

AN ASSESSMENT TO INTEGRATE AQUACULTURE MODULES IN AQUACULTURE - RELATED QUALIFICATIONS AT SOUTH AFRICAN INSTITUTIONS OF HIGHER LEARNING

Final Report

August 2025



FUNDED BY:



higher education
& training
Department
Higher Education and Training
REPUBLIC OF SOUTH AFRICA



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Abbreviations and Acronyms

APC	Academic Programmes Committee
CHE	Council on Higher Education
CPUT	Cape Peninsula University of Technology
CUT	Central University of Technology
DFFE	Department of Forestry, Fisheries and the Environment
DHET	Department of Higher Education and Training
ECSA	Engineering Council of South Africa
HEQSF	Higher Education Qualifications Sub-Framework
HDI	Historically Disadvantaged Institution
HPCSA	Health Professions Council of South Africa
IMTA	Integrated Multi-Trophic Aquaculture
IOHLS	Institutions of Higher Learning
LED	Local Economic Development
MUT	Mangosuthu University of Technology
NDP	National Development Plan
NGO	Non-Governmental Organization
NMU	Nelson Mandela University
NWU	North-West University
OP	Operation Phakisa
p.a.	per annum
PAC	Program Advisory Committee
RAS	Recirculating Aquaculture Systems
RU	Rhodes University
SMME	Small, Medium, and Micro Enterprises
SPU	Sol Plaatje University
SU	Stellenbosch University
TUT	Tshwane University of Technology
TVET	Technical and Vocational Education and Training
UCT	University of Cape Town
UFH	University of Fort Hare
UFS	University of the Free State
UJ	University of Johannesburg
UKZN	University of KwaZulu-Natal
UL	University of Limpopo
UMP	University of Mpumalanga
UNISA	University of South Africa
UNIZULU	University of Zululand
UP	University of Pretoria
UWC	University of the Western Cape
UVenda	University of Venda
VUT	Vaal University of Technology
Wits	University of the Witwatersrand
WSU	Walter Sisulu University

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Executive Summary

This study underscores the critical need to address skills shortages in South Africa's aquaculture sector through the expansion of aquaculture education at higher education institutions. A desktop analysis revealed that only eight of the country's 26 public universities currently offer aquaculture modules, with notable regional disparities in infrastructure and resources.

Departments such as Animal Sciences, Agriculture, Zoology, and Biological Sciences are already well-positioned to integrate aquaculture-focused content. Furthermore, departments like Engineering, Food Science, Business Management, and Agricultural Economics could potentially incorporate aquaculture modules or content to expand the various critical aquaculture skills identified as crucial to the sector's future development.

The study identified Stellenbosch University, Rhodes University, University of Limpopo and the University of Fort Hare as fitting universities to approach for incorporating new aquaculture modules into other aquaculture-related curricula based on their existing infrastructure, diverse aquaculture focus, existing aquaculture expertise/capacity, potential for interdisciplinary integration, and alignment with regional needs.

A cost-benefit analysis compared two approaches: the first involved integrating accredited aquaculture modules into existing curricula, offering comprehensive education but requiring lengthy development processes. The second approach proposes offering introductory lectures on aquaculture principles and career opportunities, which is quicker to implement but faces challenges such as limited space in academic schedules and potential staff resistance.

The study's business case emphasized the potential economic and social benefits of strengthening aquaculture education, aligning with national priorities such as food security and rural development. Findings suggest that targeted investments and collaboration between academia, government, and industry are essential to building a skilled workforce and ensuring the sector's sustainable growth, which will ultimately contribute to South Africa's economy and food systems.

Additional steps that will enhance aquaculture education in South Africa include increasing student awareness of available programs, offering scholarships, and promoting postgraduate diplomas. Encouraging interdisciplinary research at the postgraduate level is also crucial—for example, engineering students can apply their expertise to aquaculture-related topics, such as mechanical engineers optimising wave-generating energy systems for abalone farms. Additionally, fostering industry collaboration and expanding training to cover the entire value chain are essential for sector growth. Efforts should focus on increasing the participation of historically disadvantaged institutions (HDIs) in both training and research, with a dedicated service provider overseeing these initiatives.

1. Background

1.1. Aquaculture industry in South Africa

Internationally, aquaculture is growing rapidly. Although South Africa has a relatively small and underdeveloped aquaculture sector, it has been identified as a key driver of growth and development in the broader agricultural landscape. In recognition of this, the South African government has developed a National Aquaculture Strategic Framework (NASF) to create 'a pragmatic and supportive pro-aquaculture enabling regulatory and operational environment to ensure food security and promote food sovereignty' (DAFF, 2013).

The above-mentioned undertaking is supported by the National Development Plan (NDP). The NDP is the country's socio-economic development blueprint, designed to create a better life for all citizens in an inclusive society. It sets the roadmap to guide the plans and policies, programmes, projects, and operations of every sector—including how budgets, skills investment, and other resources are allocated to move South Africa forward (National Planning Commission, 2012). The NDP provides a framework in which government, organised business, labour, and citizens can work together to accelerate economic growth and address the triple challenge of unemployment, poverty, and inequality. Operation Phakisa (OP) is one of the mechanisms in place to achieve the NDP's goals.

The OP is a fast-results delivery programme launched in July 2014 to assist in implementing the NDP, with the ultimate goal of boosting economic growth and creating jobs. Operation Phakisa is a cross-sector programme where various stakeholders engage to implement initiatives and concrete actions aimed at addressing constraints to delivery in prioritised areas, with a focus on public accountability and transparency. Therefore, OP is designed to fast-track the implementation of solutions to critical development issues. One of OP's projects is the Oceans Economy Labs, where aquaculture was identified as key area of growth. Since 2014, there is a new process underway to develop a Master Plan for the Oceans Economy which includes other sectors such as fisheries.

The government of South Africa has identified aquaculture as a priority for the country and the African continent. The challenges of climate change, population growth, and food insecurity position aquaculture as a powerful tool for sustainable development. It also presents an opportunity to enhance nutrition and food security, generate employment (especially in rural areas) and drive economic growth while protecting the environment and promoting the sustainable utilisation of natural resources.

In 2022, aquaculture became the leading source of aquatic animals for the first time in history, accounting for 51% of total global production, surpassing capture fisheries. Global aquaculture production reached a record 130.9 million tonnes, including 94.4 million tonnes of aquatic animals and 36.5 million tonnes of algae. Africa contributed 2.3 million tonnes of aquatic animals through aquaculture, representing 2.5% of the global total. While this may seem modest, Africa's aquaculture sector has experienced remarkable growth, increasing by 455% from 2000 to 2022 in terms of aquatic animal and algae production, the highest growth rate worldwide, highlighting the growing interest in the industry. To maintain current per capita consumption levels, Africa will need to increase its aquatic animal food supply by 74% by 2050 (FAO, 2024).

The change drivers that influence skills demand and supply in the aquaculture sub-sector include the COVID-19 pandemic, consumer patterns, red tide, power cuts, global warming, aquaculture co-operatives, export, food safety requirements, new technology, and the organisation of inland fisheries. The sub-sector needs to take these drivers of change into consideration to ensure its workforce has the necessary skills and knowledge to remain productive and efficient (AgriSETA, 2022).

Aquaculture represents a sector with the potential to make a significant contribution to the South African economy through the creation of skills-based employment and the sale of aquaculture products in both domestic and foreign markets.

Projected Aquaculture Demand and Production Trends in South Africa (2020–2030) (FAO, 2022)

- Given the 6.44 kg baseline per capita fish and seafood consumption, 424,627 tonnes of fish and seafood will be needed to satisfy the demand of South Africa's total population of 65,956 thousand in 2030. This is 42,796 tonnes higher than the 381,831 tonnes of baseline fish and seafood demand. However, it should be noted that the baseline per capita fish and seafood consumption likely does not account for consumption from informal traders and markets.
- If South Africa could increase its preference for fish and seafood to the world average, its per capita fish and seafood demand could rise to 20.3 kg/year by 2030, an increase of 13.86 kg compared to the baseline. Under this scenario, 956,782 tonnes of additional fish and seafood supply would be required to meet the extra demand generated by both population growth and increased preference.
- South Africa's aquaculture production increased from 6,730 tonnes in 2015 to 9,753 tonnes in 2020. Following the linear trend from 2015 to 2020, the country's aquaculture production could reach 15,221 tonnes by 2030. However, the 5,468 tonnes of extra supply compared to the baseline would still fall short of covering the 42,796 tonnes of additional demand driven solely by population growth (with a deficit of 37,328 tonnes). Furthermore, it would not be sufficient to cover the 956,782 tonnes of extra fish and seafood demand driven by both population growth and increased preference (with a shortage of 951,314 tonnes).
- South Africa's aquaculture production would need to grow by 18% per year between 2020 and 2030 in order to generate enough extra supply to meet the 42,796 tonnes of additional demand driven by population growth alone. It would need to grow by 58% per year to meet the 956,782 tonnes of additional demand driven by both population growth and increased preference. These growth targets should be aligned with future skill requirements to prioritize training across different cohorts of farm operations, as detailed in the Aquaculture Skills Inventory & Needs Analysis (SAIMI, 2017). Furthermore, it should also include projections for essential skills in sectors such as research, academia, and policy and governance, to ensure that training aligns with future needs across the entire aquaculture sector.

1.2. SWOT Analysis of Aquaculture in South Africa

Aquaculture has emerged as a vital component of sustainable food systems, addressing global challenges such as overfishing, food security, and economic development. In South Africa, the sector holds significant potential due to the country's diverse aquatic ecosystems, favourable climate, and increasing demand for fish and seafood products. However, the development of aquaculture in South Africa is shaped by a complex interplay of factors, including environmental regulations, market dynamics, socio-economic considerations, and the diverse climates and conditions that demand tailored innovations and technologies suited to local needs. To better understand the current state and future prospects of aquaculture in the country, it is essential to analyse its strengths, weaknesses, opportunities, and threats.

In 2021, Adeleke *et al.* published an article titled “*Aquaculture in Africa: A Comparative Review of Egypt, Nigeria, and Uganda Vis-À-Vis South Africa.*” In this article, they conducted a SWOT analysis of the aquaculture sectors in Egypt, Nigeria, Uganda, and South Africa. A summary of the results for South Africa is presented in **Error! Reference source not found.** below. This SWOT analysis provides a comprehensive overview of the sector, highlighting key internal and external factors that shape its development and inform strategic planning.

Table 1.1 Summary of the SWOT analysis of the aquaculture sector in South Africa by Adeleke et al. (2021).

<u>STRENGTHS</u> Diverse Aquaculture Species South Africa has the capability to culture a variety of aquaculture species, which can enhance biodiversity and market opportunities for different fish types. Efficient Production Technology The sector benefits from the use of efficient production technologies, which can lead to improved yields and lower operational costs, making aquaculture more competitive. Production of Freshwater and Marine Species South Africa is involved in the production of both freshwater and marine species, allowing for a broader range of products and catering to different market demands. Commercial Scale Aquafeed Manufacturing Capacity The presence of commercial scale aquafeed manufacturing capacity supports the aquaculture industry by ensuring a steady supply of quality feed, which is crucial for fish growth and health. Vast Coastline for Mariculture With a vast coastline, South Africa has significant potential for mariculture, which can be leveraged to expand the aquaculture sector and increase production. Research and Development Capacity The country possesses a strong research and development capacity, which can drive innovation and improvements in aquaculture practices, leading to better sustainability and productivity. Food Processing Capacity South Africa has established food processing capabilities, which can add value to aquaculture products and enhance marketability. Established Aquaculture Producer Associations The presence of established aquaculture producer associations can facilitate collaboration, knowledge sharing, and advocacy for the sector, helping to address challenges and promote growth.
<u>WEAKNESSES</u> Unprotected Open Coastal Sites Many coastal sites are exposed to high wave energy, which can pose risks to aquaculture operations and affect the sustainability of marine farming practices. Focus on High-Value Species with Low Production Output The sector tends to concentrate on high-value species, but this focus has resulted in low overall production output, limiting the potential for growth and market supply. Limited Research into Various Segments of Aquaculture There is a lack of comprehensive research across different segments of aquaculture, which can hinder innovation and the development of best practices in the industry. Lack of Extension Services The absence of effective extension services means that aquaculture producers may not receive the necessary support and information to improve their practices and productivity. Limited and Overstretched Freshwater Resources The aquaculture sector faces challenges due to limited freshwater resources, which are often overstretched, impacting the ability to sustain production levels. Absence of Functional Government Hatcheries Limited and underperforming government hatcheries can restrict access to quality fish seed, which is essential for successful aquaculture operations. Limited Suitable Land There is a scarcity of suitable land for aquaculture development, which can constrain the expansion of the sector and the establishment of new farms.

