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RE: Docket No. 2019–14621, NOAA R&D Plan Public Comment on Draft Plan.

The Good Food Institute (GFI) appreciates the opportunity to submit these comments to the U.S. National Oceanic and Atmospheric Administration (NOAA) Research and Development (R&D) Plan for 2020-2026.

The plan identifies an urgent need to develop innovative tools and technologies for more sustainable seafood production in light of demands on marine ecosystems for seafood and energy production, depleted fish stocks and declines in protected species, sea level rise, and ocean warming and acidification. To meet these needs, NOAA should expand the plan to include R&D to support plant-based and cell-based seafood.

"Plant-based seafood" refers to products created using plant-derived ingredients to replicate the flavor and texture of seafood. Using advanced food science techniques, companies are able to break down conventional seafood products into their most basic components and use plant ingredients to build nearly identical products. "Cell-based seafood," sometimes called cultivated seafood, is produced by cultivating cells from aquatic animals. Properly produced, cell-based seafood should be identical to the seafood on the market now in terms of taste and texture.

The Good Food Institute is a global 501(c)(3) nonprofit organization that shares NOAA's goal of building a sustainable food system.[1] Our scientists, entrepreneurs, lawyers, business analysts, and policy experts harness the power of food innovation and markets to accelerate the transition of the world's food system to plant-based and cell-based meat, eggs, and dairy.

[1] "NOAA"s Goals," National Oceanic and Atmospheric Administration, accessed August 23, 2019, https://www.performance.noaa.gov/goals/.

One purpose of the R&D Plan is to support NOAA's vision of a future with "healthy ecosystems, communities, and economies that are resilient in the face of change."[2] As indicated in the plan, a key component of that vision is a growing sustainable supply of seafood. Question 2.1 asks "How can knowledge, tools, and technologies be leveraged to better understand, protect, and restore ecosystems?" and Question 2.3 asks, "How can the growth of sustainable aquaculture in the United States be accelerated?"

Additional R&D in plant-based and cell-based seafood would:

1. **Promote the development of truly sustainable and healthy seafood.**
   Providing consumers with seafood that does not harm ocean and terrestrial ecosystems, is free from harmful contaminants, and competes with conventional products on taste and nutrition will promote healthy ecosystems and communities.

   Both plant-based and cell-based seafood can be produced anywhere in the United States. Both industries can therefore be located away from fragile coastal and inland ecosystems, environments that are often damaged by aquaculture. Both methods are expected to have lower greenhouse gas emissions than the most carbon-intensive fishing or aquaculture operations, cause none of the marine environmental damage associated with destructive fishing practices, and exhibit higher efficiencies than cycling caloric value through animals, among other environmental benefits.

   Nutritionally, plant-based and cell-based seafood can be designed to be nutritionally similar to wild-caught and farmed seafood. In addition, these new forms of seafood are made in controlled environments without the risk of exposure to pollutants, such as mercury and plastic.

   Research and development to further develop these products will promote the supply of healthy and safe seafood at significantly lower environmental cost than current methods, and therefore move NOAA closer to its vision of healthy ecosystems and communities.

2. **Reduce the U.S. seafood trade deficit.**
   By advancing new methods of seafood production in the United States, R&D in plant-based and cell-based seafood will also promote a healthy economy. The United States is currently importing almost 90 percent of our seafood by value and the trade deficit continues to grow.[3]

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[2] "Our Mission and Vision," National Oceanic and Atmospheric Administration (2008), https://www.noaa.gov/our-mission-and-vision; "Draft NOAA Research and Development Plan, 2020-2026," National Oceanic and Atmospheric Administration (2019), lines 679-680, https://nrc.noaa.gov/LinkClick.aspx?fileticket=omoYjsC59Gs%3d&portalid=0.

[3] "Fisheries of the United States, 2017 Report," National Oceanic and Atmospheric Administration (2018), https://www.fisheries.noaa.gov/resource/document/fisheries-united-states-2017-report.

While aquaculture has grown within the United States to make up for stagnating supply from wild-caught fisheries, the industry has grown more slowly than elsewhere around the world.

