POSITIVE FEEDBACK LOOP BETWEEN JELLYFISH & SALMON FARMING

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Executive summary
Salmon farming is exacerbating jellyfish blooms, which are in turn impacting ecosystem stability and industry viability. Peculiarities of the jellyfish life cycle mean that two quite different life forms are both threatening the health of salmon and other species. Threats from jellyfish include direct stinging, suffocation by mucus, gill damage leading to necrosis, hydroid seeding whereby the pest problem is multiplied each time the holding pens are cleaned, adding to the nutrient load, and legacy degradation of the ecosystem. I make this submission to the Fin Fish Farming in Tasmania Inquiry out of great concern over a worsening ecological problem that is already influencing long term viability of the industry; my concerns specifically address all the Inquiry's terms of reference.

Background
"*Huon Aquaculture have felt the sting of a jellyfish bloom that resulted in a 64 per cent drop in full-year profit…*" (AAP 2019). These opening words in a media story portray the devastating effects of a fish kill and its knock-on losses. An estimated million and a half fish were killed, either acutely by stinging and suffocation, or slowly by gill disease and necrosis that infected the survivors.

As shocking as a 64 per cent loss is, the more serious part is that this is not the first time it has happened, and probably not the last. In fact, all evidence points to current salmon farming practice making the jellyfish problem worse, with increasingly bigger losses over the last several decades.

While some may argue that a company has a right to lose money and may even assert a right to destroy the natural resources on which its future viability depends, I argue that this right does not extend to destruction of publicly owned property and native species downstream. These increasingly destructive jellyfish blooms fueled by salmon farming are causing legacy environmental damage that will likely never return to normal.

Duality of threats of the jellyfish life cycle
The unusual life cycle of jellyfish presents a duality of threats. Unlike most species familiar to us, jellyfish have essentially two adult stages, the more familiar medusa, or free-floating sexual stage, and the less familiar polyp, which is like a tiny sea anemone or coral polyp that sticks to surfaces. When jellyfish reproduce, the young grow up to become polyps, and vice versa. These two different life cycle stages cause very different threats to farmed salmon, other farmed species, native species, and the habitat.

Under certain conditions, jellyfish quickly breed into super-abundances, called blooms or swarms. While blooms occur naturally, they also may be stimulated by changes like warming water, which cause them to bloom more, and by any impacts on their predators and competitors (fish), like pollution, overfishing, and introduced species. In this way, jellyfish blooms are often a visible indicator that something is out of balance in the ecosystem. Moreover, jellyfish can be a threat multiplier for other impacts, adding to the stress that species must cope with.

Lack of leadership to manage this problem
I've spent the last 28 years researching jellyfish blooms, including those affecting farmed salmon. It's a thorny problem. Unfortunately, while I was with CSIRO for more than seven years, I was unable to

research this subject to the extent it deserves. As awkward is this is to say, CSIRO is not as independent as many people believe. CSIRO requires a minimum of 60 per cent industry co-investment on all new projects, which means that only the data and outcomes that industry is willing to fund actually go on to become active projects. Research on the jellyfish blooms problem was actively minimized by CSIRO management on numerous occasions, on the basis that it was a sensitive subject with industry. Even on two occasions when industry appeared to be pushing for research, CSIRO stalled and ducked, resulting in collapse of the projects. As a result, we are left without the proper data or strategies to fully understand the complexities of this problem in a Tasmanian context, or to deal with it in locally appropriate ways. We have our heads in the sand on this issue, and it will only get worse. Strong leadership is needed on this issue.

Jellyfish and salmon farming interact in four main ways, as outlined below, creating a positive feedback loop, with no positive outcome. My points of concern relate to all three Terms of Reference (TOR), as detailed in each section.

1. Medusa threats

Depending on medusa size, they either get stuck onto the outside of the nets, similar in principle to how a plastic wrapper gets sucked into a pool filter screen, or if small enough or fragmented enough, they penetrate the cages. Some people have speculated that if enough jellyfish are stuck on the cages, this could block the flow of oxygenated water, suffocating the fish; I have not seen data to substantiate this, but it seems theoretically possible.

The more accepted mechanism of fish kills happens with a combination of mucus and nematocysts (microscopic stinging cells). When jellyfish are stressed, such as when they are caught up in a net or a cageful of frantic fish, they exude copious amounts of mucus, which contains countless nematocysts. Stings to the gills panic the salmon, so they breathe faster, inhaling more mucus. The mucus coats the surface of the gills, preventing oxygen uptake. Simply, the salmon suffocate. A typical fish kill event is over and done with in a half hour or so, leaving hundreds of thousands of fish dead.

For the surviving fish, it's not over. Nematocysts in the gills cause microscopic injuries, which often lead to gill disease (Baxter et al. 2012; Bosch-Belmar et al. 2017). Moreover, some types of jellyfish actually carry bacteria associated with gill disease, such that the jellyfish may act as vectors or their stings may act as threat multipliers (Ferguson et al. 2010; Småge et al. 2017).

