5.3.10 Zone 10 North of Mangrove Embayment - 189 Glenbrook Beach Road North

The diverse rush marsh - salt marsh habitat extended north of the embayment continuing but becoming patchy and narrower as the protection from the extensive area of mangroves diminished. In the upper areas where the rush marsh became patchy, herbaceous salt marsh plants are present, forming long linear meadows in the upper intertidal. On the western most point a slightly raised area of low growing native coastal vegetation with mingimingi, oioi, salt-marsh ribbon-wood and karamu marked the northern most extent of the rush and salt marsh band from the embayment (Photo 21). North of this point, although some mangrove habitat is present in the upper intertidal area, the intertidal was mostly bare of salt marsh and rush marsh (Photo 22).

The terrestrial coastal vegetation is mainly pine with patchy areas of native shrubs, mainly salt-marsh ribbon-wood and flax as the vegetation became more terrestrial. A small area of remnant tree ferns is present on the northern coast of the embayment, and further north a small area of low growing native shrubs, mingimingi, flax, bracken (*Pteridium esculentum*), karamu, are present on the cliff edge.

Photo 21 Rush marsh, mangrove, flax and salt-marsh ribbon-wood, backed by pasture and pines.

Photo 22 Northern outlet coast of embayment, mangroves but no salt marsh or rush mash.

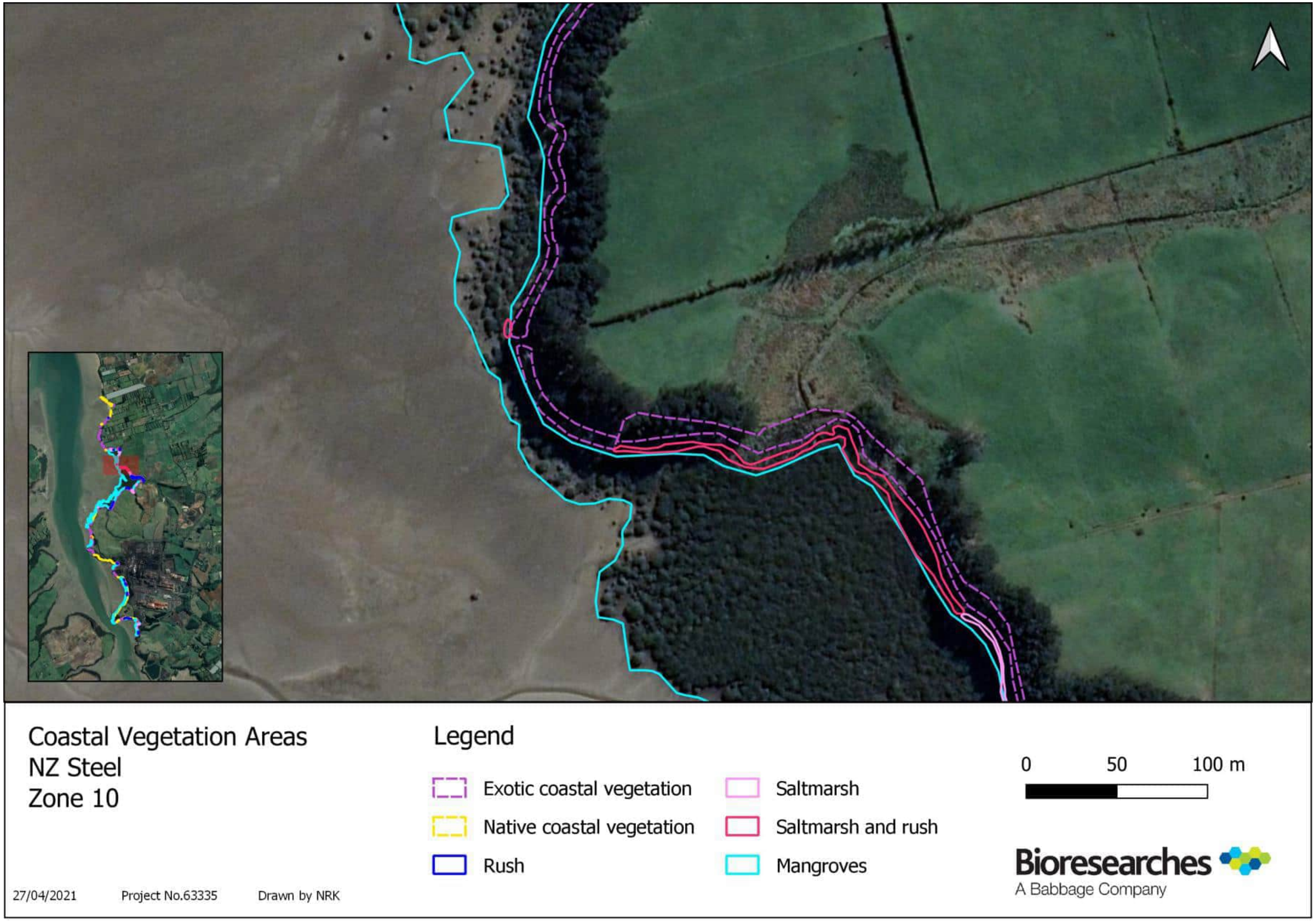

Figure 5.10 Zone 1 0 North of Mangrove Embayment – 189 Glenbrook Beach Road

5.3.11 Zone 11 Embayment 277 Glenbrook Beach Road

Immediately north of the large mangrove filled embayment a smaller mangrove filled embayment is present where a minor stream entered the coast (277 Glenbrook Beach Road). The mangroves covered an area of just under 2 hectares. Between the two embayments the upper intertidal is sandy with occasional small patches of oioi (Photo 23). The coastal edge vegetation is limited to pasture with a row of pines.

On the south-eastern banks of the embayment, where the upper intertidal was sheltered, areas of glasswort (Photo 24) and orache (*Atriplex prostrata*) are present, with occasional patches of sea rush, oioi and bastard grass. Closer to the stream outlet the glasswort covered extensive areas and at one point stretched over 60 m into the intertidal on a raised promontory.

Mangroves, glasswort, sea rush, flax and bastard grass surrounded the mouth of the stream, with salt-marsh ribbon wood, flax, pampas, gorse and pasture grasses transitioning to the pine lined pasture on the land.

North of the stream mouth the glasswort in the upper intertidal in patchy band, occasionally spreading out into large meadows (Photo 25). The glasswort and other salt marsh plants became patchy and scarce as the coastline became less protected outside of the embayment.

Out of the embayment the coast reverted to steep cliffs and a patch of pōhutukawa is present on the outermost northern part of the embayment (Photo 26). The remainder of the coastal terrestrial vegetation is pasture with a row of pine.

Photo 23 Mix of upper intertidal coastal vegetation on south-western shore of the embayment.

Photo 24 Glasswort meadow in upper intertidal of the embayment.

Photo 25 Vegetation near stream mouth, view north.

Photo 26 Patch of pōhutukawa on open coast north of the embayment.