Plant-based and cell-based seafood offer the opportunity to grow the U.S. seafood industry sustainably. Not only will R&D in these sectors promote an increased supply of seafood from the United States, but it will also promote industries ripe with employment and business opportunities. The United States has the unique opportunity to take advantage of our talented and creative workforce to become the world leader in these new fields.

3. **Create seafood supplies resilient to change.**
   Resilience is key to NOAA's mandate and plant-based and cell-based seafood both allow for a more flexible and resilient supply of seafood. Not only have overfishing and destructive fishing methods endangered our future supply of fish, but extreme weather events and warming waters associated with climate change also jeopardize both our wild-caught and farmed seafood supplies. Plant-based and cell-based seafood, however, are not exposed to the same risks and are more resilient to a changing and dynamic environment.

   The plant-based and cell-based seafood industries will also be more resilient to market shocks and fluctuations. With more rapid and flexible production processes, these novel seafood sources can be scaled up or down more quickly in response to consumer demand than wild-caught and farmed fish. In addition, plant-based and cell-based seafood provide more flexibility in the species produced. Being able to swap out one species for another in response to demand is an advantage afforded by the similar equipment, inputs, and production processes utilized for several species.

Other governments have identified the opportunities above and are already investing in this exciting and promising field. Israel,[4] the Netherlands,[5] Japan,[6] and Singapore[7] have all already put public funding into the development of cell-based meat, including seafood. U.S. government investment in R&D would help the United States compete for leadership in the plant-based and cell-based seafood sectors.

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[4] Niamh Michail, "Aleph Farms CEO on its 3D cultured beef: 'Unlike other companies, our meat grows together like real meat', *Food Navigator*, May 2, 2018, https://www.foodnavigator.com/Article/2018/05/02/Aleph-Farms-CEO-on-its-3D-cultured-beef-Unlike-other-companies-our-meat-grows-together-like-real-meat.

[5] Elie Dolgin, "Sizzling interest in lab-grown meat belies lack of basic research," *Nature*, February 6, 2019, https://www.nature.com/articles/d41586-019-00373-w.

[6] Lester Wan, "Japanese clean meat firm Integriculture raises ¥300m to fund new plants," *Food Navigator,* July 17, 2018, https://www.foodnavigator-asia.com/Article/2018/07/17/Japanese-clean-meat-firm-Integriculture-raises-300m-to-fund-new-plants#.

[7] Yoolim Lee and Joyce Koh, "Singapore Backs Lab-Grown Meat, Robots in $535 Million Push," *Bloomberg*, March 17, 2019, https://www.bloomberg.com/news/articles/2019-03-27/singapore-will-invest-s-724-million-in-technology-transformation.

There remain several key research opportunities to advance plant-based and cell-based seafood. Progress is needed in several areas of fundamental technical research to advance the development of both the plant-based and cell-based seafood sectors. By including some or all of these essential research categories in the NOAA R&D Plan for 2020 to 2026, NOAA can enable the development of a future with truly safe and sustainable seafood.

1. **Many research areas apply to both plant-based and cell-based seafood.**
   An essential area for research for both the plant-based and cell-based industries is a detailed characterization of the molecular and cellular properties of popular seafood products. Understanding the molecular composition of muscle tissue from a number of different species, as well as biophysical analyses of the structural patterns, cellular arrangements, and textural properties that define these products, will be essential for the design of new products that match the sensory experience and nutritional quality of conventional seafood.

2. **Research specific to plant-based seafood will ensure high-quality products, innovative ingredients, and fool-proof processes.**
   There are several key areas for R&D that, if addressed in the coming several years, will significantly benefit the growth of the plant-based seafood industry. While this list is not exhaustive, it does offer a sample of opportunities for NOAA.

   In order to achieve appealing products at an accessible price, novel ingredients are required, especially given the fact that many seafood species achieve their taste and nutritional profiles partly through a diet of aquatic organisms, rather than land plants. For this reason, extensive canvassing of the algae kingdom will be an important step towards producing nutritious plant-based seafood.

