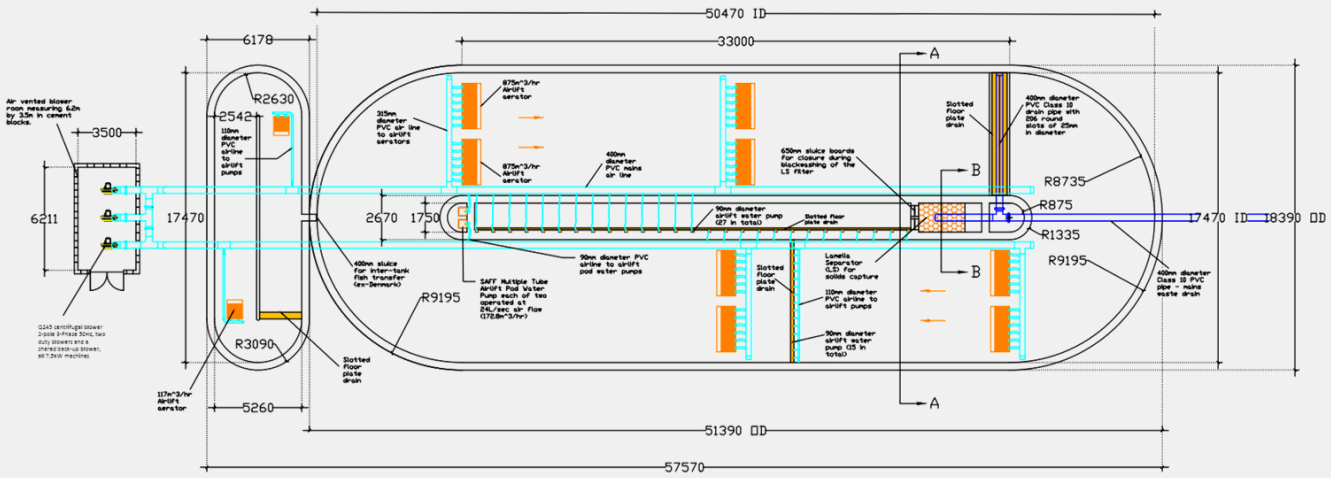
Next step for Mozambique tilapia seawater culture at the Food Security Research Institute (FSRI).

Marine Tilapia Industry Incubator (MTII) [Mozambique tilapia seawater culture] objectives at the outset include;

1) Definitive technology proof-of-concept at a semi-commercial scale based upon a 50% scaled exact replica of a full-scale commercial Biofloc Technology (BFT) SAFF-R-ended grow-out tank culture system.
2) Demonstration of a working marine tilapia BFT grow-out unit specifically adapted for the west Cape coast of South Africa to foster interest in the development of the first commercial cluster capable of producing 20,0000 tonnes per annum offering an ideal platform for a skills development programs at the FSRI to support the forthcoming commercial marine tilapia farming sector.
3) A 50% scaled 2nd generation exact replica (125tpa) of a 250 tonne per annum (tpa) R-ended BFT grow-out tank will provide the proof-of-concept project needed to seed and canalize a new alternative farmed whitefish industry to replace increasing unaffordable Cape hake. Output results will provide needed confidence for a commercial hatchery operation which aims to supply improved gene lines of seedstock to develop a scalable commercial sector.

766m³ SAFF-R-ended multi-cohort sequential grow-out production tanks at Chambo Fisheries the first BFT tank farm to employ the *SAFF- One-Tank Fish Husbandry Approach.*

Plan-view layout of a 2nd generation 1250m³ multi-cohort sequentially stocked and harvested R-ended BFT grow-out tank capable of producing 30 tonnes per annum (100kg/m³/year) for placement in temperate climates. The MTII tank system is a scaled down replica of larger scale 250 tonne per annum BFT integrated R-ended tank systems intended for industry scale-up.



Current Projects at the Food Security Research Institute (FSRI)

FSRI

Atlantic salmon (Salmo salar)

The SAFF-marine RAS producing the Guilthead sea bream (*Sparus aurata*) in Tartous, Syria in 2009.

Interest in the production of land-based tank farmed Atlantic salmon has existed for some time in South Africa. The hurdles which need to be overcome are a proof-of-concept land-based Recirculation Aquaculture System (RAS) which delivers salmon competitively against imported Norwegian salmon air-delivered to South Africa two or three times a week targeting the local fresh salmon market for sushi for import replacement with returns high enough to off-set the risks associated.

Since interest is high in the production of land-based RAS farmed Atlantic salmon in South Africa a start-up project may be scaled to achieve modest returns through the pilot phase of no less than 200 tonnes per annum. However, if scaled to 50 or 100 tonnes per annum considered a sub-economic in scale, a pilot project may then best be developed within the Food Security Research Institute (FSRI).

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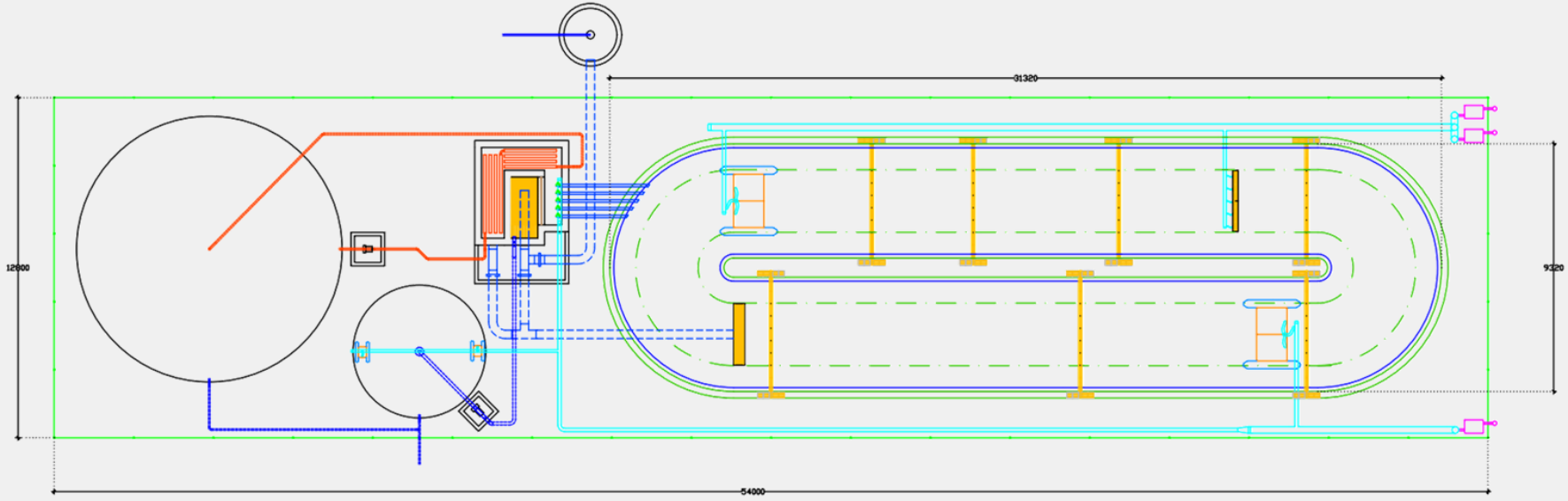
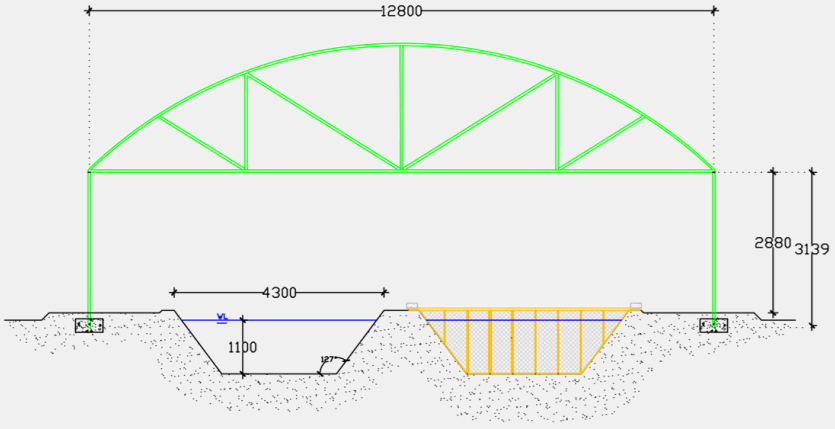
Current Projects at the Food Security Research Institute (FSRI)