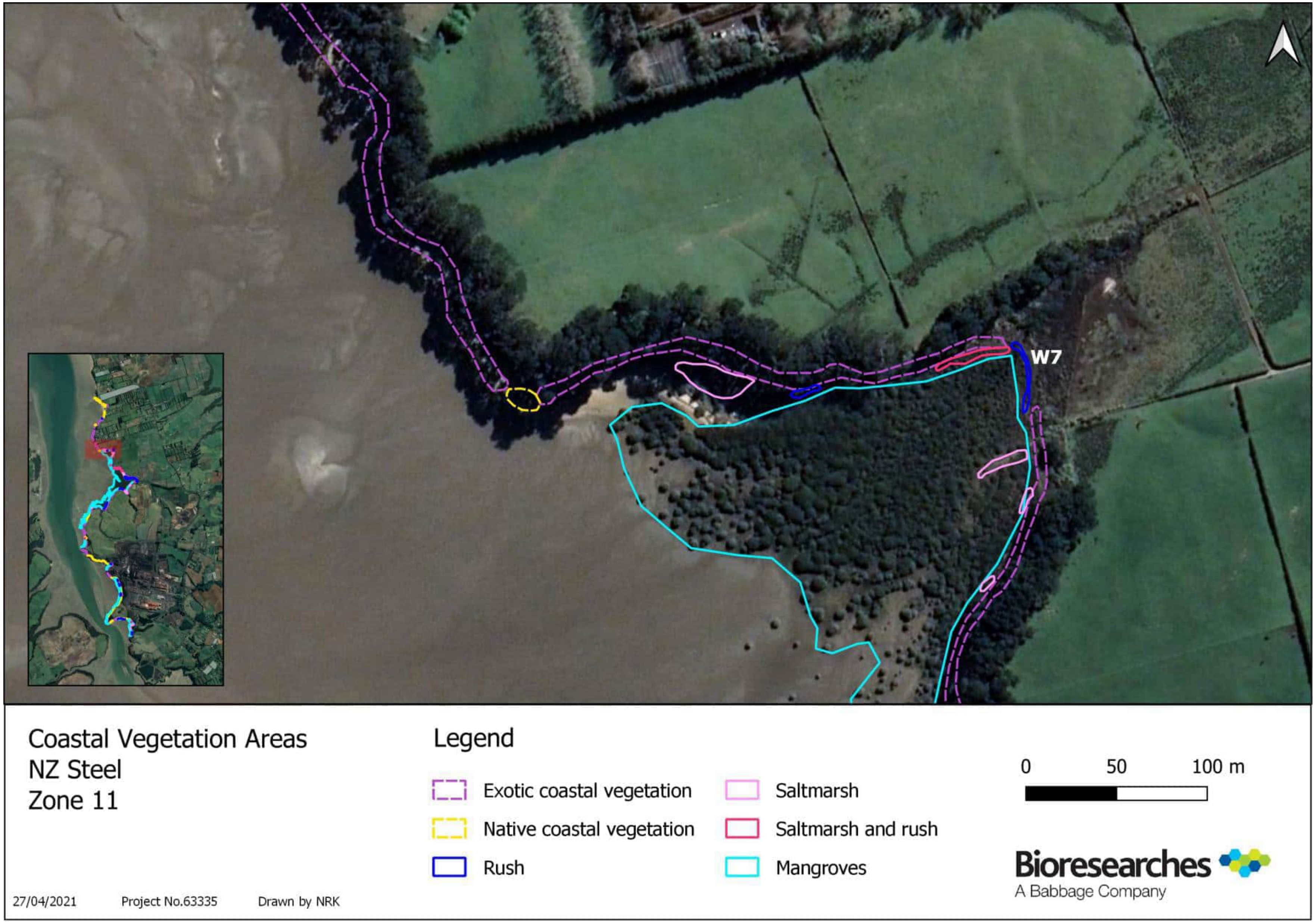

Figure 5.11 Zone 11 Embayment 277 Glenbrook Beach Road

5.3.12 Zone 12 Coast 305 Glenbrook Beach Road

The coastal vegetation off 305 Glenbrook Beach Road (Photo 27), north of the small mangrove embayment, was depauperate. No or only very small patches of coastal intertidal vegetation are present (Photo 28) and the upper cliff is lined with a row of pines, backed by pasture.

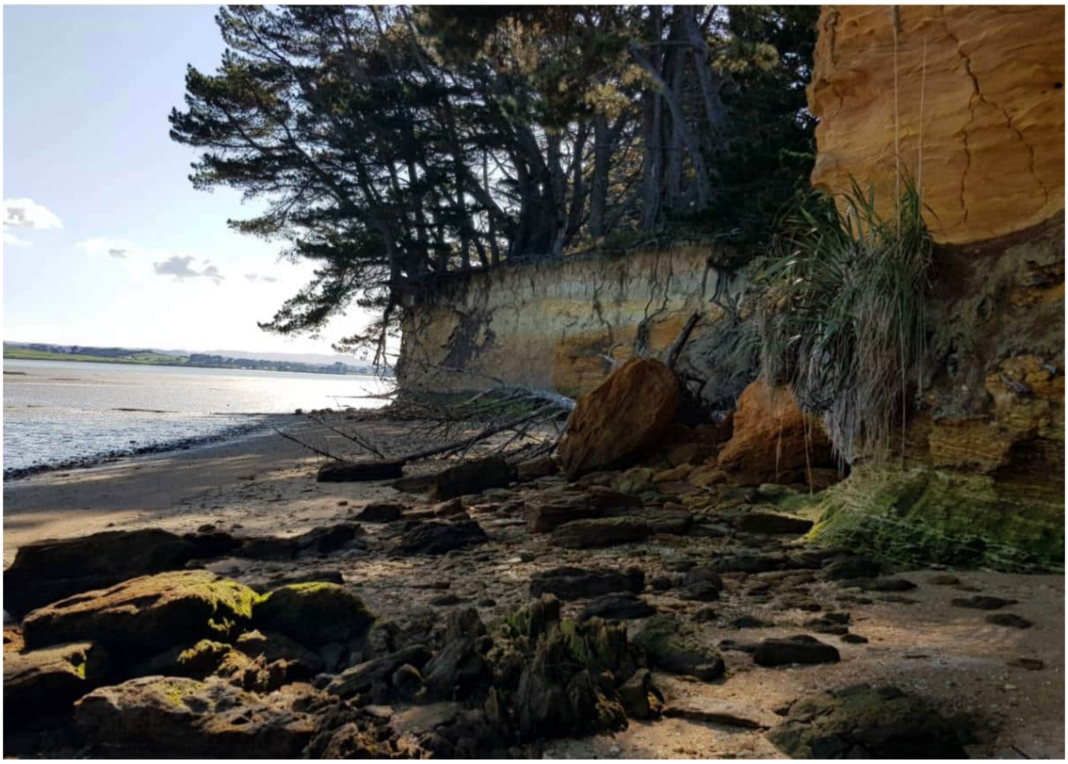

Photo 27 Coast off 305 Glenbrook Road.

Photo 28 View north, illustrating lack of intertidal vegetation and line of pines on coastal margin.

Figure 5.12 Zone 12 Coast 305 Glenbrook Beach Road

5.3.13 Zone 13 Coast 377 Glenbrook Beach Road

The coastal margin northwards, at the properties comprised from 377 Glenbrook Beach Road, have been altered and maintained as lawn with amenity plantings of pōhutukawa on the coastal edge. A rock retaining wall ran approximately 160 m along the foreshore between the coastal cliffs (Photo 29), with intertidal coastal vegetation limited to one small patch (<4 m²) of oioi. The beach is divided by a cliff with a large remnant pōhutukawa (Photo 30), at the base of which an area of rush marsh was present. The northern property, maintained a more naturalised coastal zone with short grass extending to the sandy beach. Areas of rushes and coastal grasses are present at the base of the cliff between the two properties on the beach and at the northern end of the beach where a small stream discharged (Photo 31).

Photo 29 Rock retaining wall at southern end of beach.

Photo 30 Cliff with remnant mature pōhutukawa dividing the beach.

Photo 31 View south along beach from northern end.

Figure 5.13 Zone 13 Coast 377 Glenbrook Beach Road

5.3.14 Zone 14 Rocky Point 381-389 Glenbrook Beach Road

North from the stream outlet at 377 Glenbrook Beach Road to the rocky promontory off 381-389 Glenbrook Beach Road (and to Glenbrook Beach) the coastal zone is vertical cliffs with remnant mature pōhutukawa alternating with mature pines (Photo 32). No intertidal coastal vegetation is present (Photo 33).

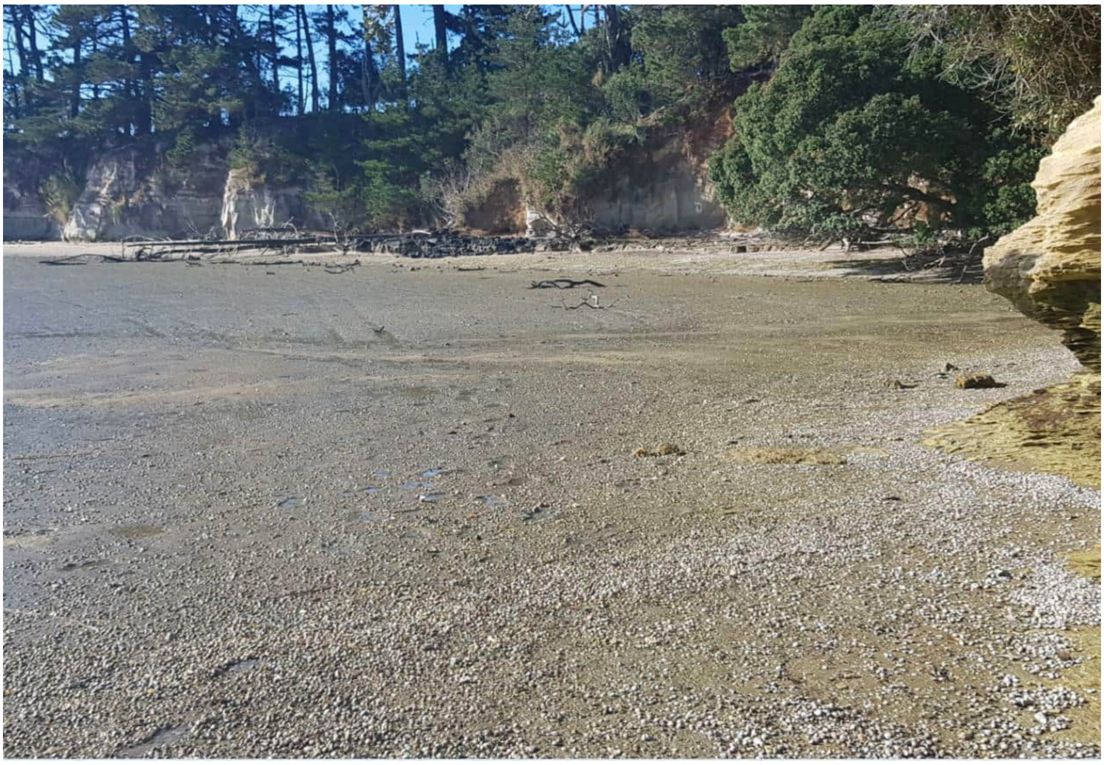

Photo 32 Pohutukawa and pine coastal vegetation.

Photo 33 Coastal cliffs and sandy intertidal, view north towards Glenbrook Beach.

Figure 5.14 Zone 14 Rocky Point 381-389 Glenbrook Beach Road

6. COASTAL BIRDS

6.1 Northside - Southside Outfall Area

The Outfall areas were surveyed from the Southside Pond site. That provided visibility (within practicable reason) to both the northern (Northside and Southside Outfalls) and southern (Ruakohua Spillway) areas. Weather conditions with air temperature, wind, and air pressure were recorded every hour (Table A4.1 in Appendix 4).

The hourly counts of birds recorded using the Northside/Southside intertidal habitat are presented in Table 6.1 to Table 6.4. Species with a national conservation rating (Robertson *et al*, 2107) are shown as ©.

