Louise Walker ID: 1719
Hearing Facilitator
Marlborough Salmon Farm Relocation
Advisory Panel

RE: Review of potential light changes of relevance to King Shags from proposed salmon farming changes.

Dear Louise,

New Zealand King Salmon (NZ King Salmon) has requested a review of evidence presented by Rob Schuckard in relation to the Fourth Minute document from the Salmon Farm Relocation Advisory Panel[1], which states:

> *An issue has been raised in the powerpoint presented by Mr Schuckard in relation to a significant adverse effect on light attenuation which he asserts arises from an increased level of chlorophyll a in the water column caused by the discharges from the proposed new sites in Waitata Reach, (including those adjacent to Blowhole Point in that description). He asserted that a consequence would be a significant adverse effect on the light levels available for foraging King Shags on the seabed, to such an extent as to effectively deny to them in practical terms use of extensive areas of their foraging grounds in and adjacent to the Reach.*

My interpretation of this statement is that Mr Schuckard is concerned about the potential effects relating to additional dissolved nutrients (primarily nitrogen) released from increased salmon farm feed inputs in Pelorus Sound. His opinion is that stimulation of phytoplankton production and biomass could occur from this increased nutrient input and that phytoplankton biomass, and the associated indicator pigment chlorophyll-*a*, could increase over a wide area. Mr Schuckard asserts that King Shags are primarily visual feeders in the benthic environment and a reduction of light-at-depth caused by a chlorophyll-*a* increase could potentially reduce the foraging area available to these birds.

In addition to the information provided in the evidence of Mr Schuckard, I have also seen Dr Niall Broekhuizen's draft notes (provided to MPI) addressing this issue.

SCOPE AND EXPERIENCE/EXPERTISE RELEVANT TO THIS SUBJECT

I graduated with a BSc and PGDipSci in Physics, and an MSc in Marine Science from the University of Otago (2002). My MSc research focused on modelling and monitoring the water column environment of Doubtful Sound, Fiordland. Since joining Cawthron in 2000, I have primarily worked on aquaculture effects and water column-related research and consulting projects.

[1] Statement 3 (iii)

I previously addressed concerns regarding impacts to King Shag foraging in the NZ King Salmon Board of Inquiry (BoI) process (Knight; 2012)[2]. I am also responsible for managing and reporting on the water quality monitoring of the NZ King Salmon sites that were consented as part of the BoI process, so am familiar with the wording and obligations relating to the water quality aspects of those consents.

The evidence I give in this letter is within my expertise, unless indicated otherwise and I note that my expertise is limited to the light attenuation, water quality and water column ecology analysis aspects of Mr Schuckard's evidence (i.e. not seabird physiology or feeding behaviour aspects). I also confirm that I have read and am familiar with section 7 of the Environment Court Practice Note 2014 which relates to expert witnesses. I agree to be bound by that Code of Conduct and confirm that I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express in this document.

KEY REVIEW FINDINGS

(i) Many factors affect light attenuation in the marine environment; phytoplankton (and associated chlorophyll-*a*) is not likely to be the main driver in this system.

Data collected by Marlborough District Council (provided by Dr Niall Broekhuizen, NIWA) highlights clear differences in the light environment between the inner and outer Pelorus Sound, with much clearer water observed in the outer sound. While some differences may be related to phytoplankton populations, the primary driver for these differences appears to be other particulate material (e.g. other living and non-living matter, measured as total suspended solids). To illustrate this, Figure 1 shows a summer satellite image of the reflected light from Pelorus Sound, which highlights the effect of suspended solids from the Pelorus River on the light environment of the inner sound.

[2] Paragraphs 146 to 150.

