



accenture

FUTURE PROOFING SHRIMP PRODUCTION

Transition to *Controlled Intensification*

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Attributions

World Wildlife Fund (WWF) is one of the world’s leading conservation organizations. WWF works in more than 100 countries, collaborating with people around the world to develop and deliver innovative solutions that protect communities, wildlife, and the places in which they live.

WWF commissioned **Accenture**, a leading global professional services and consulting firm, to explore the conceivable future of resource-efficient, intensified global shrimp production. This report examines the business and environmental case for change in shrimp aquaculture and outlines transition pathways and accelerators capable of mobilizing change at scale.

This publication is funded by an initiative established by the **Gordon and Betty Moore Foundation**.

Disclaimers

All companies named in this report are illustrative examples. Use of company names does not represent an explicit endorsement from Accenture or the World Wildlife Fund. All monetary figures are presented in U.S. dollars unless otherwise indicated. All tons are metric tons unless otherwise indicated.

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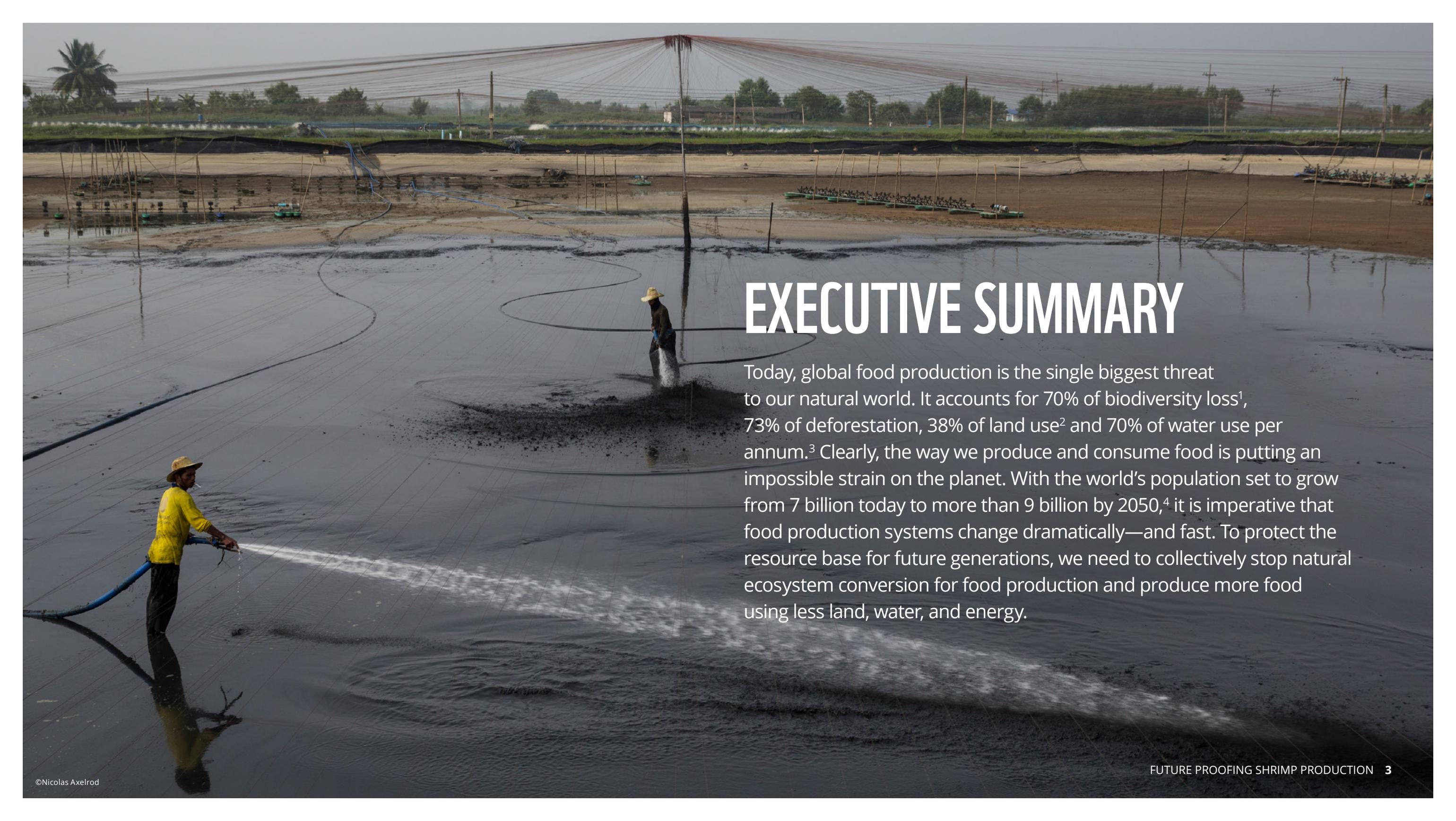
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A wide-angle photograph of a large-scale aquaculture pond. In the foreground, a worker in a yellow shirt and a hat is using a blue hose to spray water. Another worker in a dark shirt and hat is standing in the water further back. The pond is filled with water and has several wooden stakes and ropes visible. In the background, a massive, circular net structure is suspended over the pond, supported by a central pole and several other poles. The sky is overcast, and there are trees and utility poles in the distance.

EXECUTIVE SUMMARY

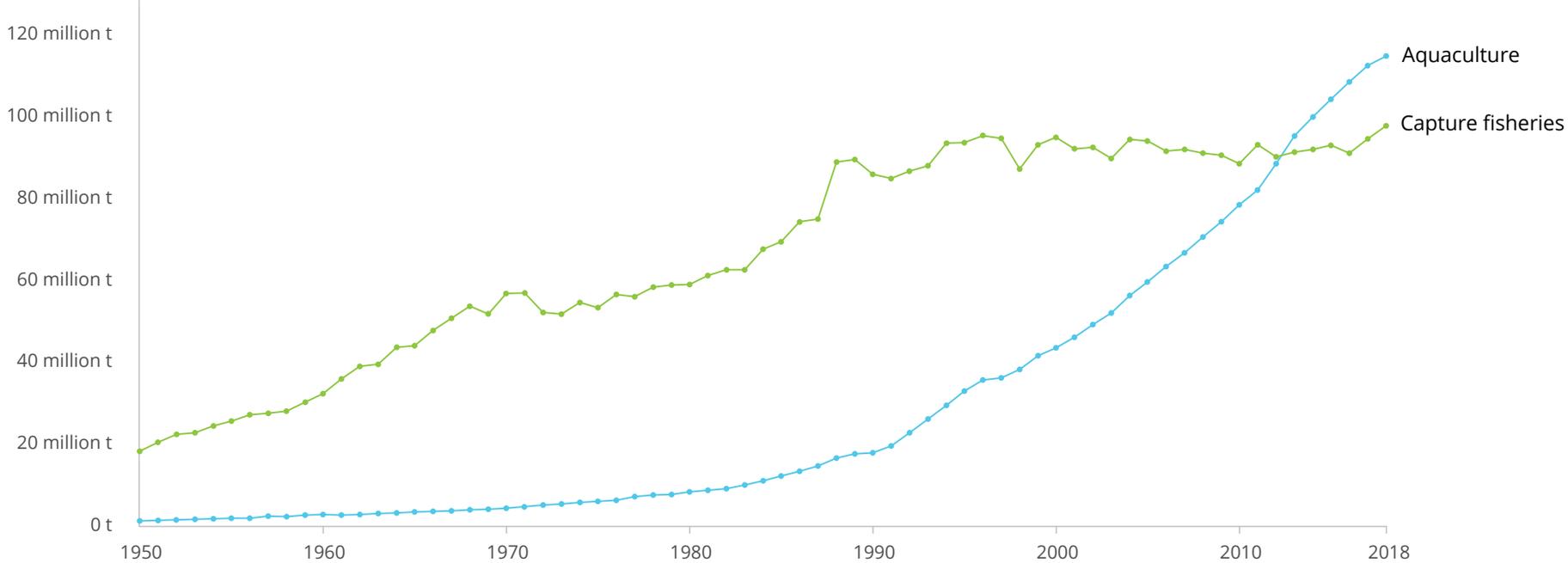
Today, global food production is the single biggest threat to our natural world. It accounts for 70% of biodiversity loss¹, 73% of deforestation, 38% of land use² and 70% of water use per annum.³ Clearly, the way we produce and consume food is putting an impossible strain on the planet. With the world's population set to grow from 7 billion today to more than 9 billion by 2050,⁴ it is imperative that food production systems change dramatically—and fast. To protect the resource base for future generations, we need to collectively stop natural ecosystem conversion for food production and produce more food using less land, water, and energy.

If we are to achieve this transition to more sustainable methods of food production, we cannot rely on age-old methods to expand farm output. It is estimated that applying the same expansive mindset of the past would require converting natural ecosystems twice the size of India to farmland in order to meet growing demand.⁵ Continuing business as usual will also make it impossible to remain below the international global warming target of two degrees Celsius.⁶

Certain industries offer more opportunities than others to adopt better practices based on environmental impacts, business opportunity, maturity, and overall market share. Global seafood is one such industry, given that seafood production has quadrupled over the past 50 years⁷ and 93% of the planet's fisheries are at or beyond their sustainable exploitation.⁸ Seafood demand is only expected to increase and so is the need for aquaculture. By 2050, conservative estimates show that the volume of seafood from aquaculture will increase by about 80%.⁹ This follows a similar trend from the past 60 years, where aquaculture increased from two million tons in 1960, to 112 million tons in 2017.

Global Seafood Production: Aquaculture vs. Capture Fisheries

Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Capture fishery production is the volume of wild fish catches landed for all commercial, industrial, recreational and subsistence purposes.



Source: UN Food and Agriculture Organization (FAO)





“

Aquaculture, done in a socially and environmentally friendly manner, is the only way to meet the growing demand for seafood, while also creating jobs, generating revenues and taking pressure off over-stretched capture fisheries.”

Randall Brummett –
Senior Fisheries and Aquaculture
Specialist at The World Bank

The Food and Agriculture Organization (FAO) purports that of all animal protein commodities in the seafood industry, shrimp will experience the largest growth in demand in the coming decades.¹⁰ Global shrimp production has already doubled between 2003 and 2016,¹¹ spurred mostly by aquaculture which has surpassed wild shrimp production to become the predominant source of production in 2007.¹² Shrimp production from aquaculture increased 500% from 2000 to 2017, and now farmed shrimp is the most valuable traded seafood commodity in the world by volume.¹³

Shrimp aquaculture, however, is not without its challenges. The industry is largely characterized by unindustrialized producers and unsustainable practices. It requires the use of natural resources that can, without proper management, result in negative impacts, such as natural habitat conversion, water pollution, over-exploitation of marine fisheries for fish meal and carbon emissions associated with electricity and farm fuel.¹⁴ One solution for reducing the use of land, water and energy in shrimp production is **controlled intensification**¹⁵—a type of aquaculture that uses more precise methods to produce shrimp at higher levels of input and output per unit of land area.

This report intends to build upon existing research and momentum to promote an industry-wide transition to shrimp production systems that are more environmentally sustainable and economically viable. It makes the case for controlled intensive production systems capable of meeting growing demand while achieving more business benefits and less environmental degradation.

The proposed transition to a more sustainable shrimp industry is designed to achieve four results.

Conversion-free production

Food production already utilizes almost half of the world’s vegetated land. Remaining ecosystems must be preserved and, if possible, expanded to provide valuable ecosystem services like air and water purification, climate change regulation and biodiversity.

