

Aquafeed Production Opportunities within Murihiku Southland



GREAT SOUTH



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Foreword

Southland's Regional Long-Term Plan 'Beyond 2025' has identified the Aquaculture Industry as one of Southland's major economic diversification opportunities. The same strategy promotes agricultural land use change and the need to extract greater value from agricultural production. All of which will lead to a more sustainable low emissions economy. This approach is being promoted by exporters and customers alike. Over 80% of New Zealand's export markets now require Climate Related Disclosures (CRDs), and Nature Related Financial Disclosures are increasingly part of New Zealand's production efficiency landscape.

Aquaculture is recognised as one of the lowest emissions protein production systems. The New Zealand finfish aquaculture industry is currently dependent on imported feeds, leaving producers vulnerable to global supply chain disruptions, rising costs, and increasing greenhouse gas emissions. With aquaculture projected to grow nationally and globally, supply chain pressures and total emissions will increase accordingly. Uncertainty surrounding the effects of increasing harvest of Antarctic Krill and the impacts on the ocean's food chain means that alternative opportunities also need to be considered.

Southland has long been recognised for its strength in agriculture and its commitment to innovation, and low-emissions quality production. There is an opportunity to leverage this production efficiency, competitive advantages in specialist cropping, process efficiency and renewable energy to support resilient low carbon aquafeed production.

Southland and New Zealand's Aquaculture industry has a relatively small but growing feed demand for finfish aquaculture. Establishing a full aquafeed production capability in Southland would require advanced technical expertise, significant capital investment, sufficient scale and a long development timeframe. However, the opportunity to produce high-quality aquafeed input crops, ingredients and protein locally remains worthy of further consideration.

Southland's highly versatile soils, temperate climate, and established agricultural base provide the foundation for cultivating sustainable feed ingredients locally, aided by new protein production systems. Localised aquafeed production can reduce reliance on imports, cut transport emissions, and create new revenue streams for farmers and businesses. This would provide both land use change opportunities and diversified economic opportunity which aligns with consumer demand for sustainable, traceable products and could position Southland as a leader in regenerative aquaculture crops and protein production systems.

This report sets out the pathways to achieve that vision. It identifies numerous potential crops, ingredients, and explores how Southland can leverage its natural advantages to build a resilient aquafeed supply chain. By doing so, we will not only meet goal 14 of the Murihiku Southland Aquaculture Pathway 2025 but also unlock new opportunities for land use diversification and export growth.

Together, we can transform Southland's aquaculture sector into one that is sustainable, competitive, and future-focused, delivering benefits for our environment, our economy, and our communities.



Executive Summary

Production Opportunities within Murihiku Southland

This report assesses the feasibility of producing more localised, sustainable aquafeeds in Southland and the lower South Island, as an alternative to traditional aquafeeds. While focused on Chinook and Atlantic salmon, the potential for use across other finfish species is also considered.

There appears to be an opportunity to develop a commercial aquafeed industry within Murihiku Southland. This report directly aligns with the Murihiku Aquaculture Pathway, specifically Project 14 (pg 61) of the pathway, to focus on local aquafeed opportunities. Building on Southland's climate, soils and coastal access, the study examines a range of locally viable aquafeed ingredients, including land-based crops, aquatic resources such as microalgae and seaweeds, insect-based protein from black soldier fly larvae (BSFL), and by-product from shellfish processing. This report does not attempt to evaluate the consenting of natural harvest of seaweed and shellfish to support an aquafeed industry.

The report identifies several potential crops and ingredients as key contributors towards more localised and sustainable aquafeeds. Investment in a full scale processing plant would require a secured off take in market of 30,000 tonnes per annum. Crops have been chosen for their functional properties and growing suitability as cool climate crops. Formulations are untested but provide an indicative order of magnitude of future crop and feedstock volume requirements.

Agronomic profiles and growing conditions for each crop are detailed within this report, with maps in the Appendices highlighting the capacity of Southland's soils to support these crops. Some crops have never been grown for cropping purposes and harvest systems will require optimisation.

Insect-based systems, particularly BSFL, present a circular economy opportunity by converting organic waste into nutrient-rich feed ingredients and biofertilizers. Marine resources like green-lipped mussels, bladder kelp and sea lettuce offer additional sustainability benefits through waste stream use, carbon sequestration and water purification, as well as high yields over minimal space. Southland is well-positioned to lead sustainable aquafeed innovation, supported by its agricultural capacity, clean coastal environment and a desire to address the growing demand for ethically and sustainability produced aquaculture feed.

Recommendations enabling the development and implementation of local, sustainable aquafeed production include conducting feasibility studies such as composition testing and cost modelling; initiating pilot trials with aquaculture industry partners; engaging with regulators; preparing a capital investment plan and business case; building cross-sector industry partnerships; and developing consumer-facing transparency tools. These steps will validate commercial viability, ensure compliance and support market readiness.

This initiative not only supports environmental and economic goals but could also position Southland as a national leader in regenerative aquaculture systems.



Potential Ingredients



Barley and
Wheat



Potato



Microalgae



Oats



Camelina



Bladder Kelp



Fava Beans



Canola
(Rapeseed)



Ulva sp.



Lucerne



Flaxseed
(Linseed)



Mussels



Lupins



Kale



Black Soldier
Fly Larvae



Peas



Purslane



Context: Challenge & Opportunity

STRATEGIC VISION

The vision is to establish a resilient, locally sourced aquafeed supply chain that transforms Southland and New Zealand's aquaculture industry, enables land use diversification, and increases the value of regional exports through sustainable innovation.

Salmon farming is projected to grow substantially over the coming decades, with national production expected to reach or exceed 75,000 tonnes per annum by 2040. This growth trajectory will significantly increase demand for reliable, high quality aquafeed. Ensuring security of feed supply will therefore be critical to supporting industry expansion and safeguarding the long term resilience of the salmon farming sector.

CHANGING MARINE CONDITIONS

Rising sea temperatures are already altering species distribution in southern New Zealand waters, with direct implications for the future composition of aquaculture and the feeds required to support it. Evidence from Fiordland, Rakiura (Stewart Island) and the wider Foveaux Strait shows an increasing presence of warm water and subtropical finfish species, including kingfish, snapper, trevally, tuna and kahawai.

These shifts reflect broader ocean warming trends and indicate that southern aquaculture environments will eventually transition away from strictly cold water systems. As species composition changes, aquaculture production profiles will also evolve. This creates a strategic imperative for aquafeed systems that are adaptable, nutritionally flexible, and capable of supporting a broader range of finfish species beyond salmon alone. Developing feed ingredient pathways with cross species applicability strengthens long term resilience in the face of climate driven ecological change. Shallow aquaculture farming sites are expected

to be more vulnerable to change relative to deeper open ocean environments. During recent years there has been a significant decline in the catch of Chinook Salmon in the South Island rivers.

VULNERABILITY OF CHINOOK SALMON AND CLIMATE RISK

Rising sea temperatures are directly contributing to increased mortality in Chinook (King) salmon. Chinook hearts are highly sensitive to heat, and even small temperature increases can reduce cardiac capacity, limit oxygen delivery, and rapidly impair swimming performance. Once waters exceed their thermal tolerance, salmon experience severe cardiac stress and mortality rates rise sharply.

Chinook salmon begin to experience physiological heat stress at temperatures above 17°C, with increasing mortality as oxygen delivery and cardiac performance are impaired. Southern South Island sea temperatures already approach this threshold during warmer summers, with recorded temperatures in Fiordland reaching approximately 16.5°C during the 2025/26 season. At current rates of warming, more frequent temperature anomalies are likely within the next decade.

This trajectory suggests that a business as usual, Chinook only aquaculture model is unlikely to remain viable over the full lifespan of future investments. Diversifying toward more temperature tolerant species such as yellowtail kingfish, hāpuku (groper), or other warm temperate finfish should therefore be considered as part of a prudent transition strategy. Aquafeed system design should consider the possibility of a transition in the farmed species to maximize the feasibility in the feed processing plant. Future species shift in mind can reduce stranded asset risk while enabling smoother industry adaptation as environmental conditions continue to change.

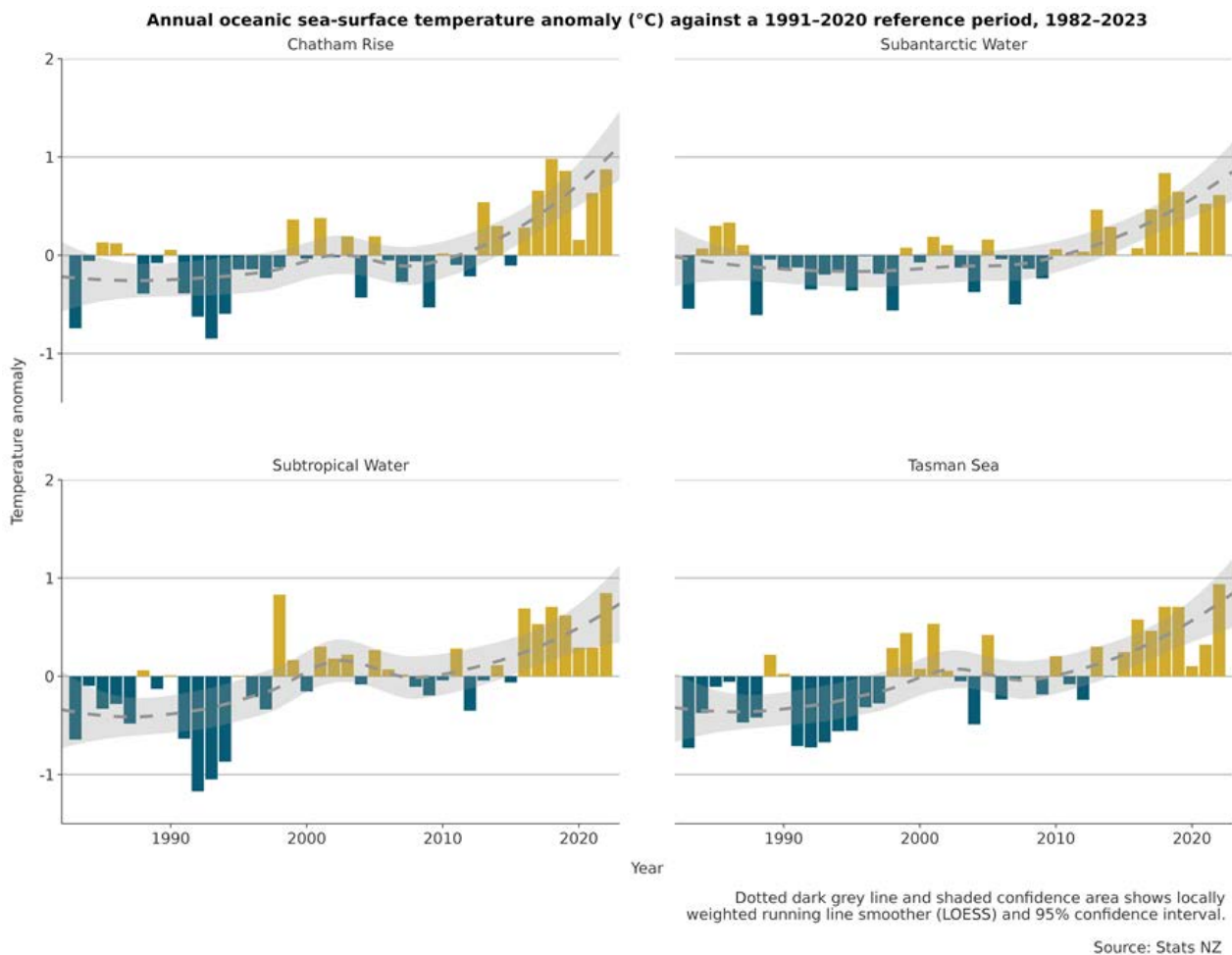


Figure 1: Annual oceanic sea-surface temperature anomaly (°C) against a 1991-2020 reference period, 1982-2023

DISEASE PRESSURE AND ANTIBIOTIC RISK

Rising sea temperatures also compound disease risk and mortality in intensive finfish aquaculture, amplifying the importance of feed formulation, fish health resilience and multispecies flexibility. In New Zealand, summer mortality events have resulted in losses exceeding 10% of national salmon production in some seasons, while international examples illustrate even higher mortality rates in warming marine environments where multiple stressors intersect.

Florfenicol is commonly used in salmonid diets to manage diseases such as Bacterial Kidney Disease (BKD). While its use can reduce disease severity, treatment does not always lead to full recovery. The reliance on antibiotic intervention carries wider ecological and industry risks. Residues and resistant bacteria can enter surrounding waters, potentially affecting non target species (including rock lobster and other fish populations, as observed in Tasmania, Australia) through microbiome disruption or antimicrobial resistance.

Antibiotic dependent disease responses also create biosecurity and trade risks, including the potential enforcement of Controlled Area Notices under the Biosecurity Act, which can result in destocking or temporary industry closure. The most recent closures in Southland occurred in 2017, due to a *Bonamia ostreae* (oyster disease) outbreak in Rakiura (Stewart Island), resulting in an industry closure. Reducing these risks requires a systems based response that includes nutritionally robust feeds, lower stress production models, and diversification into species with greater thermal tolerance. Avoiding antibiotic use wherever possible is therefore critical to protecting salmon health and the broader marine industries that rely on clean, uncompromised ecosystems.

RELIANCE ON IMPORTED AQUAFEED AND SUPPLY CHAIN EXPOSURE

New Zealand's finfish aquaculture industry is currently heavily reliant on imported aquafeeds, both as finished products and as raw materials. This dependency exposes producers to global supply chain volatility, rising transport costs and increased greenhouse gas emissions. With aquaculture forecast to expand nationally and internationally, demand for high quality, sustainable raw materials is expected to rise over coming decades, intensifying supply pressures and increasing prices for key components such as fishmeal, soy and specialised additives.

Southland and New Zealand has a unique opportunity to reduce this exposure by developing a locally sourced, sustainable aquafeed supply chain. Localisation can strengthen supply chain resilience while mitigating costs and emissions associated with long distance transport.

REGIONAL AND AUSTRALASIAN MARKET OPPORTUNITY

Beyond meeting domestic demand, there is substantial potential for Southland and New Zealand to supply aquafeed into the wider Australasian market. Australia's expanding finfish aquaculture sector, combined with New Zealand's comparatively small internal consumption, creates an opportunity to scale production beyond national requirements.

Access to a broader regional market would strengthen commercial viability for processors, support investment in local manufacturing capability and enable economies of scale that reduce per tonne production costs. This outward looking approach aligns with New Zealand's reputation for high quality, sustainably produced primary products, positioning locally produced aquafeed as a competitive, low emissions alternative within the Australasian supply chain.

SOUTHLAND'S STRATEGIC ADVANTAGE

The Murihiku Southland Aquaculture Pathway 2025 identifies aquafeed development as a critical enabler for industry growth. Under the goal to "grow the value of existing activity on land and water," Project 14 specifically recognises that Southland's strong agricultural sector and fertile soils provide a foundation to produce the crops required for aquafeed, while also identifying affordable solutions to improve business viability.

Southland is uniquely positioned to respond to this opportunity. The region's temperate climate, high quality soils and established agricultural infrastructure provide an ideal foundation for cultivating a wide range of land based crops. Coastal access and clean waters create opportunities for marine seaweed production, while strong agricultural and waste stream linkages support the potential integration of insect based protein systems.

BENEFITS OF LOCALISING AQUAFEED PRODUCTION

Localising aquafeed production presents multiple strategic benefits. These include:

- Improved supply chain resilience through reduced reliance on imported feed
- Environmental gains from lower transport emissions and support for regenerative farming practices
- Economic development through new revenue streams, job creation, land use change and investment opportunities within Southland
- Market differentiation that aligns with growing consumer demand for sustainable, traceable and ethically produced aquaculture products.

STRATEGIC IMPERATIVE

Great South believes there is both a significant opportunity and a strategic imperative to diversify and localise aquafeed production in Southland for New Zealand. This report provides a foundation for that transition by identifying viable ingredients, assessing regional suitability and outlining pathways for implementation.

By leveraging Southland's natural advantages and aligning with global sustainability trends, this initiative not only supports Goal 14 of the Murihiku Southland Aquaculture Pathway but positions the region more strongly at a national level as aquaculture systems transition toward regenerative and climate resilient models. Ensuring sustainable aquaculture with clear provenance is critical not only for environmental and social outcomes, but also for the long term profitability and resilience of the industry.



Introduction

Aquaculture is undergoing a global transformation, driven by rising consumer awareness, environmental imperatives and the need for resilient food systems. This report investigates the commercial-scale feasibility of producing sustainable, organic, locally sourced aquafeed in Murihiku Southland, New Zealand, specifically for Chinook and Atlantic salmon.

As traditional fishmeal and animal-derived feed ingredients face increasing scrutiny due to ecological degradation, resource scarcity, and ethical concerns, the aquaculture industry is shifting toward feed solutions that are more sustainable for aquatic species, more transparent for consumers and aligned with regenerative practices. Southland's aquaculture sector, particularly salmon farming in Big Glory Bay and processing in Bluff, is a significant regional industry poised for growth. Growing fish production both at local and market level will lead to potential growth in feed demand. Many of the suggested crops present soil and agronomic benefits for sustainable feed solutions.

Southland is uniquely positioned to lead this transition. With its fertile soils, temperate climate, abundant freshwater, coastal access and a strong agricultural base, the region offers an ideal setting for developing a resilient, circular aquafeed supply chain. By harnessing a diverse array of locally available ingredients – including land-based crops such as lupins, fava beans, peas, barley, wheat, oats, lucerne, kale, purslane, flaxseed, canola and camelina; marine resources like bladder kelp, sea lettuce, green-lipped mussels and microalgae; and insect-based proteins such as black soldier fly larvae – Southland can formulate nutritionally robust aquafeed tailored to salmon health, growth and welfare.

This initiative is not only environmentally compelling but also commercially strategic. Localising aquafeed production reduces reliance on imported ingredients, lowers transport emissions and enhances supply chain transparency, factors increasingly valued by consumers and regulators alike. Moreover, integrating circular economy principles, such as converting organic waste into insect protein, strengthens Southland's sustainability credentials

and supports regional waste minimisation goals. Developing a local aquafeed supply chain not only supports environmental goals but also presents economic development opportunities through job creation, regional investment and value-added processing.

The report is structured in three parts: firstly, feed composition, detailing estimates of current and proposed possible ingredient ratios and nutritional profiles of the suggested cropping alternatives. Secondly, the agronomic profiles of the proposed crops, evaluating the functional attributes, growing conditions and regional suitability of each crop and marine resource. Thirdly, analysis will be done towards insect protein systems, exploring the role of black soldier fly larvae and system design considerations for scalable production. To close, the report offers a concise summary and targeted recommendations to support implementation.

It is important there is careful consideration of crops selected, as everything has an impact on the environment. Thus, it is imperative the crops selected do not amount to the impact caused by traditional fish and meat meal. While not all crops in this report may be suitable, they have been carefully considered for their potential.

This initiative aligns with New Zealand's commitments to sustainable food systems, climate resilience and circular economy principles, while also responding to global aquaculture trends. By aligning with global trends in sustainable aquaculture, leveraging Southland's natural and infrastructural assets, and responding to consumer demand for ethical and traceable food systems, this initiative presents an economic diversification, high-impact opportunity to position Southland as a national leader in aquafeed innovation.

Such an opportunity would likely require a market size of between 30,000 tonnes to 60,000 tonnes to de-risk the investment. Aquafeed production also requires specialised technical expertise and feed manufacturing knowledge to establish a viable industry. Aquafeed accounts for 60-90% of the production costs in most fish farming around the world. Meaning every pellet must count.

Formulations for Murihiku Aquafeed Production

The formulation and manufacture of aquafeed pellets is a highly technical process that requires careful integration of nutrition science, ingredient functionality, site specific considerations and processing precision.

Fish feed pellet production involves several key stages, including grinding, mixing, pelletisation or extrusion, drying, cooling, and oil coating.

The precision of each step has a direct impact on the quality and performance of the final pellets.

Slow sinking aquafeed pellets are ideal for salmon. This form of pellet provides more feeding time for the fish.

Effective formulation therefore requires a balanced approach that integrates high quality protein, fats, carbohydrates (including functional starches), vitamins, minerals and binders in proportions that meet the physiological needs of salmon, while ensuring pellet integrity during manufacture, transport and feeding.

The following section outlines the standard (present) and suggested (future) ingredient compositions for aquafeed production within Murihiku, with a focus on functional performance, nutritional adequacy and suitability for local and sustainable ingredient sourcing.

STANDARD FORMULATION FOR SALMON AQUAFEED

Current Target Composition of Juvenile Chinook Salmon Feed:

- ⦿ Protein – 45%
- ⦿ Fat / Lipid – 24-25%
- ⦿ Ash (Vitamins & Minerals) – 8-10%
- ⦿ Starch – 7-8%
- ⦿ Moisture – 7-8%

Typically, this composition is made up of the following ingredients:

- Fish and other animal meals
- Soybean meal
- Corn meal
- Wheat flour
- Fish oil
- Soybean/vegetable oil
- Vitamin and mineral pre-mix



The Role of Protein

Protein is the primary nutritional component in aquafeed, essential for fish growth, tissue development, immune function and overall health. Salmon have a high dietary requirement for protein and are highly efficient at utilising digestible, high quality protein sources, making protein the dominant contributor to feed performance and cost. The selection of protein sources must therefore prioritise amino acid balance, digestibility and bioavailability to support optimal growth rates, feed conversion efficiency and fish welfare.