Small-scale Nile tilapia (*Oreochromis niloticus*) – freshwater culture



Plan view layout of a 20 tonne per annum freshwater BFT tilapia system for Nile tilapia



Major section through a 20 tonne per annum freshwater BFT tilapia system for Nile tilapia

The FSRI has designed the least cost and most productive freshwater BFT tilapia farm specifically for raising 20 tonnes per annum of Nile tilapia year-round in the Western Cape using a state-of-the-art design approach to maximize efficiencies. The system uses solar PV power and solar PV/heat pump driven heating including a thermal reservoir.

The financial analysis indicated that the CAPEX of R3.7m would be US$10.28/kg annual production, way above the US$3.00-4.00/kg annual production range for efficient tilapia production. The depreciation contribution to total production costs amounted to R12.53/kg of tilapia produced. Selling prices would require to be R72.90/kg LW (to achieve an IRR of 8.0%). Such high selling prices are higher than that of broiler chickens thus rendering small-scale tilapia farming uncompetitive and therefore offers no food security impact potential unalike large-scale professionally managed BFT tilapia farming.

Current Projects at the Food Security Research Institute (FSRI)

Small-scale Nile tilapia (*Oreochromis niloticus*) – freshwater culture

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R 4.1 m (US$ 227,777.78)
Total capital

R 3.7m (US$ 205,555.56)
Capital expenditure (CAPEX)

R 400,000.00 m (US$22,222.22)
Operating capital

100 %
Total capital
R 4.1 m

Production output
13.3 tonnes LW year 1
20 tonnes LW year 2… ∞

Income
R 656,100.00 year 1
R 7,551,000.00 year 2… ∞

Profit
22.1%
R 16.10/kg

10 year economic performance indicators (after-tax)

Selling price
R 72.90/kg as LW

Average cost/kg
R 56.80/kg as LW

10.6 %
Return on Investment (ROI)

8.0 %
Internal Rate of Return (IRR)

1,444,937.52
Salvage Value at end year 10

135 months
Pay-back Period after-tax

14.4 %
Labour-Capital Ratio

R1,850,000.00
Cost per job

R 441,943.19
Net Present value (NPV)

Notes

Small-scale tilapia culture simulation modelling using a highly efficient Biofloc Technology (BFT) approach in the cooler climate of the Western Cape (Vredenburg) would be viable only at selling prices higher than broiler chickens at R72.90/kg.

The chief problem is capital cost expenditure (CAPEX) which runs high at US$10.28/kg above the optimum cost range of US$3.00-4.00/kg annual production capacity a benchmark for cost efficient tilapia culture. The higher CAPEX erodes profitability via depreciation which runs at R12.53/kg of production.

Despite a very detailed and concerted effort at cost savings through design integration, the use of a multi-cohort sequential stocking and harvesting regime and BFT all to no effect due to the higher CAPEX costs to establish a 20 tonne per annum off-grid and solar PV heated production unit.

Selling prices of R72.90/kg would be required to achieve an IRR of 8% equal to the cost of borrowed capital. The simulation study indicated that small-scale tilapia culture would not be viable in the western Cape when priced competitively against broiler chickens at R60.00/kg. Large-scale marine BFT tilapia culture however achieves cost competitiveness against broiler chickens.

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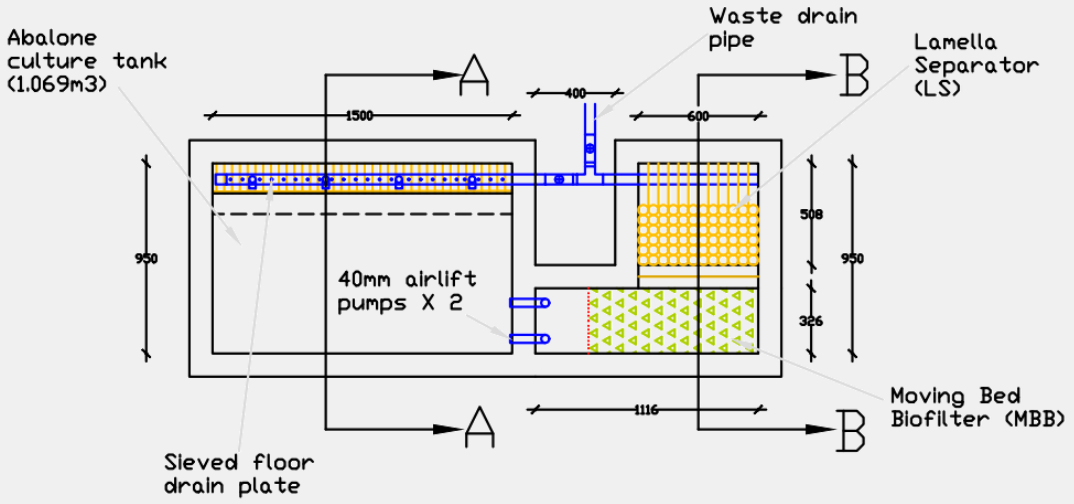
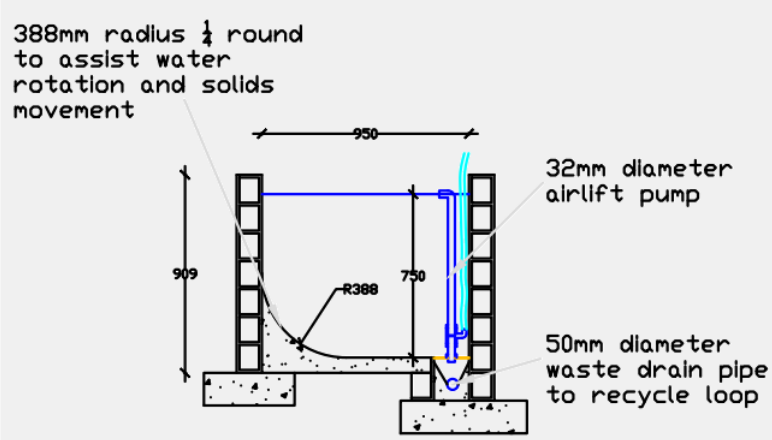
Current Projects at the Food Security Research Institute (FSRI)

Abalone (Perlemoen)





Experimental Abalone culture unit using a Recirculation Aquaculture System (RAS) with varying salinities from 0ppt to 35ppt

The current Abalone farming industry, largely concentrated in the Western Cape Province, faces a number of challenges. The greatest challenge is having to contend with diseases introduced through seawater supply sources and the large volumes of seawater needed, and therefore, the high costs for filtration and disinfection of seawater prior to use to reduce the risks of the introduction of pathogens and parasites.

