BEFORE THE BOARD OF INQUIRY
TAMARIND DEVELOPMENT DRILLING APPLICATIONS

EEZ100016

IN THE MATTER	of the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012
AND	
IN THE MATTER	of a Board of Inquiry appointed under s52 of the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 to decide on Tamarind Taranaki Limited's marine consent and marine discharge consent applications

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STATEMENT OF EXPERT EVIDENCE OF ALISON BRONWYN MACDIARMID FOR TAMARIND TARANAKI LIMITED

Dated: 20 July 2018

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MAY IT PLEASE THE BOARD

1. Executive Summary

1.1 In my statement of evidence, I provide an independent review of the IA as it relates to plankton, marine fish, sharks, and reptiles; and consider and assess the potential impacts of the proposed activities on zooplankton, marine fish, sharks, and reptiles. I also respond to issues relevant to my expertise raised by the Board of Inquiry, the EPA and/or submitters.

1.2 I assess the potential effects of suspended sediments on plankton; effects of suspended sediments on fish, sharks, and marine reptiles; effects on fish and sharks of seafloor deposition of sediments; the sensitivity of fish, sharks, and marine reptiles to underwater noise; effects of discharges from the drilling rig deck drains on plankton, fish, sharks, and marine reptiles; and the exposure of plankton, fish, sharks and marine reptiles to diesel spills and to hydrocarbons following a loss of well control event.

1.3 Overall, I conclude that the effects of the proposed activities on the populations of plankton, fish, shark, and marine reptile species in the STB will be negligible. At most there may be some very localised effects of suspended and/or deposited sediments causing individual fish to move away from the area immediately around the anchors and mooring lines, and possibly some localised effects of noise from the drilling operations on communication among individuals of vocalising fish species.

1.4 In the unlikely event of a crude oil spill (in a worst-case scenario), or a spill of diesel, marine reptiles, pelagic fish eggs and larvae and phytoplankton and zooplankton in the vicinity of the spill will be the most vulnerable, followed by shallow inshore obligate reef fish and invertebrate species. Less likely to be exposed in all situations are pelagic fish and shark species occurring near the water surface. The fish least likely to be exposed in all situations are the deeper water demersal and benthic fish and shark species.

1.5 Neither the EPA key issues report nor any of the technical reviews raised concerns about the effect of the proposed activities on plankton, fish, sharks, or marine reptiles.

1.6 None of the submitters raised concerns about the effect of the proposed activities on plankton or marine reptiles. A small number of submitters raised concerns about potential effects of the proposed activities on fish.

1.7 Te Korowai o Ngāruahine Trust requested that the consent holder agree to fund, over the course of the consent period fish population surveys to robustly assess the direct, indirect and cumulative impacts of the programme on potentially affected marine species. I consider that given the likely negligible and unmeasurable effects of the proposed activities on fish populations in the STB that such a survey would not achieve the desired outcomes.

1.8 Robert Warrington's submission raises concerns about whether the proposal and any ‘pollution’ would harm the run of tuna (short and long-finned eel) from Hokio beach near Levin. In my opinion this is highly unlikely and that effects of the proposed activities on tuna during their adult ocean migratory phase (tuna heke or tuna whakaheke) from, or larval return to, any of the river systems feeding into the STB would be negligible and unmeasurable.

2. Introduction

2.1 My full name is Alison Bronwyn MacDiarmid.

2.2 I hold the following qualifications:

2.2.1 Bachelor of Science, University of Auckland (1979)
2.2.2 Master of Science, University of Auckland (1981)
2.2.3 PhD in Zoology, University of Auckland (1988)

2.3 Since 2015 I have held the position of Regional Manager at the Wellington campus of the National Institute of Water and Atmospheric Research (NIWA), where I have been employed since 1987 in a variety of research roles.

2.4 I have 31 years of professional experience in marine ecology and fisheries, including zooplankton, reef fish, spiny lobsters and other reef associated species, and have previously served on Ministry for Primary Industries fisheries stock assessment working groups for several species, the Biodiversity Research Advisory Group, and Aquatic Environment Working Group. I have broad interests and experience in marine biodiversity, historical marine ecology, marine ecosystem goods and services, the state of the marine environment, and human impacts on marine ecosystems. In addition, over the last 10 years I have led many investigations for commercial clients on a variety of research questions including patterns of fish and plankton distribution in the South Taranaki Bight (STB).

2.5 I have read the following information in preparation of my evidence:

2.5.1 The Marine Consent Application and Marine Discharge Consent Application (the "Applications") and the Impact Assessment and Annexures, which accompanied the Applications (the "IA"), in particular, the sections that relate to the description of the activity and plankton, fish and marine reptiles.

2.5.2 The statements of evidence by:

a) Mr Jason Peacock;
b) Mr Iain McCallum;
c) Dr Brian King;
d) Dr Simon Childerhouse;
e) Dr. Sharon de Luca;
f) Ms Nicola Gibbs;
g) Dr David Thompson;
h) Dr Alison Lane; and
i) Mr Fraser Colegrave.