The Role of Fat

Fat is an important energy source in aquafeed, providing highly digestible energy that supports growth while sparing protein for tissue development rather than metabolism. In salmon diets, fats supply essential fatty acids, particularly omega 3s, which are vital for fish health, immune function, flesh quality and nutritional value for consumers. The level and type of fat included must be carefully balanced to optimise feed conversion efficiency, pellet stability and fish welfare without increasing excess oil loss or environmental impact.

The Role of Ash

Ash represents the mineral component of aquafeed. In salmon diets, minerals such as calcium, phosphorus, magnesium and trace elements must be present in appropriate forms and ratios to support growth, bone strength and physiological function. Ash levels must be carefully managed, as excessive inclusion can reduce digestibility and pellet quality, while insufficient mineral content can negatively impact fish performance and welfare.

The Role of Starch

Starch is a critical functional component in aquafeed formulation, underpinning the production of high quality salmon pellets. Starch derived from ingredients such as potato, wheat, barley and oats plays a central role in pellet binding, enabling slow sinking behaviour, high water stability and minimal fines (fragments of the pellets) during handling and feeding. When properly processed and gelatinised, these starch sources help reduce oil, protein and micronutrient leaching, supporting feed efficiency and maintaining water quality. However, salmon are physiologically adapted to high protein, high fat diets and have a limited capacity to digest starch and fibre, which constrains the overall inclusion rate of carbohydrate ingredients. As a result, the use of high quality, functional starches, such as potato starch for strong binding, and wheat, barley and oat starches for their complementary binding and textural properties, is essential to achieve pellet integrity at low inclusion levels.

Current negative impact of aquafeed pigmentations (astaxanthin)

Wild salmon naturally acquire their pink-red flesh colour by consuming krill and other crustaceans rich in astaxanthin, a marine-derived pigment. In contrast, farmed salmon rely on synthetic astaxanthin or aquafeed containing harvested krill to replicate this coloration. However, increasing global harvesting of krill, especially to produce aquafeed and pet food, has led to significant ecological concerns.

Krill and phytoplankton are keystone species in marine ecosystems. Krill serves as the primary food source for whales, seals, penguins and fish, while also playing a critical role in carbon sequestration of atmospheric carbon, supported by phytoplankton, transporting carbon to deep ocean layers. Overharvesting krill disrupts food chains and undermines biodiversity, particularly in the Southern Ocean where krill fisheries are expanding despite climate-related threats to krill populations.

Similarly, phytoplankton, often harvested for larval and smolt feeds, form the base of aquatic food webs and are essential for oceanic carbon cycling. Their removal from natural systems risks destabilising marine ecosystems and reducing ocean productivity.

As consumer markets increasingly favour natural, low-impact ingredients, both for health and ecological concern, it is vital to explore sustainable alternatives to synthetic and wild-harvested pigments. Natural colourants such as microalgae offer promising solutions for aquafeed pigmentation, supporting fish health while protecting marine ecosystems.

Other microalgae species can produce eicosapentaenoic acid (EPA) and/or docosahexaenoic acid (DHA) rich oils, thereby providing sustainable alternatives to fish oil for these essential long-chain polyunsaturated fatty acids (LC-PUFA). Prioritising microalgal carotenoids and oils therefore strengthens the sustainability profile of aquafeed formulations, supports reduced reliance on krill derived pigments, and aligns with commercial market demand for natural and sustainable alternatives.

While standard aquafeed formulations provide a useful reference point, they do not fully reflect the sustainability considerations relevant to salmon farming.

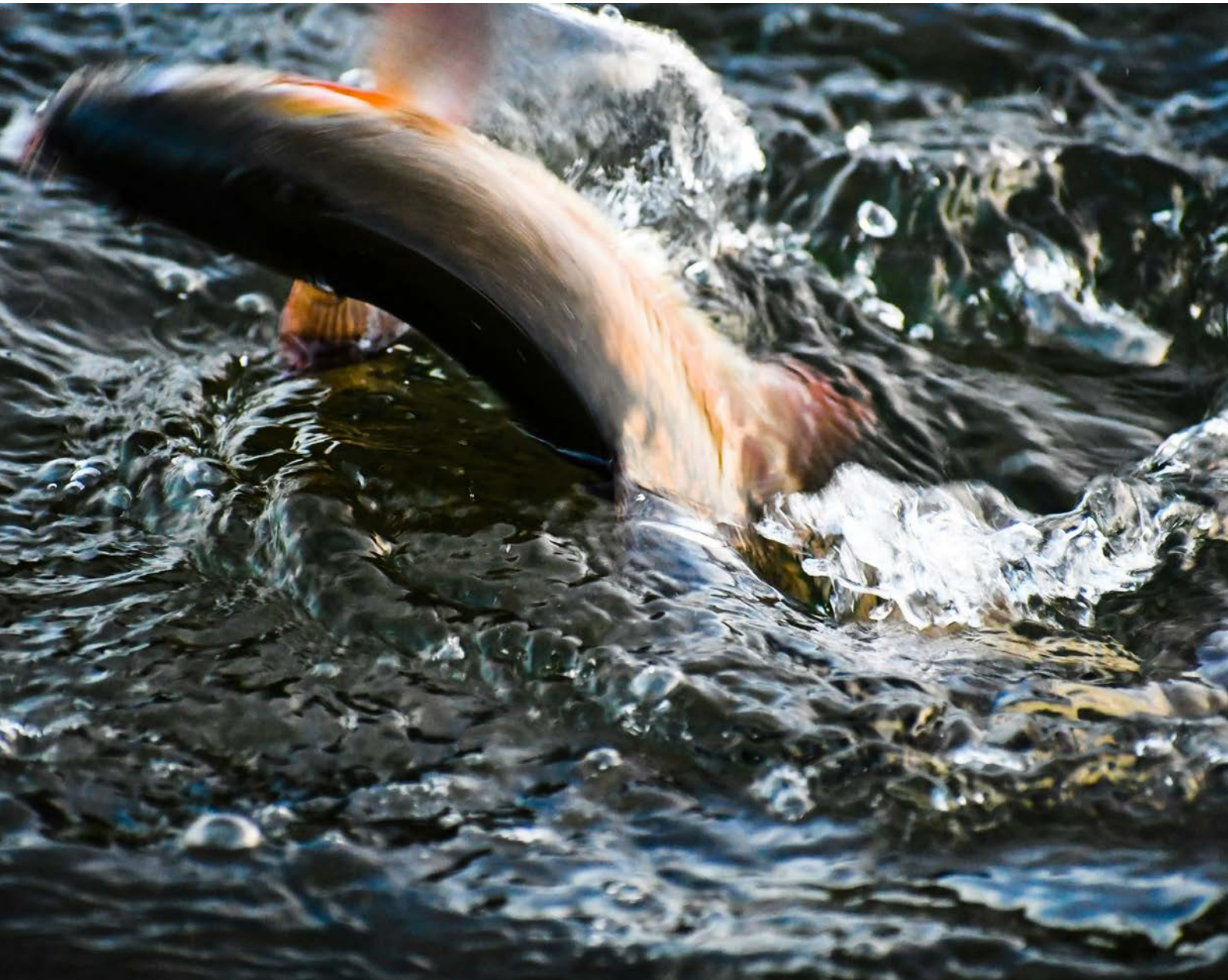
Feed formulation requirements differ significantly between salmon species, with Chinook (King) salmon exhibiting higher feed conversion ratios (FCR) than Atlantic salmon.

- Chinook salmon typically achieve FCRs in the range of 1.7-1.8
- Atlantic salmon typically achieve FCRs in the range of 1.1-1.2

Many imported aquafeed diets currently used in New Zealand are optimised primarily for Atlantic salmon and may not fully account for the physiological, behavioural and growth characteristics of Chinook salmon, potentially reducing feed efficiency and increasing overall feed demand.

With national salmon production projected to reach at least 75,000 tonnes per annum, an average FCR of 1.7 would translate to approximately 130,000 tonnes of aquafeed required annually in New Zealand by 2040.

Feed represents approximately 50% of on farm operating costs in salmon farming, making feed efficiency a critical determinant of economic viability. In addition, aquafeed is responsible for an estimated 70-90% of the carbon, nitrogen, phosphorus and freshwater footprint of salmon production, underscoring the importance of species appropriate, nutritionally optimised and sustainably sourced feed formulations.



SUGGESTED FORMULATION FOR SALMON AQUAFEED

It is desirable to have protein, fat, and starch sources that are grown and manufactured as locally as possible.

The following ingredients are already, or have the potential to be, grown and produced within Murihiku Southland. The following potential ingredients have been ranked based on the highest to lowest dry basis macronutrient (e.g., protein, carbohydrate, lipid) contents.

Protein Sources

These are essential for growth and tissue repair in aquatic species.

- Black Soldier Fly Larvae (BSFL) – High-quality animal protein (60%) and fat.
- Green-lipped Mussels – Very high protein content and bioactive compounds.
- Microalgae – High in protein, omega-3 fatty acids and micronutrients.
- Lupins – Excellent plant-based protein source.
- Fava Bean – High in protein, also contains carbohydrates and fibre.
- Sea Lettuce – Contains protein, vitamins and minerals.
- Peas – Good protein content, also provides carbohydrates.
- Purslane – Good source of protein, also high omega-3 fatty acids.
- Lucerne (Alfalfa) – Rich in protein and vitamins.
- Flaxseed (Meal) – Contains protein and high omega-3 fatty acids.
- Canola (Meal) – Moderate protein, also contains fats.

Starch and other carbohydrates

Used for energy and as binders in feed pellets.

- Potato – High starch content provides readily digestible energy.
- Wheat – Rich in starch, often used as a binder.
- Barley – High in starch, fibre and beta-glucans.
- Oats – Contains carbohydrates and fibre, some protein and beta-glucans.
- Purslane – High carbohydrate levels when dried.
- Peas – Contains digestible starch.
- Fava Bean – A good carbohydrate source.
- Lucerne – Contains fibre and some carbohydrate.

Lipid / Fat Sources

Important for energy and essential fatty acids.

- Flaxseed (Oil) – High in omega-3 fatty acids.
- Canola (Oil) – Rich in omega-3 and omega-6 fatty acids.
- BSFL – Contains beneficial fats.
- Green-lipped Mussel – Contains beneficial fats.
- Microalgae – Source of DHA and EPA (omega-3 fatty acids).
- Bladder Kelp – Contains some lipids, though not a primary source.

Vitamin / Mineral Sources

Support metabolic functions, immunity and bone health.

- Sea Lettuce – Contains high levels of vitamins and minerals.
- Microalgae – Excellent source of vitamins (B12, A, D) and minerals (iodine, iron).
- Bladder Kelp – High in iodine and other trace minerals.
- Purslane – Highest level of omega-3 fatty acid for land species.
- Lucerne – Rich in vitamins A, C, E and minerals.
- BSFL – Contains trace minerals like calcium and phosphorus.

Colourant Sources

- Microalgae – Contains astaxanthin and other carotenoids.

It is important to consider natural, low-impact supplement alternatives for astaxanthin in krill which can offer pigmentation and nutritional benefits, without compromising marine ecosystems or carbon sequestration processes. While some research has been undertaken towards colourant sources, there are potentially more options.



Ingredient	Crude Protein %	Crude Fat %	Ash %	Carbohydrate %	Starch %	Moisture %
Wheat, soft	11.0	1.4	1.5	73.0	60.0	13.1
Barley, hull-less, Streaker	13.3	2.7	1.8	72.9	55.4	9.3
Oats	9.4	4.7	2.5	71.0	36.8	12.4
Fava (faba) beans, dehulled	25.5	1.3	3.3	56.5	38.3	13.4
Lupins, white, dehulled	33.5	8.5	3.5	42.6	6.2	11.9
Peas, dehulled	20.3	1.2	3.1	62.6	44.7	12.8
Lucerne (dry matter basis)	31.8	3.0	10.3	54.9	0.1	18.7
Forage Kale (DM basis)	16.7	3.4	13.9	66.0	low	14
Rapeseed (low erucic canola)	18.6	44.1	4.0	25.7	3.5	7.6
Linseed (Flaxseed), whole	20.7	34.6	3.9	32.8	5.5	8.0
Camelina Seeds	27.3	39.5	4.4	21.8	4.0	7.0
Purslane (dry matter basis)	18	5	33	44	0	NA
Giant Kelp (<i>M. pyrifera</i>), dried	13.4	1.4	35.7	39.5	0	10.0
Sea Lettuce (<i>U. Lactuca</i>) (DM)	18.1	1.0	18.0	62.9	0	NA
Greenshell mussel powder	40.6	10.3	15.8	21.6	23.4	9.9
Defatted Black Soldier Fly Larvae	51.9	11.0	11.8	17.0	0.8	8.3
Hoki Meal	67.3	8.7	19.3	0.0	0.0	4.7
Poultry by-product meal	67.8	14.6	14.3	0.0	0.0	3.3
Blood Meal	87.7	1.9	3.1	0.0	0.0	6.0
Potato pulp, dried	4.7	0.4	3	78.8	38.5	13.1

Table 1. Estimated nutritional composition of all explored species on a percentage basis.
Source: Feedinamics (<https://feedtables.com/>).

Table 1 illustrates the estimated nutritional contributions of each studied crop and species. To further analyse crops refer to references on page 59. Table 2 offers suggested key ingredients proposed in Option 1 for Southland's sustainable aquafeed formulation. Black soldier fly larvae (BSFL), microalgae and lucerne emerge as foundational components due to their multifunctionality – each contributing protein, fats and essential micronutrients. BSFL stands out for its exceptionally high protein and fat content, alongside trace minerals, making it a cornerstone of the blend. Microalgae and Ulva (sea lettuce) offer marine-derived omega-3 fatty acids (EPA/DHA), vitamins and minerals, while bladder kelp adds iodine and antioxidants. Lucerne

provides plant-based protein, fibre and vitamins A, C, and E and acts as a binder. Peas and fava beans contribute digestible starch, fibre and moderate protein, supporting both energy and pellet structure. Flaxseed enhances the lipid profile with omega-3 fatty acids and adds protein. Wheat and barley serve primarily as carbohydrate sources and binders, ensuring pellet cohesion. Together, these ingredients replicate the nutritional profile of conventional fish and meat meal-based feed while leveraging Southland's local agricultural and marine resources. Their combined roles in protein, carbohydrate, fat, vitamin/mineral and binder categories demonstrate a balanced, regionally viable aquafeed solution.



SUGGESTED COMPOSITION/S FOR FUTURE MURIHIKU AQUAFEED

To create a more sustainable, locally sourced and produced aquafeed using the standard composition of 45% protein and 24% fat, there is a suggested blend below with the rate of inclusion by percentage.

Ingredient	Inclusion rate (%w/w)
Hoki Meal	13.0
Fish hydrolysate (palatant)	2.0
Fish oil	7.5
Poultry by-product meal	16.0
Poultry fat (± BSFL fat ± canola oil)	8.0
Blood meal	5.0
Defatted black soldier fly larvae meal, 60% protein	10.0
Lucerne protein concentrate, 60% protein	10.0
Wheat gluten	5.0
Lupins, white (or faba beans), dehulled	7.5
Potato or tapioca (cassava) starch	2.5
Wheat	8.2
Monocalcium phosphate	2.0
Lecithin ± lysolecithin	1.0
Choline chloride 50% CWS	0.25
Antioxidant (BHT/BHA blend)	0.02
Taurine	0.2
Nucleotides	0.2
Salmon mineral premix	0.2
Vitamin premix (incl. astaxanthin), Rovimix Stay-C, vitamin E	0.45
TOTAL	100.0

Table 2. Possible Murihiku Southland formulation for aquafeed.

This table represents one of several potential formulations for a more sustainable aquafeed. However, further trials and testing will need to be conducted, as this is an estimated percentage of ingredients. It is important to note that the feed size and make-up will depend on the fish age and size, and the specific density of the feed will depend on the specific characteristics of the aquafarming location ranging from on shore, near shore to open ocean settings.

Regional Need Tonnage

Southland's salmon farms produce approximately 3,000 tonnes of King (Chinook) salmon annually. This production is primarily located in Big Glory Bay, Rakiura Stewart Island, with processing undertaken at a facility in Bluff. The farm gate value of this salmon production is estimated at approximately \$39 million. Based on a typical Feed Conversion Ratio (FCR) for Chinook salmon of between 1.7 and 1.8:1, meaning 1.7-1.8 kg of feed is required to produce 1 kg of salmon, the total annual aquafeed requirement is estimated to be between 5,100 and 5,400 tonnes. To meet the nutritional needs of Southland's salmon industry, this volume of aquafeed would be required annually, translating into the approximate ingredient requirements outlined in Table 2 based on the proposed formulations.

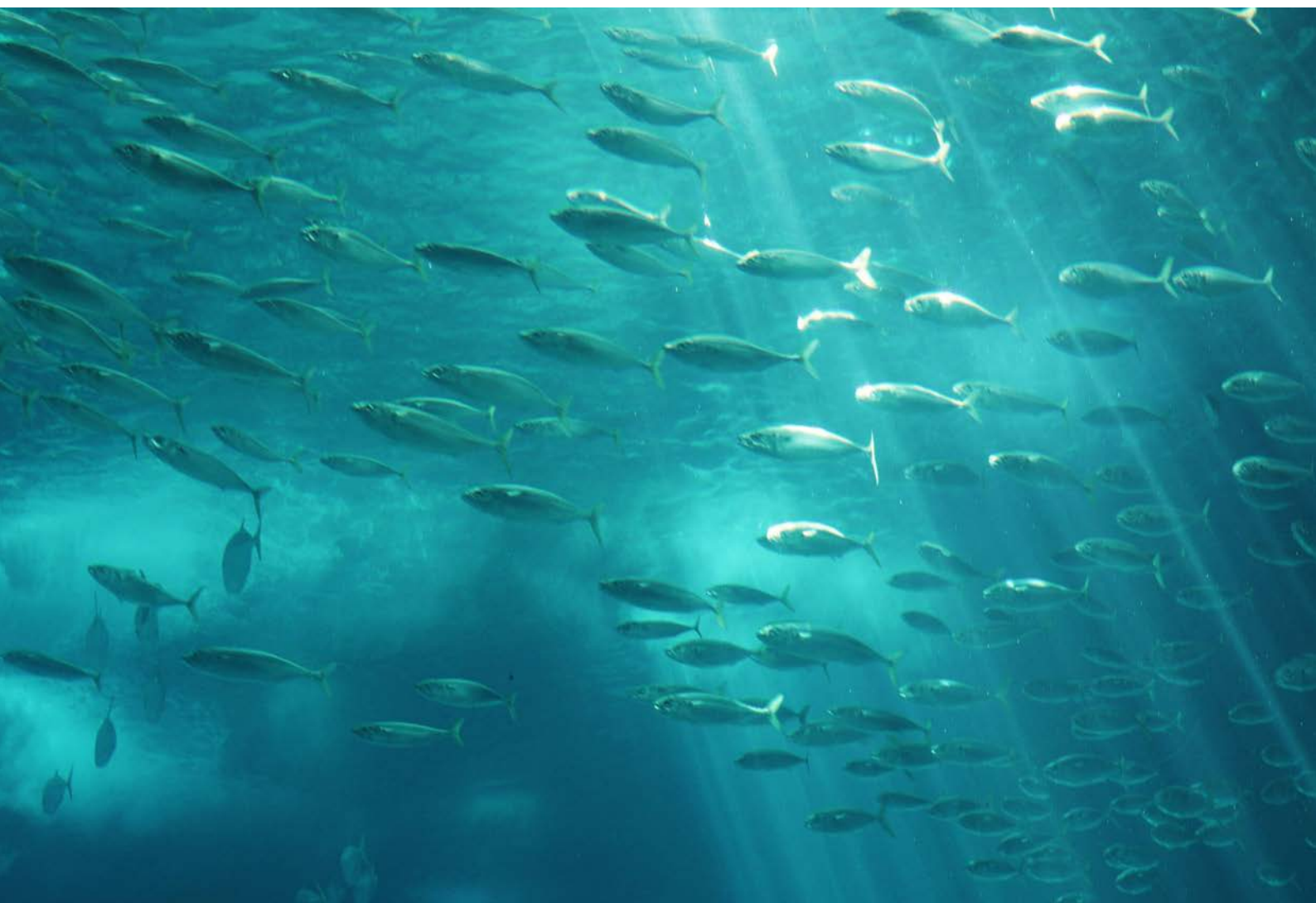
This volume highlights the scale of opportunity for Southland to develop a regionally integrated aquafeed supply chain, leveraging its unique climate, agricultural capacity, and coastal resources. By sourcing ingredients locally, the region can reduce reliance on imported feed, lower transport emissions, and enhance traceability and consumer trust. Further feasibility studies, pilot trials, and industry collaboration will be essential to validate this formulation and ensure its commercial viability.

