Before Southland Regional Council

APP-20157616-V1

under: the Resource Management Act 1991

in the matter of: Applications by Sanford Limited to change the conditions of various resource consents that authorise the farming of salmon in Big Glory Bay, Stewart Island

by: **Sanford Limited**
Applicant

Statement of evidence of Dr Mark Richard James

Dated: 11 March 2019

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INTRODUCTION

1 My full name is Mark Richard James.

QUALIFICATIONS AND EXPERIENCE

2 I am an aquatic ecologist holding the following degrees, BSc Victoria University, Wellington; BSc (Hons) Victoria University, Wellington and PhD (Aquatic Biology), University of Otago, Dunedin.

3 I am the Director of Aquatic Environmental Sciences Limited (*AES*).

4 I have advised Sanford Limited (*Sanford*) on the application to change the conditions of several resource consents that it holds for salmon farming in Big Glory Bay (*the Application*). I am familiar with the contents of the Application documents, including the scientific reports and findings prepared by Aquadynamic Solutions Sdn Bhd.

5 I have a background in basic and applied research in marine and freshwater ecology and biology with over 40 years' experience including research, consulting and management of science organisations.

6 Following two years with the Institute of Nuclear Sciences, Department of Scientific & Industrial Research (*DSIR*) I was employed in 1982 by the Taupo Research Laboratory, DSIR, then moved to Christchurch in 1992 as a scientist with the National Institute of Water & Atmospheric Research (*NIWA*). In 1994 I was appointed as a Project Director and led large multi-disciplinary Foundation for Research, Science & Technology (*FRST*) funded programmes including "Lake Ecosystems" and "Sustainability of coastal ecosystems". In 2000 I moved to Hamilton to take up the position of Regional Manager with NIWA and in 2002 was appointed as NIWA's Director Operations. In 2008 I retired from this position taking up a brief position as Chief Scientist for Environmental Information before leaving NIWA in late 2008 and setting up as an independent environmental consultant and ecotour operator.

7 Since 1982 I have been involved in research on the ecology of freshwater and marine systems. These studies aimed to gain a better understanding of ecological processes in lakes, rivers, coastal and open ocean systems. I have worked in New Zealand, Finland, Denmark, Australia and in Antarctica. My research has been published in over 45 papers in scientific journals and books. These publications have included scientific papers in international journals and book chapters on the ecology of freshwater and marine invertebrates, freshwater management, coastal sustainability as well as the effects of sediments, lake level management, and other anthropogenic activities on aquatic ecosystems.

8 During my 40 years' experience I have been involved with Regional Councils, government departments and industry in establishing guidelines for ecological assessments, providing descriptions of freshwater and marine communities and assessments of potential ecological effects for a wide range of projects throughout New Zealand.

9 I have been involved in aquaculture research throughout New Zealand since the 1980s. My specific experience with Big Glory Bay (*BGB*) started in the late 1980s when I was involved in studies on understanding the ecological processes in the Bay including collecting information for the establishment of nutrient budgets.

10 More recently and over the last 5 years I have been:

10.1 Leading a Seafood Innovation/Sanford/Marine Farming Association funded programme that includes BGB with the aim of establishing relationships between mussel growth and local and wider environmental variables. This includes a better understanding of what drives production in the Bay and forecasting conditions over the next 3-12 months;

10.2 Providing advice to Sanford on monitoring programmes in BGB;

10.3 Providing advice on aquaculture development in the Firth of Thames;

10.4 Co-ordinating the Peer Review Panel set up as part of the final conditions of consent held by New Zealand King Salmon for salmon farming in the Marlborough Sounds; and

10.5 Co-ordinating a technical ecological advisory group advising the Tasman District Council on development of aquaculture in the region.

CODE OF CONDUCT

11 Although these proceedings are not before the Environment Court, I have read the Environment Court's Code of Conduct for Expert Witnesses and I agree to comply with it as if these proceedings were before the Court. My qualifications as an expert are set out above. I confirm that the issues addressed in this brief of evidence are within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

SCOPE OF EVIDENCE

12 The purpose of my evidence is to set out:

12.1 A description of the BGB environment and environmental changes over time;

12.2 A detailed assessment of the environmental effects of this proposal;

12.3 The key monitoring and farm management matters I consider to be necessary;

12.4 A summary of why I consider that the Application can be granted, subject to appropriate monitoring and farm management practices and procedures put in place; and

12.5 My response to the matters raised in submissions and in the staff report.

13 My evidence is based on a number of monitoring reports since the early 1990s, modelling of hydrodynamics, water quality and benthic environment to assess the effects of the proposal (ADS 2016, 2017a, b, c, d, e) and an ecological assessment carried out by AES (James et al. 2018).

EXECUTIVE SUMMARY

14 Overall, I consider that, in light of the conditions proposed by Sanford, as attached to the evidence of **Dr Phil Mitchell**, the potential environmental effects of the Application can be avoided, remedied or mitigated and the increase in nitrogen proposed can be accommodated and will not cause ecologically significant changes to the health of BGB.

15 Salmon farms in New Zealand have not been shown to cause significant adverse effects on the water column and seabed environment in which they are situated. Effects are generally characterised as benign or minor, and confined to within the immediate vicinity of the salmon farm (within 100 m). Benthic effects are highly localised and can be reduced with mitigation methods.

16 The information available for describing the historical and present environment in Big Glory Bay (*BGB* or *the Bay*) is based largely on work carried out as part of consent compliance by salmon and mussel farmers. There is no 'State of the Environment' monitoring in BGB other than these reports.

17 BGB covers an area of 12 km^2 in the north-east of Stewart Island. The Bay is influenced by local tides, winds and stream inputs as well as large scale currents and offshore upwelling. Currents are generally weak (< 5 cm/s) with stronger flows along the northern and southern shorelines and towards the mouth of the Bay. There is

little, if any, stratification in BGB and residence time has been estimated as 28-30 days.

Water quality

18 Chlorophyll *a* (chl-*a*) concentrations[1] in BGB ranged from 0.1 to 17 µg/L between 1997 and 2017. High levels indicative of bloom conditions (> 5 µg/L) occurred in 1988, 1989, 2010, 2012, 2013 and 2017 (17 µg/L). Though measurements have been patchy at times, summer chl-*a* concentrations overall were lower in 2017/18 than 2016/17 which in turn were similar to the period 1998-2005 but lower than in 1993/94, 1997/98 and the period 2006-2009. Overall there have been high levels at times throughout this period, and there has been no significant trend in chl-*a* since 1997 with peaks often attributed to inputs of nutrient-rich upwelled offshore water.

19 Chl-*a* concentrations were generally higher in late winter/spring and lower in late autumn/early winter. The reverse was found for dissolved inorganic nitrogen (ammonia-N and nitrate-N), with levels increasing at the end of summer then decreasing in late winter/spring largely in response to phytoplankton growth. Seasonal changes in 2015-2017 for ammonia-N levels showed concentrations were considerably higher in late autumn/winter and reached an average for the control site of 80 mg/m^3 in 2016 and 60 mg/m^3 in 2017. There were occasions, mostly in winter, when ammonia-N was slightly higher in the Bay than at the entrance but for most of the year there was no gradient. There was no observed difference between the control site in the middle of the Bay and at the control site at the mouth for nitrate-N.

Benthic environment

20 The benthic environment in Big Glory Bay is a patchwork of different habitats depending on the location in the Bay, history of the different sites and the activities carried out. In summary benthic monitoring data shows that in recent years sites near the head of BGB, including the control site, had a higher proportion of mud than those in the middle of the Bay or towards the entrance. Levels of organic matter and total organic carbon (TOC) at the control sites were in the range for similar sandy/mud environments elsewhere, with organic enrichment of sediments variable and generally below 10% (TOC <2.5%) depending on the site's history and location in the Bay. Generally, where there was enrichment at farm sites but sediment conditions improved within 100 m of the farm boundary to similar levels to controls.

21 Concentrations of copper and zinc were elevated above typical background levels under some farms but below ANZECC (2000)

[1] Chl-*a* is an easily measured proxy for phytoplankton biomass

thresholds within 100 m from the farm boundaries and at control sites.

22 Species richness and diversity of infauna[2] generally remained moderately high at most salmon farm stations, as well as at the control sites, and tended to be higher at the control site in the mouth of the Bay than the control at the head of the Bay. Low diversity was recorded under the salmon smolt farm LI 339 (recently moved and left to fallow). Opportunistic polychaetes were observed beneath all farms and a range of polychaetes and bivalves were observed at control sites as well as farm sites.

23 Generally, there were few epifauna[3] observed at all sites but conspicuous holes and burrows were found at the control site at the head of the Bay, yellow sponges at both the head and mouth of the Bay, and coralline, green and red algae and brachiopods at the mouth of the Bay.

24 The presence of *Beggiatoa* mats (bacterial mats are indicative of sulphur-rich sediments) was recorded at one site in 2016. No mats were observed in 2017. Mats were observed again at a number of sites in early 2018 but not mid-2018.

25 Salmon sites that have been fallowed show an improvement in the quality of benthic habitat between years and overall there appeared to be an improvement between 2016 and 2017 at fallowed farm sites.

26 Commercial fishing is banned in the Bay. However, there is likely to be some recreational and cultural fishing activity taking place.

27 Stewart Island is home to a range of coastal bird species including several threatened species. The birds that rely on the aquatic environment include the Stewart Island, pied and spotted shags; yellow-eyed, little blue and Fiordland crested penguins; red-billed, black-billed and black-backed gulls; and sooty shearwaters (or muttonbird). Most of these birds feed on small fish in the bays, coastal areas or offshore. The sooty shearwater (mutton bird) is an important species for Maori with large colonies found around Stewart Island.

28 A number of marine mammals have been recorded around Stewart Island, but most are transitory except for fur seals which have haulouts in BGB and bottlenose dolphins which are known to frequent BGB. The sea lion population has also increased in recent years.

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[2] Animals living in the sediment of the seabed

[3] Animals living on the surface of the seabed

Assessment of effects

29 Key considerations with the current proposal are that:

29.1 The proposal is to allow for an increase in feed levels in order to better use already consented farm space;

29.2 All activities will be within existing consent areas i.e. no new space is requested;

29.3 BGB is the only area in Stewart Island in which aquaculture can occur;

29.4 Farm management includes fallowing unlike other operations in New Zealand; and

29.5 Only 3% of the Bay is allocated for salmon farming and only 0.3% is used for salmon farming at any one time even with the proposed increase in feed and fish numbers.

30 The key potential effects on the receiving environment are from increased nitrogen inputs and changes in dissolved oxygen in the water column and, for the benthic environment, deposition of faecal material and waste feed which can impact on organic matter, dissolved oxygen, biochemical reactions including release of hydrogen sulphide, and changes to benthic communities. Other considerations are biosecurity and the effects on wild fisheries, mammals and birds.

31 The effects of the proposal on the environment from increased nitrogen inputs to the water column and deposition on the seabed have been assessed and modelled and can be summarised as follows (details of the modelling work will be presented in evidence of **Dr Neil Hartstein**):

31.1 There is no evidence that farming has impacted on the overall water quality in the Bay. Excess total ammonia-N is predicted to increase by up to 0.030 g/m^3 with the additional inputs being applied for, compared with background average levels of up to 0.080 g/m^3. Levels of inorganic nitrogen will remain below levels identified as potentially leading to nuisance algal blooms.

31.2 Assuming all the increase in nitrogen is converted into phytoplankton biomass (this is a very conservative assumption) then chl-*a* could increase by up to 4 µg/L compared with existing levels at control sites of 0.01 to 5.2 µg/L, apart from a bloom of 17 µg/L in August 2017. Actual levels are expected to be significantly less than this as modelling does not take into account various other environmental factors which will limit algal growth, uptake by mussels and zooplankton or export of nitrogen out of the Bay when mussels are harvested. There is no evidence over the last 20 years that chl-*a* has changed in BGB as a result of the presence of salmon farms. The expected increases will not change the trophic state or result in more algal blooms. A comprehensive monitoring plan and set of standards have been developed to ensure any unexpected effects are detected and managed.

31.3 Oxygen levels can be reduced around salmon farms through respiration and breakdown of organic matter on the seabed. With increased drawdown of oxygen with expanded farm production dissolved oxygen levels are predicted to remain over 6 mg/L, a level that will maintain healthy salmon and naturally occurring biota. There is no evidence that dissolved oxygen levels have been adversely affected in the Bay to date or will be as a result of this variation.

31.4 The maximum production now being applied for in BGB is 659 t of nitrogen sourced from salmon farming, although this will be staged. I consider that these levels of nitrogen input are, and will be sustainable.

31.5 Effects on the benthic environment as a result of salmon farms will depend on the history of the farm site, type of activity (on-growing, smolt, brood or being fallowed) and state of the benthic environment. Existing information shows that effects on grain size, organic content and copper and zinc levels are restricted to within 50-100 m of the pen boundaries and are generally within the range of concentrations for these parameters at control sites. High copper levels at some farms are likely to be due to historic, now discontinued, anti-fouling practices.

31.6 Deposition modelling has shown that the deposition of faeces and waste feed will generally remain within the boundaries of the consented area and deposition outside that area will be confined to within 50-100m of the boundaries. Opportunistic polychaete worms are observed beneath all farms and in some cases overall species diversity is low. These changes are not observed beyond 100 m of the pens and the same is predicted for the proposed variation.

31.7 Mats of the bacteria *Beggiatoa* have been recorded in the past under farms but were not observed in 2017. They reappeared in early 2018 but were not found later in 2018. It is likely that these will develop under some farms but not beyond the farm boundaries due to salmon farming. Fallowing, coupled with the proposed monitoring, will ensure any future mats are able to be managed.

32 It is important to note that all effects, if they were to occur, are reversible if the management plan is followed. A key management strategy included in the proposed conditions to avoid adverse effects at the farms themselves is to undertake fallowing and it is recommended that farms be fallowed for at least 5 years after 2 years of occupation, or earlier than 2 years, if there are signs of significant adverse effects under farms. If there are no signs of significant adverse effects under farms then they could be occupied longer.

33 Standards to be met for the water column and benthic environment are recommended along with an outline of monitoring and mitigation. These have been agreed with Department of Conservation staff, and I understand them to be acceptable to **Dr Grange**. It is important that standards are set to ensure BGB does not become more eutrophic, that there is no increased risk of algal blooms, oxygen is not depleted to levels that will affect biota and that benthic effects are constrained to within farms and are not different to control sites beyond 50-100 m. Standards have been set in Sanford's proposed conditions to ensure the system stays in its present trophic state and are lower than predicted by the modelling to prevent adverse effects.

THE BIG GLORY BAY ENVIRONMENT

34 BGB is a small Bay off Paterson Inlet in north-eastern Stewart Island (see **Figure 1**). The Bay covers an area of 12 km^2 and is influenced by local tides, winds and stream inputs as well as large scale currents. The main current affecting Paterson Inlet and BGB is the Southland Current which entrains mainly sub-tropical waters off the west coast of the South Island and occasionally sub-Antarctic waters into Foveaux Strait. Currents in BGB are generally weak (< 5 cm/s) with eddies forming in several places and stronger flows along the northern and southern shorelines and towards the mouth of the Bay.

35 Most of the Bay is shallow with water depths less than 20 m and has an average depth of 15.9 m. There is little, if any, stratification[4] in BGB and residence time[5] has been estimated as 28-30 days.

36 The catchment is mainly bush covered with relatively minor inputs of nutrients off the land. Upwelling provides episodic inputs of water

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[4] Stratification is where light and more buoyant water overlies heavy, denser water and can be caused by differences in temperature or salinity or both. It affects the physical, chemical and biological properties.

[5] Residence time is the time it takes to replace most of the water in a bay. This affects the retention, uptake and dispersion of nutrients and the relative importance of in-situ production

with relatively high nutrients particularly nitrate-N, which can stimulate blooms in the Bay.

Water quality

37 Along with light availability, temperature and currents, water quality is an important driver of eutrophication and the risk of phytoplankton blooms. Phytoplankton growth depends on the level of nutrients available including macronutrients such as nitrogen and phosphorus and micro nutrients such as iron and other elements. In winter light availability and temperature are major drivers of algal growth. Zooplankton[6] can also control phytoplankton biomass.

38 Water quality data is available from 1988/89 (Jan/Feb), 1993-2010 (Nov-Feb), 2011-2013 (monthly – limited parameters), and 2015-2017 (monthly) (see **Figure 2** for sampling sites, mostly close to mussel farms, and a control site at the head of the Bay and one at the mouth). The historical and present status of water quality in BGB are summarized below.

39 Chl-*a* concentrations in BGB reached 5.4 µg/L during the limited sampling in February 1988 and January 1989. Summer chl-*a* was relatively high in 1993/94 and 1997/98, was lower from 1998-2005 and then increased again (see **Figure 3**). Site averaged chl-*a* in 2015-17 ranged from 0.3 to 3.1 µg/L.

40 Chl-*a* in BGB between 2011-2015 was highest in spring and autumn with peaks up to 7 µg/L in March 2012 (near one of the farms to the south), 14 µg/L in March 2013 (control site at head of Bay) and 8 µg/L in March 2013 (at the control site at the mouth of the Bay).

41 There was a very high chl-*a* level in August 2017 indicative of an algal bloom at the time (see **Figure 4**). Summer chl-*a* concentrations overall in 2017/18 were slightly lower than in 2016/17 which in turn were similar to the period 1998-2005 but lower than in 1993/94, 1997/98 and the period 2006-2009. Peaks in summer 2015/16 and 2016/17 occurred at the control site near the mouth and there was a very high level in August 2017 at most sites including control sites (**Figure 5 and 6**). The relatively low summer concentrations in 1998-2006 and 2016-2018 (<1.5 µg/L) could have been due, at least in part, to larger scale climatic conditions leading to reduced inputs from deep-nutrient rich waters.

42 Chl-*a* concentrations were generally higher in late winter/spring and lower in late autumn/early winter. The reverse was found for dissolved inorganic nitrogen, with levels increasing at the end of summer then decreasing in late winter/spring largely in response to phytoplankton growth. The ‘nuisance bloom’ in 1989 which caused

[6] Planktonic animals such as copepods, crustacean and fish larvae which float around in the currents

fish deaths was attributed to pulses of nutrient-rich water from offshore during a period of low nutrient concentrations and warm water temperatures during the long daylight hours. Summer peaks in phytoplankton can also occur, as was seen in Jan 1989 and Feb 2017. There was only a very slight trend in chl-*a* since 1997 and it was for declining levels, but the trend wasn't statistically significant (**Figure 7**) (noting that in some years samples were only taken over summer).

43 Summer ammonia-N levels in the Bay were higher in 1989 than 1988, but at similar levels in 2016/17 to those observed in 1989 (samples were not collected for ammonia-N in 2011-2013 or summer of 2014/15). Seasonal changes in 2015-2017 for ammonia-N levels showed concentrations were considerably higher in late autumn/winter and reached an average for the control site of 80 mg/m^3 in 2016 and 60 mg/m^3 at control sites in 2017 (see **Figure 8**). Concentrations were generally low in summer reflecting uptake by phytoplankton. There were occasions, mostly in winter, when ammonia-N was slightly higher in the Bay than at the mouth, but for most of the year there was no gradient.

44 Average summer nitrate-N concentrations were low (< 5 mg/m3) in the period 1998-2005 and higher (7-10 mg/m3) in other years, including pre- and post this period (**Figure 3**). Seasonally nitrate-N was higher in winter than summer in 2016/17 at control sites, reaching a maximum of 90 mg/m3 in July 2016 (see **Figure 9**), probably as a result of the input of nutrient-rich deep or offshore waters and uptake by phytoplankton in summer. There was no observed difference between the control site in the middle of the Bay and at the control site at the mouth.

45 Plankton communities (phytoplankton and zooplankton) are highly variable in time and space. They are carried around by currents and their growth will be determined by a range of physical, nutrient and biological processes. Zooplankton are major grazers of phytoplankton and can often control the populations. Zooplankton in turn are an important food source for a number of higher trophic levels including shellfish, fish, crustacea and even mammals.

46 There is little data on the plankton communities in BGB other than the routine monitoring for harmful algal species. The bloom in 1989 that caused large salmon losses was due to a micro-flagellate *Heterosigma* and most of the time the phytoplankton community is likely to be dominated by diatoms and dinoflagellates. The only measurements of primary production were in the 1990s and showed relatively high levels for New Zealand marine waters. The peak in 1989 was attributed to the input of nutrient-rich upwelled water and Pridmore and Rutherford (1990) concluded that the salmon farms at the time were only having a "marginal effect".

47 Nitrogen is considered the limiting nutrient for phytoplankton growth in New Zealand's coastal waters. Mean concentrations of ammonia-N and nitrate-N at control sites in BGB in 2016/17 and 2017/18 were 24-27 mg/m^3 for ammonia-N and 16-29 mg/m^3 for nitrate-N with lower levels in 2017/18. The levels at control sites are higher than ANZECC (2000) guidelines for estuarine environments and coastal waters (15 for both for ammonia-N and 15 and 5 mg/m^3 respectively for nitrate-N), based on default values from south-east Australia. However, the median total nitrogen was lower than the ANZECC guidelines. Based on preliminary national objective framework standards for New Zealand estuaries the concentrations in BGB would mean the Bay would be considered "Good" in terms of status.

