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Aquaculture is the breeding, rearing, and harvesting of fish, shellfish, plants, algae, and other organisms in all types of water environments – NOAA
Key Conclusions

1. The aquaculture sector is approaching an inflection point similar to agriculture, as resource constraints, demographic and consumer preference shifts, and the introduction of new technologies drive change along the entire value chain.

2. U.S. consumption will continue to grow, spurring a need for increased domestic production.

3. Traditional fish farming is a large, mature industry, offering limited opportunity for sustainable growth, innovation, and investment.

4. Next-generation aquaculture is attracting considerable interest, notably in closed-loop, land based recirculated aquaculture systems (RAS).

5. Patient capital is required as upfront investment costs are high and payback periods long, particularly for cold water fish.

6. The market for inputs is expanding as early-stage investors explore the potential in genetics, equipment, and feed.

7. Aquaponics remains a small, boutique niche not yet economically feasible at scale and subject to a high degree of biological risk.

8. Offshore aquaculture’s potential has been limited by domestic regulatory challenges but is growing internationally.

9. The 2018 global aquaculture market was estimated at $180 billion with aquafeed representing an additional $100 billion.

10. The U.S. RAS salmon market alone could represent $3.5 to $4.5 billion in capital expenditures over the next five years with aquafeed totaling another $520 million.

11. EQ believes aquaculture will offer promising investment opportunities in the next three to five years, particularly in RAS and feed production.

12. North America represents the most promising RAS market, with robust demand drivers. Europe has historically been a leader but widespread acceptance has created significant competition. Asia remains in the very nascent stages of sustainable fish production.

Global Aquaculture Overview
Global Aquaculture

- The controlled production of fish and shellfish is key to addressing growing human consumption, as well as to rebuilding wild stock populations and coastal habitats.
- With capture fishery production remaining static since the late 1980s, aquaculture has increased its share of total fish production and is the fastest growing segment in the entire agriculture sector.
- Global fish production peaked in 2016 (the most recent data available) at 171 million metric tonnes, or 188 million U.S. tons, with aquaculture as a whole (including but not limited to fish for human consumption) representing 47 percent.
- Since 2013, aquaculture has contributed more fish for human consumption than have capture fisheries.
- The World Bank predicts that by 2030, two-thirds of fish being consumed will be farmed.
- Farmed food fish production can be broken down as follows:
  - 68 percent finfish
  - 22 percent molluscs
  - 10 percent crustaceans
- In 2016, total first sale value of fisheries and aquaculture production was estimated at $362 billion, $232 billion of which was from aquaculture.
- Annual growth in production averaged 5.8 percent from 2000 to 2016.
- China has produced more farmed fish than the rest of the world since 1991. Excluding China, aquaculture’s share of global fish production equates to 30 percent.
- Other major producers include India, Indonesia, Vietnam, Bangladesh, Egypt, and Norway.
- Increased production has driven increased consumption, as have population growth, reduced wastage, better utilization, improved distribution channels, rising incomes, urbanization, and increasing health consciousness.
- Globally, per capita fish consumption grew to 20.5 kilograms in 2015, an average annual increase of 1.5 percent since 1961.

Global Aquaculture

TYPES OF AQUACULTURE

- Aquaculture production is increasingly focused on inland systems that are typically freshwater environments.
  - Earthen ponds remain the most common facility; however, raceway tanks, above-ground tanks, pens and cages are also widely used.
  - Finfish farming dominates inland aquaculture; however, the past decade has seen relatively strong growth in the farming of other species, notably crustaceans in inland aquaculture in Asia, e.g., shrimp, crayfish, and crabs.
- Marine (sea-based) and coastal (practiced in human-made structures adjacent to the sea) aquaculture is comprised mainly of shelled mollusk farms (60 percent of production) with finfish and crustaceans accounting for the balance.
- Aquaculture does include the production of fry or fingerlings in hatchery environments; however facilities that release juvenile fish into the wild, for recreational fishing or to supplement natural numbers, are not considered part of the segment.

SUPPLY CHAIN INTEGRATION

- Compared to capture fisheries, aquaculture producers have fewer natural resource constraints and external biological considerations.
- This allows for greater control over production processes and enhanced responsiveness to the evolution of consumer preferences, e.g., around sustainability and product origin.
- Consequently, the sector lends itself to vertically and horizontally integrated supply chains.
- The globalization of fish and fish products means that, increasingly, product produced in one country may be processed and consumed in others.
- However, as with the broader agriculture sector, there is also a growing emphasis on locally-produced product.