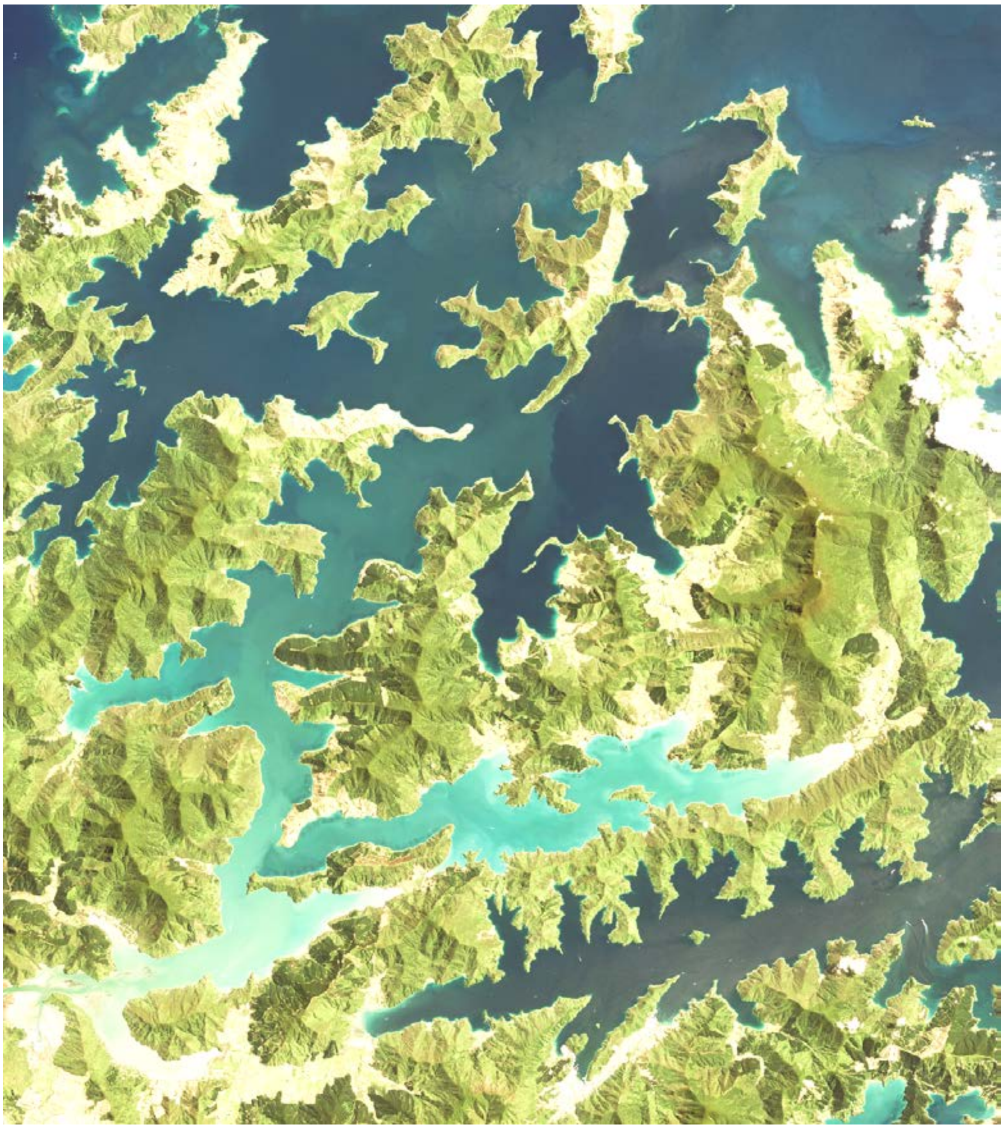

Figure 1. Quasi-true colour satellite (LandSat8) image of Pelorus Sound from 13 February 2015, showing the differences in light reflected from suspended particulate material. It appears that the suspended material is primarily sourced from the Pelorus River. As this was a period of 'normal' summer weather (not associated with flood conditions) some of the turbidity may also be a result of resuspension from wind and waves in the shallower inner areas of the sound. Image Source: USGS/NASA.

(ii) Changes in phytoplankton abundance discussed by Mr Schuckard are greater than that predicted by the modelling work by Dr Broekhuizen.

