The sustainable intensification of marine tilapia aquaculture for food security in South Africa

Marine Cultivated Tilapia

Working to achieve;

SDG 2:
End hunger, achieve food security and improved nutrition and promote sustainable agriculture [and aquaculture]

SDG 14:
Healthy oceans for food security, nutrition and resilient communities [via substitution, reduced capture fisheries pressure]

Marine Tilapia Aquaculture Project, west Cape coast, South Africa

Advancing a scalable, sustainable, affordable and inclusive marine tilapia fish farming industry for the production of affordable fish protein on the West Cape coast of South Africa

Project Introduction

August 2024

FSRI

Historical development of the Marine Tilapia Aquaculture Industry vision.

1) Declared one of the priority projects in the *Eastern Cape Provincial Oceans Economy Masterplan* launched in March 2020 by the Minister of Department of Environment Fisheries and Forestry and in turn by the Eastern Cape MEC for Rural Development; also contained in the MEC Policy Speech 2020/21.
2) At the time THAPI Aqua-Kulcha, a local BBBEE company, along with provincial development partners, the *Eastern Cape Rural Development Agency* (ECRDA), led a successful submission to the *Sustainable Infrastructure Development Symposium* (SIDS) selection process at the Presidency resulting in the gazetting of the *Marine Tilapia Aquaculture Vision 2035* as *Sustainable Infrastructure Project* 23 or abbreviated as SIP 23 project.
3) Fumbled at a provincial level in the Eastern Cape Province the project saw a period of dormancy which still exists today. The marine tilapia vision has been clearly articulated in the June 2022 issue of the *World Aquaculture* magazine (a *World Aquaculture Society* (WAS) publication (see overleaf).

4) As the lead visionary and originator of the vision Ramon Kourie, voluntarily donated the blueprints, developed during 2017-March 2022 for the *Marine Tilapia Vision 2035,* to the *Food Security Research Institute (FSRI)* to continue with the mission to support the marine tilapia industry from pilot to full-scale production through seeding and catalytic interventions.
5) Note that the Food Security Research Institute (FSRI) is a private sector led Non-Profit Company (NPC) founded specifically to bridge the missing gap between fundamental research and the need to demonstrate technical & commercial viability of marine and freshwater commercial aquaculture opportunities in the oceans economy space.
6) The prime 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.

7) FSRI is the only institution to carry the flag with a definitive plan and strategy to bring a more affordable marine cultivated fish species alternative to scale, and of comparable quality and palatability, to that of Cape hake to tackle food insecurity in South Africa.

Articulation of the Marine Tilapia vision originally located on the eastern seaboard of South Africa published in the June 2022 issue of the *World Aquaculture* magazine (a *World Aquaculture Society* publication), pages 27-32, now relocated to the Western cape Province.

Marine Tilapia — South Africa's New Affordable Whitefish Alternative

R. Kourie and N. Dladla

FIGURE 1. *A 3D generated architectural impression of the Mbhashe Marine Tilapia Industry Incubator (MbMTII) earmarked to produce 2,000 t of seawater-farmed Mozambique tilapia annually.*

FIGURE 2. *Mozambique tilapia* Oreochromis mossambicus *harvested from a large-scale Biofloc Technology farming system in Malawi.*

Despite a significant annual Cape hake quota that fluctuates from around 100-140 thousand t/yr in South Africa, fish has become increasingly unaffordable for most food insecure households (THAPI Aqua-Kulcha 2021a). Wholesale prices of Cape hake, South Africa's most favoured fish and chips choice, have climbed in recent years to above R45/kg (R15 = US$1) on a whole-weight basis. Similarly, retail prices of tinned pilchards, a national favourite food basket item, have climbed above R60/kg on a drained weight basis, putting food insecure households increasingly at risk of not being able to acquire adequate omega-3 fatty acids in their diets.

Building on a concept vision sourced from private innovators — THAPI Aqua-Kulcha — identified through an open call for expressions of interest in 2019, the Eastern Cape Rural Development Agency (ECRDA) has taken the lead to address this undesirable fish supply situation by taking aim at an ambitious project to domesticate the local Mozambique tilapia *Oreochromis mossambicus* species for seawater culture in a project called the Marine Tilapia Industry (MTI).

Over and above the MTI project being a response to a hake market that will grow more constraining in affordability, along with the threat of diminishing ocean stocks from marine catches, this project aims to take advantage of the natural bounty that is the endowment of South Africa's temperate seaboard stretching along the coastline of the Eastern Cape and KwaZulu-Natal provinces.

The ambition is to establish and develop a veritable value chain for an industry that is intended to grow to a scale of 100,000 t of marine cultivated tilapia by 2035 (THAPI Aqua-Kulcha 2021b). The growth trajectory maps the course of an industry that will start with the establishment of a Marine Tilapia Industry Incubator in Mbhashe (MbMTII) as the base for growing a range of commercial clusters along the coastline of the Eastern Cape and KwaZulu-Natal over the years.

Mbhashe MarineTilapia Industry Incubator (MbMTII)

The MbMTII will be situated at the Mbhashe Local Municipality coastline with a clear set of seeding and catalytic output objectives, including improved genetic lines of pure breeds of Mozambique tilapia and an ongoing human resource development program to feed into the commercial growth phases to follow.

Why Tilapia and why Mozambique Tilapia in Particular?

Mozambique tilapia are indigenous to the east coast territory of the Eastern Cape and KwaZulu-Natal and as such the commercialization of marine tilapia aquaculture poses no biodiversity risks to endemic fish fauna. Mozambique tilapia are a low trophic level species with a highly efficient digestive system capable of good growth on animal-free, all-plant based feeds, therefore contributing to the alleviation of food insecurity due also to their low-cost production.

Mozambique tilapia grow 1.66-2 times faster in seawater than they do in freshwater (Howerton *et al*. 1992, Kuwaye *et al*. 1993, Ron *et al*. 1995, Shepard *et al*. 1997, Sparks *et al*. 2002). Palatability of tilapia is improved when grown in seawater, on par with the best line fish, offering improved meat texture and flavour properties and therefore greater marketability. Sold as a marine fish, seawater-farmed Mozambique tilapia overcomes market biases favouring the consumption of marine fish in South Africa (Head *et al*. 1994, Infofish 2003, Fraga *et al*. 2015, Cheng *et al*. 2019, Cheng *et al*. 2020)

(CONTINUED ON PAGE 28)

1. What is Marine Tilapia? And why is it important for national food security in South Africa?

Problem statement 1: The year 2006 marked a shift in pricing when broiler chicken meat became the least cost source an animal protein in South Africa taking the crown from capture based fisheries where prior Cape hake (and marine capture based fisheries) was the least cost animal protein source.

Fish has always played a central role in the diets of the poor in South Africa prior to 2006 when Cape hake and fish in general was the least cost animal protein source in South Africa. The price of Cape hake became uncompetitive against terrestrially produced meat proteins over the period 2006/07 which marked the transition point when broiler chickens became the least cost meat protein in South Africa. Given present and future pricing scenario's Cape hake has little merit as an affordable alternative meat protein targeting food insecure households in rural and urban South Africa from a cost perspective. A 2021 study (Kourie, 2021) revealed that marine capture fisheries, and in particular the MSC certified Cape hake catch and tinned pilchards, have retrospectively seen year-on-year (y-o-y) price inflation of 9.5% (over 2010-2019) and 7.9% y-o-y (2005-2020) respectively somewhat higher than the 2005-2020 CPI of 5.28%

What is Marine Tilapia and why is it important for national food security in South Africa?

Marine Tilapia is pure Mozambique tilapia (*O. mossambicus*) grown in seawater

Specific growth rate: 12g fingerlings grown to 240g in 147 days achieving a SGR of 1.55g day^{-1} at 27°C in seawater (35ppt) [Thermal Growth Coefficient (TGC) = 1.25/1000)]

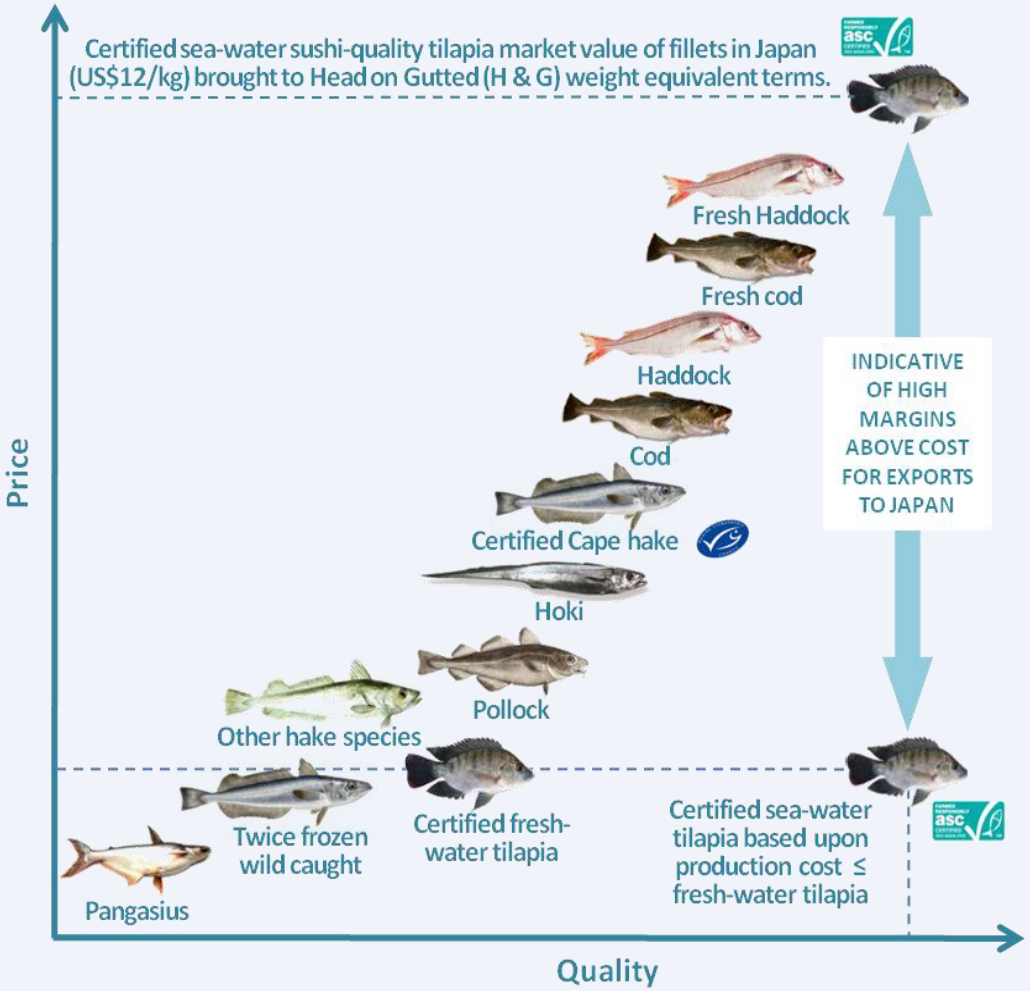
(Indigenous farmed strain, largely unimproved)

(Source data: FSRI, Vredenburg, experimental saline BFT tank culture unit, 2023/24)

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 due to elevated levels of Free Amino Acids (FAA) including umami and sweet amino acids** (Head et al., 1994; Infofish, 2003; Fraga et al., 2015; Cheng et al., 2019; Cheng et al., 2020)
- ✓ **They use feed fed more efficiently in seawater** (Barreto-Curiel *et al*., 2015; Ron *et al*., 1995; Moorman *et al*., 2016; Iwama *et al*. 1997)
- ✓ **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 indicative of market value and acceptance** – In Japan marine cultivated sushi quality, *izumidai,* or Taiwanese seawater grown 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).
- ✓ **Affordably priced, cheaper than chicken, in South Africa at < R50.00/kg (US$2.50/kg) at retail –** detailed costing studies indicate potential selling prices to a first receiver of R40.00-R44.00/kg (US$2.20-2.40/kg) for Head-on-Gutted (HoG) fish given scale- and scope economies.
- ✓ **Low Trophic Level species, contribute to food security; highly efficient digestive system, low-cost production**

Marine cultivated Mozambique tilapia is a more marketable alternative to freshwater grown tilapia [valued higher, leveraged for market acceptance and market share, rather than exports] and would make for an excellent fish choice to replace increasingly unaffordable Cape hake in South Africa



Perceived quality versus prices for the most common global whitefish species from Geldenhys (2013) and Lallemand *et al.* (2014). Aquaculture Stewardship Council (ASC) certified Marine Tilapia (*izumidai,* sushi-quality) and Marine Stewardship Council (MSC) certified hoki were added above based upon their market value.

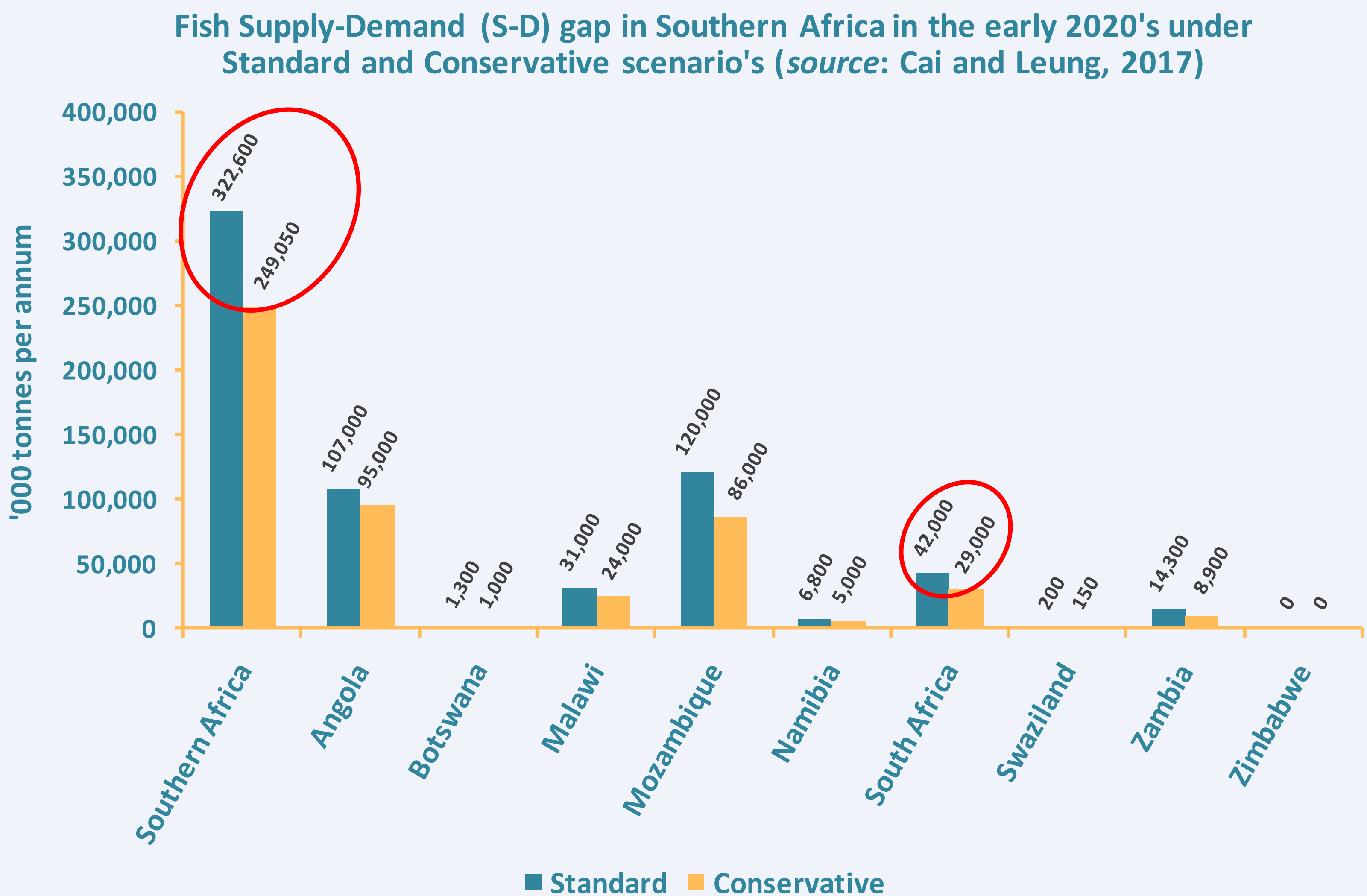
Why do Mozambique tilapia taste far better when raised in seawater?

