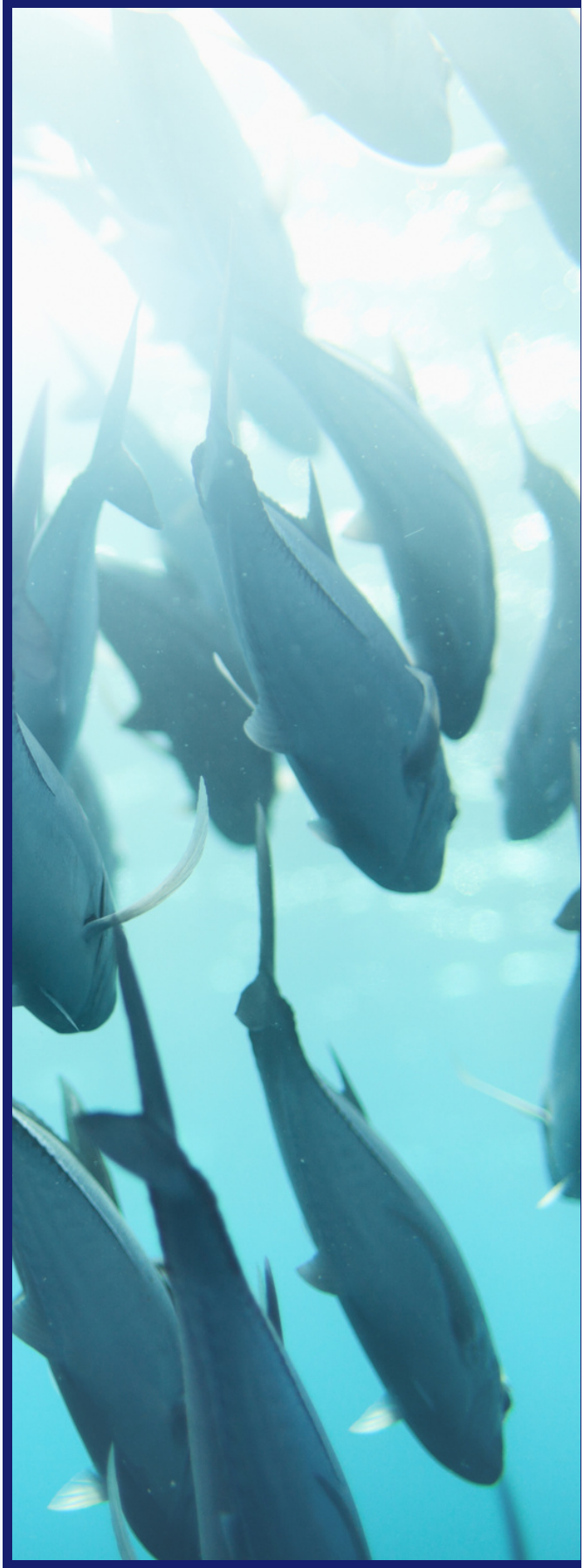
BlueNalu

BLUEFIN TUNA

THE MOST PRIZED FISH IN THE SEA

A deep dive on this critical species



DEEP DIVE • UPDATED SEPTEMBER 2022

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EXECUTIVE SUMMARY

Bluefin tuna is sometimes described as the “wagyu beef of the sea” for its marbled texture, buttery flavor and status as one of the most prized fish in the sea. Although accounting for just 1% of global tuna catch by weight, these fish account for about 6% of the global tuna end value due to demand for the fish and its premium price. An estimated 80% of the world’s bluefin tuna is consumed in Japan where highly experienced chefs prepare the medium-full flavored delicacy for sushi dishes using cuts such as akami (“lean” muscle portion), chu-toro (“medium” fatty belly portion) or o-toro (“very fatty” belly portion).

Unfortunately, the supply of bluefin tuna has been heavily depleted due to overfishing and illegal fishing in the past few decades. While there have been some conservation efforts to combat the steep population decline, the species still faces severe challenges due to high demand. According to market research completed by BlueNalu, it is estimated that the market for bluefin tuna could be 3x-10x larger if a greater supply of the fish was available.

