BEFORE THE EPA
CHATHAM ROCK PHOSPHATE MARINE CONSENT APPLICATION

IN THE MATTER of the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012

AND

IN THE MATTER of a decision-making committee appointed to consider a marine consent application made by Chatham Rock Phosphate Limited to undertake rock phosphate extraction on the Chatham Rise

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STATEMENT OF EVIDENCE OF MIKE PAGE FOR CHATHAM ROCK PHOSPHATE LIMITED

Dated: 28 August 2014

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EXECUTIVE SUMMARY

1. The Chatham Rise supports diverse and productive pelagic and benthic ecosystems. Non-motile plankton (phytoplankton and zooplankton) are plants and animals that are not able to swim away from a sediment plume. Plankton are predominant in the top 100 m of water and not likely to encounter the sediment plume released on the seafloor. Non-motile fish eggs and larvae can be distributed throughout the water column and can therefore potentially be impacted by a sediment plume.

2. I conducted two separate reviews on the potential effects of Total Suspended Solids (**TSS**) on fish in the CRP licence area 50270. The first reviewed information on the effects of sediment on fish eggs and larvae and the second reviewed the potential avoidance responses of mobile juvenile and adult fish in the vicinity of mining licence 50270. There are no published data on the effects of TSS on the eggs and larvae of the specific species found in the marine consent area, or the avoidance responses of juvenile and adult fish species found in the marine consent area.

3. There is data on spawning distributions of 32 deepwater and 35 coastal species in New Zealand. There are 17 benthic and 46 demersal or pelagic fish species known to occur in the CRP licence area. Of these species, 15 spawn on the Chatham Rise and 5 occur in the licence area. The species are ling, hake, giant stargazer, lemon sole and lookdown dory.

Fish eggs and larvae

4. The presence of fish eggs and larvae in the region of the proposed mining can be inferred from maps of the distribution of spawning fish. Ling, hake, and some spawning of silver warehou, giant stargazer, and lookdown dory occur in the CRP area. Ling and giant stargazer are benthic spawners whereas hake, lookdown dory and silver warehou spawn in the water column. Skate and ghost sharks are present in the licence area, but there is insufficient data to determine the presence of eggs.

5. Many deepwater fish release pelagic eggs that drift in the water column for up to 10 days during hatching and development. Sediment adhesion to the egg chorion and the gills of larvae could affect their dispersal and survival.

Hake and ling eggs are susceptible to adhesion of sediment whereas silver warehou eggs are less adhesive.

~~6.~~ Studies demonstrate that sensitivity of eggs and larvae to sediment is highly variable as it is species and life-history specific. There are no studies on the species expected to occur in the marine consent area. In the only study relevant to assessment of the potential impact on offshore species, a TSS concentration threshold tolerance of 2 mg/L where no effects were detectable, was determined for eggs and larvae of demersal Atlantic cod and pelagic herring and flounder.

7. Benthic species that live and breed on the seafloor on the Chatham Rise such as ling, giant stargazer, lemon sole, skates and rays are more likely to be affected by a sediment plume than are demersal species such as hake and lookdown dory that spend a lower proportion of time close to the seafloor. Pelagic species are likely to spend more time above the majority of the plume.

8. The majority of hake spawn from September to January, ling spawn from July to November, and silver warehou from September to December. Giant stargazer spawn from June to December.

Juvenile and adult fish avoidance

9. Physiological and behavioural responses of juvenile and adult fish are species- and life-history specific. There are no studies on the species expected to occur in the marine consent area. Overseas studies show demersal and pelagic species avoid TSS concentrations of approximately 3 – 5 mg/L. Threshold concentrations for avoidance of TSS of 10 mg/L for demersal Atlantic cod and pelagic herring, and 50 mg/L for benthic flatfish species have been determined for benthic disturbance in the Baltic Sea.

10. The potential effects of TSS on fish eggs, larvae, juvenile and adult fish from mining on the Chatham Rise can be best assessed if there is information on the spatial and temporal distribution of eggs and larvae present in the region, and knowledge of the species- and life-stage-specific tolerance to TSS. These affects and avoidance response thresholds must be based on broad comparisons with relevant studies on deepwater species overseas. Experimental and field studies could be undertaken to observe the effects of TSS on specific species and life stages.

INTRODUCTION

Qualifications and experience

11. My full name is Michael John Page. I am a marine ecologist based in Nelson. I have a wide range of experience in fisheries, biodiversity, taxonomy and chemical ecology. I have worked in Nelson since 2001 and previously employed at NIWA at Greta Point, Wellington.

12. I have an MSc (Hons) degree in freshwater fish ecology from Canterbury University. I am a member of the New Zealand Marine Sciences Society.

13. I am currently employed as a Marine Ecologist for NIWA and have held that position since 2002. Prior to that, I worked for: Canterbury University Marine Chemistry Group as a Scientist/diver 1989 – 1992; the DSIR New Zealand Oceanographic Institute/NIWA as a technician 1992 – 1996; the Department of Marine and Wildlife Resources (DMWR) American Samoa as an Inshore Fisheries Biologist, 1996 – 1998; and NIWA as a biologist for the Marine Biotechnology Programme 1998 – 2002.