Table 6.1 Numbers of Birds Recorded Using the Northside/Southside Habitats – May 2020

TIME	0900	1000	1100	1200	1300	1400	mean
TIDAL STATE	HW+1	HW+2	HW+3	HW+4	HW+5	LW	
Banded dotterel©	-	-	-	1FI	-	-	0.2
Black-backed gull	-	-	1REI	1REI	1REW	-	0.5
Caspian tern©	-	1FW	1REI	2REI	1REI	1REI	1.0
Little black shag©	-	3FW	-	-	-	-	0.5
Little shag	-	1FW	1FW	2REI	-	1FW 1REI	1.0
Mallard	-	11REW	14FW 14REI	2FW 24REI	10FI 1REI 36REW	49FW	26.8
Pied shag©	-	2FW	2REI	2REI	2FW	1REI	1.5
Pied stilt	-	-	4FI	39FI	29FI	41FI	18.8
Red-billed gull©	-	-	-	2REI	2REI	1REI	0.8
South Island pied oystercatcher©	-	-	54FI 4REI	72FI 10REI	60FI 46REI	124FI 6REI	62.7
Variable oystercatcher©	-	-	1REI	1REI 1FI	3FI	2FI	1.3
White-faced heron	-	-	-	5FI	12FI	27FI	7.3
White-fronted tern©	-	-	1REI	-	-	-	0.2
TOTAL NUMBER	**0**	**18**	**97**	**164**	**203**	**254**	**122.7**

Table 6.2 Numbers of Birds Recorded Using the Northside/Southside Habitats – August 2020

TIME	0900	1000	1100	1200	1300	1400	mean
TIDAL STATE	HW+3	HW+4	HW+5	LW	LW+1	LW+2	
Australasian gannet	-	2FW	3FW	1FW	-	-	1.0
Black-backed gull	9REI	5REI	5REI	2REI	-	-	3.5
Black shag©	-	-	1REI	1REI	1REI	1REI	0.7
Canada goose	12REW	9REI	7FI	9FI	9REI	9REI	9.2
Caspian tern©	1REI	-	1REI	-	-	-	0.3
Eastern bar-tailed godwit©	-	-	3FI	-	-	-	0.5
Kingfisher	-	1FI	-	-	-	-	0.2
Little shag	1REI	1REI	1REI	-	-	3REI	1.0
Mallard	4REI	2REI	-	2REI	4REW 2FW	1REW 2FW	2.8
Pied shag©	2REI	1REI	-	10REI	3REI	-	2.7
Pied stilt	-	4FI	16FI 6REI	29FI	8REI 25FI	I 6FI	15.7
South Island pied oystercatcher©	3REI 1FI	10FI	3REI 8FI	11REI 5FI	8REI 5FI	2REI 11FI	11.6
Variable oystercatcher©	1FI	1FI	1REI	1REI	1FI	1FI	1.0
White-faced heron	2FI	1FI	1FI	3FI	1FI	-	1.3
TOTAL NUMBER	**36**	**37**	**56**	**74**	**67**	**36**	**51.0**

Table 6.3 Numbers of Birds Recorded Using the Northside/Southside Habitats – October 2020

TIME	1030	1130	1230	1330	1430	1530	mean
TIDAL STATE	HW+1	HW+2	HW+3	HW+4	HW+5	LW	
Black-backed gull						2REI	0.3
Caspian tern©			2REI				0.3
Kingfisher			1ROP				0.2
Mallard				1FI 3REI		2FW	1.0
Pied stilt						1FI	0.2
Royal spoonbill ©				3FI	4FI	3FI	2.3
South Island pied oystercatcher©			10FI	8FI 2REI	10FI 2REI	12FI	7.3
Variable oystercatcher©					1FI		0.2
White-faced heron		1FI	1FI	4FI	12FI	11FI	4.8
TOTAL NUMBER	**0**	**1**	**14**	**21**	**29**	**31**	**16.0**

Table 6.4 Numbers of Birds Recorded Using the Northside/Southside Habitats – January 2021

TIME	1000	1100	1200	1300	1400	1500	mean
TIDAL STATE	HW+4	HW+5	LW	LW+1	LW+2	LW+3	
Black-backed gull	-	1REI	-	-	-	-	0.2
Caspian tern©	2REI	1REI	-	-	1REI	-	0.7
Eastern bar-tailed godwit©	21FI	61FI	65FI	2FI	-	-	24.8
Lesser knot ©	1FI	-	-	-	-	-	0.2
Little shag	-	1REI	1REI	-	-	-	0.3
Mallard	-	5FW	5FW	1FI	-	-	1.8
Pied shag©	1REI	7REI	5REI	8REI	7REI	1REI	4.8
Pied stilt	14FI	38FI	31FI 6REI	15FI 1REI	1FI	-	17.7
South Island pied oystercatcher©	66FI 16REI	58FI 19REI	43FI 14REI	50FI 43REI	65FI 50REI	30FI 56REI	82.5
Variable oystercatcher©	-	-	1FI	1FI	2REI	-	0.8
White-faced heron	2FI	4FI	-	3FI	3FI	-	2.0
White-fronted tern©	-	1FW	1FW 1REI	-	-	-	0.5
TOTAL NUMBER	**123**	**196**	**173**	**125**	**129**	**87**	**138.8**

6.1.1 Diversity Across Seasons

A total of 20 species were recorded, which is a relatively high diversity and indicates favourable overall habitat conditions for coastal birds. Of those species, 12 have national conservation ratings with 3 threatened species (banded dotterel, caspian tern and lesser knot) and 9 at risk species (black shag, eastern bar-tailed godwit, little black shag, pied shag, red-billed gull, royal spoonbill, South Island pied oystercatcher, variable oystercatcher and white-fronted tern). The remaining species are not considered to be of national conservation concern (Robertson *et al.* 2017) – Australasian gannet, black-backed gull, Canada goose, kingfisher, little shag, mallard, pied stilt and white-faced heron.

6.1.2 Seasonal Abundance and Dominance

The abundance of all species combined per seasonal survey is summarised in Table 6.5.

Table 6.5 Total numbers of birds – Northside/Southside Habitats

DATE	Mean	SD	Maximum
18 May 2020 (Autumn)	122.7	102.1	254
14 August 2020 (Winter)	51	17.1	74
14 October 2020 (Spring)	16	13.4	31
22 January 2021 (Summer)	138.8	39.1	196

The highest numbers of birds were recorded in the autumn and summer surveys with relatively low numbers in winter and spring, mainly related to the absence of most of the overseas migrants (e.g. eastern bar-tailed godwit and lesser knot) in winter, and the absence of most of the birds that migrate within New Zealand to breed (e.g. South Island pied oystercatcher and banded dotterel) in spring. In addition, a number of species such as white-faced heron and pied stilt may move inland to feed and breed during winter and spring. Non-breeding birds of both overseas and internal migrant species can remain in the Manukau Harbour habitats over the winter period.

The dominance of species in the Northside/Southside habitats based on the average numbers recorded in each survey is presented in Table 6.6.

Table 6.6 Dominant species by number – Northside/Southside Habitats

DATE	Most dominant	Second most dominant	Third most dominant
18 May 2020 (Autumn)	SIPO	mallard	pied stilt
14 August 2020 (Winter)	pied stilt	SIPO	Canada goose
14 October 2020 (Spring)	SIPO	white-faced heron	royal spoonbill
22 January 2021 (Summer)	SIPO	eastern bar-tailed godwit	pied stilt

Note: SIPO stands for "South Island pied oystercatcher"

Overall, the most dominant species in the Northside/Southside area was the South Island pied oystercatcher with notable numbers of eastern bar-tailed godwit, mallard and pied stilt present at times. The average numbers of the most common species are summarised in Table 6.7.

Table 6.7 Summarised average numbers of dominant species – Northside/Southside

Dominant species	Autumn	Winter	Spring	Summer
South Island pied oystercatcher	62.7	11.6	7.3	82.5
Pied stilt	18.8	15.7	0.2	17.7
Mallard	26.8	2.8	1	1.8
White-faced heron	7.3	1.3	4.8	2
Eastern bar-tailed godwit	0	0.5	0	24.8
Canada goose	0	9.2	0	0
Royal spoonbill	0	0	2.3	0

The above results illustrate the seasonal changes in the numbers of the dominant species; low numbers of South Island pied oystercatcher were present in autumn and spring with most birds having moved to breeding habitats mainly in the South Island. Similarly, pied stilt numbers were low in spring with most of the population having moved to nesting habitats beyond the Harbour and bar-tailed godwits were virtually absent until birds returned from Northern Hemisphere (western Alaska) nesting areas. Conversely, the average number of white-faced herons was relatively high in spring; that was likely to be the result of birds remaining along the coastal edge to nest in tall pines in particular, and juveniles moving to the intertidal habitats in spring.

Therefore, the above results reflect normal seasonal changes in the coastal bird population and do not infer that there was any deterioration of the Northside/Southside habitats in winter and spring for example. In summer, a notable coastal bird population was present. That population in summer was most abundant five hours after high water and at low water and the key habitats appeared to be the intertidal area between the spit and the shoreline and the landward edges of the spit itself; an attraction of this part of the coastline is likely to be the diversity of habitat types that are present. Notable numbers of birds present in the summer survey were 65 eastern bar-tailed godwit, 8 pied shag, 38 pied silt and 115 South Island pied oystercatcher.

6.1.3 Habitat Use

Feeding was the predominant habitat use activity with an overall average of 65.6% (range 48.5 – 85.4) followed by feeding in the intertidal habitat – average overall = 26.0% (range 11.5 – 43.0) (Table 6.8). The other activities were relatively minor. The increase in resting records for the winter survey was the result of the increased presence of species that typically rest rather than feed in exposed intertidal areas – black-backed gull, black shag, canada goose, little shag, mallard and pied shag – and does not suggest that the intertidal area was less attractive for feeding in that period. The overall feeding to roosting ratios are typical in a situation where there is no high tide roost present (pers. obs.). Wading birds typically rest following a period of feeding and may cease feeding entirely after about half tide rising, to 'stage' or aggregate prior to moving to a high tide roost elsewhere.