As demand continues to grow, it will be critical to have sustainable alternatives available to meet the growing gap between demand and supply for bluefin tuna and other species that are difficult to farm, impacted by issues that affect human health, vulnerable to environmental or social challenges, transported great distances between points of harvest and consumption, or limited in supply.

BlueNalu will be focused on bluefin tuna toro (“fatty” belly portion of the fish) for its first product to market, representing the most coveted and most difficult cut to source from this premium fish.

The cell-cultured food industry provides significant potential benefits for consumers and operators, and solutions to challenges with the traditional seafood supply. This option can complement the existing global seafood supply, increase the size of the market, and meet unmet demand in a way that is healthy for humans, humane for sea life, and sustainable for the planet.

THE GROWING DEMAND FOR SEAFOOD

Global demand for seafood is at an all-time high and is anticipated to increase significantly in the decades ahead. At present, seafood is the largest traded animal protein on the planet and the only major source of animal protein that continues to rely on the widescale harvesting of wild animals. Furthermore, the fragmented seafood industry has several layers of the value-chain that each can introduce unacceptable levels of food safety risk, food waste, the potential for supply chain disruption, and wildlife conservation concern, particularly for large pelagic animals whose slow growth cycles are disrupted by industrial fishing.

One such case is that of the bluefin tuna, whose population has been heavily depleted due to overfishing and illegal fishing in the past few decades (Sekiyama, 2017). Yet, even with these challenges, the bluefin tuna continues to be valued as a premium seafood product with worldwide demand. As seafood consumption continues to rise, the management of bluefin tuna and the need for alternative solutions to satiate demand for this highly prized species must be addressed.

AN INTRODUCTION TO TUNA

Tuna is a popular finfish with a wide variety of products and species available to consumers worldwide. Most of the market is made up of four tuna species: skipjack, followed by yellowfin, bigeye, and albacore. Bluefin tuna, the species facing the most conservation challenges, makes up 1% of the global tuna catch (World Wildlife Fund, 2022).

In the wild, tuna is one of the few fish that can maintain a body temperature higher than that of the surrounding water. An active and agile predator, the tuna has a sleek, streamlined body, and is among the fastest-swimming pelagic fish in the world, migrating transcontinental routes. The species vary widely in size, from as small as the bullet tuna at less than a meter, up to the bluefin tuna which can reach 3 meters or more. In total, there are 15 species of tuna across 5 genera.

AN INTRODUCTION TO THE BLUEFIN TUNA

The bluefin tuna is the largest of the tuna fish. These predatory tunas are found migrating widely throughout the open waters, with three main types of bluefin: Atlantic bluefin tuna, Pacific bluefin tuna, and Southern bluefin tuna, each of which inhabits various ocean regions and migratory patterns.

Bluefin tuna swim in deep ocean waters, down to the chilly depths of 3,000 feet. With adults reaching up to 3 meters long and a maximum of 680 kilograms, the bluefin tuna are among the world's largest fish. Reaching maturity at approximately 5 years of age and with an average lifespan of about 15 years, these apex predators mainly feed on schools of smaller fish like mackerel, sardines, and anchovies.

The largest bluefin tuna ever caught was in 1979 in Nova Scotia. The fish weighed 679 kg.

Photo courtesy of IGFA/ifga.org

THE MARKET & FINANCIAL APPEAL

Bluefin tuna is a highly desired seafood species. Although accounting for just 1% of global tuna catch by weight, ranging from 40,000 to 68,000 metric tons each year, these fish generate an estimated $610 million to $800 million for fishers, accounting for about 6% of the global tuna end value ($2 billion to $2.5 billion) due to demand for the fish and its premium price (Pew Charitable Trusts, 2020). According to market research completed by BlueNalu, it is estimated that the market for bluefin tuna could be 3x-10x larger if a greater supply of the fish was available.

Bluefin tuna is considered the most premium tuna in terms of mouthfeel and flavor, with wholesale edible portions priced up to $265/kg, or more, depending on the cut of the fish. Consumers can pay anywhere between $10 and $80 for a dish featuring bluefin tuna. It is most often used in high-end sushi restaurants with other premium ingredients like caviar, truffles, and uni.

Estimates indicate that up to 80% of the global bluefin tuna catch is consumed in Japan, where bluefin tuna, or “maguro”, is quickly sold in accordance with the limitations around supply (Mutter, 2022).