14. My current principal role is as a specialist taxonomist for the biodiversity and biosecurity programme. I have also been involved in fisheries research projects in Tonga and American Samoa. I am a co-author of a research paper on the distribution of hoki eggs and larvae on the West of the South Island (Zeldis et al. 1998) and have analysed the vertical distribution of hoki eggs and larvae in Cook Strait. I have been involved in biodiversity research programmes in the Ross Sea and in Fiordland. My previous research has been in chemical ecology and aquaculture of marine sponges for supply of bioactive compounds. I have 20 years of experience in marine ecology. I am principal author of six and co-author of 27 peer-reviewed publications in the international scientific literature, have written 23 commercial reports, and written and designed two web-based identification guides.

15. I have practical experience in fisheries research surveys, and inshore commercial fishing. I worked for two years as an Inshore Fisheries Biologist in American Samoa, leading a project on the impact of a SCUBA spear fishery on reef fishes on the Island. I completed a resource survey on selected deep water fish on the Tongan seamounts in 2008, and I am currently involved in a New Zealand Foreign Affairs and Trade Aid Programme project on Improved Governance Management, Economic and Biological Sustainability of a Demersal Line Fishery in Tonga.

Code of Conduct

16. I confirm that I have read the Code of Conduct for expert witnesses contained in the Environment Court of New Zealand Practice Note 2011 and that I have complied with it when preparing my evidence. Other than when I state that I am relying on the advice of another person, this evidence is entirely within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Role in marine consent application

17. I am the author of two reports commissioned by Chatham Rise Rock Phosphate Limited (**CRP**) that review information the effects of total suspended solids on fish eggs and larvae on the Chatham Rise (Page, 2014a) and fish avoidance of total suspended solids on the Chatham Rise (Page, 2014b).

Scope of evidence

18. In this brief of evidence, I will review information on impacts of TSS on:

(a) Effectively, non-motile organisms that cannot move away from a sediment plume are plants (phytoplankton) and animals (zooplankton, fish eggs and fish larvae);

(b) Effects on adult fish, and

(c) Juvenile and adult fish avoidance of a sediment plume.

THE IMPACTS OF PLUME ON NON-MOTILE FISH EGGS AND LARVAE

19. Non-motile organisms in the Chatham Rise pelagic ecosystem are microscopic plants (phytoplankton) and animals (zooplankton, fish eggs and larvae) that cannot effectively swim away from a sediment plume.

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20. The spatial distributions of phytoplankton and zooplankton communities and their ecological dynamics (grazing and growth) on the Chatham Rise are relatively well understood e.g. (Bradford-Grieve et al. 1998; James and Hall 1998). Phytoplankton and zooplankton biomass on the Chatham Rise is predominantly concentrated in the top 100 m of the water column (Chang and Gall 1998; Bradford-Grieve et al. 1999). I therefore consider that most phytoplankton and zooplankton are unlikely to encounter the sediment plume from mining in MPL 50270 predicted to be no higher than 50 m from the seafloor, infrequently reaching concentrations 5 mg/L as high as 20 m above the seafloor (Deltares 2014b).

21. My evidence deals with the effects of suspended particles on fish eggs larvae and fish. As described in the evidence of Ms Jamie Lescinski and in Deltares (2014b) (Appendix 25 to the EIA), the plume generated from the discharge of sediment is limited principally to the 10 m of water above the seabed. At times, suspended particles predicted to reach 50 m for a limited amount of time. The euphotic zone is defined as the depth to which 1 % of light penetrates. This depth varies depending upon water properties (e.g., the amount of particulate material in the water) but the depth beyond which photosynthesis is not possible lies typically about 150 m (Widder 2014). As such, the plume does not extend vertically to reach the photic zone and will not directly disrupt primary production.

22. Fish eggs and larvae can occur throughout the water column. I found no published data on the distribution of fish eggs or larvae in the vicinity of MPL 50270, or the area predicted to be influenced by the plume as modelled by (Deltares 2014b) for MPL50270 on the Chatham Rise. The effects of total suspended sediment on eggs and/or larvae can be most reliably predicted if there is knowledge of the distribution of species impacted and the effects on different life stages. However, it is possible to infer effects based on comparisons with studies of other species.

23. There is data on spawning distributions of 32 deepwater and 35 coastal species in New Zealand (Hurst et al. 2000; O'Driscoll et al. 2003). There are 17 benthic and 46 demersal or pelagic fish species known to occur in the CRP licence area (Table 1). Of these species, 15 spawn on the Chatham Rise, but only five occur in the licence area. The presence of fish eggs and larvae from commercially fished species in the region of the mining is inferred from distribution maps of ripe, running-ripe and spent spawning fish (Hurst et al. 2000; O'Driscoll et al. 2014). With the exception of hake, ling and lookdown dory, most commercially important deepwater species spawn on the northern and southern flanks of the Chatham Rise. Ling and hake in spawning condition have been recorded from the mid-Chatham Rise in licence area 50270 and some spawning of silver warehou, giant stargazer and lookdown dory may also occur within combined CRP regions (Hurst et al. 2000; O'Driscoll et al. 2003). Observations using acoustic ecosounders suggest hake spawn higher than 50 m above the seafloor (Page 2014a). Ling are thought to be benthic spawners, laying eggs on the seafloor (P. Horn pers. comm.). Giant stargazer may also spawn on the seafloor.

24. Eggs and larvae spawned by fish to the west and north of the mining licence MLP50270 could be transported into the mining areas by hydrographic conditions. Egg dispersal distance is unknown but dependent on factors such as spawning location, egg buoyancy and hydrographic conditions at the time of spawning.