Table 6.8 Summary of Northside/Southside habitat use (percentages of the records)

SEASON	HABITAT USE				
	Feeding in intertidal	Feeding in water	Resting on intertidal	Resting on water	Resting/Roosting on tree/structure
18 May 2020 (Autumn)	65.8	10.3	17.4	6.5	-
14 August 2020 (Winter)	48.5	2.7	43	5.8	-
14 October 2020 (Spring)	85.4	2.1	11.5	-	1.0
22 January 2021 (Summer)	69.2	1.4	29.4	-	-
Overall	*65.6*	*5*	*26*	*3.3*	*0.1*

Note: data compiled from Table 6.1 to Table 6.4

6.2 Ruakohua Spillway Area

The spillway area was surveyed from the Southside Pond site. Weather conditions (air temperature, wind, and air pressure) were recorded every hour (Table A4.1 in Appendix 4)

The hourly counts of birds recorded using the Ruakohua Spillway embayment intertidal habitat are presented in Table 6.9 to Table 6.12. Species with a national conservation rating are shown as ©.

Table 6.9 Numbers of Birds Recorded Using the Ruakohua Habitats – May 2020

TIME	0900	1000	1100	1200	1300	1400	mean
TIDAL STATE	HW+1	HW+2	HW+3	HW+4	HW+5	LW	
Kingfisher	-	-	1FI	-	-	-	0.2
Little shag	5REI	4REI	-	-	-	-	1.5
Mallard	-	2REW	-	-	-	-	0.3
Pied shag©	1REI	3REI	-	-	-	-	0.7
Pied stilt	-	2FI 2REW	10FI 2REI	9FI 3REI	12FI	10FI	8.3
Red-billed gull©	-	-	1REI	1REI	-	-	0.3
Royal spoonbill©	-	-	-	-	-	1FI	0.2
South Island pied oystercatcher©	-	4FI	1REI	24FI	36FI	23FI	14.7
Variable oystercatcher©	-	-	-	-	-	1FI	0.2
White-faced heron	6REI	30FI 9REI	63FI	38FI	34FI	32FI	35.3
TOTAL NUMBER	**12**	**56**	**78**	**75**	**82**	**67**	**61.7**

Table 6.10 Numbers of Birds Recorded Using the Ruakohua Habitats – August 2020

TIME	0900	1000	1100	1200	1300	1400	mean
TIDAL STATE	HW+3	HW+4	HW+5	LW	LW+1	LW+2	
Black-backed gull	-	-	-	1REI	-	-	0.2
Canada goose	9REI	-	-	-	-	-	1.5
Kingfisher	1FI	1FI	-	-	-	1FI	0.5
Little shag	-	3REI	-	-	-	-	0.5
Pied stilt	4FI	-	-	-	3FI	4FI	1.8
Red-billed gull©	-	-	-	-	-	7FI	1.2
South Island pied oystercatcher©	-	-	4REI	-	5FI	-	1.5
White-faced heron	-	1REI	5FI	2FI	3FI	6FI	2.8
TOTAL NUMBER	**14**	**5**	**9**	**3**	**11**	**18**	**10.0**

Table 6.11 Numbers of Birds Recorded Using the Ruakohua Habitats – October 2020

TIME	1030	1130	1230	1330	1430	1530	mean
TIDAL STATE	HW+1	HW+2	HW+3	HW+4	HW+5	LW	
Black-backed gull					2REI	2REI	0.7
Caspian tern©				1FW		2REI	0.5
Kingfisher				1FI			0.2
Mallard		2FI	2FW				0.7
South Island pied oystercatcher©					10FI	31REI	6.8
Variable oystercatcher©						2FI 2REI	0.7
White-faced heron		16REI	28FI	18FI	27FI	46FI	22.5
TOTAL NUMBER	**0**	**18**	**30**	**20**	**39**	**85**	**32.0**

Table 6.12 Numbers of Birds Recorded Using the Ruakohua Habitats – January 2021

TIME	1000	1100	1200	1300	1400	1500	mean
TIDAL STATE	HW+4	HW+5	LW	LW+1	LW+2	LW+3	
Pied stilt	1FI	-	-	-	-	-	0.2
South Island pied oystercatcher©	-	-	1REI	-	-	-	0.2
White-faced heron	8FI	11FI	13FI	11FI	9FI 3REI	12FI	11.2
White-fronted tern©	-	1FW	1FW	2FW	-	-	0.7
TOTAL NUMBER	**9**	**12**	**15**	**13**	**12**	**12**	**12.2**

6.2.1 Diversity Across Seasons

Relative to the other two survey areas, the embayment adjacent to the Spillway is small and presents limited habitat that is dominated by a muddy substrate and rock outcrops. Nevertheless, a total of fourteen species were recorded including one threatened species (caspian tern) and six at risk species – pied shag, red-billed gull, royal spoonbill, South Island pied oystercatcher, variable oystercatcher and white-fronted tern. The remaining species, that are not considered to be of conservation concern, were black-backed gull, kingfisher, canada goose, little shag, mallard, pied stilt and white-faced heron. Species diversity was moderate but less than that recorded in the Northside/Southside habitats.

6.2.2 Seasonal Abundance and Dominance

The abundance of all species combined per seasonal survey is summarised in Table 6.13.

Table 6.13 Total numbers of birds – Ruakohua Spillway Habitats

DATE	Mean	SD	Maximum
18 May 2020 (Autumn)	61.7	26.0	82
14 August 2020 (Winter)	10.0	5.6	18
14 October 2020 (Spring)	32.0	29.1	85
22 January 2021 (Summer)	12.2	1.9	15

Numbers of birds were relatively low throughout the surveys; the average number was highest in autumn and enhanced by notable numbers of pied stilt (max. = 12), South Island pied oystercatcher (max. = 36) and white-faced heron (max. = 63) given the small area of feeding habitat. Numbers were low in summer, in contrast to the Northside/Southside habitats, and equally low in winter.

The dominance of species in the Ruakohua Spillway embayment based on the average numbers recorded in each survey is presented in Table 6.14

Table 6.14 Dominant species by number – Ruakohua Spillway Habitat

DATE	Most dominant	Second most dominant	Third most dominant
18 May 2020 (Autumn)	white-faced heron	SIPO	pied stilt
14 August 2020 (Winter)	white-faced heron	pied stilt	SIPO Canada goose
14 October 2020 (Spring)	white-faced heron	SIPO	Mallard Black-backed gull Variable oystercatcher
22 January 2021 (Summer)	white-faced heron	white-fronted tern	pied stilt SIPO

Note: SIPO stands for "South Island pied oystercatcher"

The most dominant species was white-faced heron that commonly utilised the muddy substrate that is likely to have supported a population of mud crabs, followed by South Island pied oystercatcher and pied stilt. Numbers of the third tier abundance species and white-fronted tern were low.

The summarised average numbers of the species of Tier 1 and Tier 2 dominance only, are shown in Table 6.15.

Table 6.15 Summarised average numbers of Tier 1 and 2 dominant species – Ruakohua Spillway

Dominant species	Autumn	Winter	Spring	Summer
White-faced heron	35.3	10.0	22.5	11.2
Pied stilt	8.3	1.8	0	0.2
South Island pied oystercatcher	14.7	1.5	6.8	0.2
White-fronted tern	0	0	0	0.7

White-faced heron was most common in autumn and spring as in the Northside/Southside habitats but the presence of other species in low numbers was more incidental rather than reflecting typical seasonal trends.

6.2.3 Habitat Use

Feeding in the intertidal area was the predominant activity with 82.2% of records overall (range = 69.8 – 89.2) with a relatively low level of resting (Table 6.16). Aside from white-faced heron, birds using this area were generally transient in comparison with the other survey areas.

Table 6.16 Summary of Ruakohua Spillway Habitat Use (percentage of the records)

SEASON	HABITAT USE				
	Feeding in intertidal	Feeding in water	Resting on intertidal	Resting on water	Resting/Roosting on tree/structure
18 May 2020 (Autumn)	89.2	-	9.7	1.1	-
14 August 2020 (Winter)	70.0	-	30.0	-	-
14 October 2020 (Spring)	69.8	1.6	28.6	-	-
22 January 2021 (Summer)	89.0	5.5	5.5	-	-
Overall	***82.2***	***1.0***	***16.2***	***0.6***	***-***

Note: data compiled from Table 6.9 to Table 6.12

6.3 Kahawai to North Streams Area

This area was surveyed from a site in coastal edge pine trees to the west of the Kahawai Stream mouth. Weather conditions (air temperature, wind, and air pressure) were recorded every hour (Table A4.2 in Appendix 4).

The hourly counts of birds recorded using the Kahawai to North streams habitats are presented in Table 6.17 to Table 6.20. Species with a national conservation rating are shown as ©.

