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Dear Michael and Lacey,

A review of water column aspects of a resource consent application for three shellfish farms in Big Glory Bay, Stewart Island

I have completed a review of the application for shellfish farms in Big Glory Bay (APP-20181316 – Zane Smith & Jim Maass Barrett). In doing so, I have not accessed a number of materials referenced in the application. I don't consider that these are essential for a review of the applications, however if you would prefer that Cawthron undertake more thorough review, including source materials, we would be happy to do so.

Scope

Environment Southland requested that Cawthron review water column aspects of a resource consent application for three shellfish farms in Big Glory Bay, Stewart Island.

Documents for review are:

1. the original consent application, submitted by Bonisch Environmental on 2 May 2018 (this document will be referred to below as 'the application')
2. a response for a request for further information, submitted by Bonisch Environmental on 17 August 2018 (this document will be referred to below as 'the RFI response')

Cawthron was asked to provide:

- a review of water column components of the application and the RFI response.
- a high-level assessment of the likely effects of mussel farming on the basis of farm size and location.
- recommendations regarding field surveys, depletion modelling, or monitoring requirements.

Below I consider the application and the RFI response with regard to:

- enrichment and depletion
    - cumulative effects/carrying capacity
- waves and currents.

I then consider the need for monitoring.

Enrichment and depletion in the water column

Enrichment effects of shellfish farms dominate discussion of water column effects in the application (page 12). This includes some apparent uncertainty regarding whether shellfish are net producers or consumers of nitrogen. The uncertainty apparently stems from interpretation of a nitrogen model for Big Glory Bay developed in the 1990s. I have not studied the details of this model, but I have the impression that some error in interpretation has occurred, or that its finding should be applied only to the seabed, not the water column. For clarity, I summarise the principal water column nutrient dynamics related to shellfish farming below.

Nitrogen is the nutrient that is most likely to limit growth in marine systems, and is therefore the most likely to cause enrichment if excess amounts become available. Nitrogen additions to the environment from shellfish farming are minor; no feed is added to the system to farm shellfish, therefore spat seeding is the only point at which nitrogen can potentially be introduced to the system. As shellfish are harvested, nitrogen that constitutes part of their bodies and shells is removed, which constitutes a loss of nitrogen from the system (see e.g., Bricker et al. 2017). Moreover, mussel farming has the potential to increase denitrification[1] in sediments beneath farms in well-oxygenated environments (Kaspar 1985, Christensen et al. 2003). An increase in denitrification further reduces the total nitrogen in the system. Accordingly, shellfish farms cause a net loss of nitrogen.

The water column in the farm does receive inorganic forms of nitrogen that are excreted by the shellfish. This nitrogen source can be used for growth by primary producers such as phytoplankton. New growth of phytoplankton can therefore increase in the water that passes through the farm. Nonetheless, all nitrogen excreted by shellfish has originally been taken from the water column (in a form of organic nitrogen, for example, when the shellfish consumed phytoplankton or other seston). While the nitrogen excreted by the shellfish may be used for the growth of phytoplankton (or other algae) in or near the farm, there is still a net loss of water column nitrogen because the shellfish incorporate a proportion of the total nitrogen in their tissues as they grow. The uncertainty communicated in the application, regarding the likelihood of shellfish in Big Glory Bay contributing nitrogen to the water column, is in my opinion unwarranted.

While shellfish farms cause a net loss of nitrogen from the wider environment, it is possible that some localised enrichment can occur. Filter-feeding shellfish (and other organisms that may settle on farm structures) capture nitrogen (and other elements) as they filter food particles from the water that passes through the farm. As a result, high biomass communities can grow on farm structures. Organic matter is deposited on the seabed via faeces, pseudo-faeces, fallen shellfish, and fallen or discarded fouling organisms. This deposition can cause a localised area of seabed enrichment. Seabed enrichment is beyond the scope of this review, and is dealt with in the review by Davidson. Potential water column implications of localised enrichment are lowering of dissolved oxygen levels and potential for mineralisation of organic bound nutrients that can result in some increases of dissolved nutrients (e.g. nitrate) in waters around a farm. The application states that "there is no indication that

[1] The production of N_2 (nitrogen gas) from other forms of nitrogen.

marine farming was impacting on DO levels in the bay". A modelled example where shellfish farming is recognised as contributing to low DO (hypoxia) events has been described for lagoons in France associated with oyster farming (e.g. Chappelle et al. 2000). I have not read the monitoring report for Big Glory Bay, but I do not know of New Zealand relevant examples where shellfish farming has produced sufficient seabed enrichment to have a large effect on either water column DO, or dissolved nutrients.