2.5.3 Submissions.

2.5.4 Proposed consent conditions.

2.5.5 EPA Key Issues Report, dated July 2018.

2.5.6 The following independent reviews commissioned by the EPA (the "technical reviews"):

a) *Technical Review of Oil Spill Modelling*, prepared by Coffey Services (NZ) Limited, dated 26 June 2018 (the "Coffey Report");

b) *Technical Review and Analysis of Operational Activities associated with Sidetrack Development Drilling and Marine Discharge Consent - Assessment Report*, prepared by Oil and Gas Solutions Pty Limited, dated 22 May 2018 (the "OGS Report"); and

c) *Review of Marine Environmental Impact Assessment*, prepared by SEAPEN Marine Environmental Services, dated 26 May 2018 (the "SEAPEN Report").

2.5.7 Tamarind's 'Response *to the s54 Request for Further Information'*, dated July 2018 ("RFI Response").

2.6 My role in relation to Tamarind's Applications has been to: undertake an independent review of the IA as it relates to zooplankton, marine fish, sharks, and reptiles; to consider and assess the potential impacts of the proposed activities on plankton, marine fish, sharks, and reptiles and to provide expert evidence on this topic; and respond to any issues relevant to my expertise raised by the Board of Inquiry, the EPA and/or submitters.

Code of conduct

2.7 I confirm that I have read the Code of Conduct for expert witnesses contained in the Environment Court of New Zealand Practice Note 2014 and that I have complied with it when preparing my evidence. Other than when I state 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.

2.8 My qualifications as an expert witness are set out above. The issues addressed in this brief relate to the application for a marine consent and marine discharge consent and are matters within my area of expertise

Scope of evidence

2.9 In this evidence, I discuss:

2.9.1 Existing Environment, including plankton production in the South Taranaki Bight, and fish, sharks, and marine reptile distribution in the STB and within the area of Tamarind's Petroleum Mining Permit 38158 (the "area of interest" or "AOI");

2.9.2 The potential impacts of Tamarind's proposed activities within the AOI on plankton communities in the water column and on marine fish, shark, and reptile species. These potential impacts include:

(a) Effects of suspended sediments on plankton;

(b) Effects of suspended sediments on fish, sharks, and marine reptiles;

(c) Effects on fish and sharks of seafloor deposition of sediments;

(d) Sensitivity of fish, sharks, and marine reptiles to underwater noise;

(e) Effects of discharges from the drilling rig deck drains on plankton, fish, sharks, and marine reptiles;

2.9.3 The potential impacts on plankton, fish, sharks, and marine reptiles from unplanned events, including:

(a) Exposure of plankton, fish and marine reptiles to diesel spills;

(b) Exposure of plankton, fish and marine reptiles to hydrocarbons following a loss of well control event.

2.9.4 Response to issues raised by the EPA Key Issues Report and technical reviews, where these are relevant to my evidence.

2.9.5 Response to issues raised by submitters where these are relevant to my evidence.

3. EXISTING ENVIRONMENT

Plankton production in the South Taranaki Bight

3.1 Before discussing the potential impacts of Tamarind's proposed activities on plankton in the AOI and wider STB region, it is useful to understand plankton production and its spatial and temporal variability.

3.2 Plankton are any organism (bacteria, algae (phytoplankton), animal (zooplankton)) in the water column that cannot swim against the flow of water. Phytoplankton are important as the primary producers upon which all other organisms higher in the food chain depend, including all fished species, whales, dolphins, and seabirds. Zooplankton, as herbivorous grazers of phytoplankton, are important intermediate organisms between the primary producers and the top predators. There may be as few as three or as many as six steps in a food chain from primary producers to top predators.

3.3 The IA shows that the AOI sits within an area of lower primary production (as measured using the sea surface concentration of chlorophyll-a, the main photosynthetic pigment which can be measured by ocean colour satellites and used as a proxy for the standing stock of phytoplankton) with higher productivity waters progressively closer to the coast. The IA references a one year (2017) seasonal averaged view of surface phytoplankton production[1], the results of which showed that in the AOI, chlorophyll-a production peaks in spring.[2] However, planktonic production is dynamic and a one-year study does not enable a fully representative understanding of this aspect. I therefore comment further on this as follows.

3.4 The STB is impacted by several large-scale, highly variable, physical phenomena that structure the distribution and biomass of phytoplankton, mediated by the grazing pressure of, and responses by, zooplankton. These large-scale physical processes include the Kahurangi / Cape Farewell

[1] Refer to the IA, page 82

[2] Refer to the IA, section 4.3.1

upwelling plume, tidal mixing, river plumes and surf beach processes. Of these, the Kahurangi/ Cape Farewell upwelling plume is the most relevant to the AOI and Tamarind's proposed activities and it is the best understood process in terms of plant nutrient renewal which impacts on primary production dynamics and its downstream impact on zooplankton. The Kahurangi / Cape Farewell upwelling plume is discussed in further detail below. Short-term and seasonal variability in these processes and consequent patterns of plankton distribution and biomass is to be expected.

3.5 Ten-year satellite observations of sea surface chlorophyll in the STB (Pinkerton et al. 2013)[3], show three-fold seasonal changes in chlorophyll-a concentrations 20-40 km offshore with April–May and November-December maxima and January-February and July-August minima (see Figure 1), as well as larger impacts of summer upwelling off the Kahurangi Shoals off north-western South Island and winter influence of near shore process including river inputs. Importantly, Pinkerton et al. (2013) found no evidence of long-term (decadal) trends in phytoplankton biomass.