Benthic environment

48 The benthic environment in BGB has been described in a number of papers and reports, mostly related to compliance monitoring. Benthic data has been collected since 1997 at a number of sites near mussel and salmon farms as well as at two control sites, one towards the head of the Bay and one near the mouth (see **Figure 10**).

49 The benthic environment is a patchwork of different habitats depending on the location in the Bay, history of the different sites and the activities carried out. The greatest benthic community diversity is towards the mouth near Bravo Island where there are brachiopods, sponges and other groups adding to the diversity. The historical and existing status of the benthic environment is described below and summarised for control sites in **Table 1**.

50 Stenton-Dozey & Brown (2009, 2010) described the benthic habitat based on surveys from 1997-2009 which focused largely on areas close to mussel farms but with controls at the head of the Bay and at the mouth which provide some indication of background conditions through that period. Levels of organic material were relatively high at the control site at the head of the Bay (generally over 10% and the control site at the mouth (up to 9%). (**Table 1**)

51 Following a review in 2011 the monitoring programme was expanded to include benthic parameters under or at the edge of salmon farms and at 50 and 100 m away. It is however important to interpret these latter results carefully taking into account the history of the farms and whether they are now fallowed (see later discussion).

52 **Figure 11** shows the sediment characteristics in 2015 as an example of surveys in 2012-2015. The surveys generally found that sediment composition at the control site at the head of the Bay was similar to that at the mouth of the Bay, although organic content tended to be higher at the mouth. The proportion of mud and sand

has varied even at the control sites but sand tended to be a little higher than mud/silt, except at times near the mouth of the Bay.

53 Enrichment of sediments at and near farms depended on their history. Total organic carbon and the percentage organic matter was low at control sites in recent years and away from salmon farms, except at LI 339 where levels were higher than controls (**Figure 12**). This is partly due to its location but conditions have improved subsequently now that the farm has been left to fallow. The main on-grower farm at that time was MF249 which showed higher organic matter at the edge of the farm but levels at 50 and 100 m were similar to controls. This farm was left to fallow in 2016.

54 The results from 2016-2018 and observations under existing farms are discussed under the effects section later in my evidence.

55 Cushion stars, ascidians and sea cucumbers are the most common epifauna and diversity is highest at the mouth of the Bay with brachiopods, sponges, and fan shells also present. As would be expected salmon farms that had previously been mussel farms had beds of live and dead mussels as well. Twenty-six epifauna taxa were recorded in 2015, 13 at control sites and 11 beneath mussel farms. Sponges and algal mats along with the bacterium *Beggiatoa* were evident close to salmon pens at MF 249 and LI 338. Burrows and holes which are evidence of crustaceans and polychaete worms were evident at control sites and at 50 and 100 m away from the salmon smolt farm (LI 339).

56 The presence of mussel shells below mussel farms and those sites previously farmed for mussels has resulted in increased localised biodiversity, along with an increased abundance of opportunistic polychaetes on the seabed at these sites.

57 A wide range of infaunal polychaete and bivalve taxa and functional groups are generally found throughout the Bay but can be patchy and abundances show high variability between years and sites. There tends to be more diversity (e.g. red algae and brachiopods of conservation interest) near the mouth of BGB (e.g. around Bravo Island).

58 Over the 4 years 2012-2015 Stenton-Dozey (2015) reported a dominance of infauna by amphipods and ostracods with some polychaetes abundant at the head of the Bay. The abundance of infauna taxa was variable with lower diversity in 2014 and 2015 than 2012 and 2013. Abundance and species richness of infauna were generally lower at the mouth than at the head of the Bay.

59 The density of infauna for the period 2012-2015 at the present smolt farm (LI 339) was generally higher at the edge of the pens and different from 50 and 100 m away from the edge of the pens

but this varied between years. Species diversity was very low at the pen edge but at 50 and 100 m was similar to controls and functional diversity was retained and this has continued (see **Figure 13**). Note pens have now been moved from LI339.

60 At the on-growing farm (MF249) densities were higher at the edge of the pens than at 50 and 100 m away, although in earlier years abundance increased away from the pens. At the brood stock farm (LI 338) abundance was higher at the pens than 50 and 100 m away. Diversity was generally low at all sites compared with similar environments elsewhere around the New Zealand coastline and dominated by opportunistic capitellid and dorvilleid polychaete worms. These taxa are often the first to colonise new areas or the areas of seabed which are regularly disturbed and some species are characteristic of enriched sediments. Many of these species play an important role in the biogeochemical cycle as they turn over and assist with oxygenation of sediments. It is not surprising that this situation has been observed around the present broodstock farm (LI 338) as it had been operated continuously for 27 years.

Fish resources

61 There has been little work carried out on enumerating fish resources and fishing in BGB.

62 Commercial fishing is banned in the Bay and the area around the salmon farms has not been identified as important for recreational fishing. However, there is likely to be some recreational and some cultural fisheries in the Bay.

63 The fish community consists of a range of pelagic and demersal species, including blue cod, flatfish, moki, butterfish, terakihi, trumpeter, wrass and rig. A number of these species are more associated with reef and inshore habitats than the soft habitats where salmon farms are located.

Bird life

64 Stewart Island is home to a range of coastal bird species, including several threatened species. The birds that rely on the aquatic environment include the Stewart Island shag (nationally vulnerable), pied and spotted shags; yellow-eyed penguin (nationally vulnerable), little blue penguin (declining) and Fiordland crested penguin (nationally vulnerable); red-billed, black-billed (nationally critical) and black-backed gulls; and sooty shearwaters (or muttonbird) (declining). Most of these birds feed on small fish in the bays, coastal areas or offshore. The sooty shearwater is an important species for Maori with large colonies found around Stewart Island.

65 Stewart Island shag are demersal feeders up to 15 km offshore feeding on small fish including flatfish, pied shag feed on small fish

inshore and spotted shag feed on deep water small cod and sprats. Sooty shearwater forage widely offshore feeding on demersal species. Yellow-eyed penguins are predominantly pelagic and feed close to the seabed at water depths of 40-80 m, little blue penguin feed on surface-schooling fish and squid, and Fiordland crested penguins feed mainly on squid, crustaceans and fish. Black-billed gulls feed on land and in coastal waters on fish and invertebrates.

Mammals

66 A number of marine mammals have been recorded around Stewart Island, but most are transitory except for fur seals which have haul-outs in BGB and bottlenose dolphins (Nationally endangered) which are known to frequent BGB and are part of a wider-ranging southern population.

67 The New Zealand sea lion population (nationally critical) has increased in recent years in the Bay using the beaches near the entrance as a haul-out area and leopard and southern elephant seals have also been recorded in the Bay.

68 Whales are likely to be very transitory and include southern right whales (Nationally vulnerable) and humpback whales.

ENVIRONMENTAL EFFECTS

69 The effects of marine farming in New Zealand on the environment are generally well understood and have been extensively documented in recent years.

70 In the case of BGB, we also have extensive monitoring of the water column and benthic habitat from which to draw conclusions about effects. A key consideration with the current proposal is that it is to allow for an increase in feed levels in order to better use farm space, but that all activities will be within existing consented areas i.e. no new space is requested. Importantly BGB is the only area in Stewart Island in which aquaculture can occur and only a small area of the Bay is used for salmon farming with the area of pens at any one time under the proposal representing only 0.3% of the area of BGB.

71 The key considerations for ecological effects on the water column are shown schematically in **Figure 14** and can be summarised as:

71.1 Localised changes to currents and water flow around farms;

71.2 Increased nitrogen inputs mainly as ammonia-N that is released through excretion by farmed fish and from break down of fish deposits (feed and faeces). Increases in ammonia-N in turn can cause increased phytoplankton biomass, eutrophication and increase the risk of algal blooms;

71.3 Reductions in dissolved oxygen through respiration uptake by the salmon and reductions at the seabed from microbial activity and uptake of oxygen;

71.4 Risk of entanglement for birds and mammals; and

71.5 Biosecurity and biofouling through the introduction of pest species.

72 In terms of the benthic environment, the main issues are:

72.1 Deposition of faecal material and waste feed which can impact on organic matter;

72.2 Reduced oxygen levels in the sediments;

72.3 Biochemical reactions including release of hydrogen sulphide, increased concentrations of heavy metals such as copper and zinc; and

72.4 Localised changes to floral and faunal communities on the seabed.

73 The potential for effects, their severity, duration and extent depend on a range of factors including the species farmed, the location of the farm and its physical characteristics, the resilience of the receiving environment, scope for mitigation, the scale of the farming activity, and the potential for reversibility and recovery from effects. The history of farms is also very important as some have been used in the past for mussel farms. The history of farms which form part of this proposal is summarised in **Table 2**.

74 The hydrodynamics and modelling of the potential effects of the proposal on the environment from increased nitrogen inputs to the water column and deposition on the seabed are described in detail in **Dr Hartstein's** evidence.

75 In my evidence below I focus on the scale and intensity of environmental effects that I have assessed as being likely and put these into context based on past monitoring in BGB.

Water column

76 Water currents are generally relatively low in BGB and the sites can be classified as low flow sites. Flow is generally higher towards the mouth of the Bay and as described earlier flushing time has been estimated as 20-30 days. Effects on currents will be localised around farms but generally will not impact on overall circulation patterns.

77 Nutrient enrichment is one of the key issues for salmon farming due to the increased nitrogen inputs. Ammonia-N will be released from

the fish during physiological processes and will be released from waste feed, fish faeces and recycled from the sediments during microbial breakdown and chemical processes.

78 Nutrient enrichment in the water column can stimulate phytoplankton growth, increase the risk of phytoplankton blooms and potentially change the composition of phytoplankton species (as a result of changes in the ratio of nutrients). If nutrient levels are very high, the water body can become eutrophic. Eutrophic waters have high primary productivity due to excessive nutrients and are characterised by low water quality and frequent algal blooms.

79 Based on the modelling carried out, as described by **Dr Hartstein** total ammonia-N is predicted to be elevated by up to 0.030 g/m^3 with the additional inputs from the increase in feed. This is on top of existing average levels of up to 0.080 g/m^3.

80 There is no evidence that salmon farming in BGB has impacted the overall water quality in the Bay. Nitrate-N levels in the Bay show a similar seasonality and range of concentrations to ammonia-N but concentrations of total nitrogen can be much higher reflecting the importance of particulate nitrogen to the nitrogen pool. Levels of inorganic nitrogen away from the farms will remain below levels identified as potentially leading to nuisance algal blooms.

81 There have been periods of relatively high and low phytoplankton biomass over the last 20-30 years but there is no significant trend in chl-a over that period (refer **Figure 7**). Thus there is no evidence from past monitoring that the operation of salmon farms in BGB has led to a consistent pattern of enrichment leading to higher chl-*a* or increased frequency or severity of algal blooms.

82 Assuming all the increase in nitrogen is converted into phytoplankton biomass (a very conservative assumption) then the predictions from ADS are that chl-*a* could increase by a maximum of 2.5 to 4 µg/L, depending on the season. This compares with existing levels at control sites of 0.01 to 5.2 µg/L in recent years and annual medians of 0.74 to 2.2 µg/L.

83 This may seem a large increase but modelling of ammonia-N and its contribution to nitrogen cycling and phytoplankton levels does not take into account that other environmental factors will limit growth of the population at times such as light availability, temperature and grazing by zooplankton and the presence of mussel farms and their influence on nutrient-phytoplankton processes. Mussel farms will remove phytoplankton biomass and ultimately some of the nitrogen will be removed from the Bay at harvest of both mussels and salmon. Thus the model outputs and effect on phytoplankton biomass (chl-*a*) can be considered conservative and worst case. I do not expect levels to be elevated by the amount predicted by the

model and in any event the proposed conditions set standards that are lower than the predicted increases.

84 A key consideration for the proposed changes to marine farming in BGB is that increases in scale or intensity do not lead to a change in trophic state. The present state of BGB can be described as mesotrophic and it is important that this does not change or the risk of algal blooms increase. This is reflected in the later section of my evidence on proposed conditions.

85 Nutrient "thresholds" and guidelines have been applied in New Zealand and overseas to assess estuarine, harbour and coastal trophic status. There are no widely applied and used guidelines for bays like BGB in New Zealand. However, ANZECC (2000) and the pilot National Objectives Framework (NOF) for Estuaries and other guidelines (reported in Green & Cornelisen 2016) do provide some guidance. The various standards or guidelines for chl-*a* (generally based on annual median values) include:

85.1 ANZECC (2000) guidelines for estuarine and coastal waters of 4 and 1 μg/L.

85.2 National Objectives Framework for Estuaries.

Chl *a* bands:

(a) Excellent: < 2 μg/L

(b) Good: 2-5 μg/L

(c) Fair: 5-15 μg/L

(d) Poor: >15 μg/L

85.3 NZ Estuary Trophic Index Toolbox – Band A <3 μg/L for healthy communities to >12 μg/L for degraded waters.

The annual median levels in BGB are presently 0.74 to 2.2 μg/L and we know they will have been higher in the past meaning that the environment will be able to accommodate some increase in chl-*a* before trophic state would change.

86 An initial upper limit for chl-*a* for BGB, developed as part of a 1988/89 study, suggested 15 μg/L as the "trigger level" for a maximum value. That study found that chl-*a* above the 15 μg/L level could lead to nuisance levels of phytoplankton and would be indicative of eutrophic conditions. Based on a nitrogen budget developed at the time of the 1988/89 study, a critical concentration was assessed as 290 mg/m^3 of dissolved inorganic. Neither of these limits would be exceeded with the predicted increases proposed in

the Application. It should also be noted here that the toxic blooms experienced in BGB in the 1989/90s were attributed to inputs of nutrient-rich upwelled water from offshore not nutrients from within the Bay.

87 Poor water quality, particularly oxygen depletion and elevated ammonia-N concentrations, can detrimentally affect the health and growth of farmed fish. Oxygenated waters are critical for the survival and performance of farmed fish. If ammonia-N concentrations are very high close to, and in the fish farm they can become toxic to fish. Excessive oxygen depletion and ammonia-N toxicity in the fish farm would stress the fish and potentially cause fish mortality. However, these effects can be addressed through appropriate farm location and management. The same methods used to protect farmed fish from exposure to excessive oxygen depletion and ammonia-N toxicity will also protect fish species beyond the farm.

88 At very high levels, ammonia-N and nitrate-N can be toxic to animals (adjusted for pH and temperature). Ammonia comes in two forms ionised ammonia-N (NH_4^+) and toxic un-ionised or free ammonia (NH_3). The sum of both is referred to as total ammonia-N (or TAN). Levels for acute and chronic toxicity are provided in **Table 3**. The predictions with the increased input of nitrogen feed are that TAN would be elevated by a maximum of 0.03 g/m^3 which would lead to maximum TAN (both forms of ammonia) of 0.11 g/m^3 or 0.11 mg/L. This is still well below even the chronic level that would cause toxicity (>0.22 mg NH_3-N/L).

89 Dissolved oxygen depletion is a consequence of increased biomass and microbial degradation, both of which consume oxygen. Microbial degradation occurs in the water column (through fish respiratory activities, degradation of phytoplankton, waste feed or fish faeces) and in the sediments (decomposition of deposited organic matter). Oxygen consumed in the sediments is replenished (if available) from the water column, thus leading to reduction of dissolved oxygen in the water column.

90 With the expected increased drawdown of oxygen with expanded farm production, dissolved oxygen levels are still predicted to remain over 6 mg/L, a level that will maintain healthy salmon and naturally occurring biota (see **Table 3**). There is no evidence that dissolved oxygen levels have been adversely affected in the Bay to date or will be as a result of this Application.

91 Another concern related to nutrient enrichment is the potential for increased occurrences of harmful algal blooms (HABs), including blooms of species that produce biotoxins (MPI 2013). However, in New Zealand, no known HABs have been linked to finfish farming (MPI 2013).

92 The maximum production being sort for BGB under this consent application is 659 t of nitrogen sourced from salmon farming, which is considered to be sustainable and will not change the trophic state of BGB or increase the risk of blooms.

Benthic environment

93 Effects on the benthic environment are shown schematically in **Figure 14**. As described earlier the level of effects will depend on the location of the farm and its physical characteristics, the resilience of the receiving environment, scope for mitigation, the scale, and potential for reversibility and recovery from effects and in the case of the benthic environment on the history of the farm and type of activity (on-growing, smolt, brood or being fallowed).

94 The effects of finfish farming on the sediment and seabed are primarily caused by the deposition of organic waste (waste feed, fish faeces, biofouling material) which in turn can lead to increasing anoxia, release of hydrogen sulphide and nutrients, and changes to biological communities.

95 Sediment microbes use different sources of energy, which results in sediment oxygen consumption and potential release of hydrogen sulphide and methane into the water column. The preferred source of energy for microbes is oxygen. This generates a flux of oxygen into the sediment, contributing to oxygen depletion in the water column. Sediments can become anoxic (oxygen-depleted) under fish farms and, if organic matter enrichment is severe, even azoic (i.e. devoid of any living organism). When dissolved oxygen is depleted in the sediments, microbes use other sources of energy to decompose organic matter, following a well-defined sequence of diminishing energy gain for microbes. This can result in the release of hydrogen sulphide (H_2S) and methane (CH_4). As dissolved oxygen levels decrease in the sediments the redox potential declines leading to anoxic conditions.

Observations around existing farms in BGB

96 Changes in the sediment conditions that have been observed around salmon farms in BGB in earlier surveys have been described earlier in my evidence. Generally, the organically enriched sediments, high infaunal abundances, dominance by opportunistic polychaete worms such as capitellids and dorvilleids, and low faunal diversity are observed under or close to the pens.

97 Existing information shows that effects from salmon farms in BGB on grain size, organic content and epifauna and infauna are generally restricted to within 50-100 m from the pens and are generally within the range of conditions observed for control sites.

98 Since 2016 benthic samples have been taken at two mussel farms and at the edge of the salmon pens (LI 338 and LI 339) or under

the pens (MF 246), and at 50 and 100 m from the salmon farms. In 2016/2017 sites near the head of BGB, including the control site, had a higher proportion of mud than those towards the mouth. The levels of organic matter and total organic carbon (TOC) in the 2017 surveys are shown for farm sites and control sites in **Figure 12**. Levels were in the range for similar sandy/mud environments elsewhere but were slightly higher at the mouth of the Bay than the head of the Bay. Organic matter was higher at the main on-grow farm (now MF 246 but was previously MF249) than control sites or at 50 and 100 m away but was within the levels recorded at the control site at the mouth. Levels were high at LI 339. This farm has now been left to fallow.

Benthic communities, species richness and diversity

99 Species richness and diversity of infauna in surveys since 2015 generally remained moderately high at most mussel and salmon farm stations, as well as at the control sites, and tended to be higher at the control or reference site in the mouth of the Bay than the control at the head of the Bay. Low diversity was recorded at the edge of the salmon smolt pens on LI 339. In 2017 species richness was similar to 2016 and was lower at the edge of MF 246 (note that the on-growing site was changed from MF 249 to MF 246 in 2016) and LI 338 than at 50 and 100 m away. Diversity was still very low at the edge of LI 339 (2 species). This farm has now been left to fallow.

100 Faunal characteristics in 2017 at the different sampling sites are shown in **Figure 13**. Apart from the edge of LI 339 the communities under or at the edge of salmon pens in 2017 retained "moderately high species richness and diversity". Opportunistic polychaete worms were observed beneath all farms and in some cases overall diversity is low. Two key indicator species for enriched sediments are the presence of Capitellid and Dorvilleid polychaete worm species. In the 2017 surveys these were relatively common at the edge of salmon pens at LI 338 and MF 246 but were only in low abundance, when present away from the pens. While these are considered indicative of enriched sediments they do provide functional services under the pens such as breaking down organic material and oxygenating the sediments. Under extreme organic enrichment anoxic conditions can develop leading to azoic conditions (nothing living). Such conditions have not been observed around any salmon farms in BGB and must be avoided as recovery would be a long process. I consider that the proposed conditions and EMP will ensure that such conditions are not reached.

101 Overall, there is lower diversity under the existing salmon farms in BGB, depending on how long the farm has been operating. This can be mitigated through the fallowing planned by Sanford. Beyond the edge of the pens the communities are only moderately changed by

the enriched organic matter and still retain functioning and diverse communities indicative of well oxygenated sediment.

102 Mats of the bacteria *Beggiatoa* have been recorded in the past under farms (e.g. 2015 at MF 249) and at 50 and 100 m (MF 249, also 2015) but were not observed in 2017. It is likely that these mats will develop under some farms as a result of the Application but not beyond the farm boundaries due to the presence of salmon farms. Fallowing and the proposed monitoring will ensure any future mats are able to be managed. Salmon sites that have been fallowed showed an improvement in quality of benthic habitat between years and overall there appeared to be an improvement between 2016 and 2017 but some deterioration in 2018 at some farm sites possibly related to algal blooms in late 2017 throughout the Bay due to natural events.