Wild Caught Bluefin

Wild-caught bluefin is fished in the high seas off the west coast of the U.S. and Japan for Pacific bluefin tuna, off the east coast of the U.S. and Mediterranean countries for the Atlantic bluefin tuna, and off the coast of Australia, Indonesia, New Zealand, and South Africa for the Southern bluefin tuna. Due to the vulnerable population status of the fish, various nations, as well as the Inter-American Tropical Tuna Commission (IATTC), have attempted to establish quotas around catch numbers, however, harmful fishing subsidies continue to jeopardize conservation efforts and contribute to overfishing of the species.

Ranched Bluefin

At present, the main producers of ranched bluefin tuna are Australia, Japan, Mexico, and areas around the Mediterranean such as Croatia, Italy, Malta, Morocco, Spain, and Turkey. According to FAO Fishstat, ranched and farmed bluefin tuna make up roughly 35%-45% of the total bluefin tuna supply, although up to 97% of ranched bluefin tuna come from captured young wild fish.

THE CULTURAL SIGNIFICANCE & FOOD HISTORY

Bluefin tuna as a food source has had an interesting history and pathway to popularity. Before the 1970s, bluefin tuna was not associated with premium foods but was instead perceived as too fatty, smelly, and strong tasting for consumption. In the United States, the fish was regularly ground up for cat food (Smithsonian Magazine, 2013). Before modern refrigeration technology, bluefin consumption was also limited by spoilage during travel, which prevented the fish from being shipped long distances (Asahi Shimbun, 2015).

With the arrival of the sushi bar in the United States, the consumer appetite for bluefin tuna, most specifically the toro, or fatty belly cut, began to rise. By the 1970s, this consumer appetite had traveled back to Japan where there was a rapid increase in demand for the fish. In fact, fishing for bluefin tuna rose by more than 2000% between 1970 and 1990 (Narula, 2014).

In 2010, attempts to ban trade on the endangered bluefin tuna were met with opposition and rejection, particularly from Japanese representatives, at the United Nations Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), given the popularity of the seafood species (Jolly & Broder, 2010). Bluefin tuna have historically been sold at the Tsukiji and Toyusu Markets in Tokyo, with the most expensive bluefin tuna ever sold in 2019 - a 278 kilogram fish sold for $3.1 million US dollars (The Asahi Shimbun, 2021).

BLUEFIN TUNA CUTS & PREPARATION

Bluefin Tuna has the fattiest flesh of all tuna. It has a distinctive medium-full flavor and firm, “meaty” texture. It is the only tuna species that provides toro, or fatty belly cuts, earning a reputation as the "wagyu beef of the sea." The following cuts of the bluefin are most consumed.

AKAMI - *Red Meat Tuna*

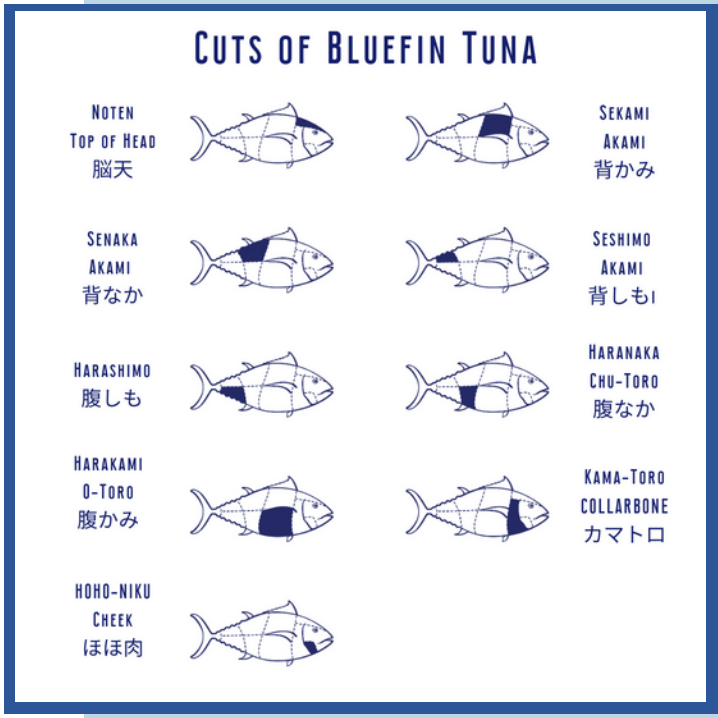
This cut holds a strong aroma from the raw freshness of the flesh. The highest quality red meat has a mellow and elegant flavor, with a hint of sourness. This is the most common part of the fish and is typically bought wholesale around $44/kg - $77/kg by foodservice operators.