An answer may be the use of a more complete and efficient Recirculation Aquaculture System (RAS) which allows for salinity manipulation and enables inland Abalone culture. A successful Abalone production trial was conducted by Llewelyn Arendse using hard (Ca and Mg hardness) and alkaline freshwater offering the possibility for freshwater or low-salinity inland Abalone culture.

A small scale experimental Abalone culture unit is about to be built at the FSRI based upon a design concept developed by FSRI staff which allows for infinite control over the most important production variables including salinity, alkalinity, water hardness and self-cleaning culture tanks, opening the door for inland Abalone culture.

Current Projects at the Food Security Research Institute (FSRI)

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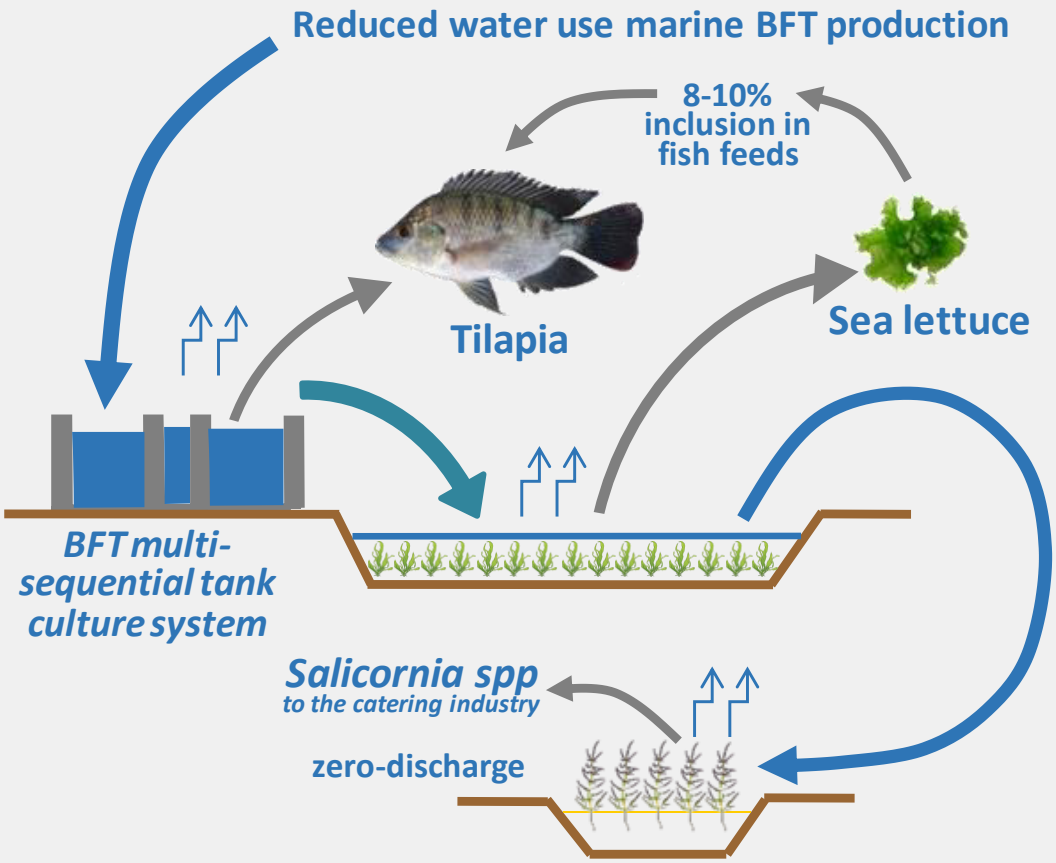
Integrated Multi-Trophic Aquaculture (IMTA)

Land-based marine Biofloc Technology (BFT) tilapia farm linked to sea lettuce paddle ponds and a *Salicornia spp* artificial wetland showing integrated sequential water/waste use for zero effluent discharge and maximum nutrient recovery and re-use or sale

Definition of "Integrated Multi-Trophic Aquaculture (IMTA)"

IMTA provides the by-products, including waste, from one aquatic species as inputs (fertilizers, food) for another. Farmers combine fed aquaculture (e.g., fish) with organic extractive (e.g., sea cucumber, shellfish, shrimp) and inorganic extractive (e.g., seaweed, micro- or macro algae, halophytes) aquaculture to create balanced systems for environment remediation (bio-mitigation), economic stability (improved output, lower cost, product diversification and risk reduction) and social acceptability (better management practices).



LEGEND:

Sequential water flow

Product flow

Evaporation / Evapotranspiration

N - Nitrogen

P - Phosphorus

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Current Projects at the Food Security Research Institute (FSRI)

Ulva spp. Sea lettuce [IMTA options]

***Ulva spp*. also known as sea lettuce are loaded with protein, carbohydrates, good fats and valuable phytogens added to tilapia [and other fish species] feeds at a rate of 8-10% of rations.**

Sea lettuce culture in paddle ponds at an abalone farm in South Africa where yields may approach 260 tonnes/Ha/ year.

Sea lettuce, *Ulva lactuca* included in the IMTA system due to its ease of culture and valuable source of nutrients and phytogens.

Sea lettuce (*Ulva spp.)* are cultivated on the waste stream of fed Abalone culture systems in the Western Cape and are an ideal addition within an *Integrated Multi-Trophic Aquaculture* (IMTA) system to recover waste nutrients which would otherwise be discharged to the environment down to around 30mg/L as nitrates (NO_3_N).

Following solids capture, the remaining dissolved nutrients require to be removed from fed aquaculture waste streams, considered the inorganic extractive component within an IMTA system, as a means to avert eutrophication [nutrient enrichment pollution] of receiving water bodies, including the ocean. The big advantage of sea lettuce is its value as a feedstock commodity for addition to fish, abalone and crustacean feeds, producing a feed cost sparing effect while adding valuable phytogens to aquatic feeds.

Current Projects at the Food Security Research Institute (FSRI)

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Glasswort *Salicornia spp.* [IMTA options}

Salicornia spp. a valuable sea vegetable for the white tablecloth catering industry

***Salicornia spp*, also known as Glasswort, a sea vegetable, desired by the catering industry both locally and abroad.**

***Salicornia spp*. Culture system at Stellenbosch University (courtesy: Henk Stander)**

In Turkey, cooks blanch *Salicornia* and splash it with olive oil and garlic. Koreans dry and grind the plant and blend it with sea salt. Italians tuck the shoots into bowls of pasta; the French do the same when making omelettes and terrines. Across cultures, it's tossed into salads and preserved as a pickle. In modern global cuisine, it's used as a garnish to infuse dishes with a pop of texture and a taste of the sea. Desired by the catering industry both locally and abroad.