Deposition

103 The results of deposition modelling for different scenarios as part of this project (ADS 2017e) is covered in the evidence of **Dr Hartstein**. This modelling has shown that the deposition of faeces and waste feed will generally remain within the boundaries of the lease and the maximum extent of deposition outside the lease will be confined to within 50-100m of the boundaries.

104 The maximum extent of the depositional footprint outside the lease boundary for the present on-growing farm (MF 246) was 100m. The maximum deposition under a lease was over 16 kg C/m^2/y. Predictions are that deposition greater than 2 kg TOC/m^2/yr or 5 kg/m^2/yr total faeces and waste solid feeds will cover most of the available area within the boundaries of MF 246 and MF 320 but extend no more than 50 m or 25 m beyond the consent boundaries for MF 246 and LF 320 respectively.

Metal concentrations

105 Metal concentrations exceeded the ANZECC ISQG-high threshold at LI 339 and LI 338 at the pens in 2017 (copper) and were low at 50 and 100 away from the pens (note that smolt on LI 339 have now been moved to another site). Prior to fallowing in 2016, copper and zinc levels were high under MF 249. LI 338 was the only site in 2018 that showed levels above the ANZECC ISQG-low or high thresholds.

106 The higher copper levels found in recent years are likely to be due to historic, now discontinued, anti-fouling practices. The remnant concentrations of copper will decrease in time and zinc, which can also come from feed, will decrease when sites are fallowed.

107 Currently, the wider New Zealand finfish aquaculture industry uses minimal chemicals such as antibiotics, parasiticides and other therapeutants and the risk of ecological effects from therapeutants is therefore considered very low (MPI 2013). However, none of

these products are used at all by Sanford. In the case of BGB with the change to mechanical cleaning of the nets instead of using antifoulants, the concentrations of contaminants such as metals (in particularly copper) will have started to reduce. In addition, Sanford in recent years has moved to using organic zinc in feeds.

Avoiding sensitive habitats

108 As mentioned earlier an important aspect of this application is that it is only to intensify existing farms within existing consented areas, not to expand them. The consented areas have been carefully chosen to avoid sensitive habitats of inshore reefs. As discussed earlier the areas in BGB that have been identified as having more diversity are near the entrance around Bravo Island where there are red algae and brachiopods of conservation interest. The deposition of material is very localised around the salmon farms and would not impact on these more sensitive communities.

Fallowing

109 Effects on the benthic environment, if they were to occur outside the farms themselves, are reversible as long as the sea bed isn't degraded to the point of anoxic and azoic conditions. An important management strategy to avoid adverse effects at the farms themselves is to undertake fallowing. To avoid long-term and irreversible effects it is recommended that farms typically be fallowed for not less than 5 years after 2 years of occupation or if there are signs of adverse effects under farms.

110 Sanford's fallowing strategy is based on recovery studies carried out in New Zealand and overseas. They have shown that consideration needs to be given to chemical and biological recovery. While chemical variables may show substantial recovery after a few months of fallowing macrobenthos[7] will be somewhat slower.

111 In a study of recovery of a salmon farm Keeley et al. (2014) found substantial recovery had occurred after 2 years and recovery was assessed as complete in 5 years. In a study of a salmon farm in BGB Morrisey et al. (2000) used data from the Bay and modelled recovery. They predicted that recovery would range from 3.4-4.5 years which corresponded to observations of decreasing waste layers. It is important to note that "recovery" in the case of salmon farms in BGB does not mean a return to pristine or even reference conditions but is to a level of seabed characteristics and communities that will allow the site to be restocked for the two years without exceeding environmental standards.

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[7] Macrobenthos are the larger animals living on the seabed such as starfish, larger bivalves, sea urchins.

Marine pests

112 Organisms that have adverse effects on the environment, including some biofouling organisms, are referred to as marine pests or harmful aquatic organisms. Marine pests can cause adverse effects on the environment including over-growing of high value biogenic habitats, and localised fouling of structures, including marine farms. These effects are potentially irreversible depending on the species.

113 Some marine pests spread naturally, either via release of microscopic life stages (e.g. seaweed spores or animal larvae) to the water column, or via release of viable fragments. Marine pests may also spread through anthropogenic pathways among farms, to other structures or to land via transfer of aquaculture gear or vessel movement.

114 In the case of this application in BGB the proposal is for an extension of existing farms and within existing leases. Thus I would not expect an increased risk of marine pests. Sanford have strict biosecurity plans which represent best practice and are aimed at eliminating or minimizing such risk.

Effects on wild fisheries

115 Fish farm structures and waste feed may attract wild fish. This might make wild fish more vulnerable to fishing pressure as marine farms are often popular recreational fishing locations. The presence of salmon farms and wild fish aggregations around the farms may attract other predators such as seals, dolphins or sharks. These effects are considered to be of minimal importance.

116 There is a risk that farmed fish may escape. In the wild, escapees may compete for resources with wild fish, predate on wild species and alter the genetic structure of wild fish populations. Escapees may also transfer pathogens to wild fish.

117 The potential effect and risk of escapees depends on a range of factors, including the farmed species, the number of escapees, the proximity of the farm to wild fish populations and the ability of escapees to survive and reproduce. At present, the likelihood of adverse escapee effects is considered low in New Zealand because of the small size of the industry, and the limited overlap of farmed and wild salmon populations. This would particularly apply to BGB and Paterson Inlet where there are no significant wild salmon fisheries.

118 Furthermore, King Salmon (unlike Atlantic salmon) spawn then die and farmed fish are all females/neo-males which means they cannot reproduce.

Mammals

119 Interactions between marine wildlife and aquaculture result from attraction to large numbers of fish in a small area, an overlap between the spatial location of the facilities and important habitats and/or main migration routes of the species. Interactions can lead to either direct effects, such as habitat exclusion, incidental entanglements or localised attraction/disturbance from artificial lighting and underwater noise generation, to indirect effects such as possible flow-on effects through the food web or changes to the habitat.

120 In the case of BGB, there is little overlap between the farms and any important marine mammal habitats. However, interactions and predation incidents involving the farms and both seals and bottlenose dolphins have become more common. With the recent shift in the location of pens to one of Sanford's farms closer to the mouth of the Bay (the farm is included in this application), and the establishment and continued growth of a sea lion colony in the 'Neck' area nearby, such incidents have increased and will likely continue to do so, particular if there are any further changes in farm size or activity.

121 The presence of the farms does not constitute habitat exclusion as BGB is not considered ecologically significant habitat for any species. Nonetheless, the attraction of individuals could, if not well managed, be a potential issue from an entanglement perspective (fatal or non-fatal) as well as having an impact on farm itself (e.g. fish losses). Dolphins are often more attracted to an increase in wild fish around finfish farms (due to excess feed or sheltering) while seals tend to be strongly attracted to the farmed fish as a food source. As a result, these species can become entangled in farms that are not properly installed and maintained or in predator nets.

122 Sanford chooses not to use predator nets around the outside of the pens to reduce or dissuade predator attacks in BGB, unlike salmon farm operations elsewhere. The lack of predator nets, along with proper cage maintenance, should reduce the risk of possible marine mammal entanglement significantly. This factor likely accounts for the zero marine mammal entanglement record of salmon farms in the Bay to date.

123 Despite this record, I consider that Sanford should prepare for the possibility of a marine mammal entanglement by developing and putting in place appropriate management practices, such as an entanglement avoidance protocol, along with a marine mammal management plan. This consideration is particularly important given the number of internationally recognised endangered or threatened marine mammal species within these waters.

Birds

124 Seabirds potentially affected by finfish farms in BGB include shags, gulls, terns and penguins. Diving seabirds may be attracted to the fish and feed pellets. The main potential effect of finfish farms on seabirds is entanglement and subsequent drowning in nets used to contain the farmed fish. However, there have been very few reported incidents of seabird deaths as a result of entanglement in BGB and this risk can be managed through best management practices.

125 Other interactions of seabirds with finfish farms have the potential to be positive, neutral or adverse; however, adverse effects are not presently considered significant. Potential positive effects include roost sites for seabirds close to foraging areas created by farm structures and additional sources of prey through aggregations of small fish near the farm. Potential adverse effects include disturbance of nesting and feeding birds by noise, boat traffic or artificial lighting.

126 Effects on seabirds can be mitigated by avoiding placing fish farms near ecologically significant shorebird and wading bird habitats. In the case of BGB there are no ecologically significant areas for these birds.

Standards and limits

127 Standards are required for the proposed variation taking into consideration general guidelines applied elsewhere in New Zealand and overseas, the specific environment in BGB and that the Bay is the only area in Stewart Island identified for aquaculture development.

128 Key elements for the water column monitoring are to ensure that the health of the Bay is sustained and should include the following standards:

128.1 No change in trophic state – the monthly median concentration of chlorophyll-*a* in the water column for all sites being not greater than 3.5 μg chl-*a* /L for 3 consecutive months;

128.2 No increase in frequency and severity of algal blooms (defined as 3 consecutive months greater than 5 μg chl-*a* /L) with no more than two of those months for any two or more sites and for the remaining month at one or more sites);

128.3 No increase in ammonia-N concentrations greater than 30 μg ammonia-N /L above a baseline from 2015-2017; and

128.4 Oxygen concentrations (as % saturation) of at least 70% at 250 m from the edge of the farm.

129 A two-tier assessment is proposed with breach of the first tier (Item 128.1 above) requiring further investigation including comparison with a reference site outside the Bay to establish if the salmon farms are potentially causing the breach. Management actions may be considered if there are persistent breaches to ensure the overall trophic state isn't changing. Tier two standards are considered as requiring more immediate action. These would be a breach of Items 128.2, 128.3 and 128.4 above and if shown to be due to salmon farming would require reduced stocking, and/or fallowing, and/or movement of the farm.

130 To ensure that the health of the seabed is not significantly impacted beyond the farm it is recommended that standards (and conditions) reflect the following Environmental Quality Standards (EQS), and the following should be achieved within 10 m from the edge of the pens:

130.1 The benthic community retains a diversity and abundance of marine taxa (other than one or two opportunistic enrichment-tolerant taxa such as Capitellid and Dorvillea worms, and nematodes) at levels which allow for sustained farm waste assimilative capacity and sufficient seabed recovery to support a farm rotation cycle with a fallowing period of not less than 5 years;

130.2 No more than 20% of the 5 replicate cores collected have no taxa present (azoic). Samples will need to be retaken if there are mussel shells present and affect the ability to obtain a representative sample;

130.3 No obvious, spontaneous out-gassing (H_2S/methane); and

130.4 Bacteria mat (*Beggiatoa*) coverage not greater than 50% of the sampled area.

131 Appropriate management plans should be put in place to minimise risk of invasion by pest species and risk to mammals and birds.

MONITORING AND FARM MANAGEMENT CONSIDERATIONS

Monitoring

132 Considerable effort has gone into developing conditions and a draft environmental monitoring plan (*EMP*) based on experience with marine farms over many years, literature reviews, comments received from Environment Southland and Department of

Conservation as well as meetings with government agencies, international researchers and salmon farmers in Tasmania. A copy of the proposed EMP is **attached** to this evidence.

Water column

133 The main aim of the water column monitoring is to provide data that will allow an assessment of whether the water quality standards are exceeded as a result of the increased input of nitrogen from the Application, and to minimise any such effects, if they were to occur, through adaptive management. Additional monitoring is proposed to provide more information on the spatial and temporal changes as the basis for assessing whether the effects are due to the farm and are ecologically unacceptable.

134 It is recommended the following monitoring be carried out at least monthly at two control sites in the Bay, a reference site outside the Bay, and at 250 m from the edge of the consented areas that are occupied at the time.

135 Details of the monitoring proposed are provided in the **attached** EMP. Briefly, the proposed monitoring includes:

135.1 For compliance: measurements of ammonia-N, chl-*a* and dissolved oxygen;

135.2 Measurements of salinity and temperature as indicators of physical processes affecting BGB, water clarity as an indicator of suspended solids in the water column;

135.3 Measurements of nutrients including total nitrogen, ammonia-N (compliance), nitrate- and nitrite-N, particulate nitrogen, and total, particulate and dissolved reactive phosphorus as an indication of water quality and potential increases due to salmon farming in BGB, if these were to occur. These measurements will be used to assess whether release of nutrients form the farms is the cause of changes in phytoplankton;

135.4 Measurements of dissolved oxygen profiles which provide an indication of whether organic material and oxygen uptake in BGB are being affected by the salmon farms (dissolved oxygen profiles should also be carried out by Sanford at the edge of the pens to ensure fish do not get stressed);

135.5 Water samples will be taken at 5 m depth to be consistent with previous surveys. Alternatively, and ideally, fluorescence should be measured continuously at a control and a potentially impacted site. I note that the continuous monitoring of chl-*a* would require a fluorescence sensor which could be attached to a farm structure and is likely to become the industry norm in the next few years; and

135.6 A full assessment of the observed effects (if any) and recommendations on monitoring and mitigation will be carried out at the end of Stage One before proceeding to full allocation of nitrogen inputs.

Benthic habitat

136 It is recommended the following monitoring of the benthic environment be carried out annually at two control sites in the Bay and at 10, 50 and 100 m from the edge of the pens on farms that are in operation. Recovery should also be followed at on-growing and smolt farms that have been fallowed at 1, 3 and 5 years at least over the next 5 years.

137 The monitoring should include:

137.1 Sampling to use the most appropriate grabs for core sampling for sediment characteristics and infauna analysis. Three to five replicate samples should be taken at each site depending on the parameter being measured;

137.2 Analyses of core samples to include visual assessment, sediment physico-chemical characteristics (grain size, redox discontinuity layer, redox potential, organic content, total free sulphides and obvious sulphur smell), and infaunal species and abundance determinations;

137.3 Epifauna communities to be characterised based on photograph quadrats and to include identification of bacteria mats and quantity of burrows/holes. Video footage or quadrat photographs should be taken for general features along at least three transects at the edge of the farms area and at least two at reference sites. Observations to include any obvious outgassing; and

138 A full assessment of the effects and review of monitoring is to be made after Stage One of the increase in nitrogen input, before proceeding to Stage Two.

SUMMARY

139 There are a number of factors that are important considerations in the context of this Application. The first is that it is only to intensify farms within existing consented areas i.e. the application is to increase the nitrogen cap to allow more pens to be placed within license areas but with no increase in density. The consented areas have been carefully chosen to avoid sensitive habitats of inshore reefs and some sites have been monitored now for some 20 years.

The areas in BGB that have been identified as having more diversity are near the entrance around Bravo Island where there are red algae and brachiopods of conservation interest.

140 Modelling, and the information based on monitoring and information gathered about BGB to date that I have summarised above, show that while the proposal in the Application may potentially elevate nutrients in the water column, particularly ammonia-N, this will be well below toxic levels. The elevated nutrient levels will potentially increase primary production by phytoplankton but the levels predicted are worst-case and very conservative as they do not include other factors determining phytoplankton growth, losses such as depletion of phytoplankton by zooplankton and mussel farms or the export of nitrogen from the Bay as mussel nitrogen.

141 Based on the information available and expert opinion, standards can be set to ensure that nutrient levels that would result in a change of trophic state or increase the risk of algal blooms are avoided. The conditions and EMP provide details of the standards to be applied to ensure these objectives are met. The management plan will ensure that if unpredicted effects did occur then the effects can be reduced through reducing stocking densities or moving the farms to another location in the Bay.

142 Observations to date and modelling of deposition footprint demonstrate and predict that the deposition of organic material will be very localised around the salmon farms, and at 50 and 100 m from the farms deposition levels will be similar to controls, and will not impact on more sensitive communities in the Bay.

143 Effects, if they were to occur, will be reversible as long as the sea bed is not degraded to the point of anoxic and azoic conditions.

144 An important management strategy to avoid adverse effects at the farms themselves (which is not carried out in the other major salmon growing area in New Zealand) is fallowing to allow the area to rehabilitate. To avoid long-term and irreversible effects it is recommended that farms be fallowed typically for at least 5 years after 2 years of occupation or if there are signs of adverse effects under farms. This would ensure that license areas are left to rehabilitate before they get to the point that farms cannot be placed in the area after the 5 years.

145 The conditions and management plan include staging which will ensure that unexpected effects if they were to occur can be readily mitigated.

146 Based on the modelling, my assessment of effects and the proposed conditions with management plans in place, if unexpected effects

were to occur then these will be detected through the proposed EMP and appropriate management actions taken.

147 Overall, I consider the increase in nitrogen input sought in the Application can be accommodated and will not cause ecologically significant changes to the health of the Bay.

OFFICERS REPORT

148 **Dr Grange** was commissioned by Environment Southland to provide technical advice on Sanford's application. This included reviewing the application, various meetings and teleconferences, and reviewing and reporting on matters of concern, the conditions and EMP. A number of matters of concern were raised in the earlier communications. The two key remaining concerns are the potential for phytoplankton blooms and the predicted high level of deposition under the pens.

149 Regarding the potential for phytoplankton blooms, while the increase in nutrients are not predicted to cause nuisance blooms, **Dr Grange** states that the standards on average are higher than previously recorded in BGB and quite high compared with coastal New Zealand waters. There is potential for an increase in phytoplankton biomass above the existing levels, predicted by modelling to be an increase up to 2.5 to 4 µg/l, but as explained in my evidence this is overly conservative. I consider the monthly median standard of 3.5 µg/l is appropriate noting that over the last 3 years monthly medians in BGB have been up to 3.4 µg/l. As stated in my evidence the standards have been strengthened from those in the original application (and predictions from modelling) and are in line with those applied in the Marlborough Sounds including areas in the outer Sounds, at levels that can be found in other coastal systems, and at levels that will ensure the trophic state of BGB is maintained at its present level.

150 **Dr Grange** also comments that the monitoring will detect persistent blooms but not short-term blooms. As **Dr Grange** states blooms can develop quite rapidly, however it is the persistent blooms that are of concern and I consider the monthly sampling will pick these up. Very short blooms are also likely to be stimulated by inputs of upwelled nitrate from outside the Bay not salmon farming. Monthly sampling is standard for monitoring programmes throughout New Zealand.

151 **Dr Grange** questions whether the 5 years of fallowing is sufficient. The 5 years is based on published studies as referenced earlier in my evidence. I also note that the conditions require a period of

fallowing of at least 5 years with monitoring to confirm that this period is appropriate.

152 In the summary of **Dr Grange's** evidence, he concluded that while the benthic modelling for the applicant showed it was within the assimilative capacity of BGB overall, there are likely to be significant adverse impacts within and beneath each consented farm site and he has some reservations about the ability of the benthic community to assimilate the deposits. However, **Dr Grange** concludes that the comprehensive EMP, staged development and the standards in the latest conditions should provide some assurance that effects can be managed if they were greater than predicted.

153 For effects on the environment the staff report relies largely on the reports and evidence provided by **Dr Grange** and notes that his concerns have been addressed, as stated above, except for the monthly sampling discussed above. The staff report concludes that the effects on the water column may be more than minor but if there are adverse effects these can be managed through the EMP and conditions proposed.

154 The staff report also notes the one outstanding concern for the benthic environment is that the five-year fallowing plan may not be sufficient to enable recovery. It also notes that the effects that may be more than minor are likely to be confined to under the pens and within 100 m of the pens. Again the staff report concludes that adverse effects can be managed based on the EMP and conditions. I would also note, as I have in my evidence, that the area actually occupied by salmon farms in BGB is negligible (<0.3% of area occupied by pens at any one time), and that the EMP includes monitoring following fallowing to ensure the timeframe is appropriate. Five years is the minimum for fallowing and is the conditions.

155 The Officers report also notes that previous salmon farms have been required to be below 5 on an Enrichment Scale (ES), which modelling indicates two of the farms would be in excess of. We have not used ES as this was developed specifically for the Marlborough Sounds based on a considerable amount of research and information. It has not been developed yet for other areas. I would note however, that some of the key parameters and ES characteristics for ES 5 have been incorporated into the standards for the BGB application. It should also be stressed that ES was developed for salmon farms in the Marlborough Sounds which are not fallowed and thus there is no recovery as part of the farm management. The fallowing plan is a key part of the application to ensure that the benthic environment does not reach an unacceptable state.

MATTERS RAISED BY SUBMITTERS

156 The Department of Conservation (DoC) made a submission on the application by Sanford with their main concern being that the application did not adequately identify potential adverse effects or sufficiently avoid, remedy or mitigate the actual or potential effects related to water quality and benthic environment. More specifically their concerns related to:

156.1 The assimilative capacity to cope with the increased nutrient loads and discharges;

156.2 The absence of any staging or adaptive management;

156.3 Lack of a nutrient-phytoplankton-zooplankton-detritus water quality

156.4 Details on key assumptions on nitrogen performance and processes in the farm;

156.5 Scale of predicted changes in chl-a;

156.6 Conditions are unclear in key areas such as how limits are to be assessed spatially and with controls or baseline;

156.7 Need to measure oxygen at all depths; and

156.8 Conditions around deposition would permit substantial enrichment of the seabed.

157 Some of these concerns will be covered in evidence by **Dr Hartstein** and **Mr Wybourne** (143.1, 143.3, 143.4 and 143.5 above).