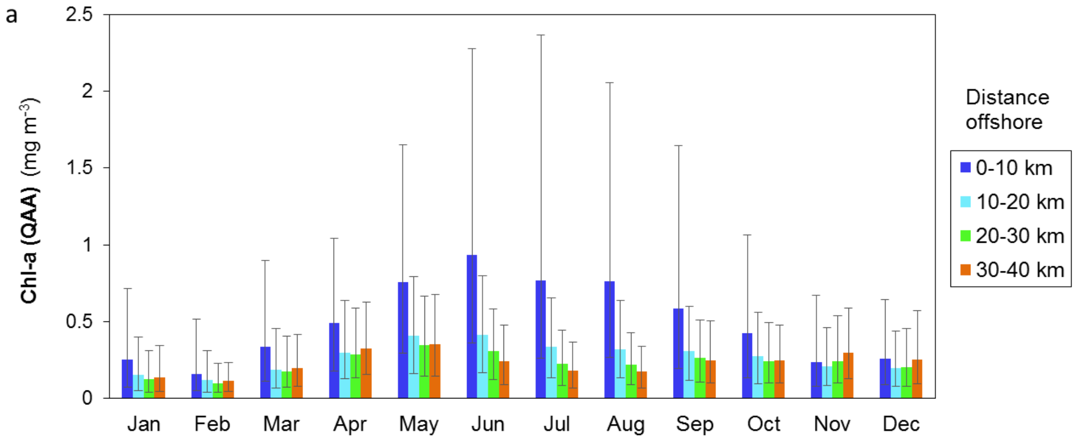

Figure 1. Chlorophyll-a concentration (chl-a, mg m^{-3}) observed by MODIS-Aqua in 4 onshore-offshore bands in the STB averaged over 10 years of observations (N=5730 files). From Pinkerton et al. (2013).

3.6 Upwelling of cold, nutrient rich waters near Kahurangi Point/Cape Farewell on the north-west of the South Island is strongly correlated with the strength of

[3] Pinkerton, M.; Schwarz, J.; Gall, M.; Beaumont, J. (2013). Satellite ocean-colour remote sensing of the South Taranaki Bight from 2002 to 2012. NIWA Client Report No: WLG2013-14, 80 p, see http://www.epa.govt.nz/Publications/Remote_sensing_of_ocean_colour.pdf.

local alongshore south-westerly winds (Heath and Gilmour 1987)[4], intensified by onshore winds at Kahurangi Point of at least several days duration (Shirtcliffe et al. 1990)[5]. The pulses of cold water are then carried north-east into the STB to produce a series of rotating cold cores which become detached from the main flow by the force of their vorticity (Bowman et al. 1983[6], Kibblewhite et al. 1982[7]). However, the movement of water and resulting dispersion from the upwelling focus differ greatly from day to day (Viner & Wilkinson 1987[8]).

3.7 This intermittent upwelling of cold nutrient-rich water and its transport north-eastwards past Farewell Spit affects the zooplankton fauna in the STB, especially those in waters greater than 50m depth, in a number of ways.

3.8 First, there is evidence of passive entrainment effects on zooplankton assemblages. This takes the form of oceanic zooplankton species being carried inshore upstream off the north-west of the South Island in the upwelling plume then north-eastwards into the STB (Bradford-Grieve et al. 1993)[9].

3.9 Second, *in situ* processes structure zooplankton populations through the growth and consumption patterns of the species involved. Although the Kahurangi / Cape Farewell upwelling plume, rich in inorganic nutrients,

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[4] Heath, R.A.; Gilmour, A.E. (1987). Flow and hydrological variability in the Kahurangi plume off north-west South Island, New Zealand. New Zealand Journal of Marine and Freshwater Research 21:125-139, DOI: 10.1080/00288330.1987.9516207.

[5] Shirtcliffe, T.G.L.; Moore, M.I.; Cole, A.G.; Viner, A.B.; Baldwin, R.; Chapman, B. (1990). Dynamics of the Cape Farewell upwelling plume, New Zealand, New Zealand Journal of Marine and Freshwater Research, 24:4, 555-568, DOI: 10.1080/00288330.1990.9516446.

[6] Bowman, M. J.; Chiswell, S. M.; Lapennas, P.P.; Murtagh, R.A.; Foster, B.A.; Wilkinson, V.; Battaerd, W. (1983). Coastal upwelling, cyclogenesis and squid fishing near Cape Farewell, New Zealand. In: Gade, H. ed., Coastal oceanography. Plenum Press.

[7] Kibblewhite, A.C.; Berquist, P.R.; Foster, B.A.; Gregory, M.R.; Miller, M.C. ed., (1982). Māui Development Study. Auckland, Shell BP & Todd Oil Services Ltd.

[8] Viner, A.B.; Wilkinson, V.H. (1987). Variation of upwelling and associated nutrient nitrogen dynamics off north-west coast of South Island, New Zealand. New Zealand Journal of Marine and Freshwater Research 21: 253-266.

