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ENVIRONMENTAL RISKS OF GENETICALLY ENGINEERED FISH

HEARING

BEFORE THE

SUBCOMMITTEE ON OCEANS, ATMOSPHERE, FISHERIES, AND COAST GUARD

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED TWELFTH CONGRESS

FIRST SESSION

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

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THURSDAY, DECEMBER 15, 2011

U.S. SENATE,
SUBCOMMITTEE ON OCEANS, ATMOSPHERE, FISHERIES, AND COAST GUARD,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Committee met, pursuant to notice, at 10:57 a.m. in room SR–253, Russell Senate Office Building, Hon. Mark Begich, Chairman of the Subcommittee, presiding.

OPENING STATEMENT OF HON. MARK BEGICH, U.S. SENATOR FROM ALASKA

Senator BEGICH. Thank you very much. Thanks for being patient. I apologize.

We were notified last night that we would have our Ninth Circuit judge up this morning, so we had to go down and put that on the record, this morning at 10:30, and I apologize for the delay.

Welcome to the Senate. Nothing's on time, and nothing's scheduled, but yet we have a schedule.

So, thank you all very much. Thank you very much and welcome to the hearing. And, again, thank you for being patient while I got here. And I know other members may attend as we move through the hearing this morning.

Usually when we have a hearing about fish, we're considering the economic and environmental aspects of taking fish out of the ocean.

Today we are here to talk about the economic and environmental impacts of adding a completely new type of fish that was created in a laboratory into our oceans.

As I speak, the Food and Drug Administration is considering a landmark decision: whether to allow the first genetically engineered animal to be produced and sold for human consumption.

This animal has been created in a lab by mixing the genes from three separate fish species. The result is a genetically engineered Atlantic Salmon that is said to grow much faster than the regular Atlantic Salmon.

The company calls the lab created fish AquAdvantage salmon. Others have given the nickname "Frankenfish." Whatever you call it, when we are talking about this genetically engineered fish, we are talking about the entire future of wild fish and fisheries.

The stakes are high. If these fish were to get out into the wild, they could wreak untold havoc on our marine and freshwater ecosystems.

Although the company that has created the fish says that they have taken precautions to make sure the fish don't escape, the prudent and responsible approach for us to take here is to assume that fish will escape. We have plenty of examples where non-native fish have escaped into the wild and wreaked environmental havoc. Look at the huge economic and environmental impacts from the uncontrolled spread of the Asian carp in the Great Lakes region. We have been trying to contain the spread of these fish for over a decade with little success.

The lesson that we should take from this and other examples is that non-native fish can, and will, get out in the wild. And once they are out, they are impossible to contain.

Now think about genetically engineered fish that have only existed in labs, and have never existed in the wild. As you can imagine, it's very difficult to assess the environmental impacts from fish that have never existed before now. And the FDA is now asked to carry out an impossible task of trying to assess the food safety and environmental impact of genetically engineered fish.

We'll leave it to the Food and Drug Administration to assess the food safety aspects, but I'm not convinced that this agency has the scientific expertise to adequately assess the environmental aspects.

Looking at the available science, scientific information, it is clear that there is no guarantee that these GE fish—genetically engineered fish—won't ever escape into the wild. And there is an alarming degree of scientific uncertainty about the environmental risk of these fish if they do escape.

I feel that America's wild salmon stock and aquatic ecosystems are too important to allow them to be guinea pigs in what will amount to basically a huge experiment with GE fish in our waters.

That is why I've introduced Senate bill 1717—the Prevention of the Escapement of Genetically Altered Salmon in the United States Act, which will prohibit the sale of Frankenfish within the United States.

This prohibition will still allow research and development of genetically engineered fish for purposes such as medical research.

My bill seeks to prevent the release of GE salmon and other marine fish into the wild until we have enough scientific evidence to show that the GE fish can be produced without risk to our Nation's wildfish stocks and aquatic environments.

By introducing this bill, I'm simply asking for more time—more science to be done before we make a decision that could have such enormous impacts to the environment.

We have convened a panel of experts here today, so that we can have a clear-eyed discussion of the environmental risk of escapement of genetically engineered fish.

I would also like to hear some ideas on how we can strengthen the Federal approval process so that all of the necessary scientific information is considered when assessing the environmental risk of producing GE fish for food.

We have four individuals today who will be testifying at this hearing, but before I introduce them I would like to ask if the Ranking Member, Senator Snowe, would like to say a few words.

STATEMENT OF HON. OLYMPIA J. SNOWE,
U.S. SENATOR FROM MAINE

Senator SNOWE. Thank you, Mr. Chairman, for calling this hearing today to explore the environmental risk posed by commercial aquaculture of genetically engineered salmon.

The case study we will examine today, the AquaBounty AquAdvantage salmon would be the first genetically engineered animal approved for human consumption, if approved by the Food and Drug Administration.

We will not be examining the food safety implications here, and rather will focus on the potential impact should these fish escape from their confined grow-out facilities and interact with wild salmon stocks or with traditional aquaculture operations.

For Maine, these risks cannot be understated. Wild-caught fisheries are a fundamental part of our heritage. Our Atlantic salmon runs have a storied history even here in Washington.

For over 100 years, the first Maine salmon caught each year would be presented to the president by the Maine congressional delegation. I was honored to participate in that rite of spring.

Sadly, this proud tradition came to an end in 1992 as populations declined to the point they were unable to sustain even a catch-and-release recreational fishery.

Atlantic salmon in eight rivers, many of them in easternmost Washington County, have been listed as endangered under the Endangered Species Act since 2000. In 2009, the designation was expanded to include all salmon populations in the watersheds of our three major river systems: the Penobscot, the Kennebec, and the Androscoggin.

Despite yeoman efforts at Maine's Atlantic salmon hatcheries, in a landmark restoration plan for the Penobscot, only 1,316 spawning fish returned to that river last year—far fewer than would be necessary to support a healthy wild population.

With so much uncertainty about the impact an escaped genetically engineered fish could have on the wild population we've gone to such lengths to protect, clearly we must proceed cautiously.

Aquaculture has long been an integral part of sustaining a coastal economy as well. Gross revenues from Maine salmon aquaculture totaled $76.8 million in 2010, second only to, and approximately a quarter of the value of, Maine's iconic lobster fishery revenues last year.

What is truly striking is the fact that salmon production in Maine has tripled over the last 4 years with over 24 million pounds harvested, and it is expected to continue growing.

Downeast Maine, where this industry thrives, is the hub of a growing biotechnology sector in the state. For communities that have worked on the water for generations, aquaculture is an innovative job creator that has huge potential to create economic growth in a rural region.

The application currently pending for AquAdvantage salmon is precedent setting, and should be treated accordingly. We have a

unique opportunity at this moment to ensure that the regulatory framework used to assess this new technology is vigorous enough to provide a complete picture of all the possible benefits and detriments of creating a new living creature.

It is imperative that we require a thorough application and review process so that the American people have confidence that their interests, and those of the living marine resources held in the public trust, are being protected.

The fact is, Congress has never legislated on the regulatory framework for approval of a GE animal, nor has the Food and Drug Administration created a process specifically designed to assess the risks to the environment, to marine fish, or to human health that may be posed by these new products.

To the contrary, the FDA is using an approval process originally created to review new animal drugs that the agency has interpreted to include genetically engineered or modified fish.

This is an outdated and inadequate approach to evaluating a technology of this magnitude.

I have supported efforts to establish a rigorous approval process before the introduction of these animals into commerce, and am strongly committed to continuing that work.

Specifically, I have called upon the FDA to halt their approval process until the agency of Congress establishes a transparent and comprehensive review process for genetically engineered animals.

Opportunities for public comment should be built in so that the industries and stakeholders who may be affected by the development of GE salmon have an opportunity to be heard. Undoubtedly, this process should also include meaningful consultation with the National Oceanic and Atmospheric Administration, otherwise known as NOAA.

FDA should be capitalizing on NOAA's expertise in marine ecology, aquaculture, and the protection of threatened and endangered living resources by engaging NOAA in a formal, consultative process.

So I look forward to working with you, Mr. Chairman, our colleagues, and also as well listening to our witnesses here today to further advance our knowledge on what is the best approach to take. Thank you.

Senator BEGICH. Thank you very much, Senator Snowe.

Let me introduce our panel. We first have Dr. Ron Stotish, President and CEO of AquaBounty Technologies.

Next we'll have John Epifanio, a molecular ecologist, Illinois Natural History Survey; Dr. George Leonard, Aquaculture Program Director, Ocean Conservancy; and Mr. Paul Greenberg, journalist and author—most recently of the bestselling book *Four Fish: The Future of the Last Wild Food*.

Let me—we're going to go from this side over, so let me first start with Dr. Ron Stotish, if you could go ahead.

And we have 5 minutes for each of you and then we'll engage in questions. The way we kind of do this is we are formal but informal in our Q&A. Sometimes you'll see us just kind of going back and forth—that's how we kind of operate at the Subcommittee here.

Dr. Stotish.

STATEMENT OF DR. RON L. STOTISH, PRESIDENT AND CEO, AQUABOUNTY TECHNOLOGIES, INC.

Dr. STOTISH. Thank you very much, Mr. Chairman, and Senator Snowe.

I appreciate the opportunity to appear before you this morning to discuss, in the context of Senate 1717, whether the AquAdvantage salmon that is the subject of a pending application before the Food and Drug Administration would present a risk to the environment if marketed.

I am the Chief Executive Officer and President of AquaBounty Technologies, the sponsor of the application. I can assure you I would not be here before you today if we had not been able to provide the FDA with dispositive science-based evidence addressing environmental concerns.

In my brief remarks this morning, I will summarize that evidence.

But first let me tell you a little about our company. AquaBounty Technologies is a biotechnology company headquartered in Waltham, Massachusetts. We have 27 current employees and have facilities in San Diego, California, Waltham, Prince Edward Island, Canada, and St. John's, Newfoundland.

Among our employees are many respected scientists. We also have a leased facility in Panama which is part of our development program for AquAdvantage.

The AquAdvantage salmon is an Atlantic salmon, which has been modified by the insertion of a gene construct containing the growth hormone gene from the Chinook salmon.

The original construct was made over 20 years ago, and a line of rapidly growing salmon has been maintained over 10 generations in our hatchery.

We've conducted a detailed series of specific regulatory studies defining the detailed biological characteristics of AquAdvantage salmon, and submitted those—the results of those studies to the FDA.

We've made the results of those studies public and available for scrutiny nearly 16 months ago.

You may be aware that over 170 pages of data, the results of the center's review, and an 84-page draft environmental assessment prepared by the firm was released in August of 2010.

The FDA"s center for veterinary medicine has concluded that the AquAdvantage salmon, in addition to being indistinguishable from Atlantic salmon, is an Atlantic salmon, and that the food from AquAdvantage salmon is the same as food from any other Atlantic salmon.

CVM has determined that the genetic change does not harm the fish, and is safe for the consuming public. It's also determined that the data and the information we have provided, as well as the conditions and controls we propose to implement, that would be required upon approval of any application, provide meaningful assurance that the AquAdvantage salmon are not expected to have a significant impact on the quality of the human environment in the United States or in foreign countries.

Atlantic salmon are perhaps the most intensively farmed fish in the world, and with the exception of a small wild-caught industry

off the coast of Iceland, there are no wild-caught Atlantic salmon fisheries. There are sport fisheries and recreational fisheries, as you've pointed out.

The United States currently imports more than 97 percent of the Atlantic salmon consumed from countries like Chile, Norway, Canada, Scotland, and the Faroe Islands.

Conventional aquaculture produces Atlantic salmon in sea cages, a practice that has a variety of environmental, ecological, and economic consequences.

The availability of a more rapidly growing Atlantic salmon, for example, the AquAdvantage salmon, could facilitate land-based cultivation of this species, much like trout, catfish, and tilapia, reducing the cost and environmental impact of transportation, as well as reducing the environmental consequences of sea cage cultivation.

In sum, the AquAdvantage salmon, when approved, would in all likelihood, approve the sustainability of salmon aquaculture, reduce imports, and create an opportunity for economic development in the United States.

Some additional facts may be helpful in your inquiry.

In anticipation of concerns of potential impacts of our products on biological diversity and the environment, we attempted to mitigate any possible risk in advance.

Our hatchery is designed with multiple redundant physical barriers that prevent escape of any life stage. We've operated this hatchery for more than 15 years, been inspected on multiple occasions by a variety of Federal agencies from two countries, and have never lost a single fish.

Our product is designed so that it is all female, and triploid, meaning the fish cannot successfully reproduce.

Last, because of their rapid growth phenotype, they can be economically reared in land-based, physically contained facilities that prevent release and interaction with the environment.

In the proposed site in Panama for the growth of the fish—there are additional geographical and geophysical barriers that make survival in the environment essentially impossible.

It is also of interest to note that the Atlantic salmon cannot breed with Pacific salmon or Alaskan salmon. They are distinct species.

Time constraints limit my ability to provide more details, but in my written testimony, which I hereby submit, contain the technical explanation and analysis, including the summary of the environmental assessment, an analysis of the production and deployment of our product candidate.

Let me, though, add that recent publications have appeared in ecology and environmental research. These publications conclude that the traits of our rapidly growing salmon reduce the reproductive fitness of the fish. Said another way, even if fertile adults were introduced into the wild population, the rapid growth phenotype would be a selective disadvantage and would not spread into the wild population.

I would point out that this would be a lower risk to biodiversity than the current practice. The references are contained in my written testimony.

CVM has publicly stated that any additional productionsites would be separately approved by FDA, and must be the subject of individual environmental assessments and CVM preapproval inspection.

Simply put, although the regulatory procedures for approving AquAdvantage and for approving any new site for the production of this fish are complex, they unquestionably provide rigorous public health and environmental precautions and protections.

We believe our technology and our product are timely examples of American and Canadian innovation. We believe it will create additional opportunities and further the interest of global food security.

Our application also represents an opportunity to validate the important American principle of science-based regulation.

I would be pleased to take your questions later.

[The prepared statement of Dr. Stotish follows:]

PREPARED STATEMENT OF DR. RONALD L. STOTISH, PRESIDENT AND CEO, AQUABOUNTY TECHNOLOGIES, INC.

1.0 Introduction

AquaBounty is seeking FDA approval for a genetically modified Atlantic salmon with enhanced growth characteristics. The enhanced growth phenotype enhances the economics of land-based production of Atlantic salmon, overcoming many of the practical and environmental issues associated with conventional sea cage aquaculture of this species. The United States currently imports approximately 300,000 metric tons of Atlantic salmon each year from a variety of foreign producing countries, but produces less than 17,000 metric tons from aquaculture. The ability to produce Atlantic salmon in land based aquaculture systems in the U.S. could reduce our dependence upon foreign sources, and create a U.S. based industry with the accompanying jobs and economic development opportunities. The availability of a fresh and desirable Atlantic salmon product closer to U.S. consumers would also reduce the sizeable "carbon footprint" associated with transport of large volumes of this food over great distances as is the current practice. Lastly, the cultivation of Atlantic salmon would not likely impact the wild caught Alaskan salmon fishery market as this product is well positioned both with respect to brand and price. The current wild Alaskan salmon catch has been stable at approximately 300,000 tons per year, with approximately 60 percent of this product exported to Japan, China and other overseas markets; the remaining Alaskan wild caught salmon satisfies approximately 26 percent of the total market demand for salmon in the US, and is a well differentiated marketed product. Interestingly, in the management of the Alaskan wild caught fisheries, five billion smolts are released into the Pacific Ocean each year from Alaskan hatcheries (Alaska Fish & Wildlife).

AquAdvantage Salmon is a genetically engineered (GE) Atlantic salmon with a rapid-growth phenotype that has been developed over the past 15 years. The genetic modification comprises one copy of a salmon growth hormone transgene that is stably integrated at a specific site in the genome in a line of Atlantic salmon. Triploid *AquAdvantage* Salmon eggs for are produced in a manner that results in the culture of an all-female population of reproductively sterile fish that are otherwise substantially equivalent to farmed Atlantic salmon. The monosex nature of the population derives from the use of a breeding strategy that is 100 percent effective; and the induction of triploidy, which renders the animal reproductively incapable, is achieved using a validated method that is more than 99 percent effective at commercial scale. The product is intended for the contained, land-based culture of Atlantic salmon for commercial sale and human consumption under the following specific conditions: production of eyed-eggs in Canada; shipment of eyed-eggs to Panama; grow-out and processing of fish in Panama; and, shipment of table-ready, processed fish to the United States for retail sale.

Assessment of the potential risks to the environment from *AquAdvantage* Salmon involves consideration of the likelihood and consequences of the fish escaping, becoming established in the environment, and spreading to other areas. If the likelihood of these events, which are analogous to "exposure" in the traditional risk assessment paradigm, is zero or close to zero, it is reasonable to conclude that the con-

sequences of these events, which are analogous to the "effects," are not of concern. In other words, if there is no exposure, there is no risk. The likelihood of escape, establishment, and spread of *AquAdvantage* Salmon is effectively zero due to redundant containment measures, including physical, physicochemical, geographic/geophysical, and biological measures that are being implemented at the sites of egg production and grow-out. The combination of these various methods results in a very high degree of control. Physical containment measures include multiple mechanical barriers to prevent escape (*e.g.,* screens, filters, etc.). A strong management operations plan ensures that these containment measures are reliably implemented. Geographical and geophysical containment is provided by the location of the egg production and grow-out sites: the environment surrounding the egg-production site in Canada is inhospitable to early-life stages of Atlantic salmon due to high salinity; and, the environment downstream of the grow-out site in Panama is inhospitable to all life stages of Atlantic salmon due to high water temperatures, poor habitat, and physical barriers (*e.g.,* several hydro-electric facilities). Biological containment is accomplished through the grow-out of all-female triploid (sterile) fish, which significantly reduces the risk of transgene propagation in the environment. The domesticated nature and lack of competitive fitness in the wild relative to native fish also constitutes a formidable barrier to survival and spread in the wild.

In summary, production and rearing of *AquAdvantage* Salmon will involve simultaneous, multiple, and redundant containment strategies of various types that serve to adequately mitigate the environmental risk. These measures consist of producing triploid, all-female salmon that will be reared in a land-based aquaculture system itself possessed of redundant physical containment measures engineered and managed to confine the fish to the culture systems. Furthermore, the facilities are located in geographical areas that are highly unfavorable to the survival, establishment and spread of *AquAdvantage* Salmon, should there be an escape. Consequently, the environmental risk associated with the production and grow-out of *AquAdvantage* Salmon under the conditions described is as low as can be reasonably expected.

2.0 Product and Production

2.1 Product Definition

The *AquAdvantage* Salmon to be sold into commerce is a triploid Atlantic salmon bearing a single copy of a stably integrated transgene (termed opAFP-GHc2) at a specific location in the genome (the α-locus) in a specific line of salmon (the EO–1α line). The product subject to regulatory approval is an eyed-egg produced in Canada and delivered to Panama for grow-out to market size and processing, pursuant to retail sale in the United States. The opAFP–GHc2 transgene is a recombinant DNA construct comprising the coding sequence from a Chinook salmon growth hormone gene and regulatory sequences (the switches that turn on the growth hormone gene) from the gene encoding the ocean pout anti-freeze protein. The founder animal from which the *AquAdvantage* line derives was a transgenic female (EO–1) generated by injecting the transgene into the fertilized eggs of wild Atlantic salmon. Two rapidly growing transgenic progeny were selected for further development. The breeding of eight subsequent generations has led to the establishment of an *AquAdvantage* Salmon line (EO–1α) which bears a single copy of the integrated transgene. The broodstock used in spawning of *AquAdvantage* Salmon are homozygous females (*i.e.,* having two copies of the transgene) that have been phenotypically sex-reversed for breeding purposes. These so-called neomales are bred with non-transgenic female Atlantic salmon to produce eggs containing a single-copy of the transgene. The fertilized eggs resulting from the cross are pressure-shocked to induce triploidy, a process which renders the fish sterile. Therefore, the salmon deriving from these eggs are females incapable of reproduction. The fish that develop from these eggs have an enhanced growth rate compared to non-transgenic Atlantic salmon.

In evaluating potential environmental risk associated with the construct itself, three specific elements of genetic engineering were taken into consideration: the selection of genes and promoters from fish; the removal of antibiotic resistance genes; and, the avoidance of viral vectors and transposons. The *AquAdvantage* construct employs a salmon growth hormone gene and a fish-derived promoter from the ocean pout. The use of an all-fish gene transfer cassette suitable for gene transfer in other fish avoids issues with genes and genetic materials from other groups of organism (Du *et al.,* 1992a). The vector used to prepare the *AquAdvantage* construct was a bacterial plasmid called pUC18. Because the plasmid was purified from the transgene prior to injection into the salmon eggs, no bacterial genes were introduced into the genome of *AquAdvantage* salmon. Viral vectors and transposons were not used in the *AquAdvantage* construct to improve transgene integration efficiency.

The absence of viral vectors and transposons eliminates a major mechanism for unexpected movement of genetic material within the genome of the GE fish or transfer to other unrelated species.

2.2 Technical Details and Logistics of Commercial Production

2.2.1 Development of *AquAdvantage* broodstock

In order to produce *AquAdvantage* broodstock, eggs from *AquAdvantage* females with two copies of the transgene are subjected to gynogenesis, an established reproductive method that generates an all-female population. These female fish are then sex-reversed to produce neomales. Neomales are genetic females (thus possessing no Y chromosome) that produce sperm, and produce only female progeny when crossed with a female. These *AquAdvantage* (neomale) broodstock are reared to sexual maturity and bred with nontransgenic females to produce 100 percent female offspring. All broodstock and egg production takes place at the production facility in Prince Edward Island (PEI).

2.2.2 Maintenance of *AquAdvantage* Broodstock for Commercial Manufacture

Subsequent generations of *AquAdvantage* broodstock can be derived from existing neomales with two copies of the transgene by using the milt from those animals to fertilize eggs from females with two copies of the transgene. The offspring are sex-reversed, graded, tagged, and genotype confirmed prior to their use as *AquAdvantage* broodstock.

2.2.3 Production of *AquAdvantage* Eyed-Eggs for Commercial Sale

The *AquAdvantage* neomales are bred with non-transgenic females to produce fertilized egg populations that are 100 percent *AquAdvantage* females with a single copy of the transgene. Triploidy in the eggs is then induced by pressure shock to render the animal sterile. The eyed-eggs will be incubated for at least 325 deg-days, at which time batch-wise sampling will be done to confirm the successful induction of triploidy via flow cytometry (FACS) prior to quality control (QC) approval for commercial sale. The eggs will then be transferred to the approved grow out site in Panama. The production plan is defined in *Figure 1.*

For production details, see the briefing packet prepared by U.S. FDA (Food and Drug Administration Center for Veterinary Medicine, 2010, p 51–60).

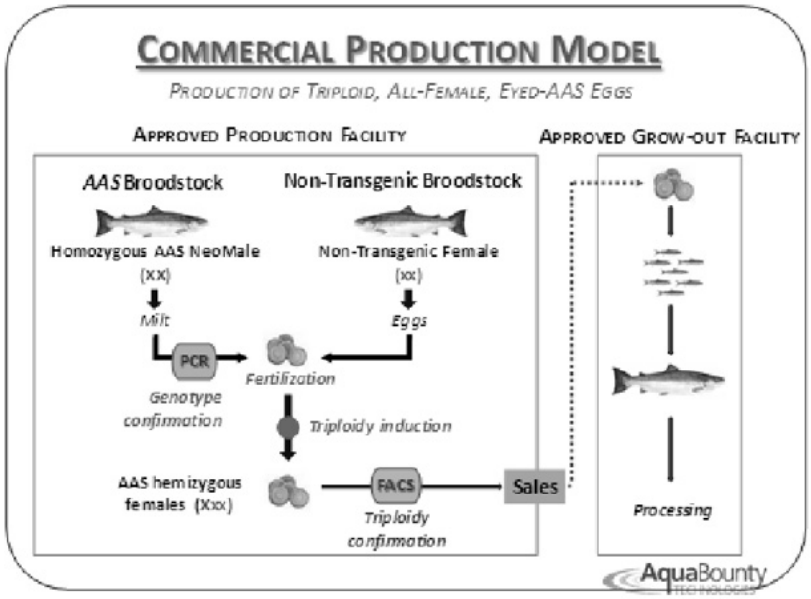


Figure 1. Production plan for *AquAdvantage* Salmon.

3.0 Environmental Risk

The environmental assessment of *AquAdvantage* Salmon has incorporated an ecological risk assessment approach, modified for the consideration of GE organisms as described by the National Research Council (NRC, 2002). Ecological risk assessment "*evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors*" (U.S. Environmental Protection Agency, 1992). Inherent in this definition is that both exposure and effects are required components of risk, *i.e.,* Risk = Exposure x Effects. Muir (2004) has presented a modification of this concept for the risk assessment of GE organisms, wherein exposure comprises two parts: 1) the probability of the organism escaping into the wild, dispersing and becoming feral; and, 2) the ability of the transgene to spread into the wild population once it has been introduced by an escaped animal. These two parts condense the five steps identified by the NRC (2002) and concisely express the two requirements for the existence of ecological risk: both exposure and effects. Without either, there can be no risk. Redundant measures can be taken to ensure that the probability of escape and establishment of *AquAdvantage* Salmon, and of the *AquAdvantage* transgene spreading, is so remote that it is essentially zero. With essentially zero exposure, the risk is essentially zero.

No single containment measure can be assured of 100 percent effectiveness. Therefore, optimum containment can be achieved by the simultaneous deployment in series of a number of independent containment measures. Three to five separate measures have been recommended (ABRAC, 1995). The NRC (2002) recommended the simultaneous use of multiple, redundant containment strategies for GE fish. By combining containment measures with different strengths, attributes and modes-of-action, the compromise of aggregate containment by the failure of a single measure becomes increasingly unlikely. GE fish are considered to pose little risk to native populations if they are adequately contained (Mair *et al.,* 2007).

The major difference between *AquAdvantage* Salmon and their non-GE counterparts is an increased rate-of-growth that is most evident during their first year of life. Muir (2004) has observed that the environmental risk of GE fish results from a chain of events: escape, followed by spread, followed by harm, such that the weakest link defines the upper-limit of risk. If the probabilities of any of the links can be shown to be close to zero, it is not necessary to quantify all of the risks.

A number of questions are pertinent when considering the environmental hazards of GE salmon (Muir, 2004; Kapuscinski *et al.,* 2007):

- Are GE salmon able to escape into the environment?
- If an accidental escape occurred, could GE salmon survive in the surrounding environment and compete with wild salmon (and escaped domestic nontransgenic salmon), or otherwise impact natural or ecological resources of global importance?
- Could the rDNA construct be transmitted to wild salmon, escaped non-GE domesticated salmon, or other species?
- Could GE salmon breed successfully with populations of wild salmon (and escaped domesticated non-GE salmon)?
- Could the offspring resulting from these hypothetical matings adversely affect the population of Atlantic salmon or other ecological resources of global importance?

These questions are important because populations of wild Atlantic salmon are in decline. The potential hazards addressed in this document center on the likelihood and consequences of *AquAdvantage* Salmon escaping, becoming established in the environment, and spreading to other areas.

3.1 Likelihood of Escape

For *AquAdvantage* Salmon, both the production of eyed-eggs and the grow-out of the fish are conducted in land-based facilities with redundant physical barriers designed to prevent escape. In general, fish are among the groups of organisms with a high degree of mobility and significant capacity to escape captivity and become feral (NRC, 2002). They can be highly mobile if the aquatic environment is sufficiently hospitable. The use of land based facilities and concurrent containment measures can reduce the potential of escape to a small fraction of 1 percent.

3.2 Likelihood of Establishment

The risk assessment paradigm involves the integration of the probability of exposure with the probability of harm resulting from exposure. In evaluating the environmental concerns associated with GE organisms, the National Research Council stated that exposure must be more than just release or escape for a GE organism

to constitute a hazard; rather the GE organism must spread into the community (NRC, 2002). The NRC (2002) thus defined exposure as the establishment of a GE organism in the community, and identified the following three variables as important in determining the likelihood of establishment: (1) the effect of the transgene on the fitness of the animal within the ecosystem into which it is released; (2) the ability of the GE animal to escape and disperse into diverse communities; and, (3) the stability and resiliency of the receiving community. The components of fitness include all attributes of the organism's phenotype that affect survival and reproduction. For example, a transgene could increase the organisms' adaptation to a wider range of environmental conditions or allow it to obtain nutrition from previously indigestible sources. A stable receiving community has an ecological structure and function that is able to return to the initial equilibrium following a perturbation; resiliency is a measure of how fast that equilibrium is re-attained (Pimm, 1984). The overall concern is a product of these three variables, not the sum; thus if the risk of any one of the variables is negligible, the overall concerns would be very low (NRC, 2002). In order for escapees to survive and proliferate, the accessible ecosystem must meet their needs for food, habitat, and environmental cues for reproduction. In addition to grow-out sites with all-female and >99 percent sterile salmon, escapee *AquAdvantage* Salmon would demonstrate life history characteristics associated with enhanced growth that would reduce survival in natural environments, and have demonstrated deficiencies in spawning behavior and securing mates.

As Kapuscinski and Brister (2001) have noted, even if the escaped fish were sterile, a type of pseudo-establishment could occur if successive waves of large numbers entered the environment, with each wave replacing the former as it dies off. This scenario implies frequent release of large numbers, which will not be pertinent to either the egg production or grow-out sites for *AquAdvantage* Salmon due to the multiple redundant containment measures employed.

It should be noted that intentional efforts to re-establish Atlantic salmon in their native habitats have been largely unsuccessful, inclusive of programs targeting Prince Edward Island and Lake Ontario, efforts in the latter case have been unsuccessful despite more than 100 years of attempting to do so. Moreover, farmed Atlantic salmon have not established themselves successfully in the wilds of North America (Council on Environmental Quality, 2001), despite the fact that they are reared in ocean pens on both coasts. *AquAdvantage* Salmon have no obvious life history advantages to suggest they would be any more invasive than conventional farmed Atlantic salmon.

3.3 Likelihood of Spread

The spread of GE fish would depend upon how many escaped and survived, their characteristics, and their reproductive potential. For example, highly domesticated fish may be ill-equipped to persist in the wild due to the effects of captivity, such as poor adaptation, reliance on artificial diets, and rearing at a high stocking density (Kapuscinski *et al.,* 2007). The reproductive potential of escapees is based upon their survival rate and fertility, and environmental conditions affecting reproduction in the affected ecosystem.

3.4 Consequences of Potential Escape, Establishment, and Spread

There are numerous factors, both genetic and environmental, that can influence the ability of *AquAdvantage* Salmon to affect the environment should they escape, survive and spread; these factors may have positive or negative impacts, which are further complicated by their mutual interaction. However, per the analogy of Muir (2004), it is not necessary to quantify the consequences (or harm, or effects) if the probability leading to the harm (the exposure) is zero or close to zero. The environmental risk posed by GE organisms is similar to that of introduced species. As discussed by Kapuscinski and Hallerman (1991), ecological impacts of GE individuals would be related to their fitness, interactions with other organisms, role in ecosystem processes, or potential for dispersal and persistence. With respect to their interactions with other organisms, *AquAdvantage* Salmon would be expected to occupy the same ecological niche as wild and domesticated Atlantic salmon, and compete for food, shelter, and other resources. As will be described later, because *AquAdvantage* Salmon are cultured as sterile females, they will be unable to reproduce. Finally, the potential for dispersal and persistence of *AquAdvantage* Salmon is very low due to the multiple redundant biological, physical, geographical and geophysical containment measures, as well as likely reduced ability to survive in natural ecosystems and reduced reproductive capacity. The scale and frequency of introductions of GE fish into a particular environment would have a large influence on the potential ecological risk. Any introductions would have to include a critical mass to allow survival of natural mortality, and would have to be of sufficient fre-

quency and occur in the proper season to allow for establishment. Kapuscinski and Hallerman (1991) have stated:

> "*Although surprising outcomes cannot be ruled out a priori, low ecological risk may be a reasonable conclusion in situations where phenotypic and ecological attributes of transgenic individuals raise concerns, but the scale and frequency of their introductions are so small that their chances of becoming established in the natural setting are extremely low.*"

4.0 Mitigation of Environmental Risk

It is not necessary to quantify the consequences of the escape, establishment and spread of GE salmon if the probability of escape leading to the exposure (*i.e.,* establishment and spread) is zero or close to zero. Therefore, the use of measures to ensure that the exposure is effectively zero is considered the best means of reducing the risk. Measures for containment of *AquAdvantage* Salmon preventing exposure are discussed in this section. It is difficult to guarantee that 100 percent containment can be achieved by any single method. Thus, several different methods are used simultaneously to provide redundancy and ensure that the likelihood for escape for GE salmon is as close to zero as can be reasonably expected. These measures are: biological containment, physical containment, geographical/geophysical containment, and life history associated barriers of *AquAdvantage* Salmon to invasiveness.

4.1 Biological Containment

Biological containment can serve as a barrier by either a) preventing any possibility of reproduction at the site, thus avoiding risk of escape of gametes, embryos, or larval stages, or b) significantly reducing the possibility of reproduction or survival of the GE organisms in the unlikely event of an escape.

4.1.1 Induction of Triploidy

Triploidy as a process is commonly applied to make fish sterile, and is used commercially in aquaculture. For example, triploidy is used to produce sterile rainbow trout for aquaculture purposes by the leading supplier of trout eggs in the world, TroutLodge (an Idaho based salmonid genetics company; *http://www.troutlodge.com/index.cfm?pageID=9C4DCE84-3048-7B4D-A93C4B67EECD271F*). Additionally, all grass carp sold commercially in the United States are rendered triploid and sterile, a program monitored by the Fish and Wildlife Service (*http://www.fws.gov/warmsprings/FishHealth/frgrscrp.html*). Triploidy has two fundamental effects on fish physiology (Benfey 2001): (1) the size of the cells increases to accommodate the extra genetic material, but the number of cells decreases so that triploids are no larger overall than diploids; and, (2) gametogenesis and gonadal development is so severely impaired that triploids are sterile. Other than their sterility, a comprehensive review of the literature conducted by Benfey (1999) reveals little difference between triploids and diploids on a whole-animal level.