Salicorna spp. are used as a secondary 'polishing' nutrient stripping stage allowing for water reuse by reducing nitrates from 30mg/L to < 10mg/L as NO_3_N within an *Integrated Multi-Trophic Aquaculture* (IMTA) system usually following the sea lettuce water treatment stage.

Future Projects at the Food Security Research Institute (FSRI)

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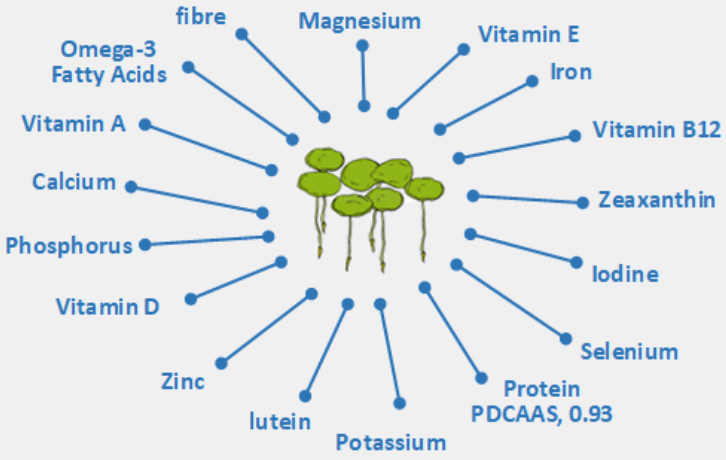
Duckweed (*Lemna spp.*) culture in land-based liner ponds [IMTA options]

Duckweed, also known as water lentils, *Lemna minor* and *Lemna gibba* grown on nutrified freshwater waste streams



***Lemna spp.* grown on nutrified freshwater waste streams offers a valuable aquatic fodder for addition to aquatic feeds for numerous fish species, and has even been assessed for human nutrition**

Lemna duckweed aquaculture systems using liner R-ended ponds with slow moving water presents a highly efficient aquatic food production system within an IMTA based upon the recovery of dissolved nutrients

The Food Security Research Institute (FSRI) will use Duckweed species (also known as water lentils) *Lemna minor* and *Lemna gibba* as a waste valorisation method in an *Integrated Multi-Trophic Aquaculture* (IMTA) system allowing for the re-use of treated water in land-based freshwater aquaculture systems.

Duckweed has been ranked as a complete superfood packed with all nine essential amino acids [up to 42% protein on an air-dried basis] and a host of nutrients meeting the nutrient requirements of ruminants, fish and humans. It's possible to use up to 70% inclusion levels of high protein [>40%] duckweed in complete tilapia rations through the grow-out phase when blended with other feedstock commodities, sparing feed costs.

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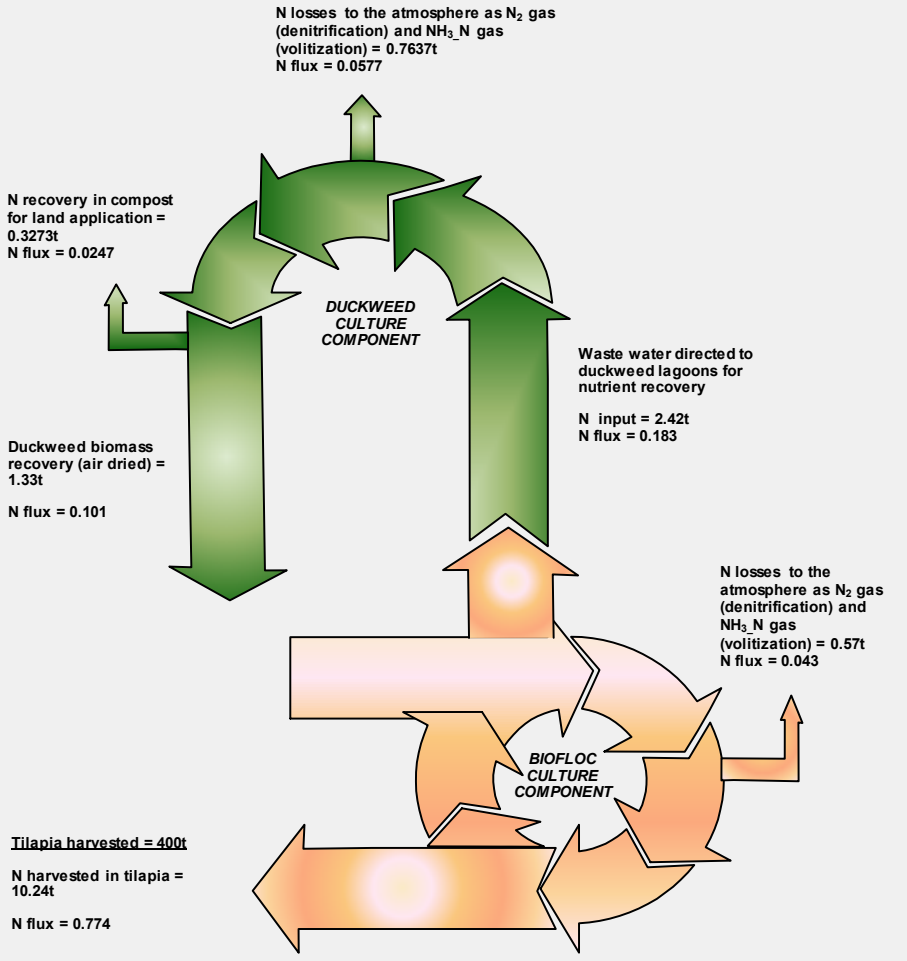
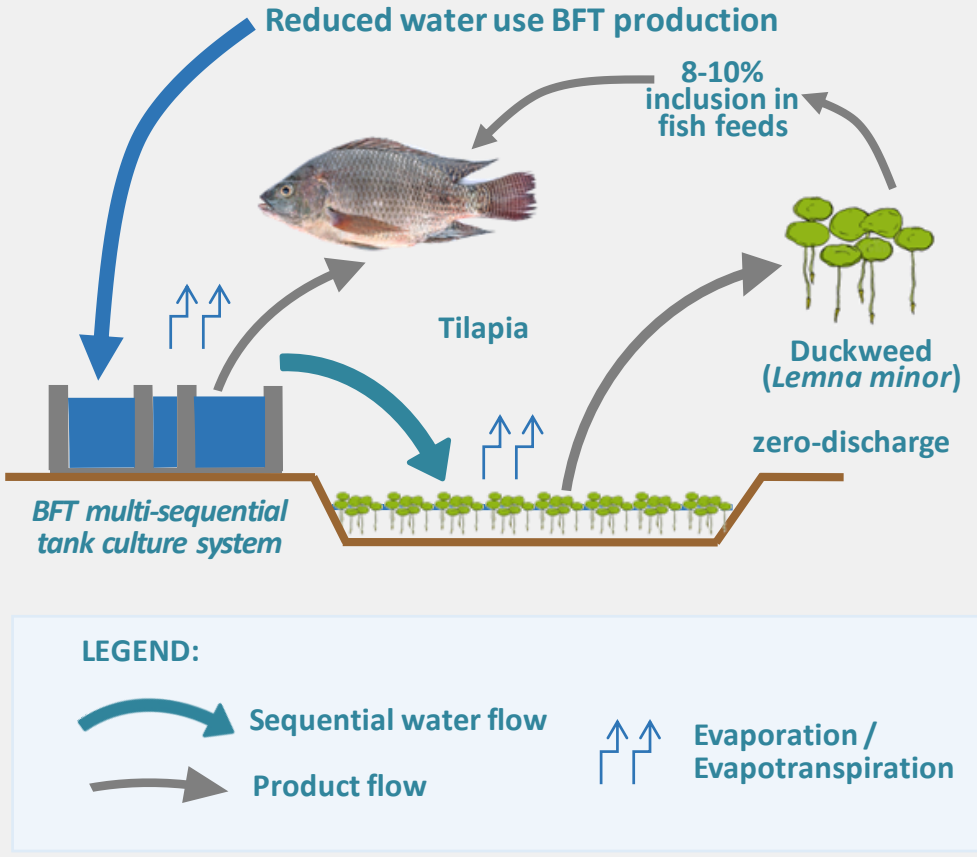
Future Projects at the Food Security Research Institute (FSRI)