Table 6.17 Numbers of Birds Recorded in The Kahawai to North streams Habitats – May 2020

TIME	1100	1130	1200	1230	1330	1430	mean
TIDAL STATE		HW+3		HW+4	HW+5	LW	
Banded dotterel©	-	-	-	-	-	1FI	0.2
Black-backed gull	-	-	-	-	-	2REI	0.3
Caspian tern©	-	-	-	1FW	-	-	0.2
Kingfisher	-	-	2FI	-	2FI	-	0.7
Mallard	14REW	10FW 2REI	10FI 17REI	12FI 26REI	14FI 17REI	1FI 38REI	26.8
Pied stilt	5FI	10FI	1FI 1REI	3FI	6FI	1REI	4.5
Red-billed gull©	-	-	-	-	-	2REI	0.3
South Island pied oystercatcher©	56FI	105FI	77FI	78FI 57REI	31FI 3REI	45FI 46REI	83.0
Spur-winged plover	-	-	-	-	-	1REI	0.2
Variable oystercatcher©	-	2FI	-	2FI	-	-	0.7
White-faced heron	8FI	21FI	23FI	22FI	17FI	13FI	17.3
TOTAL NUMBER	**83**	**150**	**131**	**201**	**90**	**150**	**134.2**

Table 6.18 Numbers of Birds Recorded in The Kahawai to North streams Habitats – August 2020

TIME	0900	1000	1100	1200	1300	1400	mean
TIDAL STATE	HW+3	HW+4	HW+5	LW	LW+1	LW+2	
Black-backed gull	1REI	2REI	2REI	5REI	2REI	-	2.0
Caspian tern©	1REI	2REI	-	-	-	-	0.5
Eastern bar-tailed godwit©	-	24FI	21FI	19FI	3FI	3FI	11.7
Kingfisher	5FI	5FI	2FI	3FI	4FI	2FI	3.5
Mallard	-	-	2FW 14REI	2FW 7REI	13REI	1REI	6.5
Pied stilt	2FI 1REI	9FI	9FI 2REI	6FI 1REI	12FI	11FI	8.8
Royal spoonbill©	-	2FI	12FI	-	-	2FI 2REI	3.0
South Island pied oystercatcher©	-	17FI 2REI	13FI	1FI 8REI	17FI 2REI	20FI 1REI	13.5
Variable oystercatcher©	-	-	-	-	-	1FI	0.2
White-faced heron	3FI	4FI	15FI	10FI	9FI	6FI	7.8
Wrybill©	-	3FI	-	-	-	-	0.5
TOTAL NUMBER	**13**	**70**	**92**	**62**	**62**	**49**	**58.0**

Table 6.19 Numbers of Birds Recorded in The Kahawai to North streams Habitats – October 2020

TIME	1000	1030	1130	1230	1330	1430	mean
TIDAL STATE	HW+1.5	HW+2	HW+3	HW+4	HW+5	LW	
Eastern bar-tailed godwit©				171FI	182FI	165FI 9REI	87.8
Kingfisher			2ROP	1FI			0.5
Lesser knot ©				21FI	18FI	42FI	13.5
Mallard	2REW	1FI	7FI 23REW	5FI 18FW 7REI	8FI 4FW 4REI	14FI 3REI	16.5
Royal spoonbill©				4REI	4FI	4FI	2.0
South Island pied oystercatcher©			8FI	23FI	11FI 26REI	13REI	13.5
Spur-winged plover						2REI	0.3
Variable oystercatcher©				2FI	1FI 1REI		0.7
White-faced heron		8FI 3ROP	20FI	28FI	23FI	38FI	20.0
TOTAL NUMBER	**2**	**12**	**60**	**280**	**282**	**290**	**154.3**

Table 6.20 Numbers of Birds Recorded in the Kahawai to North streams Habitats – January 2021

TIME	1000	1100	1200	1300	1400	1500	mean
TIDAL STATE	HW+1	HW+2	HW+3	HW+4	HW+5	LW	
Black-backed gull	-	-	-	1REI	-	1REI	0.3
Caspian tern©	1FW	1FW	-	1REI	-	1REI	0.7
Eastern bar-tailed godwit©	-	-	-	85FI	30FI 2REI	-	19.5
Kingfisher	1ROP	-	1ROP	-	-	-	0.3
Lesser knot ©	-	-	-	76FI	140FI	-	36.0
Little shag	1REI	1REI	-	-	-	-	0.3
Pied stilt	4ROP	3ROP	-	2FI	3FI	7FI	3.2
Pūkeko	-	1FI	-	-	-	-	0.2
South Island pied oystercatcher©	-	-	103FI	124FI	10FI 33REI	8FI 24REI	50.3
Variable oystercatcher©	-	-	3FI	1FI	2FI	3REI	1.5
White-faced heron	-	7FI 1ROP	15FI	19FI	22FI	27FI	15.2
TOTAL NUMBER	**7**	**14**	**122**	**309**	**242**	**71**	**127.5**

6.3.1 Diversity Across Seasons

A total of 17 species were recorded, which is a relatively high diversity that is similar to that recorded in the Northside/Southside area and also indicates favourable overall habitat conditions. Of the 17 species, 9 have a national conservation rating with 4 threatened species (banded dotterel, caspian tern, lesser knot and wrybill) and 5 at risk species (eastern bar-tailed godwit, red-billed gull, royal spoonbill, South Island pied oystercatcher and variable oystercatcher). The remaining species, that are not of national conservation concern, were black-backed gull, kingfisher, little shag, mallard, pied stilt, Pūkeko, spur-winged plover, and white-faced heron.

6.3.2 Seasonal Abundance and Dominance

The abundance of all species combined per seasonal survey is summarised in Table 6.21.

Table 6.21 Total numbers of birds – Kahawai / North streams Area

DATE	Mean	SD	Maximum
19 May 2020 (Autumn)	134.2	43.7	201
28 August 2020 (Winter)	58.0	26.2	92
27 October 2020 (Spring)	154.3	143.4	290
25 January 2021 (Summer)	127.5	123.8	309

Relatively high numbers of birds were recorded in autumn, spring and summer with lower numbers in winter. The averages for autumn, spring and summer were similar (chi-squared = 2.8; not significant). In contrast to the Northside/Southside area, the average number of birds in the Kahawai/North streams habitats was relatively high in spring as a result of the presence of a large number of eastern bar-tailed godwits. That may be related to the later time of the October survey in the Kahawai/North streams area in comparison with the Northside/Southside area.

The dominance of species in the Kahawai/North streams area based on the average numbers recorded in each survey is presented in Table 6.22.

Table 6.22 Dominant species by number – Kahawai/North Streams

DATE	Most dominant	Second most dominant	Third most dominant
19 May 2020 (Autumn)	SIPO	mallard	white-faced heron
28 August 2020 (Winter)	SIPO	Eastern bar-tailed godwit	pied stilt
27 October 2020 (Spring)	Eastern bar-tailed godwit	white-faced heron	mallard
25 January 2021 (Summer)	SIPO	lesser knot	Eastern bar-tailed godwit

Note: SIPO stands for "South Island pied oystercatcher"

The most common species overall was the South Island pied oystercatcher with notable numbers of eastern bar-tailed godwit and lesser knot, both overseas migrants. The dominance of oystercatchers is mostly consistent with the results for the Northside/Southside habitats, the difference being that pied stilt and eastern bar-tailed godwit were the co-dominant at Northside/Southside and at Kahawai/North streams respectively.

As described for the Northside/Southside habitats, the average numbers of the numerically dominant species in the Kahawai/North streams area also reflect typical seasonal changes in the coastal bird population (Table 6.23). The average numbers of South Island pied oystercatcher were relatively low in winter and spring with a high proportion of the population having left the Harbour to breed, mainly, in the South Island. The populations of both eastern bar-tailed godwit and lesser knot were highest in spring and summer with most of those birds leaving the Harbour in autumn to breed in the Northern Hemisphere. The mallard population was most dominant in autumn; that may have been enhanced by birds moving to the Harbour during the duck shooting season. White-faced herons are generally common throughout the wider area where the intertidal areas are clearly attractive feeding habitats and there are numerous riparian trees, especially pines, for roosting and nesting. Pied stilt was not as common in this area as in the Northside/Southside habitat.

The results indicate a diverse and at times abundant coastal bird population, with high numbers generally occurring towards or at the time of low water. In this area in the summer survey, the total numbers at low water were lower than those after half tide falling as a result of birds either following the low tide line, that had moved beyond the survey area, or moving to exposed habitats nearby and closer to the main low tide channel, but also beyond the survey area.

Notable maxima in spring and summer when the overseas migrants had arrived were 182 bar-tailed godwit and 140 lesser knot using the habitat for feeding. In summer when South Island pied oystercatchers had returned to the Harbour, a maximum of 124 was recorded feeding generally indicating high quality feeding habitat.

Table 6.23 Summarised average numbers of dominant species – Kahawai/North Streams

Dominant species	Autumn	Winter	Spring	Summer
South Island pied oystercatcher	83.0	13.5	13.5	50.3
Eastern bar-tailed godwit	-	11.7	87.8	19.5
Mallard	26.8	6.5	16.5	-
White-faced heron	17.3	7.8	20.0	15.2
Lesser knot	-	-	13.5	36.0
Pied stilt	4.5	8.8	-	3.2

6.3.3 Habitat Use

Feeding was the predominant habitat use activity with an overall average of 81.9% (range 70.4 – 89.5) followed by resting in the intertidal area – average overall = 14.8% (range 7.5 – 26.5) with the other activities minor (Table 6.24). Although there seemed to be an increase in the proportion of feeding birds in the Kahawai/North streams habitat (81.9%) relative to the Northside/Southside habitat (65.6%), that was not ratified by a chi-squared test (chi-squared = 1.8; not significant). Both habitats were notable feeding areas for coastal birds; the main difference between the two areas was that the Kahawai/North streams intertidal habitat was immediately adjacent to a significant high tide roost.