[9] Bradford-Grieve, J.M.; Murdoch, R.C.; Chapman, B.E. (1993). Composition of macrozooplankton assemblages associated with the formation and decay of pulses within an upwelling plume in greater Cook Strait, New Zealand. New Zealand Journal of Marine and Freshwater Research 27: 1-22.

promotes phytoplankton (diatoms, dinoflagellates, and autotrophic bacteria) growth above background levels (Bradford et al. 1986[10]; Viner & Wilkinson 1987), at the beginning of the upwelling plume primary production is just getting underway and zooplankton ingestion exceeds potential phytoplankton production with minimum breeding activity by zooplankton (James & Wilkinson 1988[11]). Further downstream in the STB nitrate levels decrease as expanding phytoplankton populations use the upwelled supplies, ammonia levels resulting from grazing zooplankton increase, and concentrations of juvenile copepods and krill *Nyctiphanes australis* (both zooplankton) are an order of magnitude greater than in the Kahurangi Point area (Bradford-Grieve et al. 1993; Bradford & Chapman 1988[12]).

3.10 Krill, a key prey species for some fish, blue whales, and some bird species is most abundant at the "downstream" north-eastern end of a plume of cold, nutrient-rich, upwelled water, extending from the Kahurangi Point-Cape Farewell north-eastwards into the STB (Foster & Battaerd 1985[13], Bradford & Chapman 1988; James & Wilkinson 1988, Bradford-Grieve et al. 1993).

3.11 The downstream position of the plume and associated primary and secondary production in the STB is highly variable (Foster & Battaerd 1985, Viner & Wilkinson 1987, Bradford & Chapman 1988, Bradford-Grieve et al. 1993).

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[10] Bradford, J.M.; Lapennas, P.P.; Murtagh, R.A.; Chang, F.H.; Wilkinson, V. (1986). Factors controlling summer phytoplankton production in greater Cook Strait, New Zealand. N.Z. Journal of Marine and Freshwater Research 20: 253-279.

[11] James, M.R.; Wilkinson, V.H. (1988). Biomass, carbon ingestion, and ammonia excretion by zooplankton associated with an upwelling plume in western Cook Strait, New Zealand. New Zealand Journal of Marine and Freshwater Research 22: 249-257.

[12] Bradford, J.M.; Chapman, B. (1988). *Nyctiphanes australis* (Euphausiacea) and an upwelling plume in western Cook Strait, New Zealand. New Zealand Journal of Marine and Freshwater Research 22: 237-247.

[13] Foster, B.A.; Battaerd, W.R. (1985). Distribution of zooplankton in a coastal upwelling in New Zealand. New Zealand Journal of Marine and Freshwater Research 19: 213-226.

Fish and Marine Reptile Distribution in the STB

3.12 The IA provides a list of fish species likely to occur in the proposal area, based on modelling of research catch data.[14] Fish species that have a more than 50% probability of occurring in the AOI include barracoota, carpet shark, cucumberfish, gurnard, john dory, scaly gurnard, school shark, spiny dogfish, silver warehou and terakihi. Species with a 10-50% probability of occurring in the AOI include frostfish, hapuka, murphy's mackerel, leather jacket, ling, lemon sole, porcupine fish, redbait, red cod, rig, silver dory, silverside, snapper, sea perch and witch. I concur with this assessment.

3.13 The IA also lists 14 species of shark that could occur in the AOI, based on MPI's NABIS database. This is the best available source of shark distributions for the area.

3.14 The IA also lists the marine reptiles that are known to occur off New Zealand's coast[15]. I concur with the IA that it is possible that marine reptiles may occur within the AOI, but lack of nearby breeding habitat and distance from known concentrations mean that they are likely to be rare.

4. POTENTIAL IMPACTS FROM PROPOSED ACTIVITIES

4.1 Section 6 of the IA[16] describes the key aspects of the proposal which have the potential to affect marine species and ecosystems. Effects considered are underwater noise and vibration, turbidity, deposition of equipment or material on the seabed, artificial lighting from the drilling rig and associated support vessels, and physical disturbance by the drilling rig and support vessels[3]. In the context of plankton, fish and marine reptiles, potential effects from the proposed activities are:

4.1.1 Increased turbidity from the placement and removal of structures, including anchor blocks, and associated activities on the seabed.

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[14] Refer to the IA, Section 4.3.4

[15] Refer to the IA, page 94

4.1.2 Underwater noise and vibration generated by operations on the drilling rig and support vessels;

4.1.3 Artificial lighting on the drilling rig and support vessels;

4.1.4 Physical disturbance or exclusion from the space occupied by a drilling rig and support vessels for the duration of operations.

4.2 I will discuss each in turn.

Turbidity

Effects on plankton of suspended and redeposited sediments

4.3 I note that there is now no discharge of drilling cuttings or muds proposed [17]. The only other significant source of suspended sediments is those disturbed from the seafloor during anchor setting or lifting operations. If these concentrations were of sufficient magnitude, extent, and regularity they could have an adverse effect on plankton communities by shading phytoplankton thus reducing primary production and the amount of food available to zooplankton grazers. High concentrations of fine sediment can clog zooplankton respiratory surfaces and/or feeding apparatus as well as impair the ability of zooplankton visual predators to find prey (Arendt et al. 2011)[18].