Did you know that Mozambique tilapia (*Oreochromis mossambicus*) exhibit greatly improved flavour quality when grown in saline (salty) water on par with the best line-fish South African coastal waters have to offer?

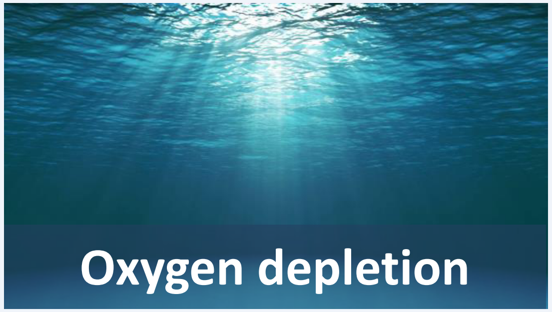
The reasons for this are related to changes in metabolism in saline water and the role sweet amino acids play in osmoregulation. According to Yang *et al*. (2019), the taste characteristics of Free Amino Acids (FAA) is what gives meats the savoury or umami flavour (Asp and Glu), or bitterness (Arg, Ile, Leu, Met, Phe, His, and Val) and/or sweetness (Ala, Thr, Gly, and Ser) tastes. Asp and Glu are important components of the umami taste, which gives meat its characteristic taste and increases the intensity of other flavours at the same time (Jinap and Hajeb, 2010). The higher Alanine (Ala) content in marine fish is mainly caused by salinity. Previous research indicated that Alanine (Ala) acts as an important organic osmolyte (Abe *et al.*, 2005; Li *et al*., 2009). Similarly, the higher levels of sweet amino acids (Ala, Thr, Gly, and Ser) and umami amino acids (Asp and Glu) found in marine fish over freshwater fish is the reason why markets prefer marine over freshwater fish. The quality of seawater farmed tilapia improves flavour and texture properties so much so that seawater farmed tilapia have been ranked higher in terms of palatability and marketability in Japan than cod and haddock (INFOFISH, 2003), ranked number 1 and 2 in the whitefish category of fishes (Kourie, 2022). In Puerto Rico seawater farmed red tilapia were ranked as highly as the nations most favoured marine line-fish, Silk snapper, *Lutjunus vivunus* (Head *et al.*, 1994).

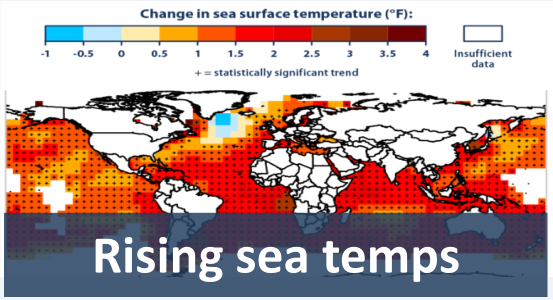
Problem Statement 2: South Africa's [and the southern African region's] food fish security and food sovereignty is at risk

Why? Scientists predict a seafood Supply-Demand gap of 29,000 to 42,000 tonnes per annum in South Africa and 249,000 to 322,000 tonnes for the southern African region by the early 2020's.



Problem Statement 3: Diminishing local marine capture fisheries, and higher costs of seafood, puts food fish security and food sovereignty at risk in South Africa (and southern Africa). Some scientists predict the complete collapse of global fisheries by 2048 (Worm, 2016)





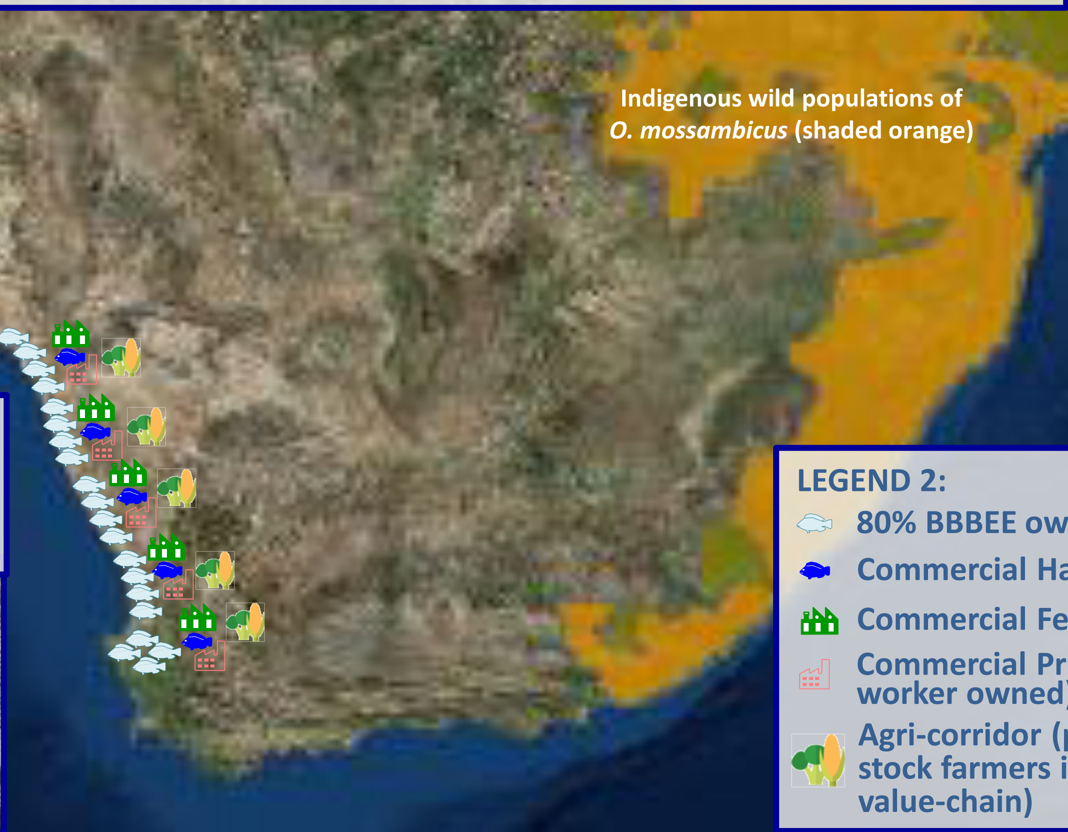
Since the 1950's some 50% of all marine life has been lost (Dryden and Duncan, 2022). Many fish species in South African coastal waters are Red Data Book listed and may no longer be traded e.g. White stumpnose, Red stumpnose, White steenbras, Galjoen etc. Cape hake catches are also impacted where South African west Cape coast capture volumes have been unable to match quotas in recent years.

The Solution to unaffordable and depressed availability of wild captured fish protein in South Africa (problem statements 1, 2 and 3) is the Marine Tilapia Vision 2035 – *A Marine Aquaculture Economy for All*

An Inclusive, Sustainable Marine Tilapia Industry for the rural West Cape coast, Western Cape, South Africa targeting 100,000 tonnes of tilapia per annum by 2035 (at Phase 7 of the development)

LEGEND 1:

Phase 1 - 125 tonnes Marine Tilapia Industry Incubator (MTII) at the FSRI
Phase 2 - 5,000 tonnes (full grow-out farm) and expansion of the hatchery at the FSRI
Phase 3 - 20,000 tonnes (1 cluster = 4 grow-out farms, plus 3 on Phase 2, to make 1 cluster)
Phase 4 - 40,000 tonnes (2 clusters, additional cluster on Phase 3)
Phase 5 - 60,000 tonnes (3 clusters, additional cluster on Phase 4)
Phase 6 – 80,000 tonnes (4 clusters, additional cluster on Phase 5)
Phase 7 – 100,000 tonnes (5 clusters, additional cluster on Phase 6)
(tonnes = tonnes per year)



The Mozambique tilapia (*Oreochromis mossambicus*) South Africa's indigenous genetic resource (shaded orange)

Marine Tilapia ONE BRAND Marketing

- Management control
- Quality control
- Traceability
- Certification
- Attains scale & scope economies
- Specialization benefits
- Production cost: < US$1.23/kg (R22.13/kg) at the farm gate (grow-out, per full cluster in the cooler W. Cape)
- Strong backward linkages to regenerative feedstock commodity farmers
- Lower environmental emissions
- >80% ownership of grow-out entities, and worker ownership throughout the value chain to create the ultimate Broad Based Black Economic Empowerment (BBBEE) business model.

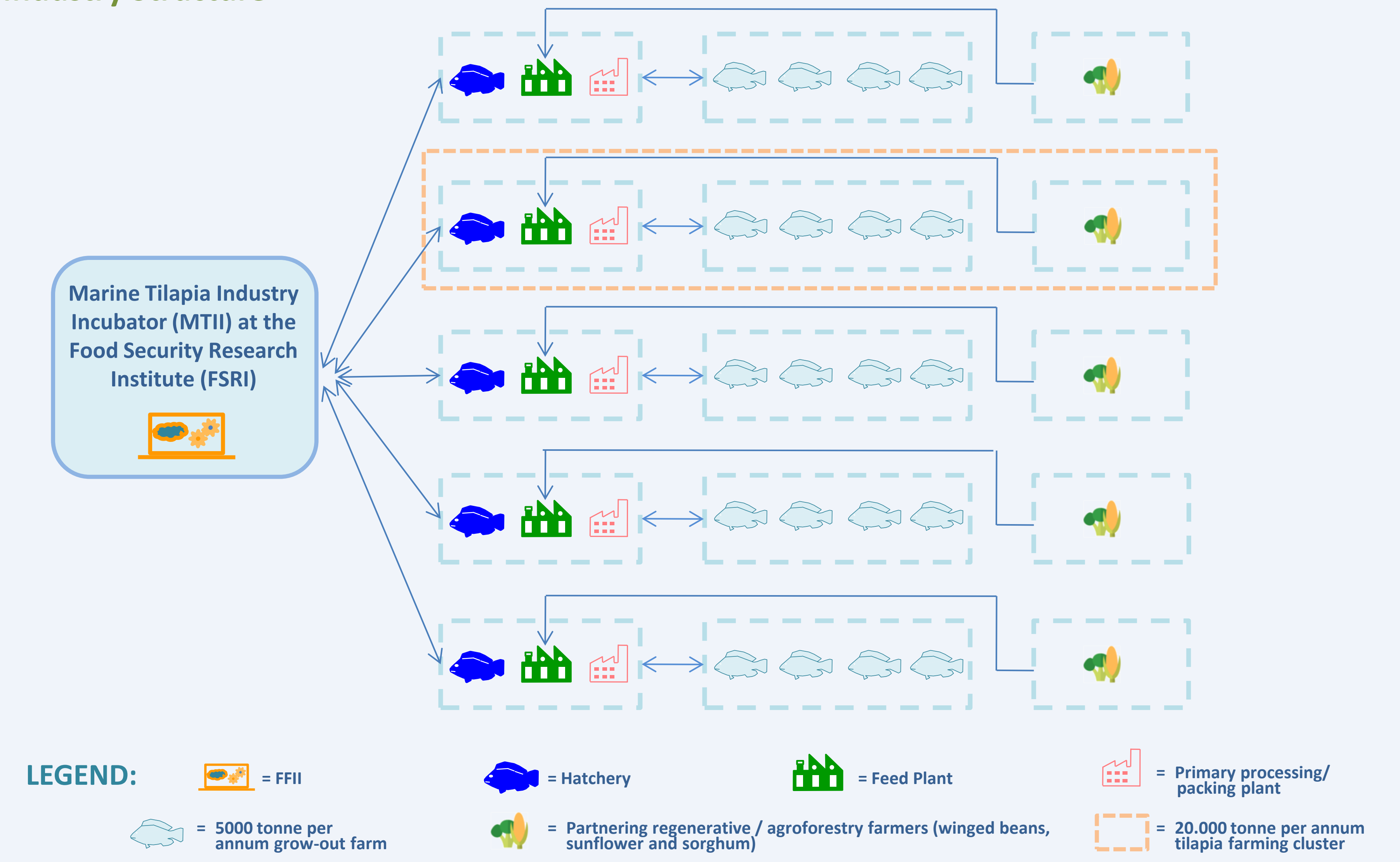
LEGEND 2:

- 80% BBBEE ownership 5000tpa grow-out farm
- Commercial Hatchery (70% worker owned)
- Commercial Feed Plant (70% worker owned)
- Commercial Primary Processing Plant (70% worker owned)
- Agri-corridor (partnering regenerative feed-stock farmers included in the Marine Tilapia value-chain)

Marine Tilapia Industry Structure up to Phase 7 (x5 Clusters producing 20,000 tonnes per annum each)

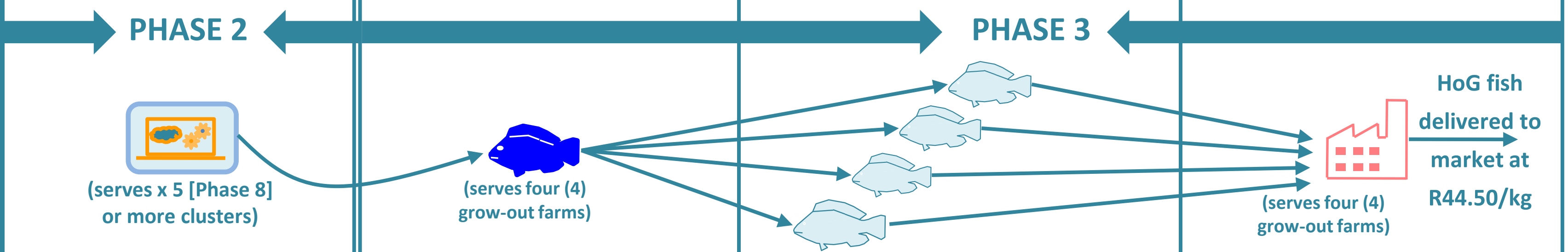
The *Marine Tilapia Industry Incubator (MTII)* at the FSRI acts as a seeding and catalytic project as well as a central management and oversight nerve centre, provides the HR pipeline, improved gene lines, quality control, traceability, laboratory services, etc. to five (5) clusters each producing 20,000 tonnes of tilapia per annum as live weight at Phase 8 to reach 100,000 tonnes by 2035 for the total replacement of the Cape hake quota (100,000-140,000 tonnes per annum)

Industry Structure



Marine Tilapia Industry Economics at Phase 3: 20,000 tonnes per annum (1/5 of the Cape hake quota) for a single cluster of five clusters planned.