OPPORTUNITIES

Growing Demand for Affordable Protein

There is an increasing demand for affordable protein sources, coupled with a shortage of traditional fish products. This presents a significant opportunity for aquaculture to fill the gap and meet consumer needs.

Potential for Export

The aquaculture sector has the potential to tap into export markets, which can enhance revenue and contribute to the overall economy. This opportunity can help South Africa position itself as a key player in the global aquaculture market.

Government Attention and Support

The aquaculture industry is receiving increased attention and support from the government, which can lead to favourable policies and funding initiatives that promote sector growth and sustainability.

Connection with Tourism

There is an opportunity to connect aquaculture with the tourism sector, potentially attracting visitors interested in aquaculture practices and seafood experiences, thereby enhancing both industries.

Conducive Economic Climate

The current economic climate is favourable for the aquaculture industry, providing a supportive environment for investment and development in aquaculture practices.

Enabling Policies and Framework

The presence of enabling policies and frameworks can facilitate the growth of the aquaculture sector, ensuring that it operates within a structured and supportive regulatory environment that encourages innovation and investment.

THREATS

Lack of Marketing Services

There is a deficiency in marketing services, structures, and penetration, which limits the ability of aquaculture products to reach consumers effectively. This can result in reduced sales and market visibility for aquaculture businesses.

Very Low Per Capita Consumption of Fish

The per capita consumption of fish in South Africa is very low, which poses a challenge for the aquaculture sector. This low demand can restrict market growth and profitability for aquaculture producers.

Complicated Permits and Registration Procedures

The aquaculture industry is burdened by complicated permits and registration procedures, which can deter potential investors and slow down the establishment of new aquaculture ventures. This bureaucratic hurdle can create barriers to entry for new businesses.

Shortage of Expertise and Aquaculture Professionals

There is a notable shortage of skilled expertise and professionals in the aquaculture field. This lack of human resources can impede the development and management of aquaculture operations, affecting productivity and innovation.

Impact of Climate Change

Climate change presents a looming threat to the aquaculture sector, potentially affecting water availability, temperature regulation, and the overall health of aquatic ecosystems. These environmental changes can disrupt aquaculture operations and reduce productivity.

1.3. The use of promotional awareness to improve the Aquaculture Sector in South Africa

Promotional awareness can be a low-cost, high-impact approach. Utilizing social media, community workshops, and partnerships with educational institutions can effectively disseminate information without

requiring significant financial investment. This can lead to a greater understanding of aquaculture and its potential benefits, thereby attracting more individuals to the field. An example is the 'Aquaculture Public Awareness and Marketing Strategy' adopted by the Department of Forestry, Fisheries and the Environment (DFFE). Awareness initiatives and programs at various education levels have the following advantages:

- **Public Awareness:** Public campaigns can educate communities about the importance of aquaculture, its benefits, and career opportunities. This can lead to increased community support and participation in aquaculture initiatives.
- **High School Level:** Introducing aquaculture concepts in high school can spark interest among students, encouraging them to pursue careers in this field. Early exposure can help cultivate a new generation of aquaculture professionals who are knowledgeable and passionate about the industry.
- **Tertiary Education:** Promoting aquaculture programs at universities and colleges can attract students to specialized courses, ultimately increasing the number of qualified professionals in the sector. This aligns with the need for skilled human resources highlighted by Adeleke *et al.* (2021), which is crucial for overcoming challenges in the South African aquaculture industry.

To fully realise the potential of promotional awareness in addressing the shortage of expertise in aquaculture (both aquaculture centred and related), it is essential to consider the structural and strategic factors that contribute to its success. While raising awareness is crucial for sparking interest and attracting talent, the long-term impact depends on how educational institutions and industry stakeholders collaborate to sustain this interest and translate it into tangible outcomes. The following considerations highlight key elements necessary for ensuring the effectiveness and sustainability of promotional efforts at the tertiary education level.

- **Curriculum Development:** Educational institutions must develop relevant and engaging curricula that reflect current industry needs and practices. This ensures that students are equipped with the necessary skills and knowledge.
- **Industry Collaboration:** Partnerships between educational institutions and the aquaculture industry can provide students with practical experience and insights into real-world challenges and opportunities.
- **Continuous Engagement:** Ongoing promotional efforts are essential to maintain interest and awareness in aquaculture, ensuring that it remains a viable career option for students.

Therefore, promoting awareness of aquaculture at various educational levels and within various disciplines can contribute towards the shortage of expertise in South Africa's aquaculture sector. By fostering interest and providing education, this approach can lead to a more skilled workforce and a thriving industry.

1.4. Critical skills for enhancing the Aquaculture Sector in South Africa

In the context of enhancing the aquaculture sector in South Africa, it is crucial to identify and develop specific skills that are currently scarce or critical. These skills are essential for addressing the challenges faced by the industry and ensuring its sustainable growth. In 2017, the Operation Phakisa Aquaculture Skills Working Group Report, funded by the South African International Maritime Institute (SAIMI), highlighted the following general skills as vital for the aquaculture sector in South Africa. These skills are captured in the Aquaculture Skills Inventory and Needs Analysis Report, and include:

- **Technical Skills:** Proficiency in aquaculture practices, including breeding, feeding, and health management of aquatic species, is essential for effective farm operations. This skill is vital for both skilled and unskilled labour in the sector.

- **Business Management:** Understanding business principles, including budgeting and financial management, is necessary for aquaculture farmers to ensure sustainability and profitability.
- **Problem-Solving Skills:** The ability to identify issues and develop effective solutions is critical, especially in a sector facing various environmental and economic challenges.
- **Soft Skills:** Skills such as communication, teamwork, and leadership are important for fostering a collaborative work environment and improving overall productivity.
- **Regulatory Knowledge:** Familiarity with local and international aquaculture regulations and standards, including environmental and health regulations, is necessary for compliance and sustainability.
- **Research and Development Skills:** The ability to engage in research and apply findings to improve practices is essential for innovation in the aquaculture sector.
- **Marketing Skills:** Understanding market dynamics and consumer preferences can help aquaculture businesses effectively promote their products and expand their market reach.
- **Technical Training:** Continuous education and training in new aquaculture technologies and methodologies are vital for keeping pace with industry advancements.
- **Environmental Awareness:** Knowledge of sustainable practices and environmental conservation is crucial for minimizing the ecological impact of aquaculture operations.
- **Quality Control:** Skills in monitoring and ensuring product quality through various stages of production are essential for maintaining standards and consumer trust.
- **Networking Skills:** Building relationships with stakeholders, including suppliers, customers, and regulatory bodies, can enhance collaboration and resource sharing.
- **Cultural Competence:** Understanding and respecting the diverse cultural backgrounds of workers and consumers can improve workplace dynamics and market acceptance.
- **Adaptability:** The ability to adjust to changing market conditions, technologies, and regulations is vital for long-term success in the aquaculture sector.

The report specifically highlighted 13 skills considered scarce or critical by managers and experts in the South African aquaculture industry for advancing the sector. Many of these skills are also perceived as scarce yet essential by aquaculture farm assistants, farmers, and managers. These skills are aligned with the future needs of the industry and are critical for ensuring its sustainable growth. They are given below:

- Management skills
- Business skills
- Practical skills fish knowledge technical skills
- HACCP systems management
- Hatchery biological skills
- Technical skills (Plumbing, electrical and welding)
- Industry packaging specialists
- Aquaculture Veterinary specialists
- Aquatic animal health specialists
- Designing and building aquaculture systems
- Qualified skippers in the mussel and oyster industries
- Qualified divers in the mussel and oyster industries
- Feed manufacturing knowledge

The SAIMI (2017) report highlighted that these skills shortages could hinder the growth of the aquaculture sector, making it imperative to address them to meet the ambitious growth targets and associated benefits. However, the report noted that due to the small size of the sector, developing full aquaculture-specific qualifications was often deemed impractical. Instead, SAIMI (2017) recommended integrating aquaculture modules into existing related qualifications offered at educational institutions. This approach not only aims to address critical skills shortages but also serves as a strategic initiative to raise awareness of aquaculture's importance within the broader agricultural landscape and equip future professionals with essential knowledge and skills.

The aim of this project is to address both the current and future skills requirements of the aquaculture sector by exploring opportunities to incorporate aquaculture modules into existing qualifications at institutions of higher learning in South Africa. This approach seeks to meet the sector's specialized skills needs by increasing exposure to aquaculture through an interdisciplinary educational framework.

2. Methodology

This study aimed to address the skills shortages in the South African aquaculture sector by investigating the potential for integrating aquaculture modules into existing qualifications at South African institutions of higher learning (IOHLs). The methodology was based on foundational reports, including the *Aquaculture Skills Inventory and Needs Analysis Report* (SAIMI, 2017) and the *Analysis of Aquaculture Infrastructure Available for Training, Research, and Skills Development Report* (SAIMI, 2024).

i. Assessment of Existing Qualifications

The study began with a desktop analysis of 26 IOHLs to assess current aquaculture-related qualifications. This involved identifying institutions offering qualifications with aquaculture modules, the relevant departments, and the qualifications in which these modules were embedded. The analysis also identified institutions where aquaculture-related topics could be incorporated based on the skills gaps outlined in the *Aquaculture Skills Inventory and Needs Analysis Report* (SAIMI, 2017). This research was supplemented by field trips to institutions across different provinces to verify the accuracy and applicability of the information provided on their websites and in reports. These visits allowed for confirmation of aquaculture training offerings and provided insights into staffing, curriculum gaps, and any ongoing or planned interventions in aquaculture education (**Error! Reference source not found.**). Field tours of aquaculture infrastructure and equipment were also conducted to assess current resources. Additionally, discussions with Non-Government Organizations (NGOs) and Small, Medium and Micro Enterprises (SMMEs) working in aquaculture in various provinces offered alternative perspectives on training needs, communication with government and the private sector, and challenges to growth and development.

Table 2.1 Field trips were conducted at the following Institutions to collect and verify information relating to this study.

Province	IOHL	TVET/NGO/Industry
Western Cape	Stellenbosch University	Elsenburg Agricultural Training Institute
	University of Western Cape	Vergelegen Trout Farm
	University of Cape Town	SU Aquaculture Unit
	Cape Peninsula University of Technology	
Eastern Cape	Nelson Mandela University	Tsolo Agriculture and Rural Development Institute
	Rhodes University	
	University of Fort Hare	

Province	IOHL	TVET/NGO/Industry
	Walter Sisulu University	
Limpopo	University of Limpopo	Tompi Seleka College of Agriculture
	University of Venda	
KwaZulu Natal	University of KZN	Northdene Agrihub
		Green Arch Innovation
Gauteng	University of Johannesburg	INMED Aquaponics
		Centre for Ecological Intelligence

ii. Interinstitutional Collaboration

A key focus of the study was exploring the potential for collaboration between institutions. This collaboration could take the form of internal integration of aquaculture modules or partnerships with other institutions to enhance training opportunities. The feasibility and practicality of such collaboration were assessed to ensure it aligned with the aquaculture sector's needs.

iii. Cost-Benefit Analysis

A cost-benefit analysis was conducted for three selected institutions of higher learning to evaluate the financial and logistical feasibility of integrating aquaculture modules into existing qualifications. These institutions were identified based on the coalescence of technical and research expertise, the availability and access to aquaculture infrastructure, the existing offering of aquaculture-related courses, and the potential for achieving the highest impact at the lowest possible cost. Where possible, the analysis also considered opportunities to integrate practical exposure to the aquaculture industry within the proposed modules. This evaluation accounted for the regulatory, administrative, and financial resources required for successful implementation.

iv. Development of a Business Case

The study culminated in the development of a comprehensive business case for the integration of aquaculture modules into existing qualifications. This business case considered the associated regulatory, administrative, human, and financial resources required for implementation. Additionally, it included an assessment of the necessary infrastructure and strategies needed to ensure the effective adoption of the proposed changes.

v. Stakeholder Engagement

Ongoing engagement with key stakeholders—such as industry representatives, educational institutions, and government bodies—was integral throughout the study. This collaboration ensured that the proposed aquaculture modules were aligned with the sector's needs and contributed to the broader objectives of the *Oceans Economy Masterplan* (DFFE, 2024). Stakeholder feedback helped refine the study's recommendations and ensured that they were grounded in the realities of the industry.

By employing this methodology, the study provided critical insights into the existing educational landscape, enabling an informed assessment of the potential to integrate aquaculture modules into institutions of higher learning in South Africa. This, in turn, supports efforts to address skills shortages in the aquaculture sector and strengthen the educational framework for aquaculture training.