AquaBounty uses triploidy to produce sterile *AquAdvantage* Salmon. One of the most important means of biological containment is the sterility of the fish. Thus, even if some *AquAdvantage* Salmon were to escape the grow-out facility and survive in the environment, and find a compatible male even though the cultured populations is all-female, they would not be able to reproduce if triploid. The induction of triploidy is the only accepted method currently available for sterilizing fish on a commercial scale. AquaBounty uses this method on all eyed-eggs destined for commercial production, achieving an induction of triploidy on a commercial scale of 99.8 percent (Food and Drug Administration Center for Veterinary Medicine 2010, p 56–57). This is significantly greater than the 95 percent minimum level of induction of triploidy recommended by FDA (Food and Drug Administration Center for Veterinary Medicine 2010, p 50).

Although the reproductive potential of triploid escaped *AquAdvantage* Salmon would be essentially nil, the method used to induce triploidy to eliminate reproductive risk is not perfect. A small proportion of *AquAdvantage* Salmon may remain reproductively capable, since the induction process, albeit greater than 99 percent effective on average, is not 100 percent in all cases. Of countervailing benefit is the fact that the production of all-female populations of *AquAdvantage* Salmon can be accomplished with 100 percent efficiency, since the process of gynogenesis offers that guarantee based upon reproductive biology.

4.1.2 All-Female Populations

The commercial deployment of all-female populations has obvious advantages in reducing risk of environmental impact and establishment of feral populations (Beardmore *et al* 2001, Devlin *et al* 2006). If all-female fish are cultivated in areas

where species with which they can interbreed are absent, then establishment of feral populations is impossible. *AquAdvantage* Salmon will be cultivated as 100 percent female populations in the highlands of Panama, which support no native salmonids. This prevents the establishment of feral populations in all escape scenarios. Production of 100 percent female populations of Atlantic salmon is a well described process that has been practiced for almost 30 years (Johnstone and Youngson 1984; Johnstone and MacLachlan 1994).

In summary, the combination of triploidy with the production of all females, is considered the most reliable for biological containment (Donaldson and Devlin, 1996). As stated by Mair *et al.* (2007)

> "*The production of all-female triploids combines the benefit of almost-guaranteed sterility of any escapees with the reduced risk of disruption of spawning in natural populations that might arise with triploid males.*" Arai (2001) has stated "*All female triploids can be used for effective biological containment of transgenic fish, so as to protect wild populations from contamination with genetically modified fish.*"

Taken together, for commercial production systems like the one in Panama, the combination of 100 percent of the AquAdvantage salmon being female and at least 99.8 percent of the fish being sterile, plus locating grow-out in areas where no native reproductively compatible salmonids exist, makes the chance of escapee salmon establishing a feral population effectively zero. Nevertheless, physical containment in the grow-out facilities has been taken very seriously to mitigate the risk of escape.

4.2 Physical Containment

Physical containment refers to measures implemented on-site, such as the use of mechanical devices, either stationary or moving (*e.g.,* tanks, screens, filters, covers, nets, etc.), or the use of lethal temperatures or chemicals to prevent uncontrolled escape. An important component of physical containment is the implementation of Standard Operating Procedures (SOPs) to ensure that proper procedures and use of devices are followed (Mair *et al.,* 2007). Security measures are also needed to prevent unauthorized access, control movement of authorized personnel, and prevent access by predators.

The potential for accidental escape could derive from any of the following components of the water system: influent water and makeup water; effluent and drawdown water; and, waste slurries collected when filters are backwashed, screens scrubbed, or rearing units cleaned by siphoning (ABRAC, 1995). In addition, it is important that all equipment that comes in contact with live GE animals is properly cleaned and drained after each use. The physical containment measures are described below for both the sites of egg production (Prince Edward Island) and grow-out (Panama).

4.2.1 Panama Grow Out

There is only one proposed FDA approved site for commercial growout of AquAdvantage Salmon anywhere in the world, a site in the highlands of Panama. The site is located more than 100 km from the Pacific Ocean, at an elevation of approximately 1800 meters. The site is equipped with a total of 21 individual containment measures, which maintain the salmon in confinement (Table 1; Draft EA for *AquAdvantage* Salmon, CVM, 2010). Physical containment to prevent the escape of fish at the grow-out facility is provided by the use of screens wherever water flows out of the system. There are a minimum of 11 sequential physical barriers in place between the fish tanks and the nearest natural body of water (a river), confining *AAS* to the site; seven of these barriers are positioned posterior to the outflow from the grow-out tanks. In addition, netting prevents the fish from being actively removed from containment by predators or passively removed in the event of any overflow of the water level. The multiple, redundant containment measures consist of tanks, screens, filters, stand-pipes, containment boxes, netting, and sedimentation ponds (Figure 2; Draft EA for AquAdvantage Salmon, CVM, 2010), making it virtually impossible for the salmon to leave the confines of the culture system and enter the environment.

Drainage from the fish tanks must pass through rigid metal screening sized to block migration of even the smallest fish in the population. The effluent from the tanks enters the drainage canal where it flows through a second concrete containment sump equipped with a 12 mm steel screen-plate, anchored in such a way that all water passing through the sump is screened. Distal to the sump, the water flows into a sequential series of four settling ponds, each of which is equipped with a 12 mm rigid-metallic outlet screen on which a secondary, variable-gauge screen is

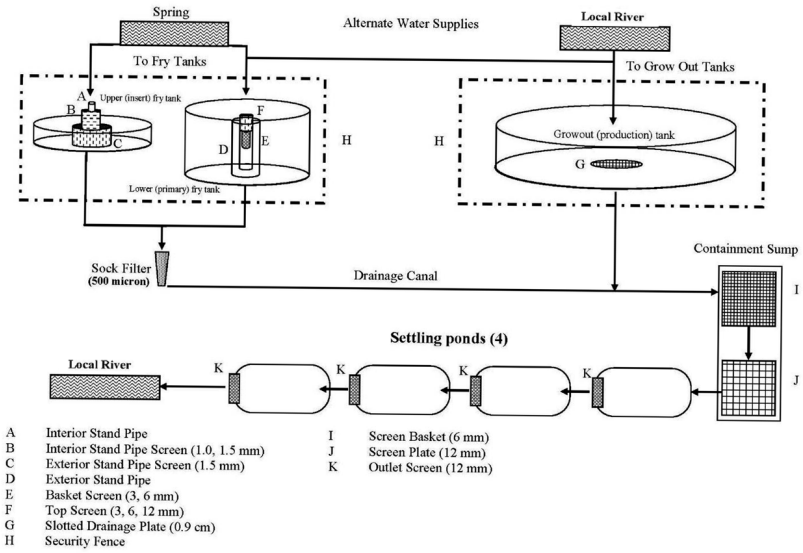
placed to facilitate flow, while maintaining exclusion of fish as they increase in size from fry to market size.

Table 1.—Key Components of Physical Containment Measures at the Grow-Out Facility

Purpose	Feature or Component
Primary containment	
To prevent escape from fry tanks via water	Center standpipe cut below tank rim to ensure water level is always below rim Netting stretched taut over top of tank to prevent fish from escaping even if tank was overflowing
	Collar-sleeve screens inserted into top of standpipes to prevent fish from entering standpipe by swimming
	Metal screen inside standpipe at base of basket screen impedes fish that entered standpipe (by jumping) from leaving the tank
	Rigid circular plastic screens surrounding the center standpipes
	Porous gravel floor around each tank allows downward percolation of overflow water but traps any fish in the overflow
To prevent escape from the fry tanks by avian predators	The building is covered and sealed by netting
	Netting stretched taut over the top of each tank
To prevent escape from the grow-out tanks via water	A single external (so no fish can jump into it) standpipe cut below tank rim to ensure water level is always below rim
	A 1 cm thick, rigid PVC slotted drain plate affixed by screws to the only drain in the tank
	Porous gravel floor around each tank allows downward percolation of overflow water but traps any fish in the overflow
To prevent escape from the grow-out tanks by avian predators	Each tank is entirely covered by netting stretched over and around the tank on a rigid support structure
	Netting stretched taut over the top of each tank
Secondary containment	
To prevent escape from fry tanks into drains	Sock filter (500 μm) on the terminal end of the only drain pipe receiving effluent from the fry tanks
To prevent escape from grow-out tanks into drains	Sealed metal cage (affixed to ground) through which all effluent from grow-out tanks must pass before entering drain canal
To prevent escaped fish from passing through the drain canal to the sedimentation ponds	Concrete structure and containment sump through which all water must pass
	Rigid metal screen affixed to bottom of containment sump through which all water must pass
To prevent escaped fish from passing from one sedimentation pond to another	Rigid metal screens on the outlet of each pond
To prevent escaped fish from entering the river from the drain canal	Four sedimentation ponds in series, each with its own outlet screen
Tertiary and Quaternary containment	
To prevent unauthorized personnel from entering the fish rearing area	The project is in a very remote location
	The project is built on the opposite side of the river from the road
	A narrow pedestrian bridge crosses the river, with access controlled by a locked metal fence
	Tall barbed wire security fence completely surrounding the perimeter of the fish rearing tanks, with locked entry gates
	Permanent presence of aggressive dogs

Figure 2. Schematic Summary of Containment Measures at the Grow-Out Facility

Figure 2. Schematic Summary of Containment Measures at the Grow-Out Facility



The fry tanks and building containing them, as well as the outdoor grow-out tanks, are covered with netting to prevent avian predation and "jumpers" (*i.e.,* fish that escape confinement by jumping out of the tank). In particular, the grow-out tanks are sealed horizontally and vertically inside a cage comprised of netting supported by a rigid structure. Escape from the tanks by jumping, or removal of fish by avian predators, is impossible. Security is provided by surrounding the fish tanks with netting and fencing topped with barbed wire to deter human or animal intrusion.

The facilities at this site are secured as follows:

- The site is located in a remote, highland area with very limited access.
- Entry onto the site requires passage via a securely gated footbridge that crosses a river, and is the only pedestrian access to the site.
- Culture facilities are enclosed by an 8-foot security fence topped with barbed wire.
- Entrance gates are securely locked and the area is protected by dogs.
- A private residence adjacent to the property provides for additional surveillance by management living on-site.

In summary, a minimum of 11 sequential physical barriers (total of 21) are in place between the fish tanks and the nearest body of water, confining the salmon to the site; seven of these barriers are installed following outflow from the grow-out tanks. In addition, netting prevents the fish from being actively removed from containment by predators or passively removed in the event of any overflow of the water level.

An additional level of physical containment is provided by several downstream hydro-electric plants, which also serve to prevent passage of any escaped fish to downstream riverine areas or the Pacific Ocean.

4.2.1.1 Thermal Containment Barriers—Panama

In addition to the numerous physical containment barriers in place at the Panama growout site, there also exists a powerful natural, geographic, thermal barrier that would effectively prevent AquAdvantage Salmon from migrating from the growout site to the Pacific Ocean. Stead and Laird (2002) have cited the upper lethal temperature for salmon as being 23ºC. Water temperature measurements recorded for the rivers leading from the aquaculture project to the Pacific

Ocean (Table 2; Draft EA for AquAdvantage Salmon, CVM, 2010) amply demonstrate that any escaped salmon attempting to migrate downstream towards the Pacific Ocean would inevitably encounter lethal water temperatures, preventing the fish from reaching the ocean.

Point	Elev (m)	Temp (°C)	
		Air	Water
1	13	28.9	26.4
2	91	31.9	28.1
3	250	29.4	26.0
4	347	28.6	25.8
5	649	24.3	22.6
6	995	21.6	19.3
7	1024	21.6	19.0
8	1086	21.7	20.7
9	1278	20.7	18.8
10	1792	17.2	15.1
11	1850	18.1	15.8

*Abbreviations: *Elev,* elevation; *Temp,* temperature.

An additional temperature related barrier to migration and survival that is present at the Panama growout location is the lack of suitable temperatures required by Atlantic salmon for spawning and egg incubation. The ideal water temperature for incubating Atlantic salmon eggs is 8° C, and temperatures in excess of 12° C result in low hatchability and viability (Stead & Laird, 2002). Based on water temperature data from the nearby river (Table 2), it is evident that ambient water temperatures in the river would not allow for spawning or hatching of eggs produced from escaped *AquAdvantage* salmon (ignoring for purposed of discussion, that the AquAdvantage salmon are sterile and all-female).

4.2.2 PEI Production

There is only one proposed approved site for the production of *AquAdvantage* Salmon eyed-eggs, the land-based, freshwater aquaculture facility on Prince Edward Island (PEI) owned and operated by AquaBounty, which comprises a main building, storage facility, and ancillary enclosures for operational structures that are secured as follows:

- *Perimeter security:* Approximately 1590 linear feet of galvanized chain-link fence of commercial quality surrounds the property, inclusive of freshwater wellheads, back-up generators, liquid oxygen containment, and the storage facility. A service entry adjacent to the storage building remains secured by a double-swing, chain-link gate except when service access to the property is required. A roll-away, chain-link gate spanning the main entry to the property, which is adjacent to the main building, is secured during non-business hours. At night, the entire perimeter remains well-lit.
- *Outside entries:* Windows on the lower-level of the main building are barred, and all exterior steel-doors on the main and storage buildings are dead-bolted. Entry into the main building requires a key or intercom-interrogation and remote unlocking by facility staff. Within the main building, access to the first-floor aquaculture facility is further protected by a cipher-locked, interior entry.
- *Security monitoring:* Eight motion-activated security cameras are positioned for maximum surveillance of the property immediately surrounding the main building. These cameras are in continuous operation and automatically capture digital images that are stored for later retrieval. Magnetic door-contacts and interior motion-detectors deployed throughout the main building, storage facility, and out-buildings comprise a network of zones that are monitored by a commercial security service.
- *Water supply & pump-house:* The primary well and pumping facilities (one primary, two back-ups) that supply the aquaculture facility are securely enclosed in a steel containment structure.

- *Remote notification of status:* Environmental alarms indicating emergent change in operational conditions (*e.g.,* water level, dissolved oxygen (***DO***) content), and security alarms indicating suspected intrusion during non-working hours, are conveyed by the security service to senior facility staff via numeric page; in addition, direct telephone contact with the facility manager or other on-call staff is pursued until successfully made, so that clear communication of the event occurs and proper and immediate response is managed.
- *Additional security:* AquaBounty may employ professional security personnel to remain on-site during non-business hours as conditions warrant. In addition to their direct surveillance of the property, these personnel would have access to the central, security-monitoring system in the main building, but would not have access to the facility at-large, which would remain locked-down and subject to the network of electronic sensors and motion-activated cameras comprising that system. An apartment in the main building provides for additional surveillance by staff living on-site.

A number of measures have been implemented to provide physical containment of the GE salmon at the Prince Edward Island facility. In general, means of physical containment comprise entrapment of animals at the immediate source of housing for cultivation (*i.e.,* via tank covers or nets), and redundancy in screening and filtration of water flows into which fish could gain access. These containment measures function at different as well as multiple levels of the containment strategy. Key components of the system are described in great detail in Aqua Bounty Protocols. The measures are summarized in Table 3 and a schematic is provided in Figure 3. Inspections for various purposes over the past 10 years have resulted in the facility having been: (1) deemed compliant with containment practice and licensed to conduct research on GE fish under applicable Canadian regulations; and (2) classified as an acceptable manufacturing establishment and judged as having no significant environmental impact by FDA.

Table 3.—Key Components of Physical Containment at the Production Facility

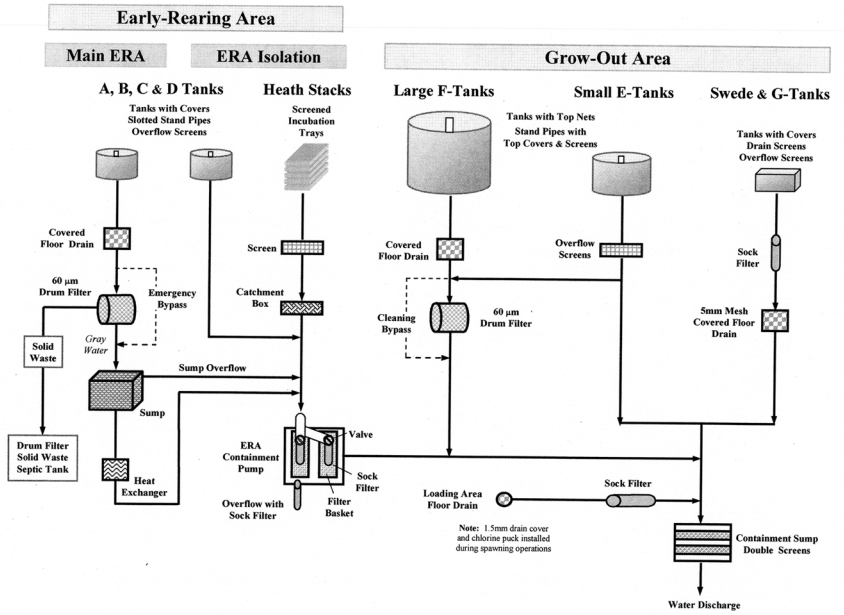
Purpose	Feature or Component
Primary containment	
To prevent escape through rearing unit or incubator water overflow	Perforated metal screens on tank bottoms
	Screens on stand pipes, top and bottom (where appropriate for size of fish to be contained)
	Incubator tray screens
To prevent escape over the side of a tank or incubator	Screened tank overflows Cover nets Jump fences Tank covers Incubator tray screens
To prevent downstream passage of newly fertilized eggs and/or gametes	Chemically lethal environment (chlorine puck) in spawning area drain
	Perforated metal drain cover in spawning area
	Closed septic system
Secondary containment	
To prevent entry of fish into drains	Floor drain covers, solid or mesh
	Incubator-stack catchment box
	Waste de-watering sieve box
To prevent downstream passage of fish within the drains	Barrier screens within drains
	Drum filter
Tertiary and Quaternary containment	
To prevent downstream passage of fish within the drains	Barrier screens within drains of various sizes & locations
	Double screens within the sump
	Mesh filter on drum-filter gray water
	Heat exchanger

Table 3.—Key Components of Physical Containment at the Production Facility—Continued

Purpose	Feature or Component
Waste treatment	
Sock filters, containment screens, basket-sieve for straining waste material from the ERA tanks	
Chlorine kill solution (5 mL Javex containing 0.52 grams sodium hypochlorite per liter of water)	
Chlorine pucks	

Figure 3. Schematic Summary of Containment Measures at the Production Facility

Figure 3. Schematic Summary of Containment Measures at the Production Facility



Hatchery-reared Atlantic salmon do inhabit the ocean waters surrounding PEI, although they are not known to frequent the area near the egg production site. Thus, the local environment does provide suitable habitat for at least some life stages during part of the year. The climate is temperate, with warm summers and cold winters. Open waters in proximity to the production facility are saline. Salmon eggs and fry are adapted to freshwater conditions and would be adversely affected by escape into the local estuarine environment. The extreme temperature conditions during the winter months at this location would be lethal to salmonids of all developmental stages. During the remainder of the year, the local environment would not be inhospitable to escaped smolt, juvenile or adult GE salmon, which have adapted to salt water and could survive. Escapees would face considerable environmental impediments to survival, one clear indication being the substantial failure of intentional efforts to re-establish Atlantic salmon in their native habitat. In fact, as noted by the Council on Environmental Quality and Office of Science and Technology Policy (*CEQ–OSTP*), farmed Atlantic salmon have not established themselves successfully in the wilds of North America (CEQ–OSTP, 2001), despite the fact that they are reared commercially on both coasts.

In 15 years of operation, there has never been a documented escape from the PEI facility.

4.2.3 Containment Infrastructure Management

The containment measures described above for the sites of egg production and grow-out include physical measures (*e.g.,* screens, covers, filters), as well as physicochemical measures (*e.g.,* chlorine) and environmental tolerances (*e.g.,* temperature).

In addition, a strong operations management plan is in place at both sites, comprising policies and procedures that meet the recommendations for an integrated confinement system for GE organisms (Kapuscinski, 2005), as summarized in Table 4. All of these factors mean that the likelihood of even a single *AquAdvantage* Salmon escaping into the wild is extremely low.

AquaBounty will comply with these same standards of effectively zero risk of establishment of feral escapee salmon populations for every facility that produces ***AquAdvantage*** *Salmon. To further mitigate risk, AquaBounty has no plans to sell eyed-eggs to any grow-out facility with drainage to native Atlantic salmon habitat.*

For additional prospective grow out facilities for AquaAdvantage Salmon, the same rigorous management and containment strategies will be employed, consistent with the terms of the NADA provisions for conditions of use. Candidate sites will be the subject of an Environmental Assessment and preapproval inspection by CVM, and additional inspections to assure compliance with the terms of the NADA. The administrative device CVM has indicated it will use for this process is the Supplemental New Animal Drug Application, or S–NADA. This is analogous to the long standing FDA process used to approve alternate drug manufacturing facilities or changes in facilities. The regulation of the grow-out sites for AquAdvantage Salmon will therefore be more rigorous than the regulation of any production site for any food animal.

Table 4.—Implementation of an Integrated Confinement System for ***AquAdvantage*** Salmon
(From: Kapuscinski, 2005)

Recommended element	Use at Production & Grow-Out Sites	
	PEI Egg Production	Panama Grow-Out
Commitment by top management	✓	✓
Written plan for implementing backup measures in case of failure, including documentation, monitoring, and remediation	✓	✓
Training of employees	✓	✓
Dedication of permanent staff to maintain continuity	✓	✓
Use of standard operating procedures for implementing redundant confinement measures	✓	✓
Periodic audits by an independent agency	✓	✓
Periodic internal review and adjustment to allow adaptive modifications	✓	✓
Reporting to an appropriate regulatory body	✓	✓

5.0 Invasiveness

A final barrier to establishment and spread of feral *AquAdvantage* Salmon populations is the potential invasiveness of GH transgenic salmon. The extent to which the genetic construct can spread into wild populations would depend on the fitness of transgenic individuals in the receiving environment, which may vary along a continuum featuring high fitness at one end—leading to the fixation of the transgene, and low fitness at the other end—leading to its elimination within a few generations (Muir and Howard 1999). If the salmon are highly effective at adapting to and competing in natural ecosystems, they may persist for long periods of time in the environment. This increases the chance for encounter with suitable mates for reproduction and establishing a reproductive population. If the transgenic fish do not adapt well to the natural environment, the risk of invasiveness is low and the transgene will likely be lost from the wild population. Additionally, in modeling the invasiveness of a hypothetical escape of transgenic fish populations, a hypothesis known as the Trojan Gene Hypothesis has been advanced (Muir and Howard, 1999). Under this hypothesis, it was calculated that escaped transgenic fish could theoretically drive a native population to extinction within as little as 40 generations. This hypothesis could be true only if the transgenic fish enjoyed an advantage in competing for mates (based on color for example), but experienced a disadvantage in overall fitness (so were unable to survive in the wild well) (Muir and Howard, 1999). As will be explained below, all indications are that *AquAdvantage* Salmon are poorly adapted for life in the wild, are remarkably ineffective in securing mates, and that

the transgenic fish would not be invasive, but would rather more likely be selected against and eliminated from wild populations.

5.1 Life History Constraints that Reduce Invasiveness

The main distinguishing feature of *AquAdvantage* Salmon is rapid growth, where growth rate is a composite of many physiological factors. *AquAdvantage* Salmon have metabolic traits that also appear in other fast-growing Atlantic salmon or in fish that have been treated with time-release GH implants (Johnsson and Bjornson, 2001). Metabolic rates influence the components of the overall energy budget for an individual; the components of the energy budget in turn influence an individual's impact on nutrient and energy flows and on other organisms. The unique attributes of the GE fish appear to be an increase in the scale of trait expression commensurate with the increase in growth rate when food is available, and the allocation of energy to current growth at the expense of stored reserves (Cook *et al.,* 2000b).

GH increases metabolic activity through several channels: lipid breakdown and mobilization are improved and energy more immediately deployed for maintenance or growth; protein synthesis is enhanced, providing the essential material for faster additions to body mass; mineral uptake is enhanced promoting skeletal development and longer, leaner fish; and, feeding efficiency (feed conversion ratio, or FCR) is improved (Bjornsson, 1997). The cost to the animal is higher oxygen need due to increased digestive demand and anabolic protein synthesis, and the need for increased feed availability. In early-generation relatives of *AquAdvantage* Salmon (hereinafter "*AquAdvantage* relatives"), feed consumption was 2.1–2.6 times higher than in non-transgenic controls; during starvation, transgenics depleted body protein, dry matter, lipids, and energy more quickly that controls, and had lower initial energy reserves (Cook *et al.,* 2000a,b). Routine oxygen uptake in these fish was 1.7 times that of controls, including the higher 'heat increment' associated with digestion (Stevens *et al.,* 1998); and, oxygen consumption under activity was 1.6 times the non-transgenic rate, further increasing with effort (Stevens and Sutterlin, 1999). Although these *AquAdvantage* relatives demonstrated an ability to reduce their metabolic rate in response to starvation, their higher metabolic effect and lower initial energy reserves suggest that they would be unlikely to grow rapidly or survive outside of culture conditions (Hallerman *et al.,* 2007). The increased requirement for oxygen exhibited by *AquAdvantage* relatives (Abrahams and Sutterlin, 1999; Cook *et al.,* 2000a; Cook *et al.,* 2000b; Deitch *et al.,* 2006) would engender a reduced tolerance for diminished oxygen content in general, and a reduced capacity for survival when DO content is critically low, compared to their non-transgenic counterparts in the wild. In experiments with *AquAdvantage* relatives, oxygen uptake was independent of oxygen concentration above 10 mg/L, but started to decrease at about 6 mg/L DO in transgenic fish versus 4 mg/L in control fish (Stevens *et al.,* 1998). Under conditions of oxygen saturation, transgenics are not at a disadvantage compared to controls, since oxygen demand is readily satisfied. Oxygen saturation is rarely encountered in natural environments.

The need for food tends to increase the predation risk for GE fish. Abrahams and Sutterlin (1999) also demonstrated that *AquAdvantage* relatives would spend significantly more time feeding in the presence of a predator than non-transgenic salmon, indicating that they possess a higher tolerance for predation risk. The transgene confers a powerful stimulation of appetite in the presence of food and a larger capacity for food consumption in the presence of opportunity, even when predators are present. *AquAdvantage* relatives consumed approximately five times more food than same-age controls that were also size-matched by delaying the hatch time of the transgenics. In part, the consumption differential reflected the greater willingness of the transgenics to feed in the presence of a predator and, in part, a higher feeding motivation in transgenics, which were 60 percent more likely to be observed feeding at both the safe and the risky sites than were the controls (Abrahams and Sutterlin 1999). GH also increased appetite in various species of salmonids (Raven *et al.,* 2006; Abrahams & Sutterlin, 1999; Devlin *et al.,* 1999), which influences behavioral traits associated with feeding, foraging, and social competition. The availability of food also influences behavior. The difference in scale between GE and other fast-growing Atlantic salmon is less quantifiable for behavioral traits and further confounded by the effects of hatchery culture, particularly in acclimation to high rates of social interaction. Salmon form dominance hierarchies around foraging opportunities, and hatchery fish have more opportunities to reinforce their social status in confinement. In nature, social dominance is dampened by a resident advantage that generally deters other fish from evicting territory holders from home ground. It is estimated that at least a 25 percent difference in size is necessary to overcome the resident advantage (Metcalfe *et al.,* 2003).

Changes in the morphology of the organism (*e.g.,* size, shape & color) could alter species interactions (ABRAC, 1995); however, it should be noted that accelerated growth is not an assured outcome for GE salmon in nature. The rapid-growth phenotype is expressed only if supported by sufficient food, as has been shown in both transgenic Coho salmon (Devlin *et al.,* 2004b; Sundström *et al.,* 2007) and *AquAdvantage* relatives (Cook *et al.,* 2000b). This is a function of both the productivity of the habitat and the density and behavior of competitors for the resource.

AquAdvantage Salmon are triploid fish, and triploidy may be another factor apart from transgenesis affecting environmental tolerance limits. Atkins and Benfey (2008) reported that triploids of Atlantic salmon had lower thermal optima than diploids, which could explain prior observations of mortality of other triploid salmonids (brown trout, brook trout, and rainbow trout) at chronically elevated, but sub-lethal, rearing temperatures. Data exist for a variety of species of fish to indicate that triploidy could be responsible for reduced survival of early-life stages and reduced survival and growth of later-life stages, particularly when environmental conditions are not optimal (Piferrer *et al.,* 2009). Ocean migration studies in Ireland revealed that male triploids returned to their natal area in nearly the same proportions as diploids, whereas female triploids mostly did not (Wilkins *et al.,* 2001). Similar results were found in another trial in which the return rate of triploid Atlantic salmon was substantially reduced (Cotter *et al.,* 2000a).

5.2 Spawning and Reproduction

Changes in the age at maturation, fecundity, and sterility could alter population and community dynamics and interfere with the reproduction of related organisms (ABRAC, 1995). However, domesticated Atlantic salmon in general have markedly reduced spawning performance relative to wild fish (), and triploid females do not engage in spawning behavior.

Varying degrees of exposure to captive environments and domestication selection have been shown to affect the breeding behavior and success of adult salmonids negatively (Fleming and Gross 1993; Fleming *et al.* 1997; Berejikian *et al.* 2001a; Weir *et al.* 2004). Thus, the captive rearing environment appears to diminish the competitive and reproductive performance of salmonids, irrespective of genetic background (Berejikian *et al.* 1997, 2001a,b). As AquAdvantage salmon will be reared in intensive cultivation systems, a similar reduction in ability to compete for mates and survive outside of the culture environment is expected.

Age at maturation is a factor in estimating the risk of invasiveness of transgenic strains, with early maturation associated with increased invasiveness. If the transgenic fish mature before non-transgenic contemporaries, they have an increased opportunity for mating success. Atlantic salmon can mature as very young parr and sneak matings from larger fish, and if transgenic salmon matured more readily as parr, an increased risk of invasiveness could be prescribed. However, recent work (Moreau *et al* 2011c) clearly indicated that AquAdvantage salmon mature **later** than nontransgenics, with very little maturation as parr. The authors conclude that this characteristic reduces the risk of transgene invasion into a wild population.

Considering AquAdvantage Salmon specifically, recent research (Moreau *et al* 2011 b) indicates that transgenic AquAdvantage Salmon (whether adults or parr) are at a significant disadvantage competing for mates and contributing genetics to subsequent generations. When in competition, nontransgenic males dominated transgenic males in securing mates, participating in over 90 percent of spawning events. Transgenic parr were also at a disadvantage compared with nontransgenic parr. Taken together, this indicates that escapee transgenic salmon males would be at a significant disadvantage in securing mates in a wild environment, reducing invasive potential. Further, in simulated streambeds, there was no advantage to transgenesis in early life just after hatch in terms of feeding or aggression that might facilitate invasion of natural systems by transgenic salmon; the transgenic fry did not displace or out-compete nontransgenic fry (Moreau *et al* 2011a). The work with GH transgenic Atlantic salmon echoes similar work with GH transgenic Coho salmon (Fitzpatrick *et al* 2011), where researchers found that in competitive mating, transgenic salmon sired less than 6 percent of offspring. Milt harvested from transgenic males also contained fewer sperm that swam slower and for shorter durations than sperm from wild males (Fitzpatrick *et al* 2011). **Together, these findings suggest very limited potential for the transmission of transgenes from cultured GH transgenic salmon through natural mating should they escape from a contained culture facility into nature and reproductively interact with a local wild salmon strain. The additional redundant biological and physical containment provisions built into the production and grow-out of**

***AquAdvantage* Salmon product effectively eliminate any potential impact on the biological diversity or ecology of wild populations.**

5.3 Summary Comparison of Atlantic Salmon and *AquAdvantage* Salmon

Atlantic salmon display a wide range of characteristics and can adapt to a variety of conditions. *AquAdvantage* Salmon share many of these traits, the notable exception being their increased growth rate and the physiologic sequelae thereof (*e.g.,* increased oxygen consumption).

Table 5 summarizes the observed differences between GH-transgenic salmonids and non-transgenic Atlantic salmon. In many cases, these differences were of greater magnitude under laboratory conditions than in a simulated natural environment. Consequently, not all of these differences may be expressed, or may be expressed to a lesser extent, in the wild.

None of these differences will lead to environmental impact unless *AquAdvantage* Salmon actually enter the environment. The likelihood of that happening is extremely remote.

Table 5.—Differences between GE- and Non-transgenic Salmonids

Trait	Transgenic Relative to Non-transgenic
Metabolic rates	Increased metabolic rates Increased growth when food is available Reduced initial energy reserves Increased oxygen consumption
Tolerance of physical factors	Reduced tolerance to low oxygen availability Reduced thermal optimum range (effect of triploidy not GH)
Behavior (lab conditions)	Increased feeding motivation and reduced prey discrimination Reduced schooling tendency Reduced anti-predator response
Resource or substrate use	Increased utilization of lower quality food (lab conditions) Increased utilization of larger prey (potential)
Resistance to disease, parasites or predation	Reduced disease resistance Reduced anti-predator response, increased predation mortality
Reproduction	Accelerated growth to sexually-mature size Larger males can have a mating advantage
Life history	Accelerated growth to smolt-size Smoltification at higher temperatures and constant light

5.4 Comment on the Trojan Gene Hypothesis

Given the poor reproductive fitness of *AquAdvantage* Salmon, the Trojan Gene Hypothesis almost certainly does not apply to any escapees. The author of the Trojan gene hypothesis (Dr. Bill Muir) has weighed in on the applicability of this doomsday scenario, concluding emphatically that the Trojan Gene Hypothesis indeed does not apply to *AquAdvantage* Salmon, both in press releases (press release from Bill Muir; http://www.purdue.edu/newsroom/research/2011/story-print-deploy-layout_1_14241_14241.html) and the peer-reviewed scientific literature (Van Eenennaamm and Muir 2011). Quoting from Van Eenennaamm and Muir 2011, pg 708:

> *As a result, the Trojan gene effect would not be predicted to occur in the unlikely event AquAdvantage salmon did escape from confinement. Rather, selection over time would be expected to simply purge the transgene from any established population, suggesting a low probability of harm resulting from exposure to* ***AquAdvantage*** *Salmon.*

5.5 Ability to Breed with Pacific Salmon

It is a well established and documented fact that Atlantic salmon *cannot* reproduce or breed with any of the five species of Pacific salmon (Fisheries & Oceans Canada, 2005; Waknitz *et al.,* 2002). Under controlled and protected laboratory conditions, where survival of hybrid offspring should be optimized, genetically viable hybrids between Atlantic and Pacific salmonid species have been impossible to produce (Waknitz *et al.,* 2002). Therefore, in the unlikely event that *AquAdvantage* Salmon should breach the numerous redundant physical containment barriers that confine it to the culture system, and by some means find their way to the northern

Pacific Ocean, they would be unable to mate or reproduce with native Pacific salmon.