158 Following DoC's submission there have been meetings, teleconferences, and email correspondence to address the concerns raised by DoC and clarification to address these concerns have been incorporated in my evidence and the latest proposed conditions.

159 The standards for the water column and benthic environment have been strengthened and have now been agreed with DoC. The modelling that has been undertaken to understand the effects of the increased nitrogen release and loadings to the seabed is described in **Dr Hartstein's** evidence and changes to conditions in **Dr Mitchell's** evidence. The key elements are:

159.1 The modelling showed that chl-*a* could increase by 2.5 to 4 µg/l under the proposed increase in nitrogen in feed. As described in **Dr Hartstein's** evidence this is very conservative and precautionary in terms of increase as it assumes all nitrogen is taken up by phytoplankton and retained in the Bay. However, at times there will be other limitations on phytoplankton growth, and uptake by mussels and zooplankton and removal of nitrogen from the system is not accounted for. Thus new and strengthened standards have been developed, as described in my evidence and in the conditions to ensure the assimilative capacity is not exceeded, that the trophic state will not change and there is no increased risk of algal blooms. These new standards are in line with Best Practice guidelines and those set for the Marlborough Sounds;

159.2 The compliance site for limits for the benthic environment have been set close to the pens and strengthened from what was originally proposed. A key element of the Sanford proposal is that standards have been set and a fallowing plan developed (unlike farms in the Marlborough Sounds) to ensure the assimilative capacity of the benthic environment is not exceeded and so that pens can be reinstated after 5 years without compromising the health of the benthic environment;

159.3 Two stages of development with consideration of monitoring results before further development have been added to the conditions;

159.4 An EMP has been developed which provides details on sites, parameters to be measured, standards to be met and baselines or references to be used in the assessment of effects. Profiles of dissolved oxygen have been added. The EMP has been developed following discussion with DoC and they have confirmed it is fit-for-purpose.

160 A submission was made on behalf of Te Rūnanga o Awarua and Te Rūnanga o Ngāi Tahu who were supportive of the development provided that it is carried out in a way that respects the environment and does not adversely affect their cultural values, customs and traditional relationship with land and water. The specific concern with respect to the environment was about the potential impacts of increased nitrogen input.

161 A number of meetings and correspondence have been had with Ngāi Tahu to address their concerns and responses have been provided. I understand that the latest set of conditions and the EMP have addressed Ngāi Tahu concerns and have provided the confidence that their values will not be adversely affected.

162 More specifically:

162.1 Concerns about sampling methods have been clarified, and a metric is in the conditions and EMP for *Beggiatoa* mats;

162.2 Conditions around standards for benthic impacts have been amended and strengthened considerably to address concerns raised by DoC and Ngāi Tahu; and

162.3 Fish health is paramount and the standards set for parameters such as dissolved oxygen will ensure fish in the Bay are not adversely impacted.

Mark James

11 March 2019

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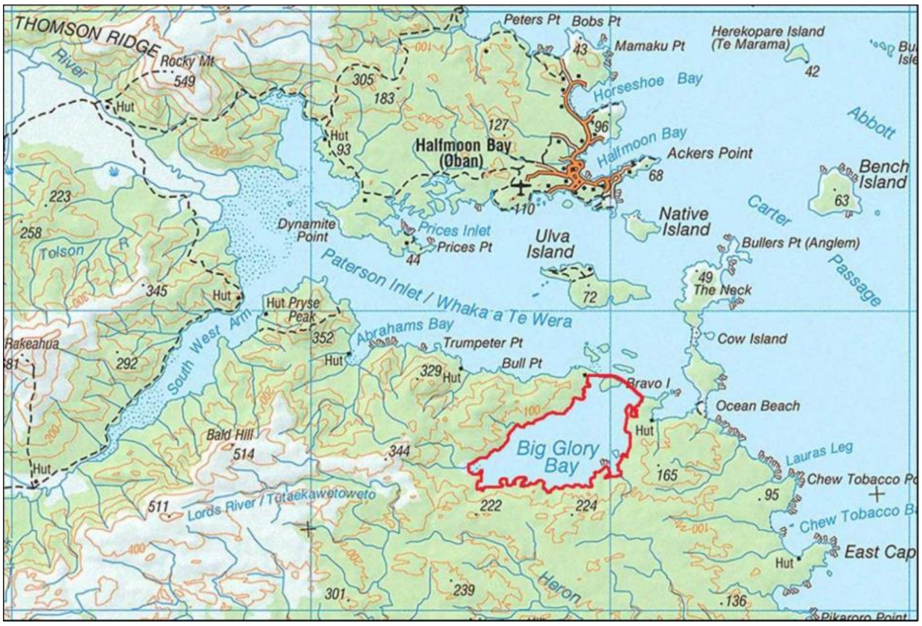


Figure 1. Map showing location of Big Glory Bay.

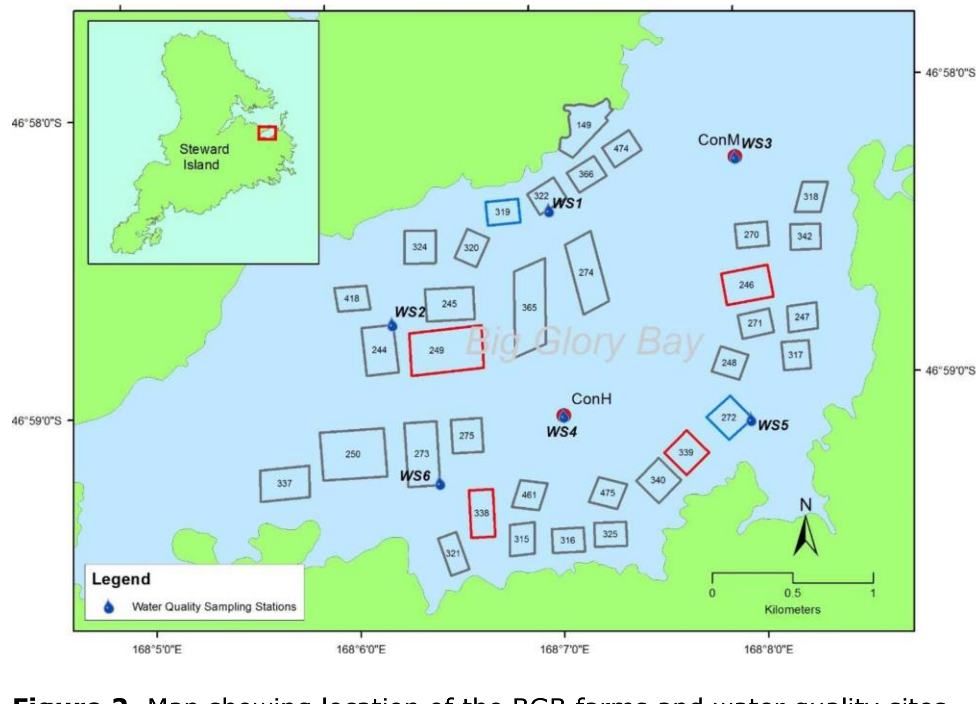
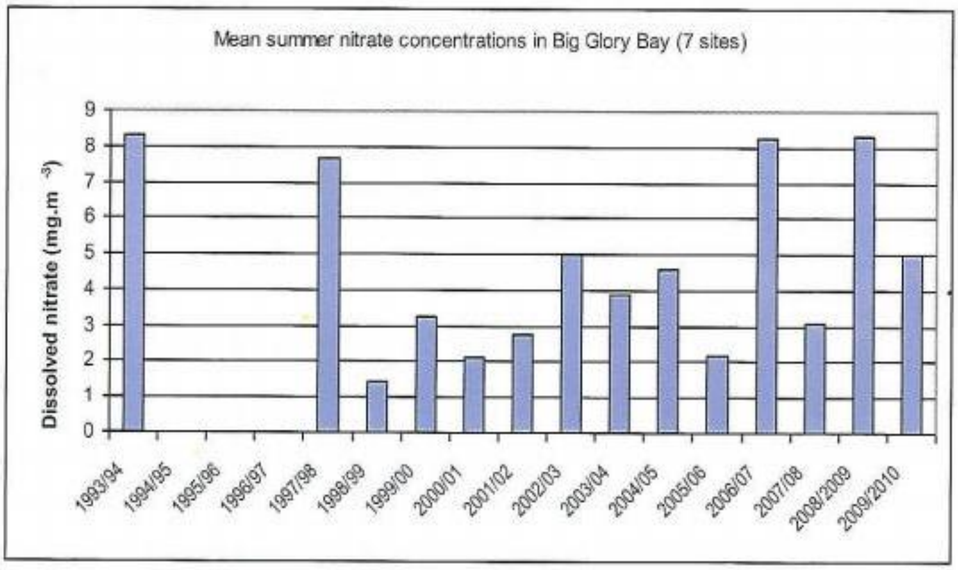


Figure 2. Map showing location of the BGB farms and water quality sites sampled in 2016. (ADS 2016). The farms in red are active salmon farm sites, noting that Site 249 is currently being fallowed.



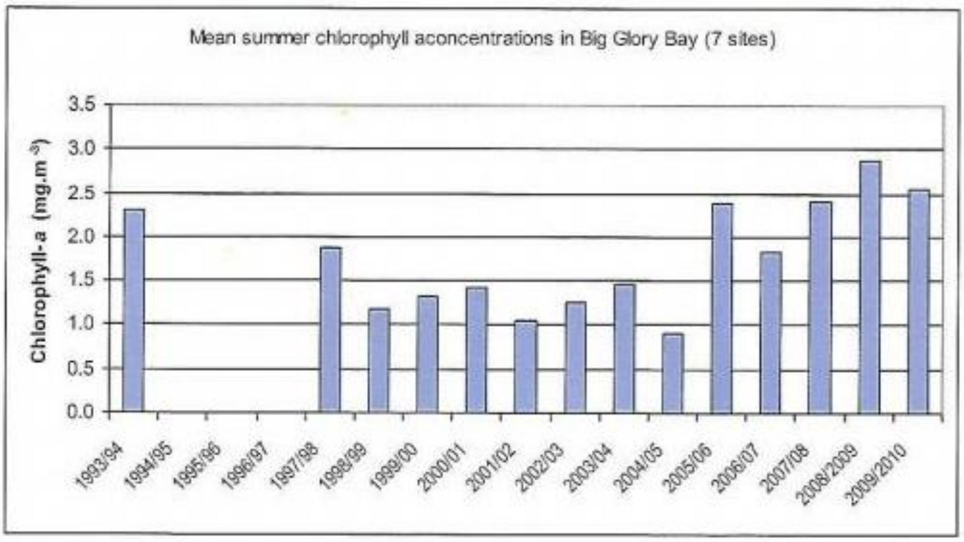


Figure 3. Average summer nitrate-N (top) and chl-*a* (bottom) concentrations in Big Glory Bay (1993-94 data from R Pridmore NIWA, 1997-2010 from Stenton-Dozey & Brown 2010).

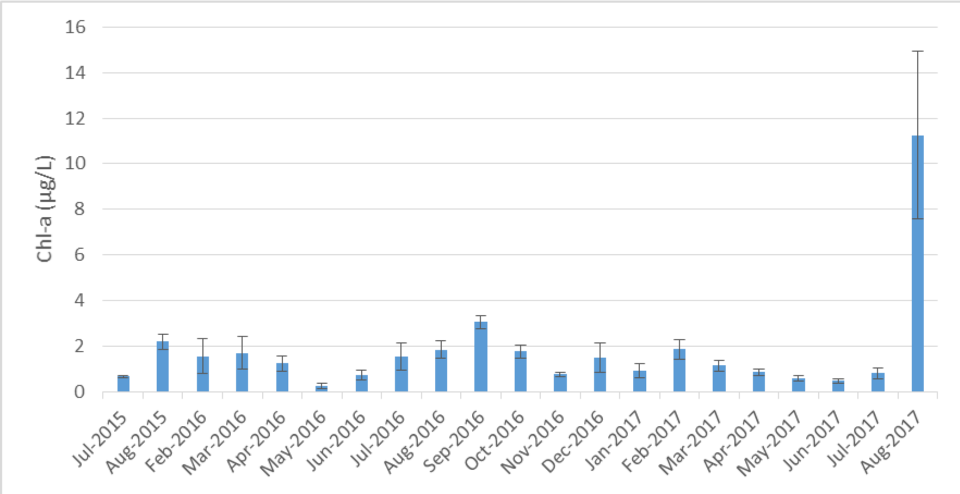


Figure 4. Site-averaged Chlorophyll-a concentrations collected as part of Sanford's monthly water quality monitoring program 2015-2017, averaged for all stations.

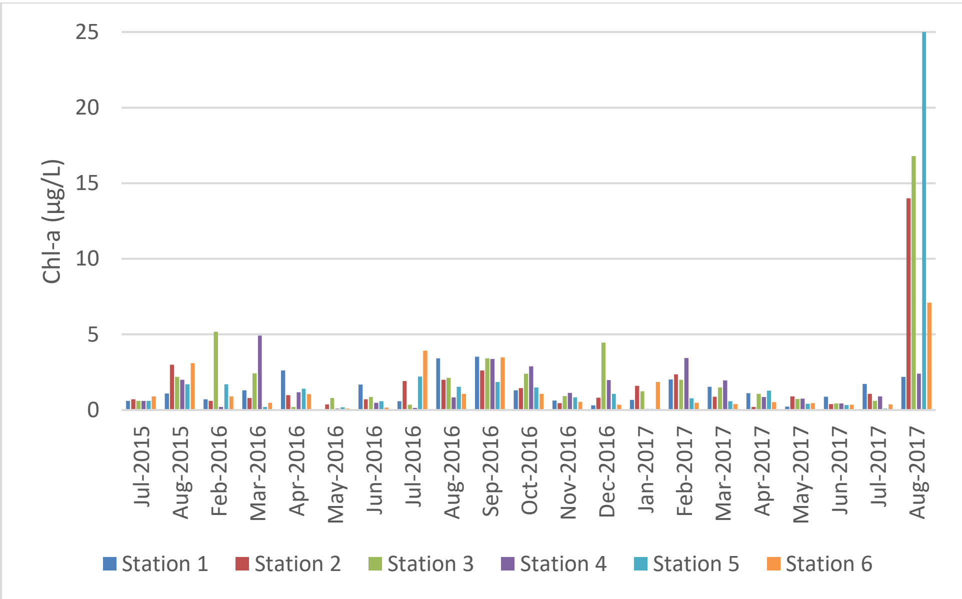


Figure 5. Site-specific chl-a concentrations collected as part of Sanford's monthly water quality monitoring program (2015-2017).

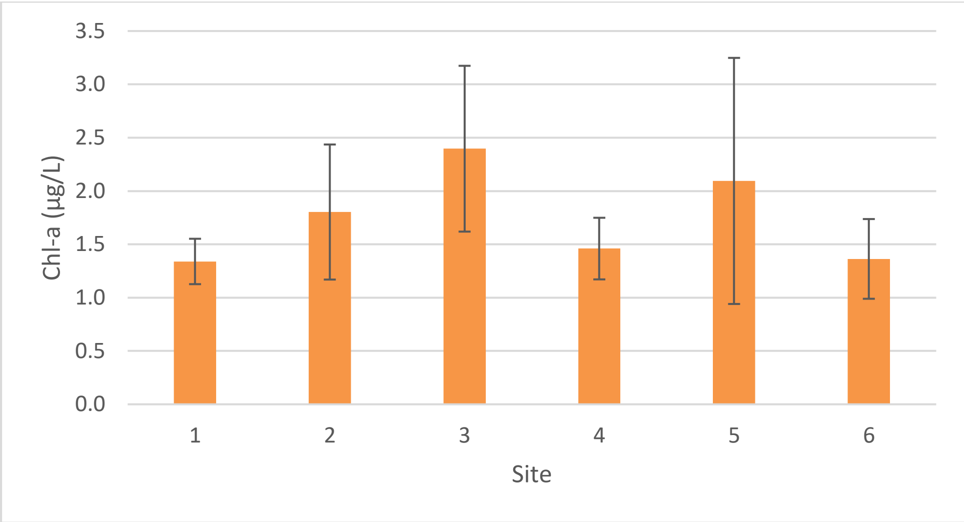


Figure 6. Time-averaged Chl-a concentrations for each site collected as part of Sanford's monthly water quality monitoring program (2015-2017).

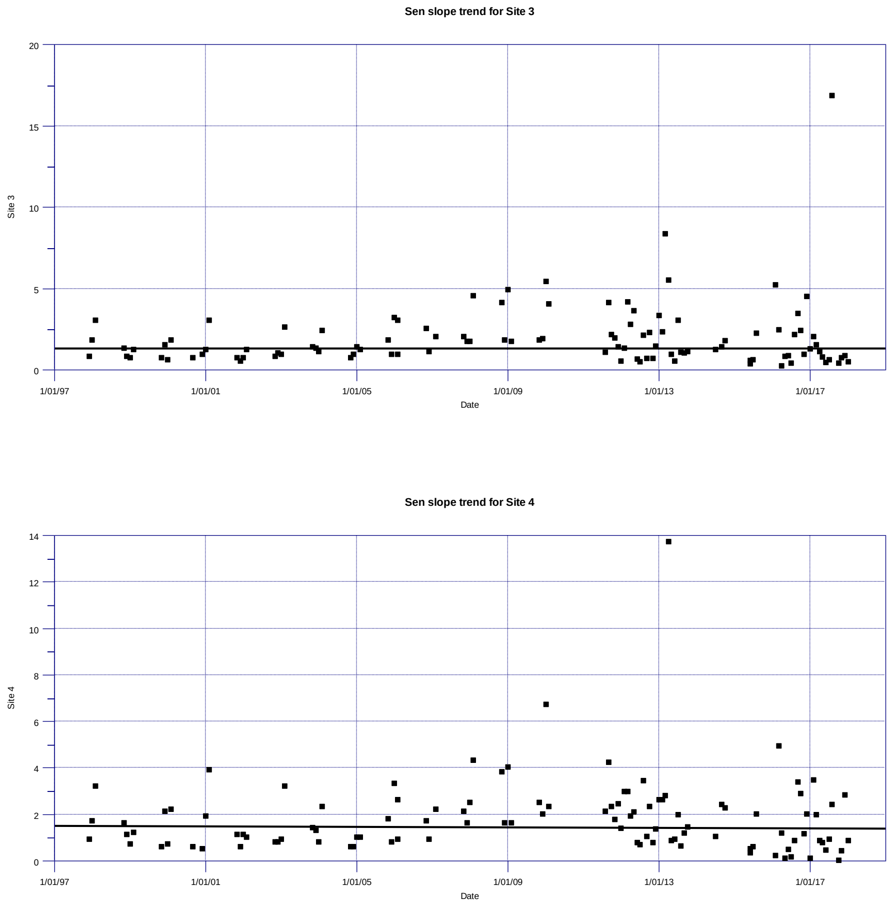
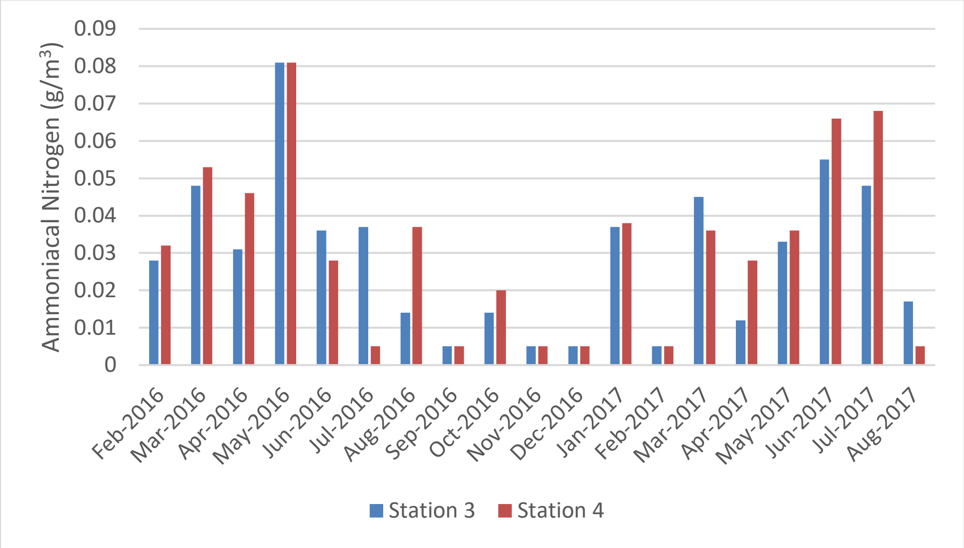


Figure 7. Chl-a concentrations for period 1997-2018. Trend analysed using Mann-Kendall test.