3. Desktop Analysis

3.1. Mapping the Landscape of Higher Education in South Africa

The higher education landscape in South Africa is characterized by a diverse array of institutions, with a total of 26 public universities that cater to a wide range of academic disciplines and student needs. The map in **Error! Reference source not found.** illustrates the geographic distribution and institutional types, including traditional universities, universities of technology, and comprehensive universities (Nyar, 2019). Each institution plays a crucial role in shaping the educational experiences of students, particularly in the context of evolving academic demands and societal needs. As we delve into the inclusion of new aquaculture modules in the curricula of these universities, it is essential to recognize how these institutions are adapting to contemporary challenges and opportunities in the field of higher education. The integration of aquaculture studies not only reflects a response to the growing importance of sustainable practices in food production but also highlights the commitment of South African universities to equip students with relevant skills for the future job market.

Key for map:



TRADITIONAL UNIVERSITIES	CAMPUSES
University of Cape Town (6)	• Upper Campus, Middle & Lower Campus, Health Science Campus, Groote Schuur Campus, Hiddingh Campus and Breakwater Campus
University of Fort Hare (3)	• Alice Campus, Bhisho Campus and East London Campus
University of Free State (3)	• Bloemfontein Campus, South Campus and Qwa-Qwa Campus
University of KwaZulu Natal (5)	• Edgewood, Howard, Medical School, Pietermaritzburg and Westville Campus
University of Limpopo (2)	• Ga-Rankuwa and Polokwane Campus
University of Pretoria (7)	• Groenkloof, Hammanskraal, HPC, LC De Villiers, Mamelodi, Medical and Onderstepoort Campus
Rhodes University (1)	• Rhodes University Campus
Sefako Makgatho Health Sciences University	• Ga Rankuwa Campus
University of Stellenbosch (5)	• Stellenbosch Main Campus, Tygerberg, Bellville Park, Saldanha, Ukwanda Rural Clinical School Campus
University of Western Cape (5)	• East, North, West, South and Central Campus
University of Witwatersrand (5)	• East, West, Education, Medical and Management Campus
COMPREHENSIVE UNIVERSITIES	CAMPUSES
University of South Africa (3)	• Muckleneuk, Sunnyside and UNISA science campus
Nelson Mandela University (6)	• North, South, 2nd Avenue, Missionvale, Birdstreet and George Campus
University of Johannesburg (4)	• Auckland Park, Bunting Road, Doornfontein and Soweto Campus
University of Venda (1)	• UV Main Campus
Walter Sisulu University (4)	• Buffalo City, Butterworth, Mthata and Queenstown Campus
University of Zululand (2)	• Richardsbay and KwaDlangezwa Campus
University of Mpumalanga (1)	• UM main Campus
North West University (3)	• Mafikeng, Potchefstroom and Vanderbijlpark Campus
Sol Plaatje University (2 buildings)	• Old Legislature and William Prescod School Buildings
UNIVERSITIES OF TECHNOLOGY	CAMPUSES
Cape Peninsula University of Technology (6)	• Granger Bay, Mowbray, Wellington, Athlone, Cape Town and Belville Campus
Central University of Technology (2)	• Welkom and Bloemfontein Campus
Durban University of Technology (7)	• Brickfield, City, Indumiso, Ml Sultan, Ritson, Riverside and Steve Biko
Mangosuthu University of Technology (1)	• Umlazi Campus
Tshwane University of Technology (6)	• Nelspruit, Pretoria, Emalahlani, Polokwane, Soshanguve and Ga-Rankuwa Campus
Vaal University of Technology (4)	• Secunda, Ekurhuleni, Upington and Vaal Triangle Campus

Figure 3.1 Map of 26 Institutions of higher learning in South Africa (Nyar, 2019)

3.2. Aquaculture at Institutions of Higher Learning in South Africa

3.2.1. Current Aquaculture Modules and Sub-modules Offered at the 26 Identified IOHLs

To lay the groundwork for identifying opportunities to integrate new aquaculture modules into other faculties and departments, it is essential first to pinpoint the institutions that currently offer aquaculture-related modules or degrees. Expanding awareness and incorporating aquaculture into a broader range of academic disciplines within South Africa's higher education sector can help foster a more comprehensive understanding of its importance and potential impact.

Based on information collected from university websites and input from academics in the field, only 8 out of the 26 higher learning institutions in South Africa were identified to offer one or more aquaculture-focused modules (Figure 3.2). These institutions include Cape Peninsula University of Technology, University of Cape Town, Stellenbosch University, Rhodes University, Nelson Mandela University, University of Fort Hare, North West University and the University of Limpopo, each contributing to aquaculture education in varying capacities. The modules offered range from highly specialized courses, such as the Postgraduate Diploma in Aquaculture at Stellenbosch University, to aquaculture components integrated within broader degrees, such as the BSc in Agriculture at North West University. Table 3.1 summarizes the aquaculture-focused modules offered by the institutions, detailing course duration, credits, and associated degrees and departments.

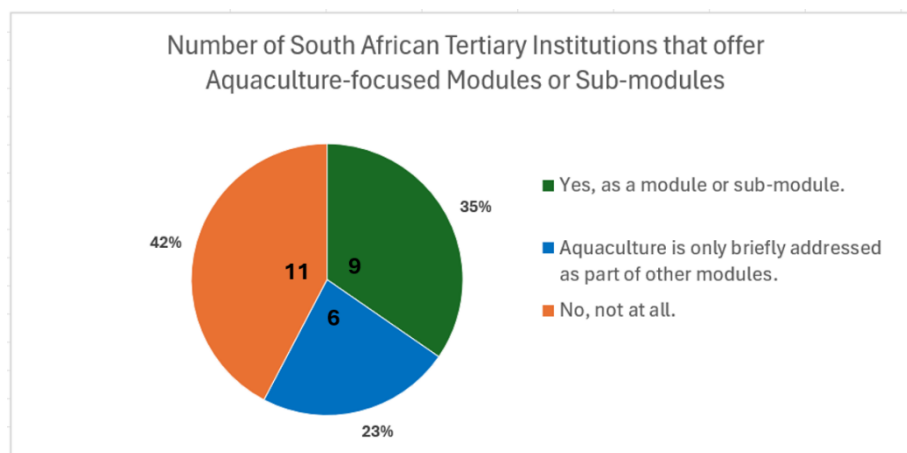


Figure 3.2: Number of IOHLs that offer Aquaculture-focused modules or sub-modules out of the 26 identified IOHLs in South Africa.

In Table 3.2 the departments, schools and institutes within South Africa's 26 institutions of higher learning (IOHLs) were identified where aquaculture modules are included; where aquaculture is only touched upon in modules; or where modules are most likely to be included. These departments primarily focus on fields related to water, aquatics, or fish, such as zoology, marine sciences, and agricultural sciences, making them the most obvious and relevant academic homes for aquaculture education. However, further investigation explored opportunities for interdisciplinary integration of aquaculture modules into less conventional departments—such as engineering, business, and agricultural economics—where aquaculture content could provide valuable skills and perspectives. Including aquaculture-related modules in these fields could enhance awareness and foster innovation, addressing critical skills required for the sector while expanding its reach across diverse disciplines.

Table 3.1: Summary of Aquaculture-focused modules or sub-modules offered by South African higher education institutions.

Province	University	Module name	Full-time Duration	Details	Department/ School/ Institute	Website
Western Cape	Cape Town University of Technology (CPUT)	Marine Aquaculture I (MAQ250S)	1 year	Year 2, compulsory module for Diploma in Marine Science	Department of Conservation & Marine Sciences	https://www.cput.ac.za/academic/faculties/appliedsciences/prospectus/course?i=452&seo=RGlwbG9tYTogTWFyaW5lIFNjaWVuY2Vz
		Marine Aquaculture II (MAQ360S)	6 months	Year 3, semester 1 elective module for Diploma in Marine Science		
	University of Cape Town (UCT)	Integrated Aquaculture	5 credits, 12 weeks	Specialised module as part of the Applied Ocean Sciences taught Master’s degree (BIO5014F)	Marine and Antarctic Research Centre for Innovation and Sustainability (MARiS)	https://maris.uct.ac.za/aos-course-structure
		Short course: Sustainable Seafood Production through Integrated Aquaculture	3 days	Summer School Short Course (January 2024 - R330.00, Staff and students R165.00)	Department of Biological Sciences	https://summerschool.uct.ac.za/sustainable-seafood-production-through-integrated-aquaculture
	Stellenbosch University (SU)	Aquaculture (46213): Aquaculture production and management systems I & II (711 & 741)	32 credits, 1 year	Compulsory modules, as part of Postgraduate Diploma in Aquaculture (6021001)	Department of Animal Sciences	https://www.sun.ac.za/english/Documents/Yearbooks/Current/AgriSciences.pdf
		Aquaculture Management Science (12910): Aquaculture review, assessment and project development I & II (724 & 754)	32 credits, 1 year			
		Aquaculture (46213): Aquaculture products (712)	16 credits, 6 months	Elective module, as part of Postgraduate Diploma in Aquaculture (6021001) (2 electives must be chosen).		
		Aquaculture (46213): Aquaculture ecology (742)	16 credits, 6 months			
		Aquaculture (46213): Aquaculture nutrition (743)	16 credits, 6 months			

Province	University	Module name	Full-time Duration	Details	Department/ School/ Institute	Website
Eastern Cape		Introduction to Aquaponic Production Systems (713)	16 credits, 6 months			
		Advanced Aquaponics Technologies (745)	16 credits, 6 months			
	Nelson Mandela University (NMU)	Aquaculture submodule in Applied Aquatic Science module (ZOOV302)	1 week of aquaculture	Given at 3 rd year of BSc in Zoology.	Department of Zoology	https://www.mandela.ac.za/getmedia/0bd96b8d-b5cc-4c60-a6a9-d596fa4396d6/Prospectus-Faculty-of-Science?disposition=attachment
	Rhodes University (RU)	Aquaculture		As part of the BSc in Ichthyology. Topics include Applied aquaculture, applied genetics, all aspects of fish biology, foundations for aquaculture.	Department of Ichthyology and Fisheries Science (DIFS)	https://www.ru.ac.za/ichthyology/studying/prospectivestudents/entryrequirementsforundergraduateichthyology/
		Aquaculture		As part of the Honours in Ichthyology and Fisheries Science. Topics include Aquaculture in Perspective, Aquaculture and the Environment, Aquaculture Nutrition, Aquaculture Systems, Integrated aquaculture, Fish health, Water quality, Aquaculture Business-planning.		https://www.ru.ac.za/ichthyology/studying/postgraduatecourses/honoursinichthyologyandfisheriesscience/

Province	University	Module name	Full-time Duration	Details	Department/ School/ Institute	Website
	University of Fort Hare (UFH)	Aquaculture submodule in Animal Ecology and Conservation I (ZOO324)	5 credits	Given at 3 rd year of BSc in Zoology.	Department of Zoology & Entomology	https://www.ufh.ac.za/departments/zoology/undergraduate
		Aquaculture submodule	8 credits	Lectured component in BSc Honours in Zoology.		
KwaZulu-Natal	University of KwaZulu-Natal	Aquaculture submodule in Applied Marine Biology (BIOL343W2)	6 lectures, 2 practicals	6 Lectures over 2 weeks; Practical 1 – Aquaculture Systems; Practical 2 – Aquaculture Species Profile.	School of Life Sciences	
North West	North West University (NWU)	Fundamentals of Aquaculture (AHDR213)	8 credits, Semester 1	2nd year module (Animal Health & Animal Science) as part of BSc in Agriculture with Animal Health (2FD K07 - N401M).	School of Agricultural Sciences	https://studies.nwu.ac.za/sites/studies.nwu.ac.za/files/files/yearbooks/2024/FNAS-UG-2024-v1.pdf
Limpopo	University of Limpopo (UL)	Four aquaculture theory modules		As part of the BSc (Honours) degree that specialises in aquaculture	School of Agriculture and Environmental Sciences	https://www.ul.ac.za/faculty-of-science-and-agriculture/school-of-agricultural-and-environmental-sciences/

Table 3.2: Departments, schools, and institutes within South Africa's 26 Institutions of Higher Learning (IOHLs) offering or positioned to include Aquaculture-related modules.