Efficient use of natural resources

Food production is not only resource-intensive in its use of land and valuable topsoil, but it also accounts for more than 30% of global energy consumption¹⁶ and uses more water than any other human activity. To overcome this trend, production models must be constructed as protected, closed loop systems that source green energy and prioritize waste and water reuse.

Reduced risk, increased resilience

Food producers must be equipped to adapt to the increasing pressure and uncertainty caused by pandemics, natural disasters, and long-term effects of climate change; with adequate investment producers can overcome challenges to transition to more reliable and resilient methods.

Ability to meet growing demand

Production must be transitioned to achieve economies of scale whenever possible, creating mature, reliable, consistent, and industrialized systems that can meet consumer demand.



Effectively meeting the nutritional demands of a growing population while balancing the needs of our natural environment requires an expedited transition. To achieve controlled, intensive shrimp production at scale, there are **three accelerators** that, if activated by producers, feed companies, processors, and financiers, would enable industry-wide change:

Accelerators



Widespread use of technology.

Producers should increasingly utilize foundational intensification technologies to establish predictability and control within their production systems. As business models become financially stable, producers should seek to integrate technologies proven by startups and well-capitalized conglomerates, optimizing production inputs, and eventually breaking through to next-generation innovation.



Intentional direction of capital.

Financiers should direct debt and equity investments to producers small and large to transition to more controlled intensification. Doing so will stabilize production output and stimulate industrialization, which if done at a large scale would result in decreased market volatility, and the crowding in of additional investment.



Democratization of knowledge.

Industry knowledge regarding more controlled intensive production should be spread equally among value chain actors and influencers. Building human capital, information access and transparency, and government buy-in are critical to ensure that intensive transition is globally scaled.

Scientific research and better aquaculture management practices can steer the sector towards industry-wide transformation. The goal is for producers, feed companies, processors, and financiers to leverage these desired results and accelerators when implementing controlled intensive practices, mobilizing strategic investments, and continuously innovating for the future. The ones who lead this collective effort will be responsible for moving the industry towards a more professionalized form of animal protein production.

THE PATH AHEAD

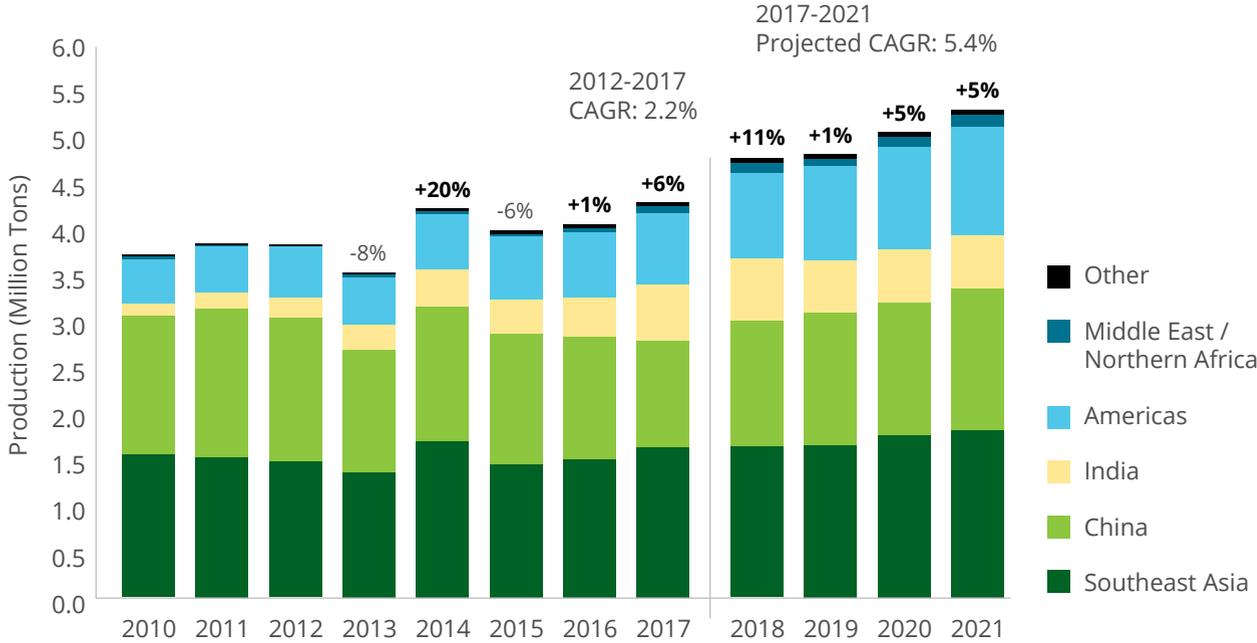
Establishing a more environmentally and economically sustainable shrimp industry requires farmers to increasingly employ controlled, intensive production methods. Pivoting the industry towards intensification is a dramatic shift from the landscape today, where most farms use extensive or semi-intensive methods, and largely depends on the financial attractiveness of emerging business models.



EXISTING PRODUCTION MODELS

Nearly all shrimp farming occurs in the developing or transitioning economies of Southeast Asia, Latin America, and South Asia. By volume and total value, whiteleg and black tiger shrimp are the most widely farmed species of the 14 tracked by FAO.¹⁷

Figure 1: Farmed Shrimp Production by Year and Region



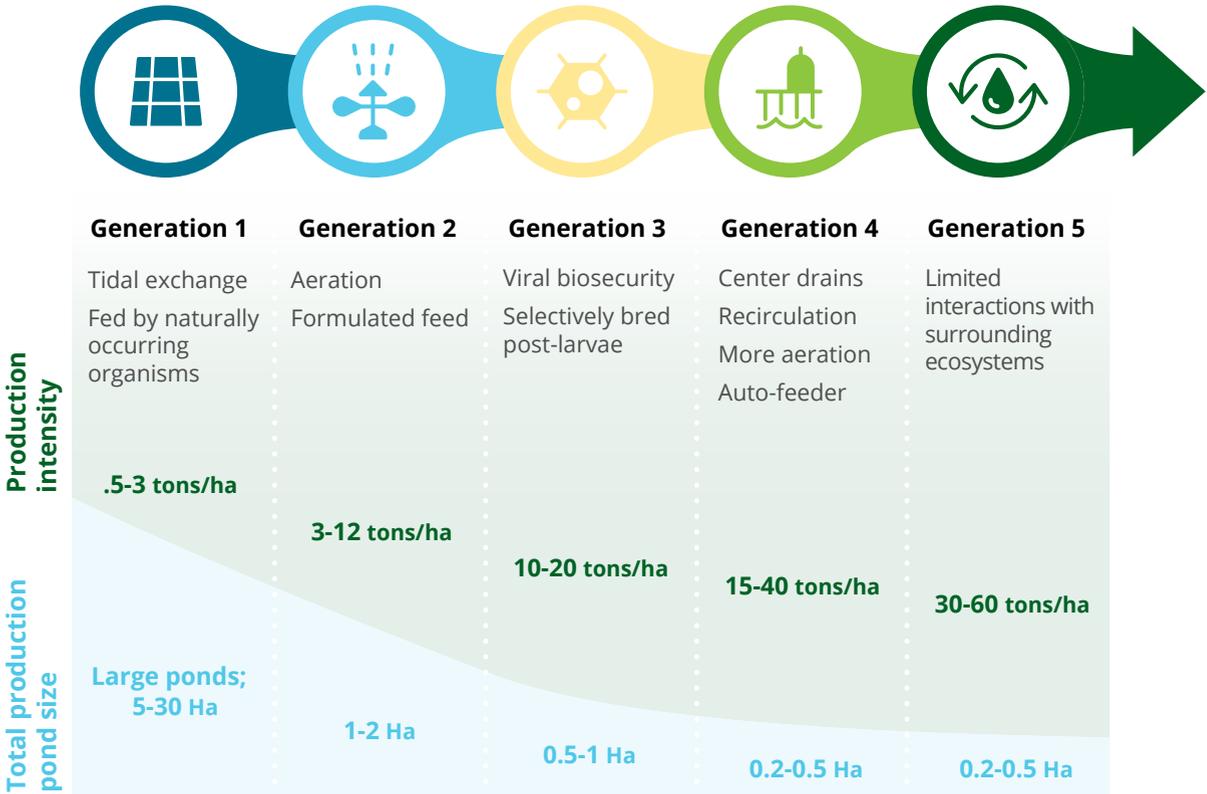
Sources: FAO (2019) and GOAL surveys (2011 to 2018) for 2010 to 2017; GOAL survey (2019) for 2018 to 2021.



Shrimp production is typically characterized by intensity level and measured as metric tons per hectare (t/ha). Extensive farms have lower production weight per unit area while intensive farms have higher production weight per unit area. In general, South and Southeast Asian countries like Vietnam, India, Indonesia and Thailand have varied production systems ranging from extensive, semi-intensive to multi-phase intensive. This is different when compared to Central and South American shrimp producers who have more uniformity in their use of semi-intensive systems.

Figure 2 describes the maturity continuum from extensive to intensive production methods. As intensity increases, so too does production output—both of which are inversely related to the land footprint.

Figure 2. Maturity Curve



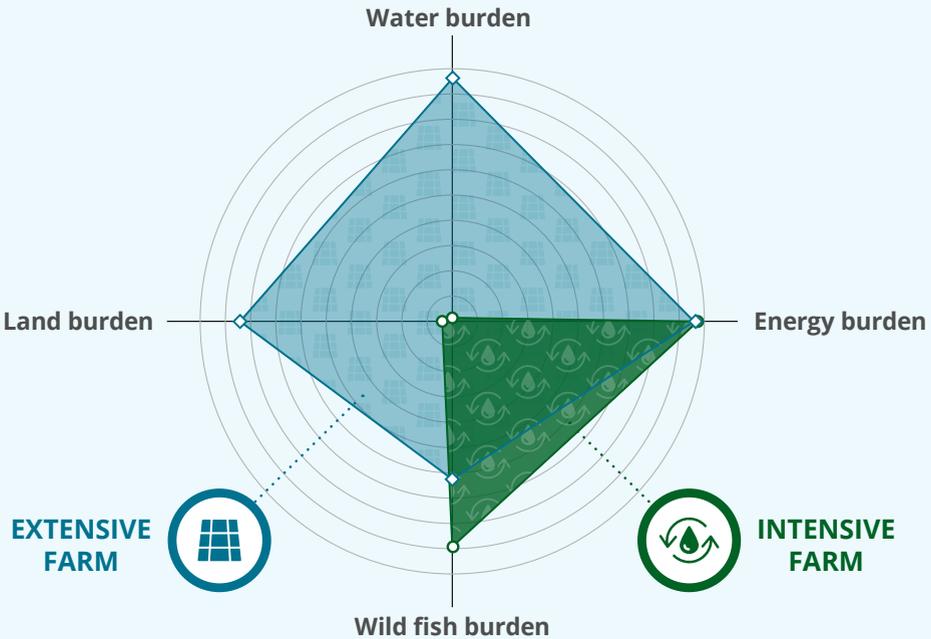
Source: McIntosh, R.

Intensive systems were designed to increase profitability and made possible by technological advances in formulated feed and aeration systems. However, intensive production alone is not a panacea. Numerous disease outbreaks have occurred due to the stress that increased stocking density imparts on a shrimp’s immune system. The response has been to push for more systematic control, eliminating or reducing the interaction aquaculture systems have with surrounding natural ecosystems.