SUSTAINABILITY

- The U.N. Sustainable Development Goal (SDG) #14, "Life below water", connects to the aquaculture sector, as do several other SDGs.
- The ecosystem approach to aquaculture (EAA), a FAO framework for planning, development, and management of sustainable aquaculture, is being mainstreamed in facilities worldwide.
- Consumer preferences for healthy, sustainably-sourced food are incentivizing environmentally-responsible production.

03 | U.S. Aquaculture Trends
U.S. Aquaculture

PRODUCTION

• The U.S. aquaculture sector is relatively small, ranking 14th in the world in terms of production volume.

• However, the country is the second largest consumer of seafood in the world (after China and ahead of Japan) and imports 90 percent of what it consumes, mainly from Norway, Chile, Canada, and other European countries.

• The U.S. imported $21 billion in edible fishery products in 2017, up 10.5 percent from 2016. This is in contrast to just $5.4 billion in imports. With the market for domestically-produced fish largely untapped, the potential for U.S. aquaculture expansion is significant.

• Current production is comprised mainly of shellfish and catfish, followed by salmon and shrimp.
  – Freshwater farmed species tend to be of lower value, e.g. catfish, crawfish, and trout. The dominance of catfish (historically nearly half the market; now closer to one-third) has declined due to Asian imports and growth in tilapia.
  – Atlantic salmon is the leading species for marine finfish aquaculture, while oysters have the highest volume of shellfish production.

• The U.S. aquaculture sector produced $1.4 billion in seafood in 2015. Because its focus is on high-value species, this equates to approximately 21 percent of the value of total U.S. seafood production, with just 6 percent of the volume. By value, top species are oysters, clams, and Atlantic salmon.

• Although a small producer, the U.S. is a major player in the value chain, supplying a variety of advanced technology, feed, equipment, and investment to other producers around the world.

• Historic barriers to the aquaculture industry’s domestic growth include regulatory, environmental, image, and sustainable feed supply issues.

• Public sector support for aquaculture is; however, gaining momentum.
  – NOAA’s stated goal of expanding sustainable U.S. marine aquaculture production by at least 50% by 2020 has led to the authorization of a growing number of aquaculture permits.
  – The trade imbalance has led Congress to introduce the AQUAA Act (Advancing the Quality and Understanding of American Aquaculture), which recognizes the need to develop and formalize the sector.

Sources: FAO; “Imports and Exports of Fishery Products”, National Oceanic and Atmospheric Administration (NOAA); California Aquaculture Association.
U.S. Aquaculture

DEMAND

- Americans’ per capita consumption of fish falls well below the global average; however, 2015 saw a significant year-over-year increase (0.5 kilograms), to 7.0 kilograms per person, per year. In keeping with nearly a decade of positive growth, this figure rose slightly in 2017, to 7.2 kilograms.
- A comparison to the global per capita rate of 20.5 kilograms indicates significant room for expansion of domestic consumption.
- A heightened focus on healthy eating is partially responsible for increased demand.
  - 32 percent of consumers want to increase fish consumption; and
  - 72 percent only want to consume fish products that are harvested in a sustainable manner.
- Historically, wild-caught fish were perceived as a more sustainable, healthy choice compared to farmed product. More recent evidence from organizations such as FAO and NOAA points to the benefits of the latter, notably preservation of wild habitats and species, lower risk of contamination, traceability, and increased freshness.

SALMON MARKET

- The U.S. is the world’s largest salmon market. Salmon is the second most-consumed species in the U.S. (after shrimp and before canned tuna) and the highest-value product on the list of the top ten most-consumed. In 2017, Americans ate an average of 1.1 kilograms of salmon per person, per year.
- 98 percent of U.S. consumed salmon is imported, equating to more than 400,000 metric tonnes, or 440,900 U.S. tons, and $4 billion in value. Two-thirds of imports are fresh.
- Imports have grown by an average of 7.6 percent per year since 2010 and are expected to grow by at least 4 percent annually through the next three to five years.
- Nearly 100 percent of global supply is produced in sea-based net pens. Increasingly restrictive regulations on this type of farmed salmon production, together with natural limits in wild-catch salmon, are translating to a supply-demand gap and higher pricing.
- The average price for a kilogram of salmon in 2015 was $9.06; three years later, this figure had increased to $12.76.
- Farmed salmon is a more sustainable and resource-efficient protein source than land animals in terms of:
  - Feed conversion ratio (feed needed to increase body weight).
  - Edible meat as a percentage of body weight.
  - Protein retention.