Province	University	Department/ School/ Institute	Course type	Topics covered that relate or can be related to aquaculture
Western Cape	UWC	Department of Biodiversity and Conservation Biology (BCB)	H, MSc, PhD	Marine biology, water quality, ecology, resource management, integrated aquaculture, algae & marine organisms research
		Institute for Poverty, Land and Agrarian Studies (PLAAS)	H, MSc, PhD	Small-scale fisheries (SSF), fisheries reform and transformation
	CPUT	Department of Conservation and Marine Sciences	D(U), D(A), D(P), MSc	Marine Science (marine biology, marine aquaculture, fisheries management, marine conservation, water quality)
	UCT	Department of Biological Sciences	BSc, H, MSc	Marine biology, Ocean sciences
		Department of Oceanography	BSc, H, MSc, PhD	Ocean & atmosphere science
	SU	Department of Animal Sciences	BSc, D(P), MSc, PhD	Aquaculture, aquaponics, production systems, animal management, monogastric nutrition
		Department of Genetics	BSc, H, MSc, PhD	Aquaculture genetics, animal biotechnology
Eastern Cape	NMU	Department of Zoology	BSc, H, MSc, PHD	Applied aquatic science, fish conservation, aquaculture, water quality, marine biology, resource management, ichthyology, fisheries science & management
	RU	Department of Ichthyology and Fisheries Science	BSc, H, MSc, PhD	Freshwater & marine ichthyology; aquaculture nutrition, systems, health, business management; fisheries management, stock assessment, conservation
	UFH	Department of Zoology & Entomology	BSc, H, MSc, PhD	Undergrad: Marine biology & ecology, conservation, aquaculture. Postgrad: Research on local aquaculture species
	WSU	Department of Biological & Environmental Sciences	H, MSc, PhD	Freshwater biology, recirculating aquaculture systems, aquaculture nutrition
KwaZulu-Natal	MUT	Department of Nature Conservation	D(A), BASc	Natural resource & conservation management, aquaculture for marine & coastal ecology, farming & conservation of fresh- & marine water species
	UKZN	School of Agricultural, Earth & Environmental Sciences	BSc, H	Marine biology (marine environment & systems, biodiversity, practical research skills in the field & laboratory relating to marine invertebrate & fish husbandry)
	DUT	Department of Maritime Studies	D(U), D(A), M	Nautical studies, maritime studies, marine engineering, navigation
	UNIZULU	Department of Zoology	BSc, H, MSc, PhD	Animal & freshwater ecology, introduction to aquaculture, South African freshwater fisheries, resource management, fish stock assessments

Province	University	Department/ School/ Institute	Course type	Topics covered that relate or can be related to aquaculture
Free State	CUT	Department of Agriculture	D(U), D(A), H, M	Agricultural management (Agricultural Production Techniques, animal production, agricultural engineering)
	UFS	Department of Agricultural Sciences	B, BSc, D(P), H, M, MSc, PhD	Agricultural Economics, Animal Science (Breeding, nutrition, physiology), Sustainable Food systems & development
North West	NWU	School of Agricultural Sciences	D(U), BSc, H, MSc, PhD	Animal health, animal science, agricultural economics (aquaculture & fisheries, water quality, marketing & food science, fishing methods & technology)
Northern Cape	SPU	Department of Biological & Agricultural Sciences	D(U), BSc, H	Agriculture, biological sciences
Gauteng	VUT	Department of Natural Sciences	D(U), D(A), D(P), MSc, PhD	Agricultural management (D(U) only), Biotechnology
	Wits	School of Animal, Plant and Environmental Sciences	BSc, H, MSc, PhD	Biodiversity Ecology, Conservation, Biological Sciences, Evolutionary Ecology, Medical Entomology, Parasitology
	UJ	Department of Zoology	H, MSc, PhD	Physiology, zoology, aquatic health (fish histology & histopathology, aquatic ecosystems, parasitology, resource management, water quality)
	UP	Department of Agricultural Economics, Extension & Rural Development	BSc, H, M, MSc, PhD	Agricultural economics (Agribusiness management, agricultural finance & policies, resource economics)
		Department of Animal Sciences	BSc, MSc, PhD	Animal breeding & genetics, animal nutrition, livestock production & ecology, production physiology & product quality.
		Department of Consumer and Food Sciences	BSc, H, MSc, PhD	Food science, consumer science development, nutrition
	UNISA	Department of Agriculture and Animal Health	D(U), D(A), BSc, D(P)	Animal health & diseases, zootechnology, agricultural economics & agribusiness, animal science
	TUT	Department of Animal Sciences	D(U), D(A), D(P), MSc, PhD	Animal Science, animal genetics & production, nutrition, health
		Department of Nature Conservation	D(U), D(A), D(P), MSc, PhD	Conservation, wildlife management, resource management
	SMU	Department of Biology and Environmental Sciences	H, MSc, PhD	Zoology, conservation biology, acarology and ethnobotany, fish parasitology and palaeontology

Province	University	Department/ School/ Institute	Course type	Topics covered that relate or can be related to aquaculture
Mpumalanga	UMP	School of Agricultural Sciences	D(U), D(A), B, BSc, H, M, MSc, PhD	Agriculture, animal production, post-harvest technology, agricultural extension & production management, resource management
		School of Biology and Environmental Sciences	D(U), D(A), D(P), H, BSc, MSc, PhD	Nature conservation, ecology (global change & biodiversity conservation, water resource conservation & management, aquatic ecology, fisheries & fisheries management)
Limpopo	UniVen	Department of Animal Science	BSc, MSc, PhD	Animal Science (Animal breeding, animal physiology & health, nutrition, production systems & management)
		Department of Agricultural Economics and Agribusiness	BSc, MSc, PhD	Agricultural economics, agribusiness management (production related challenges, value adding, marketing)
	LU	School of Agricultural and Environmental Sciences	H, MSc, PhD	Aquaculture
B – Bachelor’s; BSc – Bachelor of Science; BASc – Bachelor of Applied Science; H – Honours; M – Master’s; MSc – Master of Science; MASc – Master of Applied Science; D(U) – Diploma (Undergrad); D(P) – Diploma (Postgrad); AD – Advanced Diploma; PhD – Doctorate. UWC – University of the Western Cape; CPUT – Cape Peninsula University of Technology; UCT – University of Cape Town; SU – Stellenbosch University; NMU – Nelson Mandela University; RU – Rhodes University; UFH – University of Fort Hare; WSU – Walter Sisulu University; MUT – Mangosuthu University of Technology; UKZN – University of KwaZulu-Natal; DUT – Durban University of Technology; UNIZULU – University of Zululand; CUT – Central University of Technology; UFS – University of the Free State; NWU – North West University; SPU – Sol Plaatje University; VUT – Vaal University of Technology; Wits – University of the Witwatersrand; UJ – University of Johannesburg; UP – University of Pretoria; UNISA – University of South Africa; TUT – Tshwane University of Technology; SMU – Sefako Makgatho Health Sciences University; UMP – University of Mpumalanga; UniVen – University of Venda; UL – University of Limpopo.				

3.2.2. Provincial and Institutional Variations in Aquaculture Focus across South African IOHL's

Figure 3.3 illustrates the proportion of aquaculture focus across South Africa's 26 identified institutions of higher learning, categorizing them by their emphasis on marine, freshwater, or both types of aquacultures. Specifically, 5 institutions focus solely on marine aquaculture, 4 institutions focus exclusively on freshwater, and 6 institutions offer programs that cover both marine and freshwater aquaculture.

To further explore this distribution, Figure 3.4 breaks down the marine and freshwater focus by province and institution. The Western Cape, for example, has four institutions—University of the Western Cape, Cape Peninsula University of Technology, University of Cape Town, and Stellenbosch University—that emphasize marine aquaculture, with Stellenbosch University also incorporating a freshwater component. In the Eastern Cape, Nelson Mandela University and the University of Fort Hare focus on marine aquaculture, while Rhodes University and Walter Sisulu University offer both marine and freshwater aquaculture programs. A similar pattern emerges in KwaZulu-Natal, where multiple institutions, including Mangosuthu University of Technology and University of KwaZulu-Natal, cover both marine and freshwater, while the University of Zululand focuses solely on freshwater aquaculture. Institutions in other provinces, such as North-West University, also show dual focus, whereas others, such as the University of South Africa in Gauteng, the University of Mpumalanga, and the University of Limpopo, focus only on freshwater aquaculture.

These findings underscore regional variations in aquaculture focus, reflecting the potential to incorporate aquaculture education and research to local needs and resources to existing qualifications in the various universities that offer aquaculture and relevant qualifications. The concentration of marine aquaculture in coastal provinces like the Western and Eastern Cape contrasts with the inland focus on freshwater systems, highlighting opportunities to strengthen and diversify aquaculture education across South Africa.

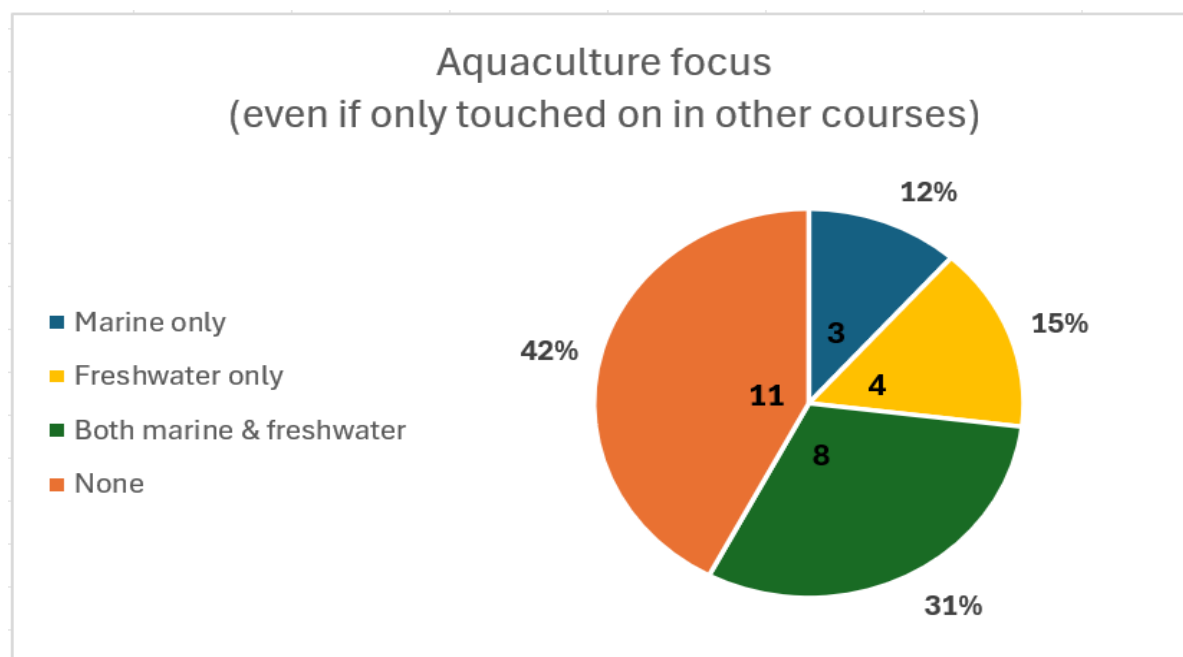


Figure 3.3:

Proportion of Aquaculture focus among South Africa's 26 Institutions of Higher Learning: Marine, Freshwater, or Both.