The main point Mr Schuckard makes is that a large change in chlorophyll-*a* (e.g. a doubling from 1 to 2 mg chl-*a*/m^3) could have an effect of deep feeding visual hunters, such as King Shag. He also discusses a water quality threshold level which is currently set at 3.5 mg chl-*a*/m^3 for farms granted under the BoI process. While the threshold is a practical level for instituting management actions (due to large natural variability), it seems unlikely that changes of this magnitude would be realised for extended periods of time in the main channels, where the majority of monitoring occurs. I note that phytoplankton 'blooms' of greater than 3.5 mg-chl-*a*/m^3 may occur for weeks or months in side embayments and may be common naturally occurring events in both sounds.

The modelling work undertaken by Dr Broekhuizen suggests that relatively small changes in chlorophyll-*a* (<5% increases[3]) will result from the highest proposed feed scenarios considered in Pelorus Sound (Broekhuizen and Hadfield, 2016). I was responsible for reviewing the modelling work of Dr Broekhuizen and noted many factors that could affect model accuracy. These factors are not unique to this model, and occur in any model where trade-offs in complexity are required. Nevertheless, **I still see the model as the best-available tool for predicting potential wide-scale effects of the proposal**.

A concern in my review was that the baseline scenario in Pelorus Sound, with respect to finfish farm feed inputs, was higher than present levels in the region. Using information available in the model report, I calculated what I considered a more realistic baseline. This would increase the magnitude of increases in total nitrogen concentrations from 1.67% (stated in the report) to 2.23% (i.e. an increase of about 30%[4]). In my opinion, this level of change would not substantially affect the conclusions of the modelling report. Assuming chlorophyll-*a* changes are also consistent with total nitrogen changes[5], then it seems a higher maximum chlorophyll-*a* increase, of up to ~6.5% above the present day baseline, is a more realistic maximum level of change expected from the proposal[6]. I make this distinction, as this is the predicted level of change that the King Shag population might experience.

Provided any proposed feeding increases are introduced slowly (e.g. 10 or more years until full production) and comprehensive monitoring is introduced, large long-term changes in measures of phytoplankton abundance (e.g. a 6.5% increase in chlorophyll-*a*) will be able to detected and management restrictions introduced, if required.

(iii) In the foraging depth calculations, Mr Schuckard appears to have used a higher value for the effect of chlorophyll-*a* on light attenuation than that used by Dr Broekhuizen and myself.

Mr Schuckard has provided the underlying information behind the calculation assumptions from his presentation. His calculations aim to show how a critical 0.5 lux light illumination level for feeding shags (Wanless *et al.* 1999) could be affected by changes in chlorophyll-*a*. He has cited Tizler *et al.* (1994) as the source of his attenuation data and has specified a surface illumination of 100 lux. Based on Tizler *et al.* (1994) a base 'no chlorophyll' attenuation of 0.06 m^{-1} is used. This base attenuation relates to the clear southern ocean

[3] A 5% increase appears to be a conservative estimate, as the largest mean chlorophyll-a changes in Broekhuizen and Hadfield (2016) appear to be circa. 2%. The highest predicted changes also appeared to occur in the inner sounds, not the outer Waitata Reach region.
[4] 30% is based on the total nitrogen change which would be 1.67% for the presented baseline, but could be up to 2.23% for a more realistic 'present day' baseline.
[5] This seems reasonable, as phytoplankton are described by nitrogen in the model.
[6] 1.3 x 5% ~ 6.5%

waters discussed in Tizler *et al.* (1994), which are associated with a secchi disc[7] depth of about 24 m. Maximum outer Pelorus Sound secchi disc depths are around 13 m (see Figure 2 below). This is an important consideration, as differences in the base attenuation value used affects the influence of chlorophyll-*a* on total light attenuation. As Mr Schuckard has assumed a lower attenuation/higher secchi depth in his calculations, this has the effect of increasing the effect of phytoplankton (and chlorophyll-*a*) on light attenuation in the region.