25. Many deep-water and pelagic fish species on the Chatham Rise spawn planktonic eggs. Changes in egg buoyancy during development is common to the development of hoki, orange roughy, hake and horse mackerel (Murdoch et al. 1990; Zeldis et al. 1995; Moser et al. 1997; Paredes and Bravo 2005). Egg buoyancy is important for dispersal. Changes in buoyancy due to adhesion of sediment could change the distribution of eggs through time and result in hatching in sub-optimal locations or depths for larval feeding. Suspended sediment adhesion can also have direct lethal and sub-lethal effects by smothering eggs and lowering developmental rates and hatching success (Morgan et al. 1983). Fish larvae are generally much less tolerant to suspended sediments than are eggs of the same species because their gills become clogged (Page 2014a, Table 4.1).

26. Sensitivity of fish eggs to sediment adhesion is species-specific and related to the morphology and chemical composition of the egg chorion and the size distribution and angularity of sediment particles (Page 2014a, Figure 4.1). Anecdotal evidence suggests that hake, hoki, barracouta and ling eggs show positive surface film adhesion, whereas silver warehou eggs are not sticky (Patchell et al. 1987; Page 2014a), but no published empirical data were found on egg adhesion for species commonly found in the region of licence 50270 on the mid-Chatham Rise.

27. No published information could be found on threshold tolerances of eggs and larvae to total suspended solid concentrations on the Chatham Rise. Published information on relevant species overseas shows high variability in sediment tolerance among species and developmental stages within species (Page 2014a; Page 2014b). Only one recent study has estimated sediment threshold concentrations from seabed disturbance for pelagic, demersal and benthic species (FeBEC 2013). FeBEC (2013) set a 2 mg/L total suspended solid concentration of no detectable effects for drifting eggs and yolk sac larvae, based on experimental dose-response studies on Atlantic cod, herring and flounder in a less saline environment in the Baltic Sea (FeBEC, 2010).

28. TSS threshold concentrations for Chatham Rise eggs and larvae cannot be directly determined from overseas data as tolerances are species and life-stage specific. Effects of TSS are best estimated by conducting empirical studies on eggs and larvae of species known to occur within the area impacted by the suspended sediments. However, if broad comparisons are drawn for benthic, demersal and pelagic species from these data then a concentration threshold of 2 mg/L TSS could be used predict effects. I note that the 2mg/L threshold is conservative and represents a value where no effects would be expected to occur.

THE IMPACTS OF SEDIMENT PLUME ON ADULT FISH

29. I have reviewed information on the effects of TSS on fish on the Chatham Rise and found no information on the direct effects of TSS for the species occurring on the Chatham Rise. There are also few published studies relevant to the effects of TSS on offshore fish species worldwide.

30. Suspended sediments may affect fish directly by reducing visibility of pelagic food and clogging gills with associated acute and chronic effects such as physiological stress, reduced growth and reproductive fitness. The biological effects are summarized in Figure 3-1 (Page 2014b) and the severity of effects summarized in Table 3-1 (Page 2014b).

31. Benthic species that live and feed on the seafloor and demersal species that spend part or all of their time within 50 m of the seabed in the CRP licence area 50270 are more likely to encounter a sediment plume from mining than are other species. Table 1 attached to my evidence (Page 2014b) details species habitat preference. Giant stargazer are benthic feeders, spawn in the vicinity of the licence area and are likely to lay eggs on or near the seafloor. Similarly, lemon sole are benthic feeders and are likely to lay eggs on or near the seafloor. Ling in spawning condition have been recorded within the licence area and are thought to be benthic spawners (P. Horn, pers. comm.). Skate and ray species along with other oviparous elasmobranch species and chimerids that lay egg cases are also susceptible to suspended sediment blocking respiratory structures. The life history and biology of other non-commercial species in the licence region is unknown, however many are likely to spawn on or near the seabed. Smothering of eggs by sediments in the immediate vicinity of mining would likely cause mortality.

THE IMPACTS OF SEDIMENT PLUMES ON FISH AVOIDANCE

32. Fish responses to increased sediment are dependent on exposure duration and TSS concentration, and also vary between species and life-history stages within a species. Unlike benthic species and early life stages with limited motility, juvenile and adult fishes are able to swim away from areas where environmental conditions are suboptimal. As a consequence, TSS levels are more likely to be manifested in sub-lethal behavioural and physiological responses rather than mortality for these species.

33. An Ocean Biogeographical Information System (OBIS) database of the distribution and abundance of living species http://en.wikipedia.org/wiki/Species in the ocean, lists species searched in

April 2014. A total of 17 benthic and 46 demersal fish species occurred within the CRP licence area 50270 (Table 1). Of these, ling, hake and giant stargazer have high commercial value.

34. Mesopelagic fishes and cephalopods have high ecological importance in the Chatham Rise ecosystem as food for larger fish (Pinkerton 2013). A small change in biomass of this group will cause large changes in other groups such as demersal and benthic fish species. Acoustic backscatter (echosounder) traces show vertical migration of the mesopelagic fish and zooplankton layer during the day to within 50 m of the seafloor (O'Driscoll et al. 2009). However, TSS concentrations are predicted to decrease rapidly with height from the seafloor; e.g. concentrations of 30 mg/L at 10m above the seafloor are predicted to last less than a day for one winter mining cycle (CRP 2014). I know of no information on the effect of a TSS plume on the vertical distribution of the mesopelagic layer in oceanic ecosystems.