CHU-TORO - *Semi-Fatty Tuna*

This cut perfectly combines quality tuna fat for flavor and texture and the great fresh aroma of the red meat. Usually, chu-toro will include a color gradient, indicating changes in the cut from lean to fatty. As the second most premium cut, this is typically bought wholesale for around $110/kg - $140/kg by foodservice operators.

O-TORO - *Fatty Tuna*

This cut is densely marbled for a mouthful of creamy sweetness, and a melt in the mouth texture. O-toro is the fattiest and most highly priced portion of the bluefin tuna. It is typically bought wholesale for $140/kg - $265/kg by foodservice operators.



Bluefin tuna is most often used for sushi and sashimi, served in simple applications to best showcase the flavors of the fish. The fish is typically eaten raw, but it can also be broiled, grilled, sauteed, smoked and dry-aged, and can be found as an appetizer in menu items like tuna tartar, carpaccio, crudo, poke and zuke in high-end establishments. Chefs may choose to buy the whole fish, which takes significant labor to cut. Alternatively, bluefin is also bought in a form called a “saku," a rectangular block of a particular cut of the fish that can be used for sashimi or portioned into cubes or slices for a variety of uses. Yield to off cut ratio for the tuna is often as low as 35% to 65%, respectively. Offcuts include bones, scales, head, organs, and intestines (Chef's Resources, 2009).

HEALTH BENEFITS & NUTRITIONAL VALUE

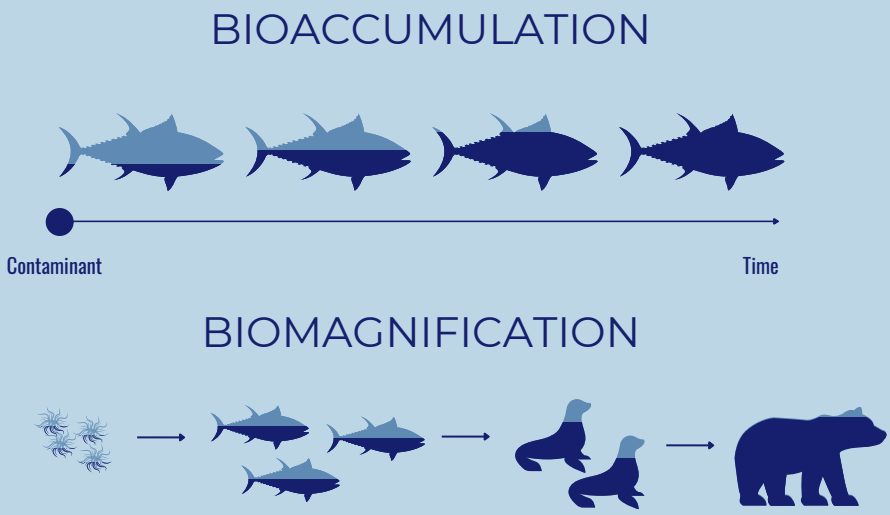
A good source of protein, tuna is considered to be nutritious for human consumption. Generally, seafood is considered to be lower in fat, saturated fat and cholesterol than an equivalent portion of a different animal protein (Seafood Nutrition Overview, 2022). Containing healthy long-chain fats like eicosapetaenoic acid (EPA) and docosahexaenoic acid (DHA), these omega-3s are considered essential for brain development and heart health (NIH Office of Dietary Supplements, 2022). Omega-3 fatty acids, which are particularly prevalent in oily fish like tuna, are also recommended for pregnant women due to their valuable benefits for brain development. A natural source of Vitamin D, seafood like tuna helps to build and maintain strong bone health. Furthermore, it is a good source of selenium and provides strong immune support (Harvard School of Public Health, 2019).