IMTA example of Tilapia BFT and Duckweed (*Lemna spp.*) culture

Land-based freshwater Biofloc Technology (BFT) tilapia farm linked to duckweed ponds/lagoons showing integrated sequential water/waste use for zero effluent discharge and nutrient recovery and re-use using a decoupled approach





Nitrogen (N) flux through a tilapia BFT→ Duckweed IMTA system

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Future Projects at the Food Security Research Institute (FSRI)

Rainbow trout (*Oncorhynchus mykiss*)

Rainbow trout production in a Recirculation Aquaculture System (RAS) as a franchise business opportunity.

Rainbow trout is a high value salmonid fish species in high demand in South Africa

RAS technology opens up the opportunity for urban Rainbow trout production as a franchise drive-trough fish farm integrated into an aquaponics unit.

The idea of a drive-through urban Rainbow trout fish farm was conceived in 1996 when Recirculation Aquaculture Systems (RAS) were less mature. Today, it is possible to add an aquaponics component onto a RAS Rainbow trout farm located within an urban environment close to consumers and the market.

The Food Security Research Institute (FSRI) may host the first RAS Rainbow trout production unit and attached aquaponics system to demonstrate the business opportunity, provide proof-of-concept for the business case and will be used for teaching and skills transfer. The objective will be to create a business opportunity through franchising Rainbow trout RAS-hydroponically grown plants, called a decoupled aquaponics approach. Production units could find their way into the parking lost of major shopping malls in South Africa.

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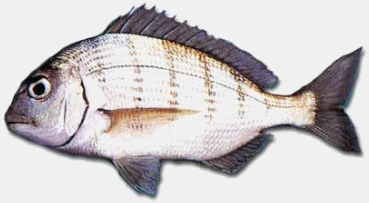
Future Projects at the Food Security Research Institute (FSRI)

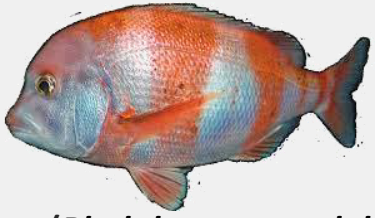
The RAS production of several marine line fish species in South Africa

Several marine linefish species can be produced efficienty in a Recirculation Aquaculture System (RAS) .

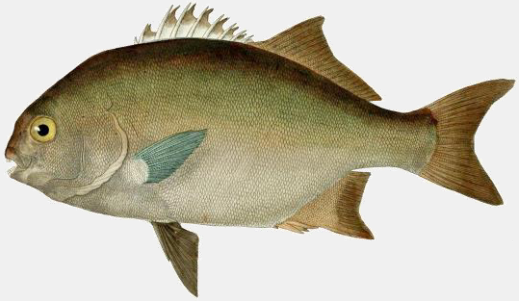
Yellowtail kingfish (*Seriola lalandi*) are popular for their firm, white, slightly oily flesh and medium strong taste. They are highly valued as a sashimi fish but are also excellent grilled or on the braai.

Dusky Kob, also known as Kabeljou (*Argyrosomus japonicus*) are a popular line caught fish **featuring succulent and firm flesh and very few bones, which makes it perfect for home preparation**.





White stumpnose (***Rhabdosargus globiceps***) and Red stumpnose (***Chrysoblephus gibbiceps***) and White steenbras (*Lithognathus lithognathus*) are a both favoured line in South Africa. All three species are on the SASSI Red List and therefore a high demand exists for these species if farmed.



Galjoen (*Dichistius capensis*) is the National Fish of South Africa. "Galjoen" is the Dutch word for "Galleon" a type of large sailboat that was designed to be a cargo ship, with lots of cannons for protection. The WWF South African Sustainable Seafood Initiative (SASSI) lists both Galjoen species as Red - i.e. as a consumer, you should not buy or consume either species of Galjoen purchased in South Africa. A good demand will exist for farmed Galjoen.

FSRI

Future Projects at the Food Security Research Institute (FSRI)

Dusky Kob (*Argyrosomus japonicus*)

The production of several marine linefish species in a Recirculation Aquaculture System (RAS) .

Close-up of Guilthead sea bream in a SAFF-marine RAS in Tartous, Syria in 2009.

RAS technology tailored for several marine linefish species where water velocities are tuned to achieve 25-35cm/sec favouring rapid growth and improved meat texture as well as reduced Feed Conversion Ratio's (FCR).

The Food Security Research Institute (FSRI) may host the first pilot SAFF-RAS tuned and adapted for the grow-out of several marine linefish species to demonstrate the business opportunity, provide proof-of-concept for the business case and will be used for skills transfer and capacity building.

FSRI would then act as an industry incubator to seed and catalyse new blue economy opportunities by demonstrating bespoke and highly integrated RAS systems based upon an efficient and practicable husbandry and stock management philosophy, feeding practices founded on the principles of bioenergetics and sensible engineering economics, all air operated under very low head-losses [< 0.1m, height water is lifted for conveyance and treatment].

Future Projects at the Food Security Research Institute (FSRI)

FSRI

Harders [*Chelon richardsonii*] (Southern mullet) [IMTA options]

Southern mullet or Harders (*Chelon richardsonii*) produced in a Biofloc Technology (BFT) system

Harders (*Chelon richardsonii*) are a delicacy in the Western Cape where they are often dried and sold as Bokoms. A fresh market also exists for Harders particularly specimens above 500g.

Biofloc Technology (BFT) tailored for Harders also known as Southern Mullet enabling reduced feed input costs due to their filter feeding behaviour capable of harvesting biofloc.

The Food Security Research Institute (FSRI) may initiate a project to raise Harders [Southern mullet] in a Biofloc Technology (BFT) system to demonstrate the business opportunity, provide proof-of-concept for the business case and will be used for skills transfer and capacity building.

FSRI would then act as an industry incubator to seed and catalyse new blue economy opportunities by demonstrating bespoke and highly integrated BFT systems based upon an efficient and practicable husbandry and stock management philosophy, feeding practices founded on the principles of bioenergetics and sensible engineering economics, all air operated under reduced feed input costs attributed to the filter-feeding capability of Harders to harvest heterotrophic plankton (also known as biofloc).