5.6 Resistance to Establishment in the Wild

In the past century, there have been numerous unsuccessful attempts in the United States and elsewhere to establish Atlantic salmon outside their native range via intentional introductions (Fisheries & Oceans Canada, 2005). At least 170 attempts to artificially introduce and establish populations of Atlantic salmon have been documented in 34 different states where Atlantic salmon were not native, including Washington, Oregon, and California. None of these efforts was successful (Waknitz *et al.,* 2002). No reproduction by Atlantic salmon was verified after introductions of fertile, mixed sex populations of Atlantic salmon in the waters of these states.

The risk of anadromous Atlantic salmon establishing self-perpetuating populations anywhere outside their home range has been shown to be extremely remote, given that substantial and repeated efforts over the last 100 years have not produced a successful self-reproducing anadromous population anywhere in the world (Lever, 1996). In the Pacific Northwest, there have been no reports of self-sustaining populations resulting from deliberate or accidental Atlantic salmon introductions (Waknitz *et al.,* 2002).

Given that escapee transgenic Atlantic salmon are likely to have diminished capacity to spawn successfully compared to wild type salmon, the risk of escapee AquAdvantage salmon establishing a feral population anywhere is very remote.

6.0 Conclusions

6.1 Escape, Establishment and Spread

The potential hazards addressed in this document center on the likelihood and consequences of *AquAdvantage* Salmon escaping, becoming established in the environment, and spreading to other areas. These hazards are addressed for the production of eyed-eggs and grow-out to market size fish. Because *AquAdvantage* Salmon is produced and grown out in secure facilities equipped with numerous redundant containment measures designed to prevent escape, the possibility that even one transgenic animal will enter the environment and survive is extremely remote. In addition, because *AquAdvantage* Salmon are produced to be triploid, all-female animals, the possibility of them reproducing in the wild is likewise extremely remote. The relatively poor reproductive fitness of *AquAdvantage* Salmon, as demonstrated in evaluations of breeding efficiency, clearly show that *AquAdvantage* Salmon fare poorly interacting with wild stocks. *AquAdvantage* Salmon are reproductively incompatible with almost all fish, in particular Pacific salmon. Finally, the inhospitable environmental conditions around the egg production and grow-out facilities further reduce the possibility of establishment and spread. In short, it is not reasonable to believe that *AquAdvantage* Salmon will have any impact on the environment by escaping, surviving and thriving in regional. This argument is reinforced by the historical fact that hundreds of worldwide attempts to intentionally introduce fertile mixed sex populations of Atlantic salmon in the wild have failed to establish self-sustaining populations.

6.2 Using Confinement Measures to Mitigate Risks

A key way to manage risks associated with the use of GE fish in aquaculture is through the application of confinement measures designed to minimize the likelihood of their causing harm to the environment (Kapuscinski, 2005). It is difficult to guarantee that 100 percent containment can be achieved by any single method. Thus, several different methods are used simultaneously to provide redundancy and ensure that it is highly unlikely that GE salmon can escape. These measures are: biological containment, physical containment (including physico-chemical containment and operations management), and geographical/geophysical containment.

The three primary aims of confinement cited by Mair *et al.,* (2007) are listed below along with the measures used for production, grow-out, and disposal of *AquAdvantage* Salmon:

- *Limit the organism: prevent the fish from entering and surviving in the receiving environment. AquAdvantage* Salmon are prevented from entering the environment by the use of redundant physical and physico-chemical barriers at the sites of egg production and grow-out. They are further prevented from surviving in the receiving environment because of geographic and geophysical issues. The immediate environs of the Prince Edward Island facility are inhospitable to early-life stage salmon due to the salinity of the local waters. The environment downstream of the Panama site is inhospitable to all life-stages due to the high water temperatures, poor habitat, predation risk, and abundant physical bar-

riers that diminish the likelihood of survival and establishment in the receiving stream. Atlantic salmon are not found in the tropical areas of Panama.

- *Limit (trans)gene flow: prevent gene flow from the GE fish.* Gene flow from *AquAdvantage* Salmon is prevented because the fish are triploid females incapable of reproduction, among themselves or with wild fish, should they escape and survive. For grow-out, species with which they could breed are not present in the surrounding environment.
- *Limit transgenic trait expression*. It is likely that the expression of the trait, not the transgene itself, poses the hazard. The enhanced growth rate of *AquAdvantage* Salmon is readily expressed under the optimum conditions provided in a commercial environment; however, in the wild, the absence of readily available food (to which they are accustomed) and consequent depletion of energy reserves decrease the likelihood of effective exploitation of their inherent growth capacity.

6.3 Redundant Mitigation Measures

Optimum containment is dependent upon the deployment of a number of independent measures in series. Biological, physical and geographical/geophysical means of containment will be used to mitigate the potential environmental risk of *AquAdvantage* Salmon. Each method has different strengths and weaknesses, but the combination results in a very high level of effectiveness. Biological containment includes the production of entirely female, triploid fish with essentially no capacity to breed with wild fish; in and of itself, this technique is considered very effective (Mair *et al.,* 2007; Arai, 2001). Physical and physico-chemical means of containment comprise additional, multiple, and redundant measures in effect at the production and grow-out sites that will effectively prevent escape. The reliability of these measures is further ensured by adherence to a strong management operations plan that includes staff training, SOPs, and routine audits and inspections. In addition, geographical/geophysical containment is provided by the specific location of the aforementioned sites.

6.4 Summary of Ecological Risk Assessment

A report by the Ecological Society of America (ESA; Snow *et al.,* 2005) has proposed six major environmental processes that may be associated with GE organisms. In Table 6, each of these processes and their theoretical ecological consequences, which remain largely undocumented to date, are presented vis-à-vis their prospective applicability to *AquAdvantage* Salmon.

Table 6.—Risk of Environmental Impact of GE Organisms*

Process	Potential Ecological Consequence	Risk Associated with *AAS*
Persistence without cultivation	Transgenic organisms able to spread and maintain self-sustaining populations could disrupt biotic communities & ecosystems, leading to a loss of biological diversity.	*AAS* are all sterile females unable to reproduce; a self-sustaining population cannot be established. NO SIGNIFICANT RISK.
Interbreeding with related taxa	Incorporation of transgenes could result in greater invasiveness or loss of biodiversity, depending on particular transgenic trait and gene flow from generation to generation.	*AAS* are all sterile females unable to breed with wild Atlantic salmon or related taxa. NO SIGNIFICANT RISK.
Horizontal gene flow	Non-sexual gene transfer is common in some microbes but rare in plants & animals; ecological consequence would depend on particular transgenic trait and gene flow.	Integrated transgene in *AAS* is incapable of being passed thru non-sexual means. NO SIGNIFICANT RISK.
Change in viral disease	In virus-resistant transgenic organisms, genetic recombination could lead to increased virulence of viral disease and undesirable effects on natural hosts.	rDNA construct used for *AAS* had no viral component; this type of recombination is not possible. NO SIGNIFICANT RISK.
Non-target & indirect effects	Loss of biodiversity, altered community or ecosystem function, reduced biological pest control, reduced pollination, and altered soil carbon and nitrogen cycling.	*AAS* escape minimized by redundant containment; low probability of establishment due to poor fitness and reproductive incapacity; likelihood of further spread is nil. NO SIGNIFICANT RISK.

Table 6.—Risk of Environmental Impact of GE Organisms*—Continued

Process	Potential Ecological Consequence	Risk Associated with *AAS*
Evolution of resistance	Pesticide resistance leading to greater reliance on damaging chemicals or other controls for insects, weeds, and other pests.	Not applicable for fish. NO SIGNIFICANT RISK.

*Process and General Consequence information derives from Snow *et al.,* 2005.

Conclusion: The production and grow-out of *AquAdvantage* Salmon under the conditions described in the USFDA NADA does not present a significant risk of adverse ecological effects.

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Senator BEGICH. Thank you very much.

And just for all the folks that are testifying, your testimony—your full testimony—is part of the record, and any information that you attach to it was part of the record, so we want to make sure.

Dr. Epifanio? I know I'm still messing it up, but I apologize. You're next please.

STATEMENT OF JOHN EPIFANIO, PH.D., FISH CONSERVATION GENETICIST, ILLINOIS NATURAL HISTORY SURVEY AND UNIVERSITY OF ILLINOIS

Dr. EPIFANIO. Thank you, Chairman Begich, Ranking Member Snowe, and the other members of the Subcommittee for convening this hearing.

I come to you today with some twenty-plus years of experience as a fishery geneticist focusing on the ecological genetic consequences from the releases of propagated or farmed fishes on their wild counterparts.

I'll focus my comments today rather narrowly on the potential hazards from potential escape of genetically engineered salmon on the biological diversity and the ecosystem services in recipient ecosystems.

The heart of the matter here today before us is whether a proposed New Animal Drug Application for commercial production of genetically engineered, growth-enhanced salmon—in light of this narrow focus, I think it's worth explicitly stating up front that although this is a specific case, it does bring critical precedent for other future applications as well.

To begin, in my career, I've studied and reviewed the ecological consequences associated with the release of fish with altered genomes, either from conventional or engineered—and engineered pathways.

Up front, to my knowledge, there are no documented or studied cases of genetically engineered salmon escaping into the wild, even though we have laboratory controlled studies—from Canada in particular—on the growth and reproductive performance of these fishes.

Therefore, to fully understand the impacts, we must rely on information from in analogous source, analogous releases of altered fishes.

Generally speaking, we can distill the concerns from any escape of genetically engineered salmon into two broad categories. One: impacts due to ecological interactions, specifically predation, competition, and second: genetic impacts from interbreeding or through animal husbandry practices. Ecologically, escape of engineered fish may represent the release of a novel top predator or a more efficient competitor, which are expected to have cascading effects throughout the entire and local food web.

The scope and scale of these effects ultimately can depend on how well we know about—how well we know about the numbers escaped, their behavioral dominance, reproductive capacity, persistence through time, and as well as other variables.

One need only consider the recent emergence of a non- native species—such as sea lamprey in the Great Lakes, snakeheads in the mid-Atlantic region, lionfish in the Caribbean, Asian carp species in the Mississippi basin—to fully comprehend the enormity of ecological effects from releases of new predators or competitors.

By extension, in the case of genetically modified salmon escaping into the wild, the full extent of its ecological impact will be determined not only by the altered characteristics of the salmon itself, but also on the ecosystem into which it escapes.

For example, an already stressed habitat and biotic community is more likely to be impacted than one that is diverse and resilient.

Another level of potential disturbance emerges where modified fishes escape wherever their wild relatives would occur. Here we face additional risks stemming from interbreeding. Based on many decades of study on salmon in particular, the fish genetics community has discovered that even very subtle genetic differences between previously isolated groups can seriously disrupt survival and reproduction in future generations.

Now, proponents may claim that genetic engineering does not differ from other forms of gene pool manipulation, which we've practiced for centuries—such as domestication and crossbreeding.

While this claim has yet to be fully substantiated, I assert that the release of modified fish through more classical modes has also proven to be problematic.

In my written testimony, I provide a couple of examples to highlight that point, but to keep things short I'll pass on those here.

In short, by failing to consider the consequences of genome manipulations, whether classical or by engineering, we risk unpredictable environmental effects unless adequate safeguards are rigorously carried out.

While the new animal drug application for genetically engineered salmon includes precautions for physical containment to prevent escapement and for reproductive sterility should that escapement occur, it is critical to consider that no established safeguard has ever proven, full proof, nor eliminates all classes of risk simultaneously or completely. I offer several observations and recommendations to the Subcommittee in conclusion.

One: salmon exhibit very complex life histories. Specific expertise in the biology of the species in question are crucial. Certainly FDA

has experience with food and drug science, where as other Federal agencies and state agencies are more versed in salmon biology and the unique qualities on the environment that they generally occupy—specifically NOAA, Fish and Wildlife Service, and the states.

Second, whereas containment and engineered sterility may in fact reduce the probability of escape or reproduction, these do not completely remove the risk of escape, reproduction, or ecological interference. A robust and formal risk assessment is generally warranted under such circumstances.

Moreover, if approved it would be prudent to treat this as a controlled experiment that is, A—actively monitored for impacts after approval, and B—can be terminated, should the need arise, without lingering environmental effects.

Last, while I recognize the confidentiality requirements of the trade secrets laws that are intended to safeguard proprietary information from potential competitors about food and drug products, a fuller transparency of the science behind environmental risk-reviews differs in a couple of material ways.

First, it promotes bringing the brightest minds and the best ideas to bear on an issue. Second, it more adequately protects the fisheries and biodiversity that are managed in public trust by our public resource agencies.

So Mr. Chairman, Ranking Member Snowe, thank you again for the opportunity to share these views, and I look forward to answering any questions you might have.

[The prepared statement of Dr. Epifanio follows:]

PREPARED STATEMENT OF JOHN EPIFANIO, PH.D., FISH CONSERVATION GENETICIST, ILLINOIS NATURAL HISTORY SURVEY AND UNIVERSITY OF ILLINOIS

I wish to thank Chairman Begich, Ranking Member Snowe, and members of the Oceans, Fisheries, and Coast Guard Subcommittee for convening this hearing and for inviting me to share my perspectives and experiences on the environmental risks and consequences to marine and freshwater ecosystems from the release of manipulated (or GE) fish genomes.

During the past 25+ years, I have had a number of relevant experiences both on the scientific side and the administrative side that have shaped my perspectives on and overall approach to this specific issue and one related to it. First, as a population geneticist serving several state agencies and universities, the scope of my students' and my own work has focused on the uses and ecological-genetic consequences from the intentional and inadvertent release of propagated fishes on populations in recipient ecosystems. As such we have examined species ranging from Pacific salmonids to American shad to largemouth bass. Second, I've also served several agencies including as Coordinator of the National Fisheries Program with the U.S. Geological Survey (in the Reston Headquarters) and Assistant Program Leader for Fisheries with the USDA–Forest Service (in the DC Headquarters), and Director for Ecology and Conservation Sciences with the Illinois state Department of Natural Resources. Third, I served as a resource scientist with Trout Unlimited, a non-governmental conservation organization, where my focus was on the scientific underpinnings of conserving salmonid biodiversity. Finally, I served on the Northwest Power and Conservation Council's Independent Scientific Review Panel (ISRP) where we review the scientific rigor of the Columbia basin's fish and wildlife program—where maintaining the integrity of Pacific salmon gene pools is a central focus for projects reviewed by the ISRP. In short, each of these and other direct experiences has contributed and given shape to the perspectives I offer today.

I intend to focus my comments narrowly on the potential hazards from the release or escapement of genetically engineered (GE) salmon on the biological diversity and full range of ecosystem services in recipient environments.[1] I ultimately defer to oth-

[1] The foundation for these comments can be made available to the Subcommittee staff if desired, and ultimately may be found in the Nation's leading professional and technically peer-

ers on issues related to product-labeling, food safety, or applications of gene transfer in fishes used as models in medical research. The heart of the matter before us today is whether a proposed New Animal Drug Application (NADA) for commercial production of a genetically engineered, growth-enhanced salmon and associated reviews has sufficiently weighed the potential consequences if a group of these modified individuals were to escape or be released into an adjacent ecosystem. In light of this narrow focus, it is worth stating explicitly and up front, the importance that the precedence this specific case brings to other future applications.

To begin, as a fish conservation geneticist, I am familiar with the ecological consequences from the release (or escape) of fish with genomes that have been modified either from conventional and transgenic pathways. It is important to state upfront that, to my knowledge, there are no documented or studied cases of genetically engineered Atlantic salmon escaping into the wild, even though we have laboratory studies from Canada on growth and reproductive performance. Therefore, we must rely on information on analogous releases of altered information. At the most general level, there are essentially two broad categories of concern that genetically modified salmon represent to marine or inland ecosystems (1) impacts due to ecological interactions (such as predation, competition, and transmission of diseases); and (2) impacts directly from interbreeding or indirectly through husbandry practices.

In terms of ecological impacts posed by potential escape of genetically engineered fish, the release of a novel top-predator or more efficient competitor is expected to have cascading effects throughout a local food web. While we might be able to make some rather wide predictions about the size and shape of potential disruptions, our ability to precisely hone in on the scale of these impacts ultimately depends on quality of previously-gathered information and the appropriate expertise brought to bear on the issue—in short, a formal Uncertainty Analysis. Moreover, our understanding several ecological attributes of released individuals are key to more accurately predicting impacts, such the number escaped, their behavioral dominance, reproductive capacity, the overall persistence (through time) of the escaped fishes, as well as how these attributes are expressed in different local ecosystems. One needs only to consider the recent emergence of non-native species such as sea lamprey in the upper Great Lakes, northern snakeheads in the mid-Atlantic region, lionfish in the Caribbean, or the various Asian carp species in the Mississippi River basin to comprehend the enormity of ecological effects on local biota from release of new predators or competitors. Ultimately, in the case of a genetically modified salmon escaping into the wild, the full extent of its ecological impact will be determined not only by the characteristics of the salmon itself, but also on the ecosystem into which it escapes. For example, an already-stressed habitat and biotic community is more likely to be impacted than one that is pristine and resilient.

Another level of complexity and potential disturbance emerges where modified fishes can escape into an ecosystem where the species' wild relatives occur. Here, we face additional risks stemming from the interbreeding. Based on three or more decades of study on salmon and other species, the fisheries genetics community has discovered that even very subtle genetic differences between previously isolated breeding groups can seriously disrupt survival and reproduction in future generations. In the case of genetic engineering (or, transgenesis), we have a case where a single gene (or a single construct of a few genes) is introduced into a genome in a way that is essentially a human-directed mutation. Such a mutation is expected and designed to have a major effect on the physiology, anatomy, or behavior of the host genome—the very reason the genetic engineering is undertaken. Whereas in nature the vast majority of random mutations are not expected to alter populations because they are generally deleterious and quickly removed from a population, human-mediated mutations may have lingering effects because they are designed for traits that are not subjected to natural selection in the wild.

To be sure, many of the long-practiced, classical modes of gene pool and genome manipulation have proven to be problematic—we should expect no exception to this pattern from transgenesis. For example, some recent work by scientists in Oregon have observed that release of steelhead, a Pacific salmonid domesticated but a few generations, are less fit than their wild counterparts. Moreover, the interbreeding between these domesticated and wild fish has conveyed an impact by lowering the overall reproductive capacity of the supplemented population. As another example, a study conducted in my home state of Illinois examined the impacts of interbreeding and moving largemouth bass from the northern and southern extremes of the state into each other's range. Here, even though the populations exhibited very

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reviewed journals by numerous research groups, including my own, as well as a number of reviews by the National Academy of Sciences.

subtle genetic-level differences between northern and southern populations, their interbred offspring had much reduced survival and reproductive rates regardless of the location they were released into.

One consistent pattern through the documented cases of this kind interbreeding penalty in bass, salmon, or other species is a failure to adequately predict the full scope of the impacts beforehand. In short, by failing to consider the consequences of even these classical modes of genome manipulations, we risk unintended environmental effects. Ultimately, the newer approaches carry similar and additional risks unless adequate safeguards are rigorously carried out. While the New Animal Drug Application for Genetically Engineered salmon includes precautions for physical containment to prevent escapement and for reproductive sterility should escape occur, it is critical to consider that no established safeguard has proven foolproof nor eliminates all risk classes simultaneously or completely.

In closing, I offer several observations and recommendations for the Subcommittee to consider as it further deliberates the issues before it.

(1) Salmon exhibit a complex suite of life-histories that will benefit from specific experience and expertise in the ecology and genetics of the species in question. Certainly, FDA has experience with food and drug science, whereas other agencies in the Federal and state sphere are more versed in salmon biology and the unique qualities of the environments they generally occupy (especially, NOAA–Fisheries for marine ecosystems, and Fish and Wildlife Service and the states for inland ecosystems).

(2) Whereas containment and engineered sterility may, in fact, reduce the probability of escape or reproduction (triploidy has proven an imperfect method of mass sterilization), these do not completely remove risks of escape, reproduction, or ecological interference. A robust and formal risk assessment is warranted. Such assessments will benefit from formal uncertainty analyses. Moreover, it would be prudent to treat any transgenic modification of fishes as a controlled experiment that is a) actively monitored for impacts after approval and that can be b) terminated should the need arise without lingering environmental effect. More specific and detailed recommendations may be found in a 2004 National Academy of Sciences report entitled, "Biological confinement of genetically engineered organisms".

(3) While I recognize the confidentiality requirements of trade secrets laws that are intended to safeguard proprietary information from potential competitors about food and drug products, a fuller transparency and debate of the science behind environmental risk-reviews differs in a couple material ways. First, it promotes bringing the brightest minds and best ideas to bear on the issues. Second, it more adequately protects fisheries and fish biodiversity that are managed in trust by public resource agencies.

As a final thought, I contend we need to consider the scientific issues surrounding the risks of Genetically Engineered salmon and other fishes based on the appropriate and full-range of scientific fields to shape the policy discussions. Based on analogous concerns and risks from release of fishes genetically altered in more traditional or conventional ways (rather than with more recent molecular and cellular biology based approaches), the risks appear to all too real, albeit to an insufficiently understood extent. Ultimately, the environmental concerns surrounding release or escape have been debated and summarized by various experts and groups including no less than three separate Panels from the National Academy of Sciences entitled "Animal Biotechnology: Science Based Concerns" (2002); "Biological Confinement of Genetically Engineered Organisms" (2004); and, "Genetically Engineered Organisms, Wildlife and Habitats" (2008). I trust the Subcommittee will encourage continued examination of these concerns by the lead and consulting agencies.

Mr. Chairman, Thank you, again, for the opportunity to share these views. I would be happy to address any questions you or the Members might have.

Senator BEGICH. Thank you very much.

Dr. Leonard.

STATEMENT OF GEORGE H. LEONARD, PH.D., AQUACULTURE PROGRAM DIRECTOR, OCEAN CONSERVANCY

Dr. LEONARD. Good morning.

Thank you, Chairman Begich, and Ranking Member Snowe, and other members of the Committee for inviting me here today.

My name is George Leonard, and I direct Ocean Conservancy's Aquaculture Program. I have a Ph.D. in Marine Ecology and Evolutionary Biology, and for about the last decade I have worked to protect the long-term health of our oceans by identifying an environmentally responsible seafood supply that is critical to America's economic strength.

It is my assessment that the existing Federal regulatory structure under the Food and Drug Administration is incapable of asking and answering the suite of questions that's needed to appropriately regulate genetically engineered fish.

More specifically, based on the available science, I conclude that we cannot be assured that the expansion of GE fish more generally, beginning with the approval of AquAdvantage farm salmon, is safe for the environment.

Approval of the first genetically engineered animal for human consumption should only be made with a full understanding of the environmental risks and the potential impacts of the broad adoption of this type of fish farming.

This decision will set a precedent that has ramifications well beyond the application now before the FDA.

The standard that we set for ourselves today will determine how thoroughly we evaluate other GE fish in the future. For, most certainly, others will follow.

What is at stake here is no less than the future of fish, natural ecosystems, and our seafood supply.

Now, proponents of GE salmon would have us believe that there is no risk that the fish will get out, and even if they do get out, there is no risk that GE salmon will take hold or reproduce with native salmon populations. I would urge the Committee to seriously question those assumptions.

We should, in fact, heed the lessons of history, which is replete with examples of other fish that have been introduced around the globe with the best of intentions, but which have left a trail of destruction in their wake.

Now, while science can't predict with certainty what the outcomes will be if GE fish escape, caution is certainly warranted.

For the purposes of this morning's hearing, I would ask you to examine this issue under the assumption that there will be fish escapes. And let's imagine the possible consequences if GE salmon compete or interbreed with wild salmon.

If the fish get out, how will this affect commercial and recreational salmon fisheries in Alaska, or perhaps along the West Coast where I live? How might this impact efforts to recover wild Atlantic salmon in New England and Maine? How might this impact our international salmon management agreements with Canada under the Pacific Salmon Treaty?

How might this impact other sectors of the economy that are already affected by Endangered Species Act restrictions, such as the Columbia River hydropower system, the use of pesticides by the agriculture industry, or flood control structures along salmon-inhabited rivers?

How might this undermine the billions of taxpayer dollars that have been invested in helping protect and restore wild salmon?

And finally, how might this reverberate throughout marine food webs? For example, what might be the effects on endangered southern resident orcas in Puget Sound, or the endangered Cook Inlet beluga whales in Alaska?

Now, Mr. Chairman, I don't have answers to those questions. In fact, nobody does. And, Mr. Chairman, that's exactly the point. Not only has the FDA failed to provide answers to those questions, they have failed to even ask the questions at all.

In my view, the question before the Federal Government, and before this committee, is whether we're going to allow the approval of GE fish under a flawed process that fails to adequately analyze these kinds of risks. We need the government to stand up and do its job.

Specifically, we request that Congress do four things. First: demand a modern, environmental risk assessment that treats uncertainty directly, before decisions are made, on this fish or any future fish.

Demand that the National Marine Fisheries Service and other agencies with expertise in fishery biology play a substantive role in assessing those risks.

Demand a far more inclusive and transparent process than has happened to date.

And, finally, demand a moratorium on GE salmon and other GE fish, including Senator Begich's bill S. 1717, until we have the science to demonstrate that there is little or no risk to wild fish in healthy oceans.

Our nation's seafood's future should not be left to a few individual private companies or to the FDA alone. We fundamentally need a public debate about the kinds of fish that we want to eat, which of those we will farm, and which of those we will catch in the wild. And decisions must be based on a clear-eyed analysis of the economic, environmental, and societal costs and benefits of doing so.

But right now, that isn't happening. And the American people deserve better.

Thank you for the opportunity to testify. I'm happy to answer your questions as well.

[The prepared statement of Dr. Leonard follows:]

PREPARED STATEMENT OF GEORGE H. LEONARD, PH.D.,
AQUACULTURE PROGRAM DIRECTOR, OCEAN CONSERVANCY

Introduction

Thank you Chairman Begich, Ranking Member Snowe and other members of the Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard for convening this hearing at such an important juncture, and for inviting me to testify. My name is George Leonard and I direct Ocean Conservancy's Aquaculture Program. I have a Ph.D. in marine ecology and evolutionary biology. For a decade I have worked to protect the long-term health of our oceans by identifying a viable, environmentally responsible seafood supply that is critical to America's economic strength.

A healthy ocean and a healthy seafood industry are critical to America's environmental and economic strength. Based on my assessment of the scientific literature and the current policy framework in the United States to regulate genetically engineered fish, we cannot yet conclude that the introduction of the first genetically engineered animal for human consumption—the AquAdvantage® farmed salmon—is safe for the environment. Furthermore, the existing Federal regulatory structure and the current application before the Federal Food and Drug Administration (FDA) are incapable of asking and answering the broader suite of questions raised by the

proliferation of genetically engineered fish farming and the range of engineered species that are likely to follow this potential first approval for GE salmon.

Genetically Engineered Salmon and the Future of Fish

The application from AquaBounty Technologies, Inc., for approval of its patented, genetically engineered farmed Atlantic salmon continues to be extraordinarily controversial. While there are numerous aspects of this specific proposal that warrant close scrutiny, much of the controversy, I believe, stems from the broader implications of approval. While the FDA, Congress, and the American public are right to pay close attention to the specific scientific and operational details of the proposed hatchery in Canada and the grow out facility in Panama, it is the broader ecological and societal consequences of the proliferation of genetically engineered salmon and other fish that are larger concerns and warrant careful scrutiny.

Chairman Begich and this Committee are to be commended for addressing this issue head-on and ensuring that these larger implications of genetically engineered (GE) fish are not ignored. What is at stake is no less than the future of fish, natural ecosystems, and our seafood supply. The issue is much larger than this single application from one private company. The critical question is whether society as a whole would be better off or worse from having this product on the market.[1] A more comprehensive analysis of the risks and benefits to our seafood supply, our current seafood industry, affected stakeholders, and natural ecosystems is desperately needed.

The specific controversy around GE salmon is embedded in a larger debate about how society hopes to procure fish protein. Unlike only three decades ago, our seafood supply is now dominated by farmed fish, with 50 percent of global seafood production coming from aquaculture.[2] Indeed, fish farming will play an important role in our future seafood choices. But aquaculture's reputation has suffered from the poor environmental and societal performance of some forms of farming, most notably the global shrimp and salmon industries.[3,4] Consumers and seafood businesses are increasingly making purchasing decisions based on the environmental impacts of their seafood choices, rewarding better environmental performance in the marketplace.[5] Without sufficient understanding of the risks, and public confidence in regulatory decision-making, adoption of GE technology has the potential to undermine a sustainable future for aquaculture, rather than secure it.

Rather than leaving the future of fish to a series of piecemeal decisions, beginning with the approval of AquAdvantage® farmed salmon, Congress should craft a broader, national vision for our future seafood supply that articulates the appropriate role of wild and farmed fish, including genetically engineered fish. Our nation's seafood future shouldn't be left to individual private companies or the FDA alone. Instead, it should be grounded in a public debate about the kinds of fish we wish to eat, involve decisions about which fish we will grow on farms and which we will catch in the wild, and be based on a clear-eyed analysis of the economic, environmental, and societal costs and benefits of doing so.

Chairman Begich and this Committee are to be commended for their role in starting the conversation.

Environmental Risks of Genetically Engineered Fish: Knowns and Unknowns

A decision to approve genetically engineered salmon should only be made with a full understanding of environmental risks and potential impacts that would accompany the broad adoption of this technology. Proponents of GE salmon have postulated that there is no risk of escapement, and that even if escapement does occur, there is no risk that GE salmon populations could take hold or otherwise reproduce with or negatively impact native, wild salmon populations or other components of the ecosystem. It would be irresponsible not to seriously question these assertions.

Given the stakes, we should take a more prudent approach. When considering approval of GE salmon and other GE fish, decision-makers should assume that there *will* be escapement. As explained in more detail below, history is replete with examples of fish and other animals that were never intended to get out, and yet they

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[1] Smith, M.D., Asche, F., Guttormsen, A. G., J. B. Wiener. 2010. Genetically Modified Salmon and Full Impact Assessment. Science 330:1052–1053.

[2] FAO Fisheries and Aquaculture Department. 2011. World aquaculture 2010. Technical Paper. No. 500/1. Rome, Food and Agriculture Organization.105 pp.

[3] Naylor, R. L., Goldburg, R. J., Mooney, H., Beveridge, M., Clay, J. Folke, C., Kautsky, N., Lubchenco, J., Primavera, J. and M. Williams. 1998. Nature's Subsidies to Shrimp and Salmon Farming. Science 282: 883–884.

[4] Ford J. S. and R. A. Myers. 2008. A Global Assessment of Salmon Aquaculture Impacts on Wild Salmonids. PLoS Biol 6(2): e33. doi:10.1371/journal.pbio.0060033.

[5] *http://www.montereybayaquarium.org/cr/seafoodwatch.aspx.*

did. Given that history, it is only prudent to assume that GE fish will eventually escape from production facilities as the technology proliferates.

To be responsible, we must imagine the possible consequences if GE salmon compete and/or interbreed with wild salmon populations. What might those impacts be? What and whom will they affect? And what will the cost be to us as a nation? These are key questions about environmental and biological consequences and risks that must be asked and answered before any application for GE fish is approved. We must undertake an honest evaluation that includes an objective and clear-eyed view not only of the probability that an event might happen, but also of the magnitude and severity of the consequences of a range of potential, unintended outcomes. These are big questions with potentially significant consequences, and we must answer them before we commit to a course.

The two general categories of environmental impacts that should concern this committee are the effects on wild salmon, and the food web impacts on other species. As the members of the Committee are well aware, wild salmon are already under considerable threat in many regions from a whole range of human activities, including coastal development, habitat loss, stream water diversions, net pen salmon aquaculture, and climate change.[6] Any additional impact from GE salmon could tip endangered or threatened populations over the edge, damaging currently healthy and commercially important salmon stocks and inhibiting recovery of those at low abundance. The mechanisms through which GE salmon escapement might damage wild salmon populations are four-fold: competition for food and habitat; pathogen or disease transmission; disruption of wild salmon reproductive behavior; and interbreeding with wild salmon. In assessing these issues, we should ask not only whether GE fish are more harmful than conventional farmed salmon, but more fundamentally, what harm can GE salmon cause and have we assessed and addressed these potential risks adequately?

Competition with wild salmon for food and habitat

Escaped GE salmon would be competitors for food,[7] habitat, and reproduction.[8] In experiments, growth-enhanced GE salmon dominated non-GE salmon for feed acquisition and exhibited strong agonistic and cannibalistic behavior when feed resources were inadequate.[9] A number of behavioral effects are reported in growth-enhanced GE fish that could affect wild populations, including significantly enhanced feeding motivation and reduced discrimination of prey choice. According to research from the Canadian Department of Fisheries and Oceans, a Coho salmon genetically engineered with a similar growth hormone gene as in the AquAdvantage® fish expressed aggressive behavior in hunting for food that even led to a collapse in wild salmon populations.[10] Studies found that GE Coho salmon are also more likely to take risks when feeding.[11] GE salmon also have greater thermal tolerance than wild fish, a trait which could give engineered fish an added advantage. GE salmon could thus potentially stress wild counterparts as they lay claim to new territory and habitat. Such an introduction could also push wild salmon into inferior habitats, which could further increase mortality.[12] [13]

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[6] Coates, P. A. 2006. Salmon. Reaktion Books Ltd. London. 216 pp.