The impacts on salmon due to jellyfish blooms also impact native species and other aquacultured species in the same ways, as well as in additional ways detailed below.

TOR 1a. Lack of research and publicly available data on these fish kill incidents hampers managing these issues, for salmon and the environment as a whole. For example, an accurate assessment of Huon Aquaculture's November 2018 fish kill took approximately nine months to be made public, with at least three other misleading loss estimates made to the community, the ASX, and shareholders. Besides being potentially unlawful, these delays and misleading statements were a breach of good faith and good business. Legislation should mandate **data transparency for the general public**. The ABC Four Corners 2016 episode on dangerous overstocking of salmon farm pens in Macquarie Harbour highlighted a lack of transparency in the governance of the sector, with court proceedings having to be initiated by Huon Aquaculture to force the State government to take the problem of over-stocking seriously. The Department of Primary Industries, Parks, Water and Environment in its 2017 *Sustainable Industry Growth Plan for the Salmon Industry* declared that its "vision" for the sector included "increasing transparency and industry accountability for environmental management" (p.4).

TOR 1b. The cramped pens characteristic of salmon farming act as both incubators and feeder sources for jellyfish blooms, which is a **biosecurity issue** for other species. A biosecurity plan should include not only effects of pest species on farmed salmon stock, but also the effects on native fish and invertebrate species, as well as other aquacultured species.

TOR 2c. Jellyfish blooms harm not only salmon, but they also permanently **degrade the environment** and affect the native species that live there. Although in theory the legislation governing salmon farming can address adverse environmental sequelae, these laws (notably the Marine Farming Planning Act 1995 and the Living Marine Resources Management Act 1995) have not been implemented robustly and the industry has been allowed to expand in defiance of concerns from local communities and environmental scientists. To ensure that the industry is regulated at arm's length without conflicts of interest, the Commonwealth should assume responsibility for regulation of fish farms in coastal waters.

2. Polyp threats

Experiments on jellyfish polyps have demonstrated that they prefer artificial surfaces (Bloecher et al. 2013; Holst and Jarms 2007). The infrastructure associated with salmon farms, therefore, offers an ideal habitat for jellyfish to flourish in.

A. Hydroid colonies on nets affect the fish

Hydroid colonies growing on nets sting fish as they swim by. Lesions on the skin make the fish less saleable, and there is the possibility for toxic contamination or infection of flesh. There is also high potential for clouds of nematocysts or debris to form as fish bump into them; nematocysts and debris have been shown to cause gill disease and necrosis (Bosch-Belmar et al. 2017). Hydroid colonies can also impede water circulation, and can add to drag of the nets in currents. Thus, the hydroids must be cleaned away regularly.

TOR 1b, 2c, 3. At least two introduced species of hydroids are now known in southern Tasmania, both of which could pose a threat to salmon and other species. Both are thoroughly unresearched; however, it seems likely from what we know about jellyfish natural history that salmon farms may be acting as incubators for these and other pest species. Robust biosecurity and sustainability plans will include jellyfish and hydroids in their monitoring and management goals.

B. Net cleaning debris causes gill necrosis

The primary threat from polyp stages comes from debris generated by net cleaning activities. Cleaning is accomplished by high pressure water blasting, or by manual brushing or scraping of the nets. Debris consists of stingy and abrasive components, both of which lead to gill injuries, amoebic gill disease, necrosis, and mortality (Bloecher et al. 2018; Bosch-Belmar et al. 2017).

As bad luck would have it, hydroid regrowth is stimulated by the mechanical action of net cleaning (Guenther et al. 2010). Laboratory experiments have demonstrated that tiny bits of hydroids left on the nets after cleaning are sufficient to regrow entire colonies, and the more frequent they are cleaned, the faster they reproduce.

Likewise, the tiny fragments created by the cleaning process act like seeds, flowing downstream and settling out to become new vigorously growing colonies. This problem was referred to in a minor way in my collaborative submission with Dr Dain Bolwell, where it formed part of that discussion on overlooked threats, while here I offer a fuller explanation as an important component of understanding the complexity of the jellyfish problem.

Hydroid seeding can be compared to the broom scene in the Disney film *Fantasia*, where each effort to destroy the brooms simply resulted in more brooms. Downstream hydroid seeding is a serious issue affecting farmed and native species alike. In the short term, it leads to a higher biomass of medusae stinging the salmon and native species, and in the long term, the extra biomass permanently alters the function of the ecosystem.

TOR 1b, 2c 3. Hydroid seeding downstream beyond the farms is a serious biosecurity issue and environmental hazard for other industries and natural habitats, with knock-on effects back to the farms in terms of increased bloom impacts; the biosecurity plan must consider this.