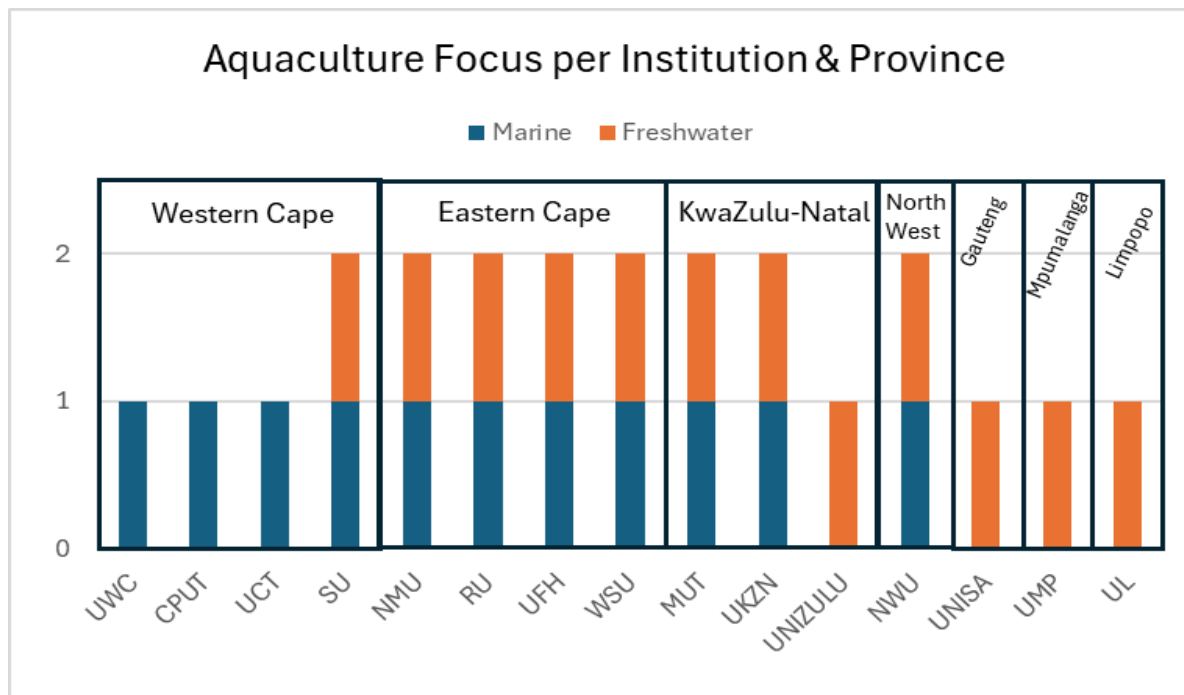


Figure 3.4: Aquaculture focus across South Africa's 26 identified Institutions of Higher Learning: Marine vs. Freshwater by province. (UWC – University of the Western Cape; CPUT – Cape Peninsula University of Technology; UCT – University of Cape Town; SU – Stellenbosch University; NMU – Nelson Mandela University; RU – Rhodes University; UFH – University of Fort Hare; WSU – Walter Sisulu University; MUT – Mangosuthu University of Technology; UKZN – University of KwaZulu-Natal; UNIZULU – University of Zululand; NWU – North West University; UNISA – University of South Africa; UMP – University of Mpumalanga; UL – University of Limpopo)

Figure 3.5 provides a summary of the key aquaculture topics covered by the 15 institutions that offer aquaculture-related modules or courses. These topics span a wide range of critical areas, reflecting the multidisciplinary nature of aquaculture education. Notably, the most commonly addressed topics include ecology, conservation, resource, and fisheries management, which are covered by 15 institutions, and water quality, addressed by 12 institutions. Topics related to health management and diseases appear in 7 institutions' curricula, while nutrition and production systems are each covered by 6 institutions.

Less commonly covered but equally important topics include business principles, aquaculture products, marketing, and food science, and IMTA (Integrated Multi-Trophic Aquaculture), each of which is taught at 3 institutions. Specialized areas such as physiology and reproduction and breeding and genetics appear less frequently, being included in the programs of only 3 and 2 institutions, respectively.

This distribution highlights the need to expand coverage of certain emerging or critical aquaculture topics, such as integrated production systems, breeding innovations, and business acumen, to ensure a comprehensive educational framework. Expanding these areas would not only enhance the depth of aquaculture education but also prepare graduates to meet the evolving demands of the sector.

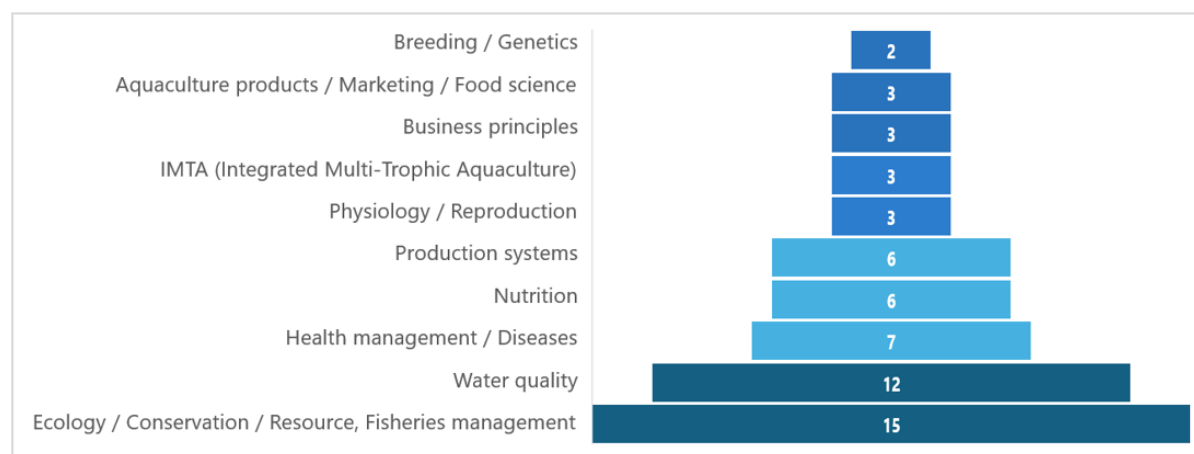


Figure 3.5: Aquaculture topics covered by Institutions offering Aquaculture-related modules or courses.

3.2.3. Availability of Aquaculture-Related Infrastructure Across South Africa's IOHL's

The availability of functional aquaculture-related infrastructure is a critical component for advancing research, training, and skills development. Figure 3.6 presents the number of IOHLs per province equipped with specific types of infrastructure for aquaculture research. This analysis draws on data collected from institutional websites, field tours, and the 2024 SAIMI report titled *Analysis of Aquaculture Infrastructure Available for Training, Research, and Skills Development*.

The findings highlight stark disparities in infrastructure availability across provinces. The Eastern Cape emerges as the most well-equipped province, with institutions such as Rhodes University, Walter Sisulu University, and the University of Fort Hare having access to both laboratories and recirculating aquaculture systems (RAS). Nelson Mandela University has aquaponics facilities available at their Missionvale campus in Bethelsdorp, supporting their research, educational initiatives, and the growth of products for the community.

In the Western Cape, Stellenbosch University has laboratories, RAS, and aquaponics systems. The University of Cape Town also has laboratories and RAS infrastructure in collaboration with DFFE's Marine Research Aquarium in Sea Point. Although the Cape Peninsula University of Technology (CPUT) uses the Marine Research Aquarium for work-integrated learning and internships, both CPUT and the University of the Western Cape do not currently have any functional aquaculture-related infrastructure on site.

In KwaZulu-Natal, the University of KwaZulu-Natal and the University of Zululand lead efforts, offering RAS and laboratory facilities. However, other institutions in the province, including the Durban University of Technology and Mangosuthu University of Technology, lack aquaculture-specific infrastructure, highlighting gaps in resource distribution.

Provinces such as Mpumalanga and Limpopo have unique facilities supporting aquaculture initiatives. The University of Mpumalanga has access to cages and laboratories, while the University of Limpopo provides ponds and aquaponics systems. Notably, the University of Limpopo is one of the few institutions offering degrees in aquaculture, reflecting its commitment to advancing education and research in this field.

In contrast, Gauteng, despite being a densely populated and industrialized province, demonstrates a severe lack of aquaculture infrastructure, with most institutions (e.g., University of Pretoria, University of the Witwatersrand, and University of South Africa) reporting no functional facilities. University of Johannesburg has an aquaponics system where aspects of aquaculture is taught in their Centre for Ecological Intelligence. The Free State, Northern Cape, and North West provinces similarly lag, with none of their institutions offering aquaculture-ready infrastructure.

This uneven distribution of aquaculture-related resources highlights the importance of strategic planning and investment to support aquaculture education and research. However, this disparity may also reflect the varying suitability of provinces for aquaculture, influenced by factors such as water access, market demand for fish products, and climate. In regions where opportunities for aquaculture development are limited, the focus on aquaculture education might naturally be less prioritized.

By mapping the specific infrastructure available at each institution (Table 3.3), this analysis provides a clearer understanding of South Africa's strengths and challenges in supporting aquaculture-focused initiatives. These insights can help guide targeted efforts to bridge the infrastructure gap where appropriate, while also aligning investment with regions where aquaculture education has the potential for meaningful impact on local economies and ecosystems.

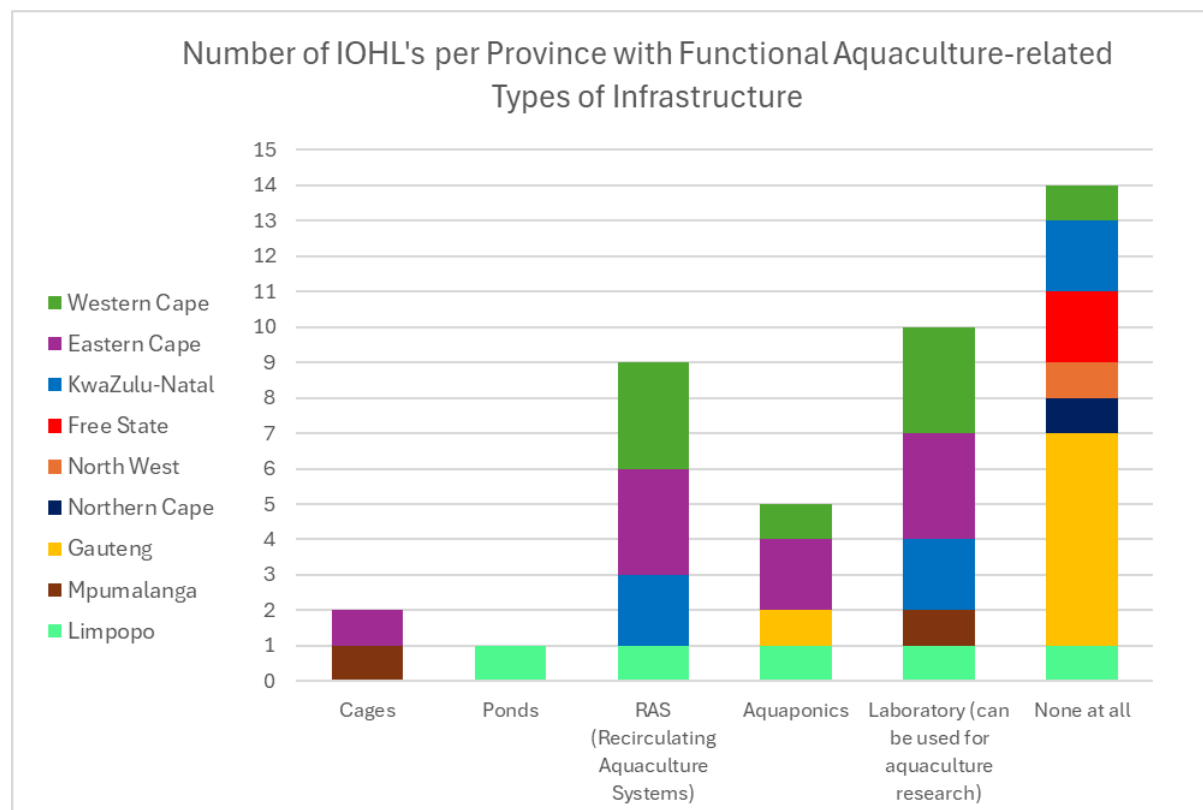


Figure 3.6: Number of IOHLs (Institutions of Higher Learning) per province with functional infrastructure available for Aquaculture research.

Table 3.3: Aquaculture infrastructure available at South African institutions by province.

Province	Institution	No Infrastructure	Cages	Ponds	RAS (Recirculating Aquaculture Systems)	Aquaponics	Laboratory (Can be used for aquaculture research)
Western Cape	UWC	X					
	CPUT				X*		X*
	UCT				X*		X*
	SU				X	X	X
Eastern Cape	NMU					X	
	RU		X		X	X	X
	UFH				X**		X
	WSU				X		X

Province	Institution	No Infrastructure	Cages	Ponds	RAS (Recirculating Aquaculture Systems)	Aquaponics	Laboratory (Can be used for aquaculture research)
KwaZulu-Natal	MUT	X					
	UKZN				X		X
	DUT	X					
	UNIZULU				X		X
Free State	CUT	X					
	UFS	X					
North West	NWU	X					
Northern Cape	SPU	X					
Gauteng	VUT	X					
	Wits	X					
	UJ					X	
	UP	X					
	UNISA	X					
	TUT	X					
	SMU	X					
Mpumalanga	UMP		X				X
Limpopo	UniVen	X					
	UL			X	X	X	X

*Make use of the Marine Research Aquarium in Sea Point. **Small scale experiments can be performed in the laboratory. UWC – University of the Western Cape; CPUT – Cape Peninsula University of Technology; UCT – University of Cape Town; SU – Stellenbosch University; NMU – Nelson Mandela University; RU – Rhodes University; UFH – University of Fort Hare; WSU – Walter Sisulu University; MUT – Mangosuthu University of Technology; UKZN – University of KwaZulu-Natal; DUT – Durban University of Technology; UNIZULU – University of Zululand; CUT – Central University of Technology; UFS – University of the Free State; NWU – North West University; SPU – Sol Plaatje University; VUT – Vaal University of Technology; Wits – University of the Witwatersrand; UJ – University of Johannesburg; UP – University of Pretoria; UNISA – University of South Africa; TUT – Tshwane University of Technology; SMU – Sefako Makgatho Health Sciences University; UMP – University of Mpumalanga; UniVen – University of Venda; UL – University of Limpopo.