Controlled intensification balances the dual goals of profitability and disease mitigation,¹⁸ making it a viable and more sustainable investment. Additionally, the unintended byproduct of these systems is better environmental outcomes. Shown in Figure 3, as farms become more intensive, their operating costs and environmental impacts tend to decrease per unit of production.

Figure 3. Resource Use

Across the board, as farms become more intensive, the operating cost and environmental burden per unit produced decreases. Optimizing an aquaculture production system for resource use also results in optimization of business value.



BUSINESS OPPORTUNITY AND TIMING

Four converging themes have created a compelling business environment for investments in controlled intensification:

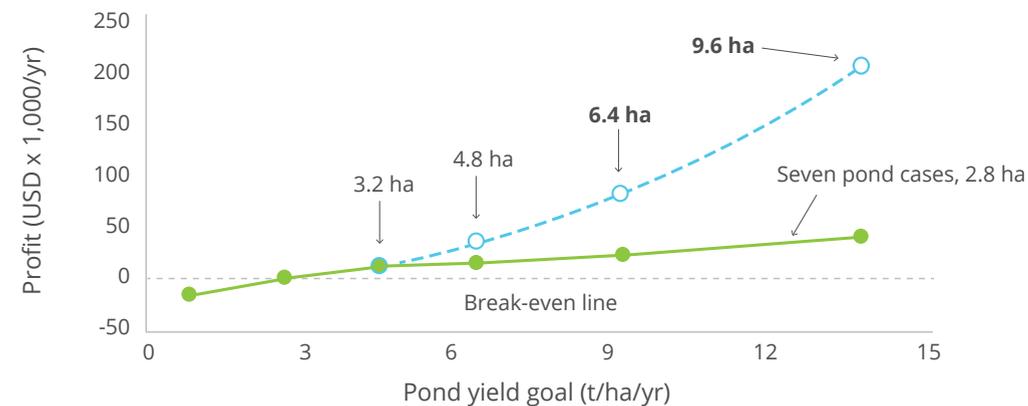
Financial Viability

Profitability in shrimp aquaculture is determined by two things: (1) controlled intensification, which increases resource efficiency and reduces risk exposure, and (2) scale, which expands top-line revenue while decreasing operating cost per unit of production.

Recent WWF research shows that controlled intensification to a moderate level of maturity—for example using production ponds, surface aerators and high-density plastic liners—becomes economically sustainable at 5 t/ha/yr at a 4.0-ha farm and a viable investment between the 10 t/ha/yr, 6.4-ha farm and the 15 t/ha/yr, 9.6-ha farm.¹⁹

Figure 4. Approximate Profits for Simulated Shrimp Farm Cases

Profits reflect cash flows after loan service



A moderate level of intensity was selected for the model because technology is widely available, principles are widely understood, and an industry-wide transition to this level of intensification would have incredibly positive environmental outcomes at a relatively low financial cost.

Prolonged Underinvestment

Widespread underinvestment has created an environment ripe with potential for performance improvements. Antiquated farming practices have resulted in underutilization of critical resources, most notably, land. Of the 2.4m ha of shrimp farms in the world, 54% of the land produces 94% of farmed shrimp. The remaining 46% of land only produces 6% of global supply.²⁰

Generational Turnover

As farmers near retirement age, there will be an opportunity to purchase land at a discount on future valuations. The longstanding notion that farms are passed down within the family is likely coming to an end as younger generations flock to urban centers for education, improved health outcomes and more diverse business opportunities.²¹ Drawing parallels to American agriculture, it is anticipated that between \$240 billion and \$1 trillion of farmland will change hands in the coming decade due to aging farmers.²²

Market Access

Gaining share in a commodity market can be challenging because of the competition from established, well-financed players. With shrimp aquaculture, however, global conglomerates have largely left production to smallholders. This leaves the door open for new entrants to deploy business models focused on farming with controlled intensive systems, unlocking value through innovation and economies of scale.

ADDRESSING CHALLENGES

Four lingering issues must be addressed to achieve an industry-wide transition:

Geopolitical Limitations

The vast majority of shrimp is farmed in developing or transitioning economies in Asia or Latin America. Conducting business in these regions can be challenging due to an entrenched reliance on middlemen who have significant influence over the market without necessarily adding proportional value. Additionally, government policies, regulations, and infrastructure—including electrification, transportation, clean water, and internet access—are critical inputs for better production practices and expanded market access.

Farmer Sentiment

Aging farmers have not historically moved quickly to integrate production-level innovations. Aerators are the most advanced technology an average farmer uses. Significant effort will be required to shift mindsets and onboard farmers onto new production and technology platforms.

Product Perception

Due to well-publicized failures that persist today, there is a lingering consumer sentiment that aquaculture poses significant environmental, social, and public health risks. This is particularly true for shrimp, which has come under fire in the last ten years for human rights abuses in the feed supply chain and hard-hitting disease outbreaks over the years that have decimated production in various geographies.

Existing Infrastructure and Farm Siting

Existing extensive farm infrastructure is constructed in the intertidal zone.^{23 24} As farms move further inland to more conducive and reliable environments, it is critical to manage the transition of old extensive farms back to coastal wetlands.



ACCELERATING THE PACE OF CHANGE

Over the next 30 years, the demand for seafood will increase; the trend towards aquaculture will accelerate; and the market for shrimp will expand. The implications of this promising future will be determined by the action or inaction of those who make up the value chain. Achieving economically and environmentally viable shrimp production that is capable of meeting growing global demand requires that shrimp production is contained to minimize impacts on the natural world.



Understanding that such a shift demands clear, coordinated effort rooted in reason, this study presents three accelerators to guide the transition in the near, medium, and long terms. The accelerators are complementary in that they create a positive feedback loop for sustained change. The widespread use of technology enables optimal resource efficiency and profitability; the intentional direction of capital equips producers with the means to effectively transition; and the democratization of knowledge elevates producers to higher standards.

Widespread use of technology

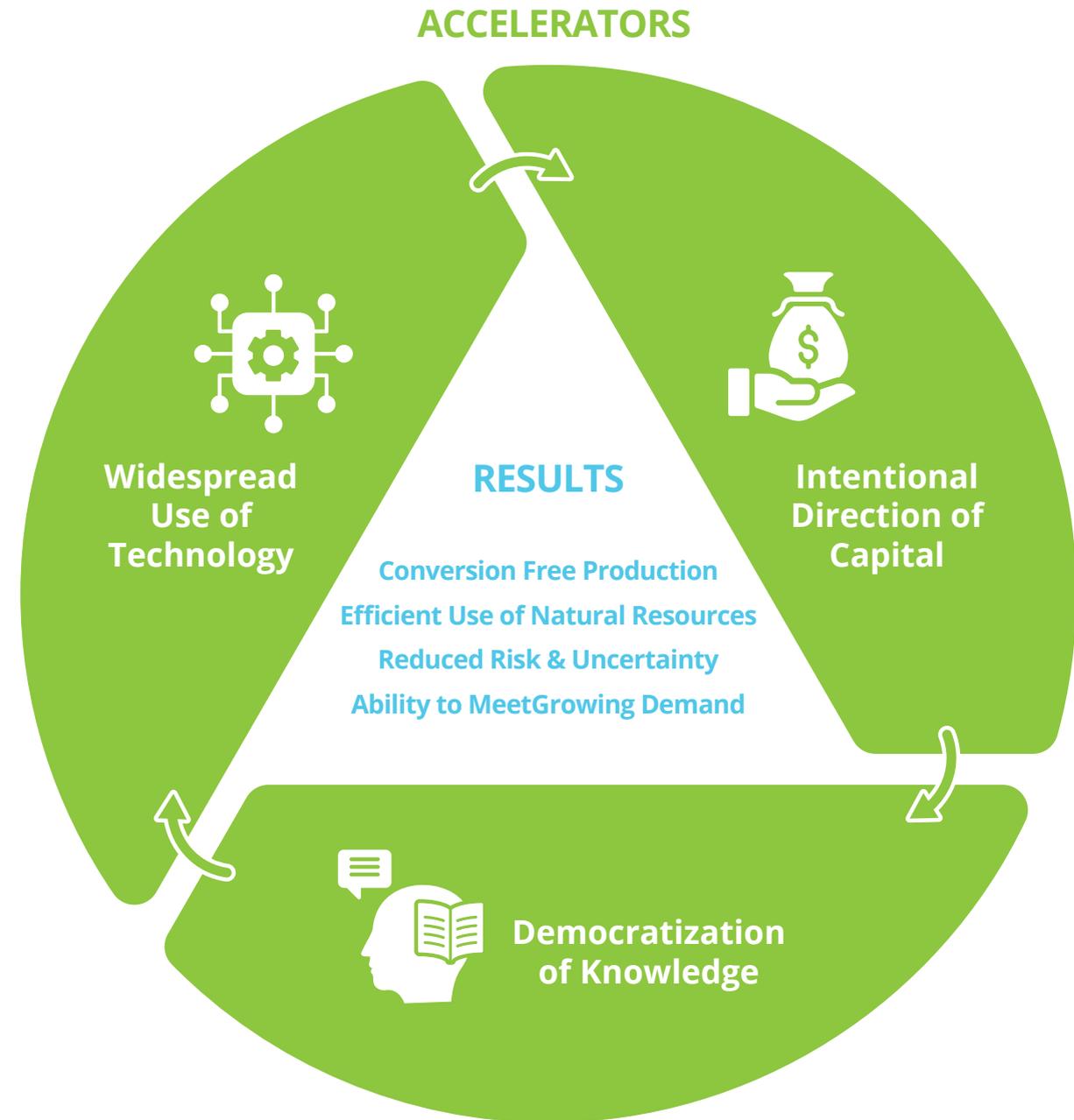
Producers should increasingly utilize foundational intensification technologies to establish predictability and control within their production systems. As business models become financially stable, producers should seek to integrate technologies proven by startups and well-capitalized conglomerates, optimizing production inputs, and eventually breaking through to next-generation innovation.

Intentional direction of capital

Financiers should direct debt and equity investments to producers small and large to transition to more controlled intensification. Doing so will stabilize production output and stimulate industrialization, which if done at a large scale would result in decreased market volatility, and the crowding in of additional investment.

Democratization of knowledge

Industry knowledge regarding more controlled intensive production should be spread equally among value chain actors and influencers. Building human capital, information access and transparency, and government buy-in are critical to ensure that controlled intensification is globally scaled.