Generally, the principal concern for the water column from mussel farming is the depletion of phytoplankton communities (MPI 2013), commonly represented by the concentration of chlorophyll-a[2]. Depletion is not considered for the individual farms in the water column section of the application, but is partially considered in the 'carrying capacity' section (see below). Section 2 of the RFI response requests 'an overview of the general impacts of the shellfish farming, including references and relevant supporting extracts'. The response also lacks robust reference to depletion effects, however we note that this issue is again considered to some extent in the 'carrying capacity' section of the RFI response, where the authors mention that mussel farms may mitigate the effects of salmon farms by consuming phytoplankton.

Depletion of phytoplankton has been measured in some mussel farming areas. However, as summarised in the MPI-commissioned review of effects of aquaculture on the marine environment, "Typically, small New Zealand mussel farms have relatively little influence on the overall concentration of phytoplankton in the water column, particularly within the context of the wider spatial area surrounding the farms" (MPI 2013). The proposed farms are relatively small to medium in size (5 and 6 ha), although Big Glory Bay is a more enclosed space, with slower flushing times, than many mussel farming areas in New Zealand. Even if individual farms do not cause phytoplankton depletion effects that are environmentally significant, or measurable, it is possible that cumulative effects of all farms in Big Glory Bay may occur.

Cumulative effects/carrying capacity

Although depletion effects of the three proposed farms alone are likely to be minor, the total amount of mussel farming in the bay is unclear from the application. It is possible that the mussel farms cumulatively could have an adverse effect on phytoplankton communities and other filter-feeding organisms that rely on phytoplankton as a food source. The section on ecological carrying capacity addresses this to some extent, in that the authors state that 'Mussel production is consistent, and there does not appear to be any "competition" between the sites for … food supply' (page 9). In the RFI response, the authors state that 'there is an obvious reduction in sites originally growing mussels' as a result of conversions of mussel farming areas to salmon farms. No detail is provided regarding this change. Confirmation of a reduction in bay-wide mussel farming intensity could resolve any concerns about the cumulative effects of depletion of the three proposed farms in addition to the existing farms.

[2] Chlorophyll-a is a light-harvesting pigment common to phytoplankton, it is typically used as a proxy for phytoplankton abundance as it can be measured relatively easily in the water column.

The issue of mussel farming as a nitrogen source is also revisited in section 6 of the 'Carrying Capacity' section of the RFI response. They refer to the conservative nitrogen model developed in the 1990s under which consent was given (now lapsed) for two of the three farms in the current application. They also provide further detail on the ways in which the model was highly conservative, given for example high production rates and not accounting for nitrogen loss at harvest. Once again, I am unsure why there is more attention to potential enrichment effects rather than depletion, although it may be that this section is directly concerned with the seabed rather than the water column.

An additional consideration noted in the RFI response is that shellfish farms may mitigate enrichment effects from salmon farms in Big Glory Bay. Given the reported results of past monitoring, it appears that mitigation is not necessary at this stage. Nonetheless, shellfish harvest is considered a possible mitigator of enrichment (e.g., Reitsma et al. 2017), and there is a case to be made for shellfish farming mitigating increased phytoplankton growth in the vicinity of feed-added aquaculture such as salmon farms. The relatively long flushing times given for Big Glory Bay would make this perhaps a more relevant consideration than in some other areas. Water is retained within the bay for between 5 and 14 days (page 10, RFI response). This is long enough for phytoplankton to have a growth response to additional nutrients from salmon farming, as phytoplankton typically have a doubling time of 1–3 days. This suggests that salmon farm nutrients could cause increased phytoplankton growth during periods of nutrient limitation in the bay (typically the summer period).

Waves and currents

Section 7 of the RFI response addressed the request for local information relevant to the effects of aquaculture on nutrients, restrictions on water movement, and wave attenuation. Issues regarding nutrients have been addressed above, so in this section I consider the hydrodynamic issues.