A



B

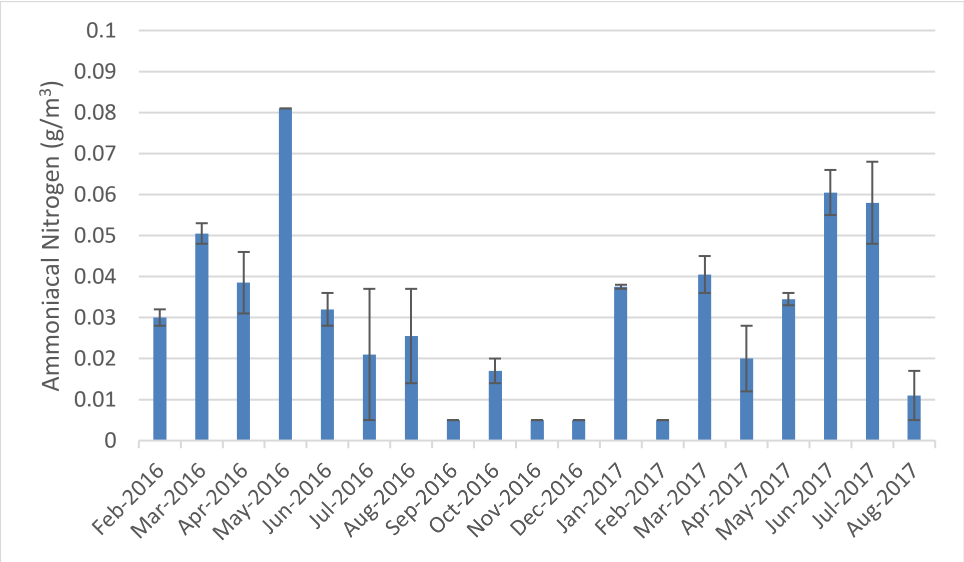
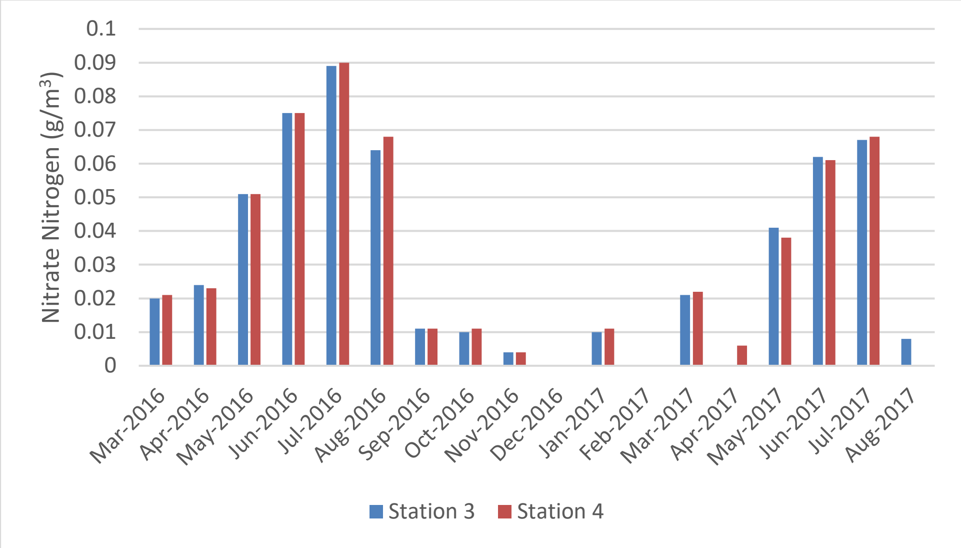


Figure 8. Site specific (A) and average (B) ammonia-N concentrations for control sites 2016-2017.

A



B

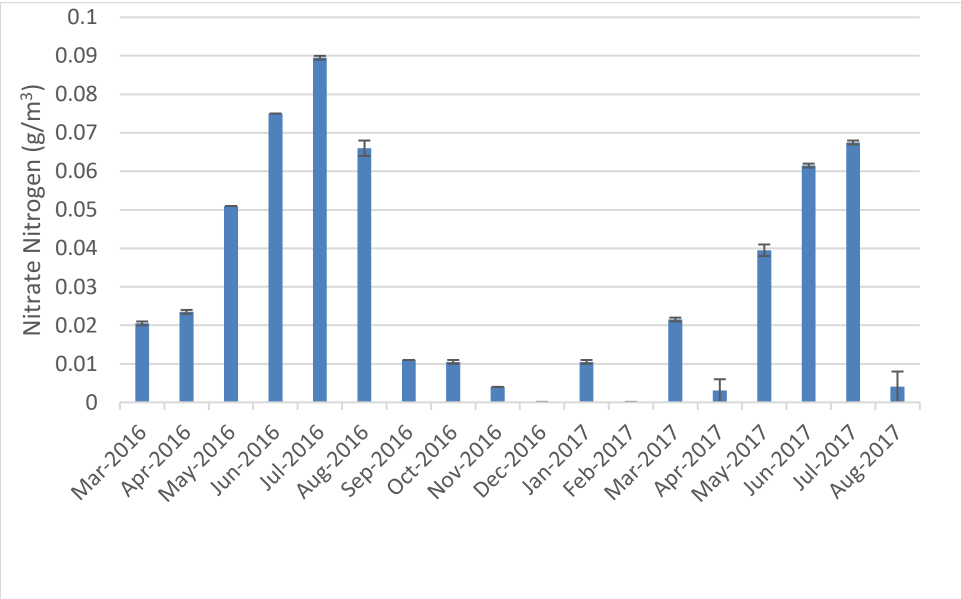


Figure 9. Site specific (A) and average (B) nitrate-N concentrations for control sites 2016-2017.

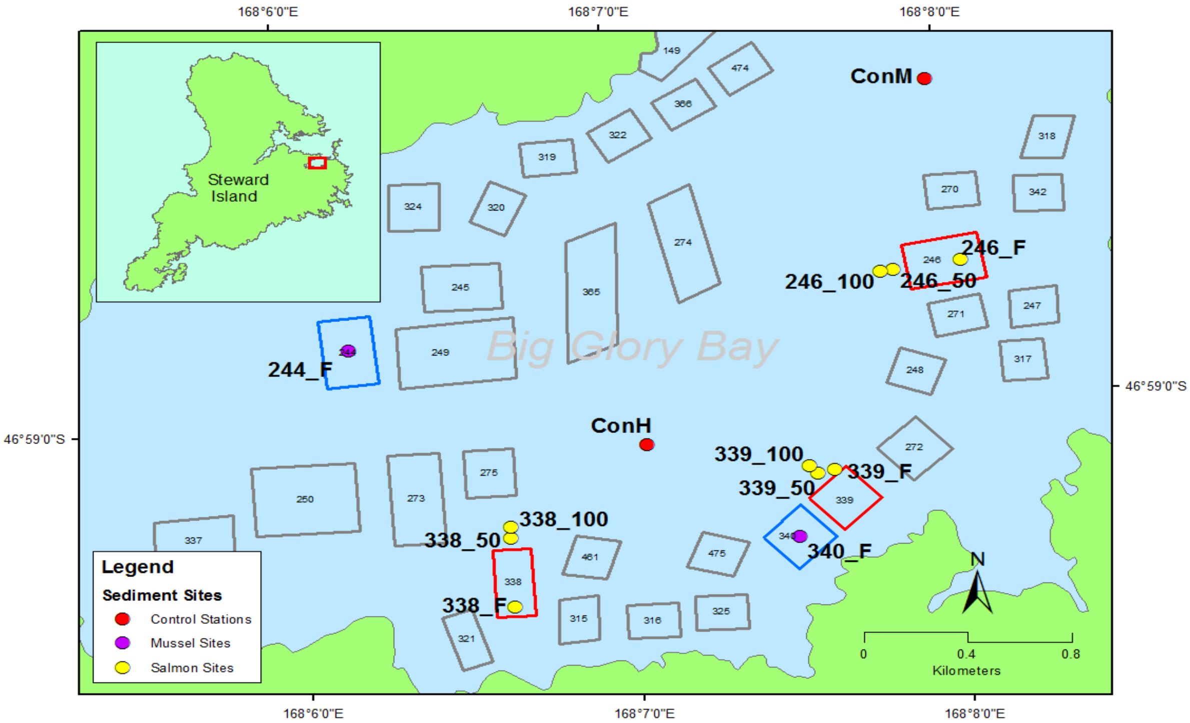


Figure 10. Benthic sites surveyed for Sanford Ltd by ADS in 2017. Red dots are control sites, and yellow dots sites around salmon farms in use. Purple dost are sites being fallowed.

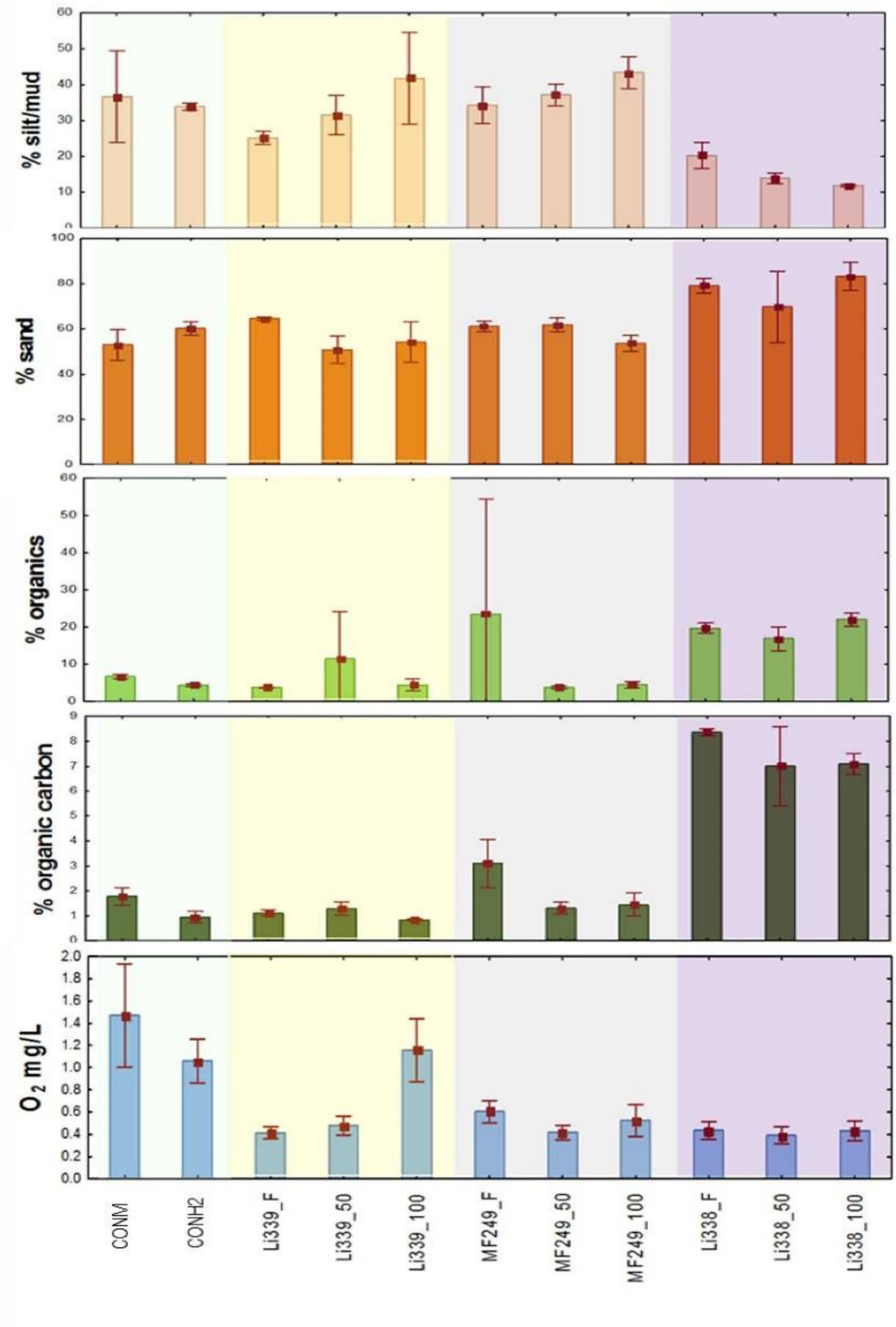


Figure 11. Sediment properties (% silt/mud, % sand, % organic matter, % organic carbon, subsurface O2 mg/L) from the area under the salmon farms LI 339, MF 249 and LI 338 (_F), and 50 m (_50) and 100 m (_100) away, and at the two control stations for 2015. CONH2 = Control Head and CONM = Control Mouth. (From Stenton-Dozey 2015)

Organic Matter

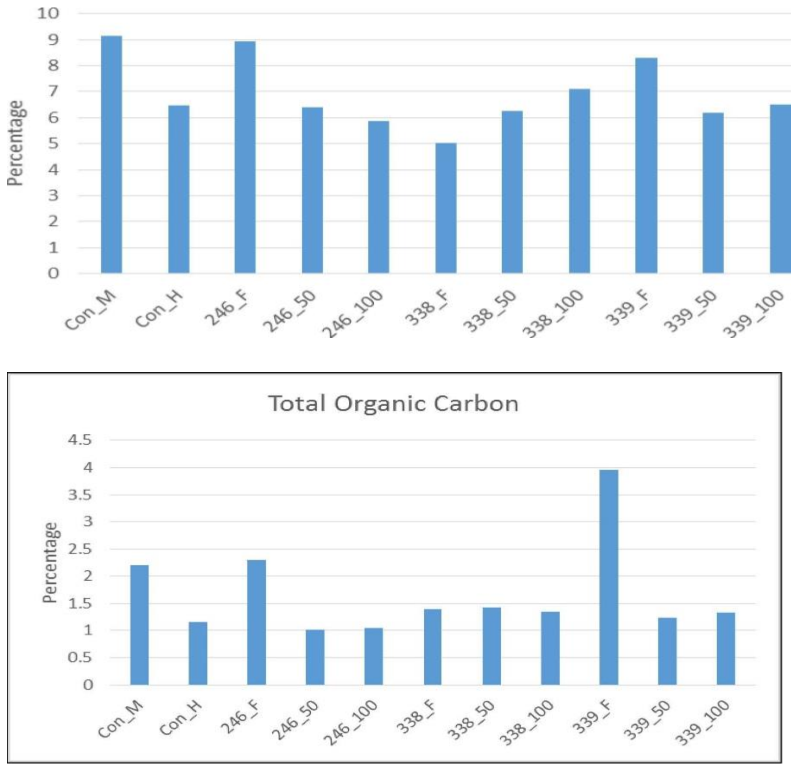
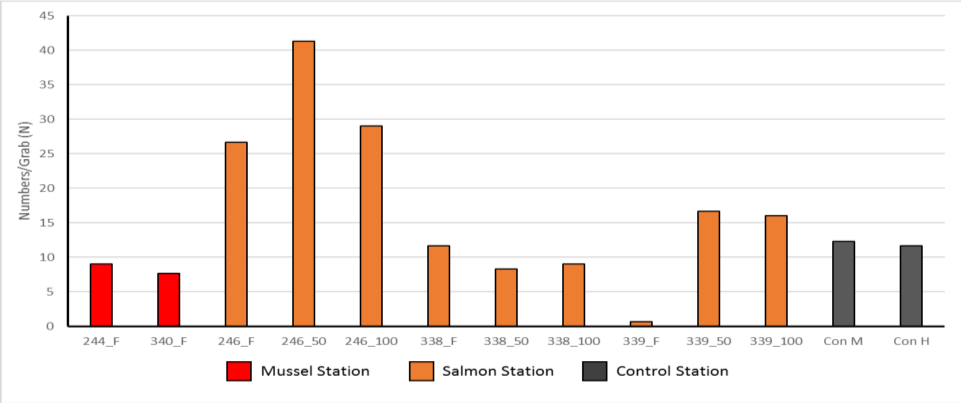


Figure 12. Sediment characteristics for control and salmon farm sites in 2017 (from Sanford 2017).



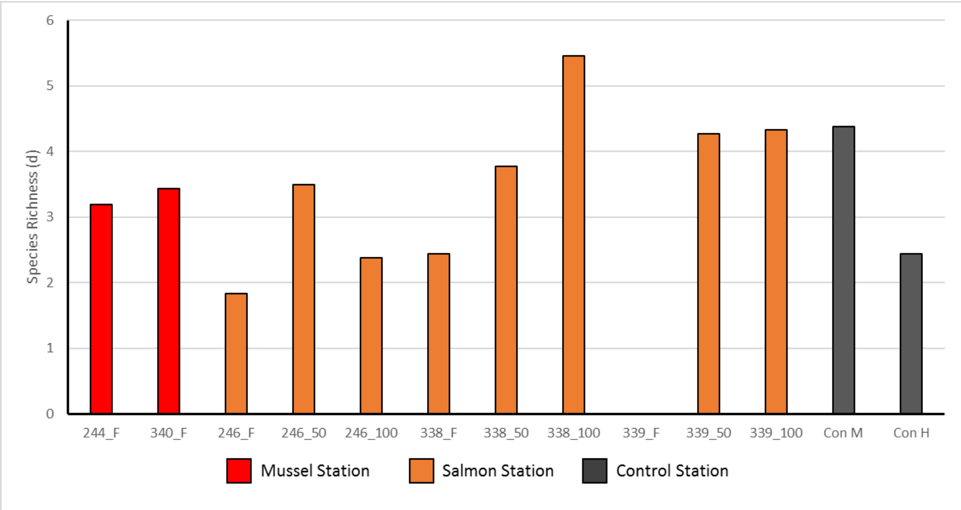


Figure 13. Benthic infauna community structure for all sites in 2017 (from ADS 2017a)

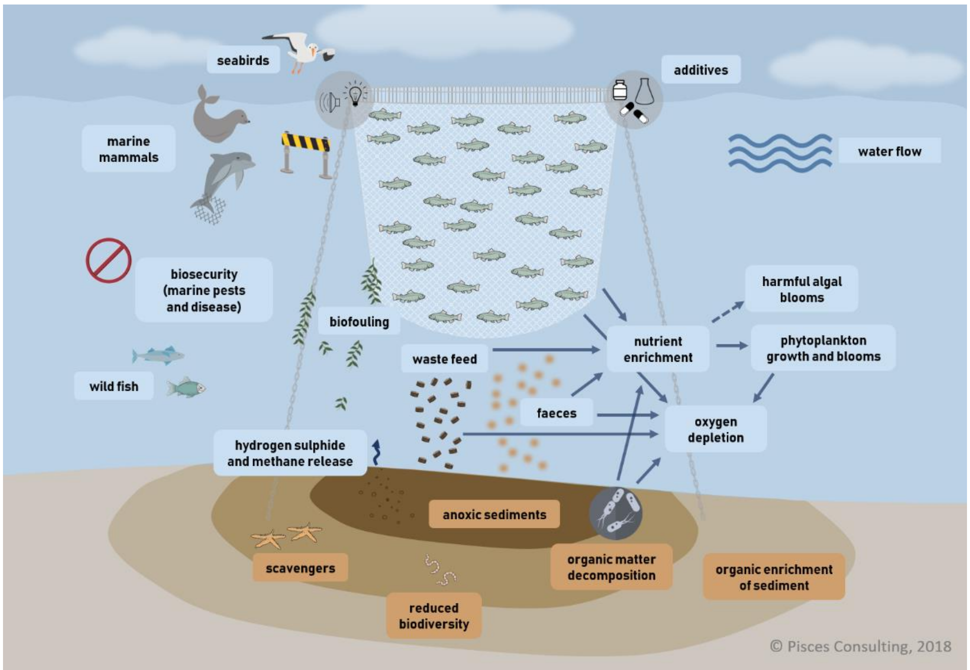


Figure 14. Illustration of the environmental effects of finfish aquaculture (provided by Hilke Giles).

Table 1. Characteristics of the benthic environment at control stations in 1998-2009 (Stenton-Dozey & Brown 2009), 2015 (Stenton-Dozey 2015), 2016 (ADS 2016) and 2017 (ADS 2017a). 1 Note that for 2012-2015 the grab sizes may have been different so cannot compare with other years.

Parameter/Site	Control at head of Bay					Control at mouth of Bay				
	1998-2010	2012-2014	2015	2016	2017	1998-2010	2012-2014	2015	2016	2017
Organic matter (%)	Over 10% most years and up to 18%	4.2-5.7	4.4	6.3	6.5	Generally around 5% and up to 9%	6.3-7.4	6.6	8.4	9.1
Mud content (%)	36-96	38-85 (2013)	34	63	66	18-65	50-57	36	35	37
Sand content (%)	36-96	12-56	60	35	31	20-73	31-46	53	57	53
TOC (% of dry weight)	2.9-17	1.1-1.3	0.9	2.5	1.2	3.8-8.9	1.2-2.2	1.8	2.3	2.2
Mean # infauna species per grab	ns	13-181	141	10	7		9-181	121	11	12
Numbers infauna/grab	ns	50-1001	1201	12	12	N/A1	25-601	601	21	12

Species richness index (Margalef's d)	ns	2.8-4.2	2.8	3.7	2.5		2.2-4.4	2.9	3.3	4.3
Copper (mg/kg DW)		5.5-9	7	9	9		6.6-8.3	8	7	7
Zinc (mg/kg DW)		27-34	34	37	32		26-35	31	38	33

Table 2. History of salmon farms in BGB.