FSRI

Future Projects at the Food Security Research Institute (FSRI)

Shrimp species, Pacific White Leg Shrimp and Tiger shrimp [IMTA options]

Pacific White Leg Shrimp (*Penaeus vannamei*) and Tiger shrimp (*Penaeus monodon*) production in a Biofloc Technology (BFT) system

All shrimp, also known as prawns, are imported into South Africa and we currently unaware of a source of fresh shrimp in South Africa. Farmed fresh shrimp would be in high demand especially when supplied competitively against imported framed frozen shrimp.

Biofloc Technology (BFT) tailored for shrimp enabling reduced feed input costs due to their filter feeding behaviour capable of harvesting biofloc as a supplementary natural food source.

The Food Security Research Institute (FSRI) may initiate a project to raise Pacific White Leg Shrimp (*Penaeus vannamei*) and Tiger shrimp (*Penaeus monodon*) in a Biofloc Technology (BFT) system to demonstrate the business opportunity, provide proof-of-concept for the business case and will be used for teaching and skills transfer.

FSRI would then act as an industry incubator to seed and catalyse new blue economy opportunities by demonstrating bespoke and highly integrated BFT shrimp culture systems based upon an efficient and practicable husbandry and stock management philosophy, feeding practices founded on the principles of bioenergetics and sensible engineering economics, all air operated under reduced feed input costs attributed to the filter-feeding mechanisms of shrimp capable of harvesting heterotrophic plankton (also known as biofloc).

FSRI

Future Projects at the Food Security Research Institute (FSRI)

Dulse and related red alga culture in land-based liner ponds [IMTA options]

Dulse (*Palmaria palmata*) and related red alga (*Rhodophyta*) culture in liner ponds with aeration for water tumbling and movement

Dulse (*Palmaria palmata*) cultivated in North America and Asia. Closely related red alga (Rhodophyta) species occur in South African coast waters which can be cultivated using a land-based aeration tumbling system in liner ponds.

Aeration tumbled Dulse (*Palmaria palmata*) cultivation in Hawaii and California, US. Closely related red alga (Rhodophyta) species can be cultivated using similar land-based culture techniques.

The Food Security Research Institute (FSRI) may initiate a project to raise Dulse (*Palmaria palmata*) and/or closely related red alga (Rhodophyta) using an aeration tumbling liner pond system to demonstrate the capability and capacity of Dulse/red alga as a waste valorisation method in *Integrated Multi-Trophic Aquaculture* (IMTA) systems allowing for the re-use of treated water in land-based aquaculture systems.

Dulse's and red alga are edible and nutritious offering good market opportunities internationally specially for high-value dried dulse.

FSRI

Future Projects at the Food Security Research Institute (FSRI)

Sea cucumber species culture in land-based liner ponds [IMTA options]

Sea cucumber species culture with horizontal water movement, self-cleaning and control over the retention time of solids in R-ended liner ponds

Sea cucumber species, particularly the sandfish (Holothuria scabra) are a valuable seafood commodity cherished in Asian markets as a functional food. South Africa coastal waters are home to over 100 species, many of which may be as valuable as the sandfish.

R-ended loner ponds would present excellent hydrodynamics and hydraulics allowing for complete control over the residence time of unwater solids, self-cleaning capability under horizontal water movement and ultimately excellent conditions for sea cucumber production

The Food Security Research Institute (FSRI) may initiate a bioprospecting project to source valuable sea cucumber species for Asian markets and pioneer production systems for the hatchery and grow-out of sea cucumbers using a land-based approach involving R-ended pond liners.

Note that sea cucumbers are an organic extractive species and are capable of scavenging on solid wastes generated by fed fish in an *Integrated Multi-Trophic Aquaculture* (IMTA) systems. As such, sea cucumbers may become a welcome addition into IMTA systems as a waste valorisation method allowing for the re-use of treated water in land-based aquaculture systems.

Se cucumbers are very valuable in Asia in a dried form fetching up to US$1,000/kg air-dried.

FSRI

Future Projects at the Food Security Research Institute (FSRI)

West coast rock lobster culture in land-based liner ponds [IMTA options]

Rock lobster culture with horizontal water movement, self-cleaning and control over the retention time of solids in R-ended liner ponds fitted with "hides" [cut PVC pipe sections]

The West Cape Coast Rock Lobster (*Jasus lalandii*) are a prized seafood commodity cherished in many international markets. The West Cape coast Rock lobster is found along the west Cape coastal waters where all production is wild captured threatening the sustainability of the resource. Farmed west coast Rock Lobster would be a welcomed alternative to the wild captured resource.

R-ended liner ponds would present excellent hydrodynamics and hydraulics allowing for complete control over the residence time of unwanted solids, self-cleaning capability under horizontal water movement and ultimately excellent conditions for Rock lobster nurseries and grow-out ponds. Ponds are fitted with removable "hides" [cut PVC pipe sections].

The Food Security Research Institute (FSRI) may initiate a west coast Rock Lobster culture project including an experiential scale pioneering production system for both the hatchery and grow-out using a land-based approach involving R-ended pond liners. Note that Rock Lobsters are an organic extractive species and are capable of scavenging on solid wastes generated by fed fish in an *Integrated Multi-Trophic Aquaculture* (IMTA) systems. As such, west coast Rock Lobsters may become a welcomed addition as an organic extractive component in a marine IMTA system as a waste valorisation method to allow for the re-use of treated water in land-based aquaculture systems.

The west coast Rock Lobster is considered a premium seafood commodity attracting high prices.

FSRI

Future Projects at the Food Security Research Institute (FSRI)

Bivalve molluscs: oysters, clams, scallops and mussels in deep land-based liner ponds [IMTA options]

Bivalve molluscs culture with horizontal water movement, self-cleaning and control over the retention time of solids in deep R-ended liner ponds

The west Cape coastline is home to a variety of bivalve molluscs which are in high demand in South Africa, and export markets. Incorporated as organic extractive species within an Integrated Multi-Trophic Aquaculture (IMTA) system offers winning benefits for waste valorisation in fed aquaculture species including finfish and abalone.

Deep R-ended liner ponds would present excellent hydrodynamics and hydraulics allowing for complete control over the residence time of unwater solids, self-cleaning capability under horizontal water movement and ultimately excellent conditions for aquaculture production of bivalve molluscs.

The Food Security Research Institute (FSRI) may initiate a bivalve molluscs culture project including an experiential scale pioneering production system for both the hatchery and grow-out west coast bivalve molluscs culture using a land-based approach involving deep R-ended pond liners. Note that oysters, clams, scallops and mussels are an organic extractive species capable of filter feeding on algae and organic particulate matter in the water column within *Integrated Multi-Trophic Aquaculture* (IMTA) systems. As such, bivalve molluscs may become a welcomed addition into IMTA systems as an organic extractive waste valorisation method by improving water quality allowing for the re-use of treated water in land-based aquaculture systems.

Many bivalve molluscs species are considered a premium seafood commodities attracting good sales prices particularly when fresh..

Future Projects at the Food Security Research Institute (FSRI)

FSRI

Marron Freshwater Crayfish culture in land-based liner ponds [IMTA options]

Marron (*Cherax tenuimanus*) culture with horizontal water movement, self-cleaning and control over the retention time of solids in R-ended liner ponds fitted with "hides" [cut PVC pipes]

The Marron (*Cherax tenuimanus*) freshwater crayfish are a prized seafood commodity cherished in many international markets. The West Cape coast Rock lobster is found along the west Cape coastal waters where all production is wild captured threatening the sustainability of the resource. Farmed Marron would be a welcomed alternative to both the wild captured west coast and east coast rock lobster resource.