Industrial Need Tonnage

While the current feed requirement for Southland's salmon industry is approximately 5,100 tonnes annually, scaling to 30,000 tonnes reflects the commercial market size required to support viable production volume necessary to justify investment in a dedicated feed manufacturing facility. To support the development of a dedicated aquafeed manufacturing facility, a minimum of 30,000 tonnes of secured feed off-take is required. This would likely require supplying a wider national market, or beyond. Using the suggested formulation, the above ingredient volumes would be needed annually. This scale of production would require significant investment in aquafeed testing, ingredient supply chains, processing infrastructure and logistics. However, it also presents a major opportunity for Southland to become a national hub for sustainable aquafeed manufacturing.

³*Marine Aquaculture in Southland Discussion Paper.pdf*

⁴<https://www.mpi.govt.nz/dmsdocument/17536-rias-inc-comparing-farm-raised-salmon-to-other-protein-source-marlborough-salmon-relocation-proposal-presentation>







A detailed background image showing a variety of seaweeds growing in a shallow, rocky pool. The seaweeds have different textures and colors, ranging from dark brown to light green. The water is clear, and the rocks are visible at the bottom.

Murihiku Plant Based Aquafeed Opportunities

This section presents a detailed analysis of potential feed ingredients, including their nutritional profiles, agronomic characteristics, growing conditions and historical or current use in Southland and across New Zealand. It is important to evaluate the feasibility of incorporating these ingredients into a locally sourced, sustainable aquafeed system.

Understanding where existing or similar crops are reliably grown, along with their growing degree day, soil requirements and rotation suitability is essential. Engaging with farm consultants, growers and farmer groups is strongly recommended, as they offer valuable, in-depth local knowledge that can further inform ingredient selection and cultivation strategies.

Barley and Wheat

(Hordeum vulgare and Triticum aestivum)

Barley and wheat are foundational cereal crops that contribute carbohydrates, starch, fibre and moderate protein levels (10–14%) to aquafeed, serving both as energy sources and effective binders in pellet formulations.

Well-suited to Southland's temperate climate and fertile soils, these grains offer reliable yields, support crop rotation systems and enhance soil structure through substantial biomass production.

TYPICAL GROWING CONDITIONS

Soil Type & pH Requirements

Both crops prefer well-drained loamy soils with a pH range of 6.0 to 7.5. Barley is slightly more tolerant of saline soils than wheat.

Germination Temperature Range

Germination occurs best between 5°C and 25°C. In Southland, sowing generally occurs in the spring, with barley sometimes sown in mid-spring (September/October) and wheat in August or September.

Moisture Needs

Require moderate moisture, especially during germination and grain fill. Barley is more drought-tolerant than wheat, but both are sensitive to waterlogging.

Climate at Harvest

Typically harvested during February and March. Dry conditions are ideal to prevent lodging and fungal infections.

Other Growing Conditions

Both crops benefit from early sowing and good seedbed preparation. Wheat is more responsive to nitrogen fertilization, while barley is often used in lower-input systems.

AGRONOMIC CHARACTERISTICS

Root Structure

Fibrous root systems with moderate depth; effective at nutrient uptake and soil stabilisation.

Nitrogen Fixing

Neither crop fixes nitrogen; both require moderate external nitrogen inputs.

Crop Rotation Suitability

Widely used in rotations with legumes and brassicas; help manage weed pressure and soil structure.

Biomass Contribution

Produce substantial above-ground biomass; straw can be incorporated to improve soil organic matter.

HISTORY IN SOUTHLAND / NZ

Local Production

Both barley and wheat are staple arable crops in Southland and Canterbury. Used for feed, milling, and forage. Cultivar trials continue to improve yield and resilience. Primarily grown in Southland on the plains and rolling hills, especially in eastern and southern areas.

Recommended Land Area for Cultivation

For spatial reference, see Appendix Figure 3 (A1 versatility) and Figure 6 (A1–A2 versatility), which highlight the most suitable soils for barley and wheat cultivation. Appendix Figure 5 (A3 versatility) may also be consulted, though A1 and A2 soils are more highly recommended.



Oats (*Avena sativa*)

Oats are a nutrient-dense cereal crop that serve as a valuable carbohydrate source in aquafeed, offering rich soluble fibre (notably beta-glucans), protein levels of 12–15% and beneficial lipids.

Adaptable to Southland's soils and climate, oats support digestive health in fish and contribute to feed structure and energy balance, while also enhancing soil quality through their biomass and rotational value. Southland is recognised as having some of the highest oat yields per hectare globally.

TYPICAL GROWING CONDITIONS

Soil Type & pH Requirements

Adaptable to a range of soils but prefers well-drained loams with pH 6.0 to 7.5. Tolerant of heavier soils compared to other cereals.

Germination Temperature Range

Germinates well between 5°C and 20°C. In Southland, oats can be sown in late summer through autumn (February to May).

Moisture Needs

Requires moderate moisture, especially during grain fill. More tolerant of wet conditions than wheat or barley.

Climate at Harvest

Harvested in late summer to early autumn (March & April). Dry conditions are ideal to prevent lodging and fungal issues.

Other Growing Conditions

Performs well in cooler climates, ideal in Southland. Early sowing improves yield of oats. Often grown in low-input systems (low fertiliser and pesticides) and as a cover crop (crop grown to cover soil and may be incorporated into the soil later for enrichment).

Southland oat growers have been very active in developing crossbred oat genetics and varieties ideally suited to Southern soils and for health and wellness attributes.



AGRONOMIC CHARACTERISTICS

Root Structure

Fibrous root system with good soil penetration and nutrient uptake.

Nitrogen Fixing

Does not fix nitrogen; requires moderate nitrogen inputs.

Crop Rotation Suitability

Useful in rotations for weed suppression and soil conditioning. Often follows legumes or pasture.

Biomass Contribution

Produces substantial straw and root biomass; improves soil organic matter and erosion control.

HISTORY IN SOUTHLAND / NZ

Local Use

Commonly grown in Southland for forage, grain, and cover cropping since the 1870s. Used in livestock feed and increasingly considered for aquafeed due to its digestibility and functional fibre.

Varieties

Includes hulled and hullless oat types; plant breeding efforts focus on disease resistance and yield stability. Southland has been developing new oat varieties for the past 15 years, resulting in crops that are optimised to the Southland growing environment. The variety 'Gardyne', also once known as PRL12-10-2, and developed in Southland, was designed for milling and recognised for its early maturity, disease tolerance and increased yield.

Recommended Land Area for Cultivation

For spatial reference, see Appendix Figure 3 (A1 versatility) and Figure 6 (A1–A2 versatility), which highlight the most suitable soils for oat cultivation. Appendix Figure 5 (A3 versatility) may also be consulted, though A1 and A2 soils are more highly recommended due to their superior rooting depth and drainage characteristics.





Fava Beans (Broad Beans)

(*Vicia faba*)

Fava beans are a high-protein legume, rich in lysine and essential amino acids, low in fat, and high in dietary fibre. This makes them a nutritionally balanced ingredient for aquafeed.

Well-suited to Southland's cool climate, they contribute to soil fertility through nitrogen fixation and offer substantial biomass, supporting both feed quality and sustainable crop rotations. Popular varieties include Broad Windsor (large seeds), Aquadulce Claudia (cold-tolerant), and Sweet Lorane (high nitrogen fixation).

TYPICAL GROWING CONDITIONS

Soil Type & pH Requirements

Fava beans prefer loamy, well-drained soils and can tolerate heavier soils if drainage is sufficient. Optimal soil pH ranges from 6.0 to 7.5.

Germination Temperature Range

Germination occurs best between 5°C and 18°C, making them suitable for early spring sowing in Southland's cool climate.

Moisture Needs

Consistent moisture is essential during germination and pod development. While fava beans are moderately drought-tolerant, they are sensitive to waterlogging, especially in poorly drained soils.

Climate at Harvest

Typically harvested in late spring to early summer. Dry conditions during harvest are ideal to prevent pod rot and seed damage.

Other Growing Conditions

Fava beans are frost-tolerant and can be sown early. They benefit from inoculation with Rhizobium bacteria for optimal nitrogen fixation. They also require full sun and moderate fertility and respond well to minimal tillage systems.

AGRONOMIC CHARACTERISTICS

Root Structure

Upright growth with a strong taproot and fibrous lateral roots; contributes to soil structure.

Nitrogen Fixing

Excellent nitrogen fixer via Rhizobium nodules; improves soil fertility for subsequent crop.

Crop Rotation Suitability

Ideal break crop in arable rotations; helps manage pests, diseases and weed.

Biomass Contribution

Produces substantial biomass, useful for green manure or soil conditioning.

HISTORY IN SOUTHLAND / NZ

Local Production

Already grown in parts of New Zealand, including Southland, for both human consumption and cover cropping. While specific fava bean production data for Southland isn't readily available, fava beans are generally grown in cooler regions, and Southland's climate would be suitable.

Recommended Land Area for Cultivation

For spatial reference, see Appendix Figure 3 (A1 versatility) and Figure 6 (A1–A2 versatility), which highlight the most suitable soils for fava bean cultivation. Figure 5 (A3 versatility) may also be consulted, though A1 and A2 soils are preferred due to better drainage and rooting depth. Additionally, Appendix Figure 8 (clayey soils) may be relevant, as fava beans can tolerate heavier soils if well-drained.

Lucerne (*Medicago sativa*)

Lucerne is a high-protein forage legume, rich in essential amino acids and minerals, making it a valuable ingredient for aquafeed.

Its deep-root system enhances drought resilience and soil structure, while its nitrogen-fixing ability supports sustainable crop rotations. Well-suited to Southland's climate, lucerne offers multiple harvests and contributes significantly to soil fertility and feed quality. Lucerne is deep-rooted drought-resistant cover crop, that can typically last well beyond 5 years.

TYPICAL GROWING CONDITIONS

Soil Type & pH Requirements

Prefers deep, well-drained loamy soils with a neutral to slightly alkaline pH 6.5 to 7.5. Sensitive to acidic and compacted soils.

Germination Temperature Range

Optimal germination occurs between 15°C and 25°C.

Moisture Needs

Requires consistent moisture during establishment but is drought-tolerant once mature due to its deep root system.

Climate at Harvest

Multiple harvests possible from late spring through autumn. Dry conditions are preferred to prevent mould and spoilage.

Other Growing Conditions

Lucerne benefits from inoculation with *Rhizobium meliloti* for nitrogen fixation. Requires good weed control during establishment and performs best under rotational grazing or cut-and-carry systems.

AGRONOMIC CHARACTERISTICS

Root Structure

Extensive taproot system reaching depths of over 2 metres, enhancing drought resilience and soil structure.

Nitrogen Fixing

Excellent nitrogen fixer; can contribute up to 150 kg/ha of nitrogen annually.

Crop Rotation Suitability

Ideal for rotations with cereals and brassicas; improves soil fertility and structure.

Biomass Contribution

High biomass yield; suitable for green manure, forage, or pelletised feed. Enhances organic matter and supports soil microbial activity. A crop can remain in the paddock for up to six years, reducing the need to cultivate and reduces soil carbon loss from ploughing and tillage.

HISTORY IN SOUTHLAND / NZ

Local Use

Widely grown in New Zealand for forage and hay. Southland's climate supports multiple cuts per season.

Recommended Land Area for Cultivation

For spatial reference, see Appendix Figure 4 (A1 versatility) and Figure 6 (A1–A2 versatility), which highlight the most suitable soils for lucerne cultivation. These soil types offer the depth, drainage, and structure required for lucerne's deep-root system and long-term productivity, while avoiding the limitations of acidic or compacted soils.



Lupins (*Lupinus angustifolius*)

Sweet lupins (low in alkaloids) are an excellent source of protein, with levels of 30-40%. The crop offers reasonable balance of carbohydrate and lipids as well, making it a solid ingredient in aquafeed.

Blue lupin, commonly known as Australian sweet lupins, historically cultivated in Canterbury for soil restoration and livestock feed, is now represented by sweet, non-shattering Australian genotypes well-suited to New Zealand conditions and promising for aquafeed applications.

TYPICAL GROWING CONDITIONS

Soil Type & pH Requirements

Prefers well-drained, moderately fertile sandy or loamy soils with pH 6.5 to 7.

Germination Temperature Range

Thrives in temperate climates; prefers dry summers and cool, moist winters.

Moisture Needs

Requires adequate moisture during spring and early summer; sensitive to waterlogging in winter.

Climate at Harvest

Harvested in late summer; dry conditions are ideal to prevent pod shattering and seed loss.

Other Growing Conditions

Lupins grow best in full sun, with minimal soil disturbance and good drainage; early sowing and Rhizobium inoculation improve performance.

AGRONOMIC CHARACTERISTICS

Root Structure

Deep taproot system that helps access subsoil moisture and contributes to soil structure.

Nitrogen Fixing

Excellent nitrogen fixer – can return up to 80 kg/ha of nitrogen to the soil when graze.

Crop Rotation Suitability

Ideal for rotation with cereals and other crops due to its soil-enriching properties. Often used as a green manure crop to improve soil fertility before planting other crops.

HISTORY IN SOUTHLAND / NZ

Local Production

Lupinus angustifolius was widely grown in Canterbury post-WWII for fertility restoration and sheep feed. Lupins grow naturally in Southland, particularly in coastal, sandy soils.

Recommended Land Area for Cultivation

For spatial reference, see Appendix Figure 9 (sandy soils), which highlights the most suitable areas for lupin cultivation due to their preference for well-drained, sandy conditions. Appendix Figure 3 (A1 versatility) and Figure 6 (A1–A2 versatility) may also be consulted, particularly where soil structure and drainage align with lupin requirements.





Peas (*Pisum sativum*)

Peas are a valuable protein and carbohydrate source, rich in starch and dietary fibre, making them ideal for aquafeed formulations.

Their adaptability to Southland's temperate climate, nitrogen-fixing ability, and role in crop rotations enhance soil fertility and structure, while contributing moderate biomass and improving phosphorus uptake. Overall, they support both feed efficiency and sustainable farming systems. Varieties include Yellow Stone, Blue Prussian, White Ivory and Partridge.

TYPICAL GROWING CONDITIONS

Soil Type & pH Requirements

Peas prefer deep, well-drained soils and perform best in loamy or sandy loam textures. They are light feeders and do well after heavy-feeding crops, meaning they require lower levels of external nutrients or fertilisers. Optimal soil pH is 6.0 to 7.5.

Germination Temperature Range

Germination occurs best between 5°C and 20°C, making them suitable for planting in early spring (September) in Southland's temperate climate.

Moisture Needs

Peas require consistent moisture during flowering and pod development. They are sensitive to waterlogging, especially during early growth stages.

Climate at Harvest

Most pea varieties are ready for harvest 10-12 weeks after planting. Typically harvested in summer from December to March in Southland. Dry conditions are preferred to avoid pod rot and seed damage.

Other Growing Conditions

Peas are frost-tolerant, making them suitable for early sowing. They benefit from full sun and moderate fertility. Inoculation with Rhizobium bacteria enhances nitrogen fixation. Peas are often grown after pasture or clover where soil nitrogen levels are high.

AGRONOMIC CHARACTERISTICS

Root Structure

Shallow to moderately deep root system with nodules for nitrogen fixation.

Nitrogen Fixing

Capable of fixing 17–83 kg/ha of nitrogen, improving soil fertility for subsequent crops.

Crop Rotation Suitability

Widely used as a break crop in cereal rotations to manage soil-borne diseases and improve soil structure.

Biomass Contribution

Peas contribute moderate above-ground and below-ground biomass, enhancing soil structure and fertility, and can increase subsequent crop yields by up to 35%. Additionally, they improve phosphorus uptake by up to 29%.

HISTORY IN SOUTHLAND / NZ

Local Use

Peas are the third most important annual cash crop in NZ arable agriculture, with Canterbury and Hawke's Bay being major production areas. Pea crops are used as feed crops in parts of Southland, especially during summer and winter. Known to be grown in the Garston district, however, there currently is not a high production amount in Southland.

Varieties

Includes threshed peas for dry grain and vined peas for fresh consumption. Suitable cultivars have been developed for NZ conditions.

Recommended Land Area for Cultivation

For spatial reference, see Appendix Figure 3 (A1 versatility) and Figure 6 (A1–A2 versatility), which highlight the most suitable soils for pea cultivation. Appendix Figure 5 (A3 versatility) may also be consulted, though A1 and A2 soils are preferred due to their superior drainage and structure, which support optimal nitrogen fixation and root development.



Potato (*Solanum tuberosum*)

Potatoes are a high-energy root crop rich in digestible carbohydrates, particularly starch, making them a useful component for aquafeed formulations where carbohydrate and binding properties are required.

Their neutral flavour, low antinutrient profile, and functional starch characteristics (notably gelatinisation, which can improve pellet cohesion) make potatoes a promising supplementary ingredient in plant-based aquafeed. Potatoes are already widely grown in Southland, with the region's cool, moist climate well suited to consistent tuber development.

TYPICAL GROWING CONDITIONS

Soil Type & pH Requirements

Prefers well-drained loamy or sandy-loam soils. Optimal pH 5.0–6.5, slightly more acidic than many arable crops. Sensitive to waterlogging and compaction – raised beds or ridging are standard practice.

Germination Temperature Range

Germinates and establishes best at 7–21°C. In Southland, planting typically occurs September to November.

Moisture Needs

Requires consistent moisture during tuber initiation and bulking. Sensitive to drought stress and waterlogging.

Climate at Harvest

Harvested March–May in Southland. Dry conditions reduce bruise risk and storage losses.

Other Growing Conditions

Performs best under cool-temperate conditions with long growing periods. Moderate fertiliser inputs can be required, especially nitrogen and potassium.

AGRONOMIC CHARACTERISTICS

Root Structure

Fibrous root system with shallow depth. Tuber formation occurs close to the soil surface, necessitating good soil tilth.

Nitrogen Fixing

Does not fix nitrogen. Requires moderate nitrogen inputs but excessive N can reduce tuber quality.

Crop Rotation Suitability

Commonly rotated with cereals, brassicas, or legumes. Helps break weed cycles but can be susceptible to soil-borne diseases if rotated too frequently. Ideally grown on a 3–4 year rotation to reduce disease pressure.

Biomass Contribution

Produces moderate above-ground biomass and substantial below-ground edible biomass. Residual plant matter can be incorporated to support soil organic content.

HISTORY IN SOUTHLAND / NZ

Local Production

Southland is one of New Zealand's major potato-growing regions, supporting both fresh market and processing industries. Potatoes thrive in Southland's cool climate and fertile soils, making them a reliable root crop.

Recommended Land Area for Cultivation

For spatial reference, see Appendix Figure 7 (A1, A2 and A3 versatility), which highlights the most suitable soils for potato cultivation. Potato's ability to grow on marginal soils means it is not restricted to high-versatility land classes.



Camelina (*Camelina sativa*)

Camelina is an ancient oilseed crop belonging to the Brassicaceae family, closely related to canola. Other investigations conducted found camelina oil to be a sustainable lipid source to fully replace fish oil in diets of Atlantic salmon. It is valued for its high content of omega-3 fatty acids, vitamin E, and antioxidants, making it a versatile ingredient.

Already used in some animal feeds, such as poultry, as well as in cosmetics and even biofuel applications such as aviation fuel, Camelina offers potential as a sustainable aquafeed ingredient due to its lipid profile and functional properties. Its adaptability to low-input systems enhances its appeal for regenerative agriculture and climate-resilient cropping systems.

Camelina oil is rich in omega-3 fatty acids (ALA), vitamin E, and antioxidants, supporting fish health and immunity. While it does not provide EPA or DHA directly, its inclusion can complement other marine-derived sources (e.g. microalgae) in aquafeed formulations. Camelina meal, a by-product of oil extraction, offers moderate protein content and can serve as a supplementary ingredient in pellet formulations.

TYPICAL GROWING CONDITIONS

Soil Type & pH Requirements

Camelina thrives in well-drained soils but is highly tolerant of marginal land. Optimal soil pH ranges from 5.6 to 6.5, though it can grow in soils as low as pH 5.0. Soil pH over 8.5 will likely cause yields to decrease.

Germination Temperature Range

Seeds germinate best between 15°C and 25°C (daytime temperature), making Camelina suitable for Southlands warmer months.

Moisture Needs

Drought-tolerant once established, Camelina requires minimal irrigation compared to other oilseed crops. Excessive moisture or waterlogging should be avoided.

Climate at Harvest

Harvest typically occurs in late spring to early summer under dry conditions to prevent seed spoilage. The harvest can be stored in silos.

Other Growing Conditions

Camelina is a low-input crop requiring minimal fertiliser and pesticide use. It performs well in short-season environments and can be easily integrated into crop rotations to improve soil health.

AGRONOMIC CHARACTERISTICS

Root Structure

Fibrous root system with moderate depth, contributing to soil stabilisation and nutrient uptake.

Nitrogen Fixing

Camelina does not fix nitrogen; moderate external inputs may be required for optimal yield.

Crop Rotation Suitability

Ideal for rotations with cereals and legumes; helps break pest cycles and improve soil structure.