The authors of the RFI response state that there are several potential effects of mussel farming that are raised in Keeley et al. 2009[3] (referred to as "the Cawthron Report" in the RFI response), that they do not directly address. In the RFI response, the authors state that there are 'gaps in our understanding of some of the processes that occur in and around farms, but filling those gaps is beyond the capacity of this one application'. I agree with the authors on this count. They go on to say 'nor is it considered necessary to do so in order to understand the significance of the potential adverse effects'. I assume that the latter statement is indicating that the knowledge gaps refer to effects that are likely to be very minor, and that the effects that are potentially adverse are better understood. In which case, I would also tentatively agree.

It is not unusual for mussel farming applications to be undertaken in the absence of information on environmental effects such as wave attenuation and effects on currents. To my knowledge, no negative environmental effects have occurred as a result of effects on waves and currents of mussel farms in New Zealand, although overall reductions in current

[3] Note that the Literature Review of Ecological Effects of Aquaculture series published by MPI in 2013 is a more current piece of work which has a similar purpose to Keeley et al. (2013).

speed are possible (Plew 2011). Habitats most likely to be affected would be near-shore, where faster currents could scour shallower areas, or change conditions for reef-dwelling organisms. In the application under consideration, the proposed farms are positioned towards the middle of the bay, i.e., further offshore than existing farms. It seems to me that any effects on waves and currents near the new farms are therefore unlikely to be greater than those already caused by existing farms.

Cumulative effects are also possible with hydrodynamic effects. In the RFI response the authors state that 'The farms will have an effect on how the water flows around the bay but they will not impact on the overall flushing time'. The rationale for this statement is unclear. I would suggest that the positions of the proposed farms are such that they could conceivably contribute to a slowing of currents in Big Glory Bay, as is demonstrated in Plew (2011).

Monitoring

Water quality has not been monitored within farms at any point in the monitoring programme in Big Glory Bay (Table 2, Section 4 of the RFI response). Without getting into the details of the other farming operations in the bay, it is difficult to comment on ways in which the proposed farms might be incorporated, or the extent to which within-farm measurements would be appropriate. It is clear, however, that single-farm monitoring of the three proposed farms is likely to have limited ability to identify environmental effects of shellfish farming on the water column. Integrated monitoring in Big Glory Bay seems to be an appropriate approach, particularly with respect to mussel farming, as each farm is relatively small, and cumulative effects would be of more concern than single-farm effects. Modelling may supplement integrated monitoring, and could potentially replace some aspects of a physical monitoring programme.

Conclusions

The three shellfish farms applied for under 'APP-20181316 – Zane Smith & Jim Maass Barrett', are each unlikely to cause environmental effects of concern on their own. However, consideration of cumulative effects on phytoplankton depletion and current speed may be appropriate.

The application focussed on nutrient enrichment potentially caused by the proposed farms, however depletion effects are a more important consideration for the water column. Depletion effects are not well considered in the application or the RFP. While the effects of small- to medium scale farms are not generally expected to be of concern, the siting of the farms in an enclosed bay with significant existing mussel farming and relatively slow current speeds increases the likelihood of phytoplankton depletion.

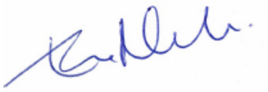
The likelihood of cumulative effects of the multiple farms within Big Glory Bay is difficult to assess. A bay-wide approach is necessary to assess cumulative effects and can range in complexity. Quantification of the historical and current levels of mussel farming is required as the first step in any such assessment. In this case, it seems that if it can be demonstrated that the three proposed farms would not increase the intensity of mussel farming beyond that of the past farming intensity (due to other farms being converted from mussel to finfish farming) and those historic effects were acceptable, then concerns regarding cumulative effects of mussel farms could be addressed. If an unacceptable degree of uncertainty remains after further information is sought, a staged approach to development (with appropriate monitoring) of the proposed farms may be appropriate.

Single-farm monitoring would not address bay-wide effects of aquaculture on the water column, and integrated monitoring and/or modelling would be a better approach.

I hope this review is of use, please do not hesitate to contact Cawthron if we can be of further assistance.

Yours sincerely

Scientist



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