[7] Devlin, R.H., J.I. Johnsson, D.E. Smailus, C.A. Biagi, E. Johnsson, and B.T. Bjornsson. 1999. Increased ability to compete for food by growth hormone transgenic coho salmon (*Oncorhynchus kisutch* Walbaum). Aquaculture Research 30: 1–4.

[8] Johnsson, J. I., and B. Bjornsson. 2001. Growth enhanced fish can be competitive in the wild. Functional Ecology 15 (5): 654–659.

[9] Devlin, R. H., M. D'Andrade, M. Uh, and C. A. Biagi. 2004. Population effects of growth hormone transgenic coho salmon depend on food availability and genotype by environment interactions. Proceedings of the National Academy of Sciences of the United States of America 101 (25): 9303.

[10] Muir, W. M. and R. D. Howard. 1999. Possible ecological risks of transgenic organism release when transgenes affect mating success; sexual selection and the Trojan gene hypothesis. Proceedings of the National Academy of Sciences.

[11] Sundström, L. F., Devlin, R. H., Johnsson, J. I. & Biagi, C. A. 2003 Vertical position reflects increased feeding motivation in growth hormone transgenic coho salmon (*Oncorhynchus kisutch*). Ethology 109: 701–712.

[12] McGinnity, P., C. Stone, J.B. Taggart, D. Cooke, D. Cotter, R. Hynes, C. McCamley, T. Cross, and A. Ferguson. 1997. Genetic impact of escaped farmed Atlantic salmon (*Salmo salar* L.) on native populations: use of DNA profiling to assess freshwater performance of wild, farmed, and hybrid progeny in a natural river environment. ICES Journal of Marine Science 54: 998–1008. McGinnity, P., P. Prodohl, A. Ferguson, R. Hynes, N. Maoiléidigh, N. Baker, D. Cotter, B. O'Hea, D. Cooke, and G. Rogan. 2003. Fitness reduction and potential extinction of wild populations of Atlantic salmon, *Salmo salar,* as a result of interactions with escaped farm salmon. Proceedings of the Royal Society of London. Series B: Biological Sciences 270: 2443.

[13] McGinnity, P., C. Stone, J.B. Taggart, D. Cooke, D. Cotter, R. Hynes, C. McCamley, T. Cross, and A. Ferguson. 1997. Genetic impact of escaped farmed Atlantic salmon (*Salmo salar*

Pathogens and disease transmission

Unlike fish escapes, where a single large-scale release (or sustained, low level "leakage") would likely be required to have significant impacts, disease transmission from farmed to wild fish can cause severe mortality even from a small number of fish. There are few data, however, on any additional impact that GE salmon could have on disease transmission because no GE salmon have been introduced into commercial aquaculture to date. But some GE fish are known to have compromised immune systems, and it has been documented that triploid GE Coho salmon are more susceptible to disease.[14] This suggests that the introduction of transgenic salmon into commercial aquaculture could increase the number of infected fish and the degree of disease transfer into the marine environment, especially if GE fish are used in net pen grow-out systems. In addition, if escapes and interbreeding were to occur, the underlying genetics of GE fish with compromised immune systems would be introduced into the gene pool for wild fish.[15]

Disruption of wild salmon reproduction

Escaped GE salmon could also interfere with wild salmon breeding. For example, scientists have observed that spawning of wild females with farmed males occasionally results in poor egg fertilization when no wild males are involved.[16] When it comes to competition for spawning sites, later arriving fish may destroy a nest from an earlier spawn.[17] There is also some evidence that the hatchery environment produces more aggressive and more territorial fish.[18] While all these findings are for interactions between wild salmon and traditional, non-GE farmed salmon, similar concerns are likely to exist with GE salmon should they enter natural ecosystems.

Interbreeding with wild salmon

Given the complexity of how novel genes function in different environments, considerable concern remains over how GE fish may impact wild populations. Wild fish have been optimally selected over many generations for various life history characteristics such as growth rate, age and size at sexual maturity and clutch size. If escaped GE salmon and wild salmon interbreed successfully, it could have dire consequences for the survival of wild fish. If gene complexes from GE salmon take hold in wild populations, wild fish populations could have reduced survival and reproduction. In addressing the risk of GE fish generally, Muir and Howard (2002) stated: "If the population is struggling for existence prior to an introduction event, the induced genetic load may be sufficient to drive the population to extinction."[19] One mechanism by which this might occur is the Trojan gene hypothesis. First postulated in 1999,[20] this hypothesis suggests that GE fish possess a mating advantage that drives the engineered gene into wild populations; but the resulting GE offspring have reduced viability, which eventually drives the wild population to extinction. There is scientific uncertainty as to whether the Trojan gene effect will manifest in AquAdvantage® GE salmon. The theory's relevance should not be dismissed

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L.) on native populations: use of DNA profiling to assess freshwater performance of wild, farmed, and hybrid progeny in a natural river environment. ICES Journal of Marine Science 54: 998–1008. McGinnity, P., P. Prodohl, A. Ferguson, R. Hynes, N. Maoiléidigh, N. Baker, D. Cotter, B. O'Hea, D. Cooke, and G. Rogan. 2003. Fitness reduction and potential extinction of wild populations of Atlantic salmon, *Salmo salar,* as a result of interactions with escaped farm salmon. Proceedings of the Royal Society of London. Series B: Biological Sciences 270: 2443.

[14] Jhingan, E., R. H. Devlin, and G. K. Iwama. 2003. Disease resistance, stress response and effects of triploidy in growth hormone transgenic coho salmon. Journal of Fish Biology 63 (3): 806–823.

[15] De Eyto, E., P. McGinnity, S. Consuegra, J. Coughlan, J. Tufto, K. Farrell, H. J. Megens, W. Jordan, T. Cross, and R. J. M. Stet. 2007. Natural selection acts on Atlantic salmon major histocompatibility (MH) variability in the wild. Proceedings of the Royal Society B: Biological Sciences 274: 861.

[16] Fleming, I., K. Hindar, I. Mjølnerød, B. Jonsson, T. Balstad and A. Lamberg. 2000. Lifetime success and interactions of farm salmon invading a native population. Proceedings of the Royal Society B: Biological Sciences 267: 1517–1523.

[17] Naylor, R., K. Hindar, I. Fleming, R. Goldburg, S. Williams, J. Volpe, F. Whoriskey, J. Eagle, D. Kelso and M. Mangel. 2005. Fugitive salmon: assessing the risks of escaped fish from net-pen aquaculture. Bioscience 55: 427–38.

[18] Sundström, L. F., M. Löhmus, and J. I. Johnsson. 2003. Investment in territorial defense depends on rearing environment in brown trout (*Salmo trutta*). Behavioral Ecology and Sociobiology 54: 249–255.

[19] Muir, W. M. and R. D. Howard. 2002. Methods to assess ecological risks of transgenic fish releases. Genetically Engineered Organisms: Assessing Environmental and Human Health Effects. D. K. Letourneau and B. E. Burrows. Boca Raton, FL, CRC Press: 355–383, p. 358.

[20] Muir, W. M. and R. D. Howard. 1999. Possible ecological risks of transgenic organism release when transgenes affect mating success; sexual selection and the Trojan gene hypothesis. Proceedings of the National Academy of Sciences. 96:13853–13856.

outright, as other studies note that behavior, genetics, and other factors can alter the likelihood of such effects. This suggests that an in-depth risk assessment is crucial before GE fish are approved.[21]

Two very recent studies have shown that escaped GE salmon will not die out quickly and, when fertile, can reproduce and pass on genes to future generations.[22] Particularly in situations where the rate of non-GE farmed salmon escapement is close to the reproductive rate of wild fish, the genetic consequences of such ongoing interbreeding could lead to an "extinction vortex," where an increase in presence of GE fish would lead to a decrease in genetic variance and adaptive potential.[23]

In addition, considerable scientific uncertainty remains regarding the evolutionary success of GE offspring in the wild; it is difficult to predict how offspring containing the engineered gene would evolve over several generations. Natural selection could either increase or decrease offspring fitness in the wild, and both could have potential impacts on the conservation of wild salmon populations.[24] A great deal more remains to be learned about the effects of GE fish on wild fish. Until a larger body of research is available, caution is crucial.

In sum, GE salmon could potentially damage already-struggling wild salmon populations through competition for food and habitat, pathogen and disease transmission, disruption of reproduction, and interbreeding. If such impacts come to pass, they could have real-world and far-reaching impacts on people, industries, and the environment. Congress should ensure that key questions are answered before GE salmon are approved for commercial production:

- If wild salmon populations are damaged by GE salmon, how will this affect commercial and recreational wild salmon fisheries in Alaska and along the West Coast?
- How might it impact our ongoing efforts to recover wild Atlantic salmon in Maine and throughout New England?
- How would it impact our existing international salmon management agreements with Canada under the Pacific Salmon Treaty?
- What implications would a further-weakening of Endangered Species Act-listed salmon stocks have on other sectors of our economy that are already impacted by ESA restrictions, such as the Columbia River hydropower system, the use of agricultural pesticides, and flood-control structures along salmon-inhabited rivers?
- Would damage done by GE salmon roll back the positive impact of billions of dollars of Federal taxpayer money that has been invested in helping protect, replenish, and restore wild salmon populations?

Beyond these direct impacts of GE salmon, we must remember that wild salmon are a major component of the marine food web. A major blow to wild salmon could reverberate throughout the system in unexpected ways. In particular, wild salmon populations damaged by the effects of GE salmon could have implications on their predators through a reduction in wild salmon availability as prey for higher trophic levels.

For example, if the effects of GE salmon impair wild salmon, how would it affect Puget Sound's iconic and endangered Southern Resident Orca population? Members of this cetacean population have been observed in an emaciated state, and the population struggles with high levels of contaminants—especially among young and newborn whales.[25] If GE salmon trigger a further collapse in the availability of wild salmon prey in the Puget Sound or somehow add to toxicity loads, it is reasonable

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[21] Ahrens, R.N.M. and Devlin, R.H. 2010. Standing genetic variation and compensatory evolution in transgenic organisms: A growth-enhanced salmon simulation. Transgenic Research 20(3):583–597.

[22] Moreau, D.T. R., I. A Fleming, G. L. Fletcher and J.A. Brown. 2011a. Growth hormone transgenesis does not influence territorial dominance or growth and survival of first-feeding Atlantic salmon *Salmo salar* in food-limited stream microcosms. Journal of Fish Biology 78:726–740. Moreau, D.T. R., Corrine Conway, and I.A. Fleming. 2011b. Reproductive performance of alternative male phenotypes of growth hormone transgenic Atlantic salmon (*Salmo salar*). Evolutionary Applications 4(6): 736–748.

[23] McGinnity, P., P. Prodohl, A. Ferguson, R. Hynes, N. Maoiléidigh, N. Baker, D. Cotter, B. O'Hea, D. Cooke, and G. Rogan. 2003. Fitness reduction and potential extinction of wild populations of Atlantic salmon, *Salmo salar,* as a result of interactions with escaped farm salmon. Proceedings of the Royal Society of London. Series B: Biological Sciences 270: 2443.

[24] Kapuscinski, A.R., Hayes, K.R., Li, S., and G. Dana, 2007. Environmental Risk Assessment of Genetically Modified Organisms: Methodologies for Transgenic Fish. Vol. 3. CABI International, Oxfordshire.

[25] *http://www.nwr.noaa.gov/marine-mammals/whales-dolphins-porpoise/killer-whales/esa-status/*.

to expect that this could further imperil Puget Sound's endangered orcas. The same question could—and should—be asked of Cook Inlet beluga whales in Alaska, another population that relies heavily on wild salmon as prey and whose endangered status has caused great consternation in surrounding communities.[26] Given the central role of salmon in marine and terrestrial food webs,[27] [28] impacts could also extend to a long list of other predator species such as bald eagles, river otters, and bears.

We know a great deal about the importance of wild salmon and healthy ecosystems. We know a great deal less about the risks and potential consequences to wild salmon and healthy ecosystems from commercial-scale production of GE salmon. The process of approving GE salmon should not proceed without rigorous and objective assessment of those risks and consequences. Thus far, the FDA has not only failed to provide answers to these questions, the agency has failed to even ask the questions at all.

Ecological Consequences of Management Decisions in the Face of Imperfect Information

As the Committee ponders the range of questions that must be answered before GE salmon are allowed in commercial aquaculture, it is worth examining a few examples of other fish species that were intentionally deployed for what appeared good reasons at the time, but that only later became recognized as poor management decisions. While these examples are not related to genetic engineering, they do highlight the dire consequences that can occur when novel species are moved outside their natural habitats. They are "object lessons" in the need for a precautionary approach when potential impacts could be dire.

The United Nations has acknowledged that the introduction of exotic (non-indigenous) species poses the second greatest threat to global biodiversity, behind only habitat loss. The peer-reviewed literature is replete with examples of plants and animals, both intentionally released and accidentally escaped, that have caused extreme ecological harm. One study has estimated that 50,000 non-indigenous species are now present in the U.S., causing major environmental damage that totals nearly $137 U.S. billion annually.[29]

In many cases, species have been introduced with little concern or evaluation of potential ecological consequences, under the belief that transporting or otherwise using species outside their natural habitat provided societal benefits. Plants have been used as erosion or predator control, while other species have been intentionally released to provide new hunting and fishing opportunities.[30] In an extraordinarily large number of cases, this has resulted in ecological harm.

In studying these examples, scientists have found that the behavior of exotic species is often puzzling. Introduced species often defy efforts to predict if and when they become established, whether they will spread, and what their impacts will be in new habitats. Resource managers have learned that it is much easier and less costly to prevent an introduction of a species than to remove it once it has been established.[31] In the absence of sufficient information, the precautionary approach is to refrain from deploying a species when there is an unacceptable risk of escape and harm. In all cases, a hefty dose of caution and skepticism is warranted. This is especially true for genetically engineered species, which can be thought of as special case of non-indigenous species, where the engineered gene could interact with the genetic makeup of wild populations in novel and difficult to predict ways.[32]

With the growth of aquaculture globally, a number of aquatic species have been distributed well beyond their natural borders and grown in non-indigenous environments. While never intended to be released, many have escaped, validating the now famous quote from Jeffrey Goldblum in *Jurassic Park* that "life often finds a way." Furthermore, the "law of unintended consequences" often governs the fate of species

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[26] *http://www.defenders.org/wildlife_and_habitat/wildlife/beluga_whale.php; http://www.biologicaldiversity.org/species/mammals/Cook_Inlet_beluga_whale/index.html.*

[27] Hocking, M. D., and J. D. Reynolds. 2011. Impacts of salmon on riparian plant diversity. Science. 331:1609–1612.

[28] Gende, S. M., Edwards, R. T., Willson, M. F., and M. S. Wipfli. 2002. Pacific salmon in aquatic and terrestrial ecosystems. BioScience 52:917–928.

[29] Pimental, D., L. Lach, R. Zuniga, and D. Morrison. 2000. Environmental and economic costs of non-indigenous species in the United States. . BioScience 50:53–65.

[30] Davis, M.A. 2009. Invasion Biology. Oxford University Press. Oxford, UK. 243 pp.

[31] Volpe, John. 2001. Super un-Natural: Atlantic salmon in BC waters. David Suzuki Foundation. 31 pp.

[32] Ahrens, R.N.M. and R. H. Devlin. 2010. Background: genotype effects on transgenes in populations: a growth-enhanced salmon simulation. Transgenic Research. DOI 10.1007/s11248–010–9443–0.

when people utilize them in ways that fail to recognize or account for the species' natural history or their potential ecological role in new habitats.

Several examples illustrate the dire consequences for natural ecosystems of management decisions made without sufficient understanding of ecological risk.

Atlantic salmon

Salmon farming began in the mid 1970s on the western coast of British Columbia, Canada, largely in response to a growing global market for farmed salmon and a provincial government focused on the economic benefits that a new seafood industry could bring to struggling coastal communities. From 1972 to 1985, salmon farms grew from zero to 185 coastal farm sites.[33] This expansion was driven by national legislation that encouraged foreign investment, combined with a weak and poorly coordinated regulatory regime in Canada. Critics have raised numerous concerns about farmed salmon, including disruption of natural ecosystems, spread of disease like sea lice and infectious salmon anemia, harm to wild salmon stocks, and pollution from feed, chemicals and waste. My comments, however, address only one main issue: regulators were repeatedly proven wrong when they made assumptions about whether farmed salmon could escape and be viable in the wild.

Starting in the mid 1980s, Federal regulators and the salmon farming industry made a series of assurances related to farmed Atlantic salmon impacts that were based on a combination of invalid assumptions, wishful thinking, and willful ignorance.[34] Long after the industry had already become entrenched, a body of research showed each of these statements to be patently false.

Particularly germane to genetically-engineered salmon and other GE fish, these assurances—in chronological order—were:

- Fish escapes are rare;
- Escapes are inevitable but fish can not survive;
- Escaped fish can survive, but they don't ascend rivers;
- Some escaped fish are found in rivers, but they can't spawn in those habitats;
- Escaped fish in rivers are likely to spawn, but their progeny are not viable; and finally
- Multi-year classes of escaped fish are not a threat to native wild salmon populations.[35]

In hindsight, all of these assurances turned out to be false when they were empirically tested. Over a period of years, information was gleaned through observations made by fishermen, concerned citizens, and a large body of empirical research (in the laboratory and in the field) by Dr. John Volpe. But by 1997, when Atlantic salmon had already been in the natural environment in British Columbia for over a decade, government regulators still had not seen fit to conduct a proper environmental analysis to evaluate the potential spawning performance of aquaculture-reared Atlantic salmon compared to native Pacific salmon. From the beginning of the industry's development, government officials and Federal scientists had been silent on the need to estimate this risk. And throughout the period, the aquaculture industry had portrayed the risk as essentially non-existent, a portrayal revealed to be false once the correct questions were asked and answered.

In contemplating this issue in 2001, Volpe concluded that the only answer to the question of the potential ecological consequences of the BC salmon farming industry should have been "we don't know," given the high levels of uncertainty regarding the impacts of ocean farming of salmon. In evaluating the effectiveness of Canadian regulators, Volpe concluded that to safeguard common resources, the government must ensure there is a rational evaluation of the industry with a full accounting, not only of benefits, but also of risks.[36] The same is equally true in the United States with respect to the proposed deployment of genetically engineered salmon and the other genetically engineered fish that are sure to follow.

Nile tilapia

Today, tilapia is likely the world's most widely distributed non-indigenous ﬁsh species—having invaded every tropical and subtropical environment to

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[33] Keller B. C. and R. M. Leslie. 1996. Sea-silver: Inside British Columbia's salmon farming industry. Horsdal and Shubart Publishers Ltd., Victoria. .

[34] Volpe, John. 2001. Super un-Natural: Atlantic salmon in BC waters. David Suzuki Foundation. 31 pp.

[35] *Ibid.*

[36] *Ibid.*

which they have gained access.[37] Since the 1980s, almost all of the worldwide introductions of tilapia have been for new aquaculture developments.[38] Over this time, there has been a shift from growing Mozambique tilapia (*Oreochromis mossambicus*) toward growing Nile tilapia (*Oreochromis niloticus*) in aquaculture.[39] Nile tilapia now dominate global tilapia aquaculture, accounting for 72 percent or 474,000 metric tons of production in 1995.[40] Throughout the world, cases of tilapia introductions are the result of both intentional release and unintentional escape. Regardless of mechanism, this has resulted in the decline of native fish and alteration of natural benthic communities globally. [41] [42]

The United States is no exception. In the U.S., Nile tilapia has been used for aquaculture since 1974, and while it was never intended to be released, it has become introduced into open waters through escape or release from fish farms.[43] Reports of Nile tilapia in the wild have come from the states of Arizona, Illinois, Massachusetts, Georgia, and the Gulf of Mexico, including Texas, Mississippi, Alabama, and Florida.[44] Studies suggest that Nile tilapia can invade coastal areas beyond their initial point of introduction by finding areas of thermal refuge from cold winter temperatures which would otherwise limit their survival. In particular, thermal gradients within a power plant cooling pond have provided Nile tilapia with the warm habitat needed for successful invasion and establishment.[45] Studies have also shown that the fish's reproduction is not hampered by the salinity of typical ocean seawater.[46]

In coastal Mississippi in particular, Nile tilapia was deployed in the state through aquaculture and has since established breeding populations.[47] The environmental conditions in coastal southeastern Mississippi appear to provide a high quality environment for the survival of released Nile tilapia.[48] This species of tilapia can spawn year-round. Fish as small as 80 millimeters in total length carry mature eggs, showing that this exotic species can survive and become established in our present ocean landscape.

Tilapia provides a second cautionary tale of the consequences of growing a fish known to pose ecological risks beyond its native range. Even with the best of intentions, fish can and do escape.

Asian carp

Asian carp is a third example of a non-indigenous fish species that has spiraled out of control. . The carp now infesting the Mississippi River Basin and threatening the fisheries of the Great Lakes were introduced both intentionally by the government and unintentionally through escapes from fish farms. In the late 1970s and early 1980s, the Environmental Protection Agency and state Fish and Game programs carried out research using bighead and silver carp to clean sewage ponds and to consume undesirable aquatic vegetation. At the time, carp were touted as an innovative breakthrough to control water pollution because the fish were a cheaper,

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[37] Costa-Pierce, Barry A. "Rapid evolution of an established feral tilapia (*Oreochromis* spp.): the need to incorporate invasion science into regulatory structure." *Biological Invasions* 5 (2003): 71–84

[38] *Ibid.*

[39] *Ibid.*

[40] FAO (Food and Agriculture Organization of the United Nations) (1997) Review of the state of world aquaculture. FAO Fisheries Circular. No 886, Rev 1. Inland Water Resources and Aquaculture Service, Fishery Resources Division, Rome, 163 p

[41] "*Oreochromis* spp. (fish)." Global Invasive Species Database. 9 Dec. 2011. <*http://www.issg.org/database/species/ecology.asp?si=813&fr=1&sts=sss.*>

[42] Canonico, Gabrielle C., Angela Arthington, Jeffrey K. McCrary, and Michele L. Thieme. . "The effects of introduced tilapias on native biodiversity." *Aquatic Conservation: Marine and Freshwater Ecosystems* 15 (2005): 463–483.

[43] "*Oreochromis niloticus* Factsheet." *United States Geological Survey.* 9 Dec. 2011. <*http://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=468*>.

[44] *Ibid.*

[45] McDonald, Jennifer L., Mark S. Peterson, and William T. Slack. . "Morphology, density, and spatial patterning of reproductive bowers in an established alien population of Nile tilapia, *Oreochromis niloticus." Journal of Freshwater Ecology* 22.3 (2007): 461–468.

[46] Schofield, Pamela, Mark S. Peterson, Michael R. Lowe, Nancy J. Brown-Peterson, and William T. Slack. "Survival, growth and reproduction of non-indigenous Nile tilapia, *Oreochromis niloticus* (Linnaeus 1758). I. Physiological capabilities in various temperatures and salinities." *Marine and Freshwater Research* 62.5 (2011): 439–449.

[47] McDonald, Jennifer L., Mark S. Peterson, and William T. Slack. . "Morphology, density, and spatial patterning of reproductive bowers in an established alien population of Nile tilapia, *Oreochromis niloticus." Journal of Freshwater Ecology* 22.3 (2007): 461–468.

[48] Peterson, Mark S., William T. Slack, and Christa M. Woodley. "The occurrence of non-indigenous Nile tilapia, *Oreochromis niloticus* (Linnaeus) in coastal Mississippi, USA: ties to aquaculture and thermal effluent." WETLANDS 25.1 (2005): 112–121.

more wholesome form of biological control than that provided by traditional chemical treatments.[49]

Yet today, we know the dire consequences of the decision to introduce this highly invasive fish. The once-desirable fish are now spreading northward, especially up and throughout the Mississippi River Basin. A growing body of evidence shows that Asian carp compete with native species for both food and habitat, may spread disease to native wild fish, and negatively affect water quality.[50]

It is not just biologists who know the dangers posed by non-indigenous carp; recreational fishermen have experienced these dangers first hand. Not only do the fish that recreational anglers seek compete with carp for food, but fishermen can be personally injured in pursuit of their catch. Enormous silver carp—weighing up to 100 pounds—can jump out of the water and have been known to injure anglers sitting in their boats.[51] Now, millions of Federal and state dollars are being spent to try to stop Asian carp from spreading into additional lakes and waterways. But this effort may be doomed to failure; just last week DNA from the invasive silver carp was found in the Mississippi River above the Coon Rapids Dam, further north than it has ever been discovered, raising the prospect that the fish may be headed to Minnesota's most popular recreational lakes.[52]

Like tilapia and salmon, Asian carp provides an example of the law of unintended consequences. With all these fish, important questions should have been asked before they were introduced and ultimately escaped.

Regulation of Genetically Engineered Fish: FDA Approval Process Is Inadequate

Given these cautionary tales and the environmental perils associated with the potential escape of GE salmon and other GE fishes, it is critical that the United States has in place a regulatory process that can anticipate, evaluate, and guard against these concerns. I have little confidence that the process led by the Food and Drug Administration is up to the task.

Under the 1986 Coordinated Framework for the Regulation of Biotechnology ("Coordinated Framework"), genetically engineered organisms (GEOs) are regulated according to the concept of "product, not process." This means that, Federal agencies evaluate GEOs as products like any other—"substantially equivalent" to their non-engineered analogues—not as a special category distinguished by their development using the process of recombinant DNA technology.[53] The Coordinated Framework assumes that the existing agencies, using existing authority, have the ability and expertise to review commercialization applications.

There are a number of problems with this approach. First, existing statutes have generally been designed to address situations where harm or risk has already been quantified, not situations where there remains a high degree of scientific uncertainty, such as is the case for genetic engineering technology. The "new animal" drug laws currently being used to regulate GE animals, for example, were written well before GE animals were ever conceptualized as a possible food source and are woefully outdated. Second, the theory of substantial equivalence is predicated on an assumption of safety; that is, it starts from a position of assumed safety, the burden of proof falls on the public to show harm.[54] Third, an agency with expertise in one area relevant to a permit application may not be best suited to evaluate the other potential effects a GEO may have when it is commercially released. This potential for problems in regulating transgenic fish and livestock under the Coordinated Framework Early was recognized as early as 1990.[55]

Pursuant to the Food, Drug, and Cosmetic Act of 1938 (FDCA), the Food and Drug Administration (FDA) is responsible for regulating food additives, food, and animal drugs. Within the Coordinated Framework, FDA regulates GE animals

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[49] See Myths, Dangers, U.S. Failures: The Truth About Asian Carp, 6 Part Series, Detroit Free Press (July 20, 2011).

[50] See, *e.g.,* Laird, C. A., and L. M. Page (1996) (The silver carp has the potential to cause enormous damage to native species because it feeds on plankton required by larval fish and native mussels); A.J. Bocek *et al.,* (1992) (Silver carp is an effective carrier of Salmonella typhimurium, and it can transport diseases to new areas).

[51] Injurious Wildlife Species: Silver Carp and Largescale Silver Carp, Federal Register: July 10, 2007 (volume 72, number 131).

[52] *http://www.startribune.com/local/135259173.html?page=1&c=y*.

[53] In fact, however, there are exceptions to this policy: the most notable, perhaps, is the USDA decision to regulate GE crops as plant pests based on their incorporation of a pesticide but also on their being genetically engineered (see Marden 2003: 769).

[54] Kelso, Dennis Doyle Takahashi. "Genetically Engineered Salmon, Ecological Risk, and Environmental Policy." *Bulletin of Marine Science* 74, no. 3 (2004): 509–28.

[55] Kapuscinski, Anne R. and Eric M. Hallerman, "Transgenic Fish and Public Policy: Anticipating Environmental Impacts of Transgenic Fish," *Fisheries* 12 (1990), p. 3.

under the concept of "new animal drugs."[56] The transgene, or recombinant DNA (rDNA) construct, used to produce a GE fish is considered the "new animal drug" under the agency's New Animal Drug Application process.[57] It is important to recognize that the actual *drug* being regulated is the rDNA construct itself in the resulting fish. The fish itself is not a drug. Yet under this system, approval of the GE drug equates to approval of the GE fish itself. If approved, therefore, the AquAdvantage Salmon® would be the first genetically engineered animal approved for human consumption.

FDA's authority was designed to provide the agency with oversight of traditional pharmaceutical drugs. Applying the new animal drug application process to GE salmon intended for interstate commerce and human consumption raises a host of problems. FDA's existing process does not ensure adequate protections for the environment, such as environmental analyses and public participation requirements.[58] Because of concerns about trade secrets, the process is open to public comment only *after* the approval of the new animal drug application, and thus, approval of the GE fish has been made.[59] Unlike applications led by USDA or EPA, FDA's approval process occurs almost entirely behind closed doors, making it nearly impossible for the public to participate meaningfully in an agency decision that could lead to devastating and irreversible ecological harm. While this process might protect confidential business information, it fails to adequately and transparently examine potentially far-reaching and serious consequences and environmental risks from GE salmon.

FDA's existing regulatory process was simply not designed to address the complex issues involved in developing genetically engineered fish for human consumption. Because the FDA's focus is on food and drug safety, the agency does not have the expertise or experience to adequately identify and analyze the environmental risks and consequences of GE salmon and other fish. In addition, the FDA approval process lacks adequate public participation, adequate consideration of the full range of environmental hazards, and the opportunity for sufficient input from other Federal agencies with expertise in fisheries and environmental risk.

As a result of these inadequacies, FDA's review process does not address the far-reaching environmental risks to fisheries and natural ecosystems. Among other issues[60], the current process fails to adequately consider threats to wild salmon populations, threats to commercial and recreational salmon fisheries, threats to fisheries targeting other species that interact with salmon, threats to marine and terrestrial food webs in which salmon are embedded, and threats to recovery efforts for salmon stocks listed as endangered or threatened under the Endangered Species Act.

Other Federal agencies with relevant expertise must play a stronger leadership role in the approval and regulation of GE fish. These include the National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service (USFWS), and the Environmental Protection Agency (EPA). NMFS and FWS have scientific expertise backed by extensive ecosystem research, and have expertise in conservation and protection of the natural resources that could ultimately be affected by GE salmon and other GE fish. EPA has knowledge and experience in the oversight and management of threats to water and watersheds. At a minimum, FDA should be required

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[56] 21 U.S.C. §§ 301–399a.

[57] The New Animal Drug Application (NADA) process, as required pursuant to 21 U.S.C. § 360ccc, is detailed in an FDA guidance policy document: Guidance for Industry #187, *Regulation of Genetically Engineered Animals Containing Heritable Recombinant DNA Constructs* (January 5, 2009).

[58] *See, e.g.,* 21 C.F.R. § 514.11(b)–(c) (stating that FDA will not disclose to the public the existence of a NADA file before approval has been published in the Federal Register, unless it has previously been publicly disclosed or acknowledged); 21 C.F.R. § 25.50(b) (asserting that "unless the existence of applications for . . . animal drugs . . . has been made publicly available, the release of the environmental document before approval of . . . animal drugs . . . is inconsistent with statutory requirements imposed on FDA"). In the case of the current GE salmon application, FDA has hosted a public hearing and has stated that it will seek public comment on the final environmental analysis documents required by the National Environmental Policy Act (NEPA) before publishing a final determination. However, such opportunities are not presently required by law and therefore may not be afforded each time the Agency is considering approval of a GE food animal application.

[59] FDA provided an opportunity for public comment in September 2010 before final approval of GE salmon, likely because the agency sensed this decision would be highly controversial; FDA, however, is not legally required to be similarly forthright when new entities seek approval from the agency for additional species or culturing conditions.

[60] Center for Food Safety v. Vilsack, No. C 09–00484 JSW (N.D. Cal.) (2009), on sugar beets, found that the USDA had improperly failed to consider environmental and economic impacts of GE sugar beets before approving its commercialization.

to consult these agencies during all stages of development and approval of GE salmon. Furthermore, if FDA is to remain the lead agency, FDA should be required not only to consult with these agencies, but also to either heed their advice or provide adequate rationale for any decisions to the contrary.

Concerns over the FDA approval process were brought to the attention of FDA in September 2010 in a letter from eleven U.S. Senators, including Senator Begich.[61] The letter requested that FDA halt the GE salmon approval process, citing concerns over unknown impacts to human health and environmental risks. These concerns are valid, and FDA is ill-equipped to deal with the environmental and biological consequences and risks associated with the farming of genetically engineered fish.

Congressional Oversight and the Need for Reform

Our nation is faced with the prospect of approving genetically engineered salmon and future GE fish under statutes that were not designed for that purpose, by a Federal agency that doesn't have the appropriate expertise to address environmental risk, and through a process that doesn't account for many of the major possible stakeholder impacts. This is not a judgment on the FDA or its many dedicated and capable public servants; we have tremendous respect for the FDA and its employees. But like all Federal agencies, the FDA has a specific perspective shaped by a particular set of statutes.

As its name implies, the FDA is charged with addressing issues of drug efficacy and safety, not matters of fisheries science, marine ecology, and evolutionary biology. So when faced with an application for an animal such as GE salmon, the FDA is structured to ask questions that reflect the laws that govern and shape the FDA—not those that govern, for example, the National Marine Fisheries Service. In the case of GE salmon—and the other GE fish that are sure to follow—an initial approval under the FDA's limited perspective falls far short of what is needed. It does not adequately reflect the full suite of public policy considerations, and it clearly does not reflect the body of concerns being expressed by citizens throughout Alaska, Maine, and other states across this Nation. As representatives of the citizenry at large, then, it is the job of members of Congress to step in and ensure that the tough questions are asked and answered.