CHALLENGES WITH CONSUMPTION & HUMAN HEALTH

Toxin Biomagnification & Mercury

Given their long life and predator status, bluefin tuna are susceptible to accumulate mercury, microplastic and other pollutants as they biomagnify in the aquatic food web. Bluefin accumulates these toxins in its fat and muscle tissues with age. This accumulation has health and safety implications for ocean health and human health.

Tuna is reported to have elevated mercury levels (EDF, 2013). Tuna sushi, often made from large bluefin tuna, which are older and therefore have higher mercury levels, contains about 1.0 part per million mercury, putting it on a par with swordfish and shark among the highest mercury containing fish (Mercury Policy Project, 2016).



Bioaccumulation is the gradual buildup of a pollutant in an organism over time. Biomagnification is the process by which a pollutant becomes more concentrated in the tissues of organisms as it travels up the food chain.

It is worth noting that the FDA does not provide information on mercury levels in bluefin tuna, perhaps due to the limited supply and availability of the fish. Despite the health benefits of the fish, bluefin tuna poses a potential risk for pregnant and nursing women and children, as mercury has been linked to developmental issues in newborns' brains and nervous systems (Centers for Disease Control and Prevention, 2021).

A paper published in the Proceedings of the National Academy of Science (PNAS) studied how various species of bluefin tuna can be used as local and global barometers for neurotoxic methylmercury. The study suggested that mercury accumulation rates in bluefin tuna may be used as a global pollution index to reveal patterns of mercury pollution and its bioavailability in the ocean (Chun-Mao Tseng et al., 2021).

Storage & Carbon Monoxide Treatment

A notoriously difficult fish to store due to its high fat content, the bluefin tuna must be cryogenically frozen to maintain freshness. Due to rapid bacteria growth, bluefin tuna should be discarded if left out for more than 2 hours at room temperature. To further extend the shelf life of raw tuna, bluefin is often frozen while still on the boat. However, given the lack of traceability in the supply chain, it is often unknown whether the fish has remained frozen from the point of catch until its final destination. Once defrosted, tuna can be kept for an additional 1 to 2 days in the refrigerator before cooking (National Fisheries Institute, 2022).

An additional area of concern for bluefin tuna is carbon monoxide treatment, when used. Carbon monoxide's properties prevent bluefin tuna's flesh from discoloring before it reaches the consumer. The gas can provide a pinkish-red coloration to tuna that may otherwise be turning brown. It is estimated that 11 million kilograms of total treated tuna (bluefin and other tunas), are annually brought into the United States, where the process of treating tuna with carbon monoxide is allowed (Moskin, 2004). The practice is also allowed in Canada, Australia, and New Zealand (Djenane & Roncalés, 2018). Other regions like Japan and the European Union have banned the practice over the fears of selling spoiled fish.

Labor Issues & Safety Risks/Hazards

It has been reported that human trafficking for labor has been present on some international fishing fleets (UNODC, 2011). Like other aspects of the fishing industry, what takes place on the high seas is difficult to observe and regulations that do exist are hard to enforce. In addition, fishing occupations are often seasonal, as fish migrations, catch quotas and changes in fish populations create fluctuating demand for labor by season and from year to year.

A report revealed that out of 35 leading global tuna companies, only 4 reported having due diligence policies and procedures that specifically addressed the risk of modern slavery in supply chains and only 3 had cascading modern slavery prohibitions throughout their entire supply chain (Business and Human Rights Resource Center, 2019).

SPECIES & OCEAN ECOSYSTEM CHALLENGES

Mislabeling

The umbrella term “tuna” encompasses a variety of tuna products and species, ranging from low-value skipjack tuna that is typically canned, to bluefin tuna, a premium global product. This umbrella term has driven up rates of mislabeling for bluefin tuna and hampered efforts towards labeling transparency.

Mislabeling rates as high as 95% have been reported for bluefin tuna and in 72% of those cases, bluefin tuna was substituted by the more common yellowfin tuna (Oceana Europe, 2015). The lack of comprehensive data has made it difficult to evaluate the full extent of mislabeling for bluefin tuna, which has impaired fisheries management efforts.