Biomass Contribution

Produces moderate biomass; seeds are the primary harvestable component, rich in oil and protein.

HISTORY IN SOUTHLAND / NZ

Local Production

Camelina has been trialled in several New Zealand regions, including Timaru, Whangarei, and Oamaru, demonstrating adaptability to diverse soils and climates. While not widely grown commercially, its resilience and low input requirements make it a promising candidate for expansion in Southland when there is a dedicated market for the crop.

Recommended Land Area for Cultivation

For spatial reference, see Appendix Figure 7 (A1, A2 and A3 versatility), which highlights the most suitable soils for camelina cultivation. Camelina's ability to grow on marginal soils means it is not restricted to high-versatility land classes. It can be considered for drier areas and areas unsuitable for traditional arable crops, supporting land-use diversification.



Canola (Rapeseed) (*Brassica napus*)

A versatile oilseed crop valued for its high-quality oil and protein content, this making it suitable for aquafeed applications.

Adapted to Southland's cool climate and loamy soils, canola contributes significant biomass and serves as an effective rotation crop, helping break pest and disease cycles while enhancing soil structure and fertility. While canola is a valuable oilseed crop for aquafeed, it typically requires moderate fertiliser inputs and careful weed and pest management to achieve optimal yields. These factors can make it more costly to grow than some lower-input alternatives, depending on the farming system and rotation strategy used.

TYPICAL GROWING CONDITIONS

Soil Type & pH Requirements

Canola prefers well-drained loamy soils with good fertility. Soil pH should ideally be between 5.5 to 7.0. Subsoil acidity should be checked, especially below 10 cm depth.

Germination Temperature Range

Germinates best between 5°C and 25°C, with optimal emergence in cooler spring conditions typical of Southland. Canola is sensitive to environmental stressors such as drought, frost and excessive moisture, which can affect germination and yield.

Moisture Needs

Requires consistent moisture during early growth and flowering. Sensitive to drought stress during flowering and pod fill stages.

Climate at Harvest

Harvested in late spring to early summer. Dry conditions are preferred to reduce seed shattering and moisture-related spoilage.

Other Growing Conditions

Canola is sensitive to soil compaction and waterlogging. It benefits from good seedbed preparation and early sowing. Hybrid varieties offer improved nitrogen use efficiency and stress tolerance.

AGRONOMIC CHARACTERISTICS

Root Structure

Taproot system with fibrous lateral roots; helps with soil penetration and nutrient uptake.

Nitrogen Fixing

Does not fix nitrogen; requires external nitrogen inputs for optimal yield.

Crop Rotation Suitability

Excellent rotation crop; helps break pest and disease cycles in cereal-dominated systems. Helps improve yields for subsequent crops, such as wheat. Should be in rotation every four or more years.

Biomass Contribution

Produces substantial residue; incorporation improves soil organic matter and potassium levels.

Other Characteristics

Produces seeds with a waxy outer layer that helps protect them during development and storage. However, this also can result in seeds remaining in the soil, subsequently causing growth within the next rotation of crop and thus, contamination. Growing canola often requires substantial investment in fertilisers, pesticides and herbicides, making it more expensive than some other crops.

HISTORY IN SOUTHLAND / NZ

Local Production

Grown in various parts of New Zealand, including Southland, for oilseed production. Canola meal is already used in livestock feed and has potential in aquafeed systems.

Recommended Land Area for Cultivation

For spatial reference, see Appendix Figure 3 (A1 versatility) and Figure 6 (A1–A2 versatility), which highlight the most suitable soils for canola cultivation. These soil types offer the drainage, fertility, and structure needed for optimal oilseed production, while minimising risks associated with compaction and waterlogging.





Flaxseed (Linseed)

(*Linum usitatissimum*)

Flaxseed, also known as linseed, is a nutrient-rich oilseed crop known for its high content of omega-3 fatty acids, protein (18–25%), dietary fibre and lignans.

A beneficial ingredient in animal nutrition, thus, a valuable potential addition to aquafeed formulations. With approximately 200 species in the *Linum* genus, flaxseed offers both nutritional and functional benefits. The Bison variety is most commonly used due to its high yield and disease resistance. There is some research and case studies showing use of flaxseed oil in fish feed and further having benefits toward them.

TYPICAL GROWING CONDITIONS

Soil Type & pH Requirements

Prefers well-drained, fertile loamy soils with a pH range of 6.0 to 7.5. Sensitive to waterlogging and compaction.

Germination Temperature Range

Optimal germination occurs between 8°C and 25°C. Suitable for spring sowing in Southland, typically late August to September.

Moisture Needs

Requires moderate moisture during early growth and flowering. Sensitive to drought during flowering and seed fill.

Climate at Harvest

Harvested in late summer to early autumn, late February to early April, when the seed heads (boils) turn brown and the plant begins to dry and turn yellow (stem). Dry conditions are ideal to prevent seed spoilage and lodging.

Other Growing Conditions

Flaxseed benefits from early sowing and minimal tillage. Weed control is important during establishment. It is often grown in low-input systems and can be integrated into rotations with cereals and legumes.

AGRONOMIC CHARACTERISTICS

Root Structure

Fibrous root system with moderate depth; contributes to soil structure and nutrient uptake.

Nitrogen Fixing

Does not fix nitrogen; requires moderate nitrogen inputs.

Crop Rotation Suitability

Useful in rotations for pest and disease management. Can follow legumes or pasture.

Biomass Contribution

Produces moderate biomass; straw can be incorporated to improve soil organic matter. Seeds are high in oil and protein, making them suitable for feed applications.

HISTORY IN SOUTHLAND / NZ

Local Use

Flaxseed has been grown in New Zealand for oil and fibre production. Specifically in Southland it is known to grow well in areas such as Heddon Bush, Wendonside and Wairio.

Recommended Land Area for Cultivation

For spatial reference, see Appendix Figure 3 (A1 versatility) and Figure 6 (A1–A2 versatility), which highlight the most suitable soils for flaxseed cultivation. Appendix Figure 8 (clayey soils) may also be relevant, as flaxseed can tolerate heavier soils if well-drained, though A1 and A2 soils are generally preferred for optimal yield and root development.



Kale (*Brassica oleracea* var. *acephala*)

Kale is a nutrient-dense leafy green belonging to the Brassicaceae family, widely recognised for its high levels of vitamins A, C, and K, antioxidants, and minerals such as calcium and magnesium. Its robust nutritional profile makes it a good potential candidate for aquafeed supplementation, particularly as a source of vitamins, minerals, and functional compounds that support fish health and immunity. Kale is already an established crop in Southland, thriving in low-input systems, tolerating cooler temperatures, and aligning well with regenerative farming practices.

While not a major protein or lipid contributor, its inclusion as a supplementary ingredient can enhance the micronutrient profile of aquafeed. Kale powder, produced by drying and milling leaves, can be incorporated at low inclusion rates to improve fish health and feed functionality.

TYPICAL GROWING CONDITIONS

Soil Type & pH Requirements

Prefers well-drained loamy soils with a pH range of 5.8 to 6.2. Kale can tolerate slightly acidic soils but performs best in fertile, well-structured soils.

Germination Temperature Range

Optimal germination occurs between 7°C and 24°C, suitable to sown from late to mid-October through to mid-February depending on climate, for harvest in winter months.

Moisture Needs

Requires consistent moisture during establishment and leaf development. Sensitive to prolonged drought but moderately tolerant once mature.

Climate at Harvest

Harvested in cooler months, typically autumn through early winter. Frost can enhance leaf sweetness, but prolonged freezing may damage plants.

Other Growing Conditions

Kale benefits from crop rotation with legumes to improve soil fertility. It is relatively pest-resistant compared to other brassicas but may require monitoring for aphids and caterpillars.

AGRONOMIC CHARACTERISTICS

Root Structure

Fibrous root system with moderate depth, effective for nutrient uptake and soil stabilisation.

Nitrogen Fixing

Does not fix nitrogen; requires moderate fertiliser inputs for optimal growth.

Crop Rotation Suitability

Ideal for rotations with cereals and legumes. Kale helps break pest cycles and improve soil health.

Biomass Contribution

Produces substantial leafy biomass, which can be dried and milled into powder for aquafeed formulations.

HISTORY IN SOUTHLAND / NZ

Local Production

Kale is widely grown across New Zealand and Southland for livestock forage and human consumption. Southland's cooler climate supports high-quality leaf production, making it suitable for both fresh market and functional feed applications.

Recommended Land Area for Cultivation

For spatial reference, see Appendix Figure 6 (A1-A2 versatility) which highlight the most suitable soils in Southland for optimal yield of kale, though kale can also grow on less versatile land with adequate drainage and fertility.



Purslane (*Portulaca oleracea*)

Purslane is a fast-growing succulent herb known for its high nutritional value and adaptability to various climates. Often considered a weed it contains the highest levels of omega-3 fatty acids (especially alpha-linolenic acid (ALA)) among leafy green vegetables. However, it does not contain EPA or DHA omega-3 fatty acids which is required for aquafeed.

Alongside high Omega-3 fatty acids, purslane contains abundant protein, vitamins A, C, and E, and minerals such as magnesium, calcium, potassium, and iron. Purslane does not need to be processed to get its nutritional benefits, but for ease of composition into aquafeed pellets, it ideally should be processed into flour. These properties make it a promising candidate for aquafeed supplementation, particularly in plant-based formulations aimed at improving fish health and immunity.

DRYING PRODUCTION SYSTEM

Drying purslane for aquafeed involves harvesting the fresh plant at peak biomass, which is typically 6 to 8 weeks after sowing, then removing excess moisture to preserve its nutritional value and make it suitable for pellet formulation. The process begins with washing and sorting to eliminate soil and debris, followed by chopping into smaller pieces to ensure uniform drying. Purslane can be dried using air-drying, solar drying, or low-temperature oven or dehydrator drying, ideally at temperatures below 45°C to retain its omega-3 fatty acids, vitamins and antioxidants. Once fully dried (targeting moisture content below 10%), the material is milled into a fine powder for incorporation into aquafeed. This drying step is essential to reduce bulk, extend shelf life and ensure compatibility with other dry feed ingredients in pellet production.

TYPICAL GROWING CONDITIONS

Soil Type & pH Requirements

Purslane thrives in a wide range of soils, including sandy, loamy and even poor or compacted soils. It prefers well-drained conditions and tolerates low fertility. Optimal soil pH ranges from 5.5 to 7.5, but it can grow in slightly acidic to neutral soils.

Germination Temperature Range

Seeds germinate best between 20°C and 30°C, making it suitable for sowing in late spring to early summer in Southland. It is frost-sensitive, so planting should occur after the risk of frost has passed.

Moisture Needs

Purslane is highly drought-tolerant once established, requiring minimal irrigation. However, consistent moisture during germination and early growth improves yield and biomass quality.

Climate at Harvest

Purslane can be harvested 6-8 weeks after sowing, with multiple cuts possible due to its rapid regrowth. It performs best in warm, sunny conditions, and can be grown throughout the summer season in Southland.

Other Growing Conditions

It is well-suited to low-input systems, often grown as a cover crop or intercropped with other species. Its prostrate growth habit suppresses weeds and retains soil moisture, making it beneficial for regenerative farming systems.

AGRONOMIC CHARACTERISTICS

Root Structure

Purslane has a shallow, fibrous root system that spreads horizontally, making it effective for soil stabilisation and nutrient uptake in the topsoil layer.

Nitrogen Fixing

Purslane does not fix nitrogen, but its biomass contributes to soil organic matter when incorporated post-harvest.

Crop Rotation Suitability

It is a useful rotation or companion crop, particularly for weed suppression and soil conditioning. Its fast growth and ground cover reduce erosion and improve soil health. An example of a companion planting would be underneath grains, such as barley and wheat, as purslane helps to suppress competing weeds, although further trials would need to be conducted.

Biomass Contribution

Produces moderate biomass, with leaves and stems rich in omega-3 fatty acids, vitamins, and minerals. Biomass can be dried and milled into aquafeed formulations.

HISTORY IN SOUTHLAND / NZ

Local Production

Purslane is not widely cultivated commercially in New Zealand but grows naturally across the country, including Southland, where it is often considered a weed. Increasing interest in nutrient-dense, climate-resilient crops has led to its recognition as a valuable species for regenerative agriculture and functional feed applications.

Recommended Land Area for Cultivation

Purslane is highly adaptable and grows naturally across Southland, often in marginal or low-fertility soils. As such, it is not restricted to specific soil versatility classes and may be found in areas not typically considered prime arable land. Thus, Appendix Figure 7 (A1–A3 versatility), Figure 8 (clayey soils), and Figure 9 (sandy soils) may all be relevant.

Potential in Aquafeed

Its high omega-3 content, vitamin profile and low input requirements make it a strong candidate for inclusion in sustainable aquafeed systems, particularly as a supplementary ingredient (rather than a core component) to enhance fish immunity and nutritional value. There are several recent studies on the use of purslane extract mixed into aquafeed, specifically for trout, tilapia and hap fish species. All studies found the inclusion of the dietary herbal supplement resulted in enhanced immune systems and improved growth due to the high omega-3 fatty acid content.





Microalgae

Microalgae offer a potent combination of high protein, essential fatty acids (EPA/DHA), omega-3 fatty acid, pigments, antioxidants and polysaccharides, making them a highly functional and sustainable component of aquafeed.

Their rapid biomass production, adaptability to integrated aquaculture systems and minimal land use make microalgae an ideal candidate for circular, low-impact feed strategies in Southland and beyond. Species selection depends on desired output: protein (e.g. Chlorella or Spirulina), antioxidants (e.g. Haematococcus) or general (e.g. Duckweed/Lemna).

Sustainable pigmentation in salmon aquafeed is increasingly focused on microalgae rather than terrestrial plant-based pigments. Microalgae, particularly Haematococcus pluvialis and other carotenoid-rich species, offer a biologically aligned solution, as they naturally produce astaxanthin and related carotenoids similar to those found in wild salmon diets. These microalgae can be cultivated in controlled systems using wastewater or nutrient-rich effluent streams, making them a scalable, low-impact and environmentally sustainable pigmentation option.

MICROALGAE OIL PRODUCTION & PROPERTIES

Ideally located near aquaculture facilities, particularly near Bluff, or dairy operations, to utilise nutrient-rich effluent, which could be anywhere throughout Southland. These controlled environments allow for year-round production, with optimal growth temperatures ranging from 15°C to 35°C. Microalgae require high light exposure, CO₂ supplementation, and balanced nitrogen and phosphorus levels, making integration with dairy effluent streams both efficient and sustainable. Commercial systems can yield 10–30 tonnes of dry biomass per hectare annually, with some species capable of doubling biomass in under 24 hours. While initial infrastructure costs are high, microalgae's rapid growth and minimal land footprint make it a viable and scalable protein and omega-3 fatty acid source for aquafeed.

The most efficient technology for producing microalgae oil is photobioreactor (PBR) cultivation, particularly closed-loop systems. These systems optimise light, CO₂, nutrients, and temperature to maximise microalgae growth and lipid (oil) production. Microalgae are cultivated in controlled environments – either in tubes, flat panels, or bags – where they photosynthesise and accumulate lipids. Once harvested, the oil is extracted using methods like supercritical CO₂ extraction or solvent extraction, which separate the oil from the biomass with high efficiency and minimal environmental impact.

Microalgae oil is rich in omega-3 fatty acids (especially DHA and EPA), making it valuable for nutritional supplements. It has a high lipid content (up to 50% of dry weight) and can be produced on non-arable land using wastewater, making it a sustainable alternative to traditional oils. Its composition can be tailored by adjusting growth conditions, offering flexibility for different industrial applications.





TYPICAL GROWING CONDITIONS

Environmental Requirements

Cultivated in aquatic systems. Grows in freshwater, brackish, or marine environments, depending on species. Optimal pH ranges from 7.5 to 9.0 for most microalgae. Requires full submersion in nutrient-rich water. Growth is enhanced by high light availability, CO₂ supplementation and balanced nitrogen and phosphorus levels.

Germination Temperature Range

Optimal growth temperatures vary by species, but generally range from 15°C to 35°C. Some can tolerate as low as 5°C. This means that most species, unless grown during summer in Southland, it will need to be in a controlled indoor environment.

Climate at Harvest

Can be harvested year-round in controlled systems. Outdoor systems in Southland may be limited to warmer months.

Other Growing Conditions

Microalgae cultivation can occur in open ponds, photobioreactors or wastewater-integrated systems. Light, temperature and nutrient control are key to maximising productivity.

AGRONOMIC CHARACTERISTICS

Genetic Make-up

No true roots, nutrients are absorbed directly through the cell wall or thallus.

Biomass Contribution

High productivity per unit area; some species can double biomass in under 24 hours. Biomass is rich in protein (up to 60%), lipids (including omega-3 fatty acids) and bioactive compounds.

HISTORY IN SOUTHLAND / NZ

Local Use

Microalgae such as *Chlorella*, *Nannochloropsis*, and *Spirulina* have been trialled in New Zealand for aquafeed and nutraceuticals.

Potential in Southland

Southland's clean water resources and proximity to aquaculture operations make it a strong candidate for microalgae cultivation, especially in integrated systems using aquaculture effluent or dairy wastewater.



Bladder Kelp (*Macrocystis pyrifera*)

Bladder kelp is a mineral-rich seaweed packed with antioxidants, polysaccharides, and bioactive compounds that support fish health and immunity, making it a valuable supplement in aquafeed systems.

Bladder kelp is naturally abundant in Southland's cool, nutrient-rich coastal waters, particularly around Rakiura Stewart Island, making it an ideal candidate for marine-based aquafeed supplementation. This kelp produces high biomass and contributes to ecosystem services such as carbon sequestration, while offering sustainable, marine-derived nutrition for salmonid diets. It is typically cultivated in marine environments using long-line systems and seeded ropes.

PRODUCTION AND PROPERTIES

Sustainable cultivation of bladder kelp, particularly within multi-trophic aquaculture systems, requires careful consideration, with controlled farming approaches still needing further trials and potentially representing a future aquaculture investment opportunity.

Commercial cultivation is achieved through long-line systems using 'seeded' ropes suspended at depths of 1–5 metres in subtidal zones. Strong water flow and good light penetration is needed, with higher yield at shallower depths. Seeded ropes involves attaching kelp spores to ropes in a hatchery, which are then deployed into the ocean. With potential yields of up to 100 tonnes wet weight per hectare annually, bladder kelp offers high scalability and contributes to carbon sequestration and ecosystem health. Its integration into IMTA systems further enhances sustainability by absorbing excess nutrients from fish farming operations.

TYPICAL GROWING CONDITIONS

Germination Temperature Range

Optimal growth occurs in cold, nutrient-rich waters, thriving in areas with naturally occurring nitrogen and phosphorus. Bladder Kelp does not persist where temperatures exceed 18–19°C for several days.

Moisture Needs

Fully submerged in seawater; requires high water movement and nutrient availability (especially nitrogen and phosphorus, of which is naturally occurring).

Climate at Harvest

Harvested year-round, with peak biomass typically in cooler months (April-August). Biofouling, which is the accumulation of living organisms from the aquaculture equipment, increases in spring, so timing is important for quality.

Other Growing Conditions

Bladder kelp can be integrated into multi-trophic aquaculture system, meaning it can be cultivated alongside other species such as fish, shellfish, or crustaceans in a way that mimics natural ecosystems, where each species plays a role in maintaining environmental balance. In this system, the seaweed absorbs excess nutrients like nitrogen and phosphorus from the water (often originating from fish waste) helping to reduce pollution and improve water quality. Overall, enhancing sustainability and increasing productivity and resilience of the aquaculture operation.

AGRONOMIC CHARACTERISTICS

Root Structure

Anchored by means of holdfasts to solid objects such as rocks in the wild, or to long lines suspended in the water in a controlled aquaculture environment. Nutrients are absorbed directly from seawater through the kelp's blades.