4. Cost/Benefit Analysis for Aquaculture Module Integration

The following chapter presents a cost/benefit analysis for integrating aquaculture modules within departments that are aligned with the 13 critical skills identified in the SAIMI (2017) report. This analysis explores the potential for incorporating aquaculture-focused content into existing qualifications, aiming to address the skills shortages that are hindering the growth of the South African aquaculture sector.

4.1. Identification of three IOHL for Cost/Benefit Analysis

4.1.1. Critical Aquaculture Skills & Potential Departments for Incorporation

Table 4.1 outlines potential departments where aquaculture modules could be integrated to address the 13 critical skills identified by SAIMI (2017) as essential for the aquaculture industry. It also provides examples of specific topics that could be incorporated within each department to develop expertise in these skills, highlighting the relevance of aquaculture education across various academic disciplines.

Notably, certain departments such as *Animal Sciences*, *Business Management/Economics & Management Sciences*, and *Veterinary Sciences* cover a broad range of the identified skills, with overlaps in areas like business management, animal health, and technical aquaculture expertise. Departments such as *Engineering* and *Food Science* are also crucial for providing specialized knowledge in system design, hatchery management, and feed manufacturing. These departments are well-positioned to incorporate aquaculture-related modules, allowing for the development of interdisciplinary expertise that aligns with the sector's future needs. By examining the relationships between these departments and the skills shortages in the industry, this analysis provides insights into the strategic integration of aquaculture education to address these gaps.

Table 4.1: Potential departments where aquaculture modules could be integrated to address the 13 critical skills identified by SAIMI (2017) as essential for the aquaculture industry.

	Department for potential integration											
	Agriculture	Animal Sciences	Business Management / Economics & Management Sciences	Engineering	Food Science	Agricultural Economics	Zoology/ Biological Sciences	Conservation Ecology/ Environmental Science	Genetics	Microbiology	Oceanography / Marine Sciences	Veterinary Sciences
a) Management skills	Experience managing agricultural enterprises		Focus on organizational leadership techniques		Management and entrepreneurship principles	Resource and business management						
b) Business skills	Farm business operations expertise		Financial planning and operations expertise			Entrepreneurship and economic principles						
c) Practical skills: fish knowledge	Applied knowledge in farmed species	Expertise in animal physiology					Focus on fish biology		Genetic selection and breeding programs			Fish health, anatomy, and clinical practices
d) HACCP systems management			Quality assurance in food systems		Food safety protocols					Microbial risk and contamination control		
e) Hatchery biological skills	Propagation of aquatic organism	Reproductive biology and husbandry		Facility engineering and process design			Understanding reproduction and breeding	Ecosystem interactions in hatchery settings	Genetic principles in breeding	Microbial interactions in hatcheries	Marine organism breeding and cultivation	Disease prevention and management in hatcheries
f) Technical skills (Plumbing, electrical, welding)				Core engineering infrastructure knowledge								
g) Industry packaging specialists			Supply chain and marketing focus		Food packaging knowledge	Market and supply chain analysis						
	Department for potential integration											

	Agriculture	Animal Sciences	Business Management / Economics & Management Sciences	Engineering	Food Science	Agricultural Economics	Zoology/ Biological Sciences	Conservation Ecology/ Environmental Science	Genetics	Microbiology	Oceanography / Marine Sciences	Veterinary Sciences
h) Aquaculture Veterinary specialists		Health and disease in animals					Animal health and veterinary care		Genetic disorders and health management	Pathogen detection and management		Veterinary care for aquatic species
i) Aquatic animal health specialists		Focus on animal well-being			Food safety and health focus		Study of aquatic diseases and health	Environmental factors affecting aquatic health	Genetic influences on disease resistance	Microbial diseases affecting aquatic animals	Marine species health and diseases	Focus on animal health and diseases
j) Designing and building aquaculture systems				Systems design and structural expertise			Biological systems and ecosystem design	Sustainable system design and management	Genetic optimization for system sustainability		Marine-based system design and management	
k) Qualified skippers in mussel/oyster industries				Vessel design and navigation systems				Sustainable marine resource management			Marine navigation and coastal ecosystems	
l) Qualified divers in mussel/oyster industries				Safety systems and underwater technology				Environmental impact of aquaculture activities			Marine exploration and underwater ecosystems	
m) Feed manufacturing knowledge	Animal feed formulation and processing	Nutrition and feed formulation specialization	Cost analysis and market dynamics		Food production and nutrition	Economic aspects of feed production				Microbial contamination in feed production	Marine feed and nutritional requirements	

4.1.2. SU, UL, and RU as Leading Institutions for Aquaculture Curriculum Development

When selecting an IOHL as a potential leading institution for aquaculture curriculum development, several key factors must be considered. These include institutional support from various stakeholders (e.g., departments, faculties, the institution itself, government, and industry); the expertise and experience of academic and support staff; existing modules or curricula related to aquaculture that can facilitate the integration of new modules; and the availability of aquaculture infrastructure to support practical training. A summary of these components is given in Figure 4.1.

For any training program to succeed, it is crucial to have these core elements in place. This foundation enables the institution to implement the program in the short term and serves as a benchmark for regularly evaluating its success through consistent enrolment, stakeholder feedback, and follow-ups. However, external factors must also be considered when initiating clustering and collaboration, such as political will and the prevailing local and national priorities for Local Economic Development (LED) and IOHLs. These factors should be carefully considered, as they could either enhance or hinder the success of the program.

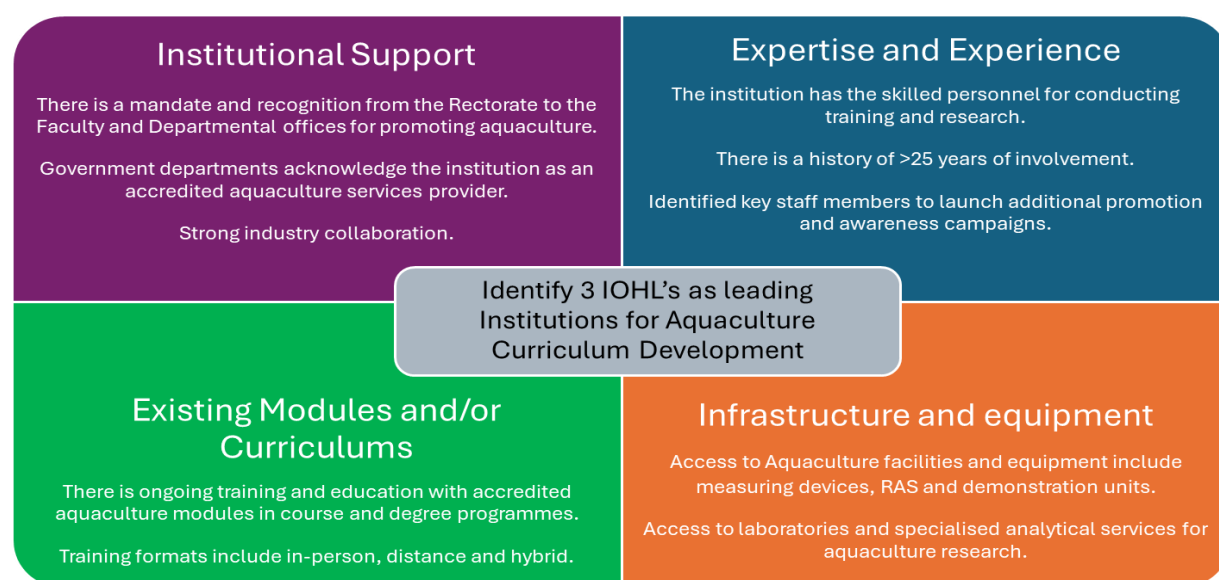


Figure 4.1 Key Components to be considered when selecting 3 IOHL's as leading institutions for aquaculture curriculum development.

Stellenbosch University, the University of Limpopo, Rhodes University and the University of Fort Hare were identified as initial candidates for a cost/benefit analysis regarding the inclusion of new aquaculture modules in their qualifications. This was supported by several factors derived from the information that was collected during this study:

Existing Infrastructure and Resources

- Stellenbosch University has established laboratories, recirculating aquaculture systems, and aquaponics systems, which provide a solid foundation for expanding aquaculture education.
- The University of Limpopo has ponds, RAS and Aquaponic systems and is noted for its commitment to advancing education and research in aquaculture, being one of the few institutions offering degrees specifically in this field.
- Rhodes University has Cage, RAS and Aquaponic systems and offers both marine and freshwater aquaculture programs, indicating a diverse approach to aquaculture education.

Diversity of Aquaculture Focus

- Collectively, these institutions cover both marine and freshwater aquaculture, which is essential for a comprehensive aquaculture curriculum. This diversity allows for a broader range of modules to be integrated, catering to various aspects of the aquaculture sector.

Potential for Interdisciplinary Integration

- As highlighted in Table 4.1, there are significant opportunities for the interdisciplinary integration of aquaculture modules into departments that may not traditionally be associated with aquaculture, such as engineering and business. The University of Limpopo offers a Faculty of Science and Agriculture with departments in Agricultural and Environmental Sciences, as well as a Faculty of Management and Law with a Department in Economics and Management. Stellenbosch University provides a diverse range of relevant departments, included within the Faculty of AgriSciences (Departments of Agricultural Economics, Animal Sciences, Food Science, Genetics), the Faculty of Economic & Management Sciences (Department of Business Management), and the Faculty of Engineering (Industrial, Mechanical, and Electrical Engineering Departments). Rhodes University also presents various integration opportunities with its Faculty of Commerce (Department of Management, Economics, Rhodes Business School) and Faculty of Science (Department of Biological Sciences). This diversity across the three institutions positions them well to integrate aquaculture modules in a way that bridges multiple fields, addressing critical skills shortages in the aquaculture sector while enhancing the overall educational offering. A summary of this information is given in Table 4.2.

Table 4.2 *Faculties and departments with potential for interdisciplinary integration of Aquaculture modules in non-traditional fields for the three identified IOHLs.*

IOHL	Faculty	Departments
Stellenbosch University	Faculty of AgriSciences	Agricultural Economics
		Animal Science
		Genetics
		Food Science
	Faculty of Economics & Management Sciences	Business Management
	Faculty of Engineering	Industrial Engineering
		Mechanical Engineering
		Electrical Engineering
Rhodes University	Faculty of Commerce	Management
		Economics
		Rhodes Business School
	Faculty of Science	Biological Sciences
University of Limpopo	Faculty of Science & Agriculture	School of Agricultural & Environmental Sciences
University of Fort Hare	Faculty of Management & Law Newly established VET Laboratory to have a critical role in the aquaculture sector	School of Economics & Management

Regional Variations and Needs

- The concentration of marine aquaculture in coastal provinces and the focus on freshwater systems inland highlight the need for tailored educational programs. These institutions are strategically located to address local aquaculture needs, making them suitable for a cost/benefit analysis.

In summary, the combination of existing infrastructure, diverse aquaculture focus, potential for interdisciplinary integration, and a commitment to education and research positions Stellenbosch University, the University of Limpopo, and Rhodes University as initial candidates for a cost/benefit analysis regarding the inclusion of new aquaculture modules in their related qualifications.

Figure 4.2 highlights the core strengths for the three selected IOHL's based on their institutional arrangement, history of presenting aquaculture curriculum and having key staff to promote and present the academic education and training.