Single cluster producing 20,000 tonnes cost competitively against both broiler chickens and Cape hake in South Africa in June 2024



	Marine Tilapia Industry Incubator (MTII) at the FSRI	Hatchery [built-in feed plant]	4 X 5000 tonne per annum grow-out farms [built-in feed plant]	Primary processing/ packing plant
FARM DIVISION WITHIN A CLUSTER and CAPEX and OPEX	CAPEX: R22m OPEX: R3m	CAPEX: R200m OPEX: R35m	CAPEX: R275m (x4 farms) OPEX: R30m (x4 farms)	CAPEX: R75m OPEX: R80m
PRODUCT FLOW AND PRICE	Improved gene lines of parent seedstock at R 75/fish sold every 2 years to commercial hatcheries, surplus sold as foodfish at R60.00/kg LW in years 1 to 3, and R35.00/kg in year 4 onwards.	4.1g fry stocking material sold to grow-out farms at R0.19/each (serves x 4 grow-out farms)	240g Live Weight (LW) marine cultivated tilapia sold to the Primary Processing Plant at R35.00/kg LW	216g Head-on-Gutted (HoG) marine cultivated tilapia delivered and sold to markets [Cape Town] year-round at R44.50/kg HoG (serves x 4 grow-out farms)
ECONOMICS BY ASSOCIATED PRODUCT FLOW AND PRICE WITHIN A FARM CLUSTER	ROI : 16.3% IRR : 8.3% SV : R 9,647,208.66 NPV : R 4,098,278.35 PBPat : 120 months L/C ratio : 23.2% Unit cost : R 30.41/kg LW Unit selling price: R 60.00/kg Unit profit : R 29.59.05/kg LW EBITDA : R4.4m (ave. 10yr)	ROI : 26.5% IRR : 17.1% SV : R 129,484,587.95 NPV : R 223,388,690.68 PBPat : 64 months L/C ratio : 5.9% Unit cost : R 0.08/fish Unit selling price : R0.19/fish Unit profit : R0.10/fish EBITDA : R80.1m (ave. 10yr)	ROI : 24.5% IRR : 17.8% SV : R116,278,519.72 NPV : R 197,952,833.03 PBPat : 75 months L/C ratio : 5.1% Unit cost : R 27.15/kg LW Unit selling price : R 35.00/kg LW Unit profit : R 7.85/kg LW EBITDA : R81.6m (ave. 10yr)	ROI : 44% IRR : 31.4% SV : R 16,255,231.75 NPV : R 152,759,982.37 PBPat : 56 months L/C ratio : 4.6% Unit cost : R 42.29/kg HoG Unit selling price: R44.50/kg HoG Unit profit : R 2.21/kg HoG EBITDA : R47.8m (ave. 10yr)
LEGEND	ROI = 10 year Return on Investment, % IRR = Internal Rate of Return, %	SV = 10 year Salvage Value, R NPV = Net Present Value at year 10, R	PBPat = Pay-back-Period after tax, months L/C ratio = Labour : Capital ratio at year 10, %	

Marine Tilapia can be raised at half the food cost to raise broiler chickens per unit of edible meat yield, and herein lies the advantage of the Marine Tilapia Vision 2035 based upon Biofloc Technology (BFT) using seawater

Biofloc Technology (BFT) tilapia feeds for fish in the size range >5g -300g are quite close in specification and cost to poultry broiler rations (19-20% protein) in South Africa anticipated to cost of around US$ 472.93/tonne (t) (R8,750/t) for broilers and US$ 486.49/t (R9,000/t; June 2024 at scale) for BFT farmed tilapia based upon an exchange rate of R18.50= US$1.00.

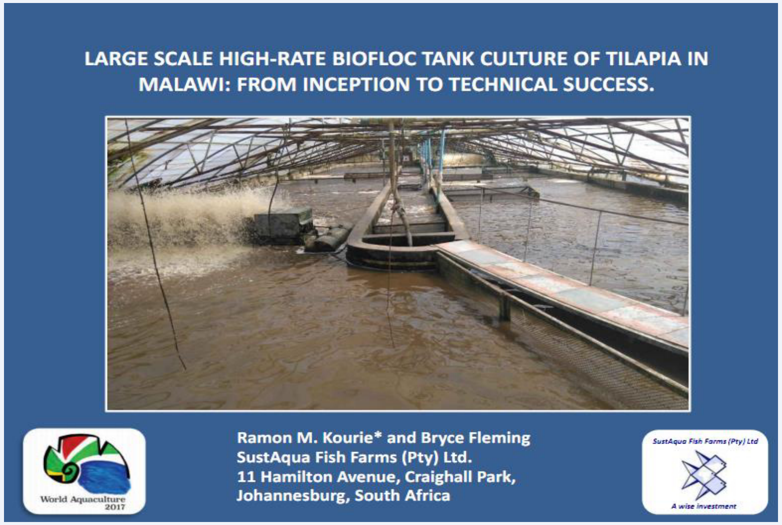
How does BFT and RAS/ Cage/ Pond grown tilapia compare to a broiler chicken production metrics, 1) in terms of feed use, 2) nutrient recovery efficiency and 3) feed cost per unit of edible meat yield? [calculated on R18.50=US$1.00]

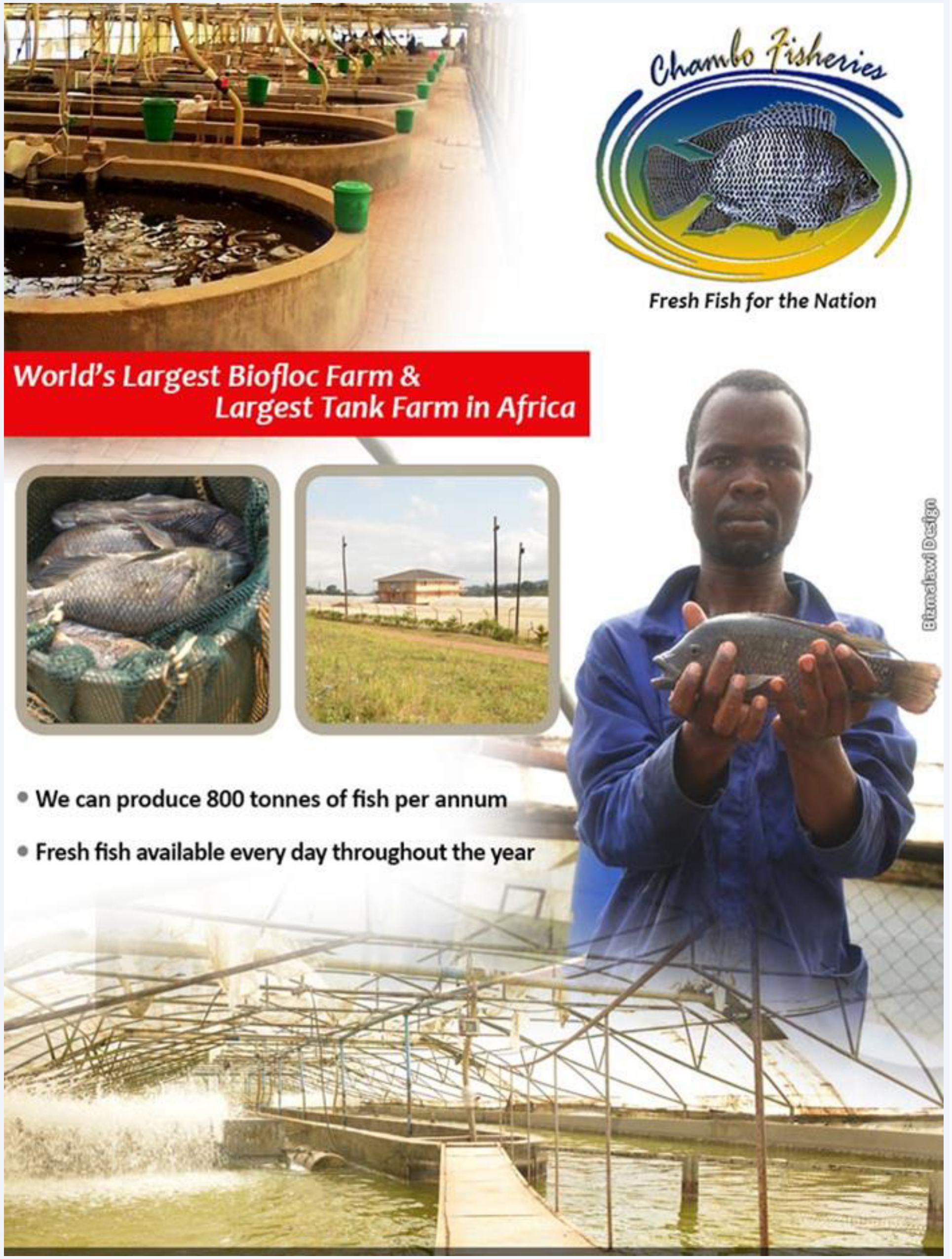
Comparative feed use, nutrient recovery efficiency and feed cost per unit of edible meat yield in BFT and RAS/Pond grown tilapia vs. broiler chickens	RAS/Pond/Cage grown tilapia (500g fish, 30% protein feed, GE 16MJ/kg)	Seawater BFT grown tilapia (500g fish, 20.2% protein feed, GE 16MJ/kg)	Broiler chicken
Feed Conversion Ratio (FCR) =	1.4 : 1.0	1.0 : 1.0	1.79 : 1.0
Net Protein Recovery, %/edible yield =	20.5%	45.6%	21%
Net Energy Recovery, %/edible yield =	20.0%	28.0%	10%
Edible meat yield, % (500g fish) =	57.6%	57.6%	46.1%
Feed cost, US$/tonne (ZAR/t)=	US$ 864.86/t (R16,000/t)	US$ 486.49/t (R9,000/t)	US$ 472.93/t (R8,750/t)
Feed cost, US$/kg (ZAR/kg) edible meat yield =	US$ 2.10/kg (R 38.89/kg)	US$ 0.84/kg (R 15.63/kg)	US$ 1.83/kg (R33.98/kg)

Note: Edible meat yield in tilapias is not the same as the fillet yield. Edible meat yield includes skins and all edible portions (see Sahu *et al*., 2017)

The Marine Tilapia Pilot Operation (MTPO) to benefit from proven large-scale Biofloc Technology (BFT) in Malawi in 2015-2017.

- World leading indigenous Biofloc Technology (BFT) developed by FSRI staff with 38 years experience in Malawi/ Zimbabwe/ Mozambique/ Zambia, and the Middle-East. See Chambo Fisheries in Malawi from inception to technical success presentation delivered at WAS 2017 Cape Town (below, advert to the right).
- Committed to growing human capabilities through applied training of community of aquaculture specialists, esp. youth at the FSRI. Skills development through the value-chain from raw material commodity supply to logistics and distribution
- Committed to clean eco-friendly production and related technologies – production process is biosecure, chemical and antibiotic free, hormone free. Farms produce zero discharge where consumptive water use < 100L/kg of fish produced.
- Resource use efficient and low-cost production of around US$1.00-1.10/kg as Live Weight (LW) at the farm gate *in the tropics*. Technology scalability; grow-out farms can produce up to 5,000 tonnes per annum, 250 tonnes per grow-out tank, 20 tanks per grow-out farm.





Filter-feeding tilapia and Biofloc Technology (BFT) in concert: the perfect feed-cost sparing fit

Biofloc Technology (BFT) is a sustainable and environmentally-friendly method of aquaculture which controls water quality and harmful pathogens along with the value-added production of microbial protein feed for the aquatic farm system. The use of microorganisms as a direct food source for fish and crustaceans [Dissolved C + N → C + N in microbes → C + N in farmed organisms] is recognized as the shortest, cheapest, and most sustainable way to produce food for humanity (Martínez-Córdova *et al.*, 2016).

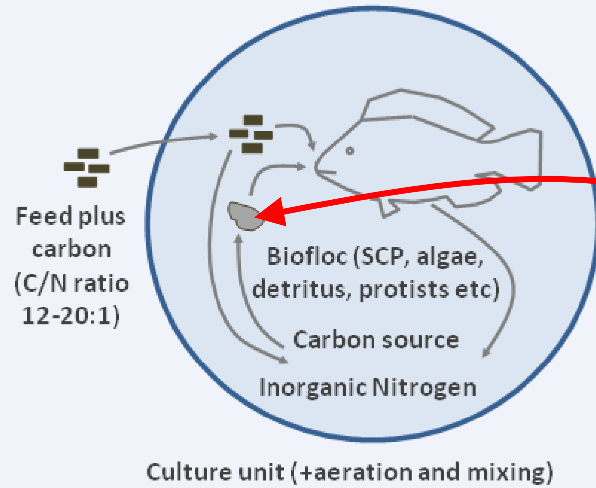
Biofloc Technology (BFT) produces large quantities of protein rich microbial floc (free-food) also called "heterotrophic plankton" which tilapias are well equipped to harvest via their apt filter-feeding mechanisms thus significantly sparing feed costs.

Feed Conversion Ratio's (FCR's) of 1 : 1 were routinely achieved at Chambo Fisheries over 2015-2016 when the farm was under professional management following the use of practical bioenergetic feeding rate models and 20.2% protein feeds comparable to broiler rations in specification.

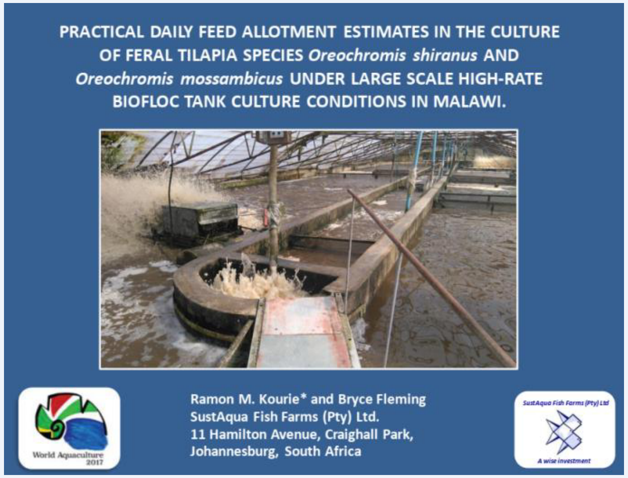
Comparative performance metrics

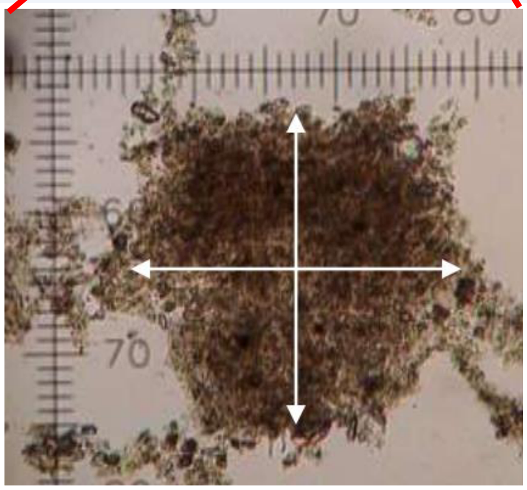
100% more efficient when gauged against Net Protein Retention (NPR) of tilapia raised in a RAS system and 162% more efficient than lake cage culture.

Anticipated break-even production costs are around US$1.00-1.10/kg (live weight) at the farm gate for 20 large-scale BFT grow-out tanks producing 5,000 tonnes per annum, four in a cluster = 20,000 tonnes by 2035 and five clusters = 100,000 tonnes per annum *in the tropics*.



The SAFF feeding philosophy, inventory results and auditing system presented at WAS 2017 in Cape Town.





Novel know-how and experience developed by FSRI staff (2013-2017) at Chambo Fisheries the worlds largest and first professionally engineered BFT tilapia tank farm in Malawi

Imhoff Cones used to measure the volume of biofloc in the water column at Chambo Fisheries four times daily.