35. I have detailed known published physiological and behavioural responses to TSS in Table 2. However, comparing published threshold values for fish species is problematic as different experimental studies use different sediment types (i.e., grain size and angularity of particles), units of turbidity and response parameters (behavioural, physiological, lethal). In addition, responses of fish to suspended solids are likely to be species-specific and dependent on individual life history. I have made broad comparisons with the relatively few overseas studies on avoidance behaviour thresholds of relevant species. A comparison of related species occurring in New Zealand to published threshold TSS concentrations overseas is given in Table 3.

36. Demersal and pelagic species (Atlantic cod and mackerel) avoid TSS concentrations of approximately 3 to 5 mg/L (table 3). A recent study by FeBEC (2013) determined an acceptable threshold of avoidance of 10 mg/L for demersal species of Atlantic cod, whiting, herring and European sprat and 50 mg/L for benthic species of flatfish to TSS from seabed disturbance. If broad threshold comparisons are used for Chatham Rise species, total suspended sediment concentrations of between 100 and 10 mg/L outside the mining block for 1 to15 km away, respectively and higher concentrations within the mining block (CRP 2014) are likely to cause avoidance of mobile benthic and demersal fish species.

RESPONSE TO SUBMISSIONS

Deep Water Group

37. At paragraph 10.5, the Deep Water Group's (**DWG**) submission suggests that fish will be exposed to "multiple cumulative stressors". The effects of multiple cumulative stressors was not determined in my report. I reviewed the effects of Total Suspended Solids (TSS) on adult fish, juveniles, eggs and larvae.

38. The DWG state that "individual and combined effects will impact on adult and juvenile fish, fish eggs and spawning behaviour". My research has shown that overseas studies suggest Total Suspended Sediment (TSS) is likely to cause avoidance behaviour and effect fish eggs and larvae within the mining block and for a distance in the vicinity of 15 km outside a mining block (CRP 2014).

39. Demersal fish species in the mining block are likely to avoid TSS concentrations greater than 3–5 mg/L (Westerberg et al. 1996; Appelberg et al. 2005). Furthermore, eggs and larvae may be affected by TSS concentrations of greater than 2 mg/L (FeBEC 2013). These concentration thresholds are same as the (ANZECC 2000) guideline trigger turbidity of 2–3 mg/L. Adults and juveniles of benthic fish species such as ling and flounder are potentially more tolerant of TSS concentrations to 50 mg/L (FeBEC 2013).

40. TSS concentrations between 10 and 100 mg/L will occur outside the mining block. However, the plume distance beyond the mining block will decrease to between 2.0 and 0.5 km for 10 and 100 mg/L TSS, respectively, after approximately 1 week. The predicted TSS plume modelled for release of sediment on the seafloor (CRP responses to EPA request 5, August 2014 (CRP 2014)) shows concentrations greater than 10 mg/L, but less than 30 mg/L persisting for more than one month over an area of 47 km^2 (Figure, 19, Table 5 (CRP 2014)). TSS concentrations greater than 30 mg/L for this mining scenario after 1 month are modelled to occur within mostly within the mining block (Figures 16, 17 and 18 (CRP 2014)).

Sanford

41. Sanford in paragraph 5 of their submission 110207; "There is a very high probability that the proposed mining works will effect fish behaviour…" Based on overseas studies on fish avoidance thresholds to total suspended solids (Appendix 2) and the modelled extent of the plume (Deltares, 2014b; CRP, 2014), fish are likely to avoid the plume within the mining block, and may avoid the plume approximately 15 km away from the mining block.

KASM

42. On page 17, bullet point 5 KASM states that demersal fish, meso-pelagic fish and phytoplankton are likely to be impacted indirectly by mining activities. There are 46 demersal or pelagic species known to occur within the licence area (Appendix 1). The sediment plume is likely to indirectly impact species within the mining block by causing migration and may cause avoidance approximately 15 km away from the mining block.

43. Meso-pelagic fish vertically migrate down to within 50 m of the seafloor during daylight hours (O'Driscoll et al. 2009). A sediment plume vertical height of the 15–20 m above the seabed at 5 mg/L for the clay fraction is predicted occur infrequently (CRP 2014, paragraph 6, pg. 272). Meso-pelagic fish may occasionally contact this plume at sediment concentrations that may cause an avoidance response.

44. Phytoplankton productivity predominantly occurs in the top 100 m of water and therefore will not be affected by the predicted sediment plume (see paragraph 20 above). Should the behaviour of meso-pelagic biota that diurnally migrate be affected, then the interaction between mesopelagic biota and phytoplankton may be affected. However, the effect will limited to the area of the plume and the time of day that the interaction occurs.

Forest and Bird

45. At paragraph 25 of Forest and Bird's submission, they state that "No one really knows what these fish will do when the encounter the sediment plume". This suggestion is not entirely correct; a number of relevant studies conducted on the effects of sediment on marine fish behaviour suggest that fish will avoid (swim away) from sediment at a certain threshold concentration. For example, Westerberg et al. (1996) determined that Atlantic Cod (a demersal species) in a large experimental flume tank exposed to increasing concentrations of sediment avoided the plume at 3 mg/L, preferring sediment-free control water. Atlantic herring have responded in a similar way at 9–12 mg/L suspended sediment (Johnston and Wildish 1981), see Table 2 attached to my evidence for a summary table of avoidance responses.