- MF 249 was a mussel farm for 12 years before the pens previously at LI 320 were shifted to the site of MF 249 and it was converted to a salmon on-growing facility in 2011. In 2016 the site was vacated and left to fallow;

- MF 246 was historically a mussel farm and since September 2016 has been Sanford's main on-growing farm. The pens will soon be moved to another site within the lease;

- LI 338 was a salmon smolt site from 1985 to 2012. Brood stock were moved to the site in December 2015;

- LI 250 shifted to LI 339 in about 1987 and the farm became a smolt site for about 6 years until 1993. It was converted to a mussel farm from 1999 to 2013 and then back to a smolt farm from 2013 to 2018. The pens have recently been moved to LI 340; and

- LI 320 (sometimes referred to as the 47 South Site) was vacated after use for 2-3 years in September 2011 and shifted to MF 249. The farm is now vacant.

Table 3. Trigger parameters and their values for acute and chronic toxicity in estuarine and marine waters as cited in Hartstein & Oldman (2015).

	Acute Concentration	Chronic Concentration
Dissolved Oxygen	< 2.3 mg/L DO (EPA, 2000)	<4.8 mg/L DO (Vaquer-Sunyer & Duarte, 2008; EPA, 2000)
Nitrate	>339 mg NO3--N/L (CCME, 2012)	> 3.7 mg NO3--N/L (Meays, 2009) > 45 mg NO3--N/L (CCME, 2012)
Nitrite	Acute levels specific to marine systems are not yet defined.	> 0.06 mg NO2--N/L (EPA) > 5 mg NO2--N/L (EPA warm water fish)
Unionized Ammonia	Worst case: > 1.4 mg NH3-N/L (EPA) (T=25°C, pH=8.6 and salinity=30 PSU)	Worst case: > 0.22 mg NH3-N/L (EPA) (T=25°C, pH=8.6 and salinity=30 PSU)

Appendix 1 Draft Environmental Monitoring Plan

Environmental monitoring plan for Big Glory Bay salmon farms

Hilke Giles[1], Mark James[2]

Prepared for Sanford Ltd

15 January 2019

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Table of contents

Executive summary

This Big Glory Bay Salmon Farm Environmental Monitoring Plan ("**EMP**") has been prepared for Sanford to assess and enable compliance with the changed conditions for the ten quinnat salmon (*Oncorhynchus tshawytscha*) farming sites in Big Glory Bay, Stewart Island, that are owned or farmed by the company. The marine farm sites subject to this variation are Sanford sites MF 246, MF 249, LI 320, LI 321, LI 338, LI 339, LI 340 and MFL 366 and MFL 474 owned by Jeff Walker, and MFL 342 owned by Peter Schofield. This EMP focusses on meeting the requirements of the changed conditions while providing for consistency with past monitoring where this is possible and meaningful.

Monitoring includes benthic and water column monitoring as well as reporting of marine mammal and seabird interactions and entanglements. An overview of monitoring requirements is provided in **Figure 1**.

This EMP provides the rationale and methodology for the conduct of monitoring surveys, annual reporting requirements as well as reporting requirements in the event of breaches of Environmental Quality Standards (EQS) and the triggering of Tier One or Tier Two action, as specified in the consent conditions.

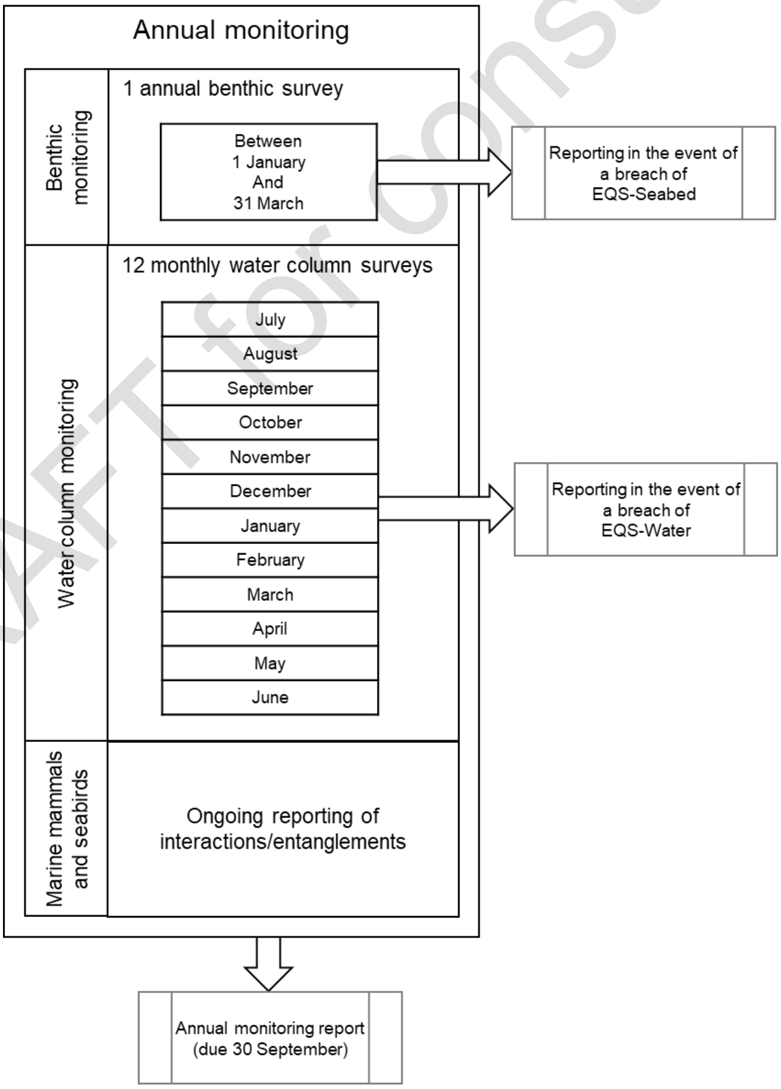

Figure 1. Overview of annual monitoring and reporting requirements.

1 Introduction

Sanford has applied for a change of conditions for its Big Glory Bay, Stewart Island, quinnat salmon (*Oncorhynchus tshawytscha*) farming sites to allow for an increase in nitrogen input. The marine farm sites subject to this variation are MF 246, MF 249, LI 320, LI 321, LI 338, LI 339 and LI 340, although the consents also allow the nitrogen from three other farm sites in Big Glory Bay to be utilised, with the consent of those farmers. Each coastal permit imposes a limit on the amount of nitrogen from feed that can be discharged. At the time of application for change of condition in 2017, the combined allowable nitrogen from feed allowed across all the Sanford salmon farms was 332.064 tonnes per year and the Bay wide nitrogen cap was 483 tonnes.

Following comprehensive environmental assessments of the assimilative capacity of Big Glory Bay for nitrogen input from feed, Sanford applied to increase the total allowable nitrogen input from feed in the Bay over all salmon farm consents to 659 tonnes per year. This is an increase of 176 tonnes per year.

Sanford has carried out environmental monitoring of the ecological effects of its salmon farms in Big Glory Bay for many years. This Environmental Monitoring Plan (“EMP”) has been prepared to assess and enable compliance with the changed conditions and will help inform future management and monitoring provisions. This EMP focusses on meeting the requirements of the changed conditions while providing for consistency with past monitoring where this is possible and meaningful.

2 General monitoring requirements

2.1 EMP objectives

This EMP specifies requirements for monitoring surveys, data analysis, reporting and responses to facilitate robust and consistent environmental monitoring of potential environmental effects of salmon farming in Big Glory Bay throughout the consent duration.

Monitoring conducted in accordance with these specifications enables the consent holder and Environment Southland to assess whether the environmental effects of salmon farming in Big Glory Bay meet the requirements of the consent and, if there are indications that effects may exceed acceptable levels, provides for timely reporting of and response to potential breaches of environmental quality standards.

Furthermore, this EMP ensures that information is collected and reported in a way that enables an assessment of the efficacy of the conditions of consent regarding environmental monitoring and thus will inform assessments of environmental effects and environmental monitoring plans for subsequent reconsenting.

This EMP reflects the requirements specified in the conditions of consent. Any deviations from the specifications of this EMP must be considered and agreed upon by the consent holder and Environment Southland. Deviations should be checked against the conditions of consent to prevent inadvertent non-compliances.

2.2 Types of monitoring

This EMP comprises specifications for annual (benthic) and monthly (water column) surveys as well as ongoing reporting of sightings of mammals and sharks and operational farming information to contextualise monitoring results.

2.3 Qualifications and laboratory analyses

Monitoring must be conducted by suitably qualified and experienced persons. Laboratory analyses must be conducted at an accredited laboratory according to standard methods that are listed in this EMP.

2.4 Monitoring sites

Monitoring sites are located relative to the location of pens for assessments of potential farm effects and in areas not expected to be affected by farming activities for assessment of environmental reference conditions (**Figure 2**).

Control sites in Big Glory Bay are identical to those used for past environmental monitoring of marine farming effects. A new control site has been added outside of Big Glory Bay to provide for a better assessment of the wider environmental state and changes over time. Benthic and water column monitoring sites have changed to reflect the conditions of consent and to provide for a more effective understanding of potential effects of salmon farming in Big Glory Bay and to allow for a better evaluation of benthic recovery during fallowing.

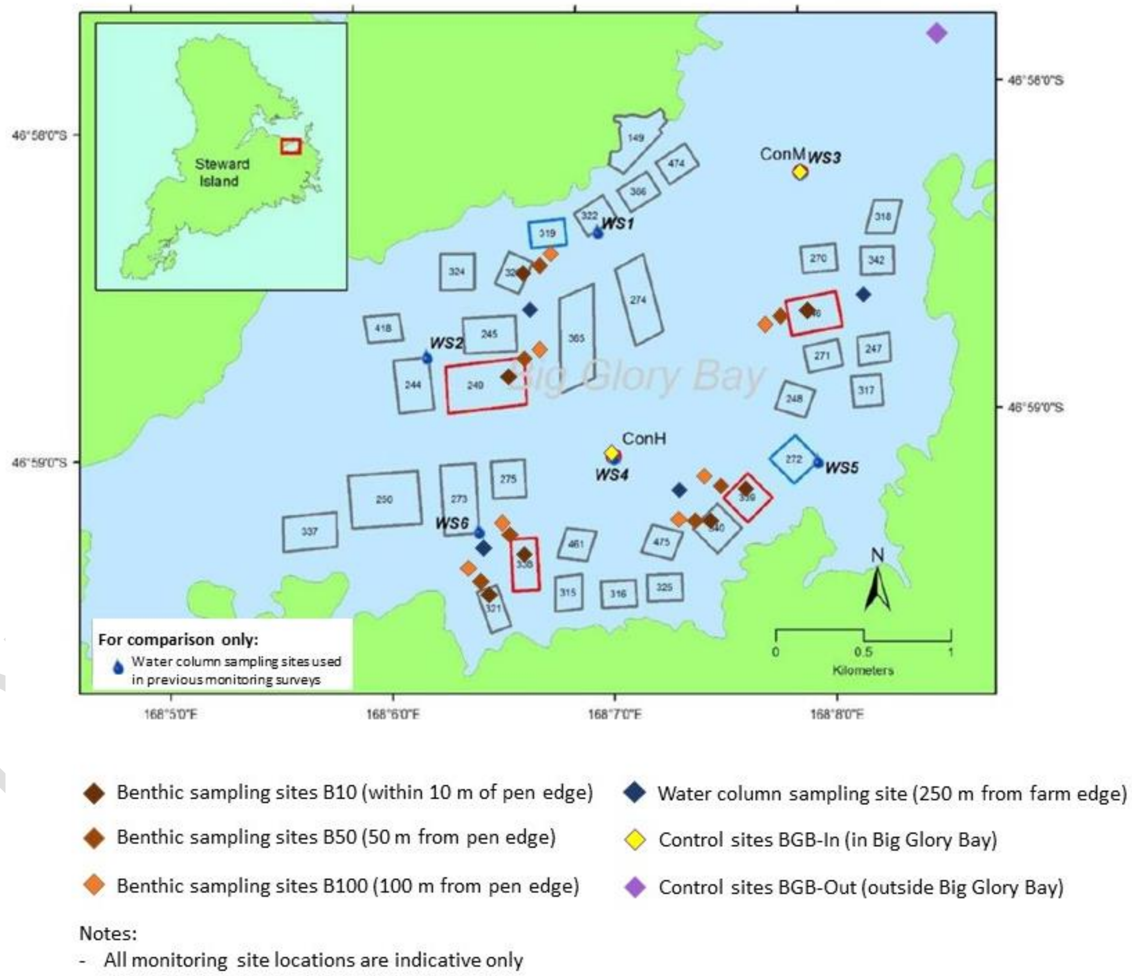

Figure 2. Marine farms and indicative monitoring sites. Sampling sites for MF366 and MF474 will be added when these farms are to be utilised but would be a similar transect for benthic sites to MF320.

As shown in **Figure 2** benthic sampling sites are located 10 m, 50 m and 100 m from edge of the pens in a downstream direction. Benthic monitoring site locations are relative to farms that are in farming or in fallow (grower and smolt farms only) at the time of monitoring and may therefore change over the duration of the consent (see **Table 2**). Water column sampling sites are located 250 m from farm boundary edges. These sites remain unchanged over the duration of the consent. Benthic and water column monitoring site locations are different to sites used in past monitoring surveys. Previous water column sampling sites are shown for comparison. Two control sites are located in Big Glory Bay (these are identical to the control sites of past monitoring surveys) and one additional new control site is located outside of Big Glory Bay (location to be confirmed but is likely to be further out than indicate don the map.

2.5 Monitoring and reporting timeframes

Monitoring shall commence as soon as practicable but no later than three months after consent has been granted. Interim timeframes for monitoring surveys and reporting to Environment Southland are shown in **Table 1** with final timeframes depending on when consent is granted.

Table 1. Overview of interim monitoring and reporting timeframes.

Monitoring period	**Benthic monitoring** (between 1 January and 31 March)	**Water column monitoring** (July to June)	**Marine mammals and seabirds**	**Report due for submission to Environment Southland by**
Monitoring to 30 June 2020	1 annual survey	12 monthly surveys	Reporting of interactions/ entanglements in monitoring period	30 September 2020
1 July 2020 to 30 June 2021	1 annual survey	12 monthly surveys		30 September 2021
1 July 2021 to 30 June 2022	1 annual survey	12 monthly surveys		30 September 2022
1 July 2022 to 30 June 2023	1 annual survey	12 monthly surveys		30 September 2023
1 July 2023 to 30 June 2024**	1 annual survey	12 monthly surveys		30 September 2024
1 July 2024 to 30 June 2025	1 annual survey	12 monthly surveys		30 September 2025

** In addition to the standard requirements, the monitoring report shall address the following objectives:

(1) Propose benthic enrichment levels descriptors for describing sediment recovery (see section 3.7)

(2) Review the efficacy of monitoring undertaken under this consent to inform subsequent consent applications.

3 Benthic monitoring

3.1 Overview of benthic monitoring process

An overview of the benthic monitoring process is provided in **Figure 3**. All components of the decision tree are explained in this section.

3.2 Frequency and timing of benthic monitoring surveys

Benthic monitoring shall be conducted annually in mid to late summer (between 1 January and 31 March), representing the period of anticipated maximum biological impact. This is in accordance with national and international best practice (Keeley et al., 2015). An overview of benthic monitoring timeframes is provided in **Table 1**.

3.3 Benthic monitoring sites

The placement of benthic monitoring sites reflects the approach taken in the best management practice guidelines for salmon farms in the Marlborough Sounds (Keeley et al. 2015). Monitoring sites represent zones of varying intensity of organic enrichment, including the zone of maximum likely impacts (within 10 m of farm edge), an outer zone of reduced effects (50 m from farm edge), a distance that is estimated to represent the outer limit of effects (100 m from farm edge), and control sites (**Figure 2**).

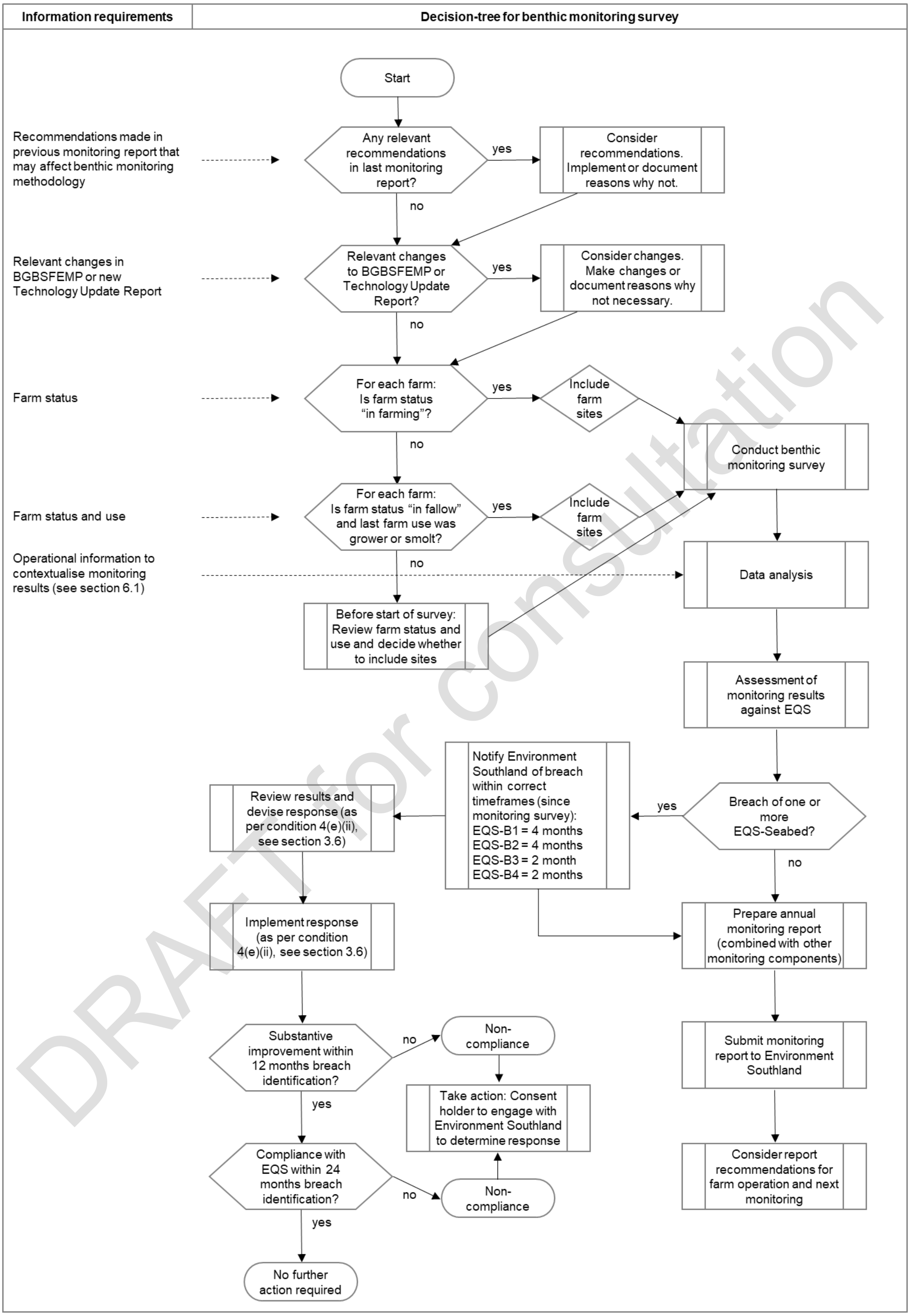

Figure 3. Overview of the benthic monitoring process, including information requirements and a decision-tree of benthic monitoring, analysis, reporting, assessing against EQS-Seabed and response to potential breaches of EQS-Seabed.

Table 2. Identification of farms to be included in annual benthic monitoring survey.

Farm status at time of annual benthic monitoring	Farm use (current or, if in fallow, during last farming)	Monitoring required?
In farming	Grower	Yes
	Smolt	Yes
	Brood	Yes
In fallow	Grower	Yes (in years 1, 3 and 5 of fallowing)
	Smolt	Yes (in years 1, 3 and 5 of fallowing)
	Brood	No

Monitoring aims to assess the effects of farms in operation and sediment recovery during fallowing. Monitoring must be conducted at those monitoring sites shown in **Figure 2** that are associated with farms that are “in farming” at the time of annual monitoring as well as smolt and grower farms that are “in fallow” at the time of annual monitoring (**Table 2**). Farms in fallow only require benthic monitoring every alternate year, in years 1, 3 and 5 of fallowing and for the short period of the existing consent this would be carried out at one smolt and one grow farm. As farms used for brood stock have very low densities and biomass, they do not require monitoring during fallowing.

The nature of salmon farming operations in Big Glory Bay means that farm layout, status and use change over time. This is explained in detail in the Big Glory Bay Salmon Farm Environmental Management Plan (“BGBSFEMP”). To ensure benthic monitoring is conducted at the correct locations, farm status and use need to be confirmed with the consent holder prior to commencement of monitoring. GPS coordinates of actual sites monitored must be recorded during each benthic monitoring survey.