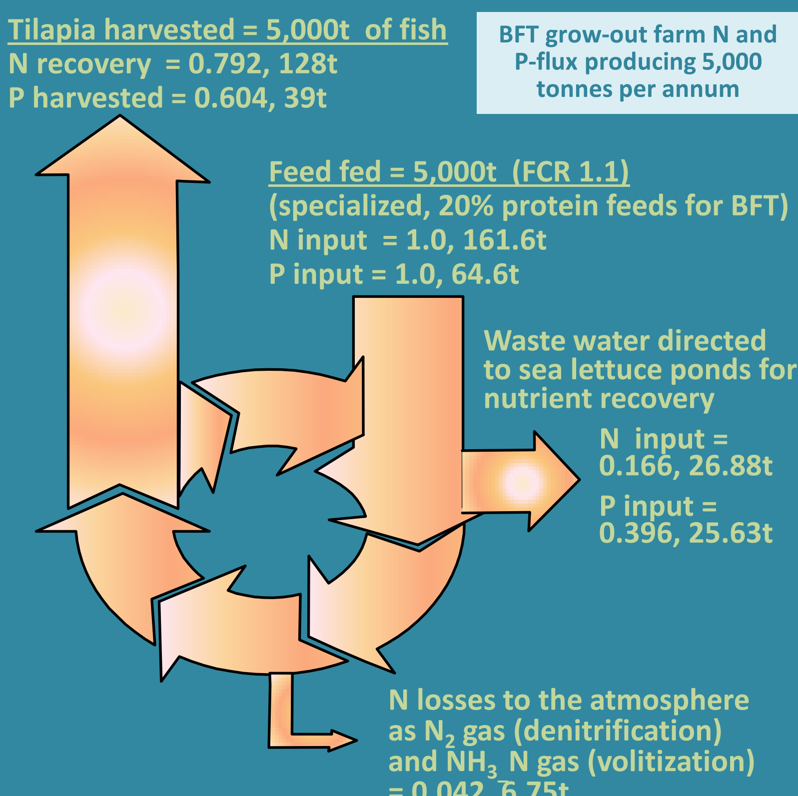
Controlled environment artificial incubation facility at Chambo Fisheries

766,000 Litre 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.*

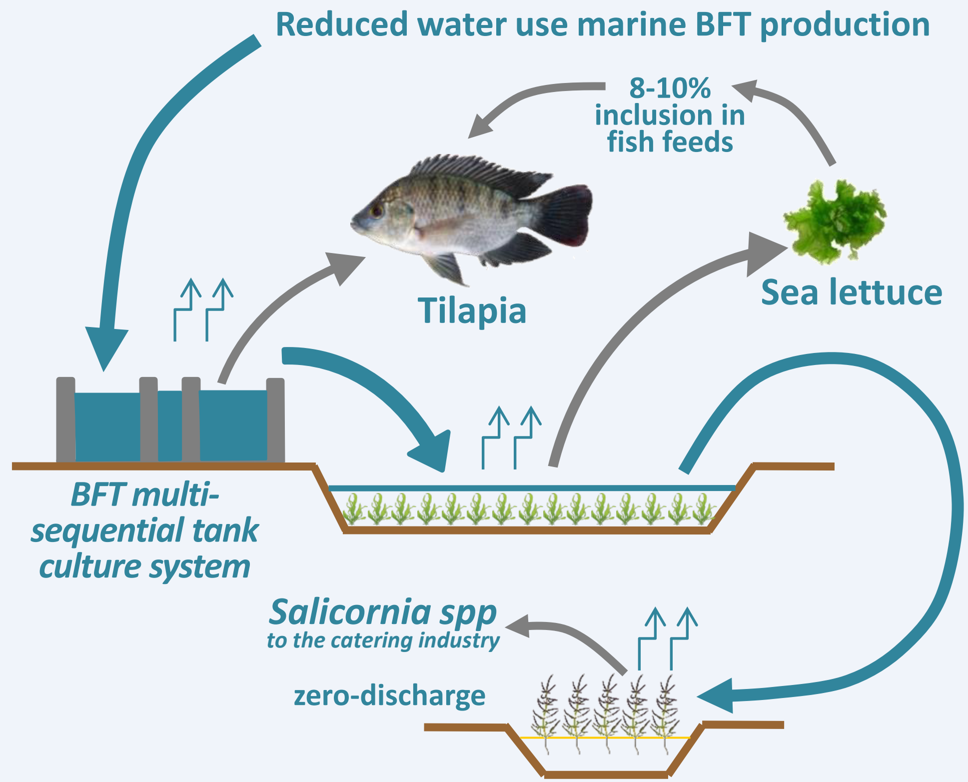
Nursery rearing R-ended greenwater tanks at Chambo Fisheries

Marine Tilapia Vision 2035 - The sustainable intensification of marine tilapia aquaculture for food security in South Africa

- Zero effluent and zero emissions to recipient water bodies, maximum nutrient recovery and reuse.
- Use of feral *O. mossambicus* pure breeds.
- Raised Without Hormones (RWH) – high density culture (>13kg/m³) suppresses reproduction
- Raised Without Antibiotics (RWA) – biosecure BFT negates the need for disease treatment protocols
- Input (fed)-Output (recovered in harvested fish) Nitrogen recovery >70% due to nutrient recycling through *heterotrophic plankton* and sea lettuce.



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



LEGEND:

Sequential water flow

Product flow

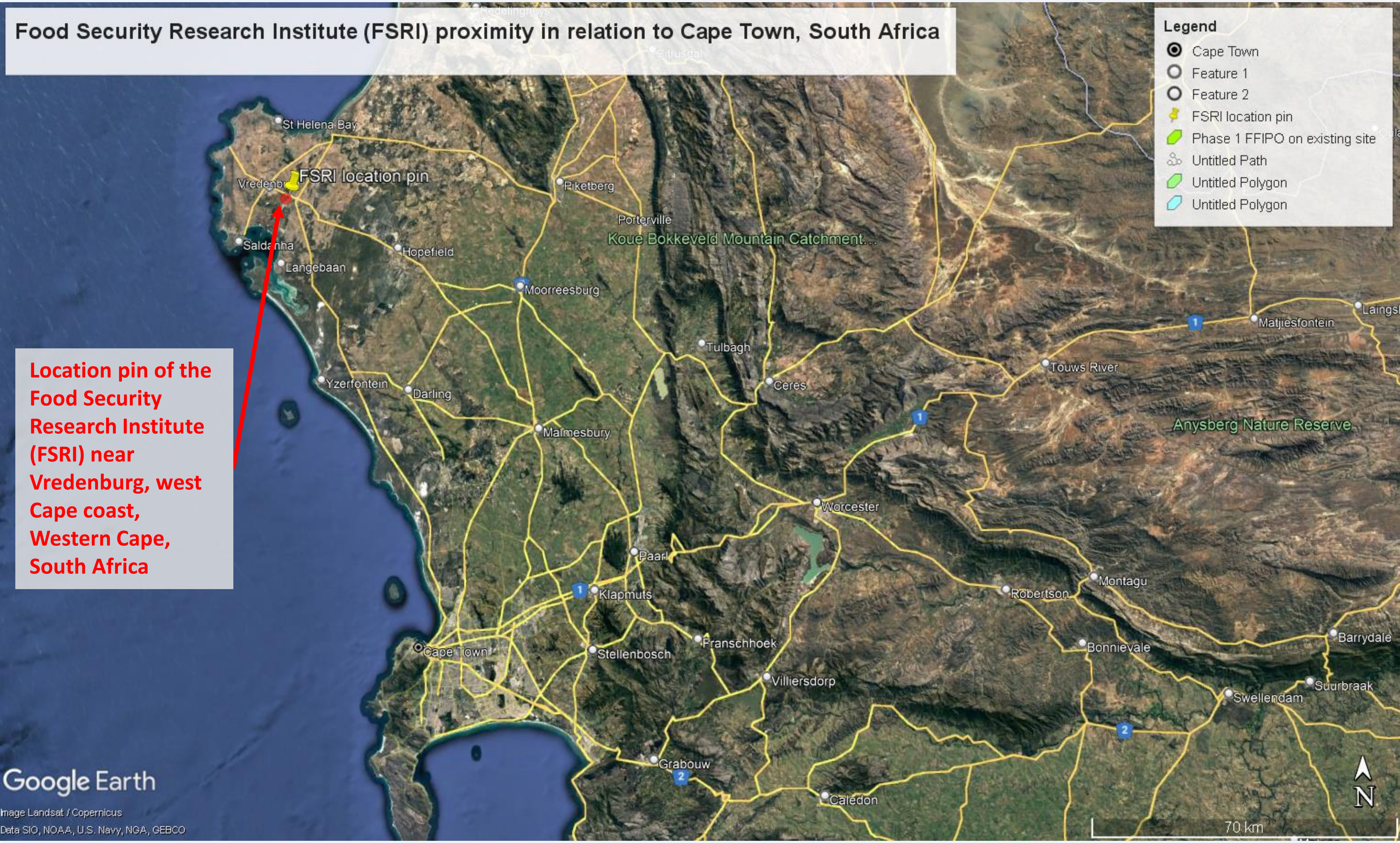
Evaporation / Evapotranspiration

N - Nitrogen

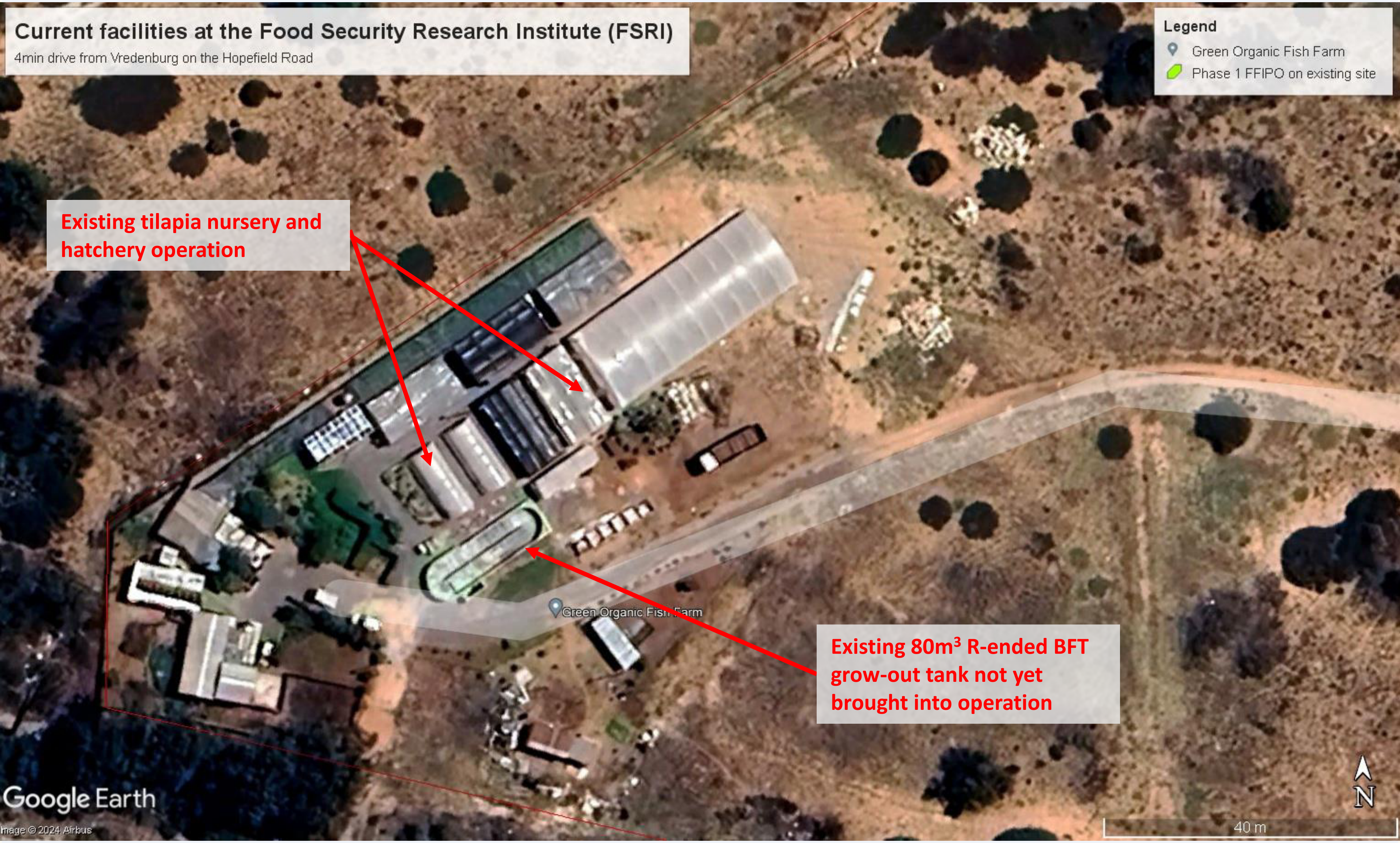
P - Phosphorus

Where will the Marine Tilapia Pilot Operation (MTPO) be located ?

At the Food Security Research Institute (FSRI) located close to Vredenburg, west Cape coast, South Africa



Google Earth birds-eye view of the location of the Food Security Research Institute (FSRI) and hosting location for the Marine Tilapia Industry Incubator (MTII) [Phase 1] near Vredenburg, west Cape coast, Western Cape, South Africa

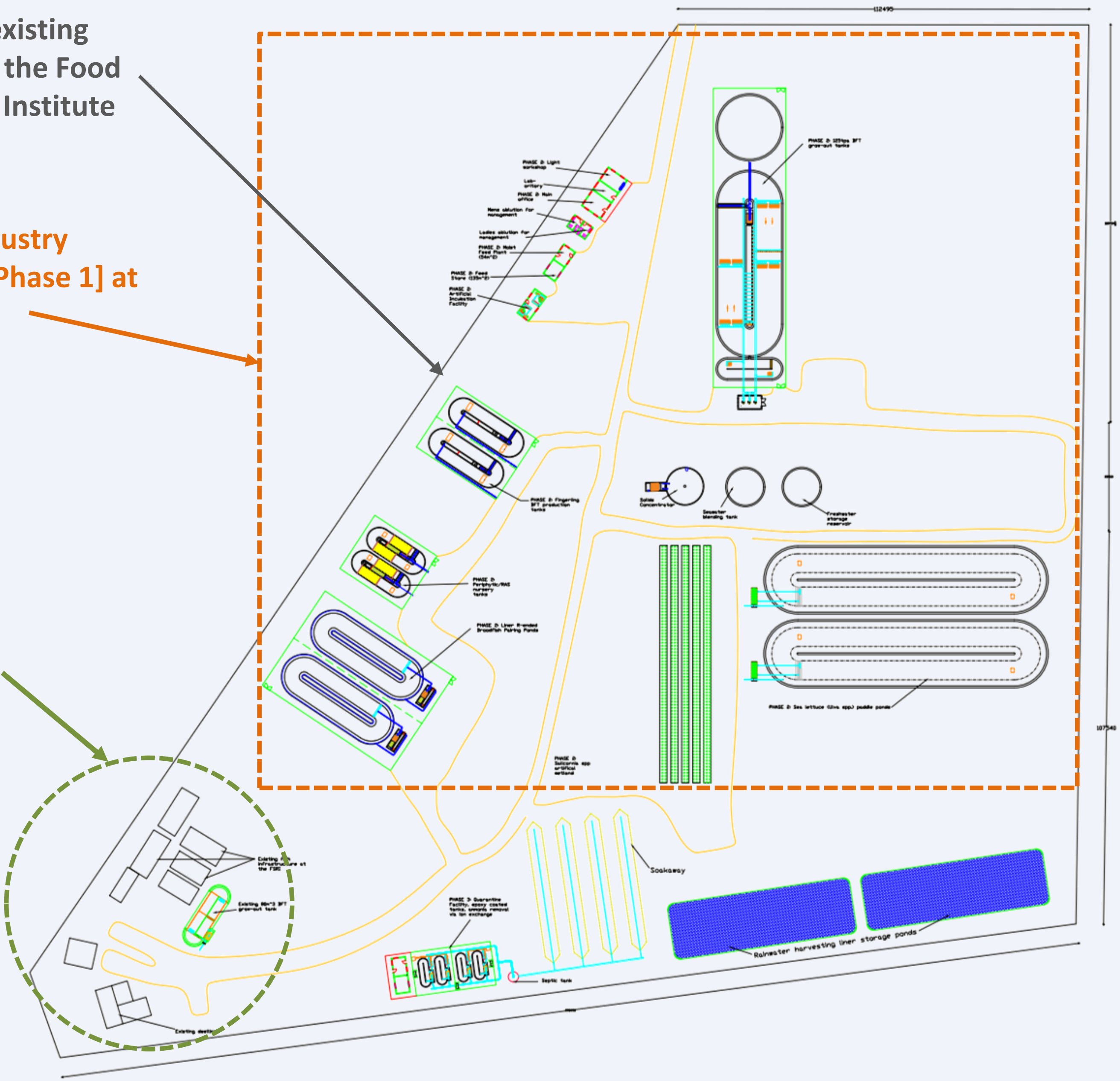


Schematic of Phase 1 the Marine Tilapia Industry Incubator (MTII) on the existing *Food Security Research Institute* (FSRI) site near Vredenburg, west Cape coast, Western Cape, South Africa

Perimeter of the existing 5.7Ha farm site at the Food Security Research Institute (FSRI)

Marine Tilapia Industry Incubator (MTII) [Phase 1] at the FSRI

Existing FSRI infrastructure



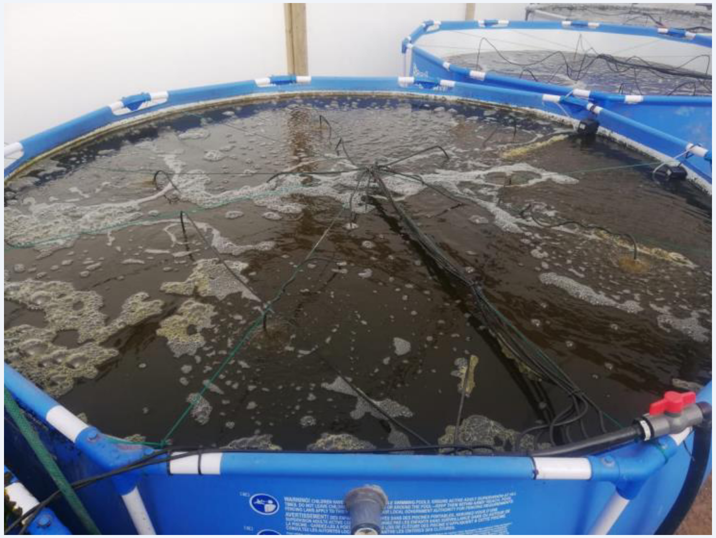
Successful post experimental stage marine tilapia production facilities at the *Food Security Research Institute* (FSRI) ready for scale-up to furnish industry support deliverables.