Table 6.24 Summary of Kahawai/North Streams area Habitat Use (percentage of the records)

SEASON	HABITAT USE				
	Feeding in intertidal	Feeding in water	Resting on intertidal	Resting on water	Resting/Roosting on tree/structure
19 May 2020 (Autumn)	70.4	1.4	26.5	1.7	-
28 August 2020 (Winter)	79.5	0.6	19.9	-	-
27 October 2020 (Spring)	86.8	2.5	7.5	2.7	0.5
25 January 2021 (Summer)	89.5	0.3	8.9	-	1.3
Overall	***81.9***	***1.4***	***14.8***	***1.4***	***0.5***

Note: data compiled from Table 6.17 to Table 6.20

6.3.4 High Tide Roost

A significant high tide roost for coastal birds is situated on raised rock platforms on the point to the west of the Kahawai Stream mouth outside, but immediately adjacent to, the Kahawai to North streams area covered in the seasonal surveys. On a Harbour-wide basis, secure and attractive high tide roosting habitats are at a premium and this area is a significant and high-quality coastal bird feature, at least in the context of the wider Waiuku Estuary area. It is secure, being separated from the land by water at high tide and the level of disturbance is very low.

The high tide roost was utilised by high numbers of some species at times, e.g. 290 eastern bar-tailed godwit, 80 lesser knot, 100 pied stilt and 320 South Island pied oystercatcher (Table 6.25). The roost was not monospecific but was utilised by 10 species including both overseas and New Zealand migrants.

Table 6.25 Numbers of Birds Recorded at the Kahawai/North streams High Tide Roost

DATE	19 May 2020 (Autumn)	27 October 2020 (Spring)	25 January 2021 (Summer)
TIME	**1000**	**0850**	**0840**
High tide time (hrs)	**0817**	**0834**	**0904**
Caspian tern©	1	-	2
Eastern bar-tailed godwit©	-	112	290
Lesser knot©	-	2	80
Little shag	1	-	1
Mallard	-	5	-
Pied shag©	4	-	-
Pied stilt	100	-	36
South Island pied oystercatcher©	320	15	320
Spur-winged plover	-	4	-
Variable oystercatcher©	6	3	2
White-faced heron	17	20	-
TOTAL NUMBER	**449**	**161**	**731**

7. SUMMARY

7.1 Surficial Sediment Quality

Metal concentrations of cadmium, chromium, copper, lead and zinc were analysed in sediments from sites Ruakohua Spillway (RS and RO), Northside Outfall (NA and NB), Southside (SC), Kahawai Stream (KS) and North Stream (MZ, SZ and OZ) in 2020, and from sites Northside Outfall (NA and NB), Southside (SC), and Taihiki Control (CD). All of the metal concentrations fell into Auckland Council's 'Green' sediment quality classification. The only exception to this was at Northside A where zinc concentrations in the total recoverable zinc concentration was in the 'Red' category, in both 2020 and 2021, triggering a benthic community assessment at Northside A.

The majority of total recoverable concentrations of cadmium were similar to that recorded in the mud fraction. The major exception was at the Northside Outfall NA site where the total recoverable concentration was significantly higher. This suggests a minor source of cadmium in the vicinity of the Northside Outfall.

The total recoverable concentrations of chromium, copper and lead were similar across all sites which suggests that these metals are not related to a discharge but more associated with fine sediment size particles. However the Taihiki Control total recoverable concentrations of chromium, copper, lead and zinc were lower than that at the mixing zone sites. When just the mud fraction of sediment was analysed the concentration of chromium was very similar across all sites while copper and lead showed a decreasing concentration from the North Stream discharge. The Taihiki Control mud fraction of sediment concentrations were largely similar to the concentrations at the northside and southside outfall sites.

The total recoverable concentrations of zinc suggest a source of zinc in the vicinity of the Northside Outfall, and the mud fraction concentrations, an association with finer sediment particles and a source at the North Stream.

Over time, the total recoverable concentrations of cadmium, chromium, copper, lead and zinc have decreased at the outfall sites between 2003 and 2021, with the exception of zinc at Southside C. The data show numerical increases for cadmium at Northside B and Southside C however thus is the result of changes in analytical detection limits.

Weak acid extraction concentrations of the mud fraction were conducted in 2008 and 2020 for copper, lead and zinc. At the mangrove (MZ) and outer zone (OZ) sites small decreases were recorded, but small increases were recorded for lead and zinc at the settling zone site (SZ). While the concentrations were classified as 'Green' the increases in total recoverable concentration of chromium, copper and zinc at the mangrove and outer zone sites suggest potential accumulative effects and an investigation of the source should be considered along with future monitoring.

In 2020, the sediments from both sites below the Ruakohua Spillway contained high proportions of silt and clay sized particles. The sediments at the three outfall sites had lower proportions of silt and clay sized particles than the spillway sites. Sediment at the Kahawai Stream settling zone site contained a low to moderate proportion of silt and clay. At the North Stream sites, the mangrove zone site contained high proportions silt and clay sized particles, the settling zone site was dominated by fine sand and the outer zone site was largely sandy with fine and very fine sand.

Between 2003 and 2021, sediments from the Northside settling zone (NA) increased in the proportion of silt and clay, while most other grain size proportions either stayed the same or decreased. Sediments from the Northside outer zone (NB) decreased in the proportion of silt and clay, while the proportion of very fine sand increased, and the proportion of all other grain sizes decreased. Sediments from the Southside setting zone (SC) decreased in the proportion of silt and clay, while the proportion of medium and coarse sand increased.

7.2 Benthic Community Health

The need for a benthic health assessment was triggered by levels of total recoverable zinc in sediment exceeding 124 mg/kg dry weight at the Northside A site in both 2020 and 2021. This triggered the assessment of the benthic community at Site Northside A in March 2020, August 2020 and October 2021 and the Control Site in September 2021. In addition, the benthic community was assessed at Northside B in March 2020.

In 2021 the Northside A site obtained a CAP Metals score of 0.0514 and a CAP Mud score of 0.0806. Benthic health was therefore ranked as 4 for both models, which is indicative of poor ecological condition. The CAP metals and CAP mud scores at Northside A have decreased between 2020 and 2021, which suggests minor improvements in benthic community health, however the changes were not sufficient to change the health score of 4.

The Control Site showed lower values than Northside A for both models. The CAP Metals score of -0.0122 was indicative of a moderate health by the model, while the CAP Mud score of 0.0468 matched a poor health condition of the benthic communities.

The TBI scores for 2021 were 0.12 at Northside A and 0.24 at the Control Site, which indicates poor ecological health with low levels of functional redundancy. Historically, TBI scores ranged between 0.1 and 0.2 at both Northside sites, the exception being during the year 2009 at Northside A with a TBI score of 0.24, similar to that of the Control Site monitored in 2021.

The combined health scores at the Northside sites were almost all 1 which matches a “poor” health, the exceptions were from 2014 in which both outfall sites had a combined score of around 0.8 which matches a “moderate” health. The low functional redundancy found in the Waiuku estuary is consistent with low scores found by the Auckland Council monitoring programme in the Manukau at sheltered creeks.

7.3 Shellfish Quality

The density of the oyster populations at Northside Sites 5, 6 and 10, Southside Sites 3 and 5 and the Taihiki Control Site showed decreases between 2010 and 2011. This was most likely the result of a naturally introduced oyster virus which caused widespread mortality of oysters in northern New Zealand. Between 2012 and 2021, the density has remained low at the Taihiki Control Site. The density of oysters at the Northside 5 Site was also very low. Data from the annual monitoring programmes indicate that there has been no outfall related effect on abundance with the Taihiki Control Site showing similar changes in abundance.

There was no particular common trend in mean length of oysters among the sites.

Between the 2020 and 2021 surveys, there was no significant change in the mean condition indices within each site (refer Figure 4.4). The condition indices at each site have generally shown decreases over time, the exception is Southside 5 at which the site location was changed resulting in increased condition indices. These changes parallel the trend in the Taihiki Control Site, indicating a no or less than minor outfall effect on the condition index of oysters.

The lowest concentration of copper was recorded at the Control Site, while Northside 6a had the highest. The dry weight copper concentrations at the mixing zone sites were not statistically different from the Taihiki Control Site, indicating the discharge of copper is not significant. Over the course of the monitoring the mean copper concentrations in oysters have increased between May 1985 and August 2021 at the Taihiki Control Site and all mixing zone sites, except Northside 5. None of the changes were statistically significant.

The lowest concentration of zinc was recorded at the Control Site, while the Northside outfall site (Northside 6a) had the highest mean concentration of zinc at 7,033 mg/kg dry weight, which was significantly higher than at all other sites. These results show an outfall effect of increased zinc in oysters in the vicinity of the Northside outfall within the mixing zone. The effects of the Northside outfall seem to be confined to relatively close to the discharge point of the Northside outfall.

The mean concentration of zinc in oysters has increased over time between 1985 and 2021 at the Taihiki Control Site. The changes over time within the mixing zone were varied with sites Northside 5 and 10 and Southside 3a and 5a all showing decreases while sites Northside 6a showed an increase. The changes over time were not statistically significant.

Wet weight zinc concentration data showed that none of the sites within the mixing zone had reached the ‘alert’ wet weight concentration of 1,000 mg/kg wet weight zinc, nor had the sites outside the mixing zone exceeded the response level of 500 mg/kg wet weight zinc. Since the late 1990s, all mixing zone sites with the exception of Northside 6 have showed declining trends with zinc concentrations becoming more similar to the concentrations recorded at the Taihiki Control Site.

7.4 Coastal Vegetation

The coastal terrestrial and intertidal vegetation on the eastern side of the Waiuku Estuary, Manukau Harbour was surveyed in 2020, from 300 m south of the Southside Outfall to 381-389 Glenbrook Beach Road, north of the Site. Much of the Waiuku Estuary is soft mud, with areas of sandstone and occasional deposits of hard substrate (mostly discarded ballast from historic shipping). The majority of the landward landscape is pasture, with some industrial land (New Zealand Steel) and to the north and south, a residential village (north) and township (south).