3.4 Parameters to be measured, sampling and sample analysis methodology

Parameters to be measured at all benthic monitoring sites are shown in **Table 3**. Samples must be collected, processed and stored appropriately to avoid introduction of errors or bias. Sample analysis methodologies must be appropriate to assess monitoring results against the EQS listed in **Table 6**, including appropriate detection limits.

Descriptions of methodologies for the collection and analysis of benthic samples is provided in **Table 3**. Alternative methodologies may be appropriate providing they allow direct comparison to previous monitoring results. Care must be taken not to change methodologies that create limitations for the assessment of change over time or for meeting monitoring objectives. The process for making and documenting changes to monitoring methodologies is described in section 7.

Table 3. Sediment parameters to be measured and description of methodologies for sample collection and analyses.

Parameter to be measured	Description of methodology
Parameters measured from sediment samples Requires sediment samples collected by SCUBA divers or from grab samples. The size of each core or grab must be enough to allow for required sub-sampling as specified for parameters below. Each replicate sample for analysis of parameters listed below must be collected from a separate sediment sample (collected sample or grab).	
Infauna	Collect a 130 mm diameter and 100 mm deep sediment core and preserve all animals that are retained on a 0.5 mm sieve for taxonomic analysis. The taxa should be identified and counted by suitably qualified staff using standard methods. Infauna community indices to be calculated are shown in Appendix 1. If any benthic sample contains a large number of mussel shells or the grab is prevented from closing due to the presence of mussel shells, the sample shall be retaken. In the event that three grab samples at any one location all contain a large number of mussel shells or the grab is prevented from closing due to the presence of mussel shells the sampling location shall be relocated approximately 10 metres distant. In any assessment under this condition, the effects of mussel shell substrate on benthic communities are to be ignored. Number of replicates: 5 (1 per grab)
Grain size	Collect a 60-80 mm diameter and 5 cm deep sediment core. Transfer into containers and cool until laboratory analysis of particle grain size into at least three fractions (< 63 µm, 63–2000 µm and > 2000 µm) as follows. • Fraction >/= 2 mm: Wet sieving with dispersant, 2.00 mm sieve, gravimetry • Fraction < 2 mm, >/= 63 µm: Wet sieving using dispersant, 2.00 mm and 63 µm sieves, gravimetry (calculation by difference) • Fraction < 63 µm: Wet sieving with dispersant, 63 µm sieve, gravimetry (calculation by difference) Number of replicates: 3
Total organic matter (TOM)	Collect a 60-80 mm diameter and 5 cm deep sediment core. Transfer into containers and cool until laboratory analysis. Laboratory method: • Air dried at 35°C and sieved, <2mm fraction • Ignition in muffle furnace 550°C, 6hr, gravimetric. APHA 2540 G 22nd ed. 2012 • Calculation: 100 - Ash (dry wt) Number of replicates: 3
Total organic carbon (TOC)	Collect a 60-80 mm diameter and 5 cm deep sediment core. Transfer into containers and cool until laboratory analysis. Laboratory method: • Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser] Number of replicates: 3

Table 3. contd.

Parameter to be measured	Description of methodology
Sediment copper and zinc	Collect a 60-80 mm diameter and 5 cm deep sediment core. Transfer into containers and cool until laboratory analysis. Laboratory method: • Air dried at 35°C and sieved, <2mm fraction • Total Recoverable digestion • Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, trace level. US EPA 200.2 Number of replicates: 3
Appearance of sulphide depth and general colour, depth of redox layer	Collect a 60-80 mm diameter and at least 100 mm deep sediment core in a clear core tube. Photograph core and record: • observations of sediment colour and any odour; • any evidence of a redox potential discontinuity (RPD) denoted by black colour demarcation and the depth from the surface at which this occurs; and • sulphide odour detection. Number of replicates: 3
Redox potential	Measure redox potential (Eh_{NHE}, mV) with an electronic meter, directly from the samples (at 1 cm depth)
Hydrogen sulphide	Collect three replicate 5 mL samples from the upper 2 cm of the sediment, analyse on shore or send overnight to laboratory for analyses or other method as appropriate.
Parameters measured from imagery of the sediment surface Requires video footage, still images taken from video footage or photos (for example via drop camera or ROV) as appropriate for qualitative assessment methods described below using best efforts if high turbidity and low visibility.	
Epifauna	Take three photos (or stills taken from video footage), at least 1 m apart. Each image must show at least 0.15 m^2 of the sediment surface with each side being no shorter than 35 cm. When analysing images record the presence of visible epifauna. Also, record the presence of other seabed features, such as burrows and holes made by seabed-dwelling organisms, and shell debris. Results are likely to be descriptive, but statistical analysis may be possible if enough numbers of epifauna are observed.
Bacteria mats (*Beggiatoa* spp.)	Take three photos (or stills taken from video footage), at least 1 m apart. Each image must show at least 0.15 m^2 of the sediment surface with each side being no shorter than 35 cm. Record scores obtained from applying the qualitative bacterial coverage classification shown in **Table 5**.
Parameters measured from diver observation or real-time video footage Requires diver observation or real-time video footage as appropriate for qualitative assessment methods described below.	
Hydrogen sulphide (H_2S) or methane outgassing	Assessment is made from diver observations of the sediment surface or from real-time video footage of the seabed. Assessment requires repeated physical contact with seabed to assess disturbance, e.g. with camera or frame.

	Record scores obtained from applying the qualitative outgassing classification shown in **Table 4**.

Table 4. Qualitative outgassing classification from Keeley et al (2015).

Outgassing classification	Description	Score
None	No outgassing observed.	0
Minor	Minor or suspected outgassing. Not obvious.	1
On disturbance	Clear outgassing on disturbance of seabed.	2
Spontaneous	Clear outgassing occurring freely without disturbance. Bubbles obvious on surface around net pens (evident in calm conditions)	3

Table 5. Qualitative bacterial coverage classification. Modified from Keeley et al (2015).

Bacterial coverage classification	Description	Score
None (natural)	No bacterial matter observed, sediment appear natural/healthy.	0
Trace	Traces of bacterial mat (*Beggiatoa* spp.) within sediments or attached to edges of cobbles or shells.	1
Patchy-minor	Obvious patches of bacterial mat (Beggiatoa spp.) on sediment surface, occupying <=50% of surface area.	2
Patchy-major	Obvious patches of bacterial mat (Beggiatoa sp.) on sediment surface, occupying >50% of surface area.	3
Mat	White mat of bacterial mat (Beggiatoa sp.) smothering sediment surface (>90% coverage).	4
None	Bacterial mat absent but sediments black, highly anaerobic and likely azoic. Very strong sulfide odours.	5*

* Image assessment can only generate an indicative score. Additional parameters (see description) must be evaluated before score can be confirmed.

3.5 Data analysis and assessment of effects

Statistical analyses must be suitable for a robust assessment of monitoring results against EQS and monitoring objectives. Data analysis must include appropriate comparison to previous monitoring results. Any relevant assumptions, limitations and uncertainties must be described within the context of the monitoring results.

To assist in the assessment of benthic effects of monitored farms, the following operational information must be provided for the grower, smolt and brood farms and used to contextualise monitoring results:

- Site layout of farm, including number of pens
- Use of farm at the time of monitoring

- Stocking densities (if currently in farming)
- Start of farming (if currently in farming)
- Start of fallowing (if currently in fallow)

Table 6. Environmental quality standards (EQS) for the seabed, parameters to be measured, assessed and reporting on, with response requirements in the event of a EQS breach.

EQS ID	EQS	Parameter to be measured for assessment	How to assess monitoring results against EQS	Maximum time delay between monitoring survey and notifying Environment Southland of a potential breach	Reason for delay in notification of a potential breach	Response
EQS-B1	The benthic infauna community retains a diversity and abundance of marine taxa (other than opportunistic species such as Capitellid and Dorvillea worms, and nematodes) at levels which allow for sufficient seabed recovery to support a farm rotation cycle with a fallowing period of not less than 5 years.	Infauna	Apply expert assessment to compare the infauna community monitoring results from farms in farming and those in fallowing to the stages of seabed degradation and recovery for salmon farm sites in Big Glory Bay shown in **Table 8**. Expert assessment on whether fallowing facilitates seabed recovery as per EQS.	Within 4 months of monitoring survey	Requires sorting and identification of infauna and data analysis	Tier 2
EQS-B2	No more than 20% of the not less than 5 replicate cores collected have no taxa present (azoic).	Infauna	Calculate percentage of replicate cores that have no taxa present. If more than 20% are azoic, the EQS is breached.	Within 4 months of monitoring survey	Requires sorting and identification of infauna but data analysis less complex than for EQS-B1	Tier 2
EQS-B3	No obvious, spontaneous out-gassing (H_2S/methane)	Hydrogen sulphide (H_2S) or methane outgassing	Use the qualitative outgassing classification (**Table 4**). Any score of 3 indicates an EQS breach.	Within 2 month of monitoring survey	Observed in real-time so minimal time delay	Tier 2
EQS-B4	Bacteria mat (*Beggiatoa* spp.) coverage not greater than 50% of the sampled area.	Bacteria mats (*Beggiatoa* spp.)	Use the qualitative bacterial coverage classification (**Table 5**). Any confirmed score of 3 or higher indicates an EQS breach.	Within 2 months of monitoring survey	Requires image analysis	Tier 2

3.6 Environmental quality standards for the seabed (EQS-Seabed) and response to potential breaches

The environmental quality standards for the seabed (EQS-Seabed) as well as reporting and response requirements are listed in **Table 6**.

All EQS-seabed require a Tier 2 response. As per condition of consent 4(e)(ii) this:

> *shall require reduced stocking and/or fallowing of the marine farm following the next harvest of salmon on that farm to achieve full compliance with the […] EQS-seabed within 24 months of the date the consent holder receives confirmed notice of such a EQS result through its monitoring. A substantive improvement within 12 months of that date is required.*

As per BGBSFEMP, farm management is responsible for taking actions in response to potential breaches of any EQS. Response actions include:

- Environment Southland shall be notified of the monitoring result; and
- The monitoring results shall be reviewed by the consent holder in consultation with a suitable qualified and experienced benthic science expert and an appropriate management response shall be devised and implemented. The objective of the management response shall be to as soon as practicable achieve compliance with the relevant EQS.
- Management actions may include, but are not limited to:
    - shifting the farm to another consented area, i.e. in less than 2-year rotation;
    - reducing fish numbers by harvesting more;
    - adapting the feeding regime or feed type; and/or
    - fallowing the site longer.

3.7 Additional monitoring objectives

In addition to assessing compliance with the EQS listed in section 3.6, this monitoring programme aims to:

- Track sediment copper and zinc concentrations over time to evaluate the level of decline of the legacy metal accumulation
- Ensure that salmon farms are managed so that 100 m from the farm edge, the chemical, physical and biological quality of Big Glory Bay sediments is within the natural variation of reference conditions.
- Improve understanding of seabed recovery during fallowing (also see section 3.8)

In order to achieve these aims, monitoring results will be used to assess progress on the objectives listed in **Table 7**.

Table 7. Additional seabed monitoring objectives, parameters to be measured and approach, for measuring progress on objectives.

Additional monitoring objective	Parameter(s) to be measured for this objective	Approach for measuring progress on objective
Over time, copper and zinc in sediments at 10 m from farm edges are expected to satisfy ANZECC ISQG values (copper: ISQG-Low = 65 mg/kg, ISQG-High = 270 mg/kg; zinc: ISQG-Low = 200 mg/kg, ISQG-High = 410 mg/kg).	Sediment copper and zinc (all benthic monitoring sites)	Assess trends at sites located 10 m from farm edges for comparison to environmental objective. Assess change over time at other sites to provide bay-wide context.
Manage salmon farms so that 100 m from the farm edge the chemical, physical and biological quality of Big Glory Bay sediments is within the natural variation of reference conditions.	Grain size, total organic matter (TOM), total organic carbon (TOC), appearance of sulphide depth and general colour, depth of redox layer, epifauna, benthic infauna (at 100 m and reference)	As a minimum, analyse for: • (statistically significant) differences between sites outside the immediate surrounds of salmon farms (100 m from edge of pens) and reference sites • (statistically significant) differences to previous monitoring results Expert assessment: • whether any statistically significant differences can be attributed to adverse effects of farm operations; • whether monitoring indicates unforeseen environmental effects that may compromise the objective of maintaining the environmental quality so that Big Glory Bay can continue to support a thriving aquaculture industry; and • whether to recommend a response or make recommendations as provided for in the conditions of consent.
Improve understanding of seabed recovery during fallowing	Infauna and sediment physical-chemical and biological parameters	By the time of consent expiry, develop a site-specific characterisation of seabed degradation and recovery through application of monitoring data to the interim characterisation described in section 3.8.

3.8 Sediment organic enrichment and recovery

3.8.1 Background

The general response of biological and physical-chemical sediment parameters to organic enrichment is relatively well understood. One of the most prominent studies has been conducted by Pearson and Rosenberg (1978) who identified a series of macrobenthic successional stages in relation to an increasing organic enrichment gradient. Many subsequent studies have compared the infaunal categories defined by Pearson and Rosenberg to other physical-chemical and biological parameters. While the general relationship between the chemical status of the sediment and the infaunal community structure can be relatively well described, there are location-specific differences in these relationships that need to be understood before quantitative or qualitative categories of organic enrichment can be developed for a specific monitoring plan for Big Glory Bay.

For example, research in Tasmania has suggested that the correlation levels between physical-chemical and biological parameters indicated in northern hemisphere studies may not be applicable to temperate Australian waters (Macleod and Forbes, 2004).

Most studies have focused on describing changes in sediments in response to organic enrichment and much less have examined the recovery of sediments once enrichment has ceased. As for the enrichment process, the rate of recovery is influenced by the prevailing environmental conditions and therefore requires site-specific assessment. In the aquaculture context, farm management aspects (including pen size, stocking density/biomass, feed input and timing/duration of farming and fallowing periods) will also be critical factors in determining regeneration (Macleod and Forbes, 2004).

Fallowing is a critical aspect of salmon farm management in Big Glory Bay. This is reinforced in the conditions of consent by the following EQS:

> *The benthic infauna community retains a diversity and abundance of marine taxa (other than opportunistic species such as Capitellid and Dorvillea worms, and nematodes) at levels which allow for sufficient seabed recovery to support a farm rotation cycle with a fallowing period of not less than 5 years.*

3.8.2 Development of a site-specific characterisation of seabed degradation and recovery for Big Glory Bay

This EMP aims to develop, over time, a robust understanding of seabed recovery during fallowing in Big Glory Bay and to evaluate the level of recovery necessary for sustainable salmon farm operation that does not result in progressive deterioration of the seabed.

The approach taken can be divided into three phases:

Phase 1: Development of an interim characterisation of seabed degradation and recovery based on information in Macleod and Forbes (2004) and Keeley et al (2015) that is specific to Big Glory Bay.

Phase 2: Gathering of site-specific data through benthic monitoring described in this EMP.

Phase 3: Development of a site-specific characterisation of seabed degradation and recovery through application of monitoring data to the interim characterisation.

This information will be used to inform any changes to the 'farming and fallowing' plan.

3.8.3 Interim characterisation of seabed degradation and regeneration

Macleod and Forbes (2004) describe nine stages of seabed degradation and recovery (**Figure 4**). Similar stages of degradation have been described by Keeley et al (2015) for the seven enrichment stages used to describe the level of benthic effects of salmon farms in the Marlborough Sounds.

The interim characterisation of seabed degradation and recovery for salmon farm sites in Big Glory Bay is shown in **Table 8**. It uses the stage numbering of Macleod and Forbes (2004) and was developed by combining the stage descriptors of Macleod and Forbes (2004) and Kelley et al (2015).

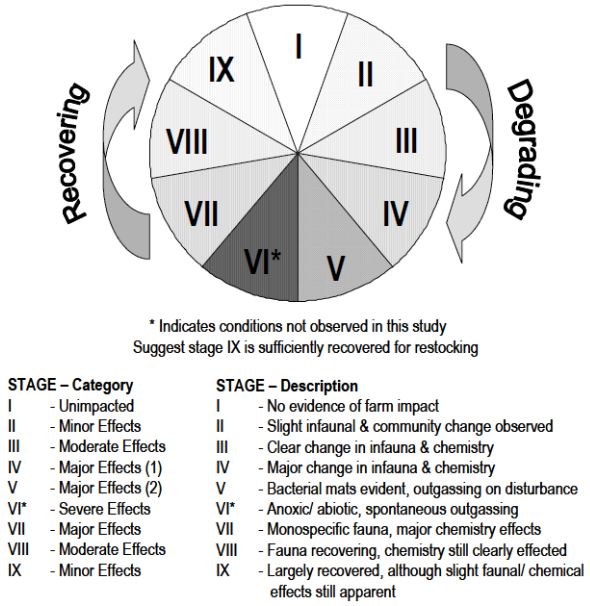

Figure 4. Nine stages of seabed degradation and regeneration used to inform the interim characterisation of seabed degradation and regeneration. Source: Macleod and Forbes (2004).

Table 8. Interim characterisation of seabed degradation and recovery for salmon farm sites in Big Glory Bay.

	Stage	Description of biological and physical-chemical parameters
No effect	I	No evidence of adverse farm impact. Species known to indicate unimpacted sites are present. Environmental variables comparable to an un-enriched reference site.
Degrading	II	Larger, long lived species and species known to indicate unimpacted sites are absent. Diversity may be greater than pristine (zone of enhancement).
	III	Rapid change in community mix; deposit feeding polychaetes / opportunists dominate. Filter / suspension feeders absent.
	IV	Opportunists (especially Capitellids) characterise community.
	V	Infaunal opportunists (especially Capitellids) dominate. Polychaetes are highly dominant.
Maximum effect	VI	No fauna. Sediments and bottom waters are anoxic
Recovering	VII	Opportunists (Capitellids) still dominate but numbers are decreasing and other species are colonising
	VIII	Transitional species prevalent. Notable increase in epibenthic opportunists
	IX	Diversification of community but absence of climax / long lived species
No effect	I	No evidence of adverse farm impact. Species known to indicate unimpacted sites are present. Environmental variables comparable to an un-enriched reference site.

3.8.4 Relevance to the assessment of benthic monitoring results against EQS

The two EQS assessing salmon farm effects on infauna, can be directly related to this characterisation of seabed degradation and recovery:

EQS-B1: "The benthic infauna community retains a diversity and abundance of marine taxa (other than opportunistic species such as Capitellid and Dorvillea worms, and nematodes) at levels which allow for sufficient seabed recovery to support a farm rotation cycle with a fallowing period of not less than 5 years".

Relevance: EQS-B1 represents the process of degradation and recovery. In order to assess benthic monitoring results against this EQS, monitoring needs to demonstrate that the characteristics of the seabed within 10 m of the farm edge transition through the recovery stages before farming is recommenced. It is important to note that the EQS does not require the seabed to reach Stage I prior to recommencing of farming but a level which allows "for sufficient seabed recovery to support a farm rotation cycle with a fallowing period of not less than 5 years". Identifying what exactly this means for the seabed in Big Glory Bay will be a core task in phase 3 (refer to section 3.8.2).

EQS-B2: "No more than 20% of the not less than 5 replicate cores collected have no taxa present (azoic)".

Relevance: EQS-B2 represents Stage VI, the highest level of impact. The EQS ensures that farming discontinues or only continues at reduced intensity if there are early indications (20% of cores at this stage) that this high level of enrichment is approached.

4 Water column monitoring

4.1 Overview of water column monitoring process

An overview of the water column monitoring process is provided in **Figure 5**. All components of the decision tree are explained in this section.

4.2 Frequency and timing of water column monitoring

Water column monitoring shall be conducted monthly, at approximately equal times of the month (i.e. at the beginning, mid or end of the month). The state of the tide does not need to be standardised but must be recorded. An overview of water column monitoring timeframes is provided in **Table 1**.

4.3 Water column monitoring sites

Water column monitoring sites are located at a distance that is estimated to represent the outer limit of effects (250 m from farm edge) and reference sites inside and outside of Big Glory Bay (**Figure 2**). Samples must be collected from all monitoring sites shown in **Figure 2**, independent of farm status or use.