Sources: FAO; “Fisheries of the United States”; NOAA; World Bank; National Fisheries Institute; USDA; National Marine Fisheries Service; “US, China are drivers of push for more salmon production”, SeafoodSource; Undercurrent News; “2018 Seafood Report”, Kantar; DNB Markets (consumption forecasts).
04 Types of Aquaculture
Traditional Technologies

- Domestically and globally, the aquaculture industry is dominated by mature, established, environmentally-unsound farming systems.
- The majority of traditional industry stakeholders have little incentive to substitute technology and write-off heavy investment in existing assets.
- Even so, more intense scrutiny of impacts, together with the evolution of systems and equipment, are driving major industry changes, notably a shift from the mechanics of farming to the implementation of advanced technological systems.

LAND-BASED OPEN PONDS

- Open pond aquaculture, or the practice of enclosing fish in bodies of fresh or salt water, is nearly as old as history, and is relatively easy and inexpensive in warm climates.
- Open pond catfish farming represents the largest segment of the U.S. aquaculture sector. In Asia, the majority of ponds are used to cultivate crustaceans (shrimp) and mollusks.
- Virtually no innovation or new investment is expected in this segment of the market.
- Environmental issues include a large footprint that can involve the destruction of natural habitat, untreated wastewater flows, and lack of disease control.

NET PENS

- The most common type of marine aquaculture in the U.S., net pens were initially intended to produce large quantities of marine fish minus the environmental damage associated with open ponds.
- While scalable (within a limited climate) and relatively capital efficient, significant issues have arisen with net pens, including the attraction of disease, contamination of sea beds, hybridization of wild stocks, and biodiversity damage.
- The best sea farming areas tend to be remote from the largest end markets, requiring significant transportation and logistics costs, and leading to reduced shelf life.
- Increasingly strict regulations and environmental limitations are expected to limit growth of the net pen market segment. In 2018, Washington banned Atlantic salmon farming from state waters; British Columbia will be phasing out 17 farms between 2019 and 2023.
- Technological advances are focusing on improving net pen solutions, with examples including software to improve feeding regimes, reduce waste, and predict spikes in sea lice numbers, as well as visualization tools to assess behavior and measure biomass.

SHELLFISH CULTURES

- Shellfish aquaculture, or the farming of aquatic invertebrates, e.g., oysters, clams, and mussels, has evolved from purely coastal/beach to technology-based systems designed for specific species and farming sites.
- In contrast to other traditional methods of farming, off-bottom culture farming is relatively sustainable although not free of a degree of public and regulatory examination.
- There is no contact with the seafloor, shellfish do not require external feed and are harvested with little to no bycatch. Additionally, filter-feeding shellfish offer ecosystem benefits by reducing nutrient load in the water.

Sources: IFCNR; “Sustainable changes in aquaculture are happening as we speak”, The Fish Site; “What is shellfish aquaculture?”, Sea West News; “Farming Techniques”, Ocean Wise; “BC to shut down 17 Atlantic salmon farms”, Aquaculture North America; “After 3 decades, Washington State Bans Atlantic Salmon Farms”, NPR.
Recirculated Aquaculture Systems (RAS)

- Defined as land-based, closed containment systems with water treatment and recycling capabilities, RAS comprises a small but growing segment of the aquaculture industry.
- Commercial-scale viability and funding have historically been challenged by the need for "technology to catch up to biology"; however, RAS is now being successfully used in commercial production in selected segments.
- RAS systems offer a number of appealing advantages over traditional farming methods.
  - Transportation: allows for placement virtually anywhere on land, eliminating costly air freight.
  - Environmental impact: reduces water consumption, CO2 emissions, and impact on wild species/habitats; also enables sludge and effluent recovery.
  - Quality control: allows for increased control over key system drivers; shorter time to market improves freshness and taste.
  - Health: results in less contamination vs. wild catch; is typically antibiotic and GMO-free; can more easily structured to qualify as organic.
  - Brand differentiators: facilitates local, all-natural, and made-in-the-U.S. labelling.
  - Consistency: enables year-round production.
  - Volume: increases harvest densities and accelerates growth.
  - Animal welfare: makes fish healthier and more disease-resistant.
  - Operations and technical risk: reduces exposure to external influences, lowering operating risk.
- These systems are not without risks and require a high degree of expertise and technological sophistication to manage biological performance, biohazard and disease threats, and water infrastructure. In some cases, offtake has been impacted by a public bias against farmed fish.