   In addition, innovation is needed in developing and improving the production processes for plant-based seafood. Seafood exhibits unique structures relative to most terrestrial meat products. The flaky, delicate texture of many finfish will likely require dedicated optimization of existing techniques like high-moisture extrusion that are routinely used to make tougher plant-based meats, or it may require novel manufacturing methods altogether. Achieving texture as close to conventional seafood as possible is necessary to gain the support of consumers. Once the sensory profiles of plant-based seafood products are indistinguishable from their conventional counterparts, reducing the cost of plant-based seafood depends on effective scaling of production processes.

3. **Research specific to cell-based seafood will lower the barriers to entry for new companies.** In addition to the research opportunities for plant-based seafood highlighted above, immediate dedicated R&D for cell-based seafood will be essential to bringing this novel source of seafood to the market as quickly as possible.

   The development of a public repository of validated cell lines representing diverse animal genera (such as bony fish, cartilaginous fish, shellfish, crustaceans, and mollusks) is an essential early step. Such cell lines are more difficult to obtain than those of mammals and currently represent a significant barrier to entry for academic researchers and for commercial ventures. Obtaining access to high-quality primary tissue may require partnering with marine research or conservation organizations, aquariums, aquaculture facilities, or even industrial or recreational fishers. Collaborations involving aquaculture research institutes may prove particularly valuable because the aquaculture industry is experienced in handling aquatic species at all stages of maturity including embryos, and it routinely uses fish cell culture for advanced breeding and to monitor stocks for pathogens.

   In addition to establishing a cell line repository, the development of cell-based seafood will require additional research into optimizing cell culture media, identifying novel methods of scaffolding, and modifying bioreactor designs for large-scale cell culture.

The development and commercialization of plant-based and cell-based seafood is essential to ensuring healthy, safe, and sustainable seafood for generations to come while also establishing the United States as an innovative leader in this rapidly developing field. By establishing R&D in plant-based and cell-based seafood as a priority in the R&D Plan for 2020-2026, NOAA has the opportunity to contribute significantly to the future of food.

Conventional seafood production poses global threats.

Overfishing and harmful fishing practices have significantly depleted global fisheries, damaged fragile marine habitat, and destabilized ocean ecosystems. As fishing moves further from coastal areas, fleets use more and more fuel to catch fewer and smaller fish each year.[8] A 2018 report by the United Nations Food and Agriculture Organization found that one-third of all fish stocks are being depleted faster than they can replenish and another 60 percent are being fished at the maximum sustainable level, leaving only seven percent of fish stocks underfished.[9] While some fisheries management programs have been

[8] David Tickler et al., "Far from home: Distance patterns of global fishing fleets," *Science advances* 4, no. 8 (August 2018), http://doi.org/10.1126%2Fsciadv.aar3279.

[9] "The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals," Food and Agriculture Organization of the United Nations (2018), http://www.fao.org/3/i9540en/i9540en.pdf.

successful, it is notoriously difficult to track the catch from fishing vessels and very few resources are expended by governments to enforce catch limits.[10]

While improving and expanding the U.S. aquaculture industry is one method of improving resiliency in the face of change, aquaculture inherently faces several significant challenges, including a continued reliance on wild fish for feed, emergence of drug-resistant pathogens, destruction of sensitive coastal habitats, and escape of non-native farmed species into wild ecosystems. While some people practice more responsible and sustainable techniques, the vast majority of aquaculture occurs in regions of the world where cheaper production methods prevail and oversight is limited or nonexistent. The adverse impacts of these aquaculture facilities can exert global reach.

It is simply not pragmatic or possible to produce many of the types of seafood that consumers value in aquaculture systems. Moreover, aquaculture is not expanding rapidly to meet growing global demand for seafood on the whole. The Food and Agriculture Organization of the United Nations projected seafood demand driven by income and population growth to reach between 23 and 25 kilograms per year per capita by the mid-2020s, up from about 20 kilograms in the mid-2010s. Aquaculture would need to grow at between 6.6 and 9.9 percent per year in order to meet this growing demand, but recent trends suggest a 4.5 percent growth rate into the mid-2020s. In fact, only 17 countries' aquaculture growth is expected to keep pace with growing seafood demand, with 170 countries projected to face unmet demand.[11]

The plant-based and cell-based meat and dairy industries have advanced significantly in recent years, but there remains significant room for growth in plant-based and cell-based seafood. While there remains significant room for growth in the industry, a handful of plant-based seafood products are already on the market. Notable emerging plant-based brands and companies include Good Catch, Terramino Foods, and Ocean Hugger, all of which have formed since 2016. Good Catch has developed plant-based flaked fish products such as plant-based tuna, crab cakes, and fish burgers. Terramino Foods debuted their prototype "salmon" burger in April 2018, produced using a fungi-based fermentation platform. Ocean Hugger uses the concept of biomimicry to replicate the texture and flavor of sushi using intact fruits and vegetables where their native flavors are replaced with those that invoke fish, such as savory umami.