4.4 I conclude that it is very unlikely that suspended sediment concentrations from the proposed setting or lifting of up to 12 anchors (8 rig anchors and 4 BOP anchors) at any one time, or small discharges of cement during drilling operations, will be sufficiently high, large enough in area, or long enough in duration to impact measurably on phytoplankton or zooplankton populations, including krill, in the AOI or the STB. My conclusion is based on the finding that phytoplankton and zooplankton communities in the STB are typical of the shelf communities found around the entire North Island (Bradford

[17] RFI Response

[18] Arendt, K.E.; Dutz, J.; Jonasdottir, S.H., ; Jung-Madsen, S.; Mortensen, J.; Møller E.F.; Nielsen, T.G. (2011) Effects of suspended sediments on copepods feeding in a glacial influenced sub-Arctic fjord. Journal of Plankton Research 33: 1526–1537

1980)[19]. Further, that the Kahurangi / Cape Farewell upwelling plume and its downstream propagation is a large-scale process operating over a considerable but variable area of the STB, possibly 15,000 - 20,000 km^2, while the area affected by suspended sediments around the anchors and lines will be relatively very small and short-lived.

4.5 I concur with the assessment in the IA that the overall impact of turbidity from the proposed activities on planktonic communities will be negligible[20].

Effects on fish of suspended and redeposited sediments

4.6 The species of fish which occur within the AOI could potentially be affected by total suspended sediments (TSS) in the water column or redeposited on the seafloor.

4.7 Most research on the effects of TSS on fish has been done overseas and I draw attention to a relevant study on the effect of TSS on a New Zealand marine fish species (Lowe 2013)[21]. Lowe (2013) examined these effects in relation to juvenile snapper (*Pagus auratus*) and reviewed the available international literature on the relationship between TSS and fish survival, sub-lethal effects and behaviour. Through a series of laboratory experiments, Lowe (2013) demonstrated that although TSS in the range 43-261 g per m^3 is unlikely to cause high mortality in juvenile snapper, prolonged exposure to concentrations greater than about 170g per m^3 can result in adverse growth and developmental effects from physiological stress (e.g. respiratory distress/disease).

4.8 Lowe (2013) also examined juvenile snapper from seven north-eastern estuaries and found that fish condition decreased, and gill damage increased as TSS increased from 4-37g per m^3. Lethal TSS thresholds have not been studied for any New Zealand marine fish; the only local fish data are for

[19] Bradford, J. M. (1980). New Zealand region, zooplankton biomass (0-200 m). New Zealand Oceanographic Institute chart, miscellaneous series 41.

[20] Refer to the IA, page 124

[21] Lowe, M.L. (2013). Factors affecting the habitat usage of estuarine juvenile fish in northern New Zealand. Unpublished PhD thesis, University of Auckland. 276 p.

freshwater species not normally occurring in areas of high TSS. For these fish, lethal TSS levels were at or above 1000g per m^3 (Rowe et al. 2000)[22] and may be indicative of the sensitivity of offshore species not normally encountering high TSS.

4.9 It is also relevant to note that many New Zealand marine fish species occur in the frequently turbid near shore waters of the STB, indicating they must have a degree of tolerance to moderately elevated TSS.

4.10 Greatly elevated levels of TSS in the water column could potentially lead to:

4.10.1 Increased risk to fish eggs and larvae of smothering or clogging of gill structures leading to altered development or mortality;

4.10.2 Increased mortality of adult fishes if exposure is high and chronic;

4.10.3 Decreased prey availability due to higher turbidity causing visual impairment or prey species leaving the area; and

4.10.4 In addition, studies show that some pelagic fish species have the ability to swim away from areas of elevated TSS (e.g., Johnson and Widish 1981[23]).

4.11 However, given that there is now proposed to be no discharge of drilling cuttings or muds[12] and the only other significant source of suspended sediments is through disturbing of the seafloor during anchor setting or lifting operations, and small discharges of cement during drilling operations, it is very unlikely that TSS will be sufficiently high or exposure long enough to impact measurably on the behaviour, or to have sub-lethal or lethal effects on wide ranging fish or shark species, or to have ecologically significant effects on drifting planktonic fish eggs and larvae that will pass through the very small area of elevated TSS.

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[22] Rowe, D.K.; Hicks, M.; Smith, J.P.; Williams, E. (2009). Lethal concentrations of suspended solids for common native fish species that are rare in New Zealand rivers with high suspended solids loads. New Zealand Journal of Marine and Freshwater Research 43: 1029-1038.

[23] Johnson, D.W.; Wildish, D.J. (1981). Avoidance of dredge spoil by herring (*Clupea harengus harengus*). Bulletin of Environmental Contamination and Toxicology 26: 307-314.

4.12 I concur with the IA assessment that the overall impact of turbidity on fish and sharks resulting from the proposed activities will be negligible[24].

Effects on fish of sediment deposition on the seafloor

4.13 Fish and sharks may be affected by deposition of sediments on the seafloor through the smothering of prey or habitat forming species, through the alteration of preferred seabed substrates, or by reducing oxygen concentrations at or near the seabed. All of these potential adverse effects may cause fish and sharks to migrate from the affected area. The magnitude of the impact depends on the geographical area affected by deposition, the thickness of the deposits, the nature of the receiving environment, and the ecological requirements of particular fish and shark species.

4.14 Given that there is now proposed to be no discharge of drilling cuttings or muds, within the context of the AOI, the area of sea floor affected by the re-deposition of sediments disturbed during anchor setting or lifting operations is likely to be very small (5.2 ha or 0.01% of the Tui Field, see RFI Response Report). In time the sea floor communities will recover as they are repopulated by settlement of planktonic larvae and around the margins by movement of sea floor life stages.