RAS ECONOMICS
- Cost of production has been a barrier to widespread expansion of the RAS segment. High upfront costs necessitate patient capital as revenues can, in the case of cold water fish such as Atlantic salmon, take up to four years to materialize. Rainbow trout, steelhead, and tilapia have shorter timeframes.
- Average cost to build varies greatly depending on technology and type of fish but is generally high compared to traditional aquaculture systems.
  - More easily cultured fish, e.g., tilapia, catfish, koi, and perch, can be farmed in land based systems costing approximately $15 to $20 per annual kilogram.
  - Sophisticated, vertically-integrated projects involving cold water fish such as salmon are more expensive, with all-in capital requirements of $25 to $30 per annual kilogram of fish grown. This figure includes RAS equipment as well as hatchery and grow out facilities.
- Scale is key to profitability; industry sources suggest minimum production of 2,500 metric tonnes per year. The majority of smaller facilities have failed.
- Depending on the level of vertical integration, most salmon RAS systems have capital requirements in excess of $50 million.
- Operating expenses are dominated by feed costs, followed by energy and labor.
- Based on prices supportable in the current market, RAS projects of sufficient scale can pencil. Where premium pricing for sustainably sources and/or local product is achievable, returns will be boosted.

RAS Production and Pipeline

As of early 2019, six RAS facilities were operating in North America, with six to eight more in various stages of planning and fund raising.

While several established facilities are producing tilapia, branzino and steelhead, most planned operations are focused on the robust market for Atlantic salmon.

Within a broader region including Canada and the Nordics, approximately ten RAS plants are operating with a 2017 estimated output of 7,000 metric tonnes. Little information on land-based production in Asia is available; existing facilities appear to be small although larger ones are planned.

By 2020, DNB Markets expects the number of facilities to double, globally; at the same time, planned output is set to increase to 150,000 metric tonnes. This represents less than five percent of current U.S. seafood imports and less than 40 percent of the country’s salmon imports alone.

Pipeline volumes continue to be pushed out due to a lack of permits, financing, and/or biological experience. DNB’s 2017 forecasts for 2019 have fallen far short of initial plans, with half the projects still not ready to break ground. Although the number of planned projects has greatly increased – to 500,000 MT of planned capacity by 2026 – it is unlikely that all or most will materialize.

Sample RAS Development Costs

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>2018 Estimate (thousands of metric tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAS equipment</td>
<td>$19M</td>
</tr>
<tr>
<td>RAS construction</td>
<td>$28M</td>
</tr>
<tr>
<td>Hatchery and smolt facility</td>
<td>$8M</td>
</tr>
<tr>
<td>Total facility cost</td>
<td>$55M</td>
</tr>
<tr>
<td>Land cost and preparation</td>
<td>$2M - $3M</td>
</tr>
<tr>
<td>Engineering, legal, permitting</td>
<td>$2M - $4M</td>
</tr>
<tr>
<td>Working capital</td>
<td>$3M - $5M</td>
</tr>
<tr>
<td>Estimated total investment</td>
<td>$62M - $67M</td>
</tr>
</tbody>
</table>

Identified planned production volumes in 2018 (thousands of metric tonnes)

Sources: National Marine Fisheries Service; “The future of salmon the the US is... Florida?”, WUSA9; “American Dream in Reach for Atlantic Sapphire”, Aquaculture North America; "Norwegian salmon producer invests $100M in new RAS farm in Miami", Hatchery International; “Seafood Special Report – A deeper dive into land-based farms”, DNB Markets; EQ interviews; company websites and investor materials.
RAS Companies

ATLANTIC SAPPHIRE
- This Norwegian-based company finished its all-in-one, 20-acre “Bluehouse” production facility south of Miami in late 2018. They own a neighboring 20-acre site and has an option to buy an additional 40 acres.
- Atlantic Sapphire’s goal to produce 10,000 metric tonnes of salmon by 2020 would make it the largest RAS operation in North America.
- Future phases will allow for expansion to 90,000 metric tonnes with additional investment of more than $500 million.

NORDIC AQUAFARMS
- Nordic Aquafarms is operating RAS in Denmark and Norway, and plans to build additional facilities in Belfast, ME, and Humboldt County, CA.
- Construction of the Belfast plant is expected to begin in 2019 with completion in 2020.
- First-year production is forecast at 16,000 metric tonnes. Upon full build-out, the facility is expected to produce more than 27,000 metric tonnes of salmon annually.
- The firm’s California Marine Investments subsidiary’s proposed Humboldt facility would produce approximately 25,000 metric tonnes of either salmon or steelhead per year.