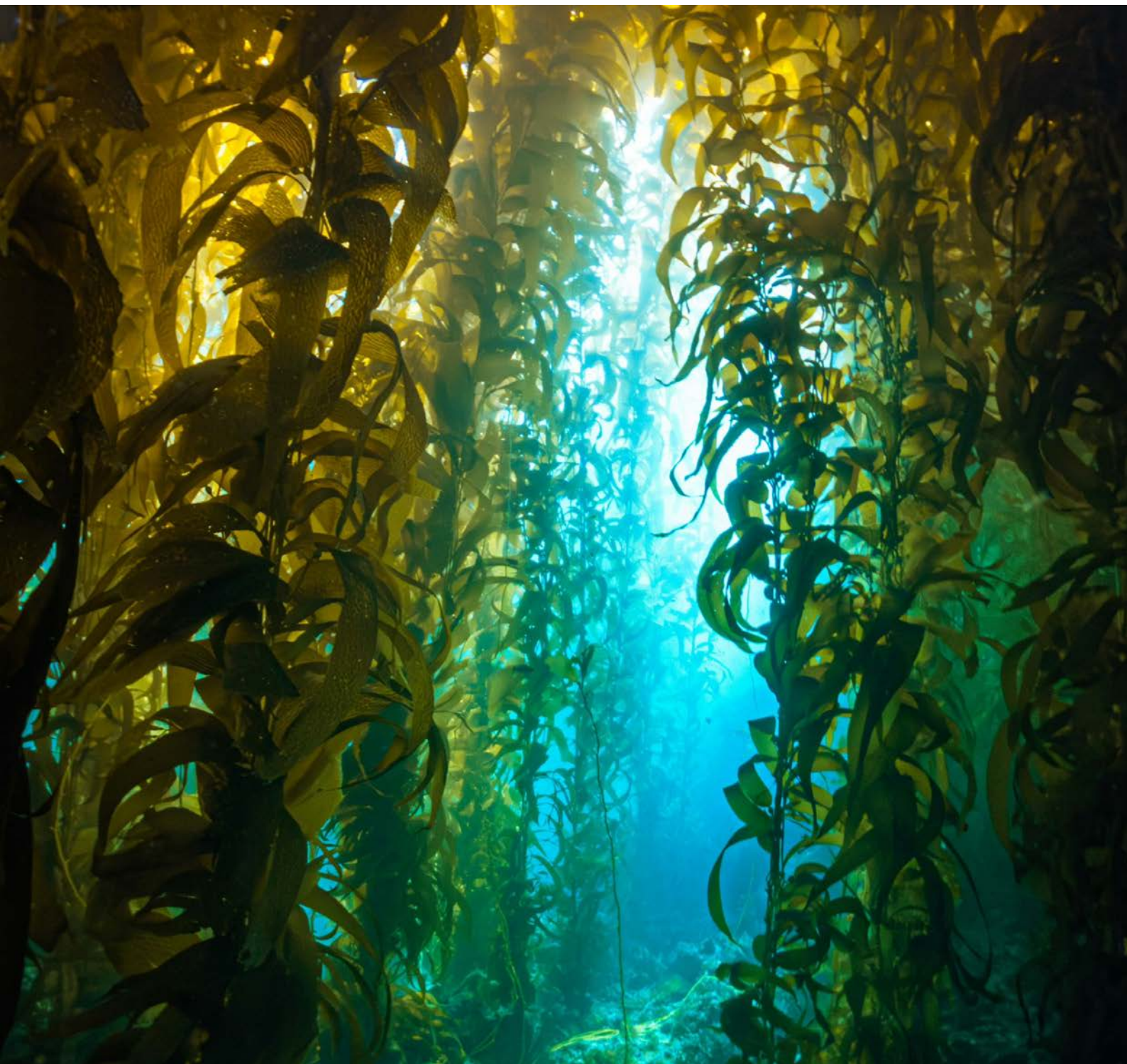
Biomass Contribution

Produces very high biomass, with forests reaching up to 20 meters tall. Valuable for carbon sequestration and ecosystem services.

HISTORY IN SOUTHLAND / NZ

Local Use

Found naturally in subtidal areas of the South Island, especially Rakiura Stewart Island. Cultivation trials have been conducted using long-line systems in regions like the Marlborough Sounds.



Ulva (Sea Lettuce) (*Ulva lactuca*)

Ulva, commonly known as sea lettuce, is a protein-rich seaweed (18% of dry matter) packed with essential amino acids, vitamins, minerals, carbohydrates, and fibre - making it a powerful supplement for fish growth and immunity.

Thriving in nutrient-rich waters and adaptable to land-based or integrated aquaculture systems, Ulva offers rapid biomass production and contributes to water quality improvement, positioning it as a sustainable and functional ingredient in aquafeed.

PRODUCTION & PROPERTIES

Ulva are well-suited to Southland's coastal and aquaculture-integrated environments, especially in Big Glory Bay in Stewart Island. They can be cultivated in land-based tanks, raceways, or integrated multi-trophic aquaculture (IMTA) systems alongside salmon farms. Commercial cultivation involves regular harvesting every 2–4 weeks, with yields reaching 20–40 tonnes wet weight per hectare annually. Once harvested, the seaweed is typically dried to preserve nutrients and then milled into a fine powder suitable for aquafeed production.



TYPICAL GROWING CONDITIONS

Cultivation System & Environments

Ulva is cultivated in marine or brackish water systems or grown in tanks or integrated aquaculture setups. Typically found in intertidal zones and coastal areas where it can be exposed to air during low tide, prefers shallower areas where sunlight can reach.

Germination Temperature Range

Ulva grows across a wide temperature range, typically thriving between 15°C and 25°C. Growth is enhanced under elevated CO₂ and nitrate conditions.

Moisture Needs

Requires full submersion in nutrient-rich water, yet within reach of sunlight. Performs well in high-nitrogen environments, including aquaculture effluent systems.

Climate at Harvest

Can be harvested year-round, with peak growth in warmer months. Cultivation in tanks allows for controlled harvest cycles.

Other Growing Conditions

Ulva adapts well to land-based cultivation and integrated multi-trophic aquaculture (IMTA) systems. It helps remove inorganic nutrients from wastewater, improving water quality. Holdfast are used, typically this is a disc-shaped anchor.

AGRONOMIC CHARACTERISTICS

Genetic Characteristics

Nutrients absorbed directly through the thallus, which is a flat, blade-like structure composed of two layers of cells.

Biomass Contribution

Rapid vegetative growth; high biomass yield in nutrient-rich conditions. Cultivated Ulva can produce substantial biomass suitable for feed and bioremediation.

HISTORY IN SOUTHLAND / NZ

Local Use

Cultivated Ulva species such as *Ulva ralfsii* and *Ulva stenophylloides* have been trialled in New Zealand, specifically Rakiura Stewart Island. Known for high protein and amino acid content, making them strong candidates for aquafeed supplementation.





Mussels (Green Lipped)

(Perna canaliculus)

Green-lipped mussels are a native New Zealand shellfish species with high nutritional value and their by-product has potential as a sustainable aquafeed ingredient. Rich in protein, omega-3 fatty acids (EPA and DHA), essential amino acids, and bioactive compounds such as glycosaminoglycans, mussel meal can enhance fish growth, immunity and feed efficiency.

The Green-lipped mussel is in high demand in New Zealand's premium export markets. The by-product of mussel processing, mussel meat, shells or powder can be repurposed into aquafeed, supporting circular economy principles and reducing waste.

PRODUCTION & PROPERTIES

Green-lipped mussels are farmed extensively in New Zealand. Mussel farming is well-established in Big Glory Bay, Rakiura Stewart Island, where sheltered waters and nutrient-rich conditions support high yields.

Mussel meal is produced by drying and grinding whole mussels, in the instance of aquafeed likely seconds, or processing waste (e.g. meat trimmings, shells). The resulting powder contains approximately 60–70% protein, 8–12% fat and a range of micronutrients including zinc, selenium, and iodine. It also contains bioactive peptides and anti-inflammatory compounds, which may support fish health and stress resilience.

Further research must be conducted, looking into quality and quantity of mussel by-product in Southland and whether it can be converted effectively into aquafeed.

TYPICAL GROWING CONDITIONS

Cultivation System & Environments

Mussels are cultivated in open water longline systems, suspended in the water column. They require clean, nutrient-rich seawater with good flow and minimal sedimentation. Harvests occur 12–18 months after seeding. Seeded ropes are designed to attract mussel larvae (spat) from the water, to then attach and grow.

Temperature Range

Optimal growth occurs between 12°C and 18°C. Southland's cool coastal waters are well-suited to mussel farming, particularly in sheltered bays.

Moisture & Nutrient Needs

Mussels are filter feeders, extracting phytoplankton and organic particles from the water. They require high water quality and are sensitive to pollution and harmful algal blooms.

Climate at Harvest

Harvesting can occur year-round, with peak yields typically in late summer to early autumn. Mussels are harvested using mechanised systems and processed locally.

Other Growing Conditions

Mussels benefit from multi-trophic aquaculture systems, where they help improve water quality by filtering excess nutrients. They can be co-cultured with salmon or seaweed to enhance ecosystem services.

AGRONOMIC CHARACTERISTICS

Nutrient Profile

Mussel meal is high in digestible protein, omega-3 fatty acids and trace minerals. It also contains taurine and glycosaminoglycans, which support fish metabolism and joint health. More research is required to understand by-product nutrients.

Biomass Contribution

Mussel farming yields are high, with up to 20 tonnes per hectare per year. Processing waste can be repurposed into feed, reducing environmental impact.

Sustainability Benefits

Mussels require no feed inputs, sequester carbon, and improve water clarity. Their inclusion in aquafeed supports circularity and reduces reliance on terrestrial protein sources.

HISTORY IN SOUTHLAND / NZ

Local Use

Mussel farming has been active in Big Glory Bay since the 1980s. While most mussels are exported for human consumption, processing waste is increasingly being explored for secondary uses, including pet food and aquafeed.

Potential in Aquafeed

Mussel meal has been trialled in salmon diets overseas with promising results, improving feed conversion ratios and fish health. Its local availability and sustainability profile make it a strong candidate for inclusion in Southland's aquafeed formulations, but competing economic factors will need consideration.



Summary of Potential Crops

Southland's cool temperate climate, fertile loamy soils, and reliable rainfall make it well-suited for cultivating the range of crops listed above for sustainable aquafeed production.

Barley and wheat are staple cereals in the region, benefiting from Southland's mild summers and contributing carbohydrates, fibre, and binding agents for pellet feed. Oats are similarly well-adapted, offer a rich source of carbohydrates, soluble fibre (beta-glucans), protein and lipids – supporting both feed structure and fish digestive health.

Potatoes provide a high-quality starch source that enhances pellet binding and physical stability in aquafeed. The root vegetable is strongly suited for Southland and has existing production capabilities in Southland.

Lupins thrive in Southland's well-drained soils and cooler growing seasons, offering high protein and nitrogen-fixing benefits ideal for crop rotations. Fava beans are already grown in the region and perform well in moist spring conditions, contributing valuable protein and soil fertility. Peas, widely adaptable to Southland's climate, grow successfully in early spring and enrich soil through moderate biomass and nitrogen fixation. Canola is a proven crop in Southland, producing oil and protein meal, but requires careful nutrient management.

Lucerne (alfalfa), a high-protein legume rich in essential amino acids and minerals, performs well in Southland's climate and contributes to soil fertility through deep rooting and nitrogen fixation. It offers multiple harvests and is a valuable addition to forage-based feed systems.

Flaxseed (linseed) is a promising oilseed crop that grows well in Southland's temperate conditions, offering high levels of omega-3 fatty acids and moderate protein. It supports soil health, requires relatively low inputs and adds economic value through its dual use in oil and meal production.

Other crops identified in academic literature as promising nutritional supplement alternatives for aquafeed include fenugreek, myrtle and peppermint. Like purslane, these crops have demonstrated potential to enhance the immune systems of various fish species. Further research could explore their suitability for cultivation in Southland, considering local environmental conditions and aquaculture needs.

In coastal and aquaculture-integrated systems, seaweeds such as Bladder kelp and *Ulva* sp. (sea lettuce) provide mineral-rich, protein-dense biomass with bioactive compounds that support fish health and immunity. Additionally, microalgae species offer high protein, omega-3 fatty acids (EPA/DHA) and pigments like astaxanthin, making them powerful supplements in fish diets. Green-lipped mussels, a native New Zealand species, further contribute to aquafeed through their high-quality protein, essential fatty acids, and bioactive compounds, with mussel meal derived from processing by-products offering a sustainable and nutrient-rich feed ingredient.

Together, these crops and marine resources align with Southland's agricultural and environmental strengths, supporting the development of a locally sourced, fish and meat-free aquafeed system that is both nutritionally robust and ecologically sustainable.







A close-up, slightly blurred photograph of several black soldier fly larvae (maggots) crawling through light brown soil. The larvae are dark, segmented, and have a distinct head with small legs. They are positioned at various depths and angles within the soil, creating a sense of movement and natural habitat.

Insect- Based Protein Production Opportunities

As aquaculture expands, the demand for sustainable, high-quality protein sources continues to grow.

Traditional feed ingredients such as meat/fishmeal and soy are increasingly scrutinised for their environmental and human impact, cost volatility and reliance on global supply chains. To build a resilient and locally sourced aquafeed system, Southland must explore alternative protein pathways that align with circular economy principles.

Insect-based protein production, particularly using species such as the black soldier fly, offers a compelling solution. These systems convert food waste and other organic waste streams into nutrient-dense biomass rich in protein, essential amino acids and beneficial lipids. Moreover, diverting waste streams out of landfill. Insects are evolutionarily compatible with fish diets and can be farmed in compact, climate-controlled environments, making them ideal for Southland's conditions. Integrating insect protein into aquafeed not only reduces reliance on imported ingredients but also enhances waste recovery, nutrient recycling and overall feed sustainability.

Black Soldier Fly Larvae (BSFL)

(*Hermetia illucens*)

BSFL are a sustainable, high-protein feed ingredient rich in essential amino acids and beneficial lipids like lauric acid, which support fish health and immunity.

Efficient at converting organic waste into nutrient-dense biomass, BSFL farming aligns with circular economy principles and offers a locally viable solution for aquafeed production in Southland. BioMar are already leading the way with this type of aquafeed meal, praising the sustainability of the insect and viability for aquafeed⁶.

FUNCTIONAL ELEMENTS

Black soldier fly larvae are increasingly recognised as a sustainable, high-quality protein source for aquafeed. Their nutritional profile includes 52% crude protein and 11% fat (dry matter), depending on the rearing substrate and processing method. BSFL are rich in essential amino acids, including lysine and methionine and contain beneficial lipids such as lauric acid, which supports fish immunity. Their evolutionary compatibility with fish diets makes them particularly suitable for salmonids like Chinook and Atlantic salmon.

FEEDSTOCK SOURCES

Commonly reared on organic waste streams such as:

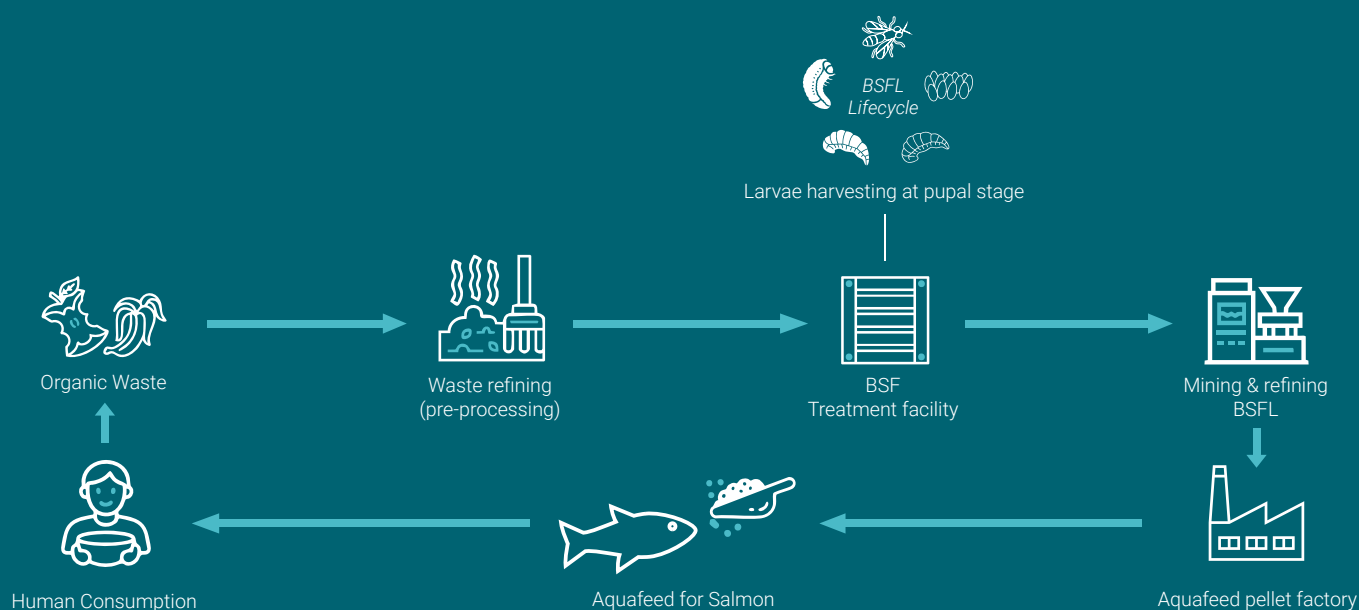
- Food waste
- Organic by-products (e.g. distillery/brewery waste)

Organic waste streams have been trialled and tested in New Zealand. These feedstocks are abundant in Southland, making BSFL production locally viable. Organic waste stream could be from industries such as the distillery market; however, Southland doesn't produce large amounts of this byproduct. On average in New Zealand, 86 kg of food waste is thrown out per household annually⁷. Further data needs to be collected or released, regarding the quantity of food/green waste produced in Southland or Invercargill to get a more precise figure. Food waste can be composted, however, on the food waste hierarchy, animal feed is higher (better) than composting⁸.

⁶*The Next Generation of Insect Meals | BioMar* - <https://www.biomar.com/insights/insights-hub/the-next-generation-of-insect-meals>

⁷*Love Food Hate Waste* - <https://lovefoodhatewaste.co.nz/food-waste/what-we-waste/>

⁸*Love Food, Not Waste - Aotea Great Barrier Island* - <https://www.greatbarrier.co.nz/love-food-not-waste/>



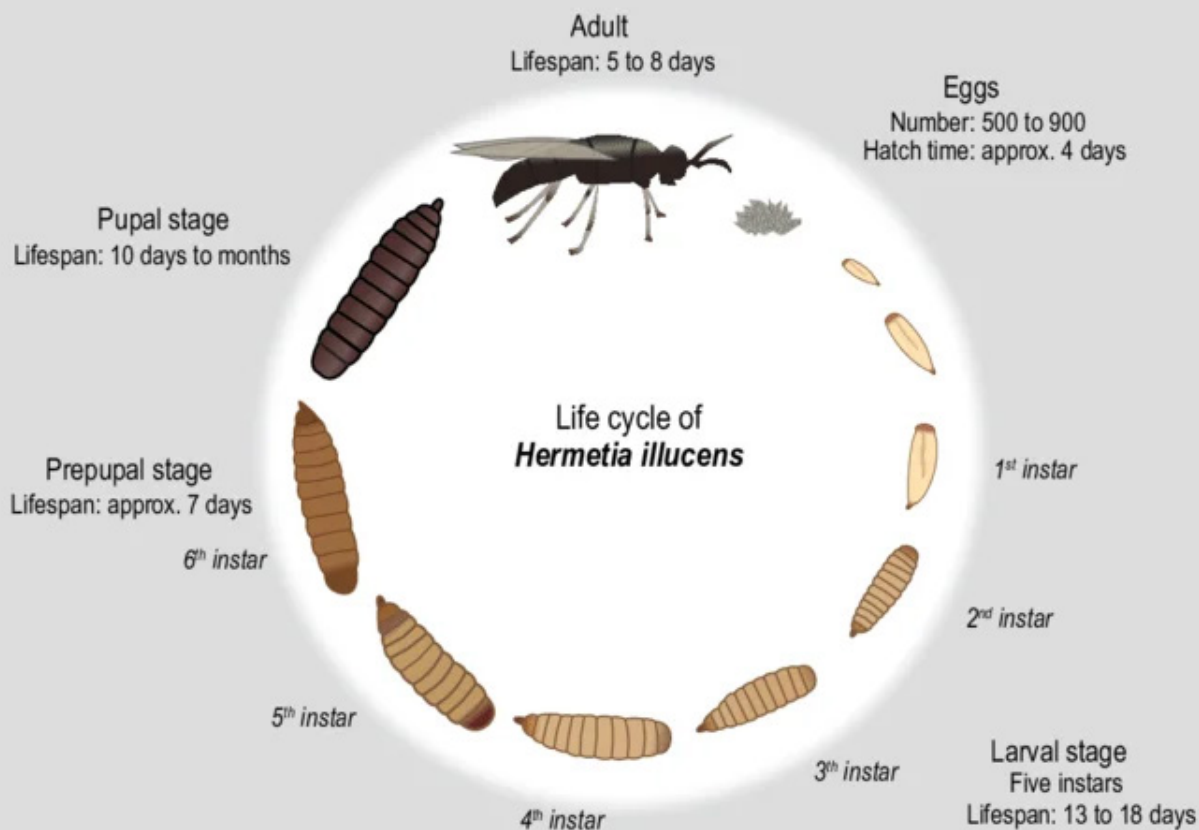


Figure 2: The life cycle of the Black Soldier Fly (*Hermetia illucens*) (source: Lievens et al., 2021, modified from De Smet et al., 2018).

FARMING SETUP

BSFL farming typically involves indoor or container-based systems with climate control. Stacked production systems have proven effective for space-efficient rearing. Requiring warm, humid conditions of 27–30°C and 60–70% relative humidity.

LIFECYCLE OF BSFL

The Black Soldier Fly life cycle begins with:

- 1. One adult fly living for 5-8 days
- 2. During which they mate and lay 500-900 eggs that hatch in 4 days
- 3. The larvae then feed intensively for 13-18 days across six growth stages (instars)
- 4. Afterward, they enter a 7 day prepupal stage, stop feeding, and migrate to a dry area
- 5. This is followed by a pupal stage lasting at least 10 days to months, during which they remain inactive before emerging as adults to restart the cycle.