3. Impacts on native species

I've alluded above to effects of jellyfish blooms on native species. Just like jellyfish and hydroids affect salmon gills, so too they affect native fish. These native fish, however, do not have the benefit of veterinary care, antibiotics, or freshwater bathing to kill gill pathogens. Moreover, some of these infected fish may be caught by recreational fishers; the effect of gill diseased fish on food safety and human health has not been investigated to my knowledge, but should be.

Likewise, the gills of bivalves like scallops, oysters, mussels, and clams are damaged by jellyfish and hydroids too. To my knowledge, the negative effects from salmon farming are poorly researched for these species, but should be considered.

Jellyfish blooms also impact native invertebrate species like bryozoans and sponges through polyps outcompeting these other species for settling space.

One of the biggest impacts, however, that jellyfish blooms have on native species is by consuming their eggs and larvae, as well as the plankton that the larvae would eat. This double whammy of predation and competition can keep other species from replenishing by continuing to consume any eggs and larvae they produce. In this way, jellyfish effectively “flip the ecosystem” to being dominated by themselves, and once flipped, these ecosystems are highly resilient against switching back to what we would consider healthy.

Besides being a hazard for salmon, other farmed species, and native species, jellyfish also negatively impact recreational fishing through reducing biodiversity, and boating by getting sucked into boat motors, causing all sorts of problems.

TOR 1a, 2c. There is no question that salmon farming is **affecting native species**; the unresearched questions are how badly and how permanently. The Act should mandate independently-conducted research and monitoring on these questions. The environmental impact and assessment processes in the existing legislation are too short-term in their scope to capture long-term environmental changes from fish farming.

TOR 1b. Fish farms attract and incubate opportunistic pests because of their artificial nature; this presents a chronic biosecurity risk to the fish. Likewise, from the point of view of native species, salmon farming presents a **biosecurity risk**, because farms breed pathogens and degrade water quality. Tasmania's new Biosecurity Act 2019 should be implemented to ensure that biosecurity plans and regulations extend beyond protection of the salmon from invading pathogens, to include the role of farms in threatening the health and habitats of native species.

4. Nutrients making it worse

Astonishingly, the take-home message from salmon farming all over the world, including Tasmania, is that the current business model of high stocking densities in coastal waters is making the jellyfish problem worse, which is in turn impacting the salmon and the habitat they require. The plan for “offshore farming” is probably not offshore enough to prevent this problem. Storm Bay is not offshore; it is a bay, which hydrologically means that the residence time of the water is longer than if it were the open ocean. And in bays, the water re-circulates, so there is some residual buildup of contaminants.

The problem comes down to nutrients. Salmon farming produces an excess of waste from excrement and uneaten food. This waste acts as fertilizer, stimulating phytoplankton (plant plankton like diatoms and dinoflagellates). An abundance of phytoplankton provides a buffet for small consumers like copepods and larvae of just about everything. These small organisms in the water column are collectively referred to as zooplankton, or animal plankton; these are the primary food of jellyfish. So the more nutrients → the more phytoplankton → the more zooplankton → the more jellyfish. And unfortunately, not many things eat jellyfish, so they typically bloom into super-abundances then die off, and when they do, they add to the nutrient load, which keeps the cycle going. Therefore, there is a positive feedback loop between jellyfish and nutrients, which is aided by salmon farming. Jellyfish swarms, therefore, are not only a visible indicator of imbalance, they are also a driver to speed the ecosystem to a much worse state.

TOR 2c, 3. Jellyfish blooms are an integral part of a positive feedback loop, together with nutrients and algae, that causes legacy damage to the environment. Jellyfish and algae blooms are normal, but not in the frequency, densities, and duration created by current fish farming practices. This is unsustainable to both the long-term viability of this industry and to the environment in the broader sense.

Recommendations

1. **Threat characterization**: Conduct scientific research to identify and understand the species of jellyfish that pose a threat to Tasmanian salmon, their seasons and bloom triggers. (**TOR 1a, 1b, 3**)
2. **Bloom monitoring**: Establish a monitoring and reporting program for jellyfish blooms in and around Tasmanian salmon farms. (**TOR 1a, 2c, 3**)
3. **Net cleaning**: Quantify and qualify the debris from net cleaning, in and around Tasmanian salmon farms, including toxic, stinging, abrasive, or other reactive material; this should include clarification of the attenuation curve of reactive debris leaving the farm. (**TOR 1a, 2c, 3**)
4. **Best-practice guidelines**: Develop industry-wide best-practice guidelines for jellyfish threats and mitigation strategies, with transparency. (**TOR 1a, 2c, 3**)
5. **Native species impacts**: Quantify and qualify the existing and potential impacts of jellyfish blooms exacerbated by Tasmanian salmon farming on native species of vertebrates and invertebrates. (**TOR 1b, 2c, 3**)

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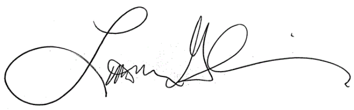
Signed,



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28 November 2019

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