WHOLE OCEANS
- As of February 2019, Portland, ME-headquartered Whole Oceans was finalizing permits to construct a RAS facility on a former paper mill site.
- An initial goal of 5,000 MT of Atlantic salmon per year will be expanded; future plans for vertical integration include a feed mill and processing operations.

PURE SALMON
- Pure Salmon, which is backed by Singapore impact investment firm, 8F Asset Management, is targeting global production of 260,000 MT of Atlantic salmon per year, in “first-phase” facilities in Poland (already operational), Japan, France or Italy, and Virginia USA.
- All will be vertically integrated with on-site hatcheries, grow-out systems, and processing facilities.

Sources: National Marine Fisheries Service; “The future of salmon the the US is... Florida?”, WUSA9; “American Dream in Reach for Atlantic Sapphire”, Aquaculture North America; “Norwegian salmon producer invests $100M in new RAS farm in Miami”, Hatchery International; “Seafood Special Report – A deeper dive into land-based farms”, DNB Markets; “Maine lands second major salmon farm”, Bangor Daily News; EQ interviews; company websites and investor materials.
Integrated Aquaculture

AQUAPONICS

• Aquaponics is the integration of aquaculture and hydroponics in a reciprocally beneficial water-based system.
• A number of RAS facilities are planning for eventual closed-loop hydroponics additions while preliminarily focusing on reusing water for irrigation and fish waste for fertilizer.
• If incorporated into early phases of an integrated facility, hydroponics can boost economics by delivering revenues earlier than aquaculture operations.
• **Superior Fresh's** 720-acre Wisconsin is the first commercial-scale, closed-loop aquaponics system in the U.S. It produces Atlantic salmon, steelhead trout, and leafy green vegetables using RAS and greenhouse technology in a 40,000 square-foot plant.
• **Future Bright's** proposed Integrated Aquaculture and Hydroponics model would produce tilapia, shrimp, arugula, mint, basil, cilantro, tomatoes, and peppers. Once at scale, a grass-based feed mill is planned to further vertical integration. On-site co-generation is intended to allow the entire project to be carbon negative.
• **Hudson Valley Farms**, a New York-based steelhead facility, began production in 2016 with 1,000 metric tonnes of fish annually. The plant was built to accommodate an aquaponics operation capable of recycling carbon dioxide produced by the fish to heat the greenhouse.
• In general, the profitability of commercial-scale aquaponics has yet to be proven at scale.

INTEGRATED MULTI-TROPHIC AQUACULTURE (IMTA)

• Farming shellfish and marine plants alongside target finfish species, e.g., salmon, trout, or shrimp, facilitates the use of target fish byproducts as a feed source for the filter feeders.
• Waste is reduced and water quality improved, while adding economic value.
• This form of aquaculture is already well-established in China; in the U.S., IMTA remains in very early stages, pending further research into production methods, biosecurity, chemical use, feeds, disease risk, species selection, economics, and community acceptance.

Sources: "North America's RAS guru joins land-based aquaponics farm in Wisconsin", Hatchery International; "Superior Fresh launches first US land-farmed salmon in Wisconsin stores", Undercurrent News; "North America's largest indoor RAS farm ramping up", Undercurrent News; "5 ways to net a sustainable future for aquaculture", World Economic Forum; NOAA; Fisheries and Ocean Canada; EQ interviews; company websites and investor materials.
Offshore Submersible Pens

- The majority of U.S. marine aquaculture efforts have focused on state waters, generally within three nautical miles of the shore.
- The open ocean offers deeper water and more powerful currents, meaning offshore systems allow for more efficient dilution of waste. Additionally, there are fewer nutrients and less biodiversity than in coastal waters, enabling a faster dispersion of fish waste with less environmental impact.
- Offshore potential is significant overseas; Norway leads production, followed by China, Chile, Indonesia, and the Philippines.
- In the U.S., offshore aquaculture faces substantial opposition, in part because concerns around coastal net pens extend to all types of pen farming.
- Similar risks of escape, disease, and equipment failure exist but can be mitigated with increasingly sophisticated technologies and assets, such as hardened pens.
- Even so, the industrial scale required for economic feasibility is difficult to achieve domestically. There are currently no commercial finish operations in U.S. federal waters.
- NOAA’s experimentation with permitting in the Gulf of Mexico has thus far stagnated. Investors have been hesitant to provoke environmentalists and fishermen without a smooth regulatory pathway. Additionally, no operation is allowed to produce more than 5,800 metric tonnes annually, which limits commercial viability.