Typically, harvesting occurs at the end of the larval feeding stage (end of stage 3.), just before they enter the prepupal stage, as they have reached peak biomass and consumed the maximum amount of organic matter.

EFFECTIVE METHANE CAPTURE

To maximise methane mitigation, it's crucial to introduce black soldier fly larvae to organic waste as early as possible. The sooner they consume the waste, the less time it has to decompose anaerobically and release methane.⁹

REDUCTION OF PATHOGENS AND PESTS

BSFL suppress harmful bacteria like *E. coli* and *Salmonella* by consuming the nutrients those bacteria need to survive. Since BSFL are very efficient eaters, they quickly use up the available resources in the waste, leaving little behind for the bacteria to grow. This process is called competitive exclusion whereby the larvae "outcompete" the bacteria for food and space.¹⁰ Additionally, their rapid consumption of waste minimises odours and deters common pests such as houseflies and rodents.

CONVERSION EFFICIENCY

BSFL can convert 1 kg of organic waste → 100-200g of dry larvae depending on feedstock quality and system efficiency.

Feed conversion ratios typically range from 1.6-8.9 kg of feed per 1 kg of fresh larvae.¹¹

Assuming a preprocessing moisture content of 60-75%, this corresponds to the dry matter range above. Overall, BSFL are considered a highly efficient system for converting low-value organic waste into protein compared to traditional livestock systems.

⁹Conversion of protein-rich waste into biodiesel by *Hermetia illucens*: Enhanced energy recovery and reduced greenhouse gas emissions - *ScienceDirect* - <https://www.sciencedirect.com/science/article/abs/pii/S2213138824002212>

¹⁰Enhancing *Salmonella* Inhibition in Black Soldier Fly Larvae (*Hermetia illucens* L.) Conversion by Bioaugmentation With Gut Microbiota - *PMC* - <https://pmc.ncbi.nlm.nih.gov/articles/PMC12721473>

¹¹Growth of Black Soldier Fly Larvae Reared on Organic Side-Streams - <https://www.mdpi.com/2071-1050/13/23/12953>

APPLICATION IN SOUTHLAND

Southland's cool climate necessitates indoor or controlled-environment systems for BSFL farming. However, the region's abundant organic waste streams make it an ideal candidate for establishing BSFL production hubs. Co-location with food processors or aquaculture facilities could enable efficient waste-to-protein conversion while supporting local feed supply chains.



BIOSECURITY AND ESCAPE PREVENTION

Black Soldier Flies do not pose a biosecurity risk in the event of accidental release. This species is already present in the natural environment within New Zealand. As a result, additional releases are unlikely to introduce new ecological pressures or disrupt existing ecosystems.

ADDITIONAL RESOURCES ON BSFL

- **Black Soldier Fly (*Hermetia illucens*) Microbiome and Microbe Interactions: A Scoping Review** - PMC - <https://pmc.ncbi.nlm.nih.gov/articles/PMC11590926/>
- **EnviroFlight's Commercial Scale Plan Unleashes the Power of a Black Soldier Fly!** - <https://www.youtube.com/watch?v=S4ykrig--yM>
- **The black soldier fly for aquafeed - International Aquafeed** - <https://www.aquafeed.co.uk/the-black-soldier-fly-for-aquafeed/>
- **Veolia insect pilot a first of its kind for New Zealand** - <https://www.anz.veolia.com/en-au/newsroom/newsroom/veolia-insect-pilot-first-its-kind-new-zealand>
- **New Perspectives in Fisheries: The Use of Insects in Aquaculture | Intech Open** - <https://www.intechopen.com/chapters/1210218>
- **Full-fat black soldier fly larvae meal and yellow mealworm meal: Impact on feed protein quality, growth and nutrient utilization of Atlantic salmon (*Salmo salar*) post smolts - ScienceDirect** - <https://www.sciencedirect.com/science/article/pii/S0044848624011104>
- **(PDF) Black Soldier Fly Biowaste Processing - A Step-by-Step Guide** - https://www.researchgate.net/publication/319402351_Black_Soldier_Fly_Biowaste_Processing_-_A_Step-by-Step_Guide
- **Environmental benefits of using BSF for waste management** - <https://www.mannainsect.com/bsf-waste-management-environmental-benefits/>

OTHER INSECT OPTIONS

While the primary insect considered for aquafeed is BSFL, other species such as **mealworms** or **crickets** could be suitable. Mealworms are high in protein and fat, with good amino acid profiles. More commonly used in poultry and pet feed, but research supports their potential in fish diets. Require grain-based feed, which may limit their sustainability compared to BSFL. Crickets are rich in protein and micronutrients. Less commonly used in aquafeed due to slower growth and higher input costs. May be viable in niche or small-scale systems.



The Ongoing Role of Animal-Derived Ingredients in Aquafeed Formulation

The feed composition explored in this report proposes an aquafeed formulation in which approximately 45% of total inclusion is derived from plant based ingredients, with the remaining proportion comprised of marine inputs, animal by products, functional lipids, palatants and micronutrient supplements.

This represents a significant reduction in reliance on traditional fishmeal and meat dominated feeds, in order to lower carbon emissions and environmental impact, while maintaining the nutritional performance required for salmonid production.

Despite this shift, a fully plant exclusive formulation is not yet nutritionally or commercially viable for Chinook and Atlantic salmon without substantial synthetic supplementation, complex processing, or performance trade offs. As such, animal derived ingredients remain present in the formulation, not as bulk protein sources, but as targeted functional components that support digestibility, amino acid balance, lipid composition, palatability and fish welfare.

Understanding the role of these inputs within a higher plant based feed is critical to assessing realistic transition pathways and identifying where alternative proteins, particularly insect based systems, can most effectively substitute existing ingredients.

FISHMEAL (HOKI MEAL)

Fishmeal inclusion is substantially reduced compared with conventional salmon diets, which often rely on fishmeal as a dominant protein source. Hoki meal serves a functional role within the suggested aquafeed formula.

Even at lower inclusion rates, fishmeal contributes:

- Highly digestible protein
- A complete and bioavailable amino acid profile (including taurine)
- Marine micronutrients
- Strong feeding cues that support feed intake

For salmonids, small quantities of fishmeal can significantly improve the performance of plant heavy diets by enhancing digestibility and reducing the need for synthetic amino acid supplementation. Its inclusion is therefore strategic and limited, rather than volumetric.

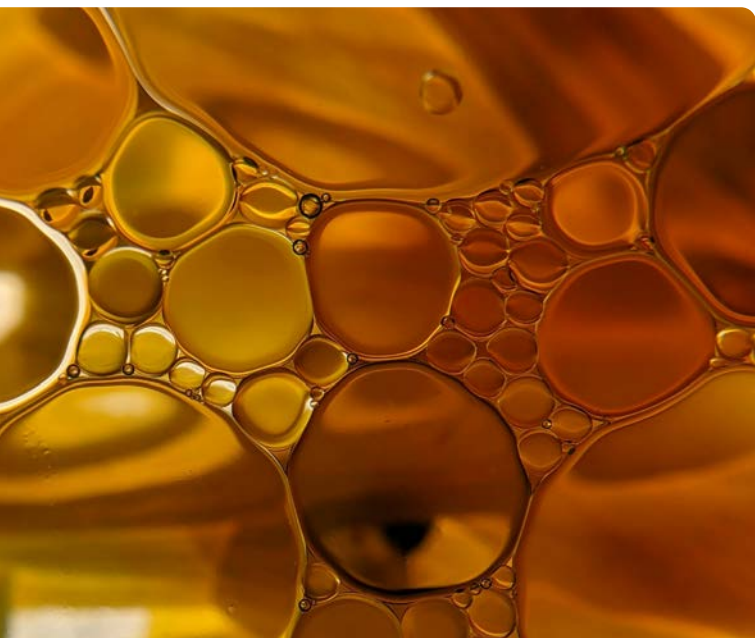
From a sustainability perspective, the use of hoki meal as a by product of New Zealand's regulated fisheries aligns more closely with circular economy principles than reliance on imported fishmeal, though further reduction remains a long term objective.

While currently a hoki processing factory is not based in Southland, they are in the South Island, including Timaru, Christchurch, Nelson and Blenheim.

FISH OIL

Fish oil remains the primary source of long chain omega 3 fatty acids (EPA and DHA) required for salmon health, growth, immune function and flesh quality. These fatty acids cannot be synthesised in sufficient quantities from plant oils alone, nor at an economical rate.

Fish oil therefore continues to play a critical functional role, even in a predominantly plant based formulation. Inclusion rates are minimised and increasingly complemented by alternative sources such as microalgae oil. Microalgae derived oils are discussed elsewhere in this report, though cost and scale remain limiting factors.



FISH HYDROLYSATE

As plant inclusion increases, palatability becomes a limiting factor. Fish hydrolysates are therefore used at low levels as palatants to ensure consistent feed intake and minimise waste.

Fish hydrolysates provide:

- Strong feeding stimulation
- Improved acceptance of plant heavy pellets
- Bioactive peptides that support digestion and nutrient uptake

In a feed where nearly half of ingredients are plant based, palatants are not optional; they are a key enabler of performance and welfare.

POULTRY MEAL (POULTRY BY-PRODUCT MEAL)

Poultry by product meal is widely used in aquafeed internationally as a high quality protein source. Derived from rendered poultry processing residues, it offers a circular economy solution by converting unavoidable by products into valuable feed inputs.

Its value lies in:

- High protein content and digestibility
- Complementary amino acid balance to legumes and cereals
- Reduced pressure on wild fisheries
- Efficient use of unavoidable processing by products

At present, the closest poultry processing facility is in the Canterbury region in Christchurch.

POULTRY FAT

Poultry fat is formulated within the suggested aquafeed composition, however, BSFL fat and vegetable oils such as canola, are in bracketed in the formulation as they may have equal properties and thus be substituted. Rendered poultry fat, Black soldier fly derived fats and vegetable oils provide concentrated energy sources and help balance lipid requirements in aquafeed.

BLOOD MEAL

Blood meal is a highly concentrated protein ingredient, rich in lysine and other essential amino acids that are comparatively limited in plant based proteins. It has a strong flavour profile which adds to the aquafeed palatability, as salmon are very taste sensitive.

In a formulation with high plant inclusion, blood meal can:

- Improve protein efficiency
- Reduce reliance on synthetic amino acids

POSITIONING FOR TRANSITION

At a 45% plant-based inclusion rate, this formulation represents a substantial step away from conventional aquafeed, while acknowledging current biological and nutritional constraints. Animal-derived ingredients remain present, but their role has shifted from bulk nutrition to precision functionality.

This creates a clear opportunity for insect-based proteins, particularly black soldier fly larvae, to replace or further reduce:

- Poultry meal
- Blood meal
- Portions of fishmeal
- Animal-derived fats

The following section explores insect-based protein production in detail, positioning it as a logical and scalable next phase in the evolution toward low-impact, locally sourced aquafeed systems in Murihiku Southland. The following section explores this opportunity in detail.



Ingredient Readiness Assessment

Ingredient readiness reflects the extent to which a feed ingredient can be technically incorporated into salmon aquafeed formulations and feasibly produced, processed, and regulated within Murihiku Southland, using existing or realistically adaptable regional systems.

This assessment focuses on technical formulation suitability, regional production capability, processing and milling compatibility, regulatory feasibility, and technical maturity, and does not constitute an economic or commercial viability assessment.

CRITERIA

Each ingredient is scored 1–5 against the following five equally weighted criteria:

1. Nutritional & Formulation Readiness

Ability to be incorporated into salmon aquafeed formulations without compromising:

- Fish health or performance
- Pellet integrity (binding, oil retention, sinking behaviour)

2. Regional Production Readiness (Southland)

Extent to which the ingredient can be:

- Grown, cultivated, or produced at scale in Southland
- Reliably supplied under local climatic and agronomic conditions

3. Processing & Systems Compatibility

Compatibility with:

- Existing or readily adaptable Southland or South Island infrastructure
- Milling, drying, oil extraction, rendering, pelleting systems

4. Regulatory & Biosecurity Feasibility

Clarity and manageability of:

- MPI feed ingredient pathways
- Biosecurity, consenting, and compliance requirements

5. Technical Maturity & Evidence Base

Level of:

- Commercial use in aquafeed or
- Robust trials in salmonids or comparable species

Score	Interpretation
5	Commercially proven and readily deployable
4	Proven with minor adaption
3	Technically feasible; pilot-ready
2	Early stage; material uncertainty
1	Conceptual or experimental



CONSOLIDATED READINESS TABLE OF ALL ANALYSED INGREDIENTS

To support a practical and industry relevant transition toward locally sourced aquafeed production, a readiness assessment was undertaken across all ingredients explored in this report. The assessment evaluates each ingredient's technical suitability for salmon aquafeed formulations, alongside its feasibility for regional production, processing, regulatory compliance, and integration with existing feed manufacturing systems in Murihiku Southland.

Each ingredient has been scored against five criteria using a conservative, evidence based approach and grouped into clearly defined readiness bands, ranging from commercially ready to pilot ready. This assessment is intended to inform ingredient sequencing and prioritisation and does not represent a full commercial or economic feasibility analysis.

Ingredient	Nutrition & Formulation (1-5)	Regional Production (1-5)	Processing Compatibility (1-5)	Regulatory Feasibility (1-5)	Evidence Base (1-5)	Total Score (/25)	Readiness Brand
Wheat	5	5	5	5	5	25	Commercially ready
Barley	4	5	5	5	5	24	Commercially ready
Potato (starch)	5	5	4	5	5	24	Commercially ready
Oats	4	5	5	5	4	23	Commercially ready
Fava Beans	5	4	4	5	5	23	Commercially ready
Canola (meal/oil)	5	4	4	5	5	23	Commercially ready
Lupins	5	3	4	5	5	22	Commercially ready
Peas	4	4	4	5	4	21	Commercially ready
Lucerne (alfalfa)	4	4	4	5	4	21	Commercially ready
Flaxseed (meal/oil)	4	4	4	5	4	21	Commercially ready
Kale	4	5	4	5	3	21	Commercially ready
Fishmeal (Hoki)	5	2	4	5	5	21	Commercially ready
Poultry by-product meal	5	2	4	5	5	21	Commercially ready
Microalgae (microalgae protein/oil)	5	3	3	4	4	19	Pilot-ready
Camelina	4	3	3	4	3	17	Pilot-ready
Green-lipped mussel (by-product)	4	4	3	3	3	17	Pilot-ready
Black Soldier Fly Larvae (BSFL)	4	3	3	3	4	17	Pilot-ready
Purslane	3	3	3	5	2	16	Pilot-ready
Ulva sp. (sea lettuce)	3	4	3	3	3	16	Pilot-ready
Bladder Kelp	3	4	3	3	3	16	Pilot-ready

The readiness assessment demonstrates a clear pathway for aquafeed development in Murihiku Southland. Cereals, legumes, oilseeds, potato starch and lucerne emerge as the most commercially ready ingredients, reflecting their strong formulation performance, established regional production, mature regulatory status and compatibility with existing milling and processing infrastructure. These ingredients represent the most immediate opportunity to localise aquafeed supply while maintaining feed reliability and industry confidence.

Insect based protein, microalgae and marine biomass inputs, while nutritionally robust and strategically important, are best positioned as pilot ready ingredients. Their slightly lower readiness scores reflect infrastructure, scaling and regulatory considerations rather than nutritional constraints. Animal derived ingredients such as fishmeal (hoki) and poultry by product meal continue to play a functional role in aquafeed formulations, despite lower regional production readiness, and provide important transition anchors as alternative protein systems are developed.

Collectively, this staged readiness profile supports a low risk, systems based transition toward more sustainable, locally integrated aquafeed production in Murihiku Southland.

Conclusion

Murihiku Southland is well positioned to play a meaningful role in the transition toward more sustainable, resilient and locally supported aquafeed systems in New Zealand.

This report has demonstrated that the region's cool temperate climate, fertile soils, established agricultural base and coastal resources provide a strong foundation for the production of a diverse range of aquafeed ingredients. These inputs have the potential to reduce reliance on imported feeds, improve supply chain security and support lower emissions aquaculture pathways as the finfish sector continues to grow.

The assessment highlights a clear hierarchy of opportunity. Cereals, legumes, oilseeds, potato starch and lucerne emerge as the most immediately ready ingredients, reflecting their proven agronomic performance in Southland, compatibility with existing processing infrastructure, straightforward regulatory pathways and established use in aquafeed formulations. These crops represent a practical starting point for localising aquafeed inputs and creating early momentum without introducing unnecessary technical or commercial risk.

Insect based protein systems, microalgae and marine biomass inputs, such as kelp, *Ulva* sp. and green lipped mussel by products, are identified as strategically important and pilot ready ingredients. While these inputs offer strong nutritional and environmental benefits, their large scale deployment will require further work to address infrastructure, regulatory clarity, processing capability and system integration. A staged approach that combines pilot trials with industry partnerships is therefore recommended to enable learning, manage risk and build confidence over time.

Animal derived ingredients, including hoki fishmeal and poultry by product meal, continue to play an important functional role in aquafeed formulations, particularly in supporting digestibility, palatability and essential nutrient supply. While their long term inclusion rates may decline as alternative proteins mature, they remain critical transition ingredients that support feed performance and fish welfare in the near to medium term.

Rising sea temperatures are already increasing mortality in Chinook (King) salmon, whose limited thermal tolerance makes them highly vulnerable to even small warming events. These climate driven pressures highlight the need for adaptable aquafeed systems that can support salmon now, while also providing the

flexibility to shift toward more heat tolerant species if future conditions require it. Furthermore, the use of antibiotics must be avoided where possible to protect wider marine ecosystems and salmon health.

Every formulation would require feed trials and significant testing for palatability, weight conversion, fish health and the taste of the harvested fish. Other physical characteristics such as optimal sinking rates, feed accessibility feed wastage and water quality are critically important considerations. A robust knowledge of the aquaculture environment in which the feed is to be consumed such as water salinity, temperature and currents all of which is essential to design feed that is suitable for the application.

Taken together, the findings of this report reinforce that the development of an aquafeed capability in Murihiku Southland is best approached as a phased, systems based transition rather than a single, immediate investment in full feed manufacturing. By prioritising ingredient production first, supporting targeted trials, and aligning with experienced feed and aquaculture partners, the region can progressively build capability while maintaining industry credibility and biological performance.

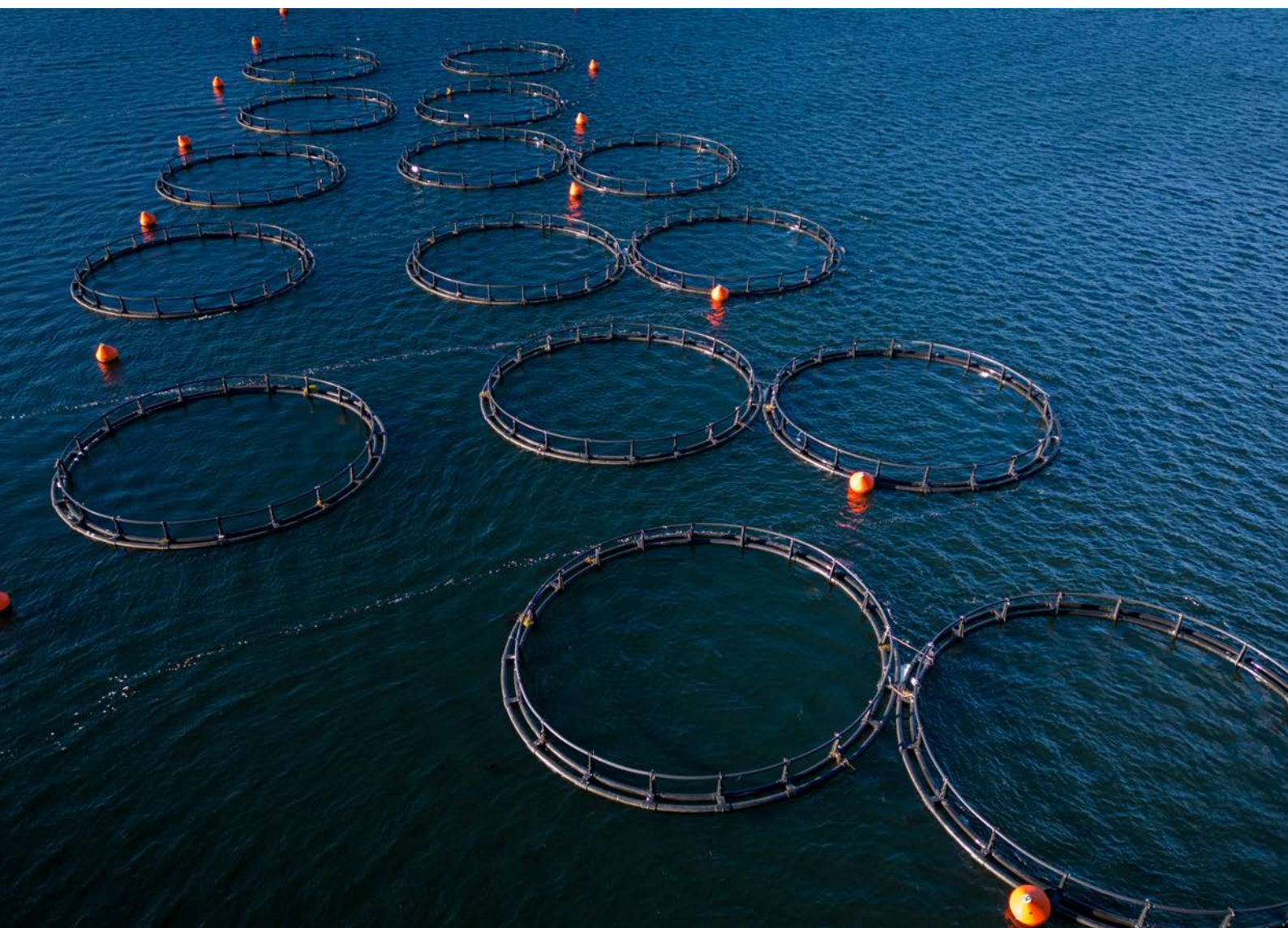
To consider such an investment, partnerships would be required with experienced aquafeed experts and producers, and a feed production facility would require secured market sales of more than 30,000 tonnes per annum. Feed industry and research partnerships are critical to the success of a new feed manufacturing industry. There seems to be merit in considering the establishment of a collaborative industry research hub to support this work.