Given the potential far-reaching consequences of genetically engineered fish, it is appropriate for Congress to use the full force of both its legislative and oversight powers to tackle this issue. Given the shortcomings of existing laws and regulations described above, it is essential that Congress take legislative action to ensure that genetically engineered salmon and other GE fish are not approved unless and until the full suite of environmental risks are thoroughly understood. And until the day comes when new legislation is enacted into law, Congress should use its oversight authority to rigorously scrutinize the FDA approval process, examine the environmental risks, evaluate the adequacy of the science being used in decisionmaking, and bring to light the possible consequences if worst-case scenarios should come to pass.

When Congress pursues both oversight and legislation, it should endeavor to achieve the four following overarching objectives:

First, Congress should demand more science and a modern, science-driven environmental risk assessment that treats complexity and uncertainty directly and objectively, using the most current methodologies[62] before GE salmon and other GE fish are given approval. Possible approval of GE salmon and other GE fish raises a whole host of new scientific questions that have not yet been answered. Merely sweeping scientific uncertainty under the rug is not an option. Comprehensive risk assessment—including a quantitative "failure analysis" would entail formulating a problem statement; identifying and prioritizing all possible risks; defining measurable assessment endpoints; estimating exposure, likelihood, and severity of consequences; identifying and appropriately treating uncertainties; and using this information to characterize the overall risk.[63] Congress should communicate to the Executive Branch that it expects the tough scientific questions to be dealt with *before* GE salmon are approved—not after. In so doing, the government should not rely solely on data from applicant companies without independent verification.

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[61] Letter to Commissioner Margaret Hamburg, Commissioner of Food and Drugs, FDA (Sept. 28, 2010).

[62] Burgman, M. 2005. Risks and Decisions for Conservation and Environmental Management. Cambridge University Press. Cambridge, UK. 488 pp.

[63] Kapuscinski, A. R., Hayes, K., Li, S., and G. Dana, eds. 200. Environmental Risk Assessment of Genetically Modified Organisms, Vol. 3: Methodologies for Transgenic Fish, CABI Publishing, UK. 304 pp.

Second, Congress should demand that the appropriate Federal and state agencies with the necessary expertise be provided a substantive role in assessing the environmental risks of GE salmon and other GE fish. FDA simply lacks the scientific expertise to identify and sufficiently analyze the full range of possible impacts from genetically engineered salmon. Other Federal agencies such as NOAA, the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, and the EPA are far better equipped with the scientific experts and institutional history to identify the impacts and assess the risks. It may even be appropriate to provide an agency such as the National Marine Fisheries Service with veto power over FDA approval if the agency concludes there is sufficient risk to wild fisheries or natural ecosystems. Other Federal bodies, such as the Regional Fishery Management Councils, could also provide valuable perspective given their emphasis on sustainable fisheries. Finally, state natural resource agencies should be involved, to take advantage of their decades of on-the-ground experience in salmon management and restoration.

Third, Congress should demand a far more inclusive and transparent approval process. Worst-case escapement and interbreeding scenarios for GE salmon could have major impacts across a wide group of stakeholders and industries. The ramifications for the public interest are of an entirely different scale and nature than those typical for drug approval. Stakeholder engagement should begin early in the process, during the problem definition phase of the risk assessment; such an approach is now considered the "state of the art" in addressing environmental risk, resulting in questions being asked and answered that are directly relevant to stakeholder concerns.[64] The current FDA process that provides for public input only *after* an approval is made is unacceptable and not in the public interest. While FDA is not presently required to provide more transparency or comprehensive public participation, the policy realities of GE fish demand that the government hold itself to a far higher standard than what is currently required of the FDA.

Finally, Congress should adopt a highly conservative, precautionary approach toward a future seafood supply that potentially entails genetically engineered fish. Given the uncertainty that surrounds GE salmon and other GE fish at this juncture, Ocean Conservancy is supportive of efforts to issue a ban or moratorium against GE salmon unless and until the scientific evidence demonstrates that GE salmon can be produced with little or no risk to wild fish and the marine environment. In this regard, we support Senator Begich's legislation, S.1717, to ban interstate commerce of genetically engineered salmon. Senator Begich's bill is a prudent step, given the considerable risks and public policy implications of allowing the production of first genetically engineered fish for human consumption.

Conclusion

Chairman Begich's decision to hold this hearing is a very important step toward achieving a better understanding of the full suite of environmental risks posed by GE salmon. I commend the Chairman for holding this hearing, and Ocean Conservancy encourages future actions to pursue rigorous Congressional oversight on this topic.

The environmental risks posed by GE salmon specifically, and GE fish in general, are real. How Congress and the Food and Drug Administration address the application for the first genetically engineered animal destined for human consumption will set a precedent for all applications for GE fish that follow it. While science cannot predict with certainty what the outcomes will be if engineered fish escape into natural ecosystems, given what is at stake, considerable caution is warranted.

Congress should take legislative action to ensure that the full suite of environmental risks is thoroughly understood before we proceed. A modern, science-driven environmental risk assessment must be applied to this issue, and stakeholder engagement and transparency must be at the heart of the process. Congress should ensure that the Federal agencies with environmental protection as their core mission—most notably the National Marine Fisheries Service—play a substantive role in fully assessing these risks. In short, Congress should ensure that the hard questions are asked and answered. If those questions cannot be satisfactorily addressed, we should not risk our oceans and our seafood supply to a future with genetically engineered fish.

Senator BEGICH. Thank you very much.
Our last speaker today, Mr. Greenberg.

[64] Kapuscinski, Anne. Professor of Sustainability Science, Dartmouth College, Hanover, NH. Personal communication, December 10, 2011.

STATEMENT OF PAUL GREENBERG, AUTHOR OF "FOUR FISH: THE FUTURE OF THE LAST WILD FOOD"

Mr. GREENBERG. Thank you. Thanks, Senator Begich, thanks Ranking Member Snowe.

I'm really glad that you have embraced this issue, because it's something that really needs to be put up to the national level in a very, very big way.

I don't have a doctor in front of my name—I'm sort of a fish guy.

Senator BEGICH. I'll give you a doctor for today.

Mr. GREENBERG. Thank you. You can call me a doctor of fishology, fish guy emeritus or whatever.

But I come here as somebody who has looked not necessarily all together from a scientific perspective, but from a social, from a historical, from a fishing perspective at aquaculture and fisheries around the world.

I've seen many fish farms; I've seen many fisheries, and all these lead me to think that this particular fish is a bad idea.

But I'm not going to get into some of the things that some of these great witnesses put forward. Rather, I wanted to put out there just one quote from the history of science expert, Carl Popper, who said, "Science may be described as the art of oversimplification—the art of determining what we may with advantage omit."

What I'd argue is that if science is the art of oversimplification, science in the service of bringing a product to market is an oversimplification of what's already been oversimplified.

And so time and again we've seen products introduced to the market where we don't have the time horizon to really adequately assess their effect.

You look at DDT, you know, DDT is synthesized in the 1870s. It's not until the 1970s that we realize it's destroyed a lot of bird life, and that we ban it. Same thing with PCBs. Not synthesized and used in this country until the 1920s, but not until the 1970s do we find that it's ruined fisheries in the Hudson River and throughout the United States.

With apologies to Dr. Stotish, if I compare this fish to a chemical, well, I mean at the same time they're trying to get this fish through FDA as a veterinary drug, so I think it's fair game.

So if we're going to have a genetically modified fish—and let's say the risks are not that big, let's go ahead with it—then I think the real essential question that has to be asked is not why shouldn't we have this particular fish, but why should we? What does this fish bring to the table?

You know, we have some genetically modified things out there in the world that have done some good. You look at Golden Rice, which delivers vitamin A to nutritionally poor countries in a very easy, cost effective way. But what does this fish do? Nutritionally, in an ideal world, Dr. Stotish says this fish is the same.

But what does it do in terms of addressing all these other environmental concerns that we worry about aquaculture? Well, first of all, the fish shortage problem—my condolences to Senator Snowe, but my enthusiasm to Senator Begich—not because of your parties, but because of your situation with salmon.

Senator Snowe, I have been to Maine, I have seen the devastated salmon rivers of Maine, and it's a tragedy. Senator Begich, you have a lot of salmon and it's just what you were born into. And we have a lot of salmon in Alaska, just a lot. I mean, over 200 million fish were caught in 2011—just a lot, a lot of fish.

And what's crazy is that 70 to 80 percent of it gets exported. So we do not have a salmon shortage problem in this country. The real threat to salmon is actually environmental destruction—which, as Senator Snowe has experienced in Maine—dams and all sorts of pollution have knocked out salmon there. In Alaska, it's huge, industrial projects like Pebble Mine, which threatened the largest salmon run left in America.

So those are the things that we're really worried about. It's not really overfishing. Alaska salmon is certified sustainable by the Marine Stewardship Council. It's a great harvest. It endures year after year—we don't have a salmon shortage.

Next problem, the salmon feed problem. OK, one of the big problems with salmon and all carnivorous fish aquaculture is that they eat a lot of other fish. And in the early days of salmon aquaculture it could take as many as five pounds of wild fish to grow a single pound of salmon.

Well, actually, the industry has begun to address this, and the feed conversion ratio and the "fish-in, fish-out" ratio has gone down dramatically, in some places by more than half. So, the industry has really cleaned up its act in that respect.

The AquaBounty fish actually turns out to be not really much more feed efficient than the regular, unmodified salmon. It eats about the same amount of food. It grows faster, but it doesn't eat less fish. So we're kind of getting the wool pulled over our eyes in this respect.

The sea cage problem, the next thing that Dr. Stotish brought up: yes, it's potentially a bad thing to grow salmon in open net cages where they can be exposed to the wild. Well, yes, we could grow some genetically modified fish in some containment facilities, but it turns out in the intervening 20 years—been 20 years since this fish was invented—lots of other fish have been found that work well in containment.

The Arctic char, which is a salmonid—I think it's delicious. Anyone have Arctic char? It's great, and it's indistinguishable from a salmon on the plate, maybe it's even a little more pleasant to eat.

But if you like salmon, and you want to have salmon, there's a company called Sweet Spring in Washington State that is now growing salmon in containment, and it only takes them 12 months to do it. And they're unmodified fish. So, why? Why would we have this fish?

Finally, there's the public perception problem. And this might be the most serious of all to both Senator Snowe, and to Senator Begich, insofar as you both have product that you're trying to put out on the market. In Senator Snowe's case, it's aquaculture Atlantic salmon. In Senator Begich's case, it's five species of wild, beautiful Pacific salmon.

The consumer, when they see salmon, they just see salmon. They don't make differentiations between it, and I can tell you this from dozens of lectures I've made throughout the country. What they do

perk up with is genetic engineering. Consumers do not want genetically engineered fish.

A *Wall Street Journal* poll said that only 36 percent of consumers would actually eat these fish. And what's really interesting, too, is that salmon farmers don't want this either.

I talked to a guy named Scott Nichols, who has a salmon farm, and he said this genetically modified fish would be bad for the salmon industry and bad for aquaculture, and that retailers—their response ranges from "unease to trepidation".

There is real concern among retailers that genetically engineered salmon might elicit a negative perception of salmon as a category. So all of your salmon products in both of your states stand to suffer extremely from the introduction of this fish.

So that's basically what I want to say. I guess the last thing I'd venture forth is that, you know, some people call this the "Frankenfish." I would call this fish the Solyndra fish, insofar as this fish represents outdated technology.

It's been on the market—or it's been in consideration for 20 years, and in those 20 years, surprise, surprise, the industry has improved. Fisheries management in America has improved. All these preconditions that we thought were a big problem have improved, and we don't need this particular fish to address those problems.

So, in conclusion, I fully support Senator Begich's legislation S. 1717, to ban interstate commerce of genetically engineered salmon. Senator Begich's bill rightly protects the American people from a risk they shouldn't be forced to take.

Thank you.

[The prepared statement of Mr. Greenberg follows:]

PREPARED STATEMENT OF PAUL GREENBERG,
AUTHOR OF "FOUR FISH: THE FUTURE OF THE LAST WILD FOOD" [1]

Introduction

Thank you Chairman Begich, Ranking Member Snowe and other members of the Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard. It's heartening to see this important issue debated on such a high level and I greatly appreciate your invitation to testify.

The historian Carl Popper once famously wrote, "science may be described as the art of oversimplification—the art of determining what we may with advantage omit." [2] I'd argue today that if science is the art of oversimplification, then science in the service of bringing a product to market is often an oversimplification of the already oversimplified. In the drive to get something saleable on supermarket shelves, omissions in research will inevitably occur and the time span needed to adequately assess the environmental risk of that new product is often insufficient. Dichlorodiphenyltrichloroethane or DDT was first synthesized in 1874 [3]. It was not banned until 1972 [4] long after it was proven that the insecticide had done profound damage to American birdlife [5]. Polychlorinated biphenyls or PCBs were launched commercially in this country in 1929. We did not get intimations that they were dangerous environmental chemicals until the 1930s and they were not determined a pollutant and banned until 1979, long after they had damaged Hudson River fisheries and other fisheries throughout the United States [6]. The genetic engineering of living organisms is a new science. In 1973 the first genetically engineered organism

[1] *www.fourfish.org* and *http://www.nytimes.com/2010/08/01/books/review/Sifton-t.html?pagewanted=all*.
[2] Popper, Karl, *The Open Universe,* W.W. Bartley, 1992, p. 44.
[3] Center for Disease Control, *http://www.cdc.gov/malaria/about/history/*.
[4] Environmental Protection Agency, *http://www.epa.gov/history/topics/ddt/01.html*.
[5] Environmental Protection Agency *http://www.epa.gov/international/toxics/pop.html*.
[6] Envirmental Protection Agency *http://www.epa.gov/osw/hazard/tsd/pcbs/pubs/about.htm*.

was created by humans [7]. We will not know the full environmental impact of their introduction into the food supply, for many, many years.

So if we take as a given that there are many unknowns about genetically engineered organisms, many potential downsides, then we should carefully weigh the factors that are motivating us to bring a genetically engineered organism into the American food system. Does that new organism have an over-weighing positive, like, for example, Golden Rice which through a gene modification was able to cheaply deliver vitamin A to nutrient deprived children in the developing world? [8] Does Aqua Bounty's AquAdvantage salmon offer anything of that importance? Nutritionally it is at best the same as other farmed salmon. So what else has it got? Instead of asking "why shouldn't we have genetically engineered salmon?" we should be asking "why should we have it?" If we look carefully at the arguments proponents of this fish have put forward in its defense then I believe a rational person would conclude that this fish doesn't really offer us very much. I'll touch on four areas where I feel the fish comes up short.

1. The Fish Shortage Problem

The proponents of the Aqua Bounty AquAdvantage salmon emphasize that the we are running out of wild fish [9]. Globally speaking it's true that there are not enough wild fish to meet demand and we will indeed need more aquaculture if we are going to feed 10 billion people. But which fish do we need more of? Certainly not salmon. The United States still has lots of it. This year's Alaska salmon harvest is projected to have been one of the largest since statehood, with over 200 million fish coming to market.[10] These salmon were harvested under strict supervision of the State of Alaska's Department of Fish and Game and nearly the entire Alaska salmon harvest has been certified as sustainable by the Marine Stewardship Council.[11] Even with these intense restrictions on salmon fishing in Alaska, we still have much more salmon than we can use. 70–80 percent of the United States' wild salmon catch is shipped abroad every year.[12] The real threat to American salmon is habitat destruction [13] or potential habitat destruction in the form of large-scale industrial development like the one proposed at the so-called Pebble Mine site in America's most important salmon fishery, the Bristol Bay watershed.[14] As long as we keep Alaska rivers clean and healthy America will have all the salmon it needs. As for the rest of the world, it will not be a cold-water Western fish like salmon that will provide protein for three billion additional people. It will be a naturally faster growing, feed-efficient, warm-water species like Indochinese swai and Nile tilapia that will do the job.[15] And lest engineers think tinkering with tilapia and swai is a good idea, I would venture that there is much improvement that can be made with the husbandry and diet of those fish, obviating the need for genetic engineering.

2. The Salmon Feed Problem

The overexploitation of wild forage fish for use as salmon feed is a grave concern. In the early days of salmon farming it could take 5 pounds of wild forage fish to grow a pound of salmon. But improvements in diet, husbandry, and plain old-fashioned selective breeding have cut what's called the "fish-in, fish-out" or FIFO ratio on the most efficient salmon farms in half.[16] The AquAdvantage salmon doesn't

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[7] Modern Genetics: engineering life, Lisa Yount, Chelsea House, 1997, p. 20.

[8] Ye, X; Al-Babili, S; Klöti, A; Zhang, J; Lucca, P; Beyer, P; Potrykus, I (2000). "Engineering the provitamin A (beta-carotene) biosynthetic pathway into (carotenoid-free) rice endosperm". Science 287 (5451): 303 5. doi:10.1126/science.287.5451.303. PMID 10634784.

[9] *http://www.aquabounty.com/PressRoom/#l0.*

[10] Bountiful Alaska salmon harvest forecast for 2011, Reuters, March 6, 2011 *http://www.reuters.com/article/2011/03/06/us-alaska-salmon-idUSTRE7252OP20110306.*

[11] *http://www.msc.org/track-a-fishery/certified/pacific/alaska-salmon.*

[12] E-mail from Andy Wink, McDowell Group, December 13, 2011 "regarding the percentage of Alaska salmon harvest sold to export markets. It depends on the year and the species of salmon, but in total, the majority of Alaska salmon is exported—typically 70–80 percent or more." *AndyW@mcdowellgroup.net.*

[13] Lichatowich, James A. *Salmon Without Rivers,* Island Press; 1 edition (August 1, 1999).

[14] "Alaska's Choice: Salmon or Gold", *National Geographic,* December, 2010 *http://ngm.nationalgeographic.com/2010/12/bristol-bay/dobb-text.*

[15] This is a commonly held hypothesis among aquaculture scientists. For a discussion of tilapia see Costa-Peirce, Barry *Ecological Aquaculture,* Wiley-Blackwell; 1 edition (January 15, 2003). For a discussion of swai also known as tra or Pangasius, see my *New York Times Magazine* article "A Catfish by Any Other Name" *http://www.nytimes.com/2008/10/12/magazine/12catfish-t.html?pagewanted=all.*

[16] Naylor, Rosamond L. *et al.,* "Feeding aquaculture in an era of finite resources", Proceedings of the National Academy of Sciences, 2009.

really bring much more in terms of feed efficiency.[17] This is an important point that media doesn't seem to get. Yes, the AquAdvantage fish can in ideal conditions grow significantly faster than non-engineered salmon. But, and this is a major "but", the engineered fish needs comparable amounts of food as the non-engineered salmon to reach market weight. AquaBounty's own predictions (and these are best case scenarios) put feed efficiency of the AquAdvantage salmon at only 10 percent better than unmodified salmon. This is not enough to justify the risks it entails. Moreover improved feed efficiency is just one pathway to decreasing farmed salmon's footprint. In the decade since the AquAdvantage fish was synthesized, vegetable-based salmon diets have been created that require no wild fish meal at all. Some of these new feeds are made from recycled agricultural byproduct that might otherwise go unused.[18] Developing alternative feed not alternative fish is, in my opinion, the critical next step for the aquaculture industry.

3. The Sea Cage Problem

The AquAdvantage salmon proponents maintain that the modified salmon grows so fast that it can be cost-effectively produced in out-of-ocean tanks.[19] For many years, conservationists have worried that salmon grown in open ocean "sea cages" where there is frequent interaction with wild fish has led to disease transfer, escapes, and pollution.[20] Tank or "containment" growing, many argue is the only safe way to farm salmon but it is energy intensive and farmers worry that slow-growing fish would not allow a farm to cover its energy costs. This barrier has already been broken with two non-engineered fish. The arctic char, a fish native to North America and Europe and haling from the same taxonomic family as salmon, turns out to have a natural adaptation for living in close quarters and does well in containment facilities. Nearly all arctic char are grown in containment and their flavor, taste, and texture in my experience is so close to that of salmon as to be indistinguishable.[21] And for those who would prefer a true salmon over a char SweetSpring of Washington State is now growing Pacific coho salmon to harvestable weight entirely in containment in just 12 months. This is comparable to the growth speed of the AquAdvantage fish.[22] If these options exist for cost-effective containment growing of non-engineered salmonids, why should we even broach the possibility of genetic contamination in the form of genetically engineered salmon?

4. The Public Perception Problem

I support the development of an environmentally sound aquaculture sector in the United States. Seafood is a deficit item in the American trade portfolio and it is dismaying to me that more than 80 percent of our seafood comes from abroad. But there is a major obstacle to the growth of American aquaculture: consumer distrust. In the many dozens of lectures and presentations I have made throughout the country consumers have demonstrated high suspicion of farmed fish and a lack of fine-scale distinction of product. To the average consumer salmon are salmon. Nevertheless one subject that makes consumers pay attention is genetic engineering. People, at least the people who come to my lectures, don't want to eat engineered fish. And salmon farmers know this. As Scott Nichols, the director of the salmon aquaculture company Verlasso wrote me earlier this week, genetically engineered salmon would, "be bad for the salmon industry" and "bad for aquaculture." Nichols goes on to say that the response of supermarkets and other retailers to genetically engineered salmon "ranges from unease to trepidation" and that "there is real concern among retailers that genetically engineered salmon might elicit a negative perception of salmon as a category".[23] In other words genetically engineered salmon could give *all* American salmon a bad name whether they are farmed Atlantic salmon hailing from Maine or wild Pacific salmon from Alaska. Moreover the majority of Americans don't want genetically engineered salmon. An online poll by the Wall Street Journal showed that only about 36 percent of consumers would willingly eat genetically en-

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[17] Environmental Assessment for AquAdvantage® Salmon, Aqua Bounty Technologies, August 25, 2010, Page 36.

[18] Frederick T. Barrows, USDA Lead Scientist and Nutritionist USDA, Agricultural Research Service *Rick.Barrows@ARS.USDA.GOV*.

[19] Aqua Bounty Press Room, *http://www.aquabounty.com/PressRoom/#l3*.

[20] Monterey Bay Aquarium, "Farmed Salmon" Seafood Watch Report, Mazure, Robert and Elliot, Matthew *http://www.montereybayaquarium.org/cr/cr__seafoodwatch/content/media/MBA__SeafoodWatch__FarmedSalmonReport.pdf* Page 2.

[21] Artic Char Assessment, Blue Ocean Institute, *http://www.blueocean.org/seafood/seafood-view?spc__id=94*.

[22] Sweet Spring *http://www.sweetspringsalmon.com/local.shtml* and e-mail (October 19, 2011) with Per Heggelund, Director, SweetSpring *per@sweetspringsalmon.com*.

[23] Nichols, Scott, Director of Verlasso, e-mail December 13, 2011 *scott@Verlasso.com*.

gineered salmon if it were labeled as such.[24] And in European markets 0 percent would eat it. Genetically engineered foods are heavily restricted in the European Union.[25] Thus having genetically engineered mixed in with non-engineered fish in the American trade portfolio would damage American exports—Europe will simply not buy it and Europe represents one of the top three markets for salmon in the world.[26]

Conclusion

In conclusion I would put forward that the AquAdvantage salmon is an idea whose time has passed, even if genetically engineered animals are perceived as belonging to the future. The problems that plagued the salmon farming industry when the AquAdvantage fish was first conceived over a decade ago—poor feed conversion, inability to grow salmon in containment, poor management of wild salmon fisheries—have been addressed in the intervening period. The AquAdvantage salmon is therefore a kind of Solyndra fish. A technology that has been made irrelevant by advances elsewhere in the marketplace yet which, for some reason still seems to draw taxpayer dollars in the form of research and development investment. This in spite its a lack of germane benefits to the improvement of the global food system. This fish is not worth the risk. We would be better pursuing a course of truly sustainable aquaculture and better management and use of our wild fisheries.

I am therefore fully supportive of Senator Begich's legislation, S. 1717, to ban interstate commerce of genetically engineered salmon. Senator Begich's bill rightly protects the American people from a risk they should not be forced to take.

Senator BEGICH. Thank you very much, Mr./Dr. Greenberg for your testimony. I will say—I'm going to ask Senator Snowe to go ahead and start with questions—she has a time constraint.

But I want to say first, Mr. Greenberg, and to all your comments about—as you said in the 1970s, 1980s, and—late 1980s, fisheries were under siege in a lot of ways, even in Alaska. But a lot of the work we did was to focus on sustainability and how to manage our fish stocks for the long-term sustainability—from stock assessments every year, to management through still somewhat controversial—but not as much as it used to be—quotas and so forth, CDQs, and many other ways to manage the product.

And because of that, the quantity and the quality has increased significantly in how we manage it, how we handle it. And we like to say from Alaska that if you're at McDonald's or you're at Costco, you're eating our fish. If you're at the finest restaurants in the world, the likelihood is you're eating our fish, because they like to advertise it.

So, we think we've done something that in the 1970s, when I was growing up, was unheard of—that we thought actually our fisheries would go away because of the poor management. And I think we have improved significantly in the last 20 years, so your point about that is well taken.

Not only in that end, but other communities that have done farm fishing have also improved in a lot of ways. So let me end there.

Before I do my questions I'll ask Senator Snowe—I know she has a series of questions, and then I'll ask some. And then, depending on time, we'll go back and forth and try to have a selection from any of you.

Senator SNOWE. Thank you, Mr. Chairman. I appreciate that.

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[24] *http://online.wsj.com/community/groups/question-day-229/topics/would-you-eat-genetically-modified-salmon?commentid=1603615.*

[25] *Wall Street Journal,* February 22, 2011 *http://online.wsj.com/article/SB10001424052748704476604576158230363494712.html.*

[26] The Great Salmon Run: Competition Between Wild and Farmed Salmon, Knapp, Gunnar *et al.,* World Wildlife Fund, January, 2007 *http://www.worldwildlife.org/what/globalmarkets/wildlifetrade/WWFBinaryitem4985.pdf.*

And I want to thank all our panelists here today for giving some thought-provoking issues to consider in this unprecedented issue that clearly raises a number of concerns and questions for policymakers, and obviously for this country.

For example, Dr. Stotish, in your plan, in your confinement proposal, did you ever consult, for example, with aquaculture operators? In the state of Maine we've had a number of organizations that came together on a mutual agreement for the aquaculture operators that ultimately has been very successful in containing the salmon. We've had no escapes in the last 7 years.

Now, as the Maine Aquaculture Association would say, that it isn't a question of the type of facility but it is a question of how it's managed. So, with respect to your proposal, and in particular your land-based containment facilities, what suggests to you—in answer to the other concerns that have been raised by the other witnesses—as to whether or not you can contain it 100 percent? That it is a fail proof system? Because I think that is essential, without putting the population at risk.

Dr. STOTISH. Thank you, Senator. That's a very good question. And the answer is, yes, we have consulted with experts in the aquaculture industry and in the fisheries sector.

We've consulted extensively, and a fundamental issue in my written testimony that I address at some length is the existence of rigorous management procedures, which are essential in the operation of any facility. Then the inclusion of rigorous, redundant, multiple biological and physical containment provisions.

Now, I think I have an opportunity to also put some of your concerns to rest, as well as some of the concerns of some of the other panelists, that this is not an FDA only review with regard to the environmental assessment. I am aware, although not privy to the details, that the environmental assessment prepared by the Center for Veterinary Medicine has also been reviewed by NOAA, National Marine Fisheries, Fish and Wildlife Service, Department of the Interior, as well as the USDA and other Federal agencies.

So, this is not a simple, one-off review by the Center for Veterinary Medicine. They've taken their responsibilities under NEPA very seriously, and there's been extensive coordinated review with other Federal agencies. Those reviews have added significantly to the approval timelines.

As I mentioned in my testimony, our documents and the results of the initial FDA reviews were made available nearly 16 months ago. So there has been extensive, serious reviews by professionals within other Federal agencies, who are skilled in the art, and I think it's worthwhile to make you aware of that. Certainly you can verify that by direct discussions with the FDA and with the CVM.

Senator SNOWE. Well, I'll follow up on that issue in one moment with the other panelists as well, because it does get to the crux of some of the concerns.

Who would be monitoring these containment facilities?

Dr. STOTISH. Well, one thing that I should also make clear—AquaBounty, as I mentioned in my testimony, is a technology company. We basically produce—and our product will be a triploid, all female egg. That egg will then be sold to FDA-approved and inspected facilities for grow-out.

The first such facility is located in Panama. That facility has already been the subject of a detailed environmental assessment and an FDA preapproval inspection.

Additional sites will be approved on a case-by-case basis by submission of an environmental assessment, review, and a preapproval process, and preapproval inspection by FDA to look at the unique attributes of the site, the management provisions in place, and the unique containment provisions required.

So, it is our belief—and we believe that the facts support that belief—that we have gone to an unprecedented length to demonstrate that not only can this technology be deployed safely, but the management procedures and the biological and redundant physical containment measures can assure perhaps a more sustainable practice than exists today.

Senator SNOWE. Do you believe that the goals of zero risk of escapement, or of 100 percent sterility are attainable?

Dr. STOTISH. Senator, as you know, I can't promise you that the sun will come up tomorrow. I can tell you that there's a high probability that it will.

I can tell you that we've consulted with experts in the field, and we believe—and experts agree with us—that we've mitigated, in every possible way, every possible imaginable risk, including failure scenarios, by using multiple and redundant containment provisions.

I will remind you, in over 15 years of operation in our hatchery we have never lost a single fish.

Senator SNOWE. Well, Dr. Epifanio, am I pronouncing that correctly?

Dr. EPIFANIO. Absolutely correct, yes.

Senator SNOWE. I'd like to hear from you and the other panelists as well on this question. It's something that the Chairman and I have discussed as well.

But in having reviewed the process, I mean, the FDA is required to consult with NOAA. But much of that information, to our knowledge, is not really available. Now, maybe Dr. Stotish, you have information. But in terms of transparency in what NOAA contributed to the process, we have no real way of knowing.

Dr. STOTISH. Senator, the only people who would know that would be the people in those agencies. As a sponsor I'm not entitled to that information, and I only know by inference and by information that we've received from other individuals.

Senator SNOWE. And that's one of the issues that we are concerned about. Because for example, we have a copy of the letter from NOAA to the Center for Veterinary Medicine back in July indicating that, in fact, the FDA decided to make a different decision on whether or not genetically engineered salmon came under the Endangered Species Act. And they said it would have no effect on the wild population.

Originally, they thought it would and then they reversed their position and said no. So we have no way of knowing what contributed to that decision, whether or not that section of the ESA should be triggered when we're talking about what could be a potential risk to the wild population.

Yes?

Dr. STOTISH. If I may, Senator, you also have, I believe, a copy of a section of a letter from the FDA to Representative Markey from Massachusetts addressing the basis for the review and the consulting reviews by other Federal agencies. It's sources of information like that upon which we rely for information. We have no direct knowledge of that. As a sponsor, we're not entitled to that.

In the discussion of transparency, we've provided far more documentation and far more data than we have received in return as a drug sponsor.

Senator SNOWE. No, and I wasn't suggesting it's your responsibility; it is on the agencies and whether or not we should construct a process that requires NOAA, for example, to be a stakeholder in this process, not just sort of an ad hoc, informal participant.

So I'd like to have others comment. Dr. Epifanio, Dr. Leonard, and Mr. Greenberg.

Dr. EPIFANIO. Senator, thank you. That's a great question. I was fortunate enough—a year ago I was on a yearlong detail with the U.S. Geological Survey, Department of Interior, where I ran the fisheries program. And during some public hearing process last fall, these discussions were out there within the department.

The level of information that was available to us, even internally to the agency—now, I don't know if I was specifically withheld from such information, but generally the full set of information was not always available to us either internally, and we are bound by confidentiality kinds of considerations and so on.

That being said, I also don't want to make FDA the punching bag in the situation here. They're very fine scientists, and they're veterinarians, et cetera, that when they do their job—and I've worked with them on traditional aquatic animal drug approval process, and it's a very meticulous, very fine process that they have.

And they do reach out. It's not necessarily—I'm not sure of the full requirements to do so, but they do. But there is some opacity to the process that I think could be improved.

Senator SNOWE. Dr. Leonard?

Dr. LEONARD. Yes, Senator, I would agree with what Dr. Epifanio says. I would add, I guess, three specific pieces. With respect to this question of 100 percent containment and the risk of getting out, I think—the documents that I've seen to date that have been released really don't do a full, modern, quantitative risk assessment of both those individual probabilities and then what the likely impacts are if they do get out.

And, in particular, there's a concept called failure analysis, which is a lot like what it sounds. It determines where along a production system there is likely to be failure, and then what are the consequences of that.

Dr. Anne Kapuscinski, who I think you invited to come to testify, is the world expert on this, and I would encourage the Committee to look at the work. She literally wrote the book on how to think about risk assessment.

With respect to the question of consultation with other agencies that have expertise in fishery knowledge, you mentioned NOAA. I think in an ideal world it would be useful to consider having NOAA or Fish and Wildlife actually in charge of the environmental assessment side of these kinds of applications, and having a very

strong—perhaps even have a veto role if they can't be convinced that those risks are addressed.

Now there's some consultation, but the final decision is ultimately left for NOAA—I'm sorry, for FDA.

Senator SNOWE. Mr. Greenberg.

Mr. GREENBERG. I'm not going to talk about the interrelatedness of different departments here. But as a citizen, I just see we have a strapped government that can't afford the regulation that it has right now.

And it's very important that you listen to Dr. Stotish's words. He's shifting the onus of control of this fish from AquaBounty over to the FDA, over to the taxpayer.

And already when you look at the fish situation, we can't afford it. We only test 2 percent of the fish coming into this country from abroad, and over 80 percent of our fish comes from abroad. So we want to add another regulatory burden on top of all this? It just doesn't seem to make any sense to me.

Senator SNOWE. Thank you. Mr. Chairman.

Senator BEGICH. Thank you very much. Dr. Stotish, let me—I want to walk through. You've described it a little bit in your written testimony and you talked about it a little bit today. And I know when we met in my office—I want to say thank you very much for coming by and having a conversation about the product and what you're trying to accomplish.

I want to walk through two steps here, just make sure I understand the process. So the salmon eggs are grown in—is it Prince Edward Island? They're grown there in Canada and then they're shipped to Panama, and then they are developed there for market, maybe U.S. or wherever. Is that——

Dr. STOTISH. Basically, Mr. Chairman—Senator Begich—that's correct.