Conservation Status & Population Decline

The volume of illegal fishing and its impacts on bluefin tuna stocks are unknown but reports of illegal, unregulated and unreported (IUU) fishing for bluefin tuna estimate a total catch that is 100% greater than what is legally reported (Europol, 2018).

By its very definition, the volume of illegal fishing and its impact on bluefin tuna and bycatch is unknown, thus accounting for the wide range of estimates. However, a variety of sources specify that this is a challenge for the bluefin tuna market as demand is much higher than supply from designated quotas (World Wildlife Fund, 2018).

The extinction risk for bluefin tuna is listed as "vulnerable" for Pacific bluefin tuna, "endangered" for Atlantic bluefin tuna," and "critically endangered" for Southern bluefin tuna. The dramatic drop in population has led to some conservation efforts, including a petition for protection under the Endangered Species Act (Center for Biological Diversity, 2022), however, the species still faces severe conservation challenges given the demand for bluefin tuna sushi and sashimi.

Limitations of Ranched & Farmed

As it is very difficult to close the lifecycle of the species, in Japan 97% of commercially farmed bluefin, where the fish lives in captivity until harvest, or ranched bluefin, where the fish is released to complete growth in the open ocean, comes from wild-captured young wild fish (Monterey Bay Aquarium, 2016). These methods do not take pressure off wild populations.

Researchers from Kindai University in Japan have been one of only a few groups to successfully close the lifecycle, spawning bluefin tuna in captivity and raising them to maturity – a difficult task due to biological challenges in spawning and larval rearing, space requirements for captive broodstock and hatchery, feed, specific conditions needed for the fish to lay eggs, and other factors (Hays, 2019).

Furthermore, bluefin tuna aquaculture relies on smaller, wild-caught baitfish like sardines, herring, and mackerel at a feed to fish ratio between 10:1 and 20:1 (Mylonas et al., 2010). Spoilage, waste, and disposal of feed into nearby waters also threaten marine ecosystems. The labor and resource-intensive nature of farming poses additional problems, although developments towards sustainable tuna feed are increasing.

Bycatch & Waste

The FAO reports that 35% of global seafood catches are wasted (FAO, 2022). About a quarter of these losses are bycatch or discards, mostly from trawlers, where fish are thrown back because they are too small or an unwanted species. The longline and purse seines fishery methods used to catch bluefin tuna are also a concern for numerous other vulnerable or endangered species, including whitetip and silky sharks, striped marlins, loggerhead and leatherback turtles, and albatross seabirds (Monterey Bay Aquarium, 2008).

Losses may also be due to a lack of equipment, such as refrigeration, needed to prevent spoiling. Waste estimates for bluefin tuna are underreported and difficult to trace, but given global rates of waste, it can be assumed that similarly high rates also apply for the bluefin tuna, given its difficulty to store.

Considering the transport distances between point of capture and point of sale, and the need for expensive refrigeration that may not be accessible to all fishing operations, it is possible that waste estimates could be even higher. This waste does not take into consideration the low yield from the fish once it is broken down by food service operators (see Bluefin Tuna Cuts & Preparation on pg. 6).

Carbon Footprint

While the carbon footprint of bluefin tuna fisheries is unknown, they may have one of the highest fossil fuel impacts due to the need for long-distance ocean fishing vessels. Longline and pole and line fishing are among the most energy-intensive fishing operations as measured by greenhouse gases produced per ton of fish landed (AsiaPacific - FishWatch, 2019). During fishing operations, direct carbon emissions from fuel combustion are estimated to be the largest known contributor to the total carbon footprint. Once fish are landed, the complex nature of tuna products in the seafood supply chain makes it difficult to measure their complete emissions life cycle. In addition to engines, other sources of GHG emissions in the bluefin tuna fishery are vessel construction, gear and bait provision, fuel production, refrigeration, and transport of tuna to the dock.

Carbon footprint for aquaculture includes emissions from capturing fish for the stock and towing them long distances. Aquaculture requiring wild-caught feed stock of smaller fish must also consider the carbon footprint associated with the wild feed, making its footprint per ton of fish produced potentially higher than wild-caught tuna. Furthermore, bluefin tuna are transported thousands of miles to reach their final destination, with the main importer being Japan.