With coordinated effort, continued innovation and careful sequencing, Southland has the opportunity to strengthen its role in New Zealand's aquaculture value chain, supporting regenerative land use, resilient supply chains and a lower impact aquaculture future.

Recommendations to progress this opportunity from concept to implementation are as follows:

- Establish industry partnerships across agriculture, aquaculture and waste management areas to support growing trials, infrastructure and innovation.
- Seek support for the funding of an aquafeed development model and feed formulation trials.
- Establish an industry development group.
- Considerations of feed palatability & conversion ratios.
- Test feasibility of composition of ingredients to ensure taste, texture, sinkability and compatibility with pellet manufacturing systems and fish feeding behaviour.
- Create aquafeed formulations and develop feed formulations for juveniles/smolt.
- Conduct feasibility studies including cost modelling (from producing crops, to producing pellets) and ingredient sourcing to validate commercial scalability.
- Develop cropping, harvest and processing trials for candidate crops.
- Initiate pilot trials with aquaculture industry partners to test feed performance and fish health outcomes.
- Engage with regulatory bodies to ensure compliance and explore certification pathways.
- Develop consumer-facing transparency tools, such as traceability systems and sustainability labelling, to meet market expectations and build brand value.
- If proven viable develop capital investment plan and a business case and investment memorandum.

With continued innovation and investment, Southland New Zealand has the potential to become a national and global example for sustainable aquafeed production – setting a benchmark for regenerative aquaculture systems.



Appendix A

TABLE 4: SOIL VERSATILITY RATING FOR ARABLE AGRICULTURE

Arable Versatility Rating			
Land qualities affecting arable production potential	A1	A2	A3
Potential rooting depth (cm)	>60	45 - 60	25 - 45
Limitation to root penetrability	moderate	severe	very severe
Limitation to profile aeration capacity	slight	moderate	very severe
Short-term waterlogging conditions	slight	moderate	very severe
Salinity (EC, mS/cm)	<0.4	0.4 - 0.8	0.8 - 0.2
Soil water deficit (mm)	0 - 200	200 - 400	400 - 500
Land qualities affecting arable management limitations			
Slope angle (degrees)	0 - 7		8 - 15
Topsoil stoniness	slight	moderate	very severe
Potential flood risk (years)	1 in 20	1 in 10	1 in 10
Land qualities affecting vulnerability of arable environmental health			
Vulnerability to structure loss and compaction	moderate	severe	very severe
Vulnerability to topsoil erodibility by water	slight	moderate	severe
Vulnerability to nutrient leaching	moderate	severe	very severe
Vulnerability to soil organic matter loss	slight	moderate	severe
Vulnerability to waterlogging	slight	moderate	severe

TABLE 5: ARABLE VERSATILITY A1 - 3 FACT SHEET

Arable versatility	Number of predominant soil series represented	Total area (ha)	% of all soils surveyed*
A1	7	10,818	1
A2	64	176,466	22
A3	120	454,466	57

*All soils surveyed (a total of 795,374 ha) includes those not considered suitable for arable agriculture.

FIGURE 3: SOUTHLAND ARABLE CROP AREAS WITH VERSATILITY A1.

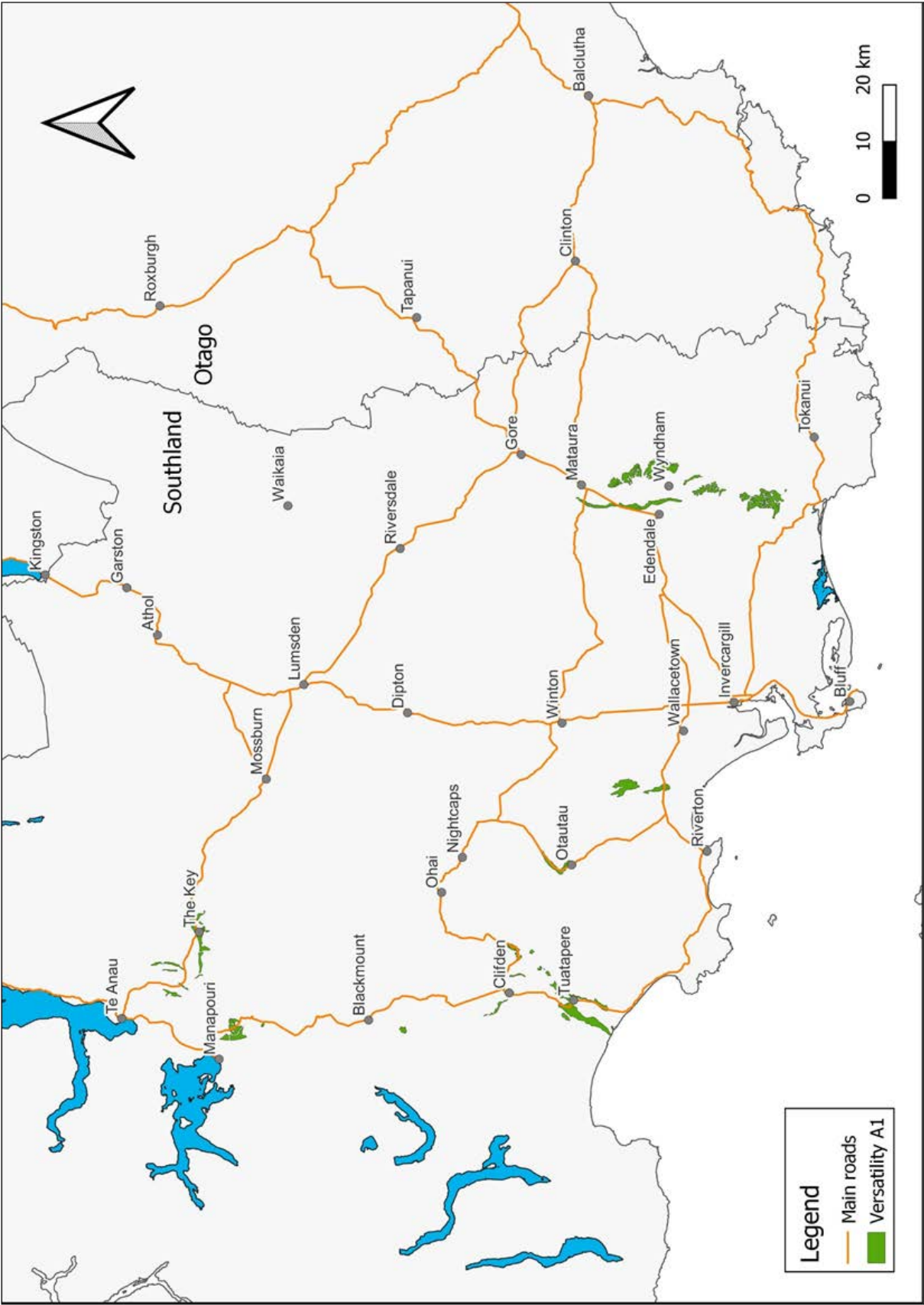


FIGURE 4: SOUTHLAND ARABLE CROP AREAS WITH VERSATILITY A2.

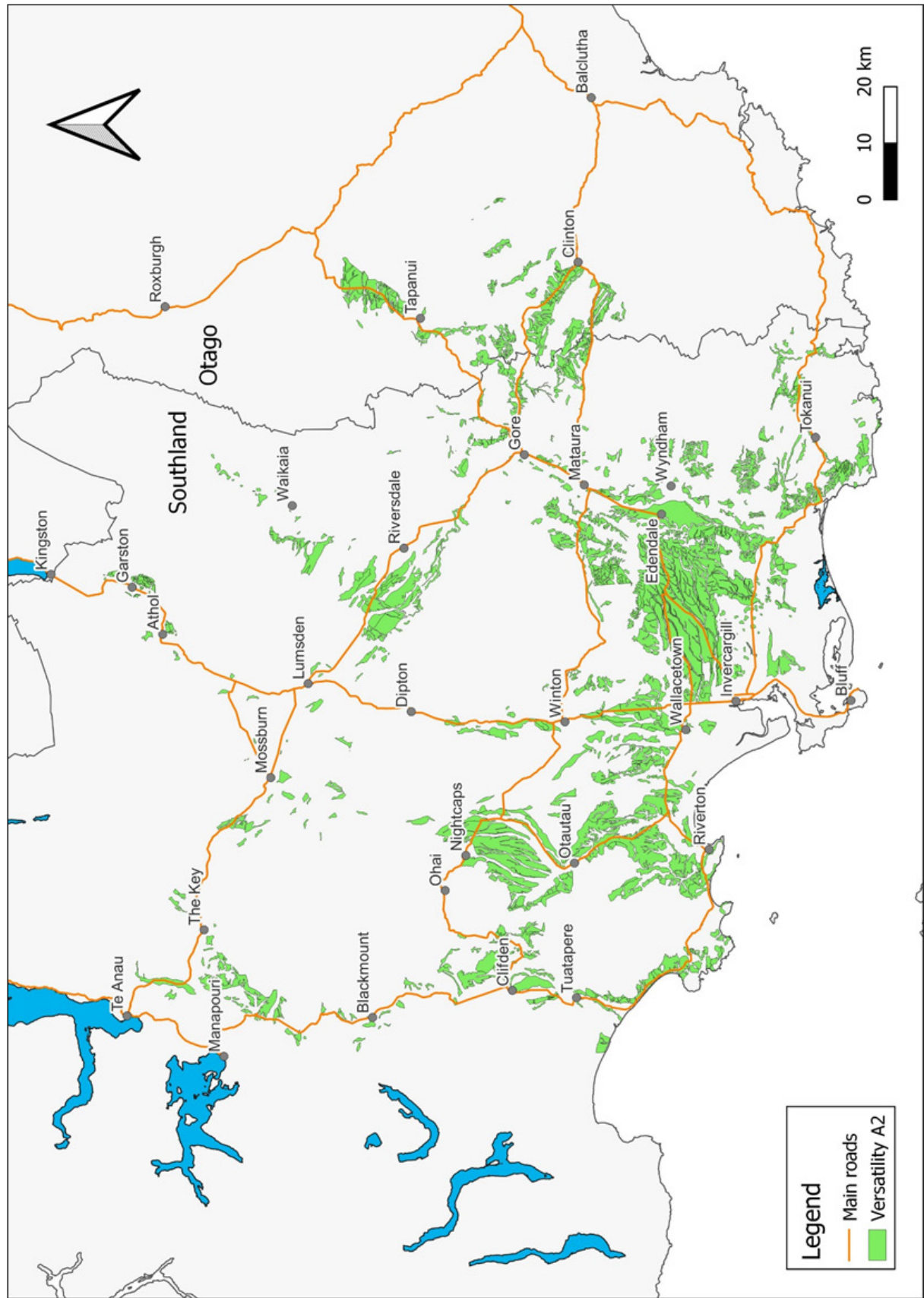


FIGURE 5: SOUTHLAND ARABLE CROP AREAS WITH VERSATILITY A3.

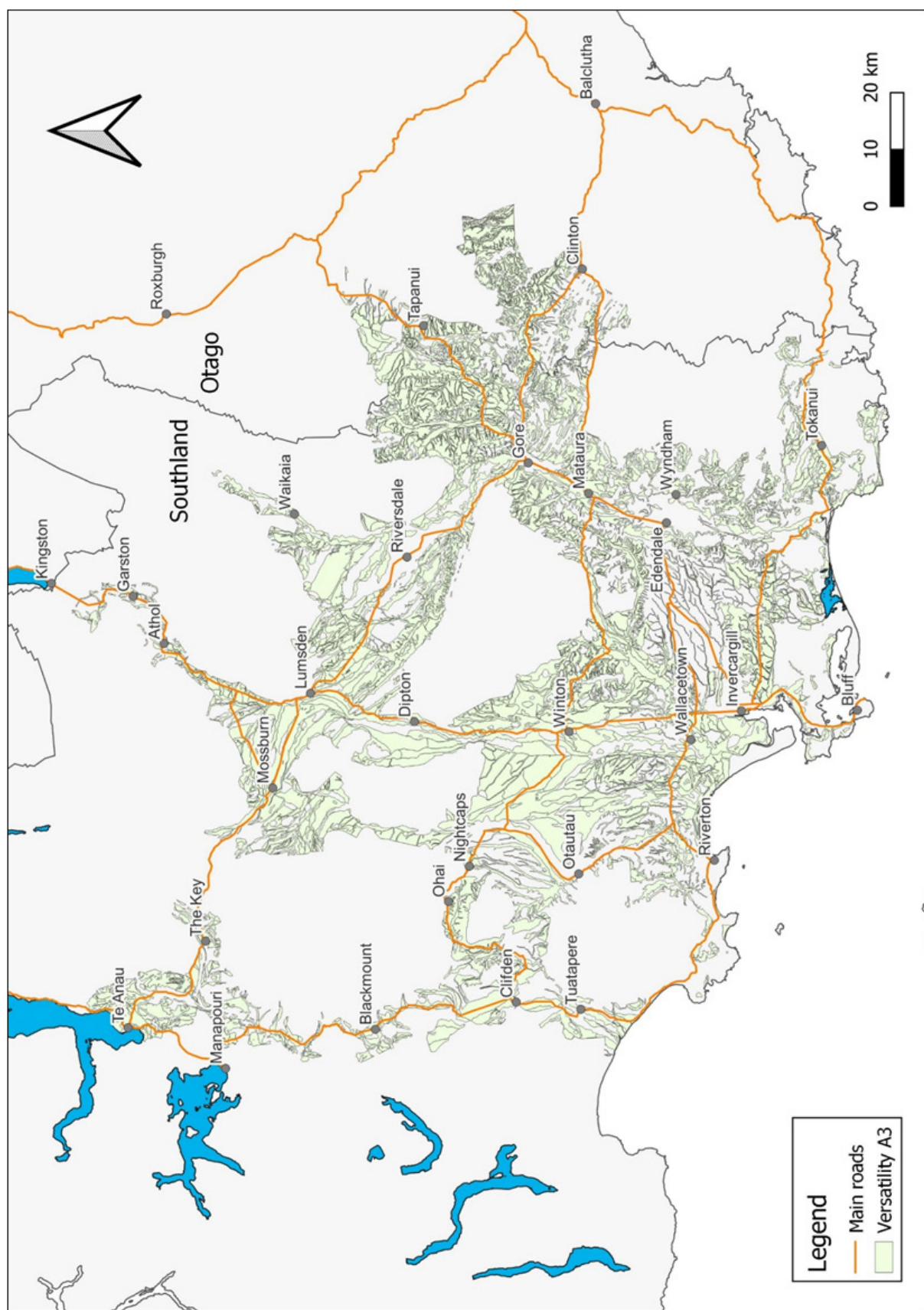


FIGURE 6: SOUTHLAND ARABLE CROP AREAS WITH VERSATILITY A1 AND A2.

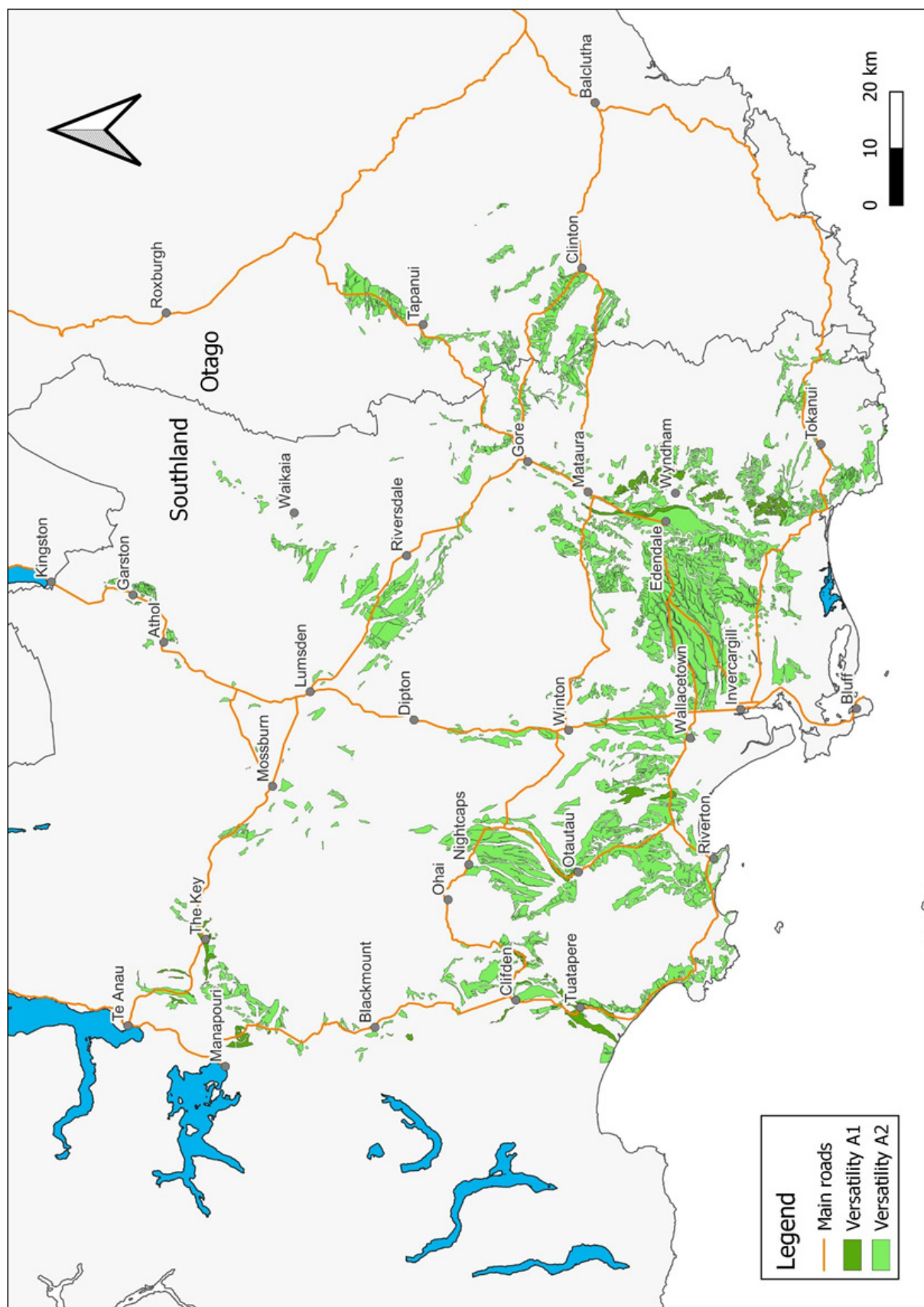


FIGURE 7: SOUTHLAND ARABLE CROP AREAS WITH VERSATILITY A1, A2 AND A3.