TRANSITION PATHWAYS

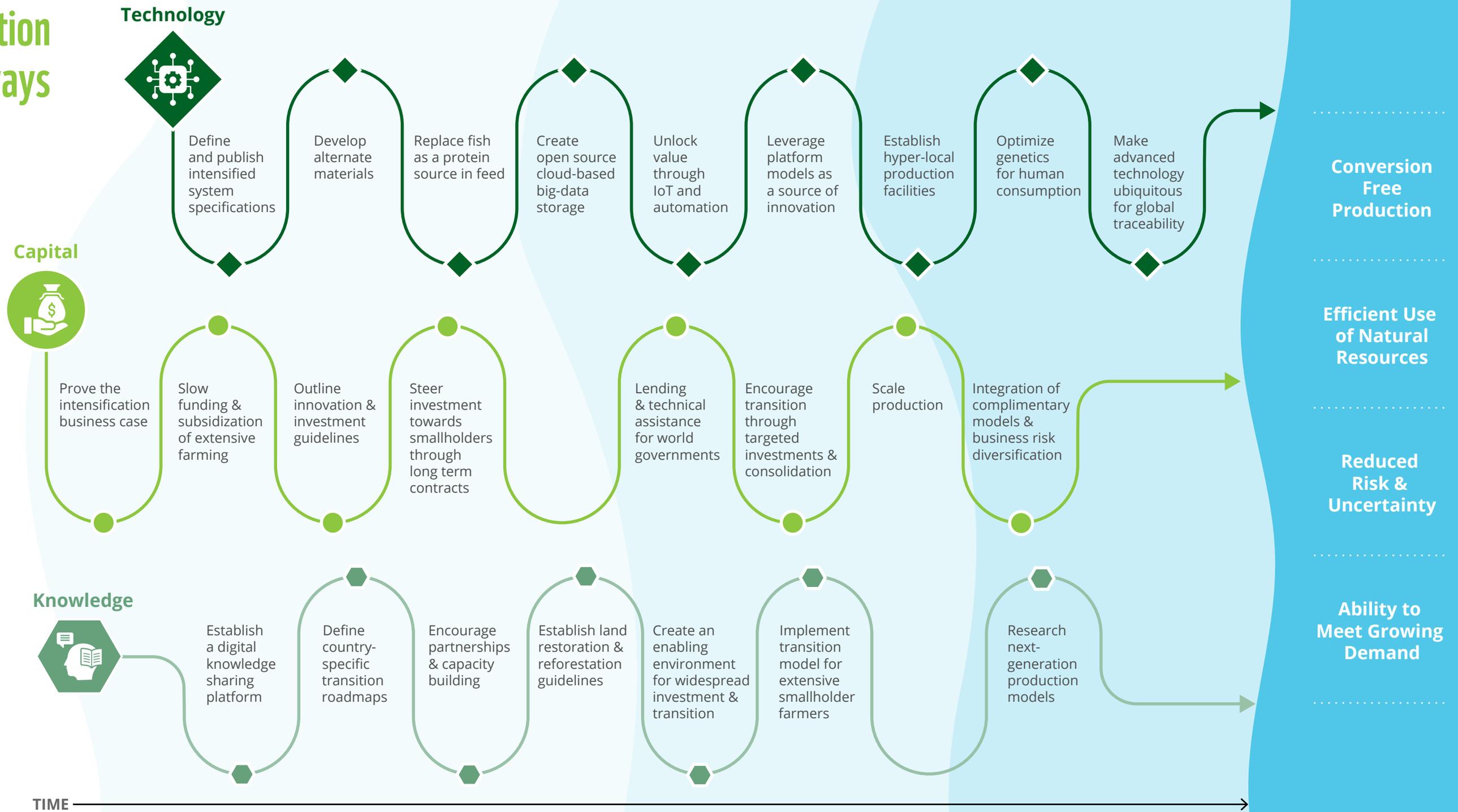
Only in recent years has the widespread use of technology emerged as a force for good in the shrimp farming sector. With regards to capital, value chain actors find it considerably challenging to attract and maintain investment. On knowledge, experts agree that large, established players and researchers know far more about better shrimp farming practices than are in use today. This blend of challenges, paired with the opportunity for shrimp producers to lead a movement towards sustainability, brings the industry to a critical inflection point. The time to act is now.

Successful efforts to transition shrimp farmers, especially during periods of uncertainty, require timely and coordinated actions from industry actors and influencers throughout the value chain. The proposed transition pathways define industry-driven actions that will play out over the course of three phases.

The following sections describe each accelerator, focusing on how the accelerator and associated value chain actors will contribute to the adoption of more controlled intensive production methods by farmers worldwide.



Transition Pathways



Near-term action should mitigate the impacts of disease by creating controlled and predictable production systems as well as facilitating farm transition.

Medium-term efforts should optimize resource use, digitize operational information to unlock value and increase farmer savings to fund future investment.

Long-term action should create an industry-wide ecosystem that encourages creative disruption and new automated solutions.



WIDESPREAD USE OF TECHNOLOGY

The rapidly growing shrimp industry has been slow to adopt technological advances. Antiquated practices, such as manual sampling, visual inspection and non-digital records, remain widespread. Without modern tools to help the industry thrive, shrimp aquaculture's potential has been held back.²⁵

PHASES OF INNOVATION

Transitioning shrimp aquaculture to more profitable methods of production hinges upon the pace and focus of technological innovation. Although it's unreasonable to expect all companies to innovate in the exact same way, accelerating movement along the maturity continuum requires focusing on technologies that promote predictability first, then seek to optimize significant drivers and finally, breakthrough to entirely new concepts and business models.

It is important to note that regardless of the chosen technology or solution, deployment must be done in a cost-efficient manner, since widespread adoption of any technology in commodity markets is largely determined by affordability. Development of new technologies and adoption of existing technologies will support an industry transition to more controlled and intensified production methods over three phases:

► Predict and control

The fundamental challenge that all shrimp farmers face today is producing a consistent crop. Over the last decade, novel diseases in shrimp aquaculture have resulted in \$20 billion in lost income globally and have kept survival rates hovering around 60%—a far stretch from the +90% survival rates with minimal variability that mature systems are capable of.²⁶

Widespread use of intensive systems that promote control through biosecurity are the bedrock of an industry-wide transition. The foundational technologies required for moderately intensified production are small ponds (0.4 ha) lined with high density plastics, closed loop water and waste management systems, selectively bred and clean post-larvae, surface aerators, and feed formulated to promote growth. Used together, these technologies serve to mitigate exposure to diseases in the natural world while creating low-stress environments capable of housing higher densities of shrimp. In the near-term, it is critical that innovators focus on producing foundational technologies at lower costs to encourage widespread adoption at the producer level. Included in Appendix 3 are blueprints of the facilities highlighted as financially viable and detailed descriptions of referenced technologies.

Figure 5. Shrimp Survival Rates & Variability Over Time

The shrimp industry overall has been characterized by low survival rates and extreme variability compared to mature systems such as total recirculation aquaculture and poultry production.

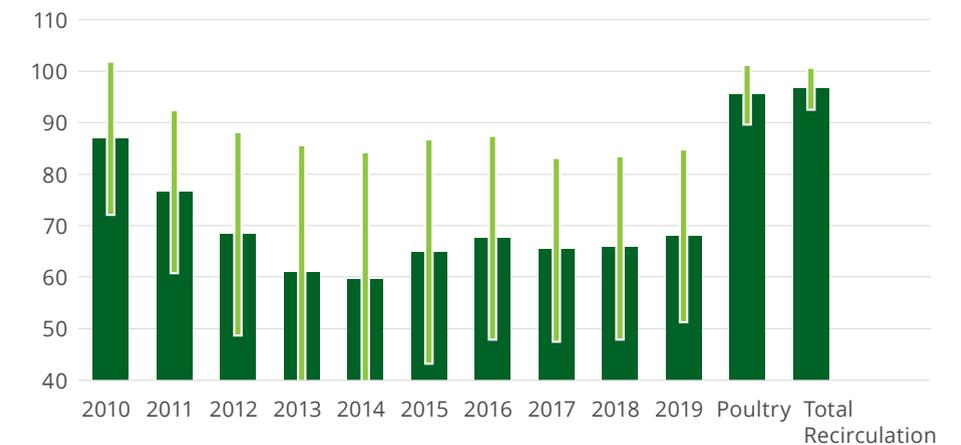
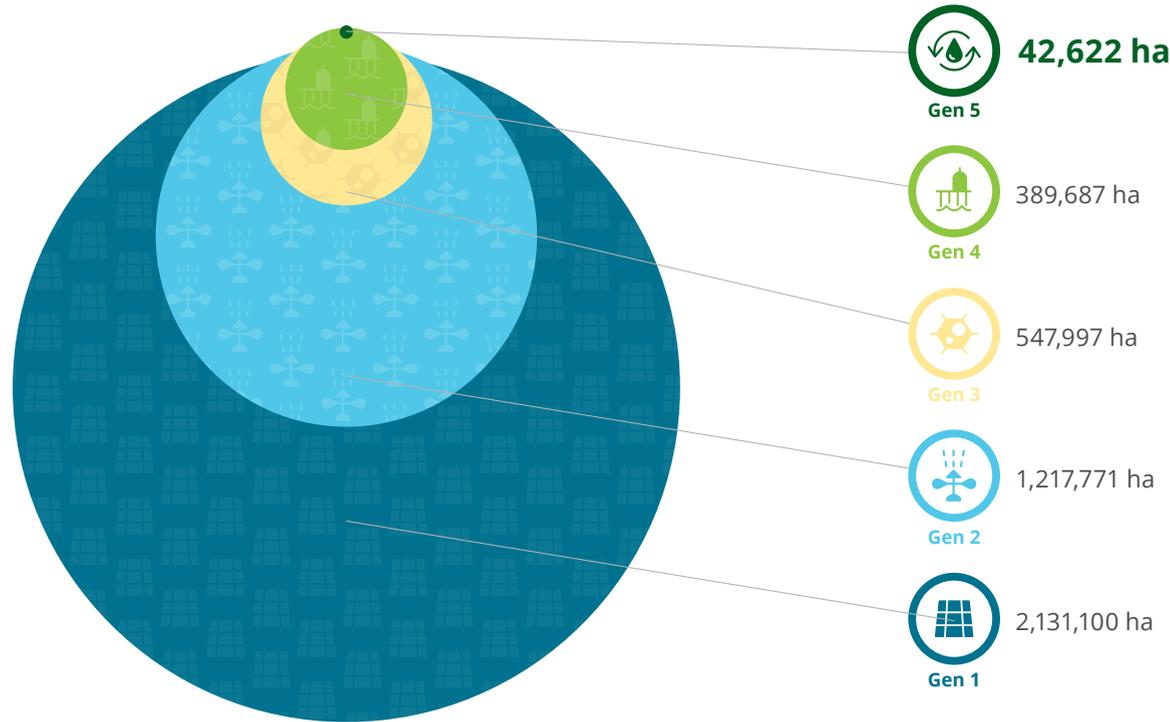


Figure 6. Area to Produce the World's Shrimp



►► Optimize

Once farmers produce shrimp consistently at moderate levels of intensity and are familiar with foundational controlled intensification technologies, then available cash and time can be spent on investments targeting resource or cost inefficiencies.

The best available proxy of efficiency in shrimp production is the total land used to meet global shrimp demand. In March 2018, a conservative estimate was placed at 2,131,100 hectares.²⁷ Recent analysis suggests that high intensity systems could meet the same demand with just 2% of the land currently in use today, roughly 42,622 hectares.²⁸

Based on previous WWF research, critical operational inputs like energy, water, feed, and labor are positively correlated with land use. The ability of higher intensity systems to reduce land use results in more viable business models that utilize operational inputs much more efficiently.

Technology that senses, records, and analyzes data combined with mechanization would help optimize costs while automating production activities and decisions. Although it is unlikely the same 98% reduction in land use will apply to other resources used in production, the order of magnitude is directionally appropriate.

►► Breakthrough

As shrimp aquaculture production becomes increasingly efficient and stable, innovators and investors will progressively challenge boundaries to reshape the industry beyond anything conceivable today.