Within the project area, the upper intertidal and mean high water springs (MHWS), the extent of the Coastal Marine Area (CMA), is often a clearly defined boundary at the base of a vertical cliff or mudstone/sandstone shelf. The intertidal vegetation to MHWS is dominated by mangroves (*Avicennia marina* subsp. *australasica*), with patches of rushes and salt marsh vegetation near the MHWS level, transitioning into pines and pasture or occasionally narrow bands of native coastal vegetation then pasture.

The coastal vegetation communities surveyed are divided into two broad groupings, coastal terrestrial vegetation and coastal intertidal vegetation. The coastal terrestrial vegetation are dominated by either: pines and exotic vegetation, New Zealand native coastal vegetation or Freshwater transitional vegetation. The coastal Intertidal vegetation areas are dominated by either: mangroves, rush marsh and coastal grass or salt marsh meadow.

7.5 Coastal Birds

Coastal bird surveys have been conducted in May, August and October 2020 and January 2021. Three areas were included in the survey, the Northside to Southside Outfall area, the Ruakohua Spillway area and the Kahawai to North streams area. A high tide roost site was also monitored at the same time periods except in winter.

The intertidal habitats abutting the Site are utilised by significant populations of coastal birds. The overall diversity was relatively high comprising 23 species; of those species 4 (banded dotterel, caspian tern, lesser knot and wrybill) are threatened on a national basis but only lesser knot was recorded in relatively high numbers. A total of 9 species are considered to be at risk on a national basis – black shag, little black shag, eastern bar-tailed godwit, pied shag, red-billed gull, royal spoonbill, South Island pied oystercatcher, variable oystercatcher and, white-fronted tern.

Overall the survey areas, the numerically dominant species were the South Island pied oystercatcher, white-faced heron, bar-tailed godwit with pied stilt and mallard also common. Notable numbers of lesser knot were present in summer. Significant total numbers were present at times; the maxima per survey area were 254 individuals in the Northside/Southside Outfall habitats (autumn), 85 in the Ruakohua Spillway embayment in spring and 309 in the Kahawai/North streams area in summer.

The numbers recorded reflected the typical seasonal behaviour of various species and did not suggest any deterioration of the intertidal habitat quality in terms of it supporting a diverse and relatively abundant coastal bird population.

The main habitat use activity was feeding in the intertidal area (overall survey area average = 76.6%) followed by resting in the intertidal area (19.0%).

A feature that enhances the coastal bird habitat values is the presence of a secure high tidal roost with low disturbance levels on raised rock platforms to the west of the Kahawai Stream mouth.

In summary, the intertidal areas surveyed provide significant feeding areas for coastal birds and a high tide roost that is notable at least in the wider Waiuku area.

8. REFERENCES

ANZECC (2000)

Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Volume 1, The Guidelines (Chapters 1-7). Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ). Paper No. 4 - Volume 1 (Chapters 1-7) October 2000.

ANZECC (2018)

https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/sediment-quality-toxicants

Anderson M.J., Hewitt J.E., Ford R.B. and Thrush S.F. (2006)

Regional models of benthic ecosystem health: predicting pollution gradients from biological data TP317, Auckland Regional Council, Auckland.

Andrews, H. P., Snee, R. D., and Sarner, M. H. (1980)

Graphical display of means. *The American Statistician*, *34*(4), 195-199.

Auckland Regional Council (2002)

Blueprint for monitoring urban receiving environments. Auckland Regional Council Technical Publication, TP168, pp 68.

Bioresearches (1985)

New Zealand Steel Annual Environmental Monitoring Outfall Mixing Zones May-June 1985. Report prepared for New Zealand Steel Limited, 72 pp.

Bioresearches (1986)

New Zealand Steel Annual Environmental Monitoring Outfall Mixing Zones May-June 1986. Report prepared for New Zealand Steel Limited, 118 pp.

Bioresearches (1987)

New Zealand Steel Annual Environmental Monitoring Outfall Mixing Zones May-June 1987. Report prepared for New Zealand Steel Limited, 107 pp.

Bioresearches (1988)

New Zealand Steel Annual Environmental Monitoring Outfall Mixing Zones May-June 1988. Report prepared for New Zealand Steel Limited, 97 pp.

Bioresearches (1989)

New Zealand Steel Annual Environmental Monitoring Outfall Mixing Zones May-June 1989. Report prepared for New Zealand Steel Limited, 78 pp.

Bioresearches (1991a)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones May - June 1990. Report prepared for New Zealand Steel Limited, 78 pp.

Bioresearches (1991b)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones May 1991. Report prepared for New Zealand Steel Limited, 77 pp.

Bioresearches (1992)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones May 1992. Report prepared for New Zealand Steel Limited, 80 pp.

Bioresearches (1994a)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones May 1993. Report prepared for New Zealand Steel Limited, 79 pp.

Bioresearches (1994b)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones May 1994. Report prepared for New Zealand Steel Limited, 84 pp.

Bioresearches (1995)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones May 1995. Report prepared for New Zealand Steel Limited, 85 pp.

Bioresearches (1996)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones May 1996. Report prepared for New Zealand Steel Limited, 101 pp.

Bioresearches (1997)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones May 1997. Report prepared for New Zealand Steel Limited, 101 pp.

Bioresearches (1998a)

Assessment of Effects of Slurry Water Discharge. Report prepared for New Zealand Steel Limited, 20 pp.

Bioresearches (1998b)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones May 1998. Report prepared for New Zealand Steel Limited, 103 pp.

Bioresearches (1999)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones May 1999. Report prepared for New Zealand Steel Limited, 103 pp.

Bioresearches (2000)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones May 2000. Report prepared for New Zealand Steel Limited, 103 pp.

Bioresearches (2001)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones May 2001. Report prepared for New Zealand Steel Limited, 64 pp.

Bioresearches (2002)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones May 2002. Report prepared for New Zealand Steel Limited, 54 pp.

Bioresearches (2003)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones August 2003. Report prepared for New Zealand Steel Limited, 40 pp.

Bioresearches (2004)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones August 2004. Report prepared for New Zealand Steel Limited, 33 pp.

Bioresearches (2005)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones August 2005. Report prepared for New Zealand Steel Limited, 46 pp.

Bioresearches (2006)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones August 2006. Report prepared for New Zealand Steel Limited, 36 pp.

Bioresearches (2007)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones August 2007. Report prepared for New Zealand Steel Limited, 50 pp.

Bioresearches (2008)

Assessment of Effects on the Marine Environment by the Proposed Site 1 Landfill, June 2008. Report prepared for New Zealand Steel Limited, 18 pp.

Bioresearches (2009)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones August 2009. Report prepared for New Zealand Steel Limited, 50 pp.

Bioresearches (2010)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones August 2010. Report prepared for New Zealand Steel Limited, 43 pp.

Bioresearches (2011)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones August 2011. Report prepared for New Zealand Steel Limited, 50 pp.

Bioresearches (2012)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones August 2012. Report prepared for New Zealand Steel Limited, 37 pp.

Bioresearches (2013)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones August 2013. Report prepared for New Zealand Steel Limited, 53 pp.

Bioresearches (2014)

New Zealand Steel Ltd Sediment and Biota Quality Within the Northside Outfall Mixing Zone April 2014. Report prepared for New Zealand Steel Limited, 17 pp.

Bioresearches (2015)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones August 2015. Report prepared for New Zealand Steel Limited, 60 pp.

Bioresearches (2016)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones August 2016. Report prepared for New Zealand Steel Limited, 42 pp

Bioresearches (2017)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones August 2017. Report prepared for New Zealand Steel Limited, 52 pp.

Bioresearches (2018)

New Zealand Steel Ltd Annual Environmental Monitoring within Outfall Mixing Zones August 2018. Report prepared for New Zealand Steel Limited, 41 pp.

Bioresearches (2019)

New Zealand Steel Ltd Annual Environmental Monitoring Within Outfalls Mixing Zone August 2019. Report prepared for New Zealand Steel Limited, pp 56.

Bioresearches (2020)

New Zealand Steel Ltd Annual Environmental Monitoring Within Outfalls Mixing Zone August 2020. Report prepared for New Zealand Steel Limited, pp 40.

Bioresearches (2021)

New Zealand Steel Ltd Annual Environmental Monitoring Within Outfalls Mixing Zone August 2021. Report prepared for New Zealand Steel Limited, pp 62.

Drylie, T. (2021)

Marine Ecology State ad Trends in Tamaki Makaurau / Auckland to 2019. Sate of the Environment Reporting. Auckland Regional Council. TR 2021/09.

Hewitt, J.E. & Ellis, J.I. (2010)

Assessment of the benthic health model. Auckland Regional Council. TR2010/034

Hewitt, J.E. , Lohrer, A. & Townsend, M. (2012)

Health of estuarine soft-sediment habitats : continued testing and refinement of state of the environment indicators. Auckland Regional Council. TR2012/012

Kelly, S., (2008)

Environmental condition and values of Manukau Harbour. Report 2009/112. Prepared by Coast and Catchment Ltd, for the Auckland Regional Council, Auckland.

Long, E. R., MacDonald, D. D., Smith, S. L., and Calder, F. D. (1995)

Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments. *Environmental Management* 19:81-97.

Robertson, H.A; Baird, C; Dowding, J.E; Elliott, G.P; Hitchmough, R.A; Miskelly, C.M; McArthur, N; O'Donnell, C.F.J; Sagar, P.M; Scofield, R.P; and Taylor, G.A (2017)

Conservation status of New Zealand birds, 2016. New Zealand Threat Classification Series 19. Department of Conservation. 23pp.