CONCLUSIONS

46. In conclusion, predicting of effects of TSS on fish eggs and larvae is dependent on:

(a) knowledge of which species eggs and larvae occur in the region of the CRP mining licence 50270 and plume;

(b) the spatial and temporal variation of the distribution of eggs and larvae; and

(c) the species- and life-stage specific tolerances of eggs and larvae to TSS released by mining in the licence area.

47. Empirical studies on both direct (sediment adherence to pelagic eggs and larvae) and indirect (predator or prey) effects would inform the assessments of the effects of exposure to TSS on fish eggs and larvae.

48. Predicting the avoidance response thresholds of juvenile and adult fishes to a sediment plume on the Chatham Rise must be based on broad comparisons with studies overseas because there are no relevant data on the effects on species expected in the consent area. Experimental laboratory and field studies would inform assessments of the effects of exposure to TSS on animal avoidance responses.

Mike Page

28 August 2014

REFERENCES

ANZECC (2000) ANZECC water quality guidelines - October 2000. https://www.mfe.govt.nz/publications/water/anzecc-water-quality-guide-02/anzecc-water-quality-guide-02-pdfs.html

Appelberg, M., Holmqvist, M., Lagenfelt, I. (2005) Øresundsforbindelsens inverkan paa fisk och fiske, Underlagsrapport 1992-2005: 230.

Blaxter, J.H.S. (1969) Visual Threshold and Spectral Sensitivity of flatfish larvae. *Journal of experimental Biology*, 51: 221-230.

Bradford-Grieve, J., Boyd, P.W., Chang, F.H., Chiswell, S., Hadfield, M., Hall, J.A., James, M.R., Nodder, S.D., Shushkina, E.A. (1999) Pelagic ecosystem structure and functioning in the Subtropical Front region east of New Zealand in austral winter and spring 1993. *Journal of Plankton Research*, 21(3): 405-428. DOI 10.1093/plankt/21.3.405

Bradford-Grieve, J., Murdoch, R., James, M., Oliver, M., McLeod, J. (1998) Mesozooplankton biomass, composition, and potential grazing pressure on phytoplankton during austral winter and spring 1993 in the Subtropical Convergence region near New Zealand. *Deep-Sea Research Part I-Oceanographic Research Papers*, 45(10): 1709-1737. Doi 10.1016/S0967-0637(98)00039-9

Chang, F.H., Gall, M. (1998) Phytoplankton assemblages and photosynthetic pigments during winter and spring in the Subtropical Convergence region near New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 32(4): 515-530.

CRP (2014) Response to items 3,4 ,5 and 7 of EPA request of 9 June 2014 for further information (August 2014). 24.

Deltares (2014b) Modelling investigations on mine tailing plume dispersion on the Chatham Rise *Report prepared by Deltares for Chatham Rock Phosphate Ltd*, Delatres Report 1209110-000-ZKS-007: 72.

FeBEC (2010) Sediment Dose Response Study. *Technical Report. Prepared for Femern A/S*, Doc. No. E4-TR-036.: 147.

FeBEC (2013) Fish Ecology in Fehmarnbelt. Environmental Impact assessment Report, Report no. E4TR0041 - Volume I: 254.

Humborstad, O.-B., Jorgensen, T., Grotmol, S. (2006) Exposure of cod Gadus morhua to resuspended sediment: an experimental study of the impact of bottom trawling. *Marine Ecology Progress Series*, 309: 247-254. 10.3354/meps309247

Hurst, R.J., Stevenson, M.L., Bagley, N.W., Griggs, L.H., Morrison, M.A., Francis, M.P. (2000) Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand coastal fish. *Final Research Report for Ministry of Fisheries Project*: 57.

James, M.R., Hall, J.A. (1998) Microzooplankton grazing in different water masses associated with the subtropical convergence round the South Island, new Zealand. *Deep-Sea Research Part I-Oceanographic Research Papers*, 45(10): 1689-1707. Doi 10.1016/S0967-0637(98)00038-7

Johnston, D.W., Wildish, D.J. (1981) Avoidance of dredge spoil by herring (Clupea harengus harengus). *Bulletin of Environmental Contamination and Toxicology*, 26(1): 307-314. 10.1007/BF01622095

Johnston, D.W., Wildish, D.J. (1982) Effect of suspended sediment on feeding by larval herring (Clupea harengus harengus L.). *Bulletin of Environmental Contamination and Toxicology*, 29(3): 261-267.

Keller, O., Lüdemann, K., Kafemann, R. (2006) Lterature review of offshore wind farms with regard to fish fauna. *BfN-Skripten*, Vol. 186: 47-130.

Lowe, M.L. (2013) Factors affecting the habitat usage of estuarine juvenile fish in northern New Zealand. *Doctor of Philosophy in Marine Science*. University of Auckland, Auckland: 238.

Meager, J.J., Utne-Palm, A.C. (2008) Effect of turbidity on habitat preference of juvenile Atlantic cod, Gadus morhua. *Environmental Biology of Fishes*, 81(2): 149-155. DOI 10.1007/s10641-007-9183-z

Messieh, S.N., Wildish, D.J., Peterson, R.H. (1981) Possible impact from dredging and spoil disposal on the Miramichi Bay herring fishery. *Canadian Technical Report on Fisheries and Aquatic Science. 1981.*, 1008: 33.

Morgan, R.P., Rasin, J.R., Noe, L.A. (1983) Sediment effect on eggs and larvae of stripped bass and white perch. *Transactions of the American Fisheries Society*, 112: 220-224.

Morinaga, T.T., Koike, T., Ootomo, K., Matsuike, K. (1988) Response of a fish school to turbid water. *Uni-Mer*, 26: 19-28.