It's hard to know exactly what the future will hold, but it may very well be based on the recent efforts of Jianhai Xiang and Fuhua Li from the Institute of Oceanology at the Chinese Academy of Sciences (IOCAS), who successfully finished decoding the genome of *L. vannamei* in early 2019.²⁹ Improving animal productivity will require a better understanding of the structure and function of animal genomes and how they interact with non-genetic components of production systems (e.g., nutrition, environment, etc.) so that management practices can be optimized to improve performance.³⁰ The initial barrier to moving from genome to phenome is mapping genetic information. With the mapping of whiteleg shrimp already complete, the technological possibilities for increasing the desired characteristics for controlled intensification is promising.

EMERGING TECHNOLOGIES

There are four categories of technologies that will have the most significant impact on a shrimp producer's ability to transition in the near-term and the profitability of intensified systems in the future.



Materials and Biotechnology

The materials and systems used in constructing intensified production systems are inspired by living ecosystems and organisms and shaped for industrial application. All foundational technologies for intensification stem from breakthroughs in materials and management systems. These technologies could affect everything from the structure of production facilities to the proteins used in feed formulation. Companies like **Protix**, **Veramais** and **Calysta** are already exploring alternative protein sources, like insects and microbes, to replace the expensive and resource-intensive wild caught fish currently used in feed formulation.



Internet of Things and Artificial Intelligence

Sensor technology can be used to capture and catalog data points ranging from feed consumption to the effectiveness of disease treatments. Paired with data analysis and artificial intelligence, these technologies remove the guesswork from daily operations and, as data sets expand, provide new insights into shrimp production. **AquaCloudAI** envisions a future where big data is exchanged across borders to generate insights for all farmers. **XpertSea's** AI-driven management platform offers real-time insights on disease spread, harvest timing and water quality.



Connectivity Platforms

Digital forums are where information, ideas, goods, and services are exchanged. **Sitka Salmon** has created a community-supported seafood model without geographic boundaries, providing direct traceability to the source. **Sizzlefish** operates like a premium brand grocer without the storefront by sourcing from various seafood providers and shipping directly to consumers' doorstep.



Mechanization

Machinery has long complimented human efforts, and aquaculture producers have used industrial equipment, like tractors and excavators, in constructing new ponds for decades. These technologies replace manual labor, allowing humans to focus on higher-level cognitive tasks. **eFishery** began the journey with a fully automatic fish feeder. Meanwhile, companies like **Cermaq** are paving the way for completely automated farms in the salmon aquaculture space.



INTENTIONAL DIRECTION OF CAPITAL

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Aquaculture, not the Internet, represents the most promising investment opportunity of the 21st Century.”

**Peter Drucker –
Management Expert and Economist**

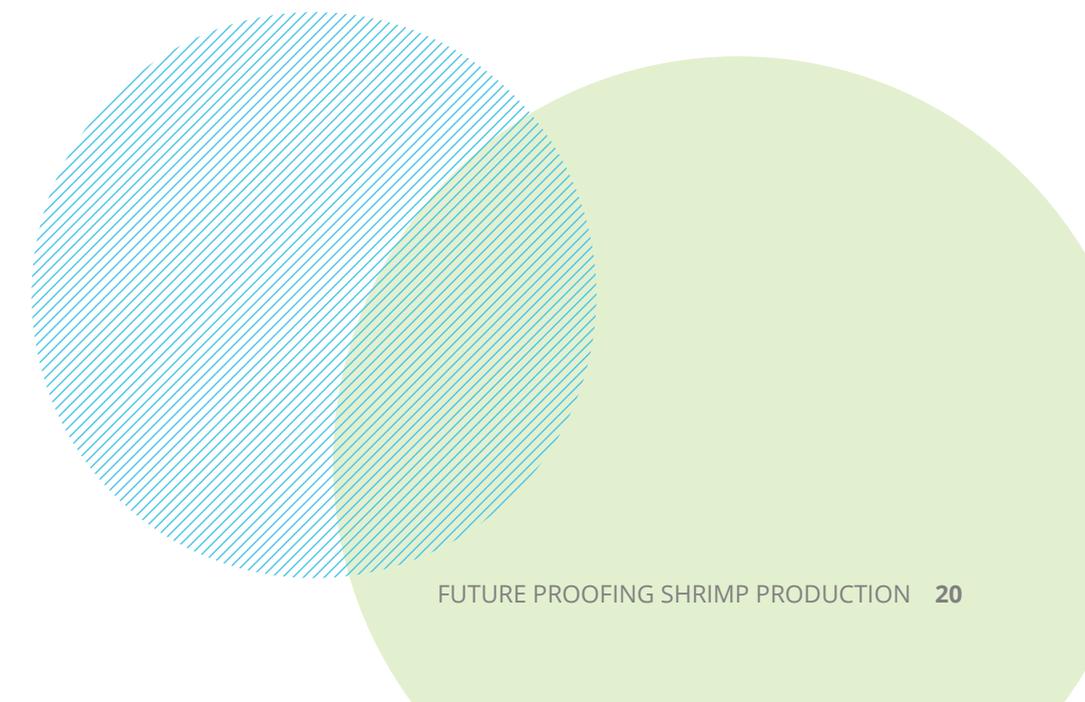
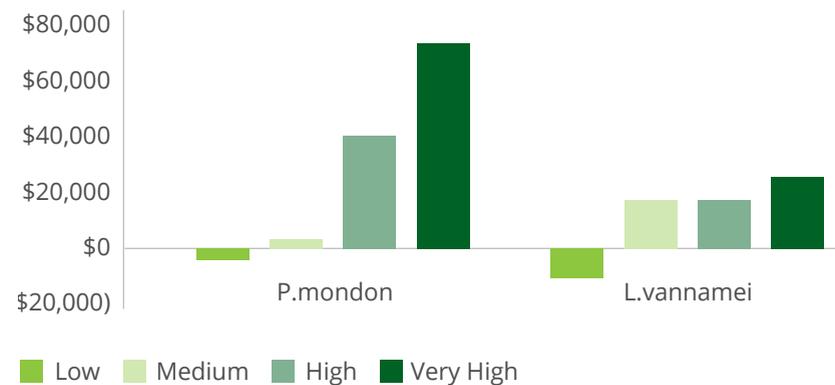
The level of investment in shrimp aquaculture has not yet coincided to meet the demands of producers with the worst forms of production. With the industry poised to accelerate at a CAGR of over 5%, substantial investment by local banks, international financial institutions and impact investors will be required to ensure growth coincides with controlled intensive production at scale. Fortunately, the industry is trending towards more controlled farming, as aquaculture business owners increasingly realize that intensive production can drive greater profits and economies of scale.³¹

Positive Returns on Intensive Production

Recent research and publications show that the value proposition for controlled intensification is clear. A 2017 study from the Journal of the World Aquaculture Society titled “Resource Use of Shrimp Production in Thailand and Vietnam” concludes that higher yields produced at greater levels of intensity result in higher volumes of shrimp sold, greater gross revenues and higher net incomes for farmers. The authors found that intensification spreads annual fixed costs over greater production volumes, thereby reducing costs per metric ton of production. Intensification also leads to lower break-even prices, which expands margins even further when production is stable.³²

Although more controlled intensive shrimp production can prove more profitable than extensive farming, a farmer’s ability to shift to these systems depends on the farm’s access to capital for aeration equipment, electricity, more skilled labor, post larvae, feed and supporting infrastructure.³³ Without direct capital flows from financiers willing to invest in farm renovations, many farmers will fail to make the transition. Beyond critical inputs, financiers can bring extra efficiency to production systems by investing in research and development (R&D) to lower the cost of entry. Targeted R&D uncovers new, cheaper materials and construction methods. It also expands margins through cheaper feed costs, less labor input, and a lower dependency on chemical amendments.

Figure 7. Net returns (US\$/ha/yr), Vietnam



There are **three main financiers** that should help close the capital gap among shrimp farmers, bring innovation and technology to the industry and encourage a trend towards controlled intensification. These financiers are presented based on their proximity to farmers in the value chain and ability to influence change.

1 Buyers and Retailers

According to WWF, buyers and retailers are starting to realize that in complex, competitive global supply chains, short-term procurement strategies cannot adequately address production stability and cost efficiency. Naturally, it is in these actors' self-interest to ensure the long-term viability of their food supply chain in order to consistently meet demand. One mutually beneficial solution is to establish long-term contracts, which can reduce short, medium, and long-term risks for buyers and retailers while helping farmers professionalize operations and produce reliable supply.

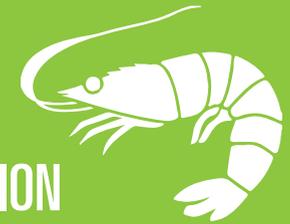
Through long-term contracts, buyers and retailers tangentially support farmers in securing loans to upgrade operations. Some experts estimate that against long-term contracts, farmers can borrow up to 40% of the contract's estimated value in working capital from local banks.³⁴ This level of investment can be the difference between a farm intensifying production or not. Farmers able to access capital can invest in foundational technologies like aeration systems, recirculation systems or biosecurity tools to better control production and produce quality harvests.

Quality is typically a major consideration within long-term contracts, as supply will only be purchased if it meets certain agreed-upon specifications.

In addition to technological investments, the security of long-term contracts can also enable farmers to improve working conditions and pay higher wages to themselves and their employees. Since commodity pricing does not always afford farmers the ability to lift themselves out of poverty, long-term contracts can provide the stability that does.

It is important to note that due to price volatility, experts recommend that long-term contracts in shrimp aquaculture not include a fixed price, but rather establish a price finding mechanism based on spot market prices that evolve over time. A separately negotiated agreement is more flexible to market shifts and prevents breach of contracts to sell at the highest price.³⁵

40%
INCREASE IN PRODUCTION



According to the World Bank and the International Food Policy Research Institute, global shrimp aquaculture production is forecasted to reach 8.1 million tons by 2030, representing an increase of **40%** from 2017 to 2030, while wild shrimp production is expected to remain flat. Southeast Asia is expected to be the main contributor to this growth (57%), followed by China (25%) and Latin America (11%).

2 Impact Investors

Impact investors aim to deploy capital to increase resource efficiency and alleviate detrimental social and environmental impacts. Given the nature of the shrimp industry today, impact investors can support the adoption of more controlled production methods and related technologies.

An example of group supporting intensive shrimp production in Indonesia is the conservation finance and impact investing group at *Rare*. The environmental conservation organization is transforming extensive shrimp farms as part of a pilot with intention to scale. The pilot created a fund to lend capital to farmers to convert large ponds into smaller, more manageable pools lined with high-density plastic to reduce seepage. Farms are also upgraded with aerators to increase stocking density. Additionally, Rare provides technical assistance during farm renovation, included in the financial model. Technicians from a leading shrimp feed company teach farmers standard operating procedures to ensure they can manage the more intensive farms on their own. The company also has a long-term contract in place with farmers to procure supply that meets its quality standards. Once harvest is complete and stock is sold, the farmers make repayments in equal installments to the Fund, with the goal of ultimately becoming self-financing in the future.³⁶

Early results are promising. On average, shrimp farms increased their yields eleven-fold and revenues by fourteen-fold. Across the board, farmer incomes more than doubled after loan repayments. In addition, early environmental indicators show

that all farms are operating within the range of responsible shrimp farming standards defined by the Aquaculture Stewardship Council.³⁷ If the project scales, it could receive further support from the *Meloy Fund*, Rare's affiliated impact investment vehicle supporting sustainable fisheries and aquaculture in Southeast Asia.