Plant-based seafood products currently comprise a very small fraction of the global seafood market, leaving almost unlimited growth potential in all segments. To date, only a handful of brands carry any

[10] Daniel Pauly and Dirk Zeller. "Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining." *Nature communications* 7 (2016), https://doi.org/10.1038/ncomms10244.
[11] Junning Cai and PingSun Leung, "Short-term projection of global fish demand and supply gaps," Food and Agriculture Organization of the United Nations (2017), http://www.fao.org/3/a-i7623e.pdf.

plant-based seafood product lines, and these lines cover fewer than a dozen of the hundreds of species of marine animals that are regularly consumed around the globe.
Cell-based seafood companies have made significant progress in the last few years towards establishing production processes. The first step is isolating a small number of cells from an aquatic animal and allowing the cells to divide in a medium of nutrients and growth factors that mimics the environment in which they would proliferate within the body. The cells are then seeded into a scaffolding material where they mature into the cell types for muscle, fat, and connective tissue. The process occurs in a bioreactor similar to a tank used for fermenting beer or yogurt. Because the starter cells are derived directly from species that are routinely used for food, the end product is the same product as the conventional seafood counterpart known to consumers and regulators.

Of the more than two dozen startup companies that have emerged since 2014 to commercialize cell-based meat, only four companies have indicated a predominant focus on seafood products. The species prioritized by these companies comprise only a small portion of the multi-billion dollar market across all marine animals, leaving immense opportunity for fledgling companies to pioneer work on additional cell-based seafood products from other species. The application of cell-based meat bioprocessing to seafood is a very young endeavor and the allocation of even modest levels of additional resources toward this effort is likely to contribute substantially to the technological maturity and commercial readiness of the field.

The speed with which cell-based seafood actually reaches the marketplace will be largely dependent on funding for the research needed to get it there, and public funding is essential. Just as federal R&D funding has sparked innovations in computing, genomics, manufacturing, and other fields, federal funding for research on plant-based and cell-based seafood can effect dramatic improvements in how we supply seafood.[12] Although private investment in plant-based and cell-based seafood research has increased recently, the total amount is still relatively small. In addition, most privately funded research is proprietary.

Question 2.1 in the draft research plan asks “How can knowledge, tools, and technologies be leveraged to better understand, protect, and restore ecosystems?” Plant-based and cell-based seafood are both prime examples of cutting-edge tools and technologies with significant applications in protecting and restoring ecosystems. Question 2.3 in the draft research plan asks “How can the growth of sustainable aquaculture in the United States be accelerated?” Research and development funding for plant-based and cell-based seafood would provide greater benefits than expansion of R&D in sustainable aquaculture.

[12] “Federally Supported Innovations,” Information Technology and Innovation Foundation (2014), https://itif.org/publications/2014/02/03/federally-supported-innovations.

Plant-based and cell-based seafood products can truly meet NOAA's objective to "balance conflicting demands as well as economic and environmental considerations,"[13] by providing a supply of seafood to meet demand without the environmental impacts of conventional seafood production.

GFI appreciates the opportunity to provide this information to NOAA. If we can be helpful as you consider the issues raised above, we would be happy to continue the discussion with you.

Please keep us informed about the next steps in this process, as well as future opportunities to engage with your agency on the development of plant-based and cell-based seafood.

Sincerely,

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The Good Food Institute

[13] "Draft NOAA Research and Development Plan, 2020-2026," National Oceanic and Atmospheric Administration (2019), https://nrc.noaa.gov/LinkClick.aspx?fileticket=omoYjsC59Gs%3d&portalid=0.