Moser, H.G., Lo, N.C.H., Smith, P.E. (1997) Vertical distribution of Pacific hake eggs in relation to stage of development and temperature. *California Cooperative Oceanic Fisheries Investigations Reports*, 38: 120-126. <Go to ISI>://WOS:A1997YK03700012

Murdoch, R., Guo, R., McCrone, A. (1990) Distribution of Hoki (*Macruronus novaezealandiae*) eggs and larvae in relation to hydrography in Cook Strait, September, 1987. *New Zealand Journal of Marine and Freshwater Research*, 24: 529-539.

Newcombe, C.P., Jensen, J.O.T. (1996) Channel Suspended Sediment and Fisheries: A Synthesis for Quantitative Assessment of Risk and Impact. *North American Journal of Fisheries Management*, 16(4): 693-727. 10.1577/1548-8675(1996)016<0693:cssafa>2.3.co;2

O'Driscoll, R.L., Bagley, N., Baird, S. (2014) Spawning areas of fish on the Chatham Rise; 2001-2014. *NIWA Client Report*, WLG2014-58: 42.

O'Driscoll, R.L., Booth, J.D., Bagley, N.W., Anderson, O.F., Griggs, L.H., Stevenson, M.L., Francis, M.P. (2003) Areas of importance for spawning, pupping or egg laying, and juveniles of New Zealand deepwater fish, pleagic fish and invertebrates. *NIWA Technical Report*: 102.

O'Driscoll, R.L., Gauthier, S., Devine, J.A. (2009) Acoustic estimates of mesopelagic fish: as clear as day and night? *ICES Journal of Marine Science: Journal du Conseil*, 66(6): 1310-1317. 10.1093/icesjms/fsp015

Page, M.J. (2014a) Effects of total suspended solids on marine fish: eggs and larvae on the Chatham Rise. *EEZ2000006*, Appendix 27: 22.

Page, M.J. (2014b) Effects of total suspended solids on marine fish: pelagic, demersal and bottom fish species avoidance of TSS on the Chatham Rise. *EEZ000006*, Appendix 28: 22.

Paredes, F., Bravo, R. (2005) Reproductive cycle, size at first maturation and fecundity in the golden ling, Genypterus blacodes, in Chile. *New Zealand Journal of Marine and Freshwater Research*, 39(5): 1085-1096. <Go to ISI>://WOS:000232744700008

Partridge, G.J., Michael, R.J. (2010) Direct and indirect effects of simulated calcareous dredge material on eggs and larvae of pink snapper *Pagrus auratus.* . *Journal of Fish Biology*, 77 227-240.

Patchell, G.J., Allen, M.S., Dreadon, D.J. (1987) Egg and larval development of the New Zealand hoki Macruronus novaezelandiae. *New Zealand Journal of Marine and Freshwater Research*, 21(2): 301-313. 10.1080/00288330.1987.9516226

Pinkerton, M. (2013) Ecosystem modelling of the Chatman Rise. *NIWA Client Report*: 157.

Rogers, B.A. (1969) Tolerance levels of four species of estuarine fishes to suspended mineral solids University of Rhode Island, Kingston.

Sherk, J.A., O'Connor, J.M., Neumann, D.A. (1975) Effects of suspended and deposited sediments on estuarine environments. In: L.E. Cronin (Ed). *Estuarine Research 2*. Academic Press, New York: 541-558.

Westerberg, H., Rönnbäck, P., Frimansson, H. (1996) Effects of suspended sediments on cod eggs and larvae and on the behaviour of adult herring and cod. *ICES CM 1996/E:26*: 13.

Widder, E. (2014) Deep light. National Oceanic and Atmospheric Administration. http://oceanexplorer.noaa.gov/explorations/04deepscope/background/deeplight/deeplight.html

Wildish, D.J., Wilson, A.J., Akagi, H. (1977) Avoidance by herring of suspended sediment from dredge spoil dumping. , ICES Doc. C.M.1977/ E:11 (mimeo.).

Zeldis, J.R., Grimes, P.J., Ingerson, J.K.V. (1995) Ascent Rates, Vertical-Distribution, and a Thermal History Model of Development of Orange Roughy, *Hoplostethus atlanticus*, Eggs in the Water Column. *Fishery Bulletin*, 93(2): 373-385. <Go to ISI>://A1995QR39200014

Zeldis, J.R., Murdoch, R.C., Cordue, P.L., Page, M.J. (1998) Distribution of hoki (Macruronus novaezelandiae) eggs, larvae, and adults off Westland, New Zealand, and the design of an egg production survey to estimate hoki biomass. *Canadian Journal of Fisheries and Aquatic Sciences*, 55(7): 1682-1694. <Go to ISI>://WOS:000076176300014

TABLES

Table 1

Ocean Biogeographical Information System (OBIS) output of species sampled by research trawl in the CRP licence area 50270, searched April 2014 (Page 2014a).