R-ended liner ponds would present excellent hydrodynamics and hydraulics allowing for complete control over the residence time of unwanted solids, self-cleaning capability under horizontal water movement and ultimately excellent conditions for Marron nurseries and grow-out ponds. Ponds are fitted with removable "hides" [cut PVC pipe sections].

The Food Security Research Institute (FSRI) may initiate a Marron [freshwater crayfish) culture project including an experiential scale pioneering production system for both the hatchery and grow-out west coast Rock Lobsters using a land-based approach involving R-ended pond liners.

Note that Marron are an organic extractive species and are capable of scavenging on solid wastes generated by fed fish in an *Integrated Multi-Trophic Aquaculture* (IMTA) system. As such, Marron may become a welcomed addition into freshwater IMTA systems as an organic extractive waste valorisation method allowing for the re-use of treated water in land-based aquaculture systems.

Marron are considered a premium seafood commodity attracting high prices particularly for live or fresh product.

FSRI

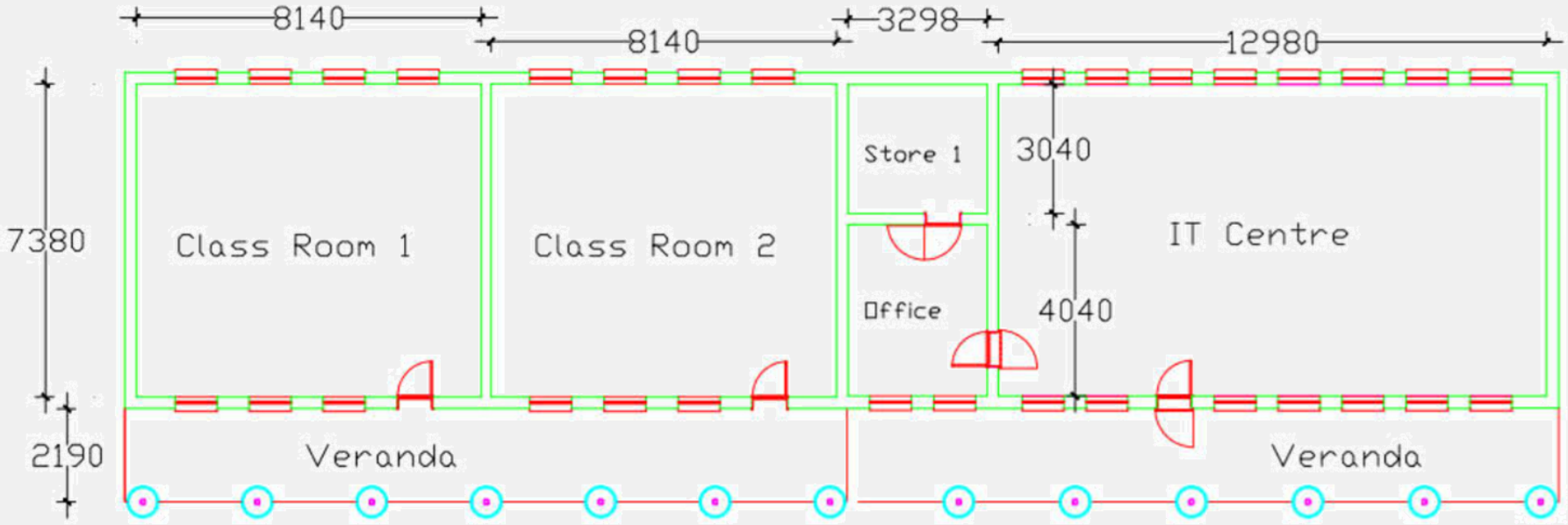
Future Projects at the Food Security Research Institute (FSRI)

Human Resource Development Centre: Skills transfer and capacity building

Skills transfer and capacity building is an important component of the Food Security Research Institute (FSR)

The Food Security Research Institute (FSRI) aims to build a Human Resource Development Centre (HRDC) targeting certificate courses for the aquaculture industry in South Africa and abroad. This objective will occur over time and in phases.

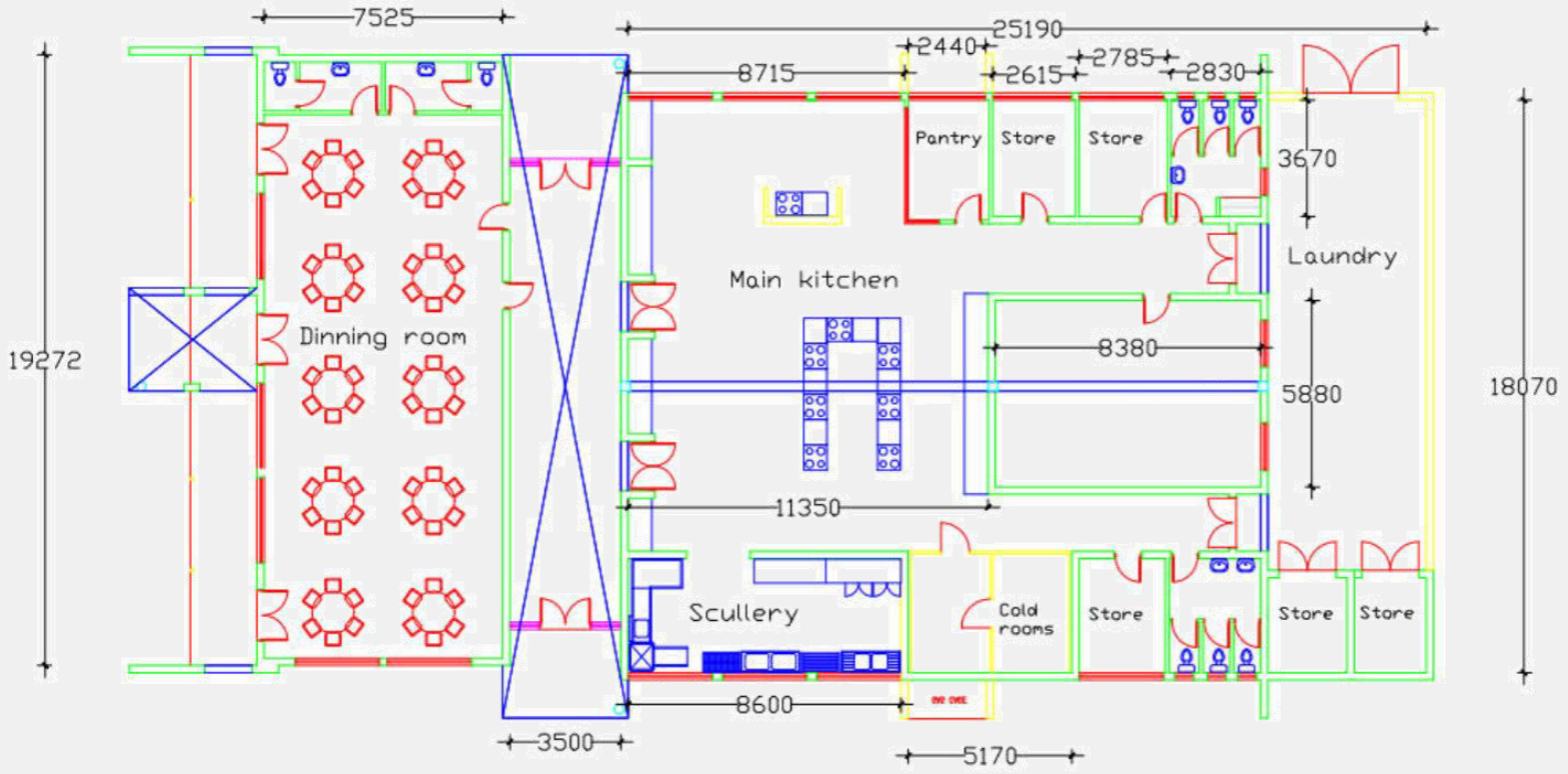
The final phase will include two class rooms or auditoriums, and an Information Technology (IT) Centre, as well as a mess (shown overleaf) and student accommodation (4-sleeper rondavel on-suite, shown overleaf).