4.15 Any adverse effects on fish and shark populations in the area will be very modest. Seafloor foraging fish such as cucumberfish, carpet shark, red gurnard, scaly gurnard, sea perch, tarakihi, dark ghost shark, giant stargazer, and spiny dogfish may temporarily move away from the immediate area around the anchors and mooring lines but the overall effect on their populations in the proposal area and STB will be negligible.

[24] Refer to the IA, page 125

Underwater noise and vibration

Sensitivity of fish and marine retiles to noise

4.16 The levels of noise likely to be generated by the proposed activities and the potential impacts of noise on the marine mammals is discussed in detail in the evidence of Dr Childerhouse.

4.17 I also refer to New Zealand based research on vocalisations and hearing in New Zealand fish species. Ghazali (2011)[25] describes vocalisations in red gurnard (*Chelidonichthys kumu*) and bigeye (*Pempheris adspersa*). Red gurnard vocalisations exceed 60dB over a frequency range of 100-500Hz, while peak sound output by bigeye is 115.8 ± 0.2dB re 1µPa at 1m, at a peak frequency of 405 ± 12Hz (Radford et al. 2015)[26]

4.18 The sensitivity of red gurnard to sound has not been described but presumably they are sensitive to the same frequency range as they produce. Radford et al. (2011[27] and 2013)[28] describe the hearing mechanism in bigeye and determined they detected sound up to 1000Hz but were most sensitive at lower frequencies (100–400Hz)[29]. Caiger et al. (2013)[30] found hapuka (*Polyprion oxygeneios*) hearing ability increased with age to reach a bandwidth of 100–1000Hz and with greatest sensitivity to 100-600Hz one year after hatching. Caiger et al. (2012)[31] found juvenile (about 55mm fork

[25] Ghazali S. (2011). Fish vocalisation: understanding its biological role from temporal and spatial characteristics. Unpublished PhD Thesis, University of Auckland, Auckland, New Zealand.167 p.

[26] Radford, C.A.; Ghazali, S.; Jeffs, A.G.; Montgomery, J.C. (2015). Vocalisations of the bigeye, *Pempheris adspersa*: characteristics, source level, and active space. Journal of Experimental Biology http://jeb.biologists.org/content/early/2015/01/15/jeb.115295.abstract.

[27] Radford, C.A.; Caiger, P.; Ghazali, S.; Higgs, D.M. (2011) A new connection: Enhanced hearing ability in the New Zealand bigeye, *Pempheris adspersa*. Journal of the Acoustical Society of America 129, 2472, http://dx.doi.org/10.1121/1.3588128.

[28] Radford CA, Montgomery JC, Caiger P, Johnston P, Lu J, Higgs DM. (2013). A novel hearing specialization in the New Zealand bigeye, *Pempheris adspersa*. Biology Letters 9: 20130163. http://dx.doi.org/10.1098/rsbl.2013.0163

[29] Although bigeye don't occur within the PMP area I have included information about their sensitivity to underwater sound to assist in describing hearing in NZ fishes generally.

[30] Caiger, P.E.; Montgomery, J.C.; Bruce, M.; Lu, J.; Radford, C.A. (2013). A proposed mechanism for the observed ontogenetic improvement in the hearing ability of hapuka (*Polyprion oxygeneios*). Journal of Comparitive Physiology A 199:653–661.

[31] Caiger, P.E.; Montgomery, J.C.; Radford, C.A. (2012). Chronic low-intensity noise exposure affects the hearing thresholds of juvenile snapper. Marine Ecology Progress Series 466: 225–232.

length) snapper had bandwidths of auditory sensitivity ranging from 100 to 2000Hz but were most sensitive to lower frequencies (100–400Hz). However, exposure of juvenile snapper to a noisy underwater environment (120dB re 1 μPa) for two weeks decreased sensitivity to the lower frequencies by up to 10dB re 1 μPa. Recovery of sensitivity was not investigated. Trevally (*Pseudocaranx dentex*) and snapper respond to high levels of noise by moving near the sea floor, swimming faster in tight groups and displaying more alarm signals[32].

4.19 A recent review of the international literature on the effects of underwater noise on marine organisms identified that not much is known about the sensitivity of marine reptiles to this sort of disturbance[33]. Loggerhead turtles, *Caretta caretta*, dive in response to noise generated with seismic airguns (array peak source level 252 dB re 1 uPa)[34] and underwater explosions can be lethal to Kemp's Ridley sea turtles (*Lepidochelys kempii*)[35].

4.20 Dr Childerhouse in his Statement of Evidence reviewed data on the underwater noise produced by a range of sources. Similar drilling operations to that proposed have a broadband energy profile at between 10Hz and 500Hz. This is the range to which the above New Zealand fish species are most sensitive.

4.21 Given the sensitivity of fish, it is possible that there may be some masking of individual fish calls in the vicinity of the drilling rig during drilling campaigns.

4.22 Movement away from the drilling rig should reduce the risk of individual fish, sharks and marine reptiles from being exposed long-term to damaging levels of sound. From a population perspective, the effects of underwater sound produced during drilling operations on fish, shark and marine reptiles in the

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[32] Fewtrell, J.L.; McCauley, R.D. (2012). Impact of air gun noise on the behaviour of marine fish and squid. Marine Pollution Bulletin 64: 984–993.