Scientific name	Family	Common family	Common name	Benthic	Demersal or Pelagic
Alertichthys blacki	Congiopodidae	pigfishes	alert pigfish		y
Ambophthalmos angustus	Psychrolutidae	toadfishes	pale toadfish	y	
Argentina elongata	Argentinidae	silversides	silverside		y
Arnoglossus scapha	Bothidae	lefteyed flounder	megrim, witch	y	
Azygopus pinnifasciatus	Pleuronectidae	righteyed flounders	spotted flounder	y	
Bassanago bulbiceps	Congridae	conger eels	swollenhead conger	y	
Bassanago hirsutus	Congridae	conger eels	hariy conger	y	
Beryx splendens	Berycidae	alfonsinos	alfonsino		y
Brama australis	Bramidae	pomfrets	southern Ray's bream		y
Coelorinchus aspercephalus	Macrouridae	rattails, grenadiers	oblique banded rattail		y
Coelorinchus biclinozonalis	Macrouridae	rattails, grenadiers	two saddled rattail		y
Coelorinchus bollonsi	Macrouridae	rattails, grenadiers	Bollons' rattail		y
Coelorinchus fasciatus	Macrouridae	rattails, grenadiers	banded rattail		y
Coelorinchus oliverianus	Macrouridae	rattails, grenadiers	Oliver's rattail		y
Coelorinchus parvifasciatus	Macrouridae	rattails, grenadiers	small banded rattail		y
Centriscops humerosus	Macrorhamphosidae	snipefishes	redbanded bellowsfish		y
Centrolophus niger	Centrolophidae	raftfishes, medusafishes	rudderfish		y
Cyttus traversi	Zeidae	dories	lookdown dory		y
Cyttus novaezealandiae	Zeidae	dories	New Zealand dory		y
Deania calcea	Centrophoridae	dogfishes	shovelnose dogfish		y
Dipturus innominatus	Rajidae	skates	smooth skate	y	
Emmelichthys nitidus	Emmelichthyidae	bonnetmouths, rovers	redbait		y
Epigonus lenimen	Apogonidae	cardinalfishes	bigeye cardinalfish		y
Epigonus robustus	Apogonidae	cardinalfishes	Robust cardinal fish		y
Etmopterus baxteri	Etmopteridae	dogfishes	lantern shark		y
Etmopterus lucifer	Etmopteridae	dogfishes	lucifer dogfish		y
Galeorhinus galeus	Triakidae	hound sharlks	Tope shark	y	
Genypterus blacodes	Ophidiidae	cusk eels	ling	y	
Halaelurus dawsoni	Scyliorhinidae	cat sharks	Dawson's cat shark		y
Halargyreus johnsonii	Moridae	morid cods	slender cod		y
Harriotta raleighana	Rhinochimaeridae	longnosed chimaeras	longnosed chimaera	y	
Helicolenus spp.	Scorpaenidae	scorpionfishes	jock stewart	y	
Hoplichthys haswelli	Hoplichthyidae	ghostflatheads	deepsea flathead	y	
Hoplostethus mediterraneus	Trachichthyidae	roughies, slimeheads	silver roughy, sawbelly		y
Hydrolagus bemisi	Chimaeridae	chimaeras, ghost sharks	pale ghost shark	y	
Hydrolagus novaezealandiae	Chimaeridae	chimaeras, ghost sharks	dark ghost shark	y	
Icichthys australis	Centrolophidae	raftfishes, medusafishes	ragfish		y

Scientific name	Family	Common family	Common name	Benthic	Demersal or Pelagic
Kathetostoma giganteum	Uranoscopidae	armourhead stargazers	giant stargazer, monkfish	y	
Kuronezumia bubonis	Macrouridae	rattails, grenadiers	bulbous rattail		y
Lepidoperca aurantia	Serranidae	sea perches, gropers	orange perch		y
Lepidorhynchus denticulatus	Macrouridae	rattails, grenadiers	javelinfish		y
Macruronus novaezelandiae	Merlucciidae	Hakes	hoki		y
Merluccius australis	Merlucciidae	Hakes	hake		y
Micromesistius australis	Gadidae	true cods	southern blue whiting		y
Mora moro	Moridae	morid cods	ribaldo		y
Neocyttus rhomboidalis	Oreosomatidae	Oreos	spiky oreo		y
Neophrynichthys latus	Psychrolutidae	Toadfishes	dark toadfish	y	
Notacanthus sexspinis	Notacanthidae	spiny eels	spineback eel		y
Notophycis marginata	Moridae	morid cods	dwarf cod		y
Optonurus denticulatus	Macrouridae	rattails, grenadiers	thorntooth grenadier		y
Oxynotus bruniensis	Oxynotidae	rough sharks	prickly dogfish	y	
Pelotretis flavilatus	Pleuronectidae	righteyed flounders	lemon sole	y	
Photichthys argenteus	Photichthyidae	lighthouse fishes	lighthouse fish		y
Polyprion oxygeneios	Percichthyidae	temperate basses	hapuku, groper		y
Pseudophycis bachus	Moridae	morid cods	red cod		y
Schedophilus huttoni	Centrolophidae	Medusafishes	New Zealand ruffe		y
Seriolella caerulea	Centrolophidae	raftfishes, medusafishes	white warehou		y
Seriolella punctata	Centrolophidae	raftfishes, medusafishes	silver warehou		y
Squalus acanthias	Squalidae	dogfishes	spiny dogfish		y
Thyrsites atun	Gempylidae	Snake mackerel	snoek		y
Trachurus symmrtricus murphyi	Carangidae	jacks, trevallies, kingfishes	slender mackerel		y
Tubbia tasmanica	Centrolophidae	raftfishes, medusafishes	Tasmanian ruffe		y
Ventrifossa nigromaculata	Macrouridae	rattails, grenadiers	blackspot rattail		y

Table 2

Table 3–2*:* Published physiological and behavioural responses to threshold concentrations of total suspended solids. Larval, juvenile and adult marine and estuarine fishes. (Page 2014b).