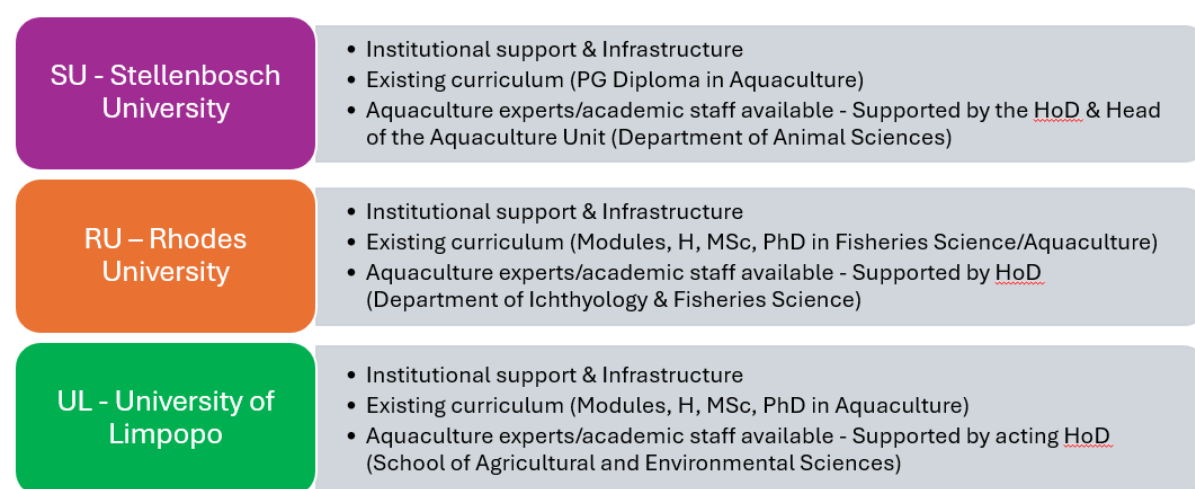


Figure 4.2 Summary of selected IOHL's with three key elements justifying as leading institutions. (PG – Postgraduate, H – Honours, MSc – Master of Science, PhD – Doctorate, HoD – Head of Department)

The three aforementioned IOHLs have demonstrated both motivation and a willingness to collaborate, supported by their existing full or partial aquaculture curricula and dedicated individuals committed to driving the process forward from 2025. This strategic approach is considered the most rational path to successfully incorporating aquaculture modules, offering the potential for maximum impact while minimizing costs.

4.2. Cost/Benefit Analysis of Aquaculture Curriculum Integration

The cost/benefit analysis evaluates the financial and practical implications of integrating aquaculture modules into the curricula of three identified IOHLs. The purpose of this analysis is to assess the feasibility of integrating aquaculture modules into existing qualifications at Stellenbosch University, Rhodes University, University of Limpopo and the University of Fort Hare where the analysis evaluates costs (financial, resources, time) and benefits (educational impact, industry exposure, skills development) to determine whether the integration is worthwhile. Two approaches were considered:

Approach 1: Incorporating new aquaculture modules into the accredited curricula of various departments at the IOHLs, with credit allocation.

Approach 2: Introducing basic lectures on aquaculture principles and practices in relevant departments to broaden academic offerings, attract new entrants and promote interdisciplinary postgraduate research.

4.2.1. Cost/Benefit Analysis for Stellenbosch University

Approach 1: Semester Aquaculture Module

Introduce a 16-credit semester module on aquaculture principles and practices in the second year (for 3-year Bachelors degrees) and third year (for 4-year Bachelors degrees) in Departments that will encourage interdisciplinary collaboration such as the Department of Process/Mechanical Engineering, Agricultural Economics, and/or Food Science.

Cost:

- Appointment of a lecturer/facilitator at R780,000 p.a. to coordinate and present the module for a 13-week semester (if incorporating this workload into an existing lecturer's portfolios is not feasible).

Benefits:

- Provides students with detailed knowledge of aquaculture principles and practices.
- Raises awareness and fosters interest in aquaculture as a career.
- Addresses skills shortages in South Africa's aquaculture sector.
- Offers the opportunity for students to register for the aquaculture module from any other degree programme, provided that they meet the prerequisite and requirements

Barriers:

- Curriculum development under the Department of Higher Education and institutional processes requires 3–5 years, delaying student registration until as late as 2029.
- Justification of the module's financial model depends on achieving minimum student number enrollment targets.

Approach 2: Introductory Aquaculture Lectures

Conduct promotional and awareness lectures in key departments to educate students about aquaculture, highlight opportunities for diversifying their academic qualifications, promote interdisciplinary research, and align with the skill requirements of the aquaculture sector (SAIMI, 2017).

Cost:

- Minimal, as existing staff can present the lectures. Coordination with departments will determine scheduling and the number of lectures. A typical semester consists of 13 weeks and includes 39 lectures.

Benefits:

- Provides students with an introduction to aquaculture and career opportunities in the field.
- Provides awareness and industry exposure to students with limited or no prior aquaculture knowledge while addressing the skills shortage in the sector.
- Facilitates interdisciplinary research in honours, masters and PhD.

Barriers:

- Limited space and time in already packed academic programs.
- Potential negative perceptions of aquaculture and low staff motivation to include it.

Short-, Medium-, and Long-Term Options Going Forward

Short-Term (from 2025):

- Deliver introductory aquaculture lectures/guest lectures in relevant departments (e.g. Animal Sciences, Agricultural Economics, Food Science and Genetics) to raise awareness and create interest.

Medium-Term (Submit in 2025 for introduction in 2028):

- Introduce a semester-long aquaculture module in the final year of relevant degrees at Departments such as Process/Mechanical Engineering, Agricultural Economics, Animal science and/or Food Science.

Long-Term:

- Introduce a taught Master's program with coursework in year one and a thesis in year two. Unlike a thesis-only program, this structure allows students to first build essential aquaculture knowledge and skills through coursework before undertaking research, making it more accessible to those without prior aquaculture experience, both locally and internationally.

5. Business case for Aquaculture Module Integration

A business case takes a broader view and considers all resources required for the implementation of the proposed intervention, including regulatory, administrative, human, and financial resources.

5.1. Regulatory and Administrative Process

The Higher Education Qualification Sub-Framework (HEQSF), published by the Council on Higher Education (CHE) in 2013, stipulates clear guidelines for the introduction or modification of academic programs:

A new program request is submitted under the following conditions:

- i. The program has not previously existed at a specific higher education institution.
- ii. Substantial changes have been made to an existing program (i.e. drastic modifications of the module's purpose, outcomes, field of study, mode of teaching, or site of delivery).

These programmatic changes may arise due to:

- Developments or advancements in the field of study or domain of practice.
- Recommendations for review and renewal of programs following self-evaluation or external peer review processes.
- Implementation of new or revised minimum education and training standards prescribed by statutory professional bodies (e.g., ECSA, HPCSA).
- Curriculum transformation initiatives.

In such cases, internal and external approvals are required from relevant national governing bodies, including the Department of Higher Education and Training (DHET), the Council on Higher Education, and the South African Qualifications Authority (SAQA).

Where a program has already been approved by the DHET, accredited by the CHE, and registered by SAQA, minor changes—defined as less than 50% of the content or structure, or minimal adjustments to the outcomes or purpose—can be approved through the institution's internal structures. Any changes that have subsidy implications must still be reported to the DHET. Importantly, both the DHET and CHE require that the Senate, as the highest academic authority of the institution, approve any modifications to an academic offering.

Although each higher education institution follows its own internal processes for curriculum restructuring, these processes aim to maintain high academic standards. At Stellenbosch University, for example, amendments to programs, such as the addition of new modules, replacement of existing modules, or changes to current modules, must go through specific internal approval structures to ensure the quality and relevance of the academic offering.

5.2. A typical approval process for introducing a New Module at an IOHL

Phase 1: Consultation and Discussion

Proposed changes are discussed in consultation with key stakeholders, including advisors from the Centre for Learning Technologies and academic advisors within the faculty. The process is led by the Faculty's Academic Committee representative of the department in which the module/course resides. Additional input may come from the Centre for Academic Planning and Quality Assurance and, where relevant, the Hybrid Learning or

Learning Technologies office. If the changes affect multiple faculties, cross-departmental and inter-faculty consultations are required, with the involvement of the Vice-Dean for Teaching and Learning.

Phase 2: Faculty Approval

All proposed changes must be reviewed and approved by the Faculty's Academic Committee and Faculty Board. This step ensures that the disciplinary context and academic integrity of the changes are thoroughly evaluated in the interest of both the students and the academic offering.

Phase 3: Institutional Evaluation and Review

Proposed program changes, including updates to yearbooks (which function as the academic contract with students), are reviewed by the institutional Programme Advisory Committee (PAC). The PAC comprises representatives from key support services (e.g., Information Governance, Academic Planning and Quality Assurance, Registrar's Division, Library, and Teaching and Learning) and academic and faculty management from all ten faculties of the institution.

Submitted changes are rigorously evaluated by PAC members, who compile a preliminary report outlining questions for clarification and recommending amendments to enhance the submission's quality. Revised submissions are then discussed at a PAC meeting, where a final report with findings and recommendations is prepared. This report is submitted to the Academic Planning Committee (APC), which functions as the Senate's academic subcommittee.

Phase 4: Senate Approval

The finalized submission, once approved by the Faculty Board, is presented to the Senate for consideration. Alongside the submission, the Senate reviews the APC report, which confirms that the proposal has been thoroughly evaluated and amended where necessary.

Upon Senate approval, any changes that need to be reported to the DHET are documented in a formal DHET amendment report, signed by the Registrar. Approved program changes are implemented in the following academic year, as students must be informed of the updates in advance.

This outlined process ensures alignment with SAQA curriculum standards and follows the internal procedures of the specific higher learning institution.

5.3. Human and Financial Requirements

The human and financial resources needed to implement an aquaculture curriculum are outlined in the cost-benefit section. The three selected IOHLs possess the necessary expertise and infrastructure to adopt Approach 2, which involves delivering a series of promotional and awareness lectures across various departments. This approach effectively leverages existing resources, providing a low-cost, high-impact solution for introducing aquaculture concepts.

On the other hand, integrating a fully accredited module involves a more complex regulatory process and requires alignment with the curriculum renewal cycle of academic departments, typically occurring every 3-5 years. This process, detailed further in the cost-benefit section, also demands adherence to the institution's financial feasibility model. Specifically, any new curriculum must ensure sufficient student enrolment to cover costs, generate revenue, and justify the appointment of dedicated staff.

5.4. Plan for Aquaculture Integration into Curriculums

The successful integration of aquaculture into academic curricula requires strategic planning and alignment with institutional processes to ensure the program's long-term sustainability. The following plan outlines the key steps necessary for effective implementation, from initial confirmation with academic stakeholders to continuous evaluation and potential expansion of the program. These steps, numbered 1-5, provide a structured approach to achieving aquaculture integration across identified institutions.

Step 1:

Reconfirm with the Academic Programmes Committee and departmental chairpersons regarding the proposed approaches (1 and 2) as outlined in this study. Explore further discussions with DHET on implementation.

Step 2:

Collaboratively develop deliverables with clear timeframes and schedule lectures for implementation.

Step 3:

Promote the academic offering to prospective students and relevant groups, targeting potential registrants. Begin the execution of the aquaculture curriculum integration.

Step 4:

Conduct quarterly assessments and benchmarking, incorporating a monitoring and evaluation plan. Revisit key outcomes, document challenges encountered, and provide solutions based on available local resources and expertise.

Step 5:

Evaluate the potential involvement of other IOHLs and departments located near the leading institutions and explore opportunities to expand the program to include additional IOHLs within the province. Partnerships should prioritise institutions that already offer aquaculture-related modules or demonstrate strong interest and potential to support aquaculture research and education. Even where infrastructure is limited, the presence of relevant academic programmes and institutional willingness are key indicators of success, as facilities and resources can be shared through inter-institutional collaboration. Figure 5.1 illustrates a long-term strategy for clustering IOHLs, designed to pilot and promote collective growth in the development of aquaculture education.