Food Security Research Institute (FSRI) entrance

New fingerling 6.5m^3 BFT tank

Operational Fingerling 12m^3 BFT tank

New multi-cohort sequential 80m^3 BFT grow-out tank (visible from the Google Earth birds-eye view)

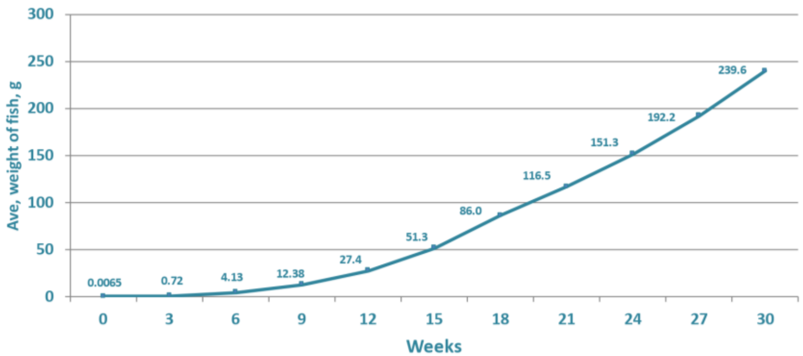


Operational multi-purpose 5.4m^3 BFT round tanks at the FSRI

Conclusions to the post experimental stage marine tilapia production facilities at the Food Security Research Institute (FSRI)

- *O. mossambicus* grew faster in moving water at 20-30cm/sec in the 12m^3 R-ended tank in saline water at 35‰ (full-strength seawater) than did freshwater reared fish in circular tanks.

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



- 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 (see insert to the right).
- 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 of 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) at the Food Security Research Institute (FSRI) will provide definitive roadmap for the scale-up of the *Marine Tilapia Vison 2035* to follow to support the first cluster of grow-out farms with improved gene lines of Mozambique tilapia for seawater culture targeting 20,000 tonnes of production [one cluster] at Phase 3.

The mandatory need for on-farm made C/N ratio aquafeeds for the Marine Tilapia Pilot Operation (MTPO) enabling the production of optimized feed formulations tuned for low-cost BFT tilapia aquaculture yielding lower Feed Conversion Ratio's (FCR's) following the use of the same equipment and protocols developed at Chambo Fisheries BFT farm in Malawi

Moist feed milling technology for low-cost on-site formulated feed manufacture from first feeding fish to biofloc C/N ratio feeds (15.5:1) for grow-out at Chambo Fisheries.

Combination built-in ribbon mixer, grinder and moist pelletizer operated at 27-32% mash moisture content

Standard hammer mill with interchangeable screens (1.5mm, 2mm, 3mm, 4mm and 5mm)

Forced convection dried to 10% moisture (±2%) using a standard horizontal dryer (*or on smaller scale operations the use of a solar drier*) before mechanized crumbling using a hammer mill (sieves 3- 5mm) and manual or shaking table sieving

3-5mm interchangeable sieves on hammer mill serves as an effective crumbling plant

Manual grading sieves;
Starter 1 - < 300 µm
Starter 2 - 300 – 600 µm
Starter Crumble 1 - 600 - 900 µm
Starter Crumble 2 - 900 - 1200 µm
Starter Crumble 3 -1200 to 1500 µm
Starter Crumble 4 – 1500- 2000 µm
and 2mm sieve for fines removal from pellets; 1.5mm, 2mm, 3mm, 4mm and 5mm in diameter

Pre-cooked ingredients; soy O/C, sunflower O/C, duckweed and uncooked maize fine rendered using a 2mm diameter screen in the hammer mill before being mixed with all the other ingredients and additives in the combination mixer, grinder and moist feed pelletizer.

Graded crumble and pellets ready for use as feed for nursery rearing and biofloc RAS grow-out fish

BAGGED and STORED for use within a week

Capital cost (CAPEX) Summary for a 125tpa Marine Tilapia Industry Incubator (MTII) at Phase 1						
Item	Quantity	Units	Rate ZAR/unit	Cost ZAR	Useful life Years	Depreciation ZAR
Construction						
Office/store	0	*n*	471,750.00	0.00	20	0.00
Feed plant room and feed store (temporary steel building structure)	1	*n*	240,000.00	240,000.00	20	12,000.00
Quarantine facility	0	*n*	850,000.00	0.00	20	0.00
Broodfish Pairing Pond (BPP)	2	*n*	180,000.00	360,000.00	20	18,000.00
Greenhouse enclosure and cladding [BPP, 31m X 42m]	1	*n*	651,000.00	651,000.00	15	43,400.00
Periphytic/RAS nursery tanks	2	*n*	210,000.00	420,000.00	20	21,000.00
Greenhouse enclosure and cladding [Periphytic nursery, 17.5m X 20m]	1	*n*	175,000.00	175,000.00	15	11,666.67
Fingerling BFT tank	2	*n*	326,250.00	652,500.00	20	32,625.00
Greenhouse enclosure and cladding [Fingerling BFT]	1	*n*	260,520.00	260,520.00	15	17,368.00
Hatchery building	1	*n*	216,000.00	216,000.00	20	10,800.00
Grow-out tank (GOT) and purging tank (PT)	1	*n*	1,255,556.85	1,255,556.85	20	62,777.84
Greenhouse enclosure and cladding (GOT and PT) [20mx82m]	1	*n*	820,000.00	820,000.00	15	54,666.67
In-tank piping, valves and fittings	1	*n*	90,000.00	90,000.00	15	6,000.00
Lamella Separator	1	*n*	219,715.55	219,715.55	15	14,647.70
Sluice (ex-Denmark) [I will estimate]	1	*n*	60,000.00	60,000.00	15	4,000.00
Air-supply line [all, set]	1	*n*	475,213.43	475,213.43	15	31,680.90
Airlift water pumps (central channel/main tank)	1	*n*	120,000.00	120,000.00	15	8,000.00
Built-in floor heat exchanger (all, HE)	1	*n*	520,052.08	520,052.08	15	34,670.14
Piping, valves and fittings (heat exchanger/HP/HE) [all, set]	1	*n*	88,541.67	88,541.67	15	5,902.78
Floor plate drains (purging tank, main tank) [set]	1	*n*	25,000.00	25,000.00	15	1,666.67
Blower room	1	*n*	184,450.00	184,450.00	20	9,222.50
Thermal Storage Reservoir (2, TSR)	1	*n*	451,037.88	451,037.88	20	22,551.89
Water supply plumbing [all, set]	1	*n*	160,000.00	160,000.00	15	10,666.67
Other, grow-out (all, set)	1	*n*	250,000.00	250,000.00	15	16,666.67
Sea lettuce liner ponds	2	*n*	150,000.00	300,000.00	15	20,000.00
Salicornia contsucted wetland	1	*n*	300,000.00	300,000.00	15	20,000.00
Fencing and security gate	1	*n*	525,000.00	525,000.00	20	26,250.00
TOTAL CONSTUCTION COST				**8,819,587.46**		
Depreciation						**516,230.09**

Capital cost (CAPEX) Summary for a 125tpa Marine Tilapia Industry Incubator (MTII) at Phase 1 (cont.)						
Item	Quantity	Units	Rate ZAR/unit	Cost ZAR	Useful life Years	Depreciation ZAR
Equipment						
Blowers [2 by ELC-P1200B380, 1.2kW single-phase]	3	*n*	62,500.00	187,500.00	10	18,750.00
Heat pumps (17.5kW (91kW heat output)	4	*n*	160,000.00	640,000.00	10	64,000.00
Geobubble surface cover in TSR [10mX10m, cut]	1	*n*	12,250.00	12,250.00	5	2,450.00
Geobubble surface cover in TSR [grow-out]	1	*n*	35,000.00	35,000.00	5	7,000.00
Solar panels/battery storage for heating system [all, set]	1	*n*	3,600,000.00	3,600,000.00	15	240,000.00
Electrical cabling, switchgear, etc for heating system [all, set]	4	*n*	60,000.00	240,000.00	15	16,000.00
Airlift aerators (2 main tank)	8	*n*	90,000.00	720,000.00	15	48,000.00
Airlift aerator (1 purging tank)	2	*n*	45,000.00	90,000.00	15	6,000.00
Multiple tube airlift water pump	2	*n*	135,000.00	270,000.00	15	18,000.00
Water supply pump (PT to GOT)	1	*n*	45,000.00	45,000.00	15	3,000.00
Solar panels/battery storage for GOT/PT [all, set]	1	*n*	1,400,000.00	1,400,000.00	15	93,333.33
Electrical cabling, switchgear, etc for GOT/PT [all, set]	1	*n*	450,000.00	450,000.00	15	30,000.00
Screens for compartments (on-farm made) [set]	1	*n*	450,000.00	450,000.00	15	30,000.00
Flake ice plant (1000kg/24hr)	1	*n*	300,000.00	300,000.00	15	20,000.00
Equipment, Quarantine Fcaility	0	*n*	450,000.00	0.00	15	0.00
Equipment, Broodfish Pairing Pond (BPP)	2	*n*	180,000.00	360,000.00	15	24,000.00
Equipment, Periphytic/RAS nursery	2	*n*	240,000.00	480,000.00	15	32,000.00
Equipment, Figerling BFT tanks	2	*n*	185,000.00	370,000.00	15	24,666.67
Equpment, hatchery	1	*n*	200,000.00	200,000.00	15	13,333.33
Equipment, sea lettuce ponds	2	*n*	60,000.00	120,000.00	15	8,000.00
Equipment, salicornia wetalnd	1	*n*	50,000.00	50,000.00	15	3,333.33
Feed plant equipment						
Moist pellet mill	1	*n*	355,000.00	355,000.00	10	35,500.00
Hammer mill	1	*n*	95,000.00	95,000.00	10	9,500.00
Grading sieves	1	*n*	12,000.00	12,000.00	10	1,200.00
Other	1	*n*	5,000.00	5,000.00	15	333.33
P&G's						
Planning, design, engineering drawings etc				350,000.00	n/a	0
Permits, permissions and EIA				650,000.00	n/a	0
TOTAL EQUIPMENT COST				**11,486,750.00**		
Depreciation						**748,400.00**
Total Capital Cost Estimate, ZAR				**20,306,337.46**		
Total annual depreciation						**1,264,630.09**
BUDGETS, adding 6.5% and rounding-up				**22,000,000.00**		**1,370,107.33**

10 year projected financials summary for Phase 1: the Marine Tilapia Industry Incubator (MTII) at the Food Security Research Institute (FSRI) near Vredenburg, Western Cape, South Africa under baseline conditions assuming 100% borrowed capital at an interest rate of 8% per annum including sales of parent broodfish

R 25 m (US$ 1,388,889.89)
Total capital

R 22m (US$ 1,222,222.22)
Capital expenditure (CAPEX)

R 3 m (US$166,666.67)
Operating capital

100 %
Total capital
R 25 m

Production output
50.3 tonnes LW year 1
125.9 tonnes LW year 2
125.9 tonnes LW year 3….∞

Income
R3,020,400.00 year 1
R 7,551,000.00 year 2
R 7,551,000.00 year 3

Selling price
R 60.00/kg as LW (food fish)

Average cost/kg
R 30.41/kg as LW

Profit
49.3 %
R 29.59/kg

10 year economic performance indicators (after-tax)

16.3 %
Return on Investment (ROI)

8.3 %
Internal Rate of Return (IRR)

R 9,647,208.66
Salvage Value at end year 10

120 months
Pay-back Period after-tax

23.2 %
Labour-Capital Ratio

R2,000,000.00
Cost per job

R 3,098,278.35
Net Present value (NPV)

Notes

The MTII, considered a pilot facility, is viable at current selling prices of R60.00/kg directly to consumers by-passing the value chain at Phase 1.

While the viability of the MTII is improved at Phase 2 with the addition of a hatchery to support the first 5,000 tonne per annum grow-out farm (shown overleaf on an added 3Ha leased site)

The FSRI will take the equivalent of a 20% equity stake (converted to donations) in Phase 2, capable of producing 5,000 tonnes per annum from a single grow-out farm to bolster income to cover maintenance costs of the MTII as well as program and broodstock development expenses and genetic selection work on the species.

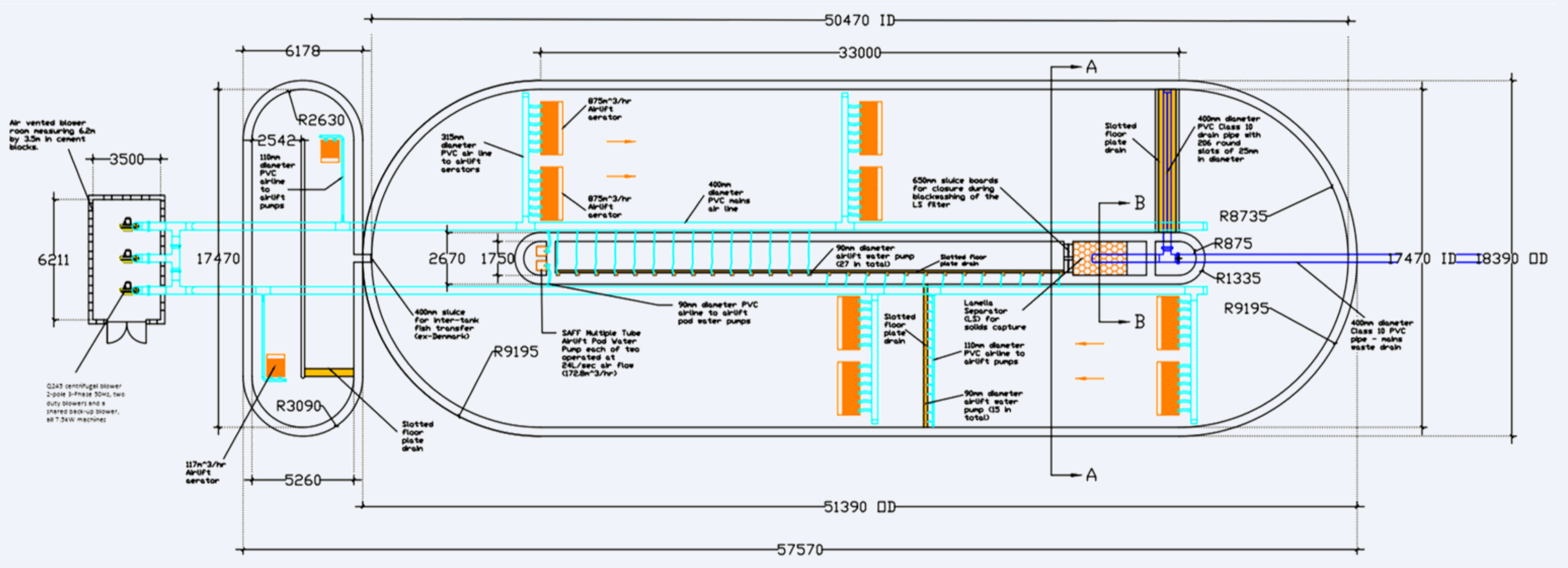
Since the marine tilapia project is a food security initiative, both scale- and scope economies require to be leveraged to realize the original vision enabling high-volume production and sales of South Africa's new whitefish alternative. See slides 10 and 35.