It has to do with the process for new animal drug approval. This is the regulatory paradigm, and I will point out there's a bit of history here.

A coordinated framework was agreed to and proposed by the Office of Science and Technology Policy, and finally approved back in 1986. In the subsequent 25 years, there was not a regulatory paradigm for the use of this policy in the regulation of transgenic food animals. As you know, there has been significant development of agricultural products.

So, with that in mind it took the majority up until 2009, of that time between 1986 and 2009, to arrive on, number one, whether these organisms needed to be regulated. As someone pointed out, this could be modern breeding technology. And if so, who should regulate them?

And in 2009, the CVM published Draft Guidance 187 that said that this was the mechanism that the Federal Government would use to regulate this technology.

Now, in light of that—and there is statutory requirement for NOAA involvement and National Marine Fisheries involvement in this process. And I think that may be in my——

Senator BEGICH. Yes, let me hold on. I'm going to come back to the NOAA thing for all the folks here, and fisheries.

I want to understand the process, which seems somewhat complicated.

Dr. STOTISH. Let me answer your question.

Senator BEGICH. Go there. That's where I want to go.

Dr. STOTISH. Yes. The brood stock are maintained in Prince Edward Island at our hatchery. The fish are bred there, and there's a diagram of the process that we use to generate all females and triploids. I won't go through that unless you want a particularly painful, technical discussion.

Dr. STOTISH. But I can assure you that that process is genetically 100 percent fidelity.

So, then the eggs will be—after release, and this is analogous to a drug release—the eggs are assayed for triploidy, so that we know the degree of triploidy. The method's been validated to greater than 99 percent.

Then they would be put into a container which contains a drug label, a secure container, and they would be shipped to the location where the grow-out occurs.

In this case, the one approved facility—or the one proposed facility—is in Panama. That site has been previously inspected and an environmental assessment has been submitted.

So the fish would be grown in tanks in a land-based facility there, and if the product were to be approved, those fish would be legal for sale in the United States and in any other country that chose to accept the imprimatur of the U.S. FDA approval.

Senator BEGICH. If I can follow—I want to understand, if you can describe a little bit, is the Panama facility one that is designed specifically for this purpose, or has it been used for something else and you're part of—who owns this facility? What's the control mechanism here? Is it just another part of whatever business is there, they've added a new line of business?

Dr. STOTISH. No, that's not it.

Senator BEGICH. So, is it specifically for your company to utilize?

Dr. STOTISH. We have leased the facility from the owner of the land, who is also the largest trout farmer in Panama. And the reason that we went to that facility is there was great interest in Panama as an economic development tool to be able to grow this fish.

We created a facility there that contains the redundant biological and physical containment that is characterized in my written testimony, and that site has been then submitted as the initial approved productionsite for AquAdvantage salmon.

Senator BEGICH. And is the FDA——

Dr. STOTISH. And the control is ours, Senator, I should mention that. We're in control of that facility.

Senator BEGICH. OK, so you're in control of that component of the facility. And FDA doesn't have someone onsite, they come and inspect the original facility to check off——

Dr. STOTISH. They have sent a team, including a member of the NOAA staff, the field inspection staff, and the FDA inspectors and inspected that facility over a year and a half ago.

They can do periodic inspections, and we're periodically inspected by authorities in Panama and the United States.

Senator BEGICH. And is there a legal requirement, they have to do that? Or because it's in Panama—I'm just trying to figure out

how that works. Because it's a foreign country, so does FDA have a legal authority to do that, or is it the company's requirement to have them come in order for you to sell product in the United States?

Dr. STOTISH. First of all—well, let me try to deal with that because you're getting into the weeds of a very thorny geopolitical issue.

Senator BEGICH. Well, let me pause you there. It's important because, I'll tell you, we've sat in this room here before on airline inspections with foreign countries and we've had to pass legislation because of the lack—even though they all tell us they're all inspected, they're great, but they've moved all their shipping or their maintenance facilities to foreign countries that have less rigorous—because our FDA guys, or in that case the FAA folks, can't get over there on a regular basis, inspect them at the levels they can here.

Dr. STOTISH. I think I can answer your question and put your fears to rest. First of all——

Senator BEGICH. That's probably a two-part question. You'll probably answer the question by the time I get to the second part, but go ahead.

Dr. STOTISH. OK, Senator. First of all, AquaBounty has a vested interest in the integrity and credibility of that site, so it's important to us that that site be inspected and approved. As I pointed out, we're subject to review by authorities in Canada, Panama, and the United States, and we have cooperated fully.

And there is a coordinated review process instituted and implemented by the Center for Veterinary Medicine and the FDA, working with those other two regulatory agencies, including meetings here in Washington, including sharing of data and sharing of information on a routine basis.

The second aspect of that is that, in the United States, we have a concept that goes back to Jimmy Carter called the Global Commons. The U.S.—and this addresses the legality of the question that you answered, and this really gets into the fine points.

The U.S. has a responsibility, and any Federal agency has a responsibility for the environmental consequences of any action anywhere in the world, that's the so-called Global Commons.

Now, that also bumps up against the issue of sovereignty of foreign nations and the right to regulate products within their own geography. In this instance, there's been a remarkable degree of international cooperation and direct cooperation between the regulatory agencies that have worked together, shared information, shared inspections.

And, in fact, the U.S. FDA is training inspectors and regulators from Panama as they implement their new regulations in this area.

So, we're not just regulated by the Center for Veterinary Medicine—we're regulated by the Environment Canada, by Health Canada, and by the Panamanian aquaculture authorities.

So there's more than enough inspection and oversight at our facility, and we have frequent inspections.

Senator BEGICH. Let me do this. I'm going to ask Senator Snowe if she has some additional questions, only because she has to leave by noon, then I'll have a few more.

Because I want to follow up on the issue of who does inspection. I want to really get to the point of NOAA, National Marine Fisheries—that component of this that I think is severely missing in this equation.

And so let me pause there and just see if Senator Snowe has some additional questions before. I know her time is limited, so.

Senator SNOWE. I wanted to ask Dr. Stotish about the fact that obviously there have been significant improvements in the traditional selective breeding of the salmon and aquaculture, and certainly that's been our experience in Maine as I said with this very unique agreement between conservationists and the aquaculture industry that achieved great success over the last 7 years in preventing any escapement of salmon.

Why is it so important to have GE salmon as opposed to pursuing traditional salmon aquaculture?

Dr. STOTISH. If I may, Senator—and that's also a very good question. It was raised earlier by one of the other panelists.

First of all, this is a very precise and specific genetic change. The feed efficiency of our fish is 10 to 20 percent greater than the wild type unmodified salmon.

It is true that Cohos are being grown in the Pacific Northwest in land-based facilities. And, in fact, land- based facilities are the way of the future.

But one of the barriers to successful land-based cultivation of Atlantic salmon are the slow growth rates in the early part of the life cycle, the first one to 3 years of life. That's specifically the part of the life cycle that is accelerated in our rapid growth phenotype.

So, the opportunity—and because of the way we carry our gene, for instance, what you can accomplish by selective stock-enhancement or breeding in 25 years we can accomplish in a single generation. We can characterize the nature of the change; we can specifically measure the change, and we can basically understand the implications of the change and the impact on production.

So, what this does enable is large scale land-based cultivation of salmonids that takes it out of the sea cage and puts it into a manageable, we believe environmentally sustainable, culture system.

We think it also create opportunity for economic development, for instance, in Midwestern states: South Dakota, North Dakota, Wisconsin, Ohio, Minnesota, where these land-based facilities could produce salmon closer to consumption centers without these long transportation lines.

We haven't talked about the cost of transportation, both the direct cost and the environmental cost. It's very expensive, Senator, to fly salmon from the south of Chile to New York markets in 747s, or to fly them from Oslo to New York or to San Francisco.

The ability to grow these fish would not only create and recreate an industry that has been largely lost in the United States. As you probably know we produce less than 17,000 tons of Atlantic salmon in the United States each year.

So, the opportunity to create that industry, to create and reduce our imports and to produce the food locally—as many people think perhaps is the way of the future—we think it's a good opportunity, and that's what we think this product will bring to the marketplace.

Senator SNOWE. How long have you been in this business? Did you submit your first application 15 years ago, is that right?

Dr. STOTISH. Again, Senator, the answer to that question is complicated by the lack of a regulatory paradigm.

The first studies were submitted in 1995. The guidance document wasn't published by the Center for Veterinary Medicine until 2009. The impetus for that publication was the imminent approval by CBER, of a medical product called ATryn, which is produced in the milk of transgenic goats.

So, the CVM released its guidance document, and that was the first transgenic animal that was approved in the United States.

I should point out, in a most unique situation, that product was approved by the European Medicines Unit 2 years before it was approved in the U.S.

The last thing I'll mention in that regard is representatives of the government of China have mentioned that they have more than 70 pending applications for transgenic animals and fish in China at the moment. Countries like Argentina, Brazil, and other countries around the world have embraced this technology and are deploying it.

So there's an opportunity here for American innovation, creation of American industry, creation of American jobs, and we believe in a safe and sustainable environment.

Senator SNOWE. Thank you. Thank you, Mr. Chairman.

Senator BEGICH. Let me, if I can—I guess one of the pieces of this equation that I'm still struggling with—and I recognize you had to work in a unique paradigm with regards to the regulatory process—that's part of the problem.

And I think of the many industries that we deal with in Alaska, and it doesn't matter if it's the natural resource development industry or, as you mentioned, Pebble Mine, you know, the regulatory process is enormous. And the amount of agencies that have to actually sign off on it, not just consult, but actually say yea or nay are pretty significant.

And let me—because you've laid out the regulatory parts. Let me ask other folks if they could comment in regards to—my instincts tell me I still look at FDA as someone who, maybe they consult with NOAA or the National Marine Fisheries or Interior, the real question is there is a different kind of impact.

I mean, when you're doing a drug it's not a whole environment you're about to touch. And so I'm trying to understand why this product should not have some approval process or joined approval process with regards to NOAA or the National Marine Fisheries in this.

And I'm struggling with this because I think it's different. I mean, when you talk about approving a drug, you know, the FDA is very good at that. Maybe they take a long time, but they're very good at it.

And once they produce it, or the result of it, then the next result is individual consumption, not a whole environment that can be touched. And you can actually pull it off the market very quickly.

And I'm trying to think of one of them that I remember I was taking some time ago for a neck pain, and they took it off the market very quickly because there were some issues with heart attack.

Well, ended that impact to the environment, which in that case was humans. So, let me—before I ask you, Dr. Stotish, to answer, I'm curious from the others if they have any comment.

That's the difference here that is significant to me. Because you can't just go back in there and yank the fish out of the pond. And I can tell you, I live off, in Anchorage, a small—in an urban setting called Cheney Lake that used to be a place we could fish.

Now there's pike in there, and that's over. You know, it's a whole different story now. And I remember as mayor we have spent a lot of money trying to get them out of there, and somewhat successful but not as much as we would like.

I don't know if folks want to—Dr. Leonard?

Dr. LEONARD. Yes, Senator, I have just a couple of comments.

I would agree with you, the question really is not, "Is there a regulatory structure?" There certainly is. The question is does it address what we as a society want to address? And I think the answer is no there.

In terms of a little bit of specifics, the new animal drug provisions within the coordinating framework under FDA, it's worth recognizing that those were developed before the concept of GE animals for human consumption was sort of on the table.

So, in that sense, they are essentially sort of antiq—they're outdated with respect to that particular issue.

Senator BEGICH. Can you tell me, how long ago were those developed? I don't recall. Do you know?

Dr. LEONARD. I don't have the date right in front of me, but I can certainly get that for you.

With respect to NOAA, I would agree, as we've said before, that I think they need a driving role in this whole process, more than is currently set up.

And I think it's also worth again sort of reiterating this issue of risk assessment, which is fundamentally what this is about. And it touches on Paul's comment about public perception.

If you look at state-of-the-art risk assessment, it involves bringing stakeholders into that process from the beginning, so that they develop basically the questions that need to be answered so that those are relevant to the questions that people care about.

And then when you spend the money and do the work you end up with answers that people want. In other words, questions they wanted answered, and it builds a lot more public trust into the outcome.

And I think much of the resistance you've seen and you've heard, and the letters that Congress has received, is because of the secretive nature of this where they haven't—those effective stakeholders have not been part of that process from the beginning.

And this is being done in other parts of the world, other agencies are beginning about how to do state-of-the-art risk assessment, and it would be worth considering for this issue.

Mr. GREENBERG. When I speak about this issue before, you know, again laypeople who aren't involved in government at all, and I mention that FDA is ultimately the approving agency, I just—people can't believe it. They just can't believe it.

So I would think any politician would be concerned about their reputation to like—it just reeks of not going a direct and honest pathway.

And I can understand there must be bureaucratic reasons why it's happening, but I'm just saying from outside of government perspective it just doesn't feel right.

Dr. EPIFANIO. I think ultimately having witnessed the—from an agency point of view, an action agency point of view from both the research side and the management side, often what we have is the regulatory framework playing catch-up ball to the state of the science.

We have potentially a very—even though this technology now is 10, 20 years old, the next version of this, the next iteration of the science is going to be out there. And the regulatory framework needs to catch up with that and needs to have the appropriate science agencies involved in it.

I'm reminded of 20 years ago when the idea of moving specific salmon from one river to another seemed absolutely logical and not a problem whatsoever.

Now we fully are beginning—you know, we certainly grasp the idea that when we do that and there's commixing and interbreeding between them, we have some problems. Populations respond and reproductive capacity is down. We're now catching up the management with where the science has taken us.

Ultimately, I think in terms of the regulatory with the risk side of things—and I'm not an expert in risk management, but it seems to me the information technology universe has what they refer to as the law of intelligent failure. Knowing that safeguards do fail, they want things to fail in a way that they can learn from it, they can improve it, and make sure it's not a big problem. We don't want the entire grid to come down, so to speak.

Senator BEGICH. To manage it.

Dr. EPIFANIO. Exactly.

Senator BEGICH. Dr. Stotish, I don't know if you want to respond to that, but you see the dilemma.

And I guess I want to agree with the last comment, that government isn't very good at keeping pace with technologies as they move forward.

I mean, I sit in this committee—also we deal with IT issues here all the time, telecom issues, and we're always trying to catch up to where the next Google might be or the next Microsoft, and we're never going to be able to do that, but we kind of scratch the back end of it as it moves to the next phase. But with food product, it just seems—it's a step that we have to be very careful about.

So let me ask you to respond, but I want to add one more thing. And I know because I've heard it a couple times here, on risk assessment. I know you have applied and I think you received a recent grant—I forget the exact amount, $300,000, $400,000, $500,000 in risk assessment in regards to this product.

Which, to be frank with you, it gets me a little concerned because if it would have been approved last year—how does this all link? And maybe you could respond to this other part about the—then this other piece about why do you need a risk assessment analysis

now when the product could have been approved last September? That's when it was lined up to be approved.

Dr. STOTISH. I'm so happy you asked me that, because I'm pleased to clarify that.

First of all, the grant you refer to is a research grant awarded by the USDA. It's a competitive research grant; it's based on the science of the application. I've made you aware——

Senator BEGICH. And the purpose of the grant is?

Dr. STOTISH. Is to explore additional ways to guarantee reproductive sterility of fish.

Senator BEGICH. So it's not a risk assessment.

Dr. STOTISH. No, sir, it is not. There was a recent request for information by the USDA for additional grants to address this issue.

But the grant that we were awarded—and we've been maligned in the press—was a competitive grant.

We have technology that we practice to 99.7 percent validation for the production of triploid. We also have research that says that we can guarantee 100 percent genetic fidelity of sterility. It's a complicated technology; I'd be glad to take you through it.

But it involves the use of, again, genetic technology to assure that—it's called a grandchild-less phenotype. You have sterile broodstock, or fertile broodstock, which produce sterile, 100 percent sterile progeny.

Senator BEGICH. Let me pause you there.

Dr. STOTISH. That's the grant.

Senator BEGICH. Right, I understand that. And different terms for different purposes, but USDA is asking for this research through a competitive process, you won, and I'm not questioning that. That's irrelevant to me on who gets it.

I'm just curious why USDA is asking the question in order to ensure 100 percent. Because they must have some feeling that——

Dr. STOTISH. Senator, I think you're still confused. Allow me again.

The request for information and request for proposals is separate from the grant that we've received.

The request for proposals were grants addressing the issue that you're referring to. And the reason they're asking for that is because this is an issue that's had so much popular attention. The grant that we've received is different——

Senator BEGICH. Let me pause you there. I don't think I'm confused. I understand there are different things out there. What I'm saying is USDA is asking the question, may they be a grant that's been approved, and/or in this case a RFP, a proposal that's being requested.

Even—you don't spend a half million dollars just because people bring up an issue and you want to just do it. It's because they must be concerned in some form. Am I missing something?

Dr. STOTISH. The USDA awards competitive grants every year based on research.

Senator BEGICH. I understand that; we get a lot in Alaska. Do you understand, my question is they don't just make a list and say, "Jeeze, we'll do this grant because we got some money." They do it because there's a reason they're trying to get information.

Dr. STOTISH. Again, sir, you misunderstand the system. They invite proposals; people submit proposals. Those proposals are peer reviewed by reviewers in the USDA and outside the USDA. They are awarded based on the scientific merit of the application and the value of the science.

Senator BEGICH. I understand that.

Dr. STOTISH. And that's the merit, the basis upon which we will receive the grant for the next generation of sterility. To further improve on the existing technology. The other request for information——

Senator BEGICH. Let me pause you again. We're saying the same thing. I'm just saying that if you were sure about the ability to have sterile eggs you're not going to continue to ask for more research. You're going to move on to other high priorities with the USDA. Because the USDA has about this much money, and this many requests of needs.

Dr. STOTISH. I have a simpler answer for your question, sir.

Because opponents of the technology have said 99.7 percent or 99.5 percent is not good enough, we've conducted research. And we conduct research in a variety of areas. That said, we can make it 100 percent.

Simply because we're aware of the sensitivity and the perception—and that's why we continue to do research in this area. We believe it's advancing the science, and we believe it's good not only for the industry, but we believe it's good for America.

Let me come back to the question about the drug approval process. I may be the only person in this room that has any experience. I've been involved in more than a dozen new animal drug approvals.

The new animal drug provisions are part of the Federal Food, Drug, and Cosmetic Act, and basically they have been used and proposed by the FDA to address the issue of genetically modified animals. There are other paradigms that are possible.

For instance, you could regulate this as a novel food, you could regulate this as a GRAS (Generally Recognized as Safe) substance, you could regulate this in a variety of other ways. And there have been proponents of all of those alternatives.

Firms like mine have waited 25 years for the government to decide which paradigm they would use. And the situation that we're involved in now, speaking purely as a CEO, purely as someone who's involved in the development of what we believe is important technology, is a lot of the discussion now is basically changing the rules of the game after the game is over.

And we've done everything that we've been asked to do, we've supplied all of the information, we've made all of our data public, we've participated in the public debate. Not one of my colleagues on this panel has made any specific reference to the environmental assessment that has been in the public domain for more than 16 months.

The risk assessment, the tools that we used, and the methods and the conclusions of that environmental assessment have been publicly available, sir.

So we are disappointed that we're not getting specific attention on the merits of the case and on the facts.

Senator BEGICH. Let me ask the basic question. I understand about the game may change in midstream, I can tell you—I come from an oil and gas state. The game changes every day. And when you have things that happen in the environment, things change.

There's a reason why oil and gas development in Alaska got delayed because of an oil spill in the Gulf. Now, should we have just said whatever happened down there just happened? No, we looked at the game and reassess what we needed to do. So, I don't buy that argument.

But let me ask you the specific question here: do you think that fisheries, maybe NOAA, or whoever—I mean, I'll say NOAA, but National Marine Fisheries are an associated group—should be a sign-off on this? Because again, the difference is, as I gave that example of the drug that I was taking for my neck pain, as soon as we got the notice——

Dr. STOTISH. It was Vioxx.

Senator BEGICH. Yes, Vioxx. I stopped, you know, because I didn't want to have a heart attack.

Dr. STOTISH. Thank you for reminding me. The same provisions that allowed the FDA——

Senator BEGICH. I understand they could do the same thing. But the difference is I could immediately do that. But if you damage the environment and then FDA said, "Stop," at that point the environment now is on a course. Because it's a different controlled mechanism, is I think the description of how you manage the impact of something you produce.

And in this case, Vioxx you could do right away and they did very successfully. Tylenol years ago, I mean, a variety of things.

Dr. STOTISH. Your question is a fair one, sir.

Senator BEGICH. So do you think NOAA or the Marine Fisheries should have a role here? Not just consulting, but an actual——

Dr. STOTISH. Sir, they have had a sign-off role in the process, but you have to consult with the FDA and the people involved.

I cannot directly testify to that. But I have—it's been my understanding that they have not only done the consulting reviews, but have signed off as a condition for going forward.

Senator BEGICH. Yes I'm not sure.

Dr. STOTISH. So I think this has been taken very seriously, and those are responsibilities under NEPA. And that is the provision that provides the legal requirement for this additional review.

I suggest if you have an interest in that, you talk to the principals involved who can directly communicate to you exactly what's happened.

Senator BEGICH. Let me finish up with if anyone else wants to make some final comments before. I know we have pushed it to the limit, but I really appreciate this conversation, but also the information in regards to the issue of genetically engineered salmon. I think it's an important issue.

I mean, I could tell you for all the reasons you said, Mr. Greenberg—the impact to what we have created as sustainable fisheries in Alaska through the right management, the long term management of our product, is in my view the right way to do this.

But, any last comments before I close?

Mr. Greenberg, we'll kind of roll down.

Mr. GREENBERG. Well, in direct comment to Dr. Stotish's comment, first of all, if we want to have containment grown fish, they don't have to be genetically modified salmon. We have striped bass, hybrid striped bass. We have tilapia. All kinds of trout that are already grown in containment, and all the economic benefits that Dr. Stotish speaks of for Midwestern states are all there already there if we want them.

And fish like tilapia are just endemically more efficient, faster growers than salmon anyway. So, if we want a product to be produced inland in containment facilities we can do it.

And my last comment is that, you know, referring to this whole question of this is going to be good for America to compete with China—well, do we really want to hold up China as this beacon of environmental regulation, you know, that we want to aspire to also?

And moreover, if this fish does get developed I have a pretty sure feeling that it's going to end up in China one way or another, either through direct—if they can steal our stealth bomber or stealth fighter, I think they can get a hold of this fish.

So I would rather see us as a country that says no to that kind of risk, let somebody else take the risk, and we'll have better fish because of it.

One of the great markets for Alaska salmon traditionally has been Asia, because these countries don't have what we have.

Senator BEGICH. That's right.

Mr. GREENBERG. And if we really want more salmon in America, well, then let's not sell 70 percent of our Alaska salmon abroad. We don't need GMO salmon in order to make up for that deficit.

Senator BEGICH. Thank you very much.

Dr. Leonard.

Dr. LEONARD. I just have three final comments. One, I would like to acknowledge AquaBounty's forthrightness in the information that they have put forth to date. It is true that information has been in the public realm for well over a year now, and that I think is helpful. It's given people a lot of opportunity to look at that.

On the other hand, the process is not obligated to do that, and so I think the question is really less about this individual application and the specifics of this, and more about whether we have a system in place that will allow us to deal with the next application that comes down.

And I think my final comment would be on an issue that we haven't touched about, but was alluded in many of the comments made by the Chairman—which is fundamentally the question about liability, and if harm happens, who's responsible?

That's really not—it's a legal question, it's not a scientific question, but I think that issue has really not been addressed at all yet and is worthy of additional consideration.

Senator BEGICH. Thank you very much.

Dr. EPIFANIO. I guess my final thought on this is—I come from the land where three species of nonnative carp, the silver, the bighead, and the grass carp, are somewhat problematic, two of the species potentially knocking on the door of Lake Michigan, the effects of which could be devastating.

Just this past 2 months ago, one of my crew collected a gravid female grass carp, which are only supposed to be triploid out there, and surely she had eggs. They weren't ripe at that particular moment because of the time of year, but she was running over with eggs. Partly because of—not that the triploidy doesn't work, but it's not 100 percent inefficient, which we heard about and we all know. So these things do happen.

The point I want to make with that story is that salmon and other fishes are a little bit more difficult to control should an escape occur, should there be some unforeseen problem—more difficult than a cow or a goat.

If Dolly the sheep, for example, was to escape, we'd go out and get in the pickup truck and go find her.

Senator BEGICH. Alaskans would hunt it.

[Laughter.]

Dr. EPIFANIO. And all of these things have been described. There's a National Academy of Sciences report, "Animal Technology and Science Based Concerns", and in one of their tables they list out sort of the relative concerns, insects and fish being at the top of the high risk, cattle and sheep being down at the low risk.

And there's a continuum based on a number of criteria based on their mobility, likelihood to escape, and so on.

The point being that there are some tractability problems here, or issues here, and there are great minds who have been thinking about this. There are no less than three National Academy reports on this suite of issues that we had, and I would urge that the Subcommittee and the agencies involve continually refer to these, and I'm sure new ones as they come about, these ideas to be deliberated in the scientific court of opinion.

Senator BEGICH. I want to say thank you very much, and to all of you, I think this is a—obviously for Alaska a big issue, for Maine a big issue—the ability to have sustainable food supplies in a broader sense is a national security issue and a very important issue for us.

I think there is a lot of evidence out there as we're developing, and especially today, to ask these questions. And they're hard questions. Mr. Stotish, I give you credit for surviving this morning. But I would say that it is important that we push these questions.

I will put—just to make sure we're clear—the reason you've had 16 months of public deliberation on this, at least the information, is because back in August, September of last year, some of us said, "Pause." Because FDA was moving that 170-page document very rapidly with limited public review.

So I appreciate when you say 16 months, because 13 of those months were supplied by myself and many others who signed a letter that forced this process to slow down, have more discussion, and have more review, which was not really occurring.

Because FDA has a procedure that is designed not for this type of product in the sense of its public review, and I think that is an important piece of this equation. So I want to make sure that's on there.

The second thing I'll say is I don't think anyone underestimates the capacity of American ingenuity, it's a question of where to put

it to make sure we have the longest benefit—may it be for the consumption of food, our environment, and a variety of things.

And so I think this—for us at least, and for the Senate—to have a review of this issue and the process, which is now becoming really a part of the equation. It's not just the product.

The product has actually brought the issue of how do we approve or not approve a food product that may have an impact that's much different than a drug product, or even a new grain that's produced.

Because as you said, fish are a little harder to catch—except in Alaska, we have good ability to do that. But compared to a sheep, you know, it's a different ballgame.

And so we have to manage this in the right way, and I think we have an important role here as the Subcommittee on Oceans, but also as the Commerce Committee in the Senate, to review this issue very carefully and make sure that, as we move forward, the right kind of input from the agencies is there.

And I understand the game change, but, you know, 25 years ago or 20 years ago a cell phone was as big as a suitcase.

So we have to put all that in perspective, that we have to look at things in a different way as time progresses. And there's no better issue than to protect our food supply and our natural food supply for the long term.

And from Alaska's perspective, we have spent 30 years doing this successfully, and we do not want to reverse this trend because of another market.

And the last thing I would say on this—and I'm going to close it off, and allow that over the next 2 weeks we'll still allow additional information and questions for the record from other members that I know have—is that we want to make sure that—and Mr. Greenberg, you kind of said it.

Alaska's very good about exporting our product, because Asia is anxious to get it. Because we have a high quality product. And I think in a lot of ways, as we look at our food supply, of how we utilize food in this country, and what products we want to consume, also will determine where we sell our product.

And I, of course, am always marketing and bragging about Alaska's product for a variety of reasons. But one of them is because it's sustainable. It is one of the food products from the ocean that we know we can—from a part of this country that is sustainable.

So, let me just say again, I want to say thank you and appreciate all the comments. And maybe they've been a little rough back and forth, but I think it's important that we have this discussion.

We will continue to be engaged in this issue. I'm not sure that sits well with Dr. Stotish because I know you've struggled through years of review, but Congress has had very little conversation about this.

And it is a new day of food product, and I will tell you as chair of this subcommittee and someone who comes from a state that produces 60 percent of the wild stock of this country, we are going to be interested in this and figuring out how it plays, and what the permitting and process will be.

Let me say thank you again to all of you that are here, and the record will be open for the next 2 weeks for additional questions by members.

This meeting is adjourned.
[Whereupon, at 12:24 p.m., the hearing was adjourned.]

A P P E N D I X

PREPARED STATEMENT OF HON. JOHN D. ROCKEFELLER IV,
U.S. SENATOR FROM WEST VIRGINIA

Good morning. We're holding this hearing today to discuss the potential environmental risks of genetically engineered fish. The hearing could not be timelier: as I speak, the FDA may be finalizing approval of the first genetically engineered animal for human consumption in the United States. This fish, the "AquAdvantage" Salmon, has been engineered to grow faster and be heartier than its natural counterpart by mixing genes from three different fish species so its filets can quickly get from the fish pen to your dinner table.

Yet, concerns abound with opening the door to the creation of genetically engineered animals for food. Food safety is an obvious nexus of contention, but a more insidious consequence of these fish is the havoc they could wreak on our natural fish stocks and aquatic ecosystems. Were these fish ever to escape into the wild, the impacts could be disastrous.

At a minimum, the escaped fish would have effects similar to invasive species by competing with other fish for food, territory, and mates, or by otherwise altering the food chain. Worse, if GE salmon were to escape into wild habitats, they could mate with wild fish, passing their artificially engineered DNA into the wider gene pool and fundamentally altering the naturally occurring species as a whole. There may also be ramifications of escapement not yet realized, given the unprecedented nature of these fish.

Now, AquaBounty, the company that developed these GE fish, has made significant investments to minimize the risks of escapement and genetic contamination. In their application to the FDA, they've touted techniques that render the fish sterile and infrastructure that thwarts escapement. They've even decided to breed them far from our shores—all the way in Panama—to alleviate these concerns. But even the establishment of a "Salmon Republic" may not be enough—evidence suggests that AquaBounty's sterilization process is not 100 percent effective, and history shows that no aquaculture containment measures are foolproof or immune from human error.

Moreover, approval of these genetically engineered animals would be precedent-setting, likely ushering in a wave of aquaculture operations here and around the world for raising genetically engineered food fish. Production on such a large scale would make the risk of GE fish escaping into the wild a near certainty.

It's clear to me that we need to operate under the assumption that these fish *will* escape, and that warrants a thorough examination of the harm of escapement. And I'm very concerned that these fish haven't received the scrutiny that's due.

The FDA review process required AquaBounty to submit an environmental assessment as part of its application. But that assessment assumed AquaBounty's escapement precautions would be 100 percent effective, avoiding the likely "what if" scenarios of escapement that have preoccupied so many people's minds. It's also troubling to me that the FDA is the sole agency leading this effort. As the guarantor of our food safety, they may be ill-equipped to oversee the kind of comprehensive environmental assessment that's needed to spell out the risks.

Hopefully, this hearing will serve as a call to reason and bring greater attention to these concerns. Because again, it's not just about this one company or this one fish. It's about the precedent that may be set. There is potential in GE animals, but we need to make sure that we fully understand the risks involved, so that we do not live to regret unleashing the environmental equivalent of a Pandora's Box.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN D. ROCKEFELLER IV TO DR. RON STOTISH

Liability for Environmental Harm from Escaped GE Fish

Examples of escapement of non-GE exotic fish species reveal the high economic and environmental costs of these events. In the case of the Asian carp, the Federal government currently spends over $7 million in electricity bills alone to maintain an underwater electric barrier to keep the fish from invading the Great Lakes. Another example in the Great Lakes is the Atlantic sea lamprey, on which the Federal government spends $20–30 million dollars annually to keep this fish under control.

Question 1. If AquaAdvantage salmon were to escape into the wild, would AquaBounty take responsibility for compensating the public for any environmental harm that is done by these fish?

Answer. We understand and appreciate concern about the possibility of an "escape of GE fish". Accordingly, as our submissions to FDA reveal, we have implemented safeguards with respect not only to the production and security controls and practices we follow but also with respect to the fish itself. These safeguards serve to, respectively, render any such "escape" a remote possibility and protect the environment in the extremely unlikely event of such an escape.

The NADA for AquaAdvantage includes specific conditions for use which require cultivation in land based physically contained facilities. In addition, AquAdvantage are all female and triploid (unable to reproduce). The conditions for use are enforced, as are all approved drugs under the Federal Food Drug & Cosmetic Act (FFDCA).

Secondly, although the two examples cited in the question were undoubtedly selected for their inflammatory impact upon the reader, neither are biologically relevant examples for Atlantic salmon. The Asian carp is a known adaptable and invasive warm water fish originally deliberately introduced into the environment to clear vegetation in the areas of catfish ponds in the Southern U.S. The Atlantic lamprey is a parasitic primitive fish that gained access to the Great Lakes in the 19th Century, probably through the system of canals constructed at that time.

Atlantic Salmon are, however, a cold water species that are known **NOT** to be highly invasive. On the contrary, attempts to introduce Atlantic salmon into nonnative or native habitats over the years have been singularly unsuccessful. In the past century, there have been numerous unsuccessful attempts in the U.S. and elsewhere to establish Atlantic salmon outside their native range (Fisheries & Oceans Canada, 2005). At least 170 attempts occurred in 34 different states where Atlantic salmon were not native, including Washington, Oregon, and California. None of these efforts was successful (Waknitz *et al.,* 2002). No reproduction by Atlantic salmon was verified after introductions of fertile, mixed sex populations of Atlantic salmon in the waters of these states. The risk of anadromous Atlantic salmon establishing self-perpetuating populations anywhere outside their home range has been shown to be extremely remote, given that substantial and repeated efforts over the last 100 years have not produced a successful self-reproducing anadromous population anywhere in the world (Lever, 1996). In the Pacific Northwest, there have been no reports of self-sustaining populations resulting from deliberate or accidental Atlantic salmon introductions (Waknitz *et al.,* 2002).