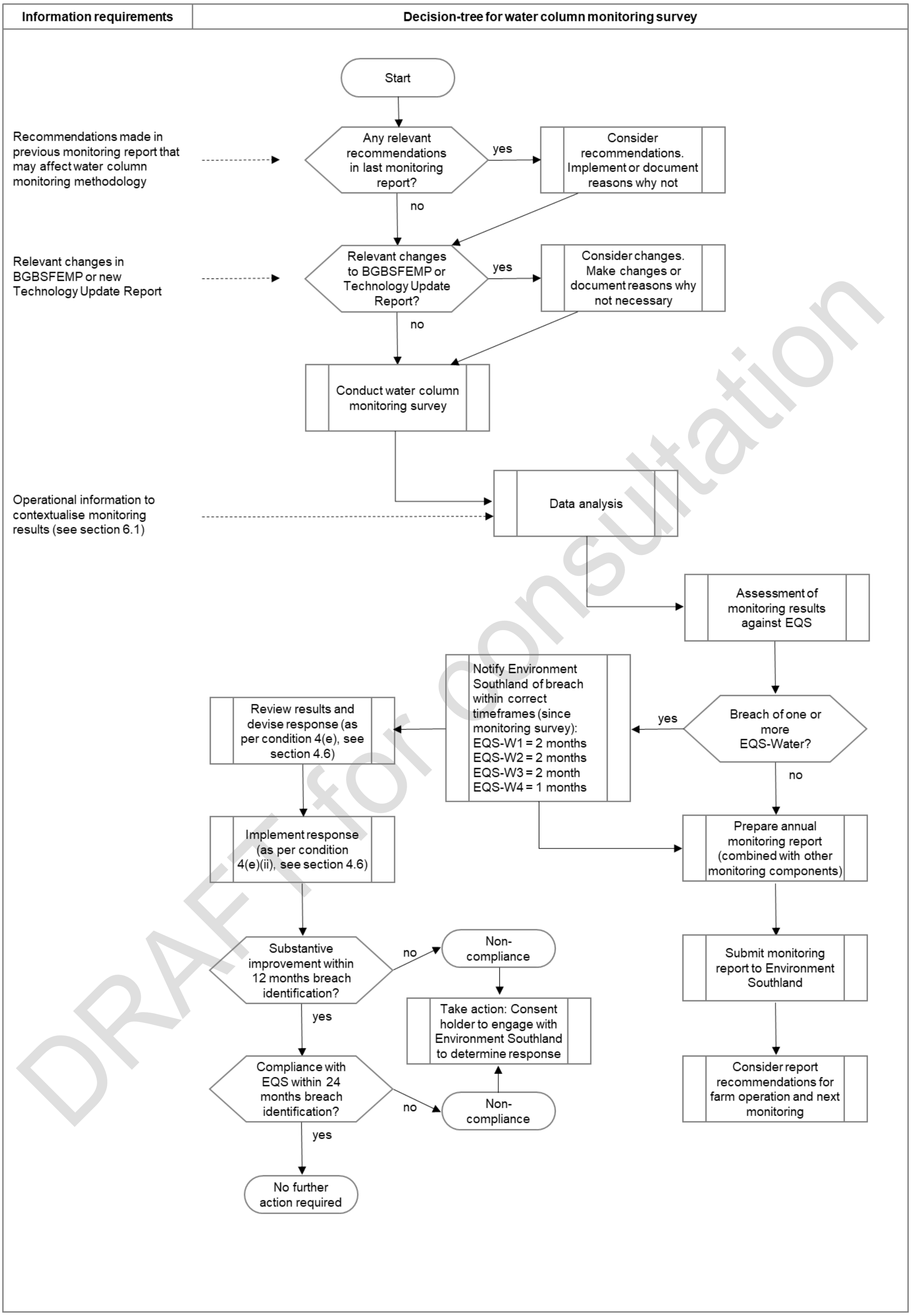

Figure 5. Overview of the water column monitoring process, including information requirements and a decision-tree of water column monitoring, analysis, reporting, assessing against EQS-Water and response to potential breaches of EQS-Water.

Table 9. Water column parameters to be measured and description of methodologies for sample collection and analyses.

Parameter to be measured	Description of methodology
Parameters measured from water column samples Water column samples are to be collected from a depth of 5 m using a Van Dorn sampler. Sample volume and number of samples collected must be enough to allow for required sub-sampling and analyses for parameters below. Sampling can be conducted by a trained staff member of the consent holder. Samples must be collected, processed, stored and transported as required for analysis of parameters listed below. Samples should be filtered on site or, if this is not possible, chilled overnight and processed the next day. No replicates are required. For quality assurance it is suggested that occasional duplicate samples are collected and analysed.	
Chlorophyll *a*	Filter promptly on receipt of sample Acetone extraction. Spectroscopy. APHA 10200 H, fluorimetry
Total ammonia nitrogen (NH_4^+ + NH_3)	Sample filtration through 0.45µm membrane filter on day of receipt Phenol/hypochlorite colorimetry. Flow injection analyser. APHA 4500-NH3 H
Nitrite nitrogen (NO_2)	Sample filtration through 0.45µm membrane filter. Automated Azo dye colorimetry. Flow injection analyser. APHA 4500-NO3 I
Nitrate nitrogen (NO_3)	Sample filtration through 0.45µm membrane filter Analyse for nitrate nitrogen + nitrite nitrogen: Filter sample on day of receipt Total oxidised nitrogen. Automated cadmium reduction. Flow injection analyser. APHA 4500-NO3 I Calculate nitrate nitrogen: (Nitrate-N + Nitrite-N) - NO2N
Total nitrogen (TN)	Sample filtration through 0.45µm membrane filter Analyse for Total Kjeldahl Nitrogen (TKN): Total Kjeldahl digestion (sulphuric acid digestion, copper sulphate catalyst) Phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-Norg D. (modified) 4500 NH3 F Calculate total nitrogen: TKN + Nitrate-N + Nitrite-N.
Total phosphorus (TP)	Sample filtration through 0.45µm membrane filter Total phosphorus digestion (Acid persulphate digestion) Ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E
Dissolved reactive phosphorus (DRP)	Sample filtration through 0.45µm membrane filter Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G
Salinity	Conductivity Meter (WTW Cond 340i with nonlinear temperature compensation according to EN 27 888). APHA 2520 B
Parameters measured on site using a hand-held probe or other device Temperature and dissolved oxygen levels are to be measured at 2-m depth intervals starting at 1 m from the surface until 21 m. The depth of 21m is near the seabed at most sites (maximum depth in BGB is about 26 m).	
Temperature	YSI O_2 probe (or alternative probe)
Dissolved oxygen (DO)	YSI O_2 probe (or alternative probe)
Water clarity	Measure using a Secchi disk. The disc is lowered slowly down in the water and the depth at which the pattern on the disk is no longer visible is taken as a measure of the transparency of the water. Note: secchi depth is related to water turbidity but cannot be directly compared to other measures of turbidity. Caution is required if a change in methodology is considered.

4.4 Parameters to be measured, sampling and sample analysis methodology

Parameters to be measured at all water column monitoring sites are shown in **Table 9**. Samples must be collected, processed and stored appropriately to avoid introduction of errors or bias. Sample analysis methodologies must be appropriate to assess monitoring results against the EQS listed in **Table 10**, including appropriate detection limits.

Descriptions of methodologies for the collection and analysis of benthic samples is provided in **Table 9**. Alternative methodologies may be appropriate providing they allow direct comparison to previous monitoring results. Care must be taken not to change methodologies that create limitations for the assessment of change over time or for meeting monitoring objectives. The process for making and documenting changes to monitoring methodologies is described in section 7.

4.5 Data analysis and assessment of effects

Statistical analyses must be suitable for a robust assessment of monitoring results against EQS and monitoring objectives. Data analysis must include appropriate comparison to previous monitoring results. Any relevant assumptions, limitations and uncertainties must be described within the context of the monitoring results.

To assist in the assessment of water column effects of monitored farms, the following operational information must be provided for each farm and used to contextualise monitoring results:

- Site layout of farm, including number of pens
- Use of farm at the time of monitoring
- Stocking densities (if currently in farming)
- Start of farming (if currently in farming)
- Start of fallowing (if currently in fallowing)

4.6 Environmental quality standards for the water column (EQS-Water) and response to potential breaches

The environmental quality standards for the water column (EQS-Water) as well as reporting and response requirements are listed in **Table 10**.

EQS-Water require a Tier 1 or Tier 2 response. These responses are described in condition of consent 4(e):

(i) Tier one: a breach of Condition 4(c)(ii) shall trigger further water quality monitoring, consideration of the wider environment, and investigations aimed to determine any contributing effect from farm operations on chlorophyll *a* levels. Where relevant, this Tier one response shall also include the consideration of, and planning for, future management responses to avoid further breaches.

(ii) Tier two: a breach of any of the Tier two standards (Conditions 4 (c)(i), (iii) and(iv); and 4(d)) shall require reduced stocking and/or fallowing of the marine farm following the next harvest of salmon on that farm to achieve full compliance with the EQS-water […] within 24 months of the date the consent holder receives confirmed notice of such a EQS result through its monitoring. A substantive improvement within 12 months of that date is required.

As per Big Glory Bay Environmental Farm Management Plan, farm management is responsible for taking actions in response to potential breaches of any EQS. Response actions include:

- Environment Southland shall be notified of the monitoring result; and
- The monitoring results shall be reviewed by the consent holder in consultation with a suitable qualified and experienced benthic science expert and an appropriate management response shall be devised and implemented. The objective of the management response shall be to as soon as practicable achieve compliance with the relevant EQS.
- Management actions may include, but are not limited to:
    - Reducing stocking density and/or fish numbers;
    - Reducing or adapting feed inputs; and
    - Move the farm operation to a higher flow consented site.

Table 10. Environmental quality standards (EQS) for the water column, parameters to be measured and assessed and reporting and response requirements for potential EQS breaches.

EQS ID	EQS	Parameter to be measured for assessment	How to assess monitoring results against EQS	Maximum time delay between monitoring survey and notifying Environment Southland of a potential breach	Reason for delay in notification of a potential breach	Response
EQS-W1	The monthly median concentrations of chlorophyll *a* in the water column within Big Glory Bay (monthly median from a data set of all monitoring sites) shall not be greater than 3.5 µg/l for three consecutive months.	Chlorophyll *a*	Calculate as per EQS and assess if EQS is met.	Within 2 months of third consecutive monitoring survey	Requires laboratory analysis of samples and comparison of three consecutive monitoring surveys.	Tier 1
EQS-W2	For three consecutive months, the concentration of chlorophyll *a* in the water column (monthly median at any sampling site within Big Glory Bay) shall not exceed 5 µg/L: a. at two or more sites for two of those three consecutive months; and b. at one or more sites for one of those three consecutive months.	Chlorophyll *a*	Calculate as per EQS and assess if EQS is met.	Within 2 months of third consecutive monitoring survey	Requires laboratory analysis of samples and comparison of three consecutive monitoring surveys.	Tier 2
EQS-W3	No increase in the average monthly excess total ammonia nitrogen in Big Glory Bay of more than 30 µg/L at the surface of the water column, when compared with baseline data from the same or comparable sampling sites from the period July 2015 to December 2017.	Total ammonia nitrogen	Calculate as per EQS and assess if EQS is met.	Within 2 months of monitoring survey	Requires laboratory analysis of samples and comparison to historic monitoring results.	Tier 2
EQS-W4	The dissolved oxygen saturation in the water column at any sampling point more than 250 metres from the farm shall not fall below 70% for three consecutive months (measured using 1 metre bins to 2 metres from the seabed).	Dissolved oxygen	Calculate as per EQS and assess if EQS is met.	Within 1 month of third consecutive monitoring survey	Measured on site so no delay due to laboratory analysis. Requires comparison of three consecutive monitoring surveys.	Tier 2

4.7 Additional monitoring objectives

In addition to assessing compliance with the EQS listed in section 4.6, this monitoring programme aims to:

- Ensure that salmon farms are managed so that 250 m from the farm edge, the water quality of Big Glory Bay is within the natural variation for the location and time of the year.

In order to achieve these aims, monitoring results will be used to assess progress on the objectives as shown in **Table 11**.

Table 11. Additional water column monitoring objectives, parameters to be measured and approach, for measuring progress on objectives.

Additional monitoring objective	Parameter(s) to be measured for this objective	Approach for measuring progress on objective
Manage salmon farms so that 250 m from the farm edge, the water quality of Big Glory Bay is within natural variation for the location and time of the year.	NO_3, NO_2, DRP, TN and TP, water clarity	As a minimum, analyse for: • (statistically significant) differences between sites outside the immediate surrounds of salmon farms (250 m from edge of pens) and reference sites • (statistically significant) differences to previous monitoring results (where comparisons are meaningful) Expert assessment: • whether any statistically significant differences can be attributed to adverse effects of farm operations; • whether monitoring indicates unforeseen environmental effects that may compromise the objective of maintaining the environmental quality so that Big Glory Bay can continue to support a thriving aquaculture industry; and • whether to recommend a response or make recommendations as provided for in the conditions of consent.
Track phytoplankton community composition over time and enable identification of changes to composition during potential algal blooms.	Phytoplankton community composition (at least for control sites in and outside the Bay)	Describe phytoplankton community composition over time and identify changes during observed algal blooms.

5 Marine mammals

The procedures and practices implemented to minimise, to the extent practicable, the interactions of marine mammals and seabirds with the farm site are described in the BGBSFEMP. The key measures put into place are:

- The Entanglement Avoidance Protocol,
- Shark Management Protocol; and
- Seabird Entanglement and Management Plan.

The annual monitoring report shall include reports of interactions with or entanglements of marine mammals, and seabird mortalities. Records of all entanglement incidents regardless of outcome (e.g. injury or mortality) shall include the date, description of the event, outcome of the event (e.g. type of injury, mortality), cause of the incident (if this can be established) and steps taken (if any) to reduce the risk of subsequent events.

6 Reporting

6.1 Farm operational information

In addition to the monitoring requirements, the information listed in **Table 12** must be recorded by the consent holder and used to inform interpretation of monitoring results and included in the annual monitoring report.

Table 12. Information to be recorded in annual monitoring report.

Information to be recorded	**Recording and reporting format**	**Reason**
Site layout of farms, including number of pens	Maps and GPS coordinates of farm corners	Contextual information to confirm adequacy of monitoring site locations
Use of farms at the time of monitoring	Tabular	Contextual information to confirm correct monitoring site selection and for assessment of effects
Start of farming (if currently in farming)	Tabular	Contextual information for assessment of effects
Start of fallowing and previous use (if currently in fallowing)	Tabular	Contextual information to confirm correct monitoring site selection and for assessment of effects
Stocking densities (if currently in farming)	Tabular	Contextual information for assessment of effects
N input from feed	Tabular showing nitrogen input from feed: • By farm; and • By month	Required to assess compliance with consented limits for total nitrogen input from feed (all farms) and allowable individual nitrogen input (for each farm). Also provides contextual information for monitoring results.

6.2 Annual monitoring report

The annual monitoring report shall reflect all monitoring and reporting requirements described in this EMP. The overall aim is to ensure that the annual monitoring report is a succinct, well-structured document that demonstrates compliance with the requirements of the EMP, facilitates easy understanding of monitoring results and clear assessment of compliance with conditions of consent and, over time, demonstrates an increased understanding of the environmental effects of salmon farming and sediment regeneration during fallowing and is useful to inform future changes.

The annual monitoring report shall include as a minimum:

- A general and farm site-specific account of any recommendations made in the previous monitoring report, what changes have been made in response to recommendations and, if recommendations were not implemented, the reasons why no changes were made;
- A description of any changes made to the monitoring approach since the previous monitoring survey in response to potential changes in the Big Glory Bay Salmon Farm Environmental Management Plan ("BGBSFEMP") or in response to a new Technology Update Report;
- Mapped monitoring sites (including GPS coordinates of actual locations);
- Description of methodologies;
- Description of monitoring results and required information;
- A clear comparison of monitoring results with Environmental Quality Standards (EQS);
- A comparison with the results of previous monitoring at the same salmon farm site (starting with the second report prepared under this consent);
- Identification of any potential environmentally significant monitoring trends, at both the site and Big Glory Bay scales;
- Identification of any proposed additional monitoring, including the rationale for it, and the proposed scale, extent and timeframes involved;
- An evaluation of the potential implications of the monitoring results from all salmon farming operations undertaken in Big Glory Bay by the consent holder on the environmental quality of Big Glory Bay;
- The extent to which the monitoring results indicate that farming practices may need to be adapted in order to address unforeseen environmental effects indicated by the monitoring results; and
- A description of any difficulties encountered during the monitoring, for example logistical (such as weather related) or methodological, that will be of value to inform the review of this EMP and/or the development of subsequent monitoring programmes.

Reporting timeframes are shown in section 2.5.

7 Review and documentation of changes

It is likely that some changes will be made to this EMP. Generally it is anticipated that changes will be limited to simple adjustments of methodologies. Any deviation to the specifications in this EMP must be approved by the consent holder and Environment Southland.

To ease consistency in monitoring over time and to ensure transparency of changes made, any changes to monitoring requirements must be documented in a change schedule managed and kept up-to-date by Sanford. This is particularly helpful in case science providers change. A clear documentation of changes and reasons why they were necessary, will also support the efficacy assessment of conditions of consent related to environmental monitoring.

Due to the short duration of the current consent, no review is scheduled for this EMP. If the need for a review is raised, the review process must be approved by the consent holder and Environment Southland prior to commencement.

It should be noted that in Tasmania, and now in the Marlborough Sounds, water column monitoring is moving to broadscale sites indicative of the overall state of the area and benthic sampling significantly reduced after several years of monitoring in the Tasmania case. Such a move should, be considered for Big Glory Bay in the future once there is sufficient data under the new nitrogen cap and be part of a review process for the next consent.

8 Recommendations

Natural variability of water column parameters creates difficulties for detecting changes among sites or over time. Installing moored instrumentation to collect chlorophyll *a* and dissolved oxygen at the edge of the main ongrow farm or at control site/s would provide high-frequency data that would allow for a more accurate and timely assessment of salmon farm effects on these water quality parameters than collecting monthly discrete water column samples. While not a requirement of the conditions of consent, deploying such moored instrumentation is recommended for future consideration.

9 References

Keeley N, Gillard M, Broekhuizen N, Ford R, Schuckard R, Urlich SC (2015) Best Management Practice guidelines for salmon farms in the Marlborough Sounds: Part 1: Benthic environmental quality standards and monitoring protocol (Version 1.0 January 2015). Prepared for the Ministry for Primary Industries by the Benthic Standards Working Group. MPI Technical Paper No: 2015/01.

Mcleaod C, Forbes S (2004) Guide to the assessment of sediment condition at marine finfish farms in Tasmania. Tasmanian Aquaculture and Fisheries Institute, University of Tasmania.

Pearson TH, Rosenberg R (1978) Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanography and Marine Biology: an Annual Review. Vol.16 : 229-311.

Appendix 1: Infauna community indices

Table A1.1. Description of infauna community indices to be calculated. Source: Keeley et al (2015)

Indicator	Calculation and description	Source reference
N	Sum (n) Total infauna abundance = number of individuals per 13 cm diameter core	-
S	Count (taxa) Taxa richness = number of taxa per 13 cm diameter core	-
d	(S-1) / log N Margalef's diversity index. Ranges from 0 (very low diversity) to ~12 (very high diversity)	Margalef (1958)
J'	*H'* / log S Pielou's evenness. A measure of equitability, or how evenly the individuals are distributed among the different species. Values can range from 0.00 to 1.00, a high value indicates an even distribution and a low value indicates an uneven distribution or dominance by a few taxa.	Pielou (1966)
H'	$- \sum_i p_i \log(p_i)$ where p is the proportion of the total count arising from the *i*th species Shannon-Weiner diversity index (SWDI). A diversity index that describes, in a single number, the different types and amounts of animals present in a collection. Varies with both the number of species and the relative distribution of individual organisms among the species. The index ranges from 0 for communities containing a single species to high values for communities containing many species with each represented by a small number of individuals.	-
AMBI	= [(0 × %GI + 1.5 × %GII + 3 × %GIII + 4.5 × % GIV + 6 × %GV)]/100 where GI, GII, GIII, GIV and GV are ecological groups (see Section 2.3). Azites Marine Biotic Index: relies on the distribution of individual abundances of soft-bottom communities according to five Ecological Groups (GI-GV). GI being species sensitive to organic pollution and present under unpolluted conditions, whereas, at the other end of the spectrum, GV species are first order opportunists adapted to pronounced unbalanced situations (*i.e. Capitella capitata*). Index values are between 1 (normal) and 6 (extremely disturbed)	Borja *et al.* (2000)
M-AMBI	Uses AMBI, S and H', combined with factor analysis and discriminant analysis (see source reference). Multivariate-AMBI. Integrates the AMBI with measures of species richness and SWDI using discriminant analysis (DA) and factorial analysis (FA) techniques. Utilises reference conditions for each parameter (based on 'pristine conditions') that allows the index to be tailored to accommodate environments with different base ecological characteristics. Scores are from 1 (high ecological quality) to 0 (low ecological quality).	Muxika *et al.* (2007)
BQI	$= (\sum_{i=1}^{n}(\frac{A_i}{totA} \times ES50_{0.05i})) \times {}^{10}\log(S+1)$ Where ES50 = expected number of species as per Hurlbert (1971) And, $ES50_{0.05}$ the species tolerance value, given here as the 5th percentile of the ES50 scores for the given taxa as per Rosenberg *et al.* (2004). Benthic quality index: uses species specific tolerance scores ($ES50_{0.05}$), abundance and diversity factors. Results can range from 0 (being highly impacted) and 20 (reference conditions).	Rosenberg *et al.* (2004)

Appendix 2: Field observation sheet

TBA