OFFSHORE AQUACULTURE PROJECTS

- **Panama’s Open Blue** is largest open ocean fish farm in the world. Founded in 2009, it harvests and ships more than 2,700 metric tonnes of cobia annually to destinations throughout Asia, Europe, and the Americas. Fully-submersible SeaStations are situated eight miles offshore, and are designed to withstand harsh ocean conditions, including strong currents, high wind, and waves.
- **Catalina Sea Ranch** is the only commercial aquaculture facility operating in U.S. waters. The 100-acre shellfish farm, located six miles off the Los Angeles coast, is slated for an expansion to 3,000 acres. A seven-year history of startup challenges includes regulatory barriers, a lack of qualified testing laboratories, and funding.
- **Manna Fish Farms** has proposed an offshore finfish operation off the Long Island, NY coast, and is also permitting one of the first farming operations in the Gulf of Mexico. The company has additional plans for a certified organic fish farm in Ontario, Canada, and is researching IMTA as a sustainable component of its offshore production.

Sources: FAO, NOAA, Undercurrent News, Open Blue, “5 ways to net a sustainable future for aquaculture”, World Economic Forum; UN FAO; “Is the US ready for offshore aquaculture?”, Ensia; “Catalina Sea Ranch’s Crüver chomping at the bit to expand mussel farm on federal waters”, Undercurrent News; EQ interviews; company websites and investor materials.
Aquaculture Feed Market

- Feed is the largest cost input for most aquaculture operations. Fishmeal prices have increased 110 percent in the last 20 years.
- Approximately one-third of all fish captured globally are used to create fishmeal or oil.
- Fishmeal has reached its sustainable supply limit of approximately five million metric tonnes per year (accounting for about 30 percent of all aquafeed). The other dominant feed source, soybean-based meal, cannot entirely substitute.
- Growth projections translate to a need for 200 to 300 million metric tonnes of additional aquafeed required each year by the end of this century.
- To meet this demand, alternative ingredient solutions will be required, including the production of feed from single cell proteins, insects, and algae.
- These alternatives need to be produced with minimal land and freshwater use, and without prompting new competition with other food sources.
- In addition to the sheer scale of demand requirements, shifting consumer preferences dictate a move to feed with less antibiotics and more nutrients.
- The confluence of these factors is driving significant investment in new feed technologies. Alternative feed products could reportedly be worth as much as $10 billion each in a total global aquafeed market estimated at $100 billion in 2017.
- By 2025, this figure is expected to grow to $265 billion. Growth will be particularly high in China, India, and Brazil, as a result of increasing demand for seafood.
- The existing market is highly fragmented; global players such as Cargill compete with numerous regional feed producers. Approximately one-third of the aquafeed market is divided among four global companies; none have more than a 12 percent market share.

Bacteria and insects have attracted the most investment

- **Plant meal**: lower protein does not work for all species.
- **Insects**: high protein and low environmental impact but hard to establish competitive advantage and high cost.
- **Algae**: high protein, considered a premium product; production limited by demand for algae biofuel.
- **Bacterial protein**: high protein, sustainable production.

Sources: Aquafeed; NOAA; USDA; World Bank; “Aquaculture’s $100bn feed challenge presents big opportunities for entrepreneurs”, AgFunder News; “Sustainable aquaculture is a $100 billion opportunity for feed producers”, Impact Alpha; FAO; “Global Aqua Feed Market 2018 Forecast to 2023”, Research and Markets; “3 Promising Alternative Feeds for Aquaculture”, Sustainable Seafood; Lux Research; OECD; NovoNutrients; Pendulum Advisors; EQ interviews; company websites and investor materials.
05 | Aquaculture Value Chain
## Value Chain Opportunities & Challenges