[33] Chao Peng, Xinguo Zhao and Guangxu Liu (2015). Noise in the Sea and Its Impacts on Marine Organisms. Environmental Research and Public Health ISSN 1660-4601 www.mdpi.com/journal/ijerph

[34] DeRuiter, S.; Larbi Doukare, K. Loggerhead turtles dive in response to airgun sound exposure. *Endanger. Species Res.* **2012**, *16*, 55–63.

[35] Klima, E.F.; Gitschlag, G.R.; Renaud, M.L. Impacts of the explosive removal of offshore petroleum on sea turtles and dolphins. Mar. Fish. Rev. 1988, 50, 33–42.

STB is likely to be, at most, minor for sensitive rare species, and negligible for all others.

Artificial lighting on the drilling rig and support vessels

4.23 Artificial lighting on the drilling rig and support vessels has the potential to attract some species of fish, sharks and marine reptiles and repel others to/from the area immediately adjacent to the light source. Species attracted to surface lighting may become more vulnerable to predation by predatory fish, sharks and seabirds. Species that spend time at or near the sea surface will have the greatest exposure to artificial light, while benthic and demersal species will have very little exposure. There is little data available to indicate the behaviour of New Zealand fish and shark species to artificial light sources.

4.24 Given that artificial lighting will be confined to areas immediately adjacent to the rig and support vessels and the very small footprint of the these areas compared to the size of the Tui field, it is highly unlikely it will have any significant ecological impact on fish, shark or marine reptile populations in the AOI.

Physical disturbance or exclusion from the space occupied by the drilling rig and support vessels

4.25 The drilling rig and its anchoring system will, for a period, create disturbance and occupy space in the water column and on the seabed normally used by a wide variety of fish, sharks and marine reptiles.

4.26 The space occupied by these structures is very small compared to the known scale of patterns of movement undertaken by fish, sharks and marine reptiles (see summary Table 4-1 in MacDiarmid, Thompson and Grieve 2015)[36].

[36] MacDiarmid, A.; Thompson, D.; Grieve, J. (2015). Assessment of the scale of marine ecological effects of seabed mining in the South Taranaki Bight: Zooplankton, fish, kaimoana, seabirds and marine mammals. NIWA Client Report WLG2015-13 Prepared TTRL. Available on the EPA website.

4.27 Consequently, it is highly unlikely that that the levels of disturbance or space occupation resulting from the proposed activities will have any significant ecological effect on fish, shark or marine reptile populations in the AOI.

5. POTENTIAL IMPACTS FROM DECK DRAIN DISCHARGES

Effects on plankton, fish, and marine reptiles

5.1 My understanding is that harmful substances would not be intentionally discharged through the deck drainage system but that residual amounts remaining after cleanup from accidental spills and splashes could be washed into it with rain water. Tamarind has recently provided details about the Offshore Processing Drainage system and a list of harmful substances that would be used on board the rig[37]. Given the intent to capture harmful substances before they enter deck drains and the likely (though undocumented) rapid rate of dilution by waves and currents in the enormous volume of water surrounding the drilling rig if discharges to the environment did occur, I concur with the IA that the overall impact of the deck drain discharges on plankton, fish, or marine reptiles in the STB is likely to be negligible[38] and without any significant ecological effect.

6. POTENTIAL IMPACTS FROM UNPLANNED ACTIVITIES

Exposure of plankton, fish and marine reptiles to hydrocarbon release from loss of well control event or diesel spill

6.1 Section 7 of IA describes a range of possible unplanned events that could occur, including: accidental spills of hydrocarbons and other chemicals (that are not discharges to the rig's deck drainage system), loss of well control; dropped objects and a marine vessel incident. Of these, accidental chemical spills, loss of well control resulting in a release of oil to the marine environment and a vessel incident resulting in the release of fuel to the marine environment, have the potential to affect plankton, fish and marine reptiles.

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[37] Refer to the RFI Response and Evidence of Iain McCallum

[38] Refer to the IA, page 179

6.2 In the unlikely event of a loss of well control event or a spill of diesel occurring, direct effects on organisms may vary. Marine reptiles, because they must come to the sea surface periodically to breath, are highly vulnerable. Research shows that when fish eggs, larvae or adults come into direct contact with oils typically heavier than Tui field crude oil various physiological and behavioural changes may occur (e.g. Clark 2001[39], Hjermann et al. 2007[40] Hodson et al. 2011[41]; Incardona et al. 2014[42,]). Toxicological mechanisms are complex, as crude oil is a mixture of different hydrocarbons and other organic and inorganic substances, and its composition varies greatly between oil types (Hjermann et al. 2007). Light volatile hydrocarbons are typically particularly toxic but evaporate to the atmosphere more quickly than heavy oils.

6.3 The most vulnerable fish life stages when spilt oil or diesel is mixed into the water column during rough conditions will be pelagic fish eggs and larvae in the vicinity of the spill. These are planktonic and, along with other plankton groups, are thus unable to escape and will be exposed to any toxic compounds in the water column.

6.4 Potentially exposed when spills of oil or diesel reach nearshore and are well mixed in shallow water, are shallow inshore obligate reef fish species such as triplefins, marblefish, and butterfish, as well as fished invertebrate species such as paua, kina, and rock lobsters as these are unlikely to move away from affected reefs.