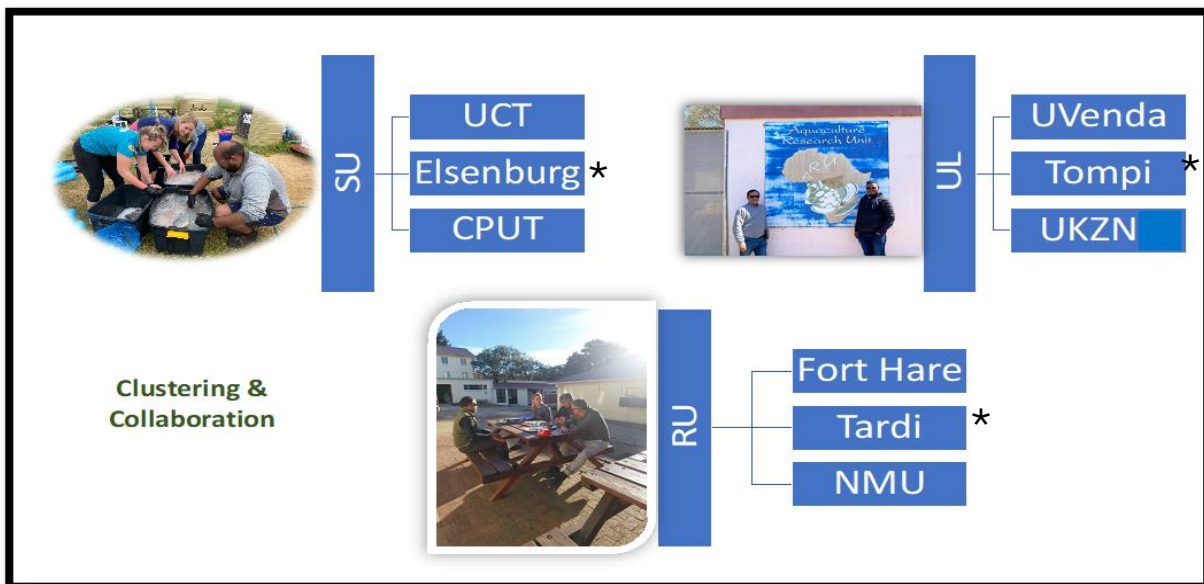


Figure 5.1: Illustrates a long-term strategy for clustering IOHLs, designed to pilot and promote collective growth in the development of aquaculture education.*Indicates Technical and Vocational Education and Training (TVET) institutions. (SU – Stellenbosch University; UCT – University of Cape Town; Elsenburg – Elsenburg Agricultural Training Institute; CPUT – Cape Peninsula University of Technology; UL – University of Limpopo; UVenda – University of Venda; Tompi – Tompi Selek College of Agriculture; UKZN – University of KwaZulu-Natal; RU – Rhodes University; Fort Hare – University of Fort Hare, TARDI – Tsoo Agriculture and Rural Development Institute; NMU – Nelson Mandela University)

It is essential to build capacity through collaboration with surrounding Historically Disadvantaged Institutions (HDIs). Therefore, it is recommended that the three identified institutions establish collaborative partnerships as a strategic approach to developing aquaculture education in the longer term. An example of proposed partnerships are as follows:

- Stellenbosch University (SU) in partnership with University of Cape Town (UCT) and Cape Peninsula University of Technology (CPUT), along with the Elsenburg Agricultural Training Institute (a TVET institution).
 - The University of Cape Town, while not primarily focused on aquaculture, contributes to the broader field through its strengths in marine biology, environmental sciences, and oceanography. The university makes use of the Marine Research Aquarium in Sea Point as a key facility for experimental marine research, supporting practical and applied studies in marine ecosystems. Research at UCT often addresses ecological, climate, and systems-level questions that are highly relevant to sustainable aquaculture development. As such, UCT holds potential as a valuable partner in interdisciplinary aquaculture research and could play a supportive or complementary role in collaborative programs, especially in postgraduate training, environmental monitoring, and/or marine spatial planning related to aquaculture.
 - The Cape Peninsula University of Technology brings applied, career-focused strengths to the aquaculture education and research landscape. The institution offers academic programmes in marine sciences, biotechnology, and environmental health, which can complement aquaculture training. CPUT's emphasis on practical skills development, coupled with its strong ties to industry and coastal communities, makes it a valuable partner for applied aquaculture initiatives. While aquaculture may not yet be a core academic offering, CPUT's capacity for work-integrated learning and technical training provides a platform for expanding aquaculture-focused modules or short courses. In partnership with Stellenbosch University

and UCT, CPUT can play a key role in broadening access, building regional capacity, and promoting innovation in sustainable aquaculture practices.

- Elsenburg Agricultural Training Institute is a strategically positioned TVET institution with a long-standing reputation in agricultural education and training in the Western Cape. Its focus on practical, hands-on agricultural skills, combined with formal qualifications ranging from learnerships to diplomas, makes it an ideal partner for expanding aquaculture education and training. Elsenburg's existing infrastructure and expertise in animal production, water management, and farm systems provide a solid foundation for integrating aquaculture into its offerings. Additionally, its close affiliation with the Western Cape Department of Agriculture enhances its potential for facilitating policy-aligned, community-focused, and extension-oriented aquaculture training. Including Elsenburg in a multi-institutional partnership with SU, UCT, and CPUT would strengthen the value chain from foundational skills development to advanced research, promoting inclusive and practice-driven aquaculture capacity-building in the province.
- University of Limpopo (UL) in partnership with University of Venda (UniVen) and the University of KwaZulu-Natal (UKZN), along with the Tompi Seleka College of Agriculture (a TVET institution).
 - The University of Venda is well-positioned to support aquaculture development through its Faculty of Science, Engineering and Agriculture, which integrates agricultural sciences with natural resource management. Located in a rural setting with access to water systems and strong community engagement, UniVen can play a vital role in community-based aquaculture research, extension services, and aquaculture-in-agriculture integration, especially in areas such as nutrition, water quality, and sustainable farming systems. Its existing agricultural focus creates natural alignment with aquaculture training and outreach.
 - The University of KwaZulu-Natal (UKZN) brings strong academic capacity in marine biology, environmental science, water resource management, rural development, and food systems — all of which are integral to interdisciplinary aquaculture research. With campuses situated near both coastal and inland water bodies, UKZN is well-positioned to contribute to ecological assessments, climate-resilient aquaculture strategies, and policy-relevant research. While not based in Limpopo, UKZN has demonstrated experience in inter-institutional collaboration, donor-funded initiatives, and curriculum reform. Its inclusion in the cluster would enhance the national academic footprint and contribute meaningfully to aquaculture initiatives through postgraduate supervision, curriculum co-development, and inter-university support. This collaboration would also provide UKZN with opportunities to strengthen its applied research profile and further its contribution to national food and water security.
 - Tompi Seleka TVET College, with its strong agricultural focus and mandate for vocational and technical training, provides an essential skills-development platform in Limpopo. Its existing programmes in crop and animal production offer a solid foundation for integrating aquaculture modules, short courses, and practical training into the TVET space. As a rural-based institution, it is ideally placed to promote youth engagement, entrepreneurship, and community-based aquaculture initiatives, especially where formal higher education may be less accessible. Its participation ensures that the aquaculture pipeline includes entry-level and technician-level training, which is critical for a functional and inclusive sector.

- Rhodes University (RU), in partnership with University of Fort Hare (UFH) and Nelson Mandela University (NMU), along with the Tsolo Agriculture and Rural Development Institute (TARDI) a TVET institution.
 - The University of Fort Hare has made significant strides in developing its aquaculture research and academic offerings and their commitment to agricultural sciences, sustainable development, and rural empowerment provides a solid foundation for expanding its aquaculture capacity. The university has established research initiatives focused on the integration of aquaculture into rural development and smallholder farming systems, which are critical for food security in the region. Emerging capabilities in agricultural sciences and a growing focus on sustainable rural development positions UFH as a key partner for expanding aquaculture training in under-served regions. Its commitment to community engagement and smallholder development offers a valuable platform for scaling aquaculture initiatives that are inclusive, context-appropriate, and aligned with national food security goals. UFH's involvement will help bridge academic research with on-the-ground implementation.
 - Nelson Mandela University, with its coastal campuses and expertise in ocean sciences, fisheries, and environmental sustainability, is uniquely situated to contribute to coastal aquaculture research and innovation. The university's strong research infrastructure, multidisciplinary orientation, and partnerships with government and industry make it a strategic player in advancing both the science and socio-economic dimensions of aquaculture. NMU's inclusion ensures that the cluster benefits from expertise in coastal and marine ecosystems.
 - The Tsolo Agriculture and Rural Development Institute offers critical vocational and technical training for rural youth and smallholder farmers, serving as an essential bridge between academic institutions and practical field implementation. With its agricultural focus and community-based orientation, TARDI is well-positioned to support hands-on aquaculture skills development, extension services, and incubation programs. Its participation will ensure that aquaculture education and training remain accessible, context-relevant, and geared toward rural livelihoods.

These partnerships focus on institutions with relevant academic programs or strong interest in aquaculture, and emphasize building capacity through collaboration, particularly with Historically Disadvantaged Institutions (HDIs). While this is an example of potential cluster collaborations, other institutions could also be included, and the approach can be adapted to different regional contexts.

6. Future Recommendations

The following are future recommendations to consider for enhancing aquaculture education and its integration into South Africa's academic landscape:

- In addition to integrating aquaculture into the curriculum or awareness programs, prospective students should be informed about the undergraduate and postgraduate programs available at South African IOHLs.
- Scholarships should be made available to target student registrations, specifically to advance their studies in aquaculture.
- Regular interactions with industry partners could provide employment opportunities through internships or new staff intakes.

- The voices of aquaculture entrepreneurs, SMMEs, and service providers should be included in strategic planning sessions, research projects and outreach efforts.
- Future training should encompass broader value chain aspects, such as the valorisation of fish farming byproducts, to create livelihoods beyond conventional fish farming, i.e. fish skin leather tanning, calcium extraction from bones and shells, isolating cosmetics ingredients, and fish oils from by-product silage.
- The aquaculture sector's right to exist should be supported by measurable deliverables, such as primary production figures, *per capita* fish consumption, and informal trading activity.
- All efforts should focus on involving more HDI institutions in collaborative training and research and development projects to build capacity.
- A service provider should be identified and supported to lead and champion the aquaculture training portfolio.

7. Conclusion

This study highlights the current state of aquaculture education in South Africa, emphasizing the need to expand the capacity of higher education institutions to support the sector's growth. A desktop analysis revealed that only nine of the country's 26 Institutions of Higher Learning (IOHLs) offer one or more aquaculture-focused modules, underscoring a significant gap in the availability of aquaculture training. This limitation presents an opportunity to broaden access to aquaculture education and enhance institutional participation to meet the growing demands of the industry.

A comprehensive assessment of critical skills essential for the aquaculture sector, informed by SAIMI's 2017 analysis, highlighted areas where capacity development is needed. Departments such as engineering, agricultural economics, and business management could integrate aquaculture-focused modules into their final-year curricula to raise awareness and promote skills development in the sector. This approach would help address industry gaps, support the adoption of advanced technologies like Recirculating Aquaculture Systems (RAS), and encourage innovative practices, ultimately fostering growth and competitiveness in South Africa's aquaculture industry.

Stellenbosch University (SU), the University of Limpopo (UL), University of Fort Hare and Rhodes University (RU) were identified as strong candidates on a cost-benefit analysis for the inclusion of new aquaculture modules in their curricula. These institutions were selected based on their existing infrastructure, diverse aquaculture focus, potential for interdisciplinary integration, and alignment with regional needs. SU, with its advanced laboratories, recirculating aquaculture systems, and aquaponics facilities, is well-positioned to expand aquaculture education, leveraging its expertise across marine and freshwater systems. RU and UFH, in the Eastern Cape, leverages their strategic location and marine aquaculture focus to drive industry collaboration and research, UFH covers relevant disciplines such as marine sciences, animal science (including pasture and livestock management), biotechnology, and environmental sciences. This interdisciplinary expertise can foster comprehensive aquaculture education covering fish biology, aquatic ecosystems, water quality, and sustainable farming practices. UL, situated in Limpopo, holds significant potential for promoting freshwater aquaculture and rural economic development, addressing regional disparities, and empowering underserved communities. Together, these institutions represent a strategic mix of resources, geographic coverage, and potential to deliver comprehensive marine and freshwater aquaculture education tailored to South Africa's diverse needs.

The cost-benefit analysis examined the feasibility of integrating aquaculture modules into the curricula of Stellenbosch University, Rhodes University, University of Fort Hare and the University of Limpopo by evaluating two potential approaches. The first approach involves adding accredited aquaculture modules with credit

allocation to existing programs, offering students in-depth knowledge, cross-disciplinary registration opportunities, and addressing critical skills shortages in the sector. However, this approach is hindered by the lengthy curriculum development process (3–5 years) and the need to justify financial viability through sufficient enrolment. The second approach proposes introductory lectures on aquaculture principles and career opportunities to raise awareness and provide industry exposure. While this approach is quicker to implement, it faces challenges such as limited space in academic schedules and potential resistance from staff. Both approaches highlight the potential to enhance education, promote skills development, and support the aquaculture sector, but they must address practical barriers to ensure successful implementation.

The business case for investing in these institutions demonstrated significant economic and social benefits. Strengthening aquaculture education and training at SU, UL, UFH and RU will enable South Africa to meet the demand for skilled professionals, foster job creation, enhance food security, and build capacity for sustainable aquaculture development. These initiatives align with national priorities, such as the National Development Plan (NDP) and Operation Phakisa, which aim to bolster rural development and economic growth.

In conclusion, the findings of this study underscore the need for targeted investments in aquaculture education and training in South Africa. By addressing critical skills gaps and enhancing institutional capacity, IOHLs can play a pivotal role in advancing aquaculture with strategic training interventions aligning skills development with sector growth. Collaboration between academia, government, and industry stakeholders is essential to ensure scalable, sustainable, and impactful solutions that position aquaculture as a key contributor to South Africa's economy and food systems.

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