Lastly, publications from laboratories exploring the specific abilities of AquAdvantage salmon to compete in an ecosystem have concluded that AquAdvantage are less fit than nontransgenic Atlantic salmon in competing for mates. This work was cited in my original testimony, but I include it again for the record.

Moreau DTR, Fleming IA, Fletcher GL, *et al.* (2011a). Growth hormone transgenesis does not influence territorial dominance or growth and survival of first-feeding Atlantic salmon *Salmo salar* in food-limited stream microcosms. *Journal of Fish Biology* **78:** 726–740.

Moreau DTR, Conway C, & Fleming IA (2011b). Reproductive performance of alternative male phenotypes of growth hormone transgenic Atlantic salmon (*Salmo salar*). *Evolutionary Applications* **4:** 736–748.

Moreau DTR & Fleming IA (2011c). Enhanced growth reduces precocial male maturation in Atlantic salmon. *Functional Ecology* **Online View:**1–7 (doi: 10.1111/j.1365–2435.2011.01941.x).

Thus, there are no facts which suggest the examples you cite are relevant to AquAdvantage salmon. Moreover, as I testified at length, the science-based petition we have pending before FDA includes specific conditions for use which requires any cultivation of fish must be in FDA inspected and certified land based physically contained facilities. AquAdvantage salmon grown from AquAdvantage eggs are all fe-

male and triploid (unable to reproduce). The conditions for use are rigorously enforced under the FFDCA.

The question of compensation or liability in light of the above facts appears to be intended to inject controversy where there is no evidence to suggest controversy exists. The short answer to this question must be there would have to be a demonstration of harm and established negligence to justify liability or compensation. This product will be regulated as all other FDA regulated products, under the FFD&C.

Question 2. Who would pay the costs associated with containing the spread of these fish and minimizing their potential environmental damage?

Answer. Again, this question assumes harm where the likelihood of such harm is extremely remote and is entirely hypothetical.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO DR. RON STOTISH

Farming Methods and Probability of Escapement

Question 1. What is the most cost effective method for rearing genetically engineered salmon: net pens, hatcheries or terrestrial above ground facilities? Please provide estimates for how much it would cost to rear *genetically engineered* salmon using each of the above methods.

Answer. Without question, the method we have developed is a cost effective method for ensuring the production of securely contained and safe fish. First, all aquacultured fish are spawned, hatched, and their early life stages reared in hatcheries, which are by definition land-based facilities. Following the hatchery stage, the salmon fingerlings or smolts can be grown to market size in different facilities, some of which are land-based, and some are located off-shore.

AquAdvantage salmon will only be approved for cultivation in FDA inspected and licensed land-based contained facilities, and will not be grown out in net pens or other systems that are not land-based.

Well designed and sited land-based systems for rearing salmon are very competitive with traditional net pen rearing systems. A technical conference in British Columbia showcased environmentally friendly, land-based, recirculating rearing systems for producing salmon for as little as US$3-$4 per kg, similar to the production costs in modern net pen systems. These systems were producing conventional salmon with growth and productivity performance that is inferior to AquAdvantage salmon, whose superior growth characteristics improve the economics for land based cultivation.

There are a wide variety of designs and associated costs for land-based systems, but our calculations of the specific cost of rearing AquAdvantage salmon in land based versus sea cage (conventional) demonstrates a significant savings of $0.50-$0.75 per kg when AquAdvantage salmon are reared in contained, land based systems versus traditional net pens. This does not include the further benefits of production systems closer to markets, further reducing the cost and environmental impact of transportation. Including benefits from reduced transportation costs in the comparison could provide an additional savings of $0.75 per kilo exclusive of the "carbon footprint" benefit.

Question 2. How does the probability of escapement vary between each method? It has been well documented in the salmon farming industry that floating net pens are susceptible to breaches and escape of the fish.

Answer. Not only is the net pen material vulnerable to invasive predators (*e.g.,* seals, sea lions, sharks) and destructive forces in the open ocean, but once breached, loss of the entire captive population is almost inevitable. Conversely, contained, land-based systems such as the kind proposed in AquaBounty's NADA possess an extremely low probability of escape risk due to the multiple containment barriers in place, and the on-land location. For example, AquaBounty's production facility in Panama possesses 21 individual containment barriers confining the fish to the rearing facility, and making escape into the environment essentially impossible

Labeling of Genetically Engineered Fish Species

Over 400,000 Americans have commented on an FDA petition which would require the labeling of genetically labeled foods. In addition, A survey conducted in 2010 by Thomson Reuters PULSE™ Healthcare Survey, "National Survey of Healthcare Consumers: Genetically Engineered Food" showed that 93 percent of Americans believe GE foods should be labeled. Genetically engineered foods are required to be labeled in the 15 European Union nations, Russia, Japan, China, Australia, New Zealand, and many other countries around the world.

Question 3. What are your thoughts on labeling genetically engineered food so that consumers can make an informed decision?

Answer. The U.S. has a long standing policy of truth in labeling, and another long standing policy requiring regulation based upon product attributes rather than method of production. The cited Thomson Reuters survey does not accurately reflect the public sentiment, as there are other surveys which suggest Americans are more intelligent and discerning than the Thomson poll portrays. The responses on this issue depend on how the question is asked. In a 2010 International Food Information Council (IFIC) poll for example, more than half the respondents would likely purchase food from a genetically modified organism if that product had been found to be safe by the FDA.

FDA's policy, affirmed by the agency and upheld in the courts, is that food labeling must be truthful and not mislead the consumer. AquaBounty supports this policy. The predicate for the potential to mandate labeling for a genetically modified food or food ingredient is that the food or ingredient is "materially different," *i.e.,* claims of higher protein, lower fat, nutrition, etc. from the conventional or traditional version of the food. In FDA's evaluation of AquaBounty's application, in which no claim other than faster growth is contained, the agency's Center for Veterinary Medicine (CVM) found no material difference between AquAdvantage salmon and other Atlantic salmon.

However, in the interest of full transparency and supported by AquaBounty, FDA's Center for Food Safety & Applied Nutrition (CFSAN) held a full-day public hearing on September 21, 2010, at which the public was invited to bring compelling legal or scientific arguments to support a call for mandatory labeling. (It should be noted CFSAN will make no decision on the parochial question of mandatory for AquAdvantage salmon unless CVM approves the long-pending AquAdvantage NADA). At that hearing, invited speaker Greg Jaffe, director of biotechnology for the Center for Science in the Public Interest (CSPI) made the following statement:

"So, now I turn my attention to the AquAdvantage salmon and the two questions presented to the public today by FDA. Based on the documents from FDA about the AquAdvantage salmon, the data and risk assessment released by the FDA's CVM earlier, and the FDA's current policy regarding mandatory labeling, as discussed this morning and also provided to the public, CSPI does not believe the AquAdvantage salmon requires any special mandatory labeling. CSPI cannot identify in the public record any material differences between the food from this salmon and from other Atlantic salmon that would require a mandatory labeling that is consistent with the FDA policy. However, if FDA does determine that there are material differences between food from this salmon and from other salmon that requires some mandatory labeling, CSPI believes it is very important that the language required by that label be neutral and informative. FDA should not necessarily require that label include the word "genetically engineered." As I mentioned earlier, there are many production methods for food products and many production methods for salmon. Identifying this production method without requiring all the other production methods to be identified would needlessly discriminate against genetic engineering and not provide the consumer with information about the material difference in this particular salmon."

As to mandatory labeling of all foods sold in the U.S. which are the product of or contain an ingredient that is the product of biotechnology, such a policy could impact a vast majority of foods grown or processed in the U.S.

Keeping in mind there are no approved biotech food animals, there are currently 89 commercial plant varieties produced using biotechnology and deregulated by the USDA, though not all have been commercialized. The overwhelming majority of all corn, soybeans, and sugar beets grown in the U.S. for both domestic and export purposes are biotech varieties, which means the by-products—oils, meals, etc.—used in food production are by definition "biotech" as well. This is testament to the broad adoption of this technology in the U.S. and in most parts of the world, and suggests "biotech" is the new "conventional." Other crops grown in the U.S. using biotechnology include alfalfa, papaya, and some varieties of squash. The exact percentages of our major crops used both domestically and exported are:

- 88 percent of all corn
- 95 percent of all sugar beets
- 94 percent of all soybeans
- 90 percent of all cotton

Globally, 15.4 million farmers in 29 countries grow some form of biotech crop on 366million acres and these numbers are increasing.

AquaBounty is not deaf to the concerns of the many consumers who are sincerely troubled by the type of technology the company employs in producing the AquAdvantage salmon. Those concerns reveal the very real fact that the use of such technology has social implications. Those implications, however, I respectfully submit, are now and should continue to be beyond the scope of governing legal authorities.

Public education on the other hand is a shared responsibility and clearly appears to have a role in addressing consumer concerns and informing consumer decisions. Once the AquAdvantage application is approved by FDA, we have reason to believe a number of organizations will join AquaBounty in the education process. These include organizations such as the Biotechnology Industry Organization (BIO), the National Fisheries Institute (NFI), the Global Aquaculture Alliance (GAA), as well as government agencies like FDA, USDA and NOAA. In fact, all responsible parties can serve a valuable role in helping to demystify the technology and allay consumer concerns.

Simply put, we believe that effective meaningful and true education calls for approaches well beyond the grocery store fresh fish counter and the restaurant menu. Requiring labeling without first insuring an informed consumer public would, in effect, create a tool for simply fostering the fear that meaningful education can reasonably address.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARK BEGICH TO DR. RON STOTISH

Infectious Salmon Anemia in AquaBounty

Canada's Department of Fisheries and Oceans recently released a document confirming that samples from AquaBounty's land-based research and GE fish egg production facility on Prince Edward Island (PEI) tested positive for the Infectious Salmon Anemia (ISA) virus in 2009.

Question 1. How did the virus get into the Prince Edward Island facility?

Answer. We do not know. There are many strains of ISA virus (ISAV) which are naturally occurring and endemic to salmon growing regions of the world. There are ISAV strains known to be present in Atlantic Canada, as well as Norway, Chile, the U.K., etc. The biology of these viruses is complex, and in some ways comparable to the influenza viruses that infect a variety of organisms, including man. ISAV is not a zoonotic or human health risk as it does not affect humans.

Question 2. Was the virus detected in the AquAdvantage salmon?

Answer. Yes. Both AquAdvantage salmon and non-transgenic salmon in our facility were equally affected.

Question 3. What other types of fish in the PEI facility tested positive for ISA?

Answer. Only Atlantic salmon, and the virus was detected in equal frequency in transgenic and non-transgenic salmon.

Question 4. Did these fish test positive for any other types of viruses or diseases?

Answer. Our stock are tested on a routine basis several times each year for a large number of diseases known to occur in salmon. There have been no other positive results for infectious viral diseases in nearly16 years of operation.

Question 5. What is known about whether AquAdvantage salmon are more or less susceptible to ISA and other viruses than non-transgenic Atlantic salmon?

Answer. AquAdvantage salmon differ from other Atlantic salmon in a single genetic locus, the additional copy of the salmon growth hormone gene. AquAdvantage are the same as other Atlantic salmon in every other measurable respect and there is no data suggesting either enhanced or reduced susceptibility to disease compared to Atlantic salmon. The Target Animal Safety studies—as part of AquaBounty's formal application—were summarized and released by the CVM for the purposes of the 2010 VMAC meeting illustrate this point.

Question 6. What was done with the fish that tested positive for ISA or other viruses?

Answer. The fish testing positive were systematically destroyed and incinerated as required by relevant regulation and company standard operating procedures (SOPs). Our entire facility was cleaned using virucidal materials, and enhanced biosecurity procedures were implemented as corrective action to further reduce the possibility of a similar event.

Question 7. How will AquaBounty ensure that ISA-infected salmon are not shipped to grow-out facilities?

Answer. AquaBounty is inspected regularly by the Canadian Food Inspection Agency (CFIA) and the Department of Fisheries and Oceans (CDFO) under the Canadian Fish Health Program. Under Canadian regulations, a facility must have a valid Fish Health Certificate in order to export fish. Additionally, AquaBounty has its own SOPs and procedures for continually monitoring fish health. In the 2009 event, AquaBounty detected the problem and immediately advised the appropriate Federal and provincial authorities, and worked closely with these Canadian authorities to resolve the issue. The Fish Health Regulations are analogous to other Federal sanitary and public health laws, programs and procedures utilized around the world to assure the health of livestock and the safety of food. These regulations are separate and distinct from considerations employed for the purposes of a NADA or Environmental Assessment (EA).

Question 8. When was the latest date that fish at the PEI facility were tested for ISA?

Answer. Our hatchery has a "clean" health certificate, and the most recent certificate was issued in December 2011. ISAV is among the agents tested in that inspection. We have had eight successful inspections since the first quarter of 201, with no findings of any of the tested pathogens, including ISAV.

Question 9. When is the latest date that fish at the PEI facility tested positive for ISA?

Answer. November 2009 was the only inspection which detected ISAV in our hatchery. Our subsequent eradication efforts, in cooperation with the Canadian government, were apparently completely successful.

Question 10. Are any fish at the PEI facility known to still be infected with ISA at this time?

Answer. Absolutely not.

Question 11. Under Canadian, U.S., and Panamanian law, could fish or fish eggs that test positive for ISA or other viruses be transported into or out of any of these countries?

Answer. No, nor would AquaBounty even consider shipping materials known to be infected with any infectious agents.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. ROGER F. WICKER TO DR. RON STOTISH

Question 1. Scientists and the aquaculture industry underscore the need to address the potential problems of genetically engineered (GE) fish, such as the impact on wild stocks. However, they also highlight the benefits of innovation in this area such as lowering costs, expanding industry, increased health benefits, and feeding a growing global population. The FDA currently has a process to address these issues on a case-by-case basis through scientific review. Would a blanket ban on commerce in genetically engineered fish inhibit innovation and competition for U.S. aquaculture companies?

Answer. A blanket ban on the use of U.S.-developed biotechnology to enhance food production both in this country and around the globe would likely bring to a complete halt all investment in research and development of new food production technologies, including aquaculture. Effectively banning the use of biotechnology in the entire food animal sector would have a chilling impact on innovation. Furthermore it would signal to the world the U.S. no longer employs science-based review and regulation, but rather has decided to politicize the technology review process and seriously marginalize innovation in food production.

Global animal biotechnology is on the rise. For instance, in China today there are more than 60 applications for genetically engineered animals, including several for fish, advancing through its regulatory agencies. A ban on GE fish in the U.S. would provide China with a global competitive advantage to launch similar products into international commerce—without the same Federal oversight expected in the U.S.—and would only serve to further inhibit innovation and job creation in this country.

Question 1a. What impact would a ban on international commerce in GE fish and GE fish products have on our country's current trade relations and treaty agreements?

Answer. Currently, the U.S. works with other "like-minded countries" to support innovation and new technology in agriculture. One of the primary tenets of U.S. policy is to regulate products based on their characteristics rather than on their methods of production. The Coordinated Framework for Regulation of Biotechnology, proposed in 1984 by the White House Office of Science & Technology Policy (OSTP), and finalized in 1986, spells out Federal policy for regulating the development and

introduction of products derived from biotechnology. A key principle of the framework is that genetically engineered organisms would continue to be regulated according to their characteristics and unique features, and not according to their method of production. In other words, if a food product produced through biotechnology is substantially the same as one produced by more conventional means, that food is subject to no additional (or no different) regulatory processes. The framework also maintains that new biotechnology products are regulated under existing Federal statutory authorities and regulation.

A U.S. ban on genetically modified fish would not only be contradictory to our long standing policy on trade in innovative agricultural products, it would constitute the type of non-tariff trade barrier the U.S. government has always opposed and is counter to American policy and values. In short, the impact on our trade and our trade agreements would be significant.

Question 2. If the FDA reviews potential environmental impacts of GE fish prior to approval of sale, and private companies are taking necessary steps to safeguard the environment, why should Congress ban all GE fish from entering the market?

Answer. There is no environmental, food safety or efficacy reason for Congress to take action or interfere in the marketing of GE fish. Pre-approval review of this technology rigorously evaluates all aspects of the product—including safety, allergenicity and environmental impact—and its intended use. Intervention by Congress constitutes political interference in this objective, science-based process, and sets a dangerous precedent for any Federal government review of a new human or animal drug application, a new device application or any application for production of a service. The U.S. objective, science-based regulatory processes developed and used by FDA, USDA, EPA and other Federal departments and agencies are recognized as global standards for science-based regulatory review, and subverting those regulatory processes for political or economic self interest not only undermines innovation and competition in the U.S., but would seriously undermine our credibility in the international community.

Question 3. The scientific review process by the FDA is designed to assess risks associated with commercial sale of GE fish and find whether such activity would pose no significant impact prior to approval—a process it has not yet completed. Could a preemptive ban on commercial production of genetically engineered fish (in this case salmon) prior to an FDA ruling undermine the scientific review process?

Answer. There is no question politicizing the objective, science-based FDA review process would undermine its effectiveness and credibility. Such action would set a precedent for Congress to unilaterally interfere in the regulatory process for political or market competition reasons to stop any application by any company or group. The impact on the regulatory process and on U.S. credibility abroad would be significant.

Question 4. The FDA is reviewing AquaBounty's application to commercially produce genetically engineered (GE) salmon, which your company calls AquAdvantage® salmon. Is there a timeline for when the FDA will complete its review of AquAdvantage® salmon?

Answer. FDA has been reviewing the AquaBounty application for more than 10 years. FDA published its preliminary review in 2010. It is our understanding the only remaining element prior to a final agency decision is FDA's decision to issue an Environmental Assessment (EA), publish it in the *Federal Register* for public comment—though this is a not a regulatory requirement—and review the comments. The Company supplied a draft EA, which was also published by FDA, in 2010. FDA has taken more than 16 months since the publication of the results of its scientific review and has still not issued its EA. The continued delay has been punitive for the Company, and threatens its economic survival.

Question 5. How soon do you expect to offer AquAdvantage® salmon on the market, once the FDA approves its sale?

Answer. The Company has eggs available for sale in its hatchery at present. Fish from those eggs will not be market size for approximately two years, or late in 2014.

Question 6. In your opinion would an outright ban on GE fish be yet another example of government overreach and unnecessary regulation of American companies?

Answer. Yes, undoubtedly. The delays encountered to date constitute onerous and burdensome Federal regulation, and demonstrate political involvement in what should be a purely science-based, objective process. A ban would be seriously damaging to American innovation, American competitiveness and to the credibility of the American regulatory process.

Question 7. Does the U.S. possess, sell, and ship other GE products meant for consumption?

Answer. There are currently 89 commercial plant varieties produced using biotechnology and deregulated by USDA, though not all have been commercialized. To single out one biotech product for such a ban would be indefensible; it can be argued any action taken to inhibit or stop the marketing of a product not yet approved FDA could be taken against those food crops which already enjoy GE crops.

The overwhelming majority of all corn, soybeans and sugar beets grown in the U.S. for both domestic and export purposes are biotech varieties. This is testament to the broad adoption of this technology in the U.S. and in most parts of the world, and proof "biotech" is the new "conventional." Other crops grown in the U.S. using biotechnology include alfalfa, papaya and some varieties of squash. The exact percentages of our major crops—used both domestically and for export—are the following:

- 88 percent of all corn
- 95 percent of sugar beets
- 94 percent of all soybeans
- 90 percent of all cotton

Globally, 15.4 million farmers in 29 countries grow some form of biotech crop on 366 million acres, and these numbers are increasing.

Question 8. If so, how has genetic engineering advanced competitiveness?

Answer. Genetic engineering has enhanced competitiveness through improvement of productivity and efficiency. Examples of the advantages of biotechnology include plants and animals which can thrive in drought-affected regions; those that withstand disease and infestation, and those that bring food crops to market far more quickly and cheaply. This technology is making a safe and sustainable food supply possible at a time of increasing population demand and diminishing natural resources.

In addition, biotechnology has led to the creation of hundreds of human and animal pharmaceuticals, and through this process pharmaceutical development saves natural resources, *i.e.,* raw ingredients, from over-exploitation. The first genetically enhanced animal approved by FDA is for the production of a therapeutic protein derived from goat's milk. These animals have been genetically engineered by introducing a segment of DNA into their genes with "instructions" for the goat to produce human antithrombin—a critical enzyme necessary in blood clotting—in its milk.

Question 9. How have advances in biotechnology helped the aquaculture industry?

Answer. Biotechnology is relatively new to aquaculture because modern aquaculture is a relatively new industry. Early aquaculture primarily grew wild marine species in captivity. The environmental consequences of expanding the scale of these relatively low-technology operations is significant, and there is a need for improved productivity, improved efficiency and reduced environmental impact of large-scale aquaculture. The use of genetic analysis and modification are uniquely suited to address these problems allowing aquaculture to meet the increased food demands of an expanding global population. Biotechnological innovation in the development of vaccines, probiotics, improved feeds, and other products has allowed aquaculture to accelerate its growth curve.

Question 10. What benefits can be gained from genetically engineered fish?

Answer. In the U.S., there is the prospect of commercial-scale salmon production in inland-based facilities inspected and approved by FDA which would reduce U.S. dependence on imported salmon, reduce the product's carbon footprint, create U.S. jobs and economic development, while producing the fresh and desirable product demanded by American consumers. More than 97 percent of farmed Atlantic salmon consumed in the U.S. is imported, primarily from Chile, Norway, Canada, Scotland and the Faroe Islands, and reduced transportation requirements—an automatic result by growing U.S. Atlantic salmon—would reduce the carbon footprint of salmon aquaculture. It would also reduce the potential impact on the ecology and biological diversity of wild populations. Globally, application of this technology can produce more food more efficiently and in an environmentally sustainable fashion to meet global food demands in the future.

Question 11. How competitive is U.S. aquaculture production compared to other countries and how would a ban on GE fish affect the domestic industry's competitiveness and future direction?

Answer. The U.S. already lags far behind other countries in embracing aquaculture. One of the major reasons behind this underdevelopment is the excessive regulatory burden placed on aquaculturists in the U.S. As stated earlier, the U.S. imports almost all seafood it consumes.

The U.S. enjoys a successful domestic catfish industry, a small domestic trout industry, a domestic wild-caught shrimp industry in the Gulf, and a robust salmon fishing industry in Alaska. Although Alaska "ranches" salmon—*releasing five billion young fish each year into the Pacific Ocean,* catching some of these as three or four-year-old fish when they return to spawn—*more than 60 percent of the Alaskan product is exported to Japan and China.* As stated, the U.S. currently imports approximately 60 percent of all salmon consumed (97 percent of the Atlantic salmon consumed) from Canada, Chile, Norway, Iceland, Scotland, and the Faroe Islands. The National Oceanic & Atmospheric Administration (NOAA) last year proposed a national aquaculture policy to address this national priority. We believe exploiting a new, U.S.-developed technology, coupled with a progressive national policy, will help stimulate the growth of American aquaculture, creating U.S. jobs, Federal tax revenues, reducing our dependence on imports, and addressing future food needs.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO JOHN EPIFANIO, PH.D.

FDA Approval Process

Question 1. Does the Food and Drug Administration's (FDA) approval process for farming genetically engineered salmon adequately assess potential environmental impacts?

Answer. Thank you for your question, Senator Cantwell. Given the precedent-setting nature of this specific case, the current scientific review process is not as complete as it should be. In my previous testimony, I asserted the importance including formal and rigorous environmental risk assessment as part of the approval review process. Moreover, I identified the absence of a technical peer-review of the science addressing ecological and genetic impacts and likelihood of a genetically engineered species escaping into the environment. This part of the science review and application has no obvious "trade secrets" value and therefore would benefit from an open review process to bring the brightest and most appropriate expertise to bear. To my knowledge, FDA has little history or institutional culture in handling the complexities of salmon life-history or its ecosystem requirements to satisfy a rigorous assessment of environmental risks. This presently resides with NOAA–Fisheries and coastal states for marine fishes or USFWS and inland states for freshwater fishes.

Question 2. For example, is the FDA evaluating how escapement of genetically engineered fish may impact ecosystems and ecosystem processes?

Answer. The FDA documents made public to date do not present a substantial assessment of the impacts from escapement of modified organisms. Much of the technical work and review is found within technical journals and several reports by the National Academy of Sciences.

Question 3. If approval is granted, will the FDA regulate how the engineered fish can and cannot be farmed (near or offshore net pens, in cages, hatcheries or in terrestrial above ground facilities)?

Answer. While the current application is specific to producing Atlantic salmon with the growth-gene construct at a site in Panama, this application will be precedent-setting more broadly. The question identifies an important uncertainty in the regulatory framework of marine vertebrates and warrants an analysis by experts in FDA rule-making. As a scientist, I do not claim sufficient expertise.

This case is complex case because the species in question is derived from and can interbreed potentially with its wild counterpart. Moreover, the wild counterpart is presently listed and protected under the Endangered Species Act. Additionally, under the current proposal, the modified salmon will be reared in Panama, for which FDA has no obvious authority. Finally, the farming in coastal or inland waters may be regulated as much by the individual states as by the Federal government. Therefore, the regulatory framework for coastal and inland farming needs to be fully described before approval granted for these kinds of activities (beyond the current application) to avoid jurisdictional conflicts or insufficient oversight.

Farming Methods and Probability of Escapement

Question 4. What is the most cost effective method for rearing genetically engineered salmon: net pens, hatcheries or terrestrial above ground facilities? Please provide estimates for how much it would cost to rear *genetically engineered* salmon using each of the above methods.

Answer. To answer this question fully requires the results from the formal risk assessment—specifically to determine both the probability of escapement occurring, the magnitude of escapement, and the resulting acute and chronic impacts if escapement occurs. The reason for this contention is because an undetermined part

of the full-range farming costs for genetically engineered salmon will be associated with bio-containment and reduction of escapement risks and associated impacts. These containment or security costs are in addition to common operational costs (*e.g.,* food, water, facilities, pharmaceticals, etc.).

Question 5. How does the probability of escapement vary between each method?

Answer. Yes, the probability of escapement varies among methods, although I am unaware of a specific estimate. As stated previously, the results of a formal risk assessment can help to estimate such a probability. Ultimately, the probability of escapement likely varies for each method. Therefore, setting a performance standard for escapement (*i.e.,* what level is "acceptable") is really a policy matter that that is informed by the probability and magnitude of the ecological risks.

Labeling of Genetically Engineered Fish Species

Question 6. Over 400,000 Americans have commented on an FDA petition which would require the labeling of genetically labeled foods. In addition, A survey conducted in 2010 by Thomson Reuters PULSE™ Healthcare Survey, "National Survey of Healthcare Consumers: Genetically Engineered Food" showed that 93 percent of Americans believe GE foods should be labeled. Genetically engineered foods are required to be labeled in the 15 European Union nations, Russia, Japan, China, Australia, New Zealand, and many other countries around the world. What are your thoughts on labeling genetically engineered food so that consumers can make an informed decision?

Answer. While this is not an issue informed by my scientific expertise, my general opinion on the matter as someone who routinely consumes fish is that disclosure and informative labeling permit me as a consumer the opportunity to select a product appropriate to my own preferences and consistent with consumption of farmed food produced in an environmentally sensitive manner.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARK BEGICH TO JOHN EPIFANIO, PH.D.

S. 1717 and the Prevention of Escapement

Question 1. Dr. Epifanio, you have recommended to us in your written statement that it would be prudent to treat any transgenic modification of fishes as a controlled experiment that: (a) is actively monitored for impacts on an ongoing basis; and (b) can be terminated should the need arise without lingering environmental effect. Dr. Leonard and Mr. Greenberg have each expressed support for a bill I introduced in the Senate, S. 1717. This bill, as I've proposed to amend it here in Committee, would make it illegal to sell, ship, possess, or release genetically engineered salmon or other marine fish, but would provide a *broad, categorical exemption* for scientific research. It sounds like the bill I've described meets your recommended criteria—allowing only for controlled experiments that can be actively monitored and easily terminated with no environmental impacts. Do you agree?

Answer. Thank you, Senator Begich. I affirm the need for allowing legitimate medical and genetic research using fishes as experimental models. Such research should be and generally is conducted in controlled settings (that is, bio-containment) for the same reasons we have concerns about genetically engineered salmon escaping. That said, my call for treating any genetic engineering activity as "a controlled experiment" is in fact aimed more broadly at any private commercial or even public production—rather than solely on research.

As a hypothetical example to illustrate this distinction, let's say a private company or government entity can produce a genetically engineered sterile version of an undesirable pest species for the purpose of its eradication as part of an Integrated Pest Management approach (or IPM). Even if the formal risk assessment was to show a low risk for releasing such a modified species, it would be prudent if we treated the release as "experimental." As such, continued monitoring following release is warranted to assess effectiveness and any unanticipated impacts. If an undesired impact was observed, being able to not only suspend, but also to reverse, the release would be prudent as well to minimize longer-term impacts.

Question 1a. Do you support S. 1717?

Answer. I am supportive of the concept for holding-at-bay the potential long-term ecological and genetic hazards posed by genetically engineered Atlantic salmon (and other species as well) to their wild counterparts and to recipient ecosystems. I am supportive also of ensuring imposition of a well-crafted review process that requires the Federal and state agencies with appropriate expertise on the species' biology and ecosystem requirements to conduct rigorous risk assessments prior to approval.

Ultimately, banning the possession, sale, or importation can help to achieve these precautionary goals while rigorous risk assessments and a more comprehensive review process is developed.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. ROGER F. WICKER TO JOHN EPIFANIO, PH.D.

Question 1. Scientists and the aquaculture industry underscore the need to address the potential problems of genetically engineered (GE) fish, such as the impact on wild stocks. However, they also highlight the benefits of innovation in this area such as lowering costs, expanding industry, increased health benefits, and feeding a growing global population. The FDA currently has a process to address these issues on a case-by-case basis through scientific review. Would a blanket ban on commerce in genetically engineered fish inhibit innovation and competition for U.S. aquaculture companies?

Answer. I am not an expert on commerce-related issues, especially related to innovation and competition for the aquaculture industry. My expertise is in the area of genetic and ecological impacts on recipient ecosystems (and the services they provide) associated with translocation and propagation/release of fishes. Ultimately, I assert that it is critical any legislative action or regulatory rule-making adequately define the activities or products being banned (or conversely, permitted) as "commercial" with a full benefit of a formal risk assessment. For example, there may be advances and products that emerge from medical research using fishes as a model organism. I further assert a need to define what kinds of manipulations would be prohibited (or permitted) under the moniker of "genetically engineered" (that is, will this be directed solely at recombinant or transgenesis processes only, or more broadly to include chromosome-set manipulation, hybridization, or other more "traditional" modes of gene pool manipulation).

Question 2. What impact would a ban on international commerce in GE fish and GE fish products have on our country's current trade relations and treaty agreements?

Answer. I have no true expertise to bring to bear on this question, although I am aware that the European Union has attempted to address the international commerce issues in part.

Question 3. If the FDA reviews potential environmental impacts of GE fish prior to approval of sale, and private companies are taking necessary steps to safeguard the environment, why should Congress ban all GE fish from entering the market?

Answer. While FDA excels at examining the risks to humans from food, cosmetics, and drugs, we need to ask whether the agency alone has the expertise and institutional culture to competently assess the environmental impacts through a formal risk assessment to recipient ecosystems. The legitimate expertise on the interaction of fishes in their environments presently resides with NOAA, USFWS, and USGS at the Federal level, with the individual state and tribal governments, and informed by experts within the academic community. A formal risk assessment goes beyond a "paper" impact review to include scientific modeling and controlled testing of assumptions (see *Environmental Risk Assessment of Genetically Modified Organisms, Vol. 3,* "Methodologies for Transgenic Fishes," by AR Kapuscinski *et al.,* CAB International).

Question 4. The scientific review process by the FDA is designed to assess risks associated with commercial sale of GE fish and find whether such activity would pose no significant impact prior to approval—a process it has not yet completed. Could a preemptive ban on commercial production of genetically engineered fish (in this case salmon) prior to an FDA ruling undermine the scientific review process?

Answer. I appreciate the Senator's concern for safe-guarding objective scientific review—rigorous and transparent examination of methodologies, analyses, results, and interpretation are pillars of the modern scientific enterprise. In general, independent scientific review adds important value to the scientific enterprise by bringing the best and brightest expert thinking to bear on a proposal and final reporting.

Regarding the Senator's question about whether a legislatively-mandated ban undermines the scientific review—it appears that a ban would reinforce the need for a more well-defined framework that incorporates scientific review of environmental impacts by an action agency well-versed on salmon life-history and ecosystems. The requirements of food and drug safety laws designed to protect trade secrets from would-be competitors lead to a FDA review process differing from expert-based peer review more traditionally applied to ecological and natural resource sciences. As such, the FDA approach appears to be appropriate for the science behind the meth-

ods and findings for production, efficacy, and health effects of transgenesis (recombinant genetic modification) of the target organism. Conversely, this approach is not appropriate to evaluating impacts and risks to the environment by modified organisms. Importantly, a competitor gains no real or unfair advantage if information from environmental review and results of formal risk assessment were to be made public.

A legislative ban can have a time component to permit the implementation of an institutional framework for shared review. Also, should the evidence for sufficient safety become available, escapement of a few individuals or a whole population of modified salmon may not be as reversible. A comparison of the levels of concern for transformed animals is presented in a National Academy of Sciences report (Table 5.1; Animal Biotechnology: Science Based Concerns, 2002). In this table, fish rank just below insects as the group with highest level of concern because of their capacity to establish to breeding populations in the wild, a likelihood of escaping captivity, overall mobility, and ecological disruptions to complex communities. Therefore, if scientific evidence comes forth to demonstrate that the product and technology are benign, the law can be repealed. However, if salmon or other species escapes, recapture or eradication may not be possible.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. ROGER F. WICKER TO GEORGE H. LEONARD, PH.D.

Question 1. Scientists and the aquaculture industry underscore the need to address the potential problems of genetically engineered (GE) fish, such as the impact on wild stocks. However, they also highlight the benefits of innovation in this area such as lowering costs, expanding industry, increased health benefits, and feeding a growing global population. The FDA currently has a process to address these issues on a case-by-case basis through scientific review.