CARBON SEQUESTRATION POTENTIAL

Bluefin tuna can live for decades and contribute to oceanic carbon cycles through carbon sequestration in their tissues (Martin et al., 2021), which is comparable to the centennial timescale of carbon storage associated with terrestrial forests. If bluefin tuna were left in the ocean, the carbon in their tissues could be sequestered to the seafloor from the deadfall of carcasses. This carbon capture process, known as blue carbon, contributes to the ocean's major role as one of the earth's largest carbon sinks (NOAA, 2022). The amount of blue carbon associated with bluefin and other large fish living in the open ocean is an area that needs further study. Research estimates that fishing prevents the sequestration of 28.8% to 94.6% of the carbon that is taken out of the ocean by fisheries (Mariani et al., 2020). Given the role that bluefin tuna have at the top of the food chain in healthy ocean ecosystems, it is possible that their blue carbon contribution could demonstrate the power of nature based solutions in drawing down greenhouse gases and mitigating the impacts of climate change, if the fish were left to thrive in the wild.

CELL-CULTURED SEAFOOD AS A THIRD OPTION

The Rise of Blue Foods

Despite the variety of challenges, demand for seafood like the bluefin tuna has continued to increase.

Consumers have been shifting from red meat to seafood for the health benefits, tremendous culinary versatility and general perception of reduced environmental impact compared to land-based animal protein.

Interest has been growing in a new category known as blue foods, defined as foods derived from aquatic animals, plants and algae that are caught or cultivated in freshwater and marine environments (Blue Foods Assessment, 2022). Although the movement has gained traction, there is a fundamental tension between transitioning diets from red meat to blue food and preserving marine ecosystems.

It will be critical that there are sustainable alternatives available to meet the growing gap between demand and seafood supply.

BlueNalu's Strategic Focus on Bluefin Tuna

BlueNalu conducted primary market research with chefs and foodservice experts to understand the product benefits of a cell-cultured bluefin tuna. Chefs repeatedly named such factors as sustainability, 100% yield, lack of mercury and other environmental contaminants, and same taste, texture and performance as conventional as key benefits of cell-cultured bluefin tuna.

Due to factors including the difficulty of the fish to farm-raise, mislabeling, traceability issues and dwindling supply, culinary value, and price premium, BlueNalu has identified bluefin tuna toro as the most suitable first product to commercialize.

Cell-Cultured Seafood - A Supply Chain Solution

Cell-cultured seafood provides significant potential benefits to consumers, chefs, foodservice operators and ocean ecosystems, and addresses many of the challenges within the traditional seafood industry.

BlueNalu seafood will provide a third option that could fill the gap in the supply of wild and farmed seafood needed to meet growing demand for bluefin tuna and other severely challenged seafood species, with added potential for a reduced carbon footprint and well-paying jobs around the world.

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ACKNOWLEDGEMENTS

Special thanks to the BlueNalu team for the development of this deep dive, including project lead Shara Narsipur, Jeffrey Cooperhouse for research insights and fact-checking, Olivia Crawford for whitepaper and infographic design, and Greg Murphy for review and oversight.

We would like to express our gratitude to Dr. Susan Wyche and Chef Gerard Viverito for helpful insights about the elusive bluefin tuna, and Dr. Toshiro Shigaki and BlueNalu Advisory Board members Sharon Natanblut and Dr. Yoni Zohar for suggestions, review and edits.

Additional thanks to all who provided helpful feedback and support for our paper, including our friends at the Good Food Institute, TMA BlueTech and McKinsey & Company.

BlueNalu

BlueNalu is a global leader in cell-cultured seafood and is committed to transparency, safety, and collaboration. We will partner with the seafood industry to bring about the greater availability and consistency of seafood worldwide, in a way that is healthy for humans, humane for sea life and sustainable for the planet.

Based in San Diego, California, BlueNalu was formed in 2017, when its founders met in Hawaii to discuss creating an innovative company that would provide a responsible solution to the global demand for seafood. The company's name is derived from the Hawaiian word "nalu," which means both "ocean wave" and "mindfulness."

BlueNalu's team includes experts with extensive experience in each of the disciplines that will be required for global leadership in this category – including food innovation, technology commercialization, cell biology, tissue engineering, bioprocessing, large-scale manufacturing, product safety, and marketing.

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