3 International Financial Institutions

International financial institutions (IFIs) have the potential to not only influence government policies related to land conversion and market regulation, but also to promote better farming practices on a large scale by linking investments with capacity building. IFIs have high investment thresholds and long-term investment horizons—5, 10, even 15-year periods—which will more likely lead to systemic change than short-term investments. These time horizons are well-suited for agriculture commodities, which often have a high investment outlay and require a longer timeline to produce a return on investment.³⁸

In shrimp aquaculture, IFIs are investing in projects that support smallholder farmer transitions to more productive and sustainable farming methods in line with their goal of poverty alleviation. The World Bank, for example, is currently running a five-year, \$281 million *project in Bangladesh* for coastal communities which includes shrimp farmers' contribution to the economy, poverty reduction and environmental sustainability. Key components are to improve sector transparency, integrity, and accountability; improve infrastructure and production practices; and support measures for improving genetic quality, biosecurity

and disease control in shrimp hatcheries. The goal is to significantly reduce exposure to devastating disease outbreaks and production crashes.³⁹

Additionally, IFIs can help rewrite government policies that support mangrove conversion for shrimp aquaculture. For example, in Vietnam, mangrove conversion for aquaculture is permitted up to 40%.⁴⁰ Given that current IFI investment in shrimp aquaculture is limited,⁴¹ the hope is that in making IFIs aware of the value of intensive shrimp farming, they are inspired to invest in profitable, sustainable production methods on a global scale.

\$67.5
BILLION DOLLARS



A **2017 report** by Future Market Insights estimates that the global shrimp market value will rise from \$39.1 billion in 2017 to \$67.5 billion by the end of 2027. During that time, sales revenue is projected to register a compound annual growth rate of 5.6%.



DEMOCRATIZATION OF KNOWLEDGE

“

We know far more about farming shrimp sustainably than the average shrimp farmer is using.”

**Dr. Claude Boyd –
Professor Emeritus at Auburn
University School of Fisheries,
Aquaculture and Aquatic Sciences**

This last accelerator centers on the notion that industry knowledge of intensive production should be spread equally among value chain actors and influencers. Sharing knowledge supports systemic transition by making farmers more aware of their environmental impacts and the business value in shifting production practices. Most importantly, farmers need to understand how to effectively apply intensive practices so they can do so independently and for the long-term.

Building Human Capital

Shifting to more controlled intensive production practices depends on capital, but also on the farmer having enough experience, knowledge and management skills to successfully operate a more intensively managed farm.⁴² In the shrimp industry today, sharing knowledge of efficient production is largely concentrated at the feed company to farmer level, since feed companies provide one of the most critical inputs to the production process and typically have frequent interactions with the farmer. In most cases, feed companies assist their customers if disease outbreaks occur, providing lab testing and access to technical teams to support diagnosis and prevention.

Some feed companies go further to train farmers on the latest technologies and efficiencies to ensure widespread understanding and adoption of better practices. For example, a Thai-based aquaculture company hosts demonstrations to upskill farmers on the use of controlled intensive production methods and a selective post-larvae and feed combination. The goal is to use the company's materials and methods to produce high-yield harvests. Additional workshops train farmers on intensive shrimp health by discussing disease control and saline water intrusion. In recent years, the company spread its technology and knowledge throughout Thailand, Vietnam, and Malaysia, emerging as one of the leading agro-industrial and food conglomerates.⁴³

Intra-value chain upskilling is mutually beneficial for farmers and producers. Farmers learn effective practices that they can put to immediate use after procuring materials and/or technology from feed companies. Feed companies and processors can sell more product and put their producers on a path towards more reliable output. Feed companies and processors should also explore opportunities to promote the business case for controlled intensive production and provide training and technical assistance to farmers to initiate or support the transition process.

Beyond the private sector, universities, nongovernmental organizations, IFIs and governments have a role to play in democratizing knowledge and supporting farmer transition. These value chain actors have distinct relationships with farmers and should leverage their interactions to extract data for research and share insights regarding new methods and technologies in a way that farmers find valuable. Touchpoints would be more valuable if they also taught farmers about controlled intensification and what it means to change current practices, recycle or reuse waste, procure new equipment and repurpose land after a transition occurs.

Information Access and Transparency

As the shrimp industry matures to better leverage digital technologies, such as automation and artificial intelligence, there is immense potential to integrate data gathered from these mediums for the benefit of the entire industry. A collective initiative to identify, address and learn from real-time failures would put the industry on a faster track to sustainability, but it requires coordination of all actors.

The salmon industry is a good example of how data sharing and transparency can promote industry transformation.

The Global Salmon Initiative (GSI), founded in 2013, is made up of 17 companies that comprise 50% of industry producers.⁴⁴ These members are committed to minimizing the environmental impact of their operations, sourcing sustainable feed and managing operations to support economic growth and stability. Through GSI, companies agree to measurably reduce environmental impacts, such as using marine ingredients in feed, antibiotic use, and fish mortality, among others.

As part of their commitment to transparency, all members publish key environmental and social data across 14 indicators per company, per region, on an annual basis. Since 2013, the initiative has made progress on key targets. This includes significantly decreasing the amount of marine ingredients used in feed, improving feed conversion ratios and averaging a 50% reduction in the use of sea lice treatments.⁴⁵ In shrimp, collective data sharing on disease outbreaks, for example, would improve industry resilience to shocks that decimate production.

Industry experts realize that there is a knowledge gap between what is known about shrimp farming and what is in use today. Like GSI, a centralized group could build a digital knowledge-sharing platform to promote reliable, trusted and unbiased information between feed companies, farmers and producers. Such data sharing would help establish control over harvests and predictability in production methods, specifically regarding management of disease outbreaks and survivability. This solution, however, is largely dependent on farmers having access to the internet, leveraging automated technologies, and utilizing open-source platforms, which may prove challenging in the near-term.

Government Buy-In

As in any industry transition, government plays a critical role in supporting and enabling acceleration. Democratizing knowledge, therefore, must also happen among policymakers responsible for national aquaculture industries.

National strategies to scale controlled intensification allows for bespoke approaches in major shrimp producing countries. Roadmaps supporting farm conversion, governance frameworks and accountability measures for achieving scaled productivity gains would signal national commitments to sustainability.

With growth on the horizon, high-producing countries are already setting ambitious targets. In 2018, Vietnam announced 2020 and 2025 production targets of 850,000 metric tons and 1.1 million metric tons, respectively.⁴⁶ The incremental production required to meet these

targets must come from converting existing agriculture or aquaculture land with appropriate siting into intensive shrimp farms. This ensures no additional land is converted from 2020 onwards. This effort will aid in the collective initiative to prevent future conversion of natural ecosystems.

Finally, governments supporting farmer transitions should develop tailored regional guidelines for land restoration and reforestation. It is expected that robust transition roadmaps coupled with market-driven change could result in under-utilized land. Therefore, it is imperative that governments and non-governmental organizations actively manage the return of coastal land to its natural habitat as part of commitments to conversion-free production. These lands provide valuable ecosystem services like water purification, carbon sinks, biodiversity preservation and soil preservation—which should be priorities of any intensive transition effort.

CONCLUSION

The scale and methods of shrimp aquaculture must be transformed in recognition of our current and future global challenges. Achieving this transformation to produce more shrimp with fewer resources is imperative. Controlled intensification is one pathway towards this end. It may not be the only pathway, but there are few options well understood and demonstrable today that would serve the same purpose.

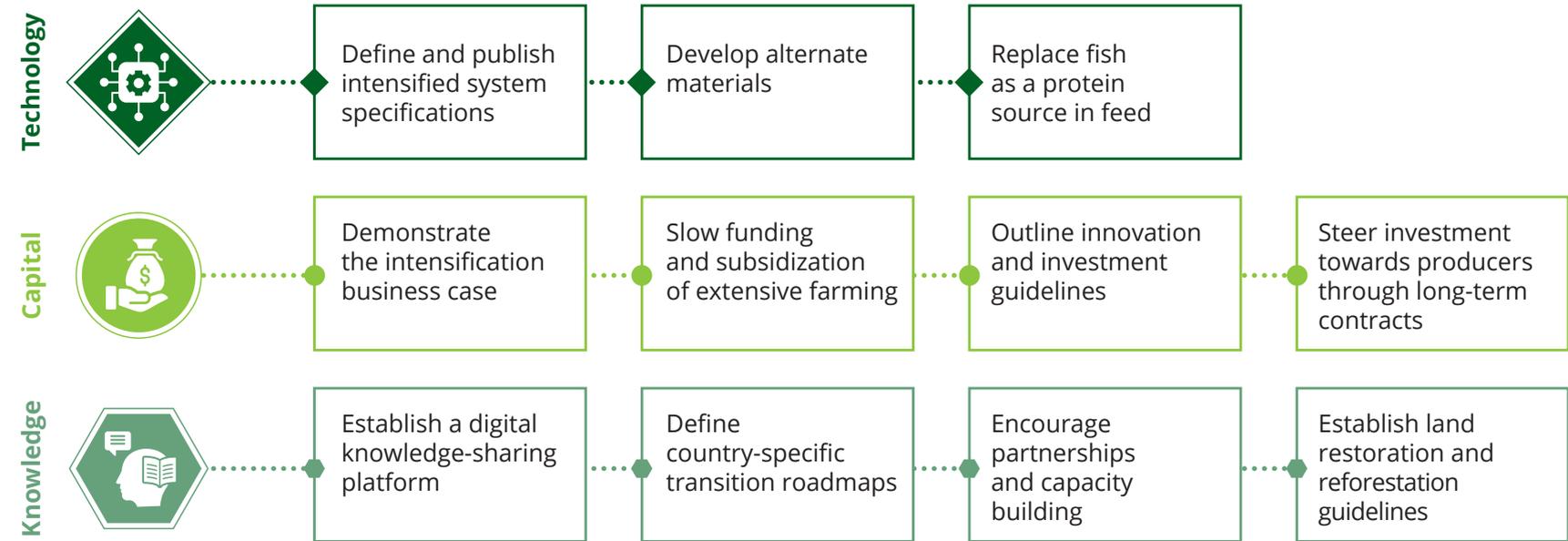


Meeting the future demand for shrimp without an erosion of the resources necessary to maintain supply is critical. Left to its own devices, the industry may trend towards further detrimental methods, leaving environmental degradation and unrealized business value in its wake. But the future is yet untold.

If supply chain actors—mainly producers, feed companies and financiers—adopt and adhere to the accelerators and transition pathways presented in this report, the shrimp industry will be more on track to expand profitably while minimizing environmental impact. These principles align with *WWF's Blueprint for Future Proofing Shrimp Supply Chains*, an initiative which challenges businesses that buy, sell, produce, or benefit from the farmed shrimp sector to demonstrate the achievement of five results by 2025.

To realize the results of this Blueprint, the following near-term pathways should be prioritized by supply chain actors. In addition to driving desired outcomes, following these pathways would also promote supply chain resilience.

Near-term Pathways*



*See Appendix for more details.

WWF's Blueprint for Future Proofing Shrimp Supply Chains*

- 1 

No conversion of natural ecosystems as of 1999.
- 2 

Farm and feed use of natural resources (land, water, energy and wild fish) decreased by 30%.
- 3 

Traceability of farmed shrimp and feed ingredients used to produce them.
- 4 

Human and labor rights secured throughout the value chain for all workers.
- 5 

Transparent reporting of progress.

*Bolded are those that can be achieved through farm transition. Please visit the Blueprint for more information.

Today, human activities put more pressure on nature than ever before, but it is also people who have the power to change this trajectory. Together, we can address the greatest threats to life on this planet and protect the natural resources that sustain and inspire us.