Would a blanket ban on commerce in genetically engineered fish inhibit innovation and competition for U.S. aquaculture companies?

Answer. There is little reason to believe that preventing the commercial proliferation of GE fish until the important environmental and regulatory questions are fully answered would undermine innovation and competitiveness within the U.S. aquaculture industry. Firstly, GE fish are not yet part of the seafood marketplace, meaning that a short-term delay or a longer-term ban would not affect the status quo.

Secondly—and most importantly—this question is based on the false premise that the only way for U.S. aquaculture to innovate or become cost competitive is through the broad application of genetic engineering technology. All current evidence is to the contrary. Although it ranks only 13th globally in terms of production, the U.S. aquaculture industry is vibrant, with over 4,000 farms in nearly every state in the nation, supplying nearly 500,000 mt of plants and animals with a value that exceeds $1.3 billion.[1] In contrast to foreign imports, many of these U.S. aquaculture products have been ranked "Best Choices" for their environmental sustainability by the well-respected Monterey Bay Aquarium.[2] Furthermore, the U.S. is also an important exporter of technology and "know how" to other countries; this intellectual capital emanates from research conducted at many of the Nation's Sea Grant colleges and universities. A key example of the level of innovation in the U.S. aquaculture industry is the annual "Aquaculture America" conference,[3] where the industry and scientists meet to discuss trends in fish farming, the status of the seafood marketplace, and innovation in U.S. fish farming that will help ensure a viable future for U.S. aquaculture. Very little of the discussion at this conference centers on the supposed need for genetically engineered fish.

Three real world examples of U.S. companies further highlight the ability of U.S. aquaculture to innovate without the need to resort to engineering their fish. Australis Aquaculture, located in western Massachusetts, is one of the largest recirculating fish farms in the world.[4] Growing barramundi in a state-of-the-art facility, this company has increased seafood choices for U.S. seafood consumers by taking advantage of this fish's naturally high growth rates. In Washington State, Sweet Spring Aquaculture[5] has pioneered a land-based salmon farm that is both cost competitive and whose product has been extremely well received by the marketplace and seafood consumers. By growing non-engineered coho salmon in freshwater sys-

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[1] *http://www.fao.org/DOCREP/003/AB412E/ab412e23.htm; http://aquaculture.noaa.gov/pdf/econ/econ__rpt__all.pdf.*

[2] *http://www.montereybayaquarium.org/cr/seafoodwatch.aspx.*

[3] *https://www.was.org/WasMeetings/meetings/Default.aspx?code=AA2012.*

[4] *http://www.thebetterfish.com/home.*

[5] *http://www.sweetspringsalmon.com/local.shtml.*

tems, this innovative company has found little need for genetically engineered fish. And finally, Kampachi Farms[6] has recently field tested a new method of growing yellowtail in the offshore ocean waters near Hawaii. In free floating ocean cages, growth and survival rates of this species were extremely high. These three examples are but a few of many in the current U.S. aquaculture industry. In none of these examples is genetic engineering central to their success.

Lastly, it is important to emphasize that not all innovation is responsible or desirable; the government's role is to ensure that the public and its natural resources are protected from potentially deleterious business practices that may cause harm to other citizens and economic sectors. With respect to GE fish, a recent publication in the prestigious journal *Science* showed that there has not been sufficient analysis done to determine if the proliferation of genetically engineered fish would ultimately be beneficial or deleterious for society.[7] Until that analysis is done, it is entirely appropriate for the government to ban or limit private initiatives that have the potential to harm society.

Question 2. What impact would a ban on international commerce in GE fish and GE fish products have on our country's current trade relations and treaty agreements?

Answer. Given that GE fish are not currently a part of the international fish trade, a ban on such fish or products would not have any foreseeable impacts on current trade relations or treaty agreements. The absence of GE fish would merely maintain the status quo. One specific concern, however, that has been raised by proponents of GE salmon is the notion that an import/export ban would constitute a "non-tariff barrier to trade" that could bring a WTO penalty or trade enforcement mechanism. As you may know, Article 20 of the General Agreement on Tariffs and Trade (GATT) allows governments to act on trade to protect human, animal or plant life or health, provided they do not discriminate or use this as disguised protectionism. Any import/export ban of GE fish would be motivated by the need to protect human, animal, and environmental life and health, and *not* be motivated by protectionism.

Such a ban, then, would not constitute a non-tariff barrier to trade for at least two specific reasons. First, a ban would be applied domestically as well as on imports/exports, giving no specific protectionist advantage to domestic producers and not giving any preference or disadvantage to specific trading partners. Second, such a ban would be based on a scientific demonstration of the risks posed to the environment and human and animal life and health, as required by WTO. In the extremely unlikely event that a WTO panel ignores those facts and finds a U.S. GE fish ban to be in violation, the U.S. would still have significant flexibility: the government could decide whether to adjust its policy, negotiate a compromise with the complaining parties, or accept retaliatory trade sanctions while maintaining the ban.

It is extremely important, however, to also ask the inverse of your question. Namely, what impact would U.S. Federal *approval* of GE fish have on our current trade relations and treaty agreements?

Answer. If FDA approves genetically engineered salmon at this time, and refuses to require the product to be labeled, a number of impacts on international relations—including trade—could result. First, the Nation's ability to export farmed salmon to Europe could be seriously undermined. The European market is generally opposed to GE food products and has strict requirements that GE food be labeled. If there is uncertainty about the genetic status of U.S. farmed salmon, European importers may simply refuse to accept U.S. product as a precautionary measure, undermining the U.S. salmon farming industry which currently does not utilize GE fish and has publically indicated it has no interest in doing so.[8]

Approval of GE salmon could also affect a number of multilateral treaties that pertain to wild salmon management and ecosystem protection. For example, the Pacific Salmon Treaty, signed in 1985, sets long-term goals for the benefit of wild salmon in both the U.S. and Canada. Interception of Pacific salmon bound for rivers of one country in fisheries of the other has been the subject of discussion between the two countries since the early part of the last century. Should GE fish escape and impact wild salmon in the Pacific Ocean, existing goals of the Pacific Salmon Commission could be undermined. In an analogous way, expansion of GE fish in the U.S. could undermine the ongoing work of the North American Commission of the North Atlantic Salmon Conservation Organization (NASCO). NASCO was established in 1984 as an inter-governmental body to conserve, restore, enhance, and ra-

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[6] *http://kampachifarm.com/*.

[7] Smith, M.D., Asche, F., Guttormsen, A. G., J. B. Wiener. 2010. Genetically Modified Salmon and Full Impact Assessment. Science 330:1052–1053.

[8] *http://www.workingwaterfront.com/articles/Wild-to-Transgenic-Salmon-in-Maine/14105/*.

tionally manage salmon in the Atlantic Ocean. Through this body, regulations and other measures have greatly reduced harvests of salmon throughout the North Atlantic. Escaped GE fish could require a reevaluation of the measures currently in place by Canada and the U.S. to restore wild Atlantic salmon.

Lastly, escaped GE fish could undermine the collaboration between the U.S. and Canada to effectively manage the Great Lakes ecosystem and their associated fisheries. The Great Lakes Fishery Commission was established by the Convention on Great Lakes Fisheries between Canada and the United States in 1955. The Commission's primary goal is to develop coordinated research programs between the two countries and make recommendations to ensure sustained productivity of fish stocks of common concern.

In all three of the examples above, the potential negative consequences of the proliferation of GE salmon farming on treaty outcomes has not been sufficiently evaluated by the FDA, the State Department, or any other Federal agency. This type of analysis must be done *before* approval to ensure that our government understands the full suite of possible ramifications of such an approval on trade relations and treaty agreements.

Question 3. If the FDA reviews potential environmental impacts of GE fish prior to approval of sale, and private companies are taking necessary steps to safeguard the environment, why should Congress ban all GE fish from entering the market?

Answer. This question assumes that the United States has a regulatory process in place that can anticipate, evaluate, and guard against the potentially far-reaching environmental risks posed by genetically engineered fish. However, the existing regulatory framework under the Federal Food, Drug, and Cosmetics Act is woefully inadequate. As I pointed out several times during my appearance before the Subcommittee, the FDA's environmental review process is ignoring a large proportion of the potential environmental impacts. Many of the key environmental impact questions are not only going unanswered by the FDA's review—those questions are not even being asked. Therefore, approval should not proceed until a full analysis of the environmental, economic, and societal impacts of the expansion of GE fish farming is done. To date, the FDA has indicated it will not evaluate the full range of environmental impacts (instead focusing only on the specific application from AquaBounty Technologies, Inc.) allowing the segmentation of environmental harms and ignoring the broader concerns of full-scale commercialization. Rather than being intentionally near-sighted, our government agencies should be forward thinking.

Under the 1986 Coordinated Framework for the Regulation of Biotechnology ("Coordinated Framework"), genetically engineered organisms (GEOs) are regulated according to the concept of "product, not process." This means that Federal agencies evaluate GEOs as products like any other—"substantially equivalent" to their non-engineered analogues—not as a special category distinguished by their development using the process of recombinant DNA technology. The Coordinated Framework assumes that the existing agencies, using existing authority, have the ability and expertise to review commercialization applications.

There are a number of flaws with this approach. First, existing statutes have generally been designed to address situations where harm or risk has already been quantified, not situations where there remains a high degree of scientific uncertainty, such as is the case for genetic engineering technology. The "new animal" drug laws currently being used to regulate GE animals, for example, were written well before GE animals were ever conceptualized as a possible food source and are woefully outdated. Second, the theory of substantial equivalence is predicated on an assumption of safety; that is, it starts from a position of assumed safety, where the burden of proof falls on the public to show harm.[9] Third, an agency with expertise in one area relevant to a permit application may not be best suited to evaluate the other potential effects a GEO may have when it is commercially released. This potential for problems in regulating transgenic fish and livestock under the Coordinated Framework Early was recognized as early as 1990.[10]

FDA's authority was designed to provide the agency with oversight of traditional pharmaceutical drugs. Applying the new animal drug application process to GE salmon intended for interstate commerce and human consumption raises a host of concerns. Because of matters of trade secrets, the process is open to public comment only *after* the approval of the new animal drug application, and thus, approval of

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[9] Kelso, Dennis Doyle Takahashi. "Genetically Engineered Salmon, Ecological Risk, and Environmental Policy." *Bulletin of Marine Science* 74, no. 3 (2004): 509–28.

[10] Kapuscinski, Anne R. and Eric M. Hallerman, "Transgenic Fish and Public Policy: Anticipating Environmental Impacts of Transgenic Fish," *Fisheries* 12 (1990), p. 3, 5.

the GE fish has been made.[11] Unlike applications led by USDA or EPA, FDA's approval process occurs almost entirely behind closed doors, making it nearly impossible for the public to participate meaningfully in an agency decision that could lead to devastating and irreversible ecological harm. While this process might protect confidential business information, it fails to adequately and transparently examine potentially far-reaching and serious consequences and environmental risks from GE salmon.

FDA's existing regulatory process was simply not designed to address the complex issues involved in developing genetically engineered fish for human consumption. Because the FDA's focus is on food and drug safety, the agency does not have the expertise or experience to adequately identify and analyze the environmental risks and consequences of GE salmon and other fish. In addition, the FDA approval process lacks adequate consideration of the full range of environmental hazards, and the opportunity for sufficient input from other Federal agencies with expertise in fisheries and environmental risk. Among other issues, the current process fails to adequately consider threats to wild salmon populations, threats to commercial and recreational salmon fisheries, threats to fisheries targeting other species that interact with salmon, threats to marine and terrestrial food webs in which salmon are embedded, and threats to recovery efforts for salmon stocks listed as endangered or threatened under the Endangered Species Act.

Other Federal agencies with relevant expertise must play a stronger leadership role in the approval and regulation of GE fish. These include the National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service (USFWS), and the Environmental Protection Agency (EPA). NMFS and FWS have scientific expertise backed by extensive ecosystem research, and have expertise in conservation and protection of the natural resources that could ultimately be affected by GE salmon and other GE fish. EPA has knowledge and experience in the oversight and management of threats to water and watersheds. At a minimum, FDA should be required to consult these agencies during all stages of development and approval of GE salmon. Furthermore, if FDA is to remain the lead agency, FDA should be required not only to consult with these agencies, but also to either heed their advice or provide adequate rationale for any decisions to the contrary.

Concerns over the FDA approval process were brought to the attention of FDA in September 2010 in a letter from eleven U.S. Senators, including Senator Begich.[12] The letter requested that FDA halt the GE salmon approval process, citing concerns over unknown impacts to human health and environmental risks. These concerns are valid as FDA is ill-equipped to deal with the environmental and biological consequences and risks associated with the farming of genetically engineered fish. Preventing GE fish from entering the marketplace at this time would provide 6 Congress the time to craft proper laws and ensure that FDA develops regulations based on these new laws that will be appropriate for this new method of farming animals.

Question 4. Could a preemptive ban on commercial production of genetically engineered fish (in this case salmon) prior to an FDA ruling undermine the scientific review process?

Answer. If the existing review process were sufficiently rigorous there would be little need to prevent the commercialization of GE fish at this time. But, as explained in detail in Question 3 above, the process is woefully inadequate and lacks credibility. Given the limitations of the existing regulatory system, the most prudent course of action is to not move forward with approval. This does not undermine the review process; it merely acknowledges its deficiencies. Should the review and regulatory process for GE animals, including fish, be revised to address our full range of concerns—including the need for additional scientific review—Ocean Conservancy would be supportive of completing the review. In the absence of such changes, however, we remain supportive of Congress' efforts to institute a ban.

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[11] FDA provided an opportunity for public comment in September 2010 before final approval of GE salmon, likely because the agency sensed this decision would be highly controversial; FDA, however, is not legally required to be similarly forthright when new entities seek approval from the agency for additional species or culturing conditions.

[12] Letter to Commissioner Margaret Hamburg, Commissioner of Food and Drugs, FDA (Sept. 28, 2010).

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN D. ROCKEFELLER IV TO TOM ISEMAN

Access to Climate and Weather Data

Question 1. How does NOAA disseminate their climate and weather data to state and local entities such as the WGA? Please provide examples.

Answer. NOAA employs a range of tools and partnerships to disseminate weather and climate information, ranging from weather forecasts and websites to on-the-ground engagement with states, private sector and local communities.

The most visible form of outreach is television and radio, and specifically the local weather forecast, where NOAA's National Weather Service field offices provide information on day to day conditions. Citizens tune into their forecast every day to decide whether to bring an umbrella or how long their morning commute might be.

Another tool is websites, like weather.gov, climate.gov, or drought.gov (which was a direct outgrowth of our partnership on the National Integrated Drought Information System (NIDIS)). These websites are designed to collect and aggregate relevant information and to make it available as a 'one-stop shop' for states and users. They allow interested viewers to find a range of information and to focus on geographic or topical issues of interest. However, these are passive services that require some user initiative and knowledge to exploit.

NOAA also provides periodic Climate Outlook Forums. In these forums, NOAA experts provide the latest climate forecasts to interested users, and they are available for dialogue and Q&A with the audience. These vary in geographic and temporal scale, from an annual climate outlook for the Nation to a seasonal climate outlook for a particular region of interest, for example, drought in the Southwest or flooding in the Upper Missouri.

Finally, NOAA works directly with states and local users to engage in the development of information services, for example in the case of 'Early Warning Systems' being developed by NIDIS. In these cases, NOAA works with stakeholders to understand the key weather and climate variables of interest for a relevant geography, and they 'co-develop' a system to monitor and report on those variables over time. NOAA's Regional Integrated Sciences and Assessments (RISAs) conduct stakeholder-driven research needed to inform these systems at the scale of watersheds, cities, and local communities where managers make decisions. Early Warning Systems are being developed for the Upper Colorado River, the Apalachicola-Chattahoochee-Flint Basin in the Southeast, and the ongoing drought in the Southern U.S.

These are the services that WGA is trying to promote through its MOU with NOAA: regional services that more actively engage states and other on-the-ground stakeholders in the identification and development of new tools to track and respond to key weather and climate events. By engaging states and other stakeholders, tools will address the key issues of interest—like how drought may affect a municipal water supply, or when flooding may delay the shipping of goods by rail, or whether infrastructure design criteria are sufficient to address severe storm events—and will be more widely adopted and employed than national websites. We recognize that regional, stakeholder-designed services may require additional resources and time; however, they are the best way to address the regional variability inherent in climate and its impacts to on-the-ground decision-making.

Question 2. What concrete improvements can be made to increase access to this information?

Answer. While portals like drought.gov have broad utility and should be continued, we support efforts to promote more active, stakeholder-initiated services that address key regional priorities. Regional systems provide a targeted assessment of key indicators, along with the expertise and resources to interpret and apply them to on-the-ground decision-making. Regional systems can stimulate efforts to plan and prepare for climate and weather events, rather than simply responding after the fact. We want to get to the point where a farmer uses the seasonal outlook to decide whether to plant certain crops, or a water utility uses long-range snowpack projections to design new infrastructure—just like you or I listen to the weather forecast to decide whether to carry an umbrella.

We recommend a rigorous assessment of existing regional early warning systems, including those developed under NIDIS, to inform the design and implementation of future efforts.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO PAUL GREENBERG

Farming Methods and Probability of Escapement

Question 1. What is the most cost effective method for rearing genetically engineered salmon: net pens, hatcheries or terrestrial above ground facilities?

Answer. If your question is which method of salmon farming has the lowest direct cost to the producer, then the easy answer is net pen aquaculture. Net pens are placed directly in a marine environment that is naturally the appropriate temperature. Wastes from said farms are released directly into the marine environment. The farmer therefore does not have to bear the costs of temperature costs and waste disposal. Those costs are passed on to the surrounding environment. That being said, AquaBounty has not proposed the growing of its GE fish in net pens. Rightly understanding the risk of escapement, they have said publicly that their fish will be grown in containment structures. However, it should be noted that AquaBounty itself is not a salmon farmer. The company is a producer of seed stock and it will be up to individual farmers that buy that stock and state and Federal regulators to determine whether individual farmers may grow the AquaBounty fish in a net pen. I am deeply concerned that the cost efficiencies of net pen culture may compel some farmers to attempt growing the GE salmon in the wild marine environment where escapement is a considerable risk. Many millions of farmed salmon have escaped from net pens in salmon farming's modern 40+ year history.

Question 2. How does the probability of escapement vary between each method?

Answer. As stated above, net pen growing of salmon has a much greater risk of escape. Seals, storms and other natural events quite frequently rupture net pens and even with technological advancements it's reasonable to assume that escapes will continue from net pens. Terrestrial above ground facilities have a lower risk of escape but in the event of a major flood (as occurred in the Northeast in September of this year) a contained facility good easily be flooded and fish could escape.

Labeling of Genetically Engineered Fish Species

Question 3. Over 400,000 Americans have commented on an FDA petition which would require the labeling of genetically labeled foods. In addition, A survey conducted in 2010 by Thomson Reuters PULSE™ Healthcare Survey, "National Survey of Healthcare Consumers: Genetically Engineered Food" showed that 93 percent of Americans believe GE foods should be labeled. Genetically engineered foods are required to be labeled in the 15 European Union nations, Russia, Japan, China, Australia, New Zealand, and many other countries around the world. What are your thoughts on labeling genetically engineered food so that consumers can make an informed decision?

Answer. I fully support the labeling of genetically modified food. The American economic system is one based on freedom of choice. If Americans cannot obtain information about the food they are eating in an easy to recognize format then they are being denied that basic right of free choice.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. ROGER F. WICKER TO PAUL GREENBERG

Question 1. Scientists and the aquaculture industry underscore the need to address the potential problems of genetically engineered (GE) fish, such as the impact on wild stocks. However, they also highlight the benefits of innovation in this area such as lowering costs, expanding industry, increased health benefits, and feeding a growing global population. The FDA currently has a process to address these issues on a case-by-case basis through scientific review. Would a blanket ban on commerce in genetically engineered fish inhibit innovation and competition for U.S. aquaculture companies?

Answer. No, quite the contrary. It's my opinion that poorly regulated countries like China will pursue GE fish at their peril. As affluence grows around the world, consumers will grow more discerning. Products that are produced naturally will gain higher value. The United States with its abundant wild fisheries has a unique opportunity to secure the high ground in the global seafood system. Already the vast majority of Alaska's wild seafood is sold abroad and prices are only rising for those foods. But this is not only the case for wild product. America's shellfish growers, aquaculturists all, are having resounding success selling their product abroad. Taylor Shellfish Farms of Washington state sells something like 35% of its product abroad, much of it going to China. These environmentally friendly products fetch a

high premium and their prices will only grow. The path forward for American seafood is quality and purity, not brute quantity.

Question 2. What impact would a ban on international commerce in GE fish and GE fish products have on our country's current trade relations and treaty agreements?

Answer. Very little. As state above we already have rich trade agreements for our wild fisheries and our products have extremely high value abroad and are greatly esteemed. In fact *allowing* GE fish into our food system would, I fear, negatively impact the reputation (and therefore pricing) of our products abroad.

Question 3. If the FDA reviews potential environmental impacts of GE fish prior to approval of sale, and private companies are taking necessary steps to safeguard the environment, why should Congress ban all GE fish from entering the market?

Answer. As I said in my written testimony, the effects of environmental pollutants are never realized until many years after their release into the environment. PCBs and DDT were not proven to have adverse environmental effects until many years after their wide-scale use. Furthermore with the regulatory burden due to be placed on an already overly burdened FDA I do not feel this country has the resources to adequately monitor the cultivation of this fish. While AquaBounty promises containment-only growing of the GE salmon, farmers will be tempted to grow the fish in open water net cages and FDA or whoever the responsible regulatory agency will be at the time will not have the human resources to monitor. It's my opinion that this fish will end up being farmed in the open ocean and that it will eventually escape.

Question 4. The scientific review process by the FDA is designed to assess risks associated with commercial sale of GE fish and find whether such activity would pose no significant impact prior to approval—a process it has not yet completed. Could a preemptive ban on commercial production of genetically engineered fish (in this case salmon) prior to an FDA ruling undermine the scientific review process?

Answer. I do not believe so because as Senator Begich pointed out during the hearing, the assessment of this organism's fitness for distribution in the United State should not lie solely in the hands of FDA. FDA by definition does not take responsibility for the health of wild salmon stocks. That is a job for NOAA/NMFS, the EPA and other agencies more closely attuned to the risks to wild animals. Therefore I believe the ban would as Senator Begich suggested, slow down the process to a point whereby more relevant agencies could have an opportunity to enhance the scientific review process.

Question 5. In your written testimony you state specific reasons why the GE salmon produced by AquaBounty Inc. should not be approved for commercial production. You then conclude with strong support for legislation that would ban ALL GE marine fish—not just AquaBounty's salmon. Is it really necessary for Congress to ban all GE fish from commercial production when the FDA considers approval on a case-by-case process?

Answer. I believe that the US should take a precautionary and sensible approach to GE fish. As I stated in my written testimony a GE fish is not necessary for the American food system at this point in time and even AquaBounty admits that they cannot be 100% certain that the fish will not escape. So, my point is, why should we introduce any GE fish into the American food system until it is absolutely necessary. There are many many ways to improve American aquaculture outside of genetic modification. Aquaculture is a new science and we have great strides ahead of us to improve feed, husbandry techniques and all the myriad factors that go into making a productive farm. GE fish is a dangerous short cut that provides only a few modest benefits alongside a host of potential risks.

STATE OF ALASKA
December 14, 2011

Hon. MARK BEGICH,
Chairman,
U.S. Senate Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard,
Washington, DC.

Hon. OLYMPIA SNOWE,
Ranking Member
U.S. Senate Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard,
Washington, DC.

RE: ENVIRONMENTAL RISKS OF GENETICALLY ENGINEERED FISH

Dear Chairman Begich and Ranking Member Snowe,

I commend the Subcommittee for its attention to the environmental risks associated with genetically engineered fish. My administration continues to have strong concerns regarding AquaBounty's application to market genetically engineered Atlantic salmon. Due to the significant potential threats genetically engineered salmon pose to the environment, consumer health, and the wild seafood industry, we have urged the United States Food and Drug Administration (FDA) to withhold approval of this application. Furthermore, we question whether the application has received sufficient scientific and public scrutiny, and are troubled by the Zack of transparency that has marked the review process.

Threat to Wild Salmon Stocks

Like many, we fear genetically engineered salmon could jeopardize the health of wild salmon stocks if released into the wild. Genetically engineered salmon could spread disease, cross-breed with wild salmon, and out-compete them for food and mates. The United States Fish and Wildlife Service (FWS) and National Oceanic and Atmospheric Administration (NOAA) have recognized these risks, and warned the FDA about the potential dangers associated with escaped genetically engineered fish in a joint letter to the FDA in 2001, and the National Academy of Sciences in a 2002 study.

While AquaBounty proposes containment measures to reduce the chance of genetically engineered salmon escapes, these measures would not eliminate the risk. That risk would grow if AquaBounty supplies genetically engineered salmon eggs to a network of commercial farms, as the company intends. Juneauskans are well aware that fish farming containment measures are not fail-safe. Commercial fishermen in Alaska have caught hundreds of Atlantic salmon, escaped from fish farms in Canada and the state of Washington.

Insufficient Consultation with National Marine Fisheries Service (NMFS)

We have urged the FDA to honor a provision authored by the late Senator Ted Stevens and Senator Lisa Murkowski, which became law as part of the Food and Drug Administration Amendments Act of 2007 (P.L. 110–85). The provision requires the Commissioner of FDA "to consult with the Assistant Administrator of the NMFS of the National Oceanic and Atmospheric Administration to produce a report on any environmental risks associated with genetically engineered seafood products, including the impact on wild fish stocks." This statutory language was intended to ensure NOAA played a role in the FDA's approval process for genetically engineered seafood products. We are not convinced that this statutory obligation has been fully met.

Threat to Human Health and Consumer Confidence in Salmon

Before genetically engineered salmon is allowed into the United States' food supply, more rigorous scientific research is necessary to ensure its long-term consumption is safe for a large cross section of the population, including sensitive populations such as young children and expectant mothers. As you know, salmon is widely recognized for its health benefits, and many consumers purchase salmon for this reason. Allowing a company to sell a genetically engineered product that has not been the subject of sufficient long-term testing would undermine consumer confidence in all salmon products as well as the health benefits of salmon consumption.

Economic Impact on Wild Seafood Industry

Genetically engineered salmon could also erode the strength of the wild seafood industry, especially if appropriate labeling is not mandated. For Alaska, the results could be devastating. Alaska's salmon industry is critically important to the state's economy, and is the primary source of employment and revenue in many of our coastal villages. Farmed salmon has already threatened the position of Alaska's wild salmon in the seafood market. Alaska salmon, however, regained its status thanks to significant investments in infrastructure, product quality, and marketing. Mar-

keters focused on distinguishing the health benefits and taste properties of Alaska salmon. Studies still show, however, that consumers struggle to distinguish seafood in the marketplace. Adding genetically engineered salmon to the store shelf could further complicate the efforts of consumers seeking healthy, wild seafood products.

Lack of Public Participation and Transparency

In addition, my administration is disturbed by the process employed by the FDA to review AquaBounty's application. The environmental and public health implications associated with genetically engineered salmon and the significance of approving the first genetically modified animal for consumption in the United States warrants the highest level of public participation and transparency. We do not believe that FDA's review process for veterinary drugs allows for a sufficiently public and transparent process.

Lack of Genetically Engineered Labeling

FDA's statements that suggest it may not be able to require labeling for AquaBounty's genetically engineered salmon is also troubling. The State of Alaska does not support approval of genetically engineered salmon for sale. If, despite significant environmental and human health concerns, the FDA approves such an application, genetically engineered salmon sold in the United States should be clearly labeled "genetically modified," so consumers can make an informed choice. This label should be prominently displayed on the front of the package in a contrasting color, and a minimum print size should be required. Alaska statutes require the conspicuous labeling of such products sold in the state.

For the reasons mentioned above, I support legislation to prevent the FDA's approval of genetically engineered salmon for human consumption and to require appropriate labeling for any genetically engineered seafood products.

I appreciate your consideration of Alaska's position on this important issue and respectfully request that this letter be included in the hearing record.

Sincerely,

SEAN PARNELL,
Governor.

cc: The Honorable John Rockefeller, Chairman, United States Senate Committee on Commerce,Science, and Transportation

The Honorable Kay Bailey Hutchison, Ranking Member, United States Senate Committee on Commerce, Science, and Transportation

The Honorable Lisa Murkowski, United States Senate

The Honorable Don Young, United States House of Representatives

The Honorable Cora Campbell, Commissioner, Alaska Department of Fish and Game

The Honorable Larry Hartig, Commissioner, Alaska Department of Environmental Conservation

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[Hon. Mark Begich, U.S. Senator from Alaska, requested that the following information, submitted by SeafordSource.com, be placed in the record. The entire report is available from *SeafoodSource.com.* or at *http://www.egeliihracatcilar.com/images/menu11-page/ABD2011ConsumerSurvey__SScomNEW__00000282.pdf.*]

"American Consumers' Finfish-Purchasing Behaviors at the Retail Level"

This SeafoodSource.com-commissioned survey gauges American consumers' finfish-purchasing behaviors at the retail level. In an online survey, 400 respondents were asked how often they buy finfish, what's preventing them from purchasing more, what finfish species and product forms they prefer and where they buy their finfish, among other questions. Additionally, dozens of independent variables were analyzed to determine what consumers are willing to pay for certain attributes, resulting in a "willingness to pay" model that seafood professionals can use to help them make smarter decisions.

Executive Summary and Key Insights

More than half of consumers purchase finfish at least once a month or more frequently for consumption at home, according to a new SeafoodSource.com survey of U.S. consumers who are the primary grocery shoppers for their household. But what are they buying? Where are they buying it? And what is most important to them when buying finfish?

By a wide margin, the U.S. consumers surveyed prefer to purchase fresh finfish over frozen finfish or prepared finfish entrées, and fillets are the most popular prod-

uct form in both the fresh and frozen categories. Furthermore, salmon and tilapia are by far the most frequently purchased species of finfish to prepare and enjoy at home. When it comes to shopping for finfish, consumers appear to be comfortable and confident in familiar channels. The supermarket/grocery store is the most popular channel for finfish purchases, and is distantly followed by club stores and mass merchandisers. Additionally, almost all consumers say they are confident in the safety of the finfish that they purchase at these retailers. Although most consumers consider themselves familiar with the terms "aquaculture" and "fish farming," it does not engender strong feelings or reactions from consumers. The majority of U.S. consumers surveyed describe themselves as neutral, without positive or negative feelings, about purchasing seafood produced by a farm.

When asked what, if anything, is keeping them from buying more finfish for home consumption, consumers most often point to the cost, saying that "fish is too expensive." However, quite a few consumers admit that they or another member of their household simply do not like to eat fish. When they are selecting finfish to bring home and prepare for themselves, consumers are actively engaged in looking at labels and understanding more than just the species and product form. Overall, the factors most important to consumers are that the finfish is fresh and free of hormones and antibiotics. They also do not favor genetically modified (GM) fish, though currently no GM fish is approved for human consumption in the United States. Other attributes, such as fish that has been produced and processed in the United States and is wild caught, are also important. While consumers may indicate that a wide range of attributes are very or somewhat important when selecting finfish to purchase, in truth consumers are only willing to actually pay extra for a few of those attributes, which are unveiled in the survey results. It is interesting to note that while there are slight differences in fish tastes and preferences due to consumers' geographic region or age/generation, there are rarely any significant differences in consumers' opinions and preferences about finfish purchases due to gender, marital status, education level, income level or household size.

BIOTECHNOLOGY INDUSTRY ORGANIZATION
December 13, 2011

Hon. JAY ROCKEFELLER,
Chairman,
Senate Committee on Commerce,
Science, and Transportation,
Washington, DC.

Hon. KAY BAILEY HUTCHISON,
Ranking Member
Senate Committee on Commerce,
Science, and Transportation
Washington, D.C. 20510

Hon. MARK BEGICH,
Chairman,
Subcommittee on Oceans, Atmosphere,
Fisheries, and Coast Guard,
Washington, DC.

Hon. OLYMPIA SNOWE,
Ranking Member,
Subcommittee on Oceans, Atmosphere,
Fisheries, and Coast Guard,
Washington, DC.

Dear Senators,

The Biotechnology Industry Organization (BIO), which is the world's largest biotechnology association with over 1,100 members worldwide, supports science-based regulation of innovative food and drug applications that have the potential to benefit the American people.

BIO members research, develop, and commercialize technologies to help heal, feed, and fuel the world. To ensure the safety and efficacy of new biotechnology products, it is essential to have in place science-based regulatory oversight, as applied by the U.S. government. Well-trained scientists within the Federal agencies are best equipped to fairly evaluate food, human, and environmental safety determinations associated with product applications.

BIO is therefore concerned by any attempt by Congress to short-circuit scientific reviews and urges you to oppose any legislative initiative that would restrict the science-based review process for genetically engineered fish at the Food and Drug Administration (FDA). Such an effort would upend the current scientifically rigorous review system and unnecessarily vilify new technologies in the eyes of the public.

The disruption of the FDA's Congressional mandate to base its assessments of applications on the best-available science underlying an application would devalue all of the research that has gone into this area over the years. Such a disruption would also diminish the credibility of the FDA approval process at home and overseas. The global reputation of FDA's science-based review procedure is based on the Agency's objectivity.

Based on projections for the year 2050, the rapidly growing global population will make it necessary to double the annual amount of food that is produced as compared to today. The adoption of new agricultural technologies, including animal biotechnology, will help to meet the challenge of sustainably achieving food security so that hungry people get enough to eat. Estimates suggest that as much as 70 percent of the required food supply in 2050 must come from new and existing technologies, which is why it is essential that FDA scientists are permitted to conduct thorough science-based reviews without political interference.

BIO urges the Senate to support science-based regulation of innovative food and drug applications and oppose any effort to weaken the government's ability to base its assessments on the best-available science.

Sincerely,

JAMES C. GREENWOOD,
President and CEO,
Biotechnology Industry Organization.