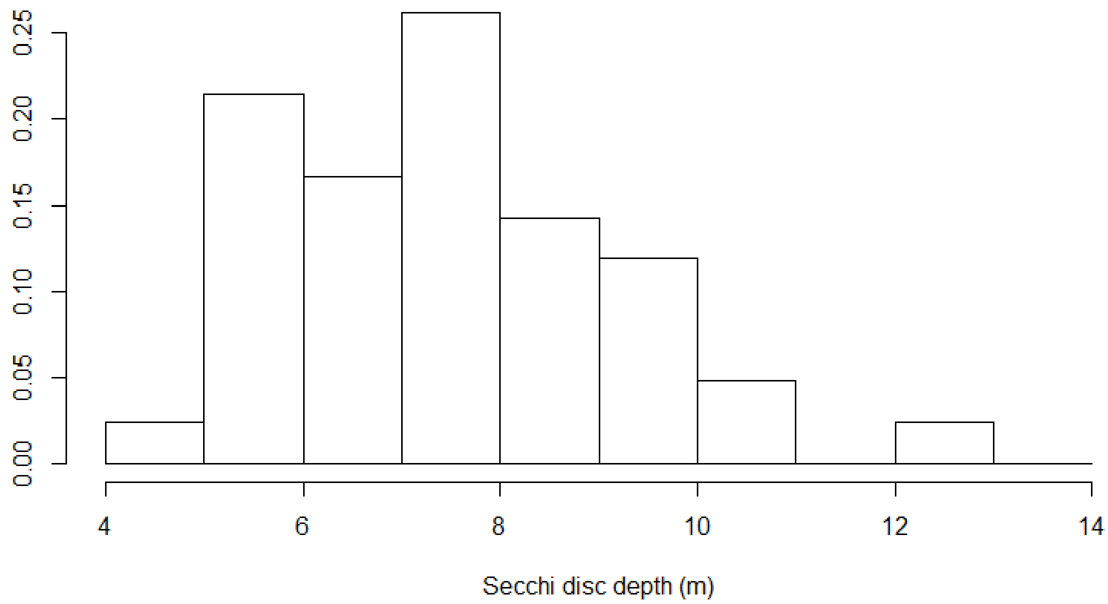

Figure 2. Frequency of monthly secchi disc depths in the outer Pelorus Sound over the period July 2012 to February 2016 (n = 42)[8].

An effect of chlorophyll-*a* on the light attenuation of 0.042 m^{-1}/(mg chl-*a*/m^3) is also applied in the calculations of Mr Schuckard. In previous calculations (Knight 2012), I have used 0.02 m^{-1}/(mg chl-*a*/m^3), based on a model parameterised value provided by Fasham *et al.* (1990)[9]. This value is slightly lower than that used by Dr Broekhuizen, 0.025 m^{-1}/(mg chl-*a*/m^3), which is based on Kirk (1983). Consequently, it appears the value used by Mr Schuckard is almost double the value used in our analyses. This does not mean that a value of 0.042 m^{-1}/(mg chl-*a*/m^3) is wrong, but that it is probably at the higher end of the range of parameter estimates. This has the effect of increasing the effect of phytoplankton (and chlorophyll-*a*) on light attenuation in the region.

I have reproduced Mr Schuckard's graph (paragraph 16 of his presentation), alongside parameterisations that use my own base attenuation values and the Fasham *et al.* (1990) and Kirk (1983) estimates of chlorophyll-*a* dependent attenuation (Figure 3). In order to use

[7] A secchi disc is a white and black circular disc that is lowered vertically to a point that it is not visible to the human eye. A high depth indicates clear water and a low depth indicates turbid water. In converting between secchi disc depth (D_s) and light attenuation (k), I use the formula $k=1.44/D_s$ (Kirk, 1983).

[8] Two months appeared to have been missing data.

[9] Note Fasham et al. (1990) states a shading coefficient of 0.03 m^{-1}/(mMol-N/m^3), which I had converted to chlorophyll-*a* assuming 1.59 mMol-N/mg Chl-*a* based on a Redfield ratio of C:N and a ratio of 50 gC/gChl-*a*.

more realistic estimates of base attenuation, I have assumed a secchi disc depth of 13 m at 1 mg chl-*a*/m^3 (based on measurements in the outer Pelorus monitoring site), which equates to base attenuation secchi depths of 16 m and 17 m for Fasham *et al.* (1990) and Kirk (1983), respectively[10].