Objectives of the Marine Tilapia Industry Incubator (MTII) the semi-commercial scale pilot plant proof-of-concept facility at the Food Security Research Institute (FSRI)

The objectives of the Marine Tilapia Industry Incubator (MTII) at the outset include;

1) Definitive technology proof-of-concept at a smaller-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 grow-out farm producing 5,000 tonnes per annum (Phase 2) and the first cluster capable of producing 20,0000 tonnes per annum (Phase 3).
3) Output results will provide needed confidence for the development of the first large-scale grow-out farm as well as the expansion of the hatchery at the FSRI to support the first large-scale grow-out farm at Phase 2.
4) The final Phase of the MTII is the addition of a quarantine unit to enable further colonies of wild germplasm to be collected from the wild (Eastern Cape rivers) to advance a genetic selection program for the new farmed whitefish industry in South Africa supplying the needed improved gene lines of seedstock to develop a scalable commercial sector at Phase 2.

Plan-view layout of a 2nd generation 1250m³ multi-cohort sequentially stocked and harvested R-ended BFT grow-out tank capable of producing 125 tonnes per annum (100kg/m³/year) for placement in temperate climates. The MTII tank system is a half-scaled replica of full-scale 250 tonne per annum BFT integrated R-ended tank systems intended for industry scale-up.



The *raison d'être* [ultimate purpose for existence] of the Marine Tilapia Industry Incubator (MTII) at Phase 2

1. The *raison d'être* [ultimate purpose for existence] of the Phase 1 the Marine Tilapia Industry Incubator (MTII) is to promote and support the development of a large-scale and inclusive tilapia farming industry along the west Cape coastline from Vredenburg/Veldrift to Elands Bay/Lamberts Bay/Doringbaai/Strandfontein/Papendorp (see slide's 8, 9 and 10).
2. The Marine Tilapia Industry Incubator (MTII) at Phase 1 is essentially a confidence building pilot operation for a the first full-scale commercial grow-out farm producing 5,000 tonnes developed outside of the FSRI.
3. Phase 2 builds onto the MTII with the addition of a hatchery to support the first commercial grow-out farm as well as a quarantine unit to enable wild germplasm to be collected from Eastern Cape river systems for the purposeful establishment of improved parent breeding stock to seed and catalyse the transformation of the aquaculture industry and rural west Cape coast economy through supportive activities;
4. Focused food sovereignty and food security through the sustainable commercialisation of the indigenous *Oreochromis mossambicus* genetic resource;
5. To develop and strengthen human and institutional capabilities and competencies for a sustainable marine tilapia aquaculture industry in South Africa;
6. Targeted improvement of rural livelihoods through jobs, income, skills and food security;
7. Public and market appreciation of the social and economic value of the Marine Tilapia Vision 2035 to grow the new sustainable intensification tilapia farming industry and value-chain;
8. Strengthened policy for the aquaculture sector;
9. Consolidated product branding, marketing, quality and food safety assurance standards and monitoring;
10. To grow the Marine Tilapia Vision 2035 through a myriad of activities aimed at facilitating an annual production level of 100,000 tonnes of tilapia (live weight) by 2035 through five (5) commercial Marine Tilapia Industry clusters (see slides 8, 9 and 10) at Phase 7.

The Marine Tilapia Industry Incubator (MTII) at the Food Security Research Institute (FSRI) will fulfil an immensely important role in the development and seeding of a new and mandatory aquaculture industry in South Africa targeting a replacement species for unaffordable and increasingly less abundant Cape hake.

Perfect specimens of the South African indigenous euryhaline species, *Oreochromis mossambicus* (Mozambique tilapia), grown in a Biofloc Technology (BFT) system under large-scale conditions in Malawi over 2016/2017

The Phase 1 Marine Tilapia Industry Incubator (MTII) aims to spawn a new sustainable oceans economy industry for food security in South Africa at the Food Security Research Institute (FSRI).

Marine cultivated tilapia will replace unaffordable marine capture based fisheries which have become prohibitively expensive for the majority of consumers in South Africa, and also increasingly difficult to fulfil quotas in recent years.

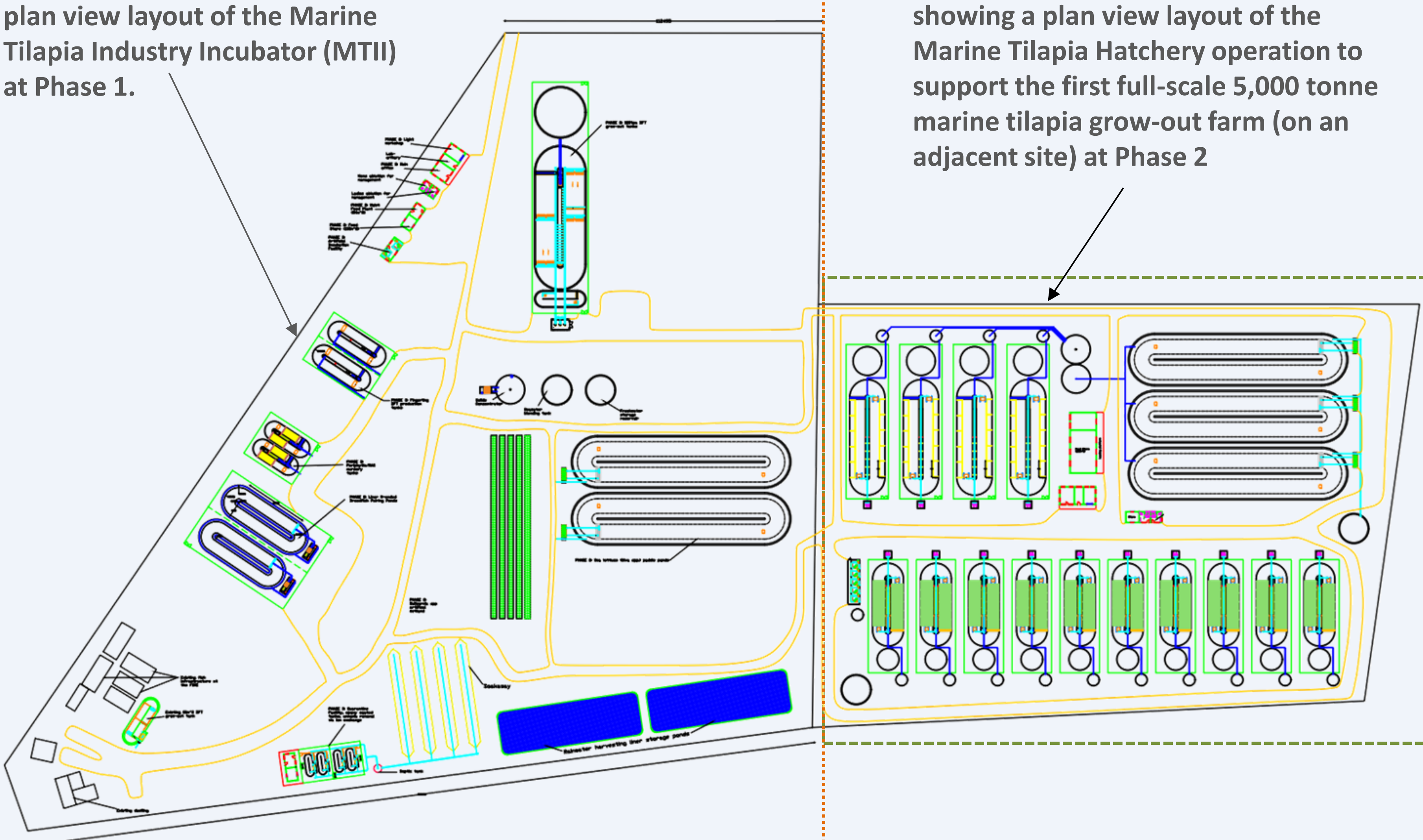
Although the MTII will be conducted at the Food Security Research Institute (FSRI) a non-profit Public Benefit Organization (PBO). The MTII will nevertheless be operated under commercial principles where any profits would be re-invested into further projects (broodstock development, genetic selection, other species etc.).

The value proposition of a full commercial cluster at Phase 3 producing 20,000 tonnes per annum of marine cultivated tilapia as given by slide 8 illustrates the potential that the MTII would unlock based upon the vision shared by slide 8.

Schematic plan view layout of the Marine Tilapia Industry Incubator (MTII) [Phase 2] at the Food Security Research Institute (FSRI) expanding into a large-scale marine tilapia hatchery operation to support the first large-scale tilapia grow-out farm producing 5,000 tonnes per annum..

Existing 5.7Ha FSRI site showing a plan view layout of the Marine Tilapia Industry Incubator (MTII) at Phase 1.

Adjacent 3Ha site leased to the FSRI showing a plan view layout of the Marine Tilapia Hatchery operation to support the first full-scale 5,000 tonne marine tilapia grow-out farm (on an adjacent site) at Phase 2



10 year projected financials summary for Phase 2: Dedicated hatchery to support a 5000 tonne per annum marine tilapia BFT grow-out tank farm adjacent to the Food Security Research Institute (FSRI) near Vredenburg, Western Cape, South Africa under baseline conditions assuming 100% borrowed capital at an interest rate of 8% per annum including sales of parent broodfish

R 63.6m (US$ 3,53m)
Total capital

R 60m (US$ 3.33m)
Capital expenditure (CAPEX)

R 3.6m (US$ 200,000.00)
Operating capital

100 %
Total capital
R 63.6 m

Production output
13.14m fry of 4.1g year 1
21.9 m fry of 4.1g year 2
21.9 m fry of 4.1g year 3....∞

Income
R10.52m year 1
R 17.53 m year 2... ∞

10 year economic performance indicators (after-tax)

Profit
61.9 %
R 0.50/fish

Selling price
R 0.80/fish for 4.1g fry

Average cost/kg
R 0.30/fish for 4.1g fry

17.4 %
Return on Investment (ROI)

10.5 %
Internal Rate of Return (IRR)

R 25,511,973.21
Salvage Value at end year 10

110 months
Pay-back Period after-tax

24.4 %
Labour-Capital Ratio

R3,000,000.00
Cost per job

R 14,699,465.80
Net Present value (NPV)

Notes

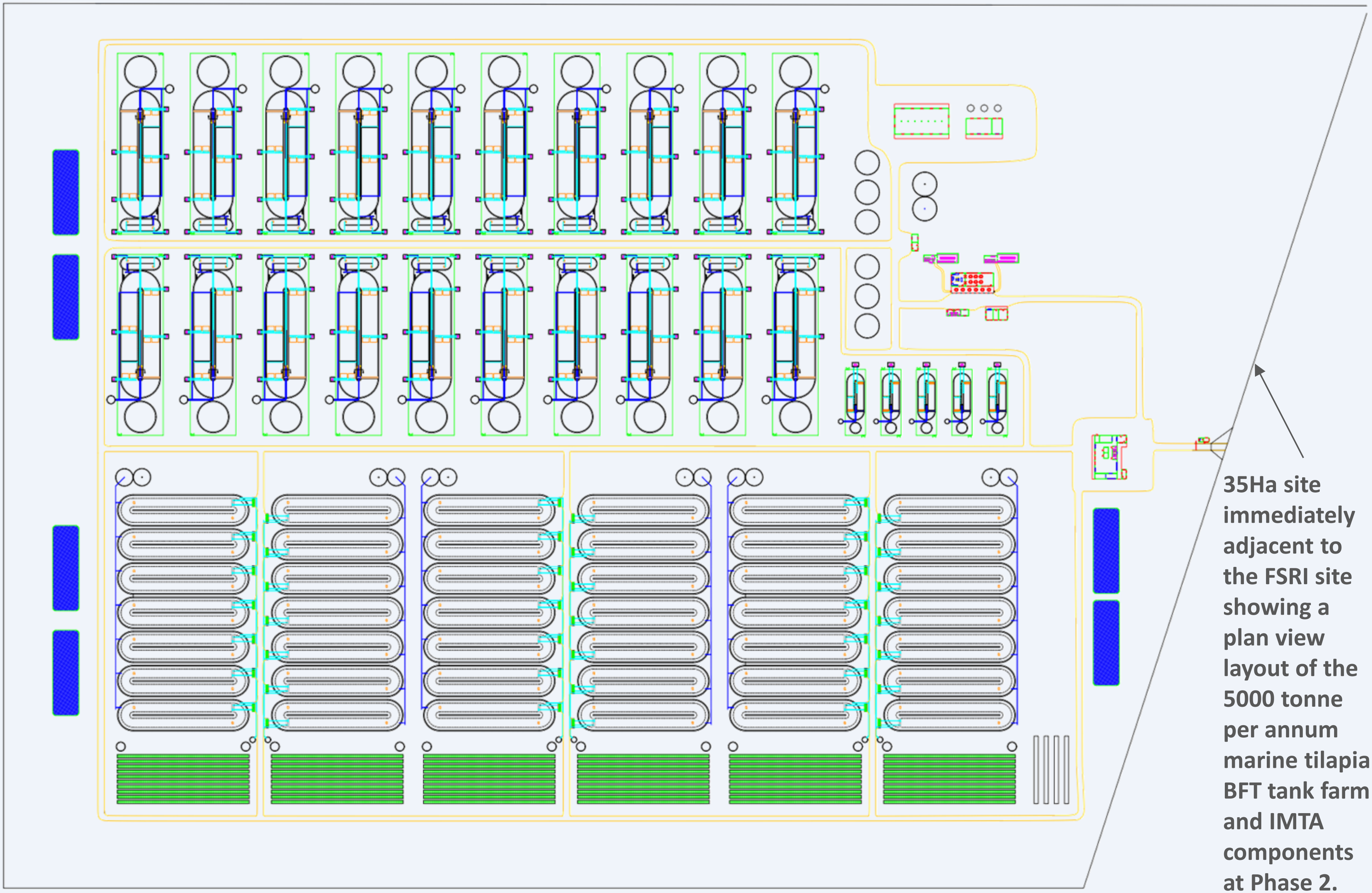
The first commercial scale hatchery producing marine tilapia fry on a semi-industrial scale in South Africa would be considered sub-optimal in scale although adequate to support the grow-out production of 5000 tonnes per annum of 240g fish.

Designed specifically to support a single dedicated grow-out production farm producing 5,000 tonnes per annum of 240g fish (average) harvest weight.

The hatchery doubles as a broodfish multiplier for the sale of parent breeding stock to new larger scale commercial hatcheries where one hatchery supports the annual grow-out production of 20,000 tonnes of 240g fish enabling sales of 4.1g fry to fall to R0.20 fish (see slide 10).

The viability of the first commercial hatchery would be greatly improved by the sale of *Specific Pathogen Free* (SPF) improved gene lines of parent broodfish in the future. While until sales of broodfish occur adequate returns can be expected when selling prices are tuned to R0.80/fish for 4.1g fry.

Schematic plan view layout of the first vertically integrated 5000 tonne per annum marine tilapia grow-out farm [Phase 2] on a site immediately adjacent to the Food Security Research Institute (FSRI) which carries a feed plant, primary fish processing plant and a training facility



35Ha site immediately adjacent to the FSRI site showing a plan view layout of the 5000 tonne per annum marine tilapia BFT tank farm and IMTA components at Phase 2.

10 year projected financials summary for Phase 2: 5000 tonne per annum marine tilapia BFT grow-out tank farm adjacent to the Food Security Research Institute (FSRI) near Vredenburg, Western Cape, South Africa under baseline conditions assuming 100% borrowed capital at an interest rate of 8% per annum including sales of parent broodfish

R 395.5m (US$ 21.94m)
Total capital

R 335m (US$ 18.6m)
Capital expenditure (CAPEX)

R 60m (US$ 3.33m)
Operating capital

100 %
Total capital R 395.5 m

Production output
2000 tonnes year 1
5000 tonnes year 2… ∞

Income
R70 m year 1
R 175m m year 2… ∞

10 year economic performance indicators (after-tax)

Profit 36.8%
R 12.87/fish

Selling price
R 35.00/kg LW

Average cost/kg
R 22.13/kg LW

18.3 %
Return on Investment (ROI)

10.7 %
Internal Rate of Return (IRR)

R 128,001,557.75
Salvage Value at end year 10

102 months
Pay-back Period after-tax

9.4 %
Labour-Capital Ratio

R 3,221,153.85
Cost per job

R 94,779,106.56
Net Present value (NPV)

Notes

The first large-scale commercial 5000 tonne per annum marine tilapia grow-out farm in South Africa would be considered the largest fish farm in the country, and largest tank farm on the continent.