To conclude, actors who **deploy technology** to drive efficiencies and innovation, **invest capital** to support large-scale farm transitions and **disseminate knowledge** to build human capital will propel the shrimp industry on a more sustainable trajectory.

The future is promising, and as evidenced by the ideas shared in this study, positive change is already occurring. To that end, WWF and Accenture thank the industry experts who provided critical insights to inform this narrative. For more information about the concepts presented, please contact aaron.mcnevin@wwfus.org.





TECHNOLOGY

Define and publish intensified system specifications

Create detailed schematic drawings for bio-secure intensified aquaculture systems, including fair market value for parts and “hacks” that can be used by enterprising farmers trying to bootstrap intensive systems.

Develop alternate materials

Research alternative materials that can be used in the construction and operation of controlled and intensified aquaculture systems, prioritizing low cost and availability in shrimp producing markets, e.g., Southeast Asia, Central Asia and Latin America.

Replace fish as a protein source in feed

Replace by-catch as a protein source and then work with alternative feed companies to increase the scalability and affordability of alternate proteins, focusing on high-potential endeavors like algae and insects.



CAPITAL

Demonstrate the intensification business case

Model the capital investment profile of controlled intensification aquaculture systems for shrimp farming. The model should explore the relationship between farm size (scale), intensity (yield) and investment, accounting for the transition cost from varying sites (e.g., existing extensive farms, retired rice farms, etc.). Ensuring that proposed solutions are viable investments for key stakeholders, including smallholders, conglomerates and community-backed aquaculture. Identify areas where cost takeout is likely to promote creative problem solving by individuals and companies planning or facilitating a transition. Monitor and publish financial results of desired business models to prove viability over time.

Slow funding and subsidization of extensive farming

Work with governments, regional banks, global banks and private equity companies to stop all investments in extensive production. Subsidize capital investments into intensive systems to promote transition while slowing the subsidization of business that employ extensive farming practices.

Outline innovation and investment guidelines

Based on a vision for low-impact, zero conversion and high efficiency production systems, outline the critical problems and potential technological solutions for investors to target. Efforts should extend beyond guiding innovation focus to bringing existing solutions to market on an accelerated timeline. Develop assets and infrastructure to facilitate the transition of early adopters by supporting business planning and project level finance.

Steer investment towards smallholders through long-term contracts

Work with value chain members and regional banks to open lending pathways for smallholder farmers with genuine interest in intensified shrimp aquaculture. Establish guidelines for the responsible use of long-term contracts to support industry transitions.



KNOWLEDGE

Establish a digital knowledge-sharing platform

Build a digital tool for reliable, trusted and unbiased information sharing primarily between producers, but expanding to other value chain members as the system matures. Initially, information that helps establish control and predictability, specifically dealing with the effective management of disease outbreaks and improving survivability, should be shared.

Define country-specific transition roadmaps

Outline transition roadmaps catering to unique environments in major shrimp aquaculture producing countries. These should outline detailed transition steps, accountability frameworks, governance models, resource and cost estimations by transition step, reskilling strategy, and desired results including measurable indicators of progress.

Encourage partnerships and capacity building

As business models are proven and investment in-flows increase, information and support should be packaged with capital, equipping farmers and producers with the resources they need to sustain lasting change.

Establish land restoration and reforestation guidelines

Transition roadmaps paired with market-driven change (e.g., falling costs of intensified systems) will result in under-utilized land. It is imperative for governments and non-profits to actively manage the return of coastal land to natural ecosystems through the application of regenerative agriculture and technologies.

MEDIUM-TERM



TECHNOLOGY

Create open source cloud-based big data storage

Develop the guidelines and protocols for data exchange and a cloud-based system for data storage. Protocols should encourage innovators to build solutions that speak a common language on the backend without limiting creativity. Data should be made available to all research institutions, innovators and value chain members seeking to improve the industry.

Unlock value through IOT (e.g. sensors) and automation

Deploy Internet of Things (IoT) to monitor and capture information on high-value production processes like feed conversion, harvest timing, disease response, water quality, waste processing and energy use. As the data pool expands, leverage artificial intelligence (AI) and robotics technology to automate decision-making and labor-intensive production processes.

Leverage platform models as a source of innovation

Expedite the pace of transition by making critical resources, such as construction equipment, transportation infrastructure and land, available on an as-needed basis at lower costs. Deploy direct-to-consumer business models to ensure all in-country demand is met locally and that producers receive equitable economic value.

Establish hyper-local production facilities

As technology continues to drive efficiencies in animal protein production, reducing the footprint required for production and reliance on cheap labor for profitability, begin piloting hyper-local community-based production facilities in dense urban areas. Local production reduces supply chain complexity, increases consumer transparency and could help eliminate negative environmental impacts associated with logistics networks.

Optimize genetics for human consumption

Utilize genetic understanding to implement better management practices that create a product better for human consumption (e.g., optimizing phenotypes that influence disease resistance, growth rates, resource needs and adult size).



CAPITAL

Lending and technical assistance for world governments

Invest in government capacity to support intensification at scale, recognizing that private industries are first movers, but governments play a significant role in systemic change. Deploy experts to help and advise.

Encourage transition through targeted investments and consolidation

As intensive farming drives down per unit cost of production and government subsidization slows, extensive farms will lose comparative advantage and may ultimately go out of business. During this time, it is critical to work with private companies to guide investments towards legacy businesses with valuable infrastructure, knowledge, or other resources, furthering consolidation.

Scale production

To realize economies of scale strategically fund large-scale farms in support of high efficiency production and accelerated industry transition.

Integration of complimentary models and business risk diversification

As human knowledge relating to the interconnectedness of natural ecosystems expands, build poly-culture production models that efficiently and profitably integrate diverse plant and animal species. Explore co-location and partnership models within and outside the industry, establishing comprehensive closed loop production models.



KNOWLEDGE

Create an enabling environment for widespread investment and transition

Work with national governments to establish economic incentives conducive to investment and transition, linking aquaculture goals to National Adaptation Plans (NAPs) that may exist from change adaptation planning formally established with the United Nations.

Implement a transition model for extensive smallholder farmers

Identify likely pathways for current shrimp farmers based on demographic information and regionally available jobs. Outline the interventions required to secure a living wage for the individuals impacted by the transition.

Research next-generation production models

Organize efforts to research next-generation production models to leverage lessons learned from more mature commodities, catalyzing advanced planning for future transitions.

LONG-TERM

DESCRIPTIONS AND CASE EXAMPLES

Maturity Phase
Predict and control



Formulated Feed

Leverage optimized feed mixes that have maximum bioavailability of proteins, amino acids, minerals and other key nutrients that promote shrimp health and growth

Regional Feed Provider



Surface Aerators

Install aerators into production ponds to provide optimal oxygenation for shrimp growth. Aerators should be operated as needed, during the night and morning when oxygen demand is the highest, and at the end of the production cycle when feeding rates increase

In-Situ



Above-ground Tanks or High-density Plastic Liners

Construction of intensified systems that have no uncontrolled exchanges with the natural environment

Regional Commercial Hardware Provider



Recirculation and Waste Management Systems

Employ closed-loop staged filtration systems to maintain clean water for shrimp production, ensuring sediment and affluent are responsibly disposed of or reused

Regional Commercial Hardware Provider



Clean and Selectively Bred Post Larvae

Facilitate the continued development of desired characteristics like disease resistance, accelerated growth or taste in shrimp through artificial selection. As a farmer, ensure post-larvae are clean and free of diseases and other contaminants

Cryoocyte

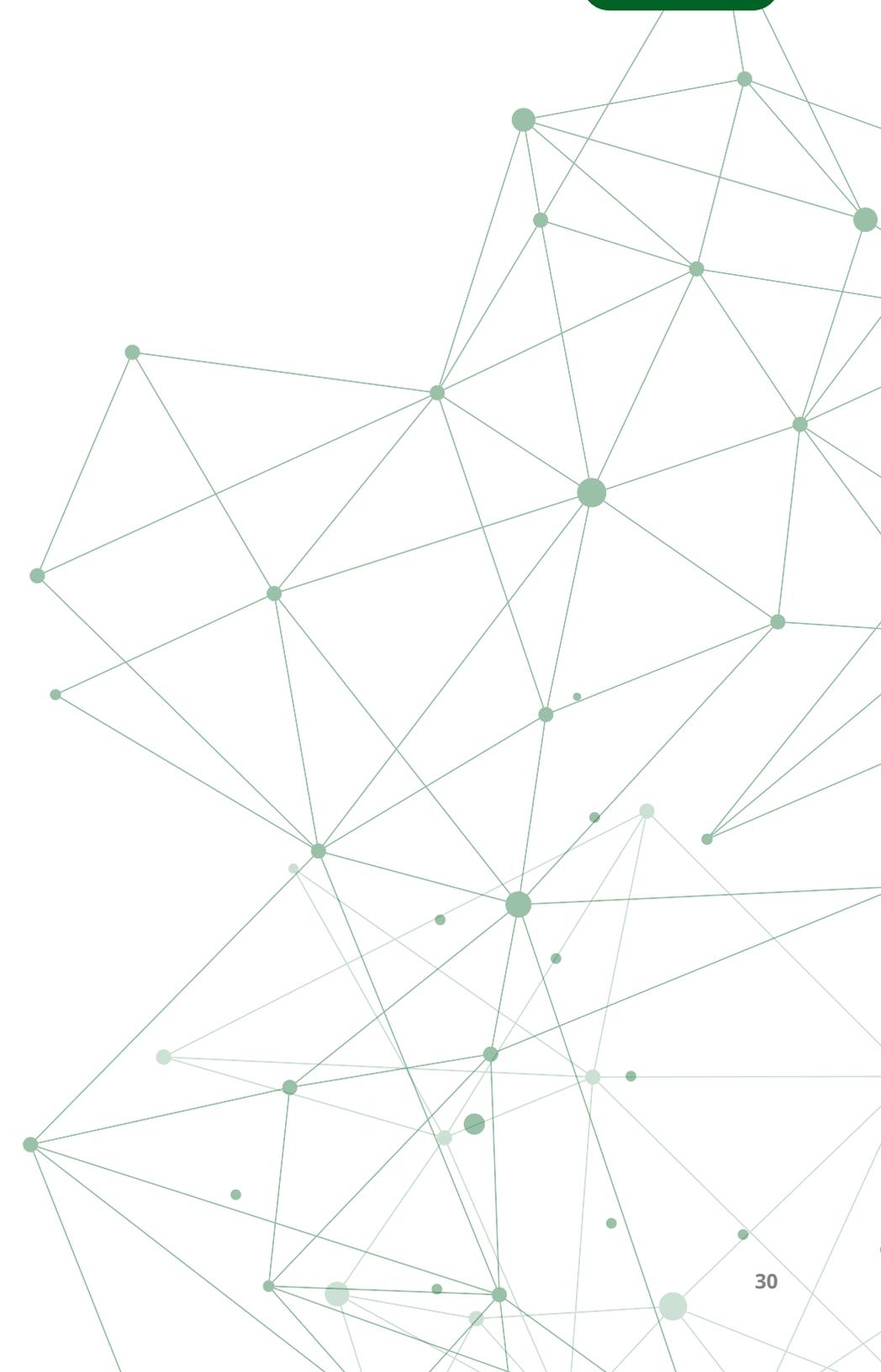


Disease Response Platforms

An information sharing platform allowing shrimp farmers to share insights regarding emerging diseases and treatments