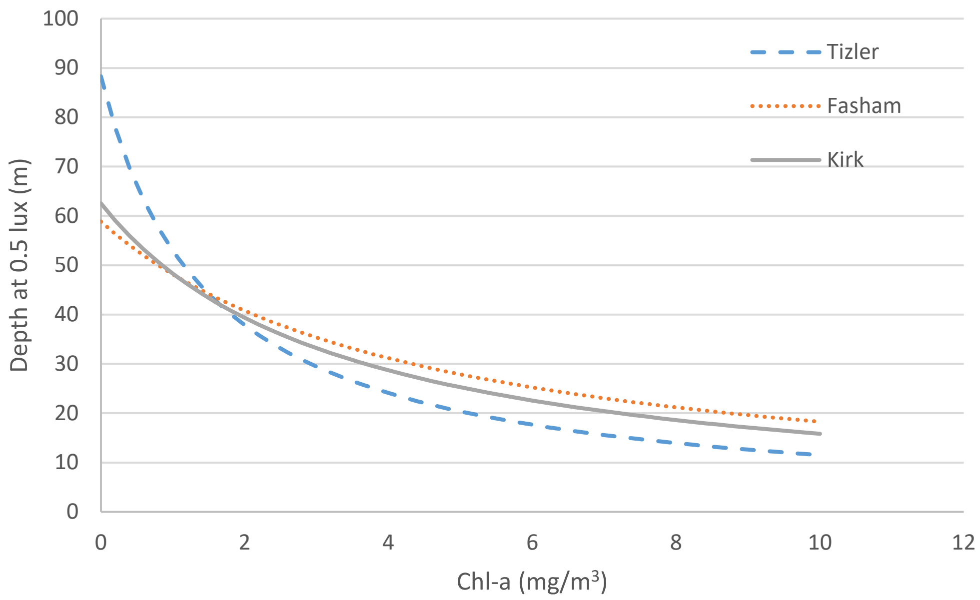

Figure 3. Effect of parameter differences on shag foraging depth range graph provided by Mr Schuckard (Tizler *et al.* 1994) and estimates undertaken by here using attenuation information from Fasham *et al.* (1990) and Kirk (1983) assuming a surface illumination of 100 lux. Note that for the 'Fasham' and 'Kirk' estimates, a secchi disc depth of 13 m for the outer sounds has been assumed at a concentration of 1 mg chl-*a*/m^3.

Assuming a 6.5% increase in chlorophyll-*a* occurs from 1 mg/m^3 to 1.065 mg/m^3, this equates to a foraging depth decrease of, at most 1.35 m (2.6%, based on Tizler *et al.* 1994), to a minimum of 0.56 m (1.2%, based on Fasham *et al.* 1990). It is difficult to envisage that these relatively small changes would have a large effect on the King Shag foraging area, particularly when secchi disc depths at the outer most site (PLS-7) have been shown to vary between 4 m and 13 m at the outermost site (Figure 2).

(iv) The value of surface illumination (100 lux) used by Mr Schuckard is very low.

A check of the surface illumination value used by Mr Schuckard is consistent with a "very dark overcast day", consequently this represents a very low surface light condition to consider the depth that 0.5 lux could be observed at (Table 1).

10 This was associated with base attenuation values of 0.09 and 0.085 m^{-1}.

Table 1. Example of typical luminance of surfaces under various conditions (source: https://en.wikipedia.org/wiki/Lux)

Illuminance (lux)	Surfaces illuminated by
0.05–0.36	Full moon on a clear night
100	Very dark overcast day
400	Sunrise or sunset on a clear day.
1000	Overcast day; typical TV studio lighting
10,000–25,000	Full daylight (not direct sun)
32,000–100,000	Direct sunlight

By assuming surface light conditions are full daylight (e.g. 10,000 lux[11]) the depth at which 0.5 lux would be observed is increased considerably (e.g. Figure 4). This implies that the potential foraging area is potentially larger and less likely to be affected by changes in the light penetration suggested in the evidence of Mr Schuckard.