<table>
<thead>
<tr>
<th>Technology &amp; Inputs</th>
<th>Production</th>
<th>Processing, Packaging &amp; Products</th>
<th>Distribution &amp; Logistics</th>
<th>Retail</th>
<th>Consumer</th>
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<tbody>
<tr>
<td>Land-based ponds</td>
<td>Limited R&amp;D/innovation</td>
<td>Environmental issues</td>
<td>Low-value products</td>
<td></td>
<td></td>
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<tr>
<td>Net pens</td>
<td>Equipment upgrades</td>
<td>Stricter regulations/bans Public opposition Environmental issues</td>
<td>Cross-border consolidation Vertical integration</td>
<td>Lack proximity to major markets High airfreight costs</td>
<td>Marketing challenges Shelf life concerns</td>
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<tr>
<td>Shellfish cultures</td>
<td>Limited R&amp;D/innovation</td>
<td>Environmental benefits IMTA and offshore farming</td>
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<tr>
<td>Recirculated aquaculture systems (RAS)</td>
<td>Equipment R&amp;D Water use &amp; recycling Vertical integration Genetics</td>
<td>Scale High upfront costs Time to production Water/biology expertise</td>
<td>Processing facilities</td>
<td>Proximity to markets Traceability</td>
<td>Consistent, year-round Long-term offtake contracts Regional sales</td>
</tr>
<tr>
<td>Integrated systems</td>
<td>Equipment R&amp;D Genetics On-site co-gen</td>
<td>Phasing Risky mixing farming types Multi-sector expertise</td>
<td>Vertical integration</td>
<td>Proximity to markets (aquaponics)</td>
<td>Value-add products</td>
</tr>
<tr>
<td>Offshore pens</td>
<td>Equipment R&amp;D</td>
<td>Scale requirements Regulatory barriers</td>
<td>Transport/logistics costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aquafeed</td>
<td>Algae, insects, bacterial proteins</td>
<td>Alternative protein options Increasing fishmeal costs</td>
<td>Vertical integration with aquaculture producers</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Large and mature
- Seafood consumption trending upward; U.S. growth potential vis-à-vis Europe
- U.S., regional, and local brand loyalty
- Premiums for farm-to-table, freshness
- Lingering aversion, negative perception of farmed fish
- Organic, Seafood Watch certification

### Shrinking, mature, and consolidated
- Large, high-value markets

### Large with some expansion potential, mature, and consolidated

### Emerging with increasing operator, investor interest
- Consistent, year-round Long-term offtake contracts Regional sales

### Emerging globally; significant U.S. barriers

### Emerging and fragmented with strong demand

**Sources:** EQ proprietary research.
Several dedicated private equity and venture capital funds are specifically targeting aquaculture investments. More broadly, food and agriculture funds are adding investments in aquaculture, as well as wild-caught seafood suppliers, processors, and consumer brands.

Historically, deterrents to a private equity-style model that can be predictably modeled, financed, and rolled out at scale have included high up-front costs, long payback periods, and difficult-to-control biological and regulatory risks.

More recently, private equity and venture capital has been drawn to an industry offering relatively low competition from other private equity players and the potential for consolidation. To-date, the focus has been on equipment, feed, pharmaceutics, and processing vs. farming.

As RAS projects begin to offer scale, (relatively) proven technologies, and viable permit pathways, investor interest is expected to grow.

### Select private equity aquaculture investors

Note: The majority are investing in companies vs. real assets

<table>
<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>Investments</th>
<th>VC?</th>
<th>Aquaculture Holdings</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADM Capital</td>
<td>U.K.</td>
<td>Mid-market opportunities and sustainable food processing and production in Europe and Australasia, 10% for &quot;nearly stage&quot; mandate</td>
<td>Y</td>
<td>Enterra Feed Corp., AeroFarms</td>
</tr>
<tr>
<td>Alimentas Ventures</td>
<td>Germany</td>
<td>Fish nutrition, health, technology and genetics</td>
<td>Y</td>
<td>Companies at the early, pre-seed stage, e.g., MicroSymbiotX</td>
</tr>
<tr>
<td>Andros Capital Management</td>
<td>U.S.</td>
<td>Agribusiness companies in upstream and midstream markets through the Americas and Western Europe</td>
<td>N</td>
<td>Andromeda Group, European fish farms, Nisuna, Solonder, Umami Sustainable Seafood, feed company, Biomega Group</td>
</tr>
<tr>
<td>Aqua-Spark</td>
<td>Netherlands</td>
<td>Seed fund dedicated to sustainable aquaculture, VC investments with goal of 50-80 investments by 2030</td>
<td>Y</td>
<td>22 investments in 14 companies, e.g., CapEco, Effity, Caysita, Ohcias Fish Farms</td>
</tr>
<tr>
<td>Devonian Capital</td>
<td>U.S.</td>
<td>Land-based aquaculture projects with a strong technology component</td>
<td>Y</td>
<td>Nearing first deal as of Dec-17</td>
</tr>
<tr>
<td>Ecolife Capital (Micro Responsible Investing)</td>
<td>U.K.</td>
<td>Marine and coastal enterprises that align ocean resource development and conservation goals</td>
<td>Y</td>
<td>The Kampachi Company</td>
</tr>
<tr>
<td>EXEDO</td>
<td>Africa</td>
<td>Food and agribusiness fund in Sub-Saharan Africa</td>
<td>N</td>
<td>TerraSan, Capital Fisheries</td>
</tr>
<tr>
<td>Ontario Teachers’ Pension Plan</td>
<td>Canada</td>
<td>Natural resources mandate to invest in the global food basket, notably sustainable sources of food production</td>
<td>N</td>
<td>Atlantic AquaFarms</td>
</tr>
<tr>
<td>Plane Schwartz Partners</td>
<td>U.S.</td>
<td>Sustainable investment opportunities across the global food and agribusiness value chain, including seafood and aquaculture</td>
<td>N</td>
<td>Devoted Iceland Seafoods, looking to diversify Scambio</td>
</tr>
<tr>
<td>Pontes Aquap Lid (Tinicum LP)</td>
<td>U.S.</td>
<td>Opportunities: $30 to $100 million investments in aquaculture companies with a focus on nutrition, fish feed and oil, hatcheries and genetics, and large-scale farming</td>
<td>Y</td>
<td>N/A</td>
</tr>
<tr>
<td>Encourage Capital</td>
<td>U.S.</td>
<td>Profitable sustainable seafood businesses in Latin America, the U.S., and Europe with focus on vertical integration and stabilizing wild fish stocks</td>
<td>N</td>
<td>N/A</td>
</tr>
<tr>
<td>Wheatcroft Investments</td>
<td>U.K.</td>
<td>Agrifood investment arm of Groenvoor Group</td>
<td>Y</td>
<td>Enterra Feed Corp., AKVA Group, AeroFarms</td>
</tr>
</tbody>
</table>