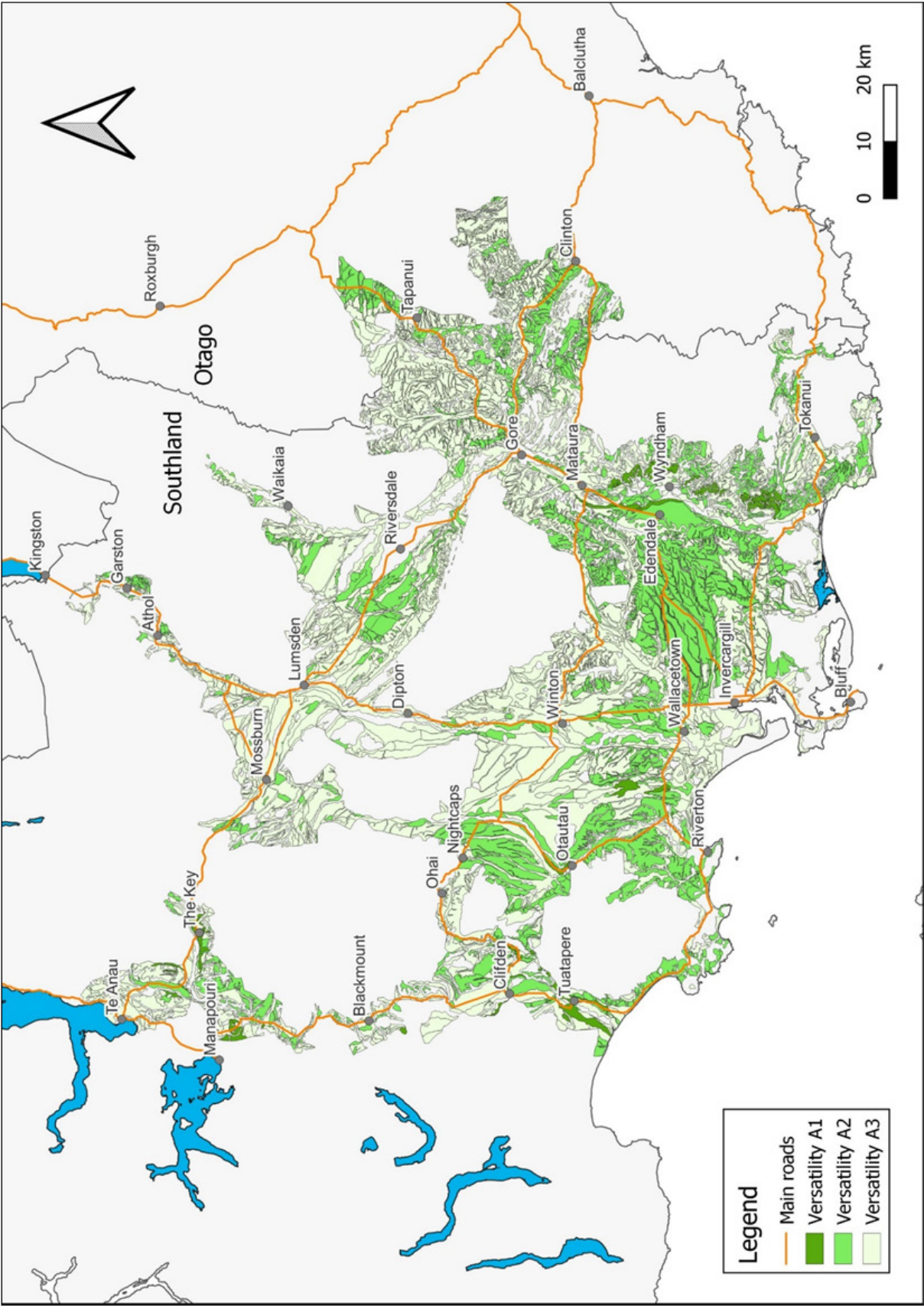


FIGURE 8: SOUTHLAND ARABLE CROP AREAS WITH CLAYEY SOIL.

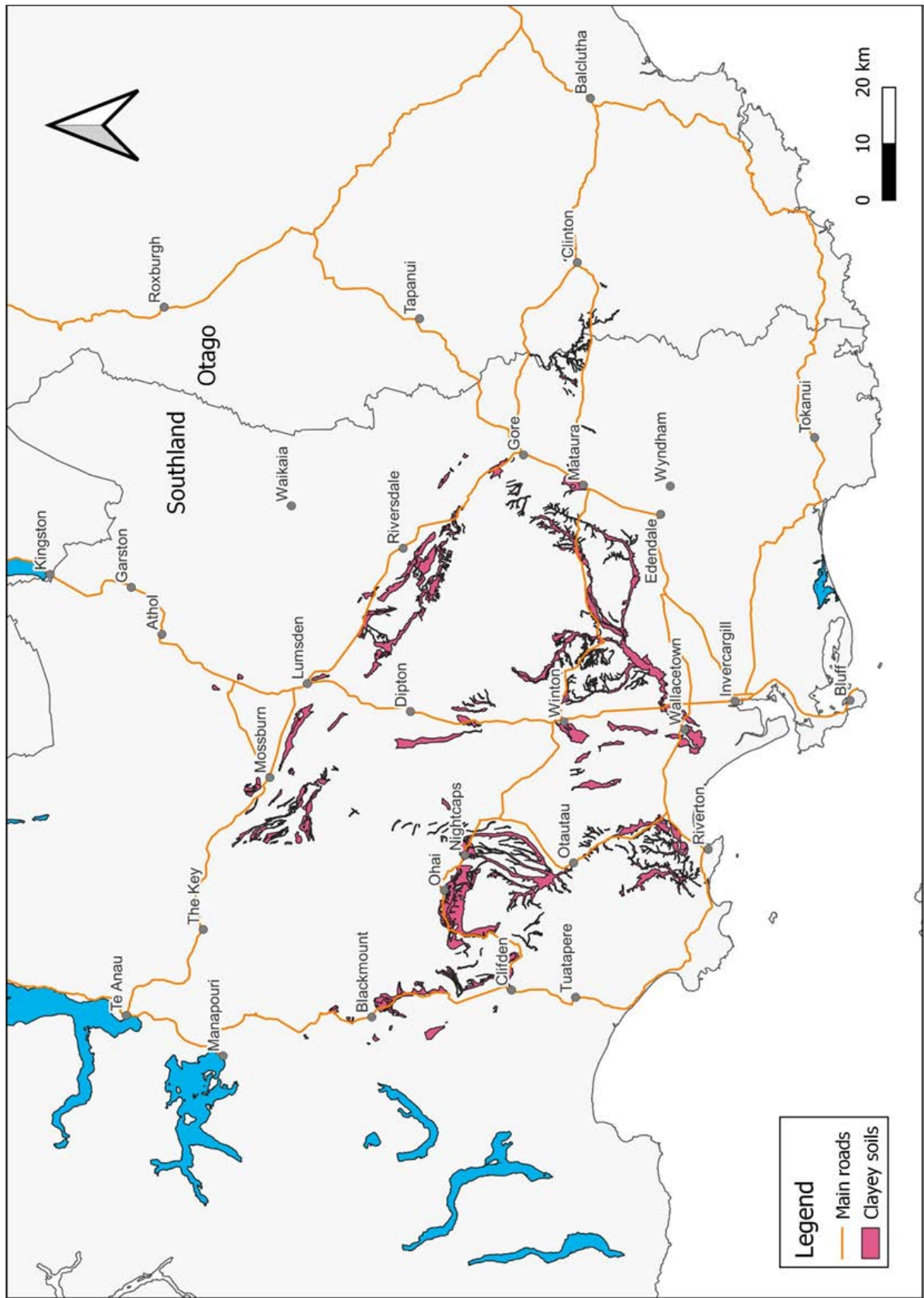
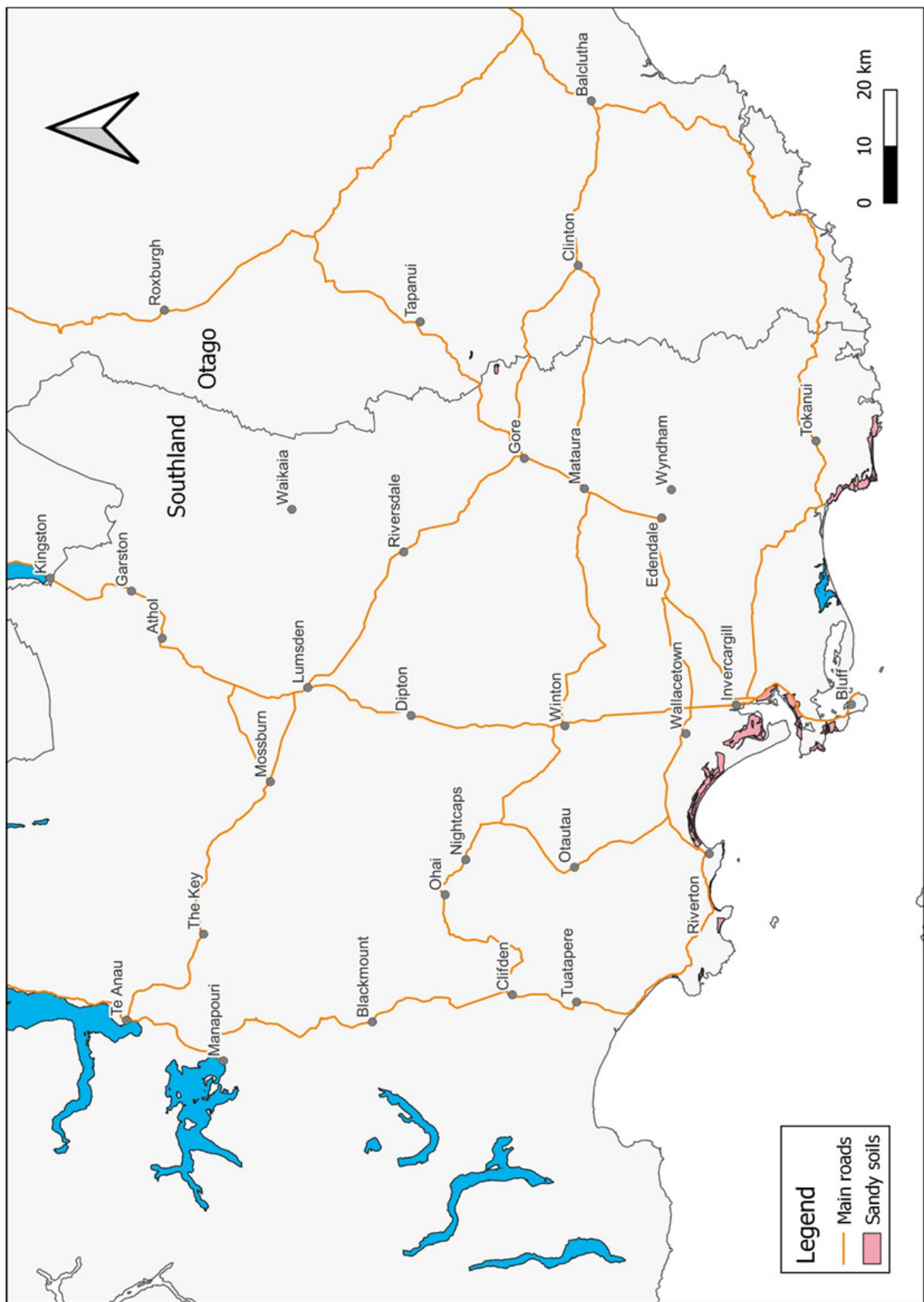


FIGURE 9: SOUTHLAND ARABLE CROP AREAS WITH SANDY SOILS.



Appendix B

Sustainability Framework

The *Aquafeed Production Opportunities within Murihiku Southland* report are aimed at upholding the principles of sustainability and ethical production which are essential element of maintaining sustainable industry development within the region.

Accordingly, this report is aligned with the United Nations Sustainable Development Goals (UN SDGs). These 17 goals outline 169 targets to take to enable positive environmental, social, and economic impact.

The influence of the UN SDGs should ideally apply across the entire aquafeed value chain; from cropping farmers to millers, aquafeed manufacturing, distributors. By applying these aspirations, this project aims to foster solutions that deliver mutual benefits across the various stakeholders and provide significant product differentiation and product branding opportunities.

The SDGs most relevant to this report are outlined below, with points of how the findings from this report best align with that goal. However, it is important to note that all SDGs intertwine and connect to across all elements of this report. This should also apply to both the terrestrial and marine environments. It is also important that the progression of these goals is recognised as part of the overall industry development and should be progressed over time.





ZERO HUNGER

- Supports sustainable food systems by enabling local aquafeed production for salmon farming
- Improving food security and resilience for Southland and consumers at large
- Reduces reliance on imported feed ingredients and strengthens regional supply chains, ensuring consistent and ethical protein sources for aquaculture
- Benefits the future of sustainable protein production in Aotearoa



GOOD HEALTH AND WELL-BEING

- Improved fish health and welfare through more sustainable aquafeed
- Promotion of healthier salmon for human consumption
- Reduced contaminants (dyes), chemical residues, and improved food safety with transparency and localisation
- Support the non-use of antibiotics in aquafeed
- Supporting consumer health and well-being



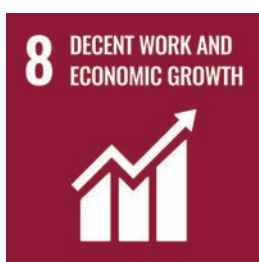
GENDER EQUALITY

- Creation of employment opportunities supporting gender-balanced participation
- Develop Technical skills development and opportunities for a female workforce, in such as agronomy, biology, circular systems design, marine science, food science, feed technology/processing, species health and development of skills and career pathway into management and governance.
- Enabling leadership opportunities in emerging sectors



AFFORDABLE AND CLEAN ENERGY

- Creation of employment opportunities supporting gender-balanced participation
- Develop Technical skills development and opportunities for a female workforce, in such as agronomy, biology, circular systems design, marine science, food science, feed technology/processing, species health and development of skills and career pathway into management and governance.
- Enabling leadership opportunities in emerging sectors



DECENT WORK AND ECONOMIC GROWTH

- Developing a local aquafeed industry creates opportunities for skills development and 21st century career opportunities in agriculture, aquaculture, and processing sectors
- Support the living wage principles
- Promote access to affordable accommodation for the workforce
- Fosters regional investment
- Foster value-added production and product branding aimed at positioning Southland as a leader in high quality sustainable aquaculture



INDUSTRY, INNOVATION AND INFRASTRUCTURE

- Supports development of fit for purpose manufacturing, milling and aquafeed processing factory's
- Recommendations in establishing pilot trials, and integrated systems (BSFL farming and microalgae cultivation)
- Promote industrial innovation and infrastructure development for a circular economy



RESPONSIBLE CONSUMPTION AND PRODUCTION

- By replacing fishmeal and meat-based feed with plant, microalgae, and insect-based alternatives, the initiative reduces pressure on wild fisheries
- Supports local, transparent, low-impact supply chains with less reliance on global supply markets
- Integrates waste-to-feed systems (BSFL), minimising food and organic waste with a more circular economy



CLIMATE ACTION

- Localising feed production
- Reduced transport and energy emissions
- Promote water efficiency and waste minimisation
- Marine resources like kelp and Ulva contribute to carbon sequestration
- Insect-based systems divert organic waste from landfill, mitigating methane emissions
- Climate mitigations are embedded at every stage
- Support the use of geospatial, satellite earth observation technology to enhance planning and environmental reporting processes



LIFE BELOW WATER

- Reduced reliance on krill as an ingredient helps protect wild krill populations
- Sustainable aquafeed reduces reliance on fishmeal, helping protect marine biodiversity
- Develop multitopic integrating filter feeders and seaweed into aquaculture systems water quality and ecosystem health





LIFE ON LAND

- Support land use change using locally produced crops.
- Promote regenerative agriculture through nitrogen-fixing crops (e.g. lucerne, fava beans, peas, lupins)
- Crop rotations that enhance soil health and biodiversity
- Encourage low-input, climate-resilient crops.



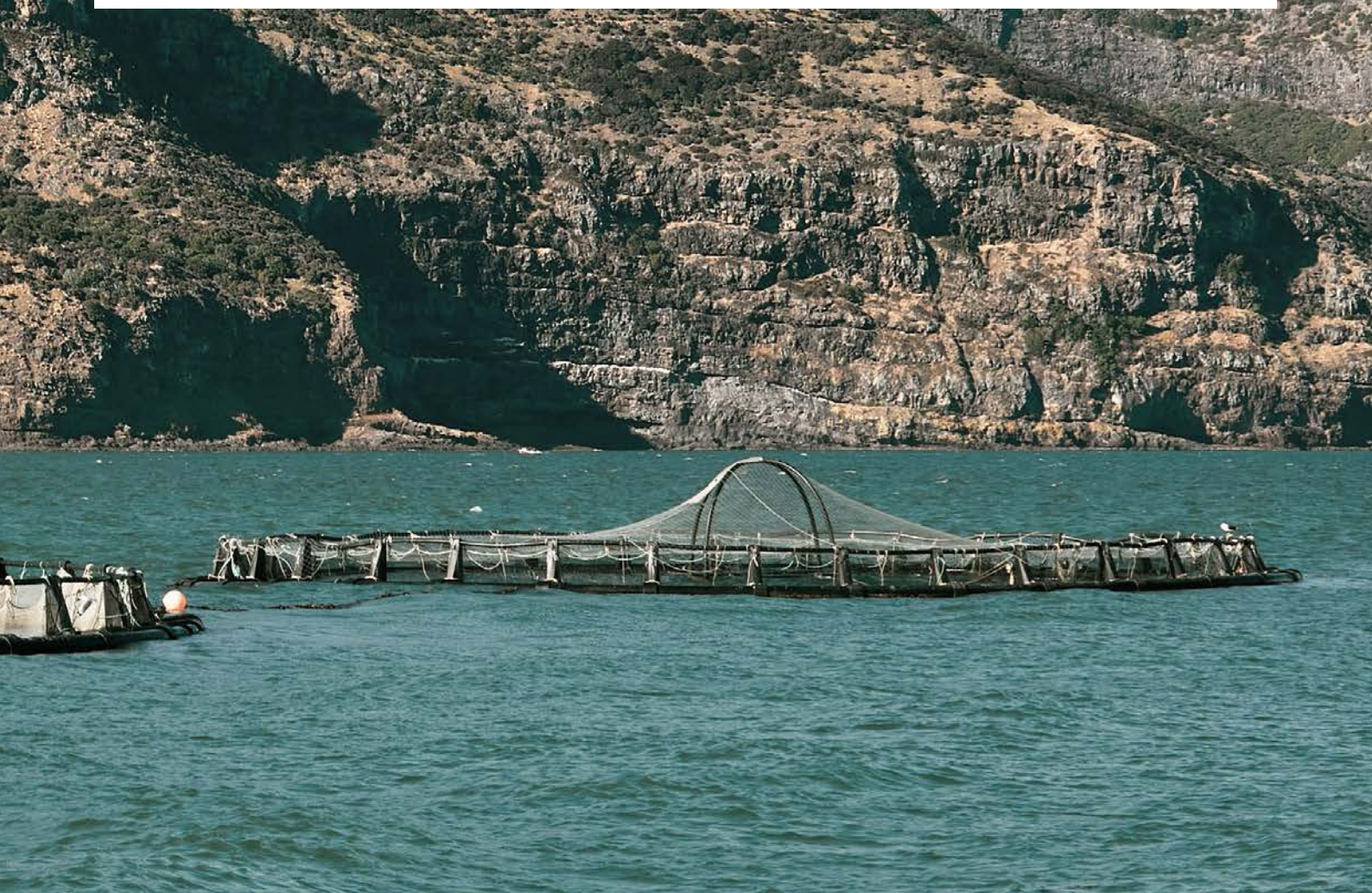
PEACE, JUSTICE AND STRONG INSTITUTIONS

- Adhering to aquaculture, food safety, and environmental regulations
- Supporting strong biosecurity standards, especially with BSFL systems
- Supporting resilient and fair economic systems
- Supporting stable employment
-



PARTNERSHIP FOR THE GOALS

- Promote iwi partnerships
- The report calls for cross-sector collaboration among agriculture, aquaculture, environmental, and regulatory bodies
- Partnerships for research, pilot trials, and consumer transparency tools
- Report regularly on environmental performance



Glossary

- **Alkaloids:** Alkaloids are anti-nutritional compounds and are also very bitter, which reduces feed palatability and therefore feed intake and growth.
- **Aquafeed:** Specialised feed formulated for aquatic animals, particularly fish, like salmon.
- **Astaxanthin:** A red pigment used to colour farmed salmon flesh; often synthetic or derived from krill. Also known as colourant.
- **Bioactive Compounds:** Naturally occurring substances in plants or animals that have biological effects, such as improving immunity or reducing inflammation.
- **Biomass:** The total mass of living organisms in a given area, often used to describe crop yield or seaweed growth.
- **Binders:** Ingredients that help hold aquafeed pellets together and maintain their shape.
- **Carbon Sequestration:** The process of capturing and storing atmospheric carbon, such as through marine plants like kelp.
- **Circular Economy:** A system that minimizes waste and maximises resource reuse, such as converting food waste into insect protein.
- **DHA:** Docosahexaenoic acid is an essential omega-3 fatty acid, supporting vision, brain function, heart health and reduces inflammation. DHA works with and alongside EPA.
- **EPA:** Eicosapentaenoic acid is a type of omega-3 fatty acid, working alongside DHA to support health, growth and reproduction of the fish.
- **Food Conversion Ratio (FCR):** The amount of feed required to produce a unit of fish biomass (e.g. FCR for aquafeed for salmon is 1.3:1).
- **Integrated Multi-Trophic Aquaculture (IMTA):** A system where multiple species (e.g., fish, seaweed, shellfish) are farmed together to mimic natural ecosystems and improve sustainability.
- **Nitrogen Fixation:** Process by which legumes convert atmospheric nitrogen into soil nutrients.
- **Pellet Feed:** Compressed feed in pellet form, designed for slow sinking to suit salmon feeding behaviour.
- **Regenerative Agriculture:** Farming practices that restore soil health, biodiversity, and ecosystem function.
- **Versatility Ratings:** Soil classifications based on rooting depth, drainage, and suitability for arable agriculture.



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