Common name/ species	Life stage	Threshold concentration on sedimentation	Effect: avoidance behaviour/lethal/sub-lethal effects	References
Demersal species				
Atlantic Cod *Gadus morhua*	Juvenile	Turbidity	No strong effect on habitat preference	Meager and Utne-Palm (2008)
	Adult	550 mg/L (1d – 10d exposure)	No mortality, some reversible morphological changes in gill epithelium occurred	Humborstad et al. (2006)
	Adult	3-5 mg/L	Avoidance behaviour	Appelberg et al. (2005) in FeBEC (2013)
	Adult	3 mg/L	Avoidance behaviour in experimental flume	Westerberg et al. (1996)
	Juvenile & Adult	10 mg/L	Threshold value for avoidance behaviour	FeBEC (2013)
Snapper (*Pagrus auratus*)	Larvae	4 mg/L	First Observable Effect Concentration	(Partridge and Michael 2010)
	Larvae	156 mg/L	50% mortality after 12 h	(Partridge and Michael 2010)
	Juvenile	20 NTU	Significant decline in foraging success after 1 h	(Lowe 2013)
	Juvenile	40 NTU	30 d exposure, maximum weight loss of 14% reached	(Lowe 2013)
	Juvenile	35 mg/L	Altered foraging strategies	(Lowe 2013)
Pelagic species				
Japanese Horse mackerel *Trachurus japonicus*	Adult	5 mg/L	Threshold value for avoidance behaviour	Morinaga et al. (1988) in Westerberg et al. (1996)
Herring (Atlantic) *Clupea harengus*	Larvae	3 mg/L	Reduced feeding rate	Messieh et al. (1981)
	Larvae	540 mg/L	Significantly reduced growth rates	Messieh et al. (1981)
	Juvenile	9-12 mg/L	Avoidance behaviour	Johnston and Wildish (1981)
	Juvenile	20 mg/L	Reduced feeding rate	Johnston and Wildish (1982)
	Juvenile	9.5-12 mg/L	Avoidance behaviour	FeBEC (2013)
	Adult	19 ± 5 mg/L fine sediment and 35 ± 5 mg/L coarse sediment	Avoidance behaviour	Wildish et al. (1977) in FeBEC (2013)
	Adult	3-5 mg/L	Avoidance behaviour	Appelberg et al.

Common name/ species	Life stage	Threshold concentration on sedimentation	Effect: avoidance behaviour/lethal/sub-lethal effects	References
				(2005) in FeBEC (2013)
	Juvenile & Adult	10 mg/L	Threshold value for avoidance behaviour	FeBEC (2013)
	Larvae	2 mg/L	Decreasing trend in Standard Length with coarse sediment	FeBEC (2010)
Benthic species				
Flatfish spp.	Larvae	Reduced light intensity	Reduced food intake	Blaxter (1969) in FeBEC (2013)
Plaice *Pleuronectes platessa*	Adult	3,000 mg/L	No mortality among plaice for 14 days exposure	(Keller et al. 2006; FeBEC (2013))
	Adult	50 mg/L	Threshold value for avoidance behaviour	FeBEC (2013)
Estuarine/Neritic species				
Atlantic silverside *Menidia*	Adult	580* mg/L	10% mortality after 24hr exposure	Sherk et al. (1975)
Anchovy *Anchoa mitchilli*	Adult	2310 mg/L	10% mortality after 24hr exposure	Sherk et al. (1975) in Newcombe and Jensen (1996)
Coastal/anadromous species				
Bass (striped) *Morone saxatilis*	Adult	1,500 mg/L	Plasma & Haemocrit increased	Sherk et al. (1975) in Newcombe and Jensen (1996)
Coastal species				
Cunner *Tautogolabrus adspersus*	Adult	28,000 mg/L	50% mortality after 24hr exposure	Rogers (1969) in Newcombe and Jensen (1996)

*LC_{10} cited incorrectly in Newcombe and Jensen (1996) and Humborstad et al. (2006) as 58 mg/l

Table 3

Table 4-1: Published data on fish species responses to total suspended solids. Related species in New Zealand (Page 2014b).

Species with published data on avoidance thresholds to TSS (data from Table 3-2)				Related species in New Zealand	
Common name	**Species**	**Family**	**TSS avoidance threshold**	**Species in NZ**	**Common name(s)**
Atlantic herring	*Clupea harengus*	Clupeidae	2–30 mg/L	*Spratttus* spp. *Sardinops neopilchardis*	Sprats Pilchards
Atlantic cod	*Gadus morhua*	Gadidae	3 mg/L	*Micromesistus australis*	Southern blue whiting
Japanese horse mackerel	*Trachurus japonicus*	Carangidae	5 mgL	*Trachrurus* spp.	Horse mackerel Murphy's mackerel Jack mackerel
Plaice	*Pleuronectes platessa*	Pleuronectidae	50 mg/L	*Peltotretis flaviatus* *Peltohampus* spp.	Lemon sole Common and slender sole
Atlantic silverside	*Menidia*	Antherinopsidae	-	None	-
Anchovy	*Anchoa mitchilli*	Eugraulidae	-	*Eugraulis australis*	Anchovy
Bass (striped)	*Morone saxatilis*	Moronidae	-	None	-
Cunner	*Tautogolabrus adspersus*	Labridae	-	*Notolabrus* spp.	Wrasses,