WeFarm

KEY  Materials & Biotechnology  Internet of Things & Artificial Intelligence  Connectivity Platforms  Mechanization



TECHNOLOGY GLOSSARY

DESCRIPTIONS AND CASE EXAMPLES

Maturity Phase
Optimize resources and costs



Growth Monitoring and Harvest Timing

Imaging sensors monitor shrimp size, providing an optimized timeline to the farmer to balance anticipated growth/value, yearly cycle capacity and time value of money

XpertSea



Alternative Proteins

In addition to algae and insects, which are already being explored, develop new sources of protein for fish meal formulation, removing by-catch as a protein source

Calysta



Hunger Sensing

Sensors monitor shrimp behavior to determine optimal feeding time and quantity, optimizing the feed conversion ratio while limiting negative effects of overfeeding, like pond acidification

Marine Instruments



Automatic Feeding

Based on data from the hunger sensing system, autonomously deploy feed to shrimp populations without human intervention, reporting on available inventory and re-order timing

eFisheryFeeder



Energy Use and As-Needed Consumption

Collect data on the use of electrical equipment on the shrimp farm and optimize energy use based explicitly on need

Sense
(Residential)



Water Quality Sensing

Measure and record the levels of contaminants and oxygen in aquaculture tanks, identifying the appropriate actions based on a shared database and constant learning

Sensorex
(Partial coverage)



Automated Aeration

Based on water quality data, create an optimal oxygen balance by autonomously operating the aeration system

In-Situ



Automated Water Quality Management

Based on water quality data, manage the deployment of chemicals into the aquaculture system to combat a variety of problems, including acidification and bacterial proliferation

YSI



Direct to Consumer Platforms

Enable the direct sale of shrimp to consumers, removing the middlemen to maximize the economic benefits to farmers and consumer

Envisible



Real-Time Supply and Demand Planning

Connect producers and retailers, helping farmers to target the most in-demand products

Bushel OMS
(Agriculture)



Sharing Economy

Pool underutilized assets and give access to farmers at a fraction of the cost, on an as-needed basis (e.g., farm-level infrastructure, construction equipment, harvesting equipment, transportation equipment, etc.)

Hello Tractor
(Rural agriculture)

KEY Materials & Biotechnology Internet of Things & Artificial Intelligence Connectivity Platforms Mechanization

TECHNOLOGY GLOSSARY

DESCRIPTIONS AND CASE EXAMPLES

Maturity Phase
Breakthrough



Alternative Construction Materials

Develop materials for aquaculture systems that are cheaper, stronger, longer lasting, easier to deploy and/or less environmentally damaging



Automated Harvesting and Processing

Build portable systems capable of simultaneously harvesting and processing shrimp on-site, allowing direct sales to local markets, or cold storage and intercontinental shipping



Automated and Individualized Disease Response

Based on a shared data model, proactively sense health issues in shrimp and provide the most effective solution



Health Factor Analysis

Based on comprehensive sensor data from shrimp producers, account for the current profile of the farm and provide guidance on combating inefficiencies and maximizing profits



Network Optimization

Based on real-time supply and demand projections, optimize the supply network to maximize economic benefit for the entire system while minimizing the use of natural resources

Regional Commercial Hardware Provider

Harvest AI (Agriculture)

FarmBot (Agriculture)

Cermaq iFarm
(Salmon Aquaculture)

XpertSea
(Partial coverage)

Kisan Network
(Agriculture)

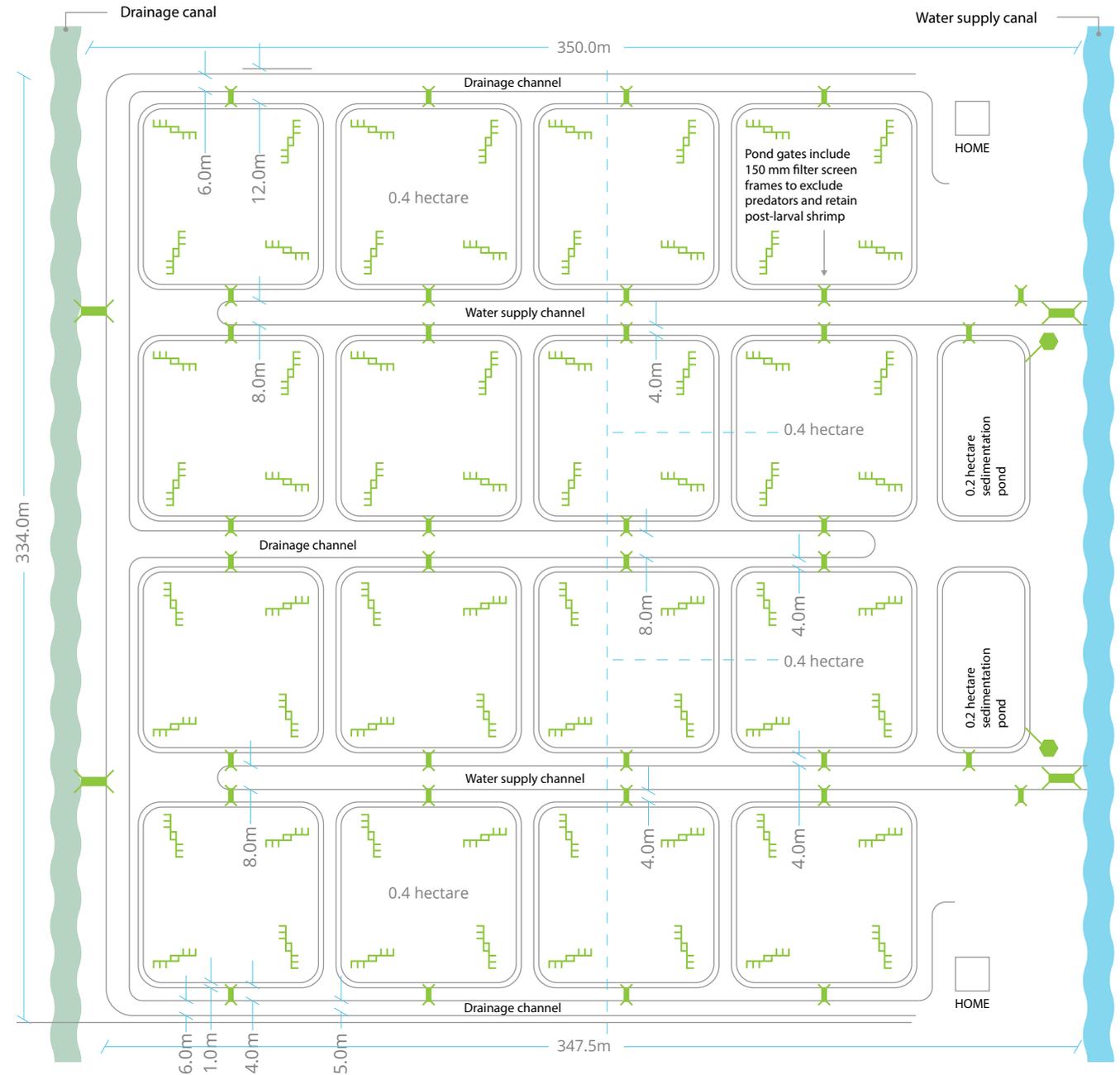
5 Metric ton/ha/year

Drawing of layout of intensive shrimp farms with eight, 0.4-ha production ponds.



10 Metric ton/ha/year

Drawing of layout of intensive shrimp farms with sixteen, 0.4 ha production ponds.

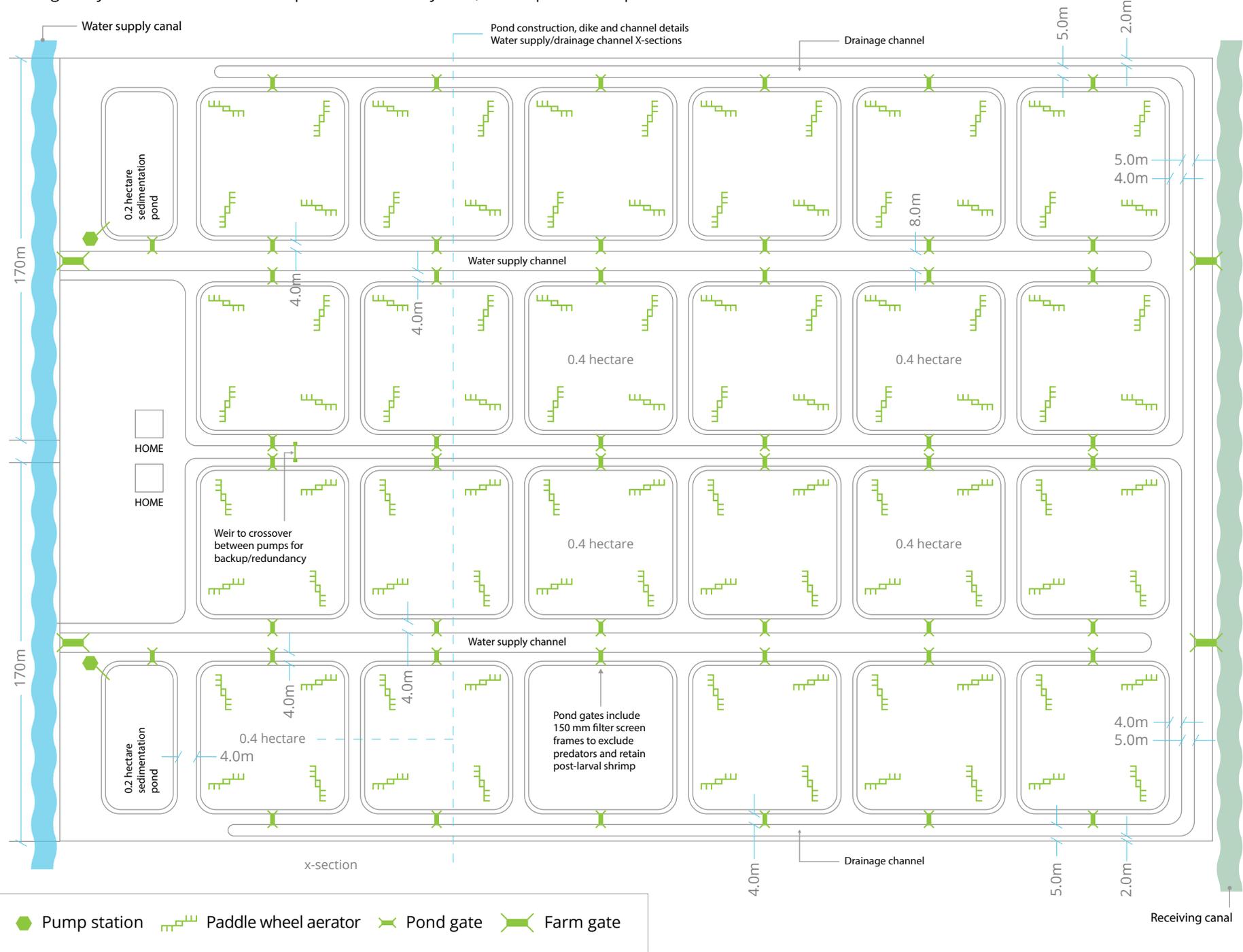


- Pump station
- Paddle wheel aerator
- Pond gate
- Farm gate

FARM SCHEMATICS

15 Metric ton/ha/year

Drawing of layout of an intensive shrimp farm with twenty-four, 0.4-ha production ponds.



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