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[39] Clark RB (2001) Marine Pollution, Oxford University Press, Oxford

[40] Hjermann, D.O.; Melsom, A.; Dingsør, G.E.; Durant, J.M.; Eikeset, A.M.; Røed, L.P.; Ottersen, G.; Storvik, G.; Stenseth, N.C. (2007) Fish and oil in the Lofoten–Barents Sea system: synoptic review of the effect of oil spills on fish populations. Marine Ecology Progress Series 339: 283–299.

[41] Hodson, Collier and Martin (2011). Toxicity of oil to fish – Potential effects of an oil spill into the Kitimat River from a Northern Gateway Pipeline Rupture, Technical Data Report, Enbridge Northern Gateway Project, 113 p.

[42] Incardona et al. (2014). Deepwater Horizon crude oil impacts the developing hearts of large predatory pelagic fish. PNAS early edition, see www.pnas.org/cgi/doi/10.1073/pnas.1320950111.

6.5 Less likely to be exposed in all scenarios, because they are highly mobile, are pelagic fish species commonly occurring near the water surface, such as horse mackerel. Juvenile and adult pelagic fish appear to be capable of avoiding water with high hydrocarbon concentrations (Hjermann et al. 2007) (Parrish 1999)[43], so pelagic fish may avoid the area immediately surrounding the site of a crude oil spill. It is possible that during calm conditions pelagic species that routinely prey on zooplankton (e.g., Jack mackerels) could perceive droplets of hydrocarbon on the sea surface as food. However, the fish may reject these droplets after initial tastes.

6.6 The fish group least likely to be exposed in all scenarios during a spill of oil or diesel includes the deeper water demersal species such as John Dory, red gurnard, and tarakihi. A spill of crude oil will rapidly ascend away from deep seafloor habitats and a surface spill of diesel is unlikely to mix to these depths.

6.7 If a spill of oil or diesel occurred during rough conditions where hydrocarbon droplets were mixed to deeper depths, a greater range of fish species would be exposed to their effects.

6.8 In the IA, the potential impact severity for a loss of well control is considered to be high[44]. I concur with this assessment. However, I note that the likelihood of a hydrocarbon release is assessed as extremely unlikely and for this reason I concur with the IA assessment that the overall impact significance from a hydrocarbon release from a loss of well control is as low as is reasonably practicable.

Cumulative effects

6.9 The IA summarises on pages 182-184 the potential for cumulative effects of the proposed operations with impacts deriving from other authorised activities in the AOI. I agree that there is some potential, albeit limited, for the cumulative effects of noise generated by proposed operations and other authorised activities on rare noise-sensitive species. In my opinion, due to

[43] Parrish, J.K. (1999). Using behaviour and ecology to exploit schooling fishes. Environmental Biology of Fishes 55: 157-181.

[44] Refer to the IA, page 164

the small and highly localised scale of the other impacts of the proposed activities, the potential for adverse cumulative effects with other authorised activities in the AOI on turbidity, sea floor disturbance, or discharge of materials with respective to zooplankton, fish, sharks and marine reptiles is negligible.

7. RESPONSE TO EPA KEY ISSUES REPORT AND TECHNICAL REVIEWS

7.1 Neither the EPA Key Issues Report nor any of the Technical Reviews raised issues or concerns about the effect of the proposed activities on plankton, fish, sharks, or marine reptiles.

8. RESPONSE TO ISSUES RAISED BY SUBMITTERS

8.1 None of the submitters raised concerns about the effect of the proposed activities on plankton or marine reptiles.

8.2 A small number of submitters raised concerns about potential effects of the proposed activities on fish and fisheries. Dr Gibbs responds with respect to fisheries in her evidence.

8.3 Te Korowai o Ngāruahine Trust requested that the consent holder agree to fund, over the course of the consent period fish population surveys to robustly assess the direct, indirect and cumulative impacts of the programme on potentially affected marine species. I consider that given the likely negligible and unmeasurable effects of the proposed activities on fish populations in the STB that such a survey would not achieve the desired outcomes.

8.4 Robert Warrington's submission raises concerns about the tuna (short and long-finned eel) run from Hokio Beach, near Levin, and whether the proposal and any ‘pollution’ would harm the run. In my opinion this is highly unlikely and that effects of the proposed activities on tuna during their adult ocean migratory phase (tuna heke or tuna whakaheke) from, or larval return to, any of the river systems feeding into the STB would be negligible and unmeasurable.

9. CONCLUSION

9.1 Overall, I conclude that the effects of the proposed activities on the populations of plankton, fish, shark, and marine reptile species in the STB will be negligible. At most there may be some very localised effects of suspended and/or deposited sediments causing individual fish to move away from the area immediately around the anchors and mooring lines, and possibly some localised effects of noise from the drilling operations on communication among individuals of vocalising fish species.

9.2 In the unlikely event of a crude oil spill (in a worst-case scenario), or a spill of diesel, marine reptiles, pelagic fish eggs and larvae and phytoplankton and zooplankton in the vicinity of the spill will be the most vulnerable, followed by shallow inshore obligate reef fish and invertebrate species. Less likely to be exposed in all situations are pelagic fish and shark species occurring near the water surface. The fish least likely to be exposed in all situations are the deeper water demersal and benthic fish and shark species.

AB MacDiarmid

ALISON BRONWYN MACDIARMID
20 July 2018