The origins of the seedstock material are the spawn from the first generation of breeding stock at the FSRI considered minimally improved and would yield a growth of 240g fish from 4.1g fry stocked 168 days prior.

The fingerling production stage involves growing fish from 4.1g to 12.4g (ave. weights) over 21 days at 27°C and grow-out production involves taking 12.4g fingerlings to 240g harvest weight at a constant water temperature of 27°C (26.5-27.5°C range).

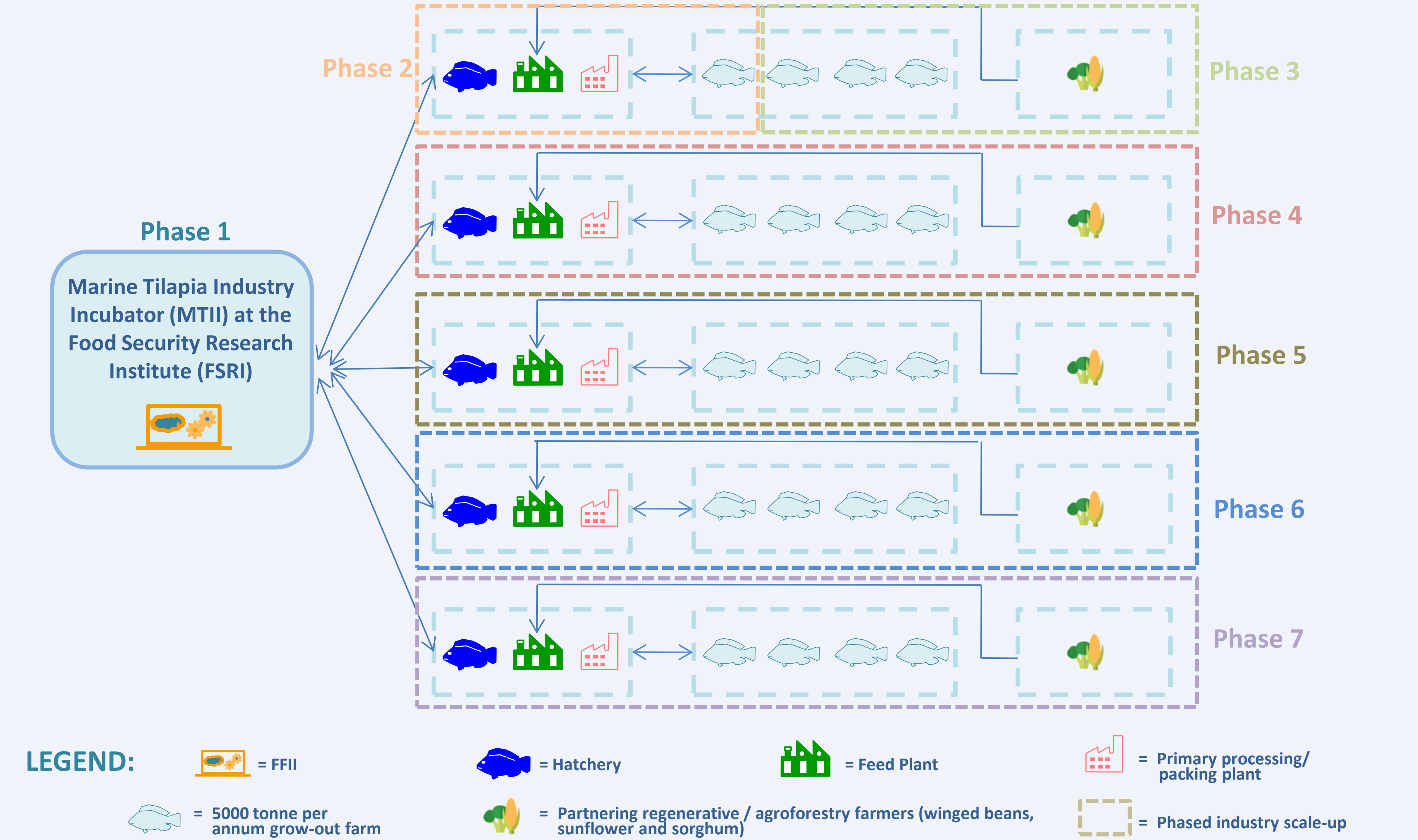
A primary processing plant and feed plant are included in the first large-scale grow-out farm as well as a training facility. Future grow-out farms would supply fish to a central processing plant and would in addition not require a training facility.

Tho total CAPEX needed is R335m (US$3.3m) and OPEX R3.6m (US$200,000.00).

A selling price of R35/kg LW would render marine cultivated tilapia the least cost farmed animal protein source in South Africa.

The pivotal position of the Marine Tilapia Industry Incubator (MTII) at the Food Security Research Institute (FSRI) to foster the growth of an expanding and scalable marine tilapia farming industry in the Western Cape, South Africa to furnish know-how, technology, skills transfer and improved gene lines of parent fish.

Industry Structure and Phased industry scale-up

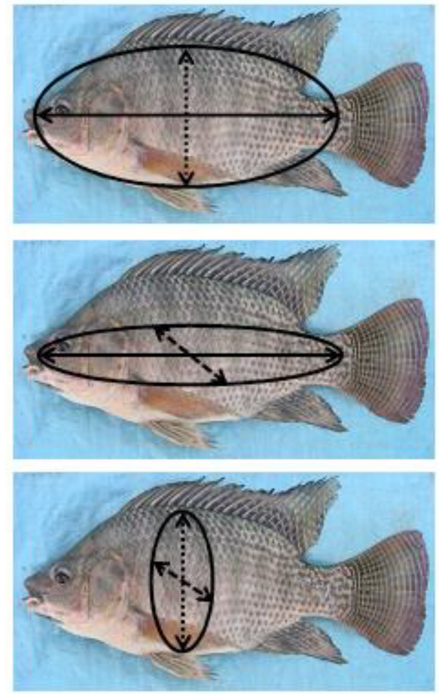


Phase 2 at the MTII: Opportunity to develop *"the Aquatic Chicken of the Sea" and the best farmed breeds of Mozambique tilapia for sea water culture in the world at the Food Security Research Institute (FSRI)*

→ Hall (2001) demonstrated that there are multiple genetically distinct populations of *O. mossambicus* all along the East coast of Southern Africa adequate to initiate a base population consisting of four or eight subsets of breeders to launch a classical genetic selection program based upon best practice according to the Holtsmark *et. al*. (2008) design philosophy.

→ The following two publications define best strategies when planning to build an aquaculture base population from animals captured in the wild;

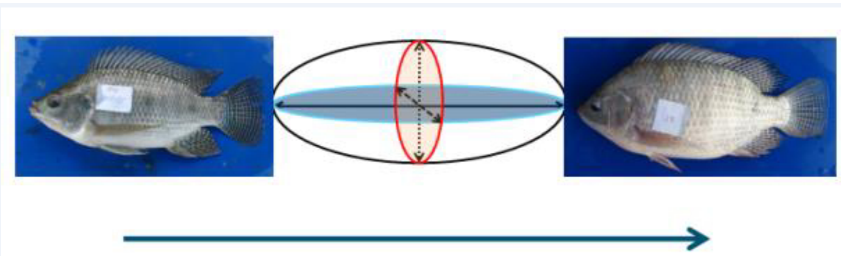
"*Establishing a base population for a breeding program in aquaculture, from multiple subpopulations, differentiated by genetic drift: I. Effects of the number of subpopulations, heritability and mating strategies using optimum contribution selection. II. Sensitivity to assumptions on the additive genetic relationships of base animals"*. 2008. Holtsmark, M., G. Klemetsdal, A. K. Sonesson and J. A. Woolliams. Aquaculture 274:232-240 & 241-246.



$$E_{L-H} = \frac{(L-H)}{(L+H)}$$

$$E_{L-T} = \frac{(L-T)}{(L+T)}$$

$$E_{H-T} = \frac{(H-T)}{(H+T)}$$



Shape and ellipticity

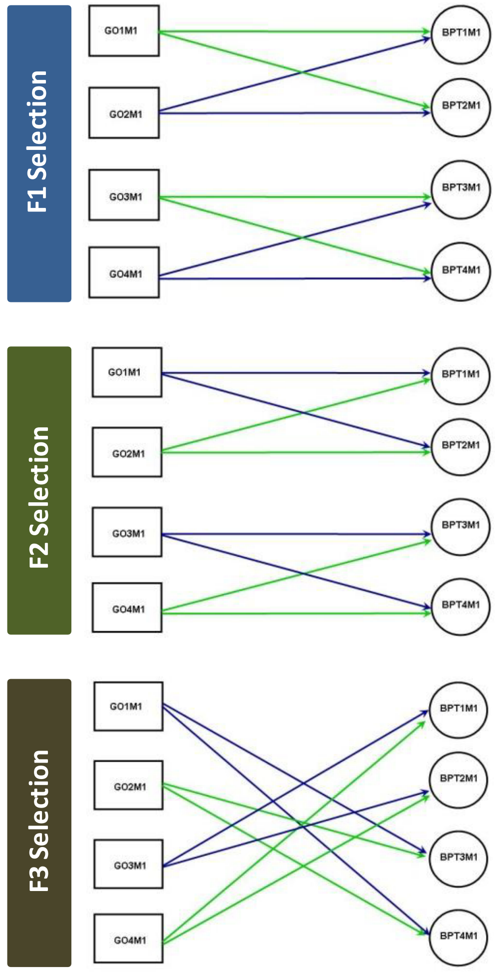
- Heavier fish are more rotund
- No effect of age (200-400 days)
- Daily Growth Coefficient and Ellipticity: fish selected for high growth rate become more rotund and thicker

Phase 2 at the MTII: Capturing maximum genetic gain in a classical genetic selection program for improved farmed traits in *O. mossambicus* at the Food Security Research Institute (FSRI)

→ The rationale for the use of four or eight gene pools is to increase genetic variation in the founders where the four/eight subsets of breeders selected exhibit minimal mutual relatedness (or maximum genetic variance) i.e. sourcing four gene pools of *O. mossambicus* from four geographically separated populations (as a surrogate for drift) when launching a genetic selection program based upon wild fish populations.

→ To capture maximum genetic gain requires that production facilities consider optimum contribution selection and numbers of subsets for progeny for grow-out. For instance, modules for fish production should be designed in four tanks per module and four modules per farm built to enable four sub-subsets of *O. mossambicus* to be reared taking full advantage of heritability and optimum contribution selection along with a large population size (*Ne*).

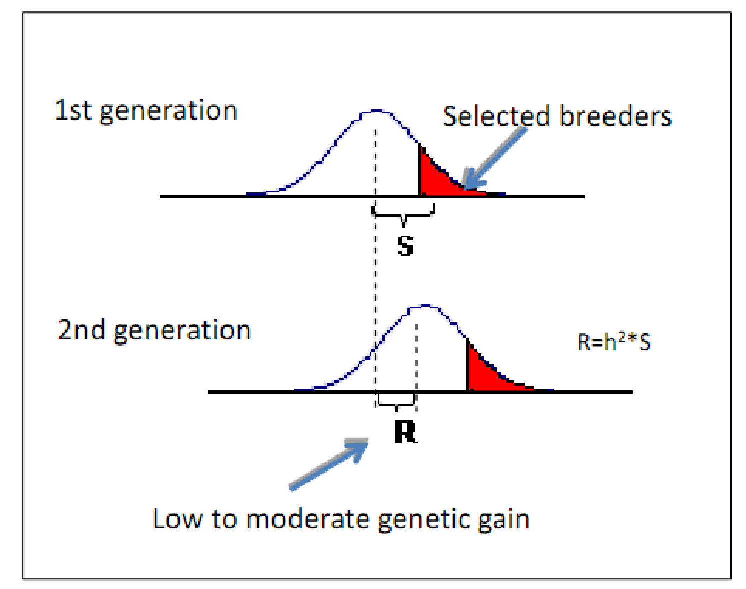
F1, F2 and F3 generations of selection within a single farm production module based upon a single gene pool using four discrete breeding colonies located in four breeding tanks applying a high population number (*Ne*)



(Blue lines represent movement of males and green lines represent the movement of females)

GIFT genetic selection program, Philippines, 1980's on *O. niloticus*

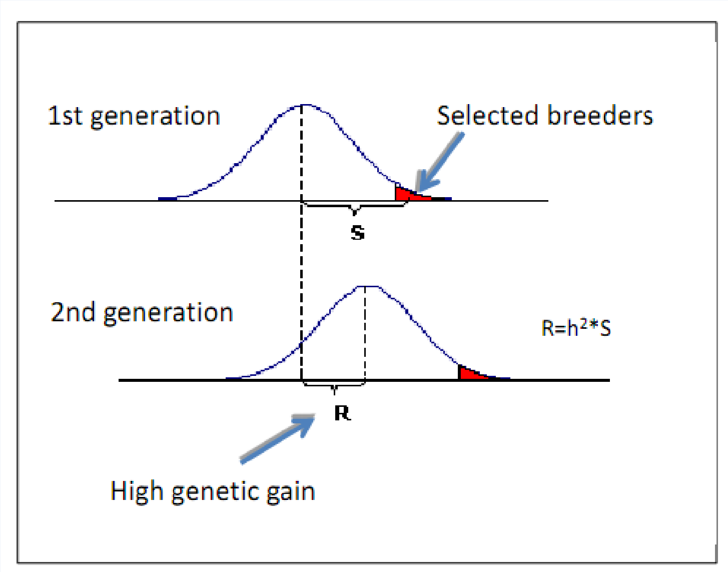
Traditional breeding program characterized by a small population size (*Ne*) and low selection pressure



Low to moderate genetic gain - slower growth enhancement, fillet yields, fillet colour etc

Industrial genetic selection program, South Africa, proposed for *O. mossambicus*

Industrial breeding program characterized by a very large population size (*Ne*) and high selection pressure

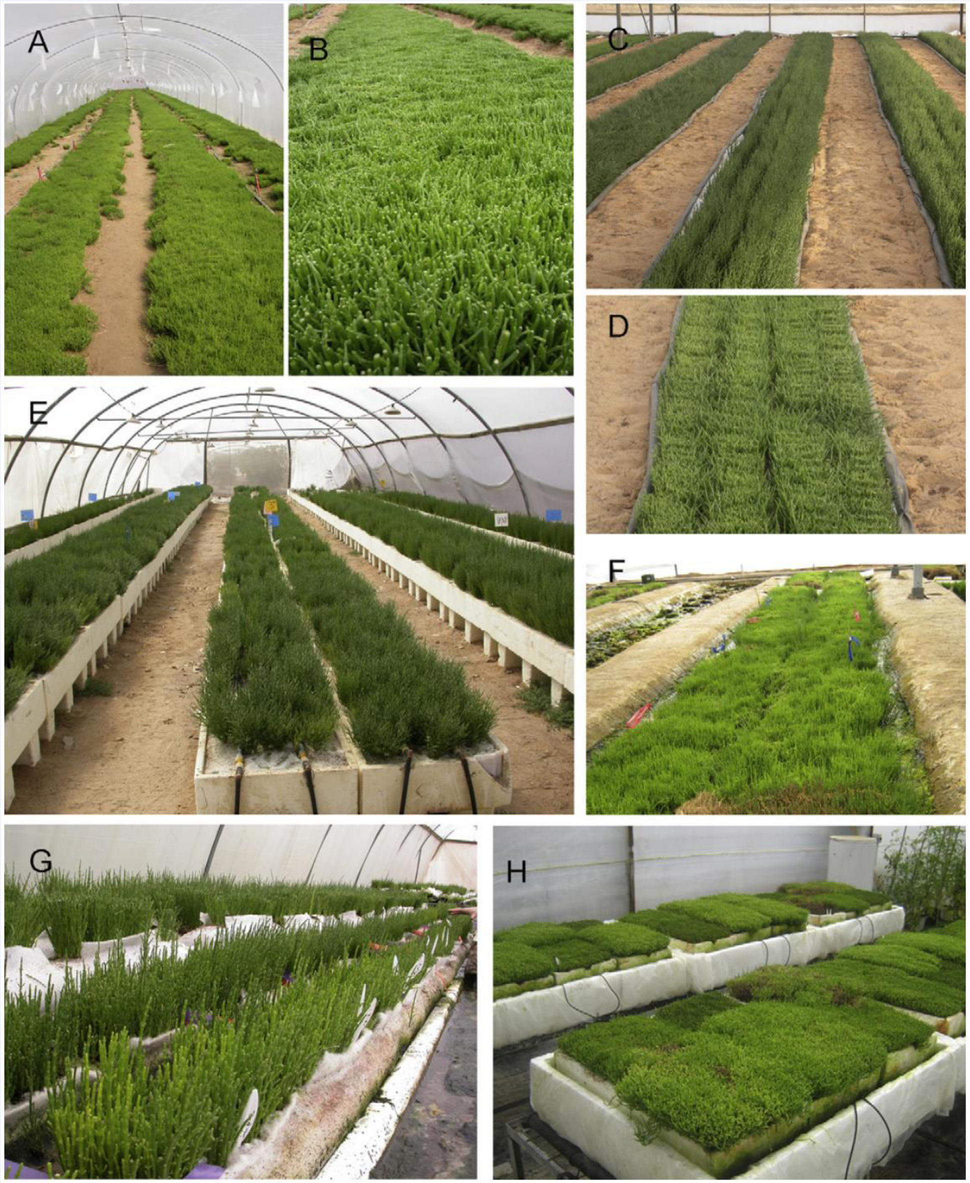


High genetic gain – accelerated growth enhancement, fillet yields, fillet colour etc

Integrated Multi-Trophic Aquaculture (IMTA) products produced on the waste streams from fish production at the FSRI at Phase 1 and 2

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.