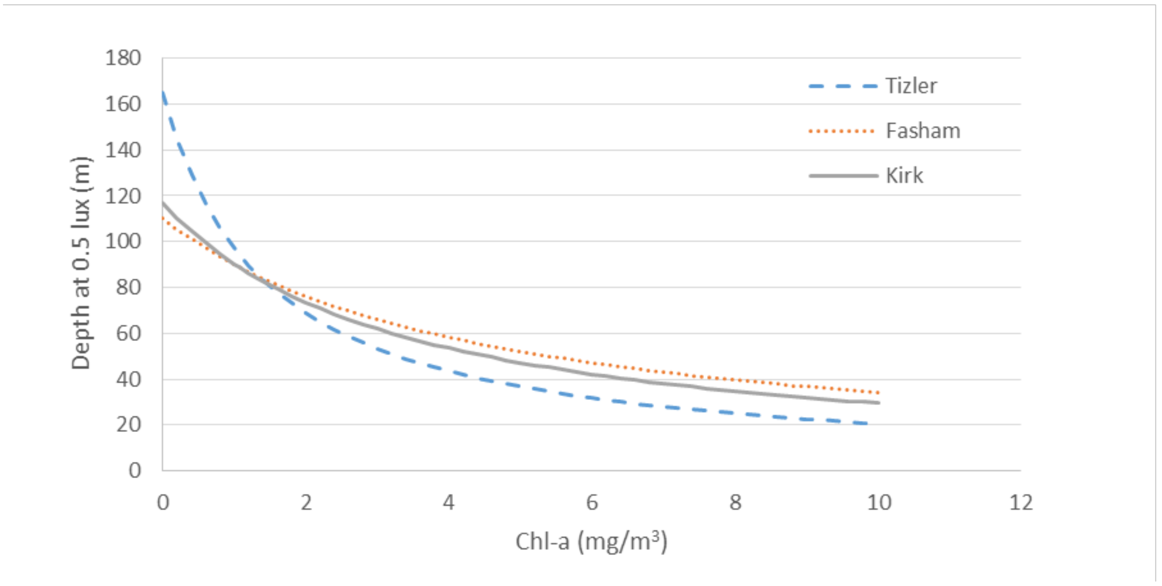

Figure 4. Effect of parameter differences on shag foraging depth range graph provided by Mr Schuckard (Tizler *et al.* 1994) and estimates undertaken by here using attenuation information from Fasham *et al.* (1990) and Kirk (1983) assuming a surface illumination of 10,000 lux. Note that for the 'Fasham' and 'Kirk' estimates, a secchi disc depth of 13 m for the outer sounds has been assumed at a concentration of 1 mg chl-a/m^3.

(v) Conclusions

There appears to be a low risk of substantial change to the light environment from the proposal. I base this conclusion on the model estimates of relatively small changes to phytoplankton populations and that previous calculations presented by Mr Shuckard appear to be highly conservative. If the relocation proposal proceeds, it will be very important that

[11] Note that some decrease below the water surface would be expected, due to surface reflection losses which are not considered here. However the value used, 10,000 lux, appears to be at the lower end of daylight illumination values.

initial model predictions of phytoplankton are routinely updated and checked against *in situ* measurements. This will require slow incremental increases in production, combined with carefully-considered and thorough monitoring. In addition, appropriate consent conditions will also be required to ensure farm management/long-term production targets can be reduced, if required.

I understand that the proposal is considering very thorough monitoring (which could also include improved light monitoring). For most sites increases in feed will occur in five stages, at three year intervals, only if monitoring demonstrates that effects remain within set water quality limits. Consequently, it seems that these considerations have been addressed.

Yours Sincerely,

Ben Knight
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Coastal & Freshwater Group
Cawthron Institute

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