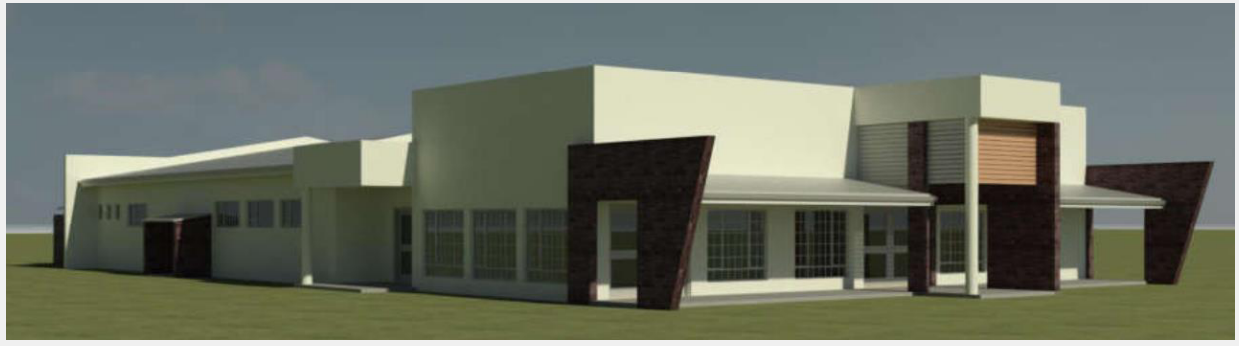
Floor plan of the fully developed Human Resource Development Centre (HRDC) showing two class rooms or auditoriums, and an Information Technology (IT) Centre

Future Projects at the Food Security Research Institute (FSRI)

Human Resource Development Centre: Skills transfer and capacity building



Floor plan of the fully developed mess (above) and computer rendered impression (below left) and 4-sleepr *en suite* student accommodation rondavel (below right)



Jean-Pierre (JP) von Hage, CEO

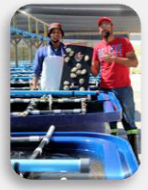
First a commercial fisherman on the high seas now turned fish farmer. JP launched the first Biofloc Technology (BFT) tilapia farm in South Africa at the Big Green Organic Fish Farm near Vredenburg, of the west Cape coast.

JP built the first R-ended BFT tank including hooded airlift aerators for tilapia culture in seawater and ran trials using the technology to conclude the first experimental scale marine tilapia BFT system at the Big Green Organic Fish Farm.

Based on hands-on experience building a BFT tilapia farm and converting the same farm to produce Mozambique tilapia (Oreochromis mossambicus) in saline water. JP is convinced that a land-based approach to tilapia farming in seawater presents the answer to South Africa's food insecurity problems and that marine tilapia can be produced at a cost lower than broiler chickens.

JP takes charge of day-to-day operations to lead daily management activities and the various programmes and projects being undertaken at the FSRI by fulfilling the role as the CEO.

Llewellyn Arendse, marine shellfish expert



As the son of a fisherman, Llewellyn was raised amid the sea-faring community and industrious factory worker of St Helenabay. At the age of sixteen, he began working in the bustling canneries during school holidays. By the time he turned twenty-two, he had joined the permanent staff of the largest sardine cannery in southern-Africa. Remarkably, at just twenty-five, he became the youngest individual to manage an entire shift, overseeing both production workers and quality assurance personnel.

In 2006, equipped with expertise in food processing and a keen understanding of advanced food safety, Llewellyn joined a team of aquaculturists at an abalone farm on the west-coast. By the end of 2007 he had advanced to the role of production manager. Over the past eighteen years, Llewellyn has become a distinguished figure in aquaculture, specializing in abalone grow-out and particularly excelling in the field of nutrition. During his time at the farm, the company has expanded its reach by acquiring additional aquaculture businesses, and the operations he managed have experienced a remarkable threefold growth increase.

However, not everything went smoothly. As early as 2011, Llewellyn became acutely aware of the ocean's changing conditions and the detrimental effects they were having on the water chemistry of the farm. Parasites and diseases began to proliferate, yet his reports were dismissed as instances of "poor husbandry". Determined to save the farm, Llewellyn embarked on a mission to address these challenges. For the past decade, he has meticulously replicated the results of his experiments, making small yet crucial adjustments to the conditions in which abalone are nurtured, as well as to their feeding practices. These efforts resulted in healthier, more resilient abalone better equipped to withstand disease and parasites. Notably, Llewellyn became the first abalone farmer to produce abalone in RAS and successfully treated seawater to control alkalinity levels- an important factor, as higher alkalinity directly impacts shellfish health.

Llewellyn brings to the FSRI his concern for the environment and offers his extensive knowledge of land-based aquaculture, mass abalone production and food safety. Lewellyn adds hands-on and astute management practices in both production and processing operations to the FSRI.

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Ramon M. Kourie, research contributor

Ramon Kourie formally the Chief Technical Officer (CTO) of SustAqua Fish Farms (Pty) Ltd. (SAFF) a registered company in South Africa, and formally the CTO of THAPI Aqua-Kulcha. Ramon has a reputation of excellence in the field of aquaculture technology through his masterful skills at the *science-engineering interface*. Ramon has 38 years of experience in the aquaculture sector both in the Middle East and Africa where he has overcome cost barriers in low-energy, air-driven freshwater and marine Recirculated Aquaculture Systems (RAS) as well as aquaponics and Biofloc Technology (BFT) farms (see photo collection to the left).

Driven by a passion for the conservation of the world's natural resources, the environment and food safety, Ramon has pioneered low cost RAS in both controlled environments and quasi-natural systems. He has developed new aquaponics, duckweed and biofloc tank culture technologies involving nutrient, energy and protein recovery loops. These technologies have special relevance today as emphasis needs to be placed on biosecure, energy and land/water conservative aquaculture practices to advance *sustainable intensification* in the sector. Ramon has written bioenergetic models for all the major tilapia farming systems in use in the world today (there are 16) including Biofloc Technology (BFT) systems at Chambo Fisheries developed by SAFF. He has also developed simple cost saving moist pellet milling technologies for on-site fish feed manufacture tuned for a variety of sustainable aquaculture systems.

Ramon has contributed a wealth of his past research work and blueprints on the development of both marine tilapia and Atlantic salmon farming industries, from pilot to full-scale production, from his past involvement in the sector at no cost to the FSRI.