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



Cultivation systems for *Salicornia* and *Sarcocornia*.

(A) Plants growing on native sand dunes, irrigated with drip irrigation.

(B) Sand dune culture after harvesting to 'cutting table' height.

(C) Troughs build with plastic sheets, detached from native soil.

(D) Troughs after the harvest.

(E) Drip irrigated soilless culture, detached from native
soil.

(F) Surface-flow constructed wetland fed with marine effluent.

(G) Sleeve cultivation irrigated with saline aquaculture effluent in subsurface-flow system.

(H) Units filled with perlite floating in seawater.

Also see slide 15

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

Sea lettuce, *Ulva lactuca* included in the IMTA system due to its ease of culture and use as a valuable source of nutrients and phytogens for inclusion in tilapia feeds

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

J Appl Phycol (2013) 25:1359–1367
DOI 10.1007/s10811-012-9965-3

The IMTA-cultivated Chlorophyta *Ulva* spp. as a sustainable ingredient in Nile tilapia (*Oreochromis niloticus*) diets

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Abstract Increasing levels of a mixture of *Ulva* spp. produced in an integrated multi-trophic aquaculture (IMTA) system were evaluated in Nile tilapia juveniles for partial replacement of dietary fish meal. A control diet (CTRL) was compared with three experimental diets containing 10 % (U10), 15 % (U15), and 20 % (U20) of *Ulva* spp. meal. Triplicate groups of fish (13 g initial body weight) were fed each diet for 63 days at 26 °C. Nutrient apparent digestibility coefficients and nitrogen retention efficiency did not vary significantly among diets. By the end of the trial, all groups of fish more than tripled their initial body weight. Specific growth rate and final body weight of U10 diet were similar to CTRL and significantly higher than U15 and U20 diets. Increasing *Ulva* dietary incorporation levels significantly increased feed conversion ratio (FCR), from 1.0 (CTRL) to 1.4 (U20). Fish fed with U10 diet had the highest protein efficiency ratio and nitrogen retention efficiency allowing this fish to growth and reach a final body weight similar to the CTRL group. Protein content was highest in fish fed with the CTRL diet, whereas the highest lipid content was observed in fish fed with U20 diet. The results show that the incorporation of IMTA-produced *Ulva* meal in Nile tilapia diets is possible up to 10 % without compromising growth performance, protein utilization, and protein retention of juveniles. The high capacity of Nile tilapia to digest all experimental diets suggests that *Ulva* meal is a practical partial replacement for fish meal in Nile tilapia diets.

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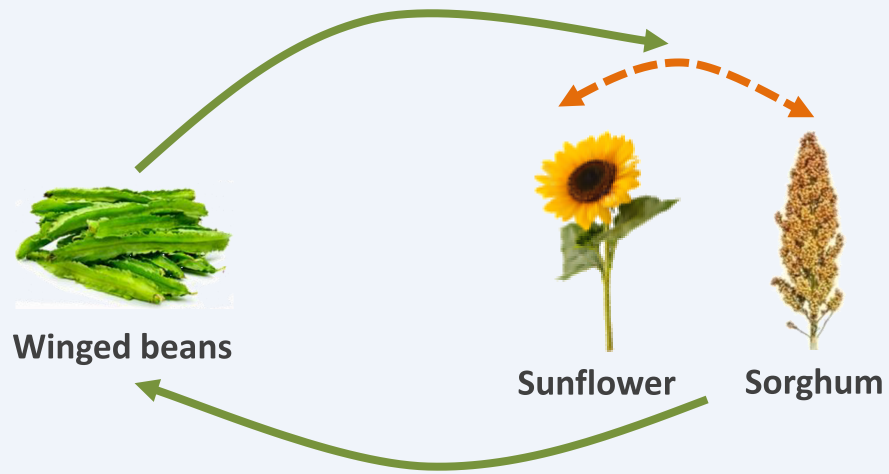
Keywords Seaweed · Digestibility · Feed ingredient · *Ulva* · Protein utilization

Introduction

Globally, aquaculture remains the fastest growing animal food-producing sector. In 2010, it had already accounted for 47 % of the total world's food fish supply, while wild capture fisheries have been relatively stable in the past decade (FAO 2012). Indeed, this sector plays a key role in providing food for a growing human population. However, aquaculture, like other animal crops, can lead to environmental degradation. Dissolved inorganic and particulate organic matter, resulting from uneaten food, feces, dead fish, and excretion products cause some of the main negative effects of intensive aquaculture (e.g., finfish and shrimp). In monoculture systems, only 21 to 24 % of total phosphorus and 26 to 27 % of total nitrogen of the feed supplied to

Also see slide 15

The future is organic and non-GMO sources of feedstock raw material commodities to feed BFT farmed tilapia from partnering organic-regenerative farmers producing winged beans, sunflower seeds and sorghum using an agroforestry approach which involves the use of nitrogen (N) fixing trees and rotational ally-cropping to support Phase 4 of the Marine Tilapia Vision 2035.



Alley cropping legumes, grains and oil seeds in-between nitrogen fixing White Acacia (*Faidherbia albida*) trees – a low-input agroforestry/ regenerative farming/climate resilient/carbon capture approach to crop production for adoption by partnering farmers.

Philosophy

Also see slide 10

Selection criteria;

Good digestibility and palatability by tilapia

Nutrient packed food sources from field-to-plate for rural communities

Carbon capture and storage

Minimal processing – just extrusion cooked/roasted, no need for oil extraction

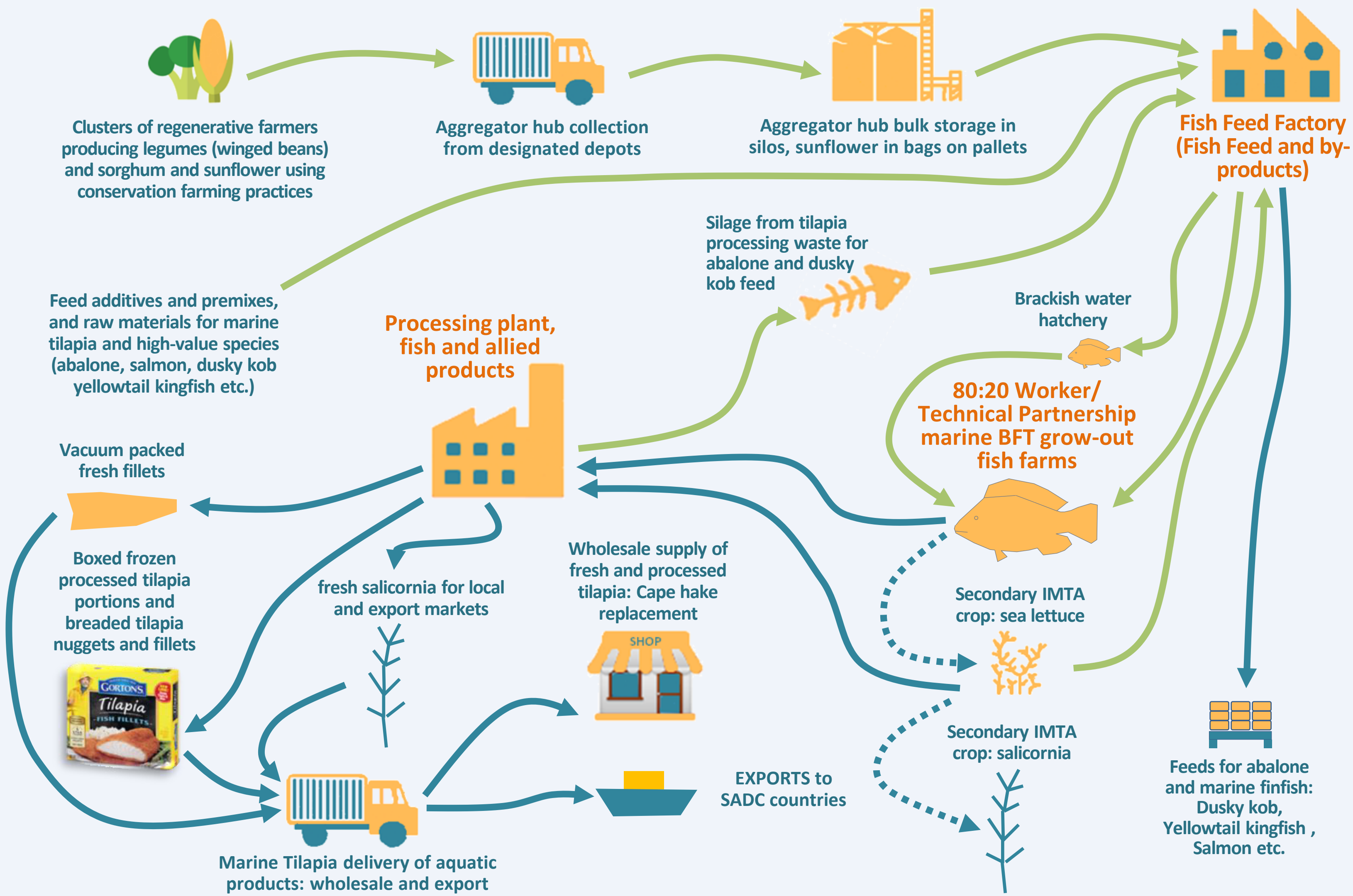
Ecological benefits:

Winged beans *(Psophocarpus tetragonolobus)* grown as a cover crop for sorghum *(Sorghum bicolor*) plus only sufficient crop volumes of high-oil yielding sunflower for energy balancing tilapia feeds (used as full-fat)

Non-GMO, no till, use of compost tea, irrigated, chemical fertilizer-free, mulching, low-input, use of ancient grains and crop varieties

Use of nitrogen fixing White Acacia *(Faidherbia albida),* a close cousin of the Acacia family of trees, also indigenous to KwaZulu-Natal. Shown to increase maize yields by 400% in Zambia and Malawi (occurs throughout Africa and in South Africa) compared to normal mono-culture practices (from 0.8t/Ha to 4t/Ha in Malawi).

Elements of the Value-Chain and Flows from Rural Farmers to Marine Tilapia & IMTA products



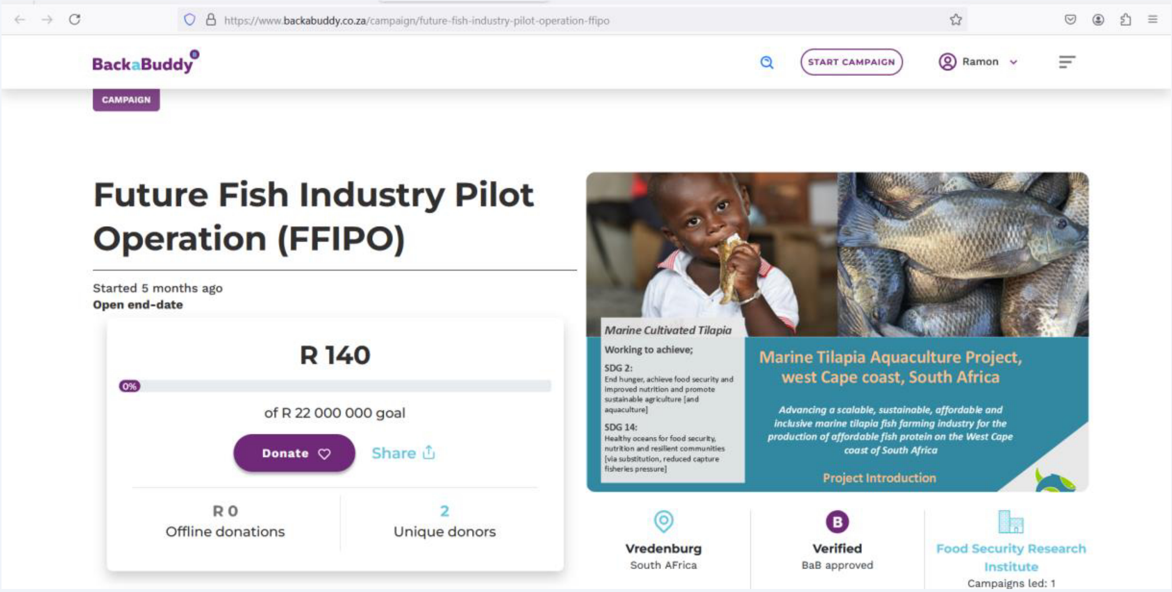
LEGEND: Raw/processed feed flow | Pre-processed/ Finished product flow | Waste stream to secondary crop production

Secure your future supply of more affordable marine cultivated tilapia to replace unaffordable Cape hake by donating to the FSRI

Donate

Your gift will go toward ensuring that the necessary seeding and catalytic work at the FSRI breaks the new ground to usher in sustainably cultivated seawater farmed tilapia to replace unaffordable Cape hake. The early seeding work to be carried out at the FSRI may spawn a commercial marine tilapia aquaculture industry in South Africa worth R4.5Bn when scaled to 100,000 tonnes per annum (=Cape hake national annual quota).

Follow the link to access the Back-a-Buddy FSRI page to donate



https://www.backabuddy.co.za/campaign/future-fish-industry-pilot-operation-ffipo

Please be patient after clicking the link above as it may take a moment to for the Back-a-Buddy page to display. The Food Security Research Institute (FSRI) is a Non-Profit Company (NPC) [registration number: 2024/163705/08] and as such your contributions, up to 10% of your taxable income in a year [in South Africa], are tax-deductible to the fullest extent of the law. Please enquire to receive a copy of the FSRI's 18 A certificate for tax clearance purposes.

Donate into the *Marine Tilapia Vision 2035* where a target of R22m requires to be raised to establish the Phase 1 pilot plant facility at the *Food Security Research Institute* (FSRI). Help us along this journey to introduce a new sustainable marine cultivated whitefish alternative to unaffordable Cape hake as a hedge against food insecurity in South Africa…a small seed planted today may spawn a scalable new industry in South Africa worth over R4.5 Bn annually [todays prices] at Phase 7 producing 100,000 tonnes per annum by the year 2035. *Your donations will secure your future whitefish supply!*

A derelict west Cape coast shallow Cape hake fishing boat of yesteryear when the resource existed in the wild in abundance.

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