#### INDUSTRY M&A

Cross-border and cross-sector consolidation is as companies look to secure access to new resources and markets. Industry players, more so than financial ones, have been driving activity. IntraFish recorded 62 seafood M&A deals, globally, in 2018.

Recent aquaculture examples include:

- AquaBounty Technologies’ (makers of genetically modified salmon) $14M investment in Alabama-based Bell Fish Company’s assets, including its RAS operation. Bell was formerly owned by Dallas-based private equity firm, Trive Capital.
- Norway-based Marine Harvest’s (the world’s largest salmon farming company) acquisition of Canada-based Northern Harvest.
- Norwegian farmed salmon producer, SalMar’s, acquisition of a 51 percent stake in offshore farming company, Mariculture.
- Aquaculture technology company, AKVA Group’s acquisition of Egersund Net, which produces nets and mooring solutions for the aquaculture industry.
- Insect meal producer, AgriProtein’s, purchase of rival fly-feed producer, Millibeter.

Sources: AgFunder News; Impact Alpha; Agri Investor; “This is what private equity investors see in aquaculture companies”, Salmon Business; “Investors Target Growing Demand for Healthy, Sustainable, Tasty Fish”, ImpactAlpha; “Was 2018 the biggest year yet for seafood M&A deals?”, IntraFish; company websites and investor materials.
Market Potential
Market Potential

SEGMENT RECOMMENDATIONS

• Sustainable aquaculture investment is best targeted toward land-based RAS farming.
• Integrated aquaponics may present future opportunities but combined closed-loop systems are far from being proven at scale. While phasing aquaculture facilities into existing greenhouse projects could allow food revenues to offset high upfront RAS costs, the risks posed by combining two complex systems are substantial.
• Commercially-scaled IMTA offers distant prospects, domestically, due to regulatory and environmental issues with sustainable pen production, including offshore submersible finfish pens.
• The aquafeed segment remains fragmented and no one solution offers a clear-cut advantage. Robust demand and a continued increase in forecasted need is, however, attracting considerable early-stage investor interest.

RAS & FEED MARKET SIZING

• If salmon consumption grows by the same CAGR as it has since 2010, i.e., nearly 8 percent, imports would have to increase by nearly 50 percent, or more than 150,000 metric tonnes over the next five years to address demand.
• Within this timeframe, the U.S. could have RAS systems producing as much as 90,000 metric tonnes although this predicated on an aggressive buildout.
• Considering RAS opportunities for other fish types, as well as the potential for the conventional sea farming market to contract, headroom exists for additional players and investment.
• Using conservative price estimates, a 150,000 MT land-based salmon production market would equate to $1.1 billion in revenue and represent $3.5 to $4.5 billion in capital requirements.
• According to Transparency Market Research, the global market for aquaculture feed will reach approximately $123 billion in 2019. Asia Pacific dominates, with 65 percent of this total, followed by Europe. Based on production totals, the U.S. feed market is estimated at $518 million.

Sources: Atlantic Sapphire; “McDowell Group: High Alaska salmon prices to be followed by stiff trade winds”, Undercurrent News; Marine Harvest; Fish Pool; NOAA; USDA; Transparency Market Research; Veolia.
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