Singers, N., Osborne, B., Lovegrove, T., Jamieson, A., Boow, J., Sawyer, J., Hill, K., Andrews, J., Hill, S. and Webb, C. (2017)

Indigenous terrestrial and wetland ecosystems of Auckland. Edited by Jane Conner, Auckland Council.

Williamson, R B and Mills, G N. (2002)

Sediment Quality Guidelines for the Regional Discharge Project. Report to Auckland Regional Council.

9. APPENDICES

Appendix 1 Sediment Data

Table A1.1 History of Metals in the Mud Fraction of Sediments by Weak Acid Extraction and Total Recoverable Metals in Whole Sediment Fraction

Site	Year	Weak Acid Extraction of Mud Fraction					Total Recoverable of Whole Sediment Fraction					
		Cadmium	Chromium	Copper	Lead	Zinc	Aluminium	Cadmium	Chromium	Copper	Lead	Zinc
Northside A	1-Oct-03	< 0.050	15.0	5.0	12.1	89.0	-	0.240	36.0	9.5	14.8	245.0
	26-Aug-05	< 0.050	16.7	5.7	11.9	84.7	-	0.200	36.9	9.7	14.0	176.0
	22-Aug-07	< 0.050	15.3	5.3	13.3	83.3	-	0.150	36.3	10.5	18.4	177.0
	26-Aug-09	< 0.064	15.3	5.3	10.7	91.0	-	0.170	39.0	11.0	18.0	200.0
	5-Aug-11	< 0.050	13.4	5.1	10.6	71.7	-	0.188	32.0	8.9	13.7	174.0
	27-Aug-13	< 0.057	13.9	4.4	12.1	77.7	22000	0.167	33.0	9.3	15.2	143.0
	4-Apr-14	< 0.057	13.7	4.9	9.9	74.0	-	0.149	29.0	8.3	13.6	141.0
	7-Aug-15	< 0.050	18.2	5.3	11.1	81.0	17900	0.157	28.0	8.1	13.8	134.0
	14-Aug-17	< 0.050	15.1	4.9	11.7	69.3	-	0.091	29.0	8.3	12.8	120.0
	7-Aug-19	< 0.050	13.4	4.2	9.5	65.3	-	0.150	30.0	8.4	14.7	160.0
	13-Mar-20	< 0.050	14.6	4.7	10.7	72.3	-	0.177	32.3	8.6	14.1	179.3
	24-Aug-20	< 0.050	16.9	4.6	11.3	78.0	-	0.177	34.7	8.6	16.4	190.0
	16-Aug-21	< 0.050	16.0	4.2	9.8	69.3	25000	0.187	35.67	9.0	14.77	191.0
Northside B	1-Oct-03	< 0.050	16.0	6.0	13.2	74.3	-	0.070	28.6	8.8	15.6	103.0
	26-Aug-05	< 0.050	14.3	5.0	10.8	67.0	-	0.090	26.4	7.5	11.4	93.5
	22-Aug-07	< 0.050	15.3	5.3	13.9	75.7	-	0.080	33.0	10.7	18.2	115.0
	26-Aug-09	< 0.050	14.3	5.1	10.9	64.3	-	0.140	33.0	9.5	16.0	150.0
	5-Aug-11	< 0.050	12.7	4.9	10.3	56.7	-	0.083	27.0	8.5	12.8	98.0
	27-Aug-13	< 0.057	13.7	4.5	11.6	76.0	22000	0.093	30.0	8.5	14.3	102.0
	4-Apr-14	< 0.053	13.2	4.5	10.1	61.0	-	0.079	25.0	7.4	12.1	93.0
	7-Aug-15	< 0.110	18.2	5.3	11.2	68.0	18700	0.077	25.0	7.4	13.5	89.0
	14-Aug-17	< 0.050	13.9	4.4	10.6	55.3	-	0.041	26.0	7.9	11.8	83.0
	7-Aug-19	< 0.050	13.7	4.4	10.3	57.7	-	0.059	27.0	8.4	14.0	99.0
	13-Mar-20	< 0.050	15.0	4.2	10.7	57.0	-	0.060	28.0	8.0	13.5	104.3
	24-Aug-20	< 0.057	14.8	4.3	10.3	59.0	-	0.049	29.0	8.0	14.5	101.0
	16-Aug-21	< 0.050	15.3	3.9	8.7	49.0	27000	< 0.10	27.0	8.0	13.03	98.67
Southside C	1-Oct-03	< 0.050	16.7	6.0	13.9	74.3	-	0.070	25.7	7.8	14.0	85.6
	26-Aug-05	< 0.050	16.0	5.7	12.1	65.7	-	0.070	25.0	7.8	12.3	78.1
	22-Aug-07	< 0.050	14.3	5.0	12.8	65.3	-	0.060	26.0	8.4	13.0	88.9
	26-Aug-09	< 0.050	12.0	4.3	8.2	47.0	-	0.100	29.0	8.0	15.0	100.0
	8-Aug-11	< 0.050	13.0	4.9	11.1	59.0	-	0.073	24.0	7.8	12.3	83.0
	28-Aug-13	< 0.057	14.6	4.7	12.3	64.7	22000	0.074	30.0	8.5	15.3	89.0
	4-Apr-14	-	-	-	-	-	-	-	-	-	-	-
	7-Aug-15	< 0.060	18.0	5.0	10.5	62.0	17200	0.061	24.0	6.8	12.0	72.0
	14-Aug-17	< 0.050	15.4	4.5	11.2	58.7	-	0.044	26.0	7.0	12.1	86.0
	7-Aug-19	< 0.050	13.3	4.0	9.9	54.3	-	0.043	23.0	7.1	12.4	81.0
	4-May-20	< 0.050	14.4	4.4	10.7	56.7	-	0.047	22.7	6.2	12.3	84.7
	24-Aug-20	-	-	-	-	-	-	-	-	-	-	-
	17-Aug21	< 0.050	15.3	4.2	10.0	55.7	30000	< 0.10	23.67	7.0	13.37	90.0
Control D	27-Sept-21	< 0.050	12.8	4.2	9.3	48.3	21000	< 0.075	19.30	5.97	9.13	59.33

Table A1.2 History of Metals in the Mud Fraction of Sediments by Weak Acid Extraction and Total Recoverable Metals in Whole Sediment Fraction

Site	Year	Weak Acid Extraction of Mud Fraction					Total Recoverable of Whole Sediment Fraction					
		Cadmium	Chromium	Copper	Lead	Zinc	Aluminium	Cadmium	Chromium	Copper	Lead	Zinc
MZ	28-Aug-97						106000.0	< 1.00	14.10	4.40	12.80	36.30
	9-Jun-08			6.80	15.00	76.30	22666.7			7.00	11.00	69.00
	4-May-20	< 0.05	16.47	6.50	13.73	65.00		0.04	30.00	10.40	16.37	98.33
SZ	28-Aug-97						3900.0	< 1.00	18.10	2.60	7.90	17.10
	9-Jun-08			5.90	11.70	58.00	3533.3			0.90	2.20	15.00
	4-May-20	< 0.05	15.23	5.57	11.97	58.67		< 0.01	4.17	0.87	2.47	15.40
OZ	28-Aug-97											
	9-Jun-08			4.60	9.80	49.00	5833.3			2.30	4.30	29.00
	4-May-20	< 0.05	13.07	3.87	9.27	45.33		0.02	11.23	3.37	6.00	43.00

Table A1.3 History of sediment grain size

Site	Date	Percentage Total Weight								Classification
		> 3.35	3.35 – 2.00	2.00 – 1.00	1.00 – 0.500	0.500 – 0.250	0.250 – 0.125	0.125 – 0.063	< 0.063	
		Gravel	Granules	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt & Clay	
Northside A	1-Oct-03	11.3	0.5	0.7	1.6	4.1	15.6	15.2	50.9	gM
	26-Aug-05	0.2	1.6	5.9	6.9	7.6	0.4	17.7	59.7	(g)sM
	22-Aug-07	0.2	0.3	0.6	1.7	3.3	9.9	10.6	73.4	(g)sM
	26-Aug-09	0.0	0.0	0.7	2.7	6.5	15.0	11.6	63.5	sM
	6-Aug-11	0.0	0.0	0.2	0.9	3.8	19.7	20.1	55.4	sM
	28-Aug-13	0.0	0.0	0.2	2.0	7.5	13.5	13.5	63.2	sM
	4-Apr-14	0.0	0.4	1.1	3.3	7.2	19.4	18.2	50.3	(g)sM
	7-Aug-15	0.7	4.1	5.7	6.8	9.6	19.3	8.2	45.5	(g)mS
	14-Aug-17	0.0	0.0	0.0	0.2	1.1	7.0	12.0	79.8	sM
	7-Aug-19	0.2	0.6	1.2	1.6	2.3	20.1	19.6	54.2	(g)sM
	13-Mar-20	0.0	0.4	0.6	0.9	4.6	15.5	8.7	69.3	(g)sM
	24-Aug-20	0.0	0.3	0.3	0.7	5.3	19.9	9.5	64.0	(g)sM
	16-Aug-21	2.6		1.0	1.1	4.2	15.1	10.7	65.3	(g)sM
Northside B	1-Oct-03	0.3	0.7	1.3	2.6	3.1	4.2	5.3	82.6	(g)sM
	26-Aug-05	0.0	0.5	1.8	3.9	6.0	0.5	19.0	68.3	(g)sM
	22-Aug-07	0.0	0.3	0.9	2.9	4.2	0.5	11.9	79.3	(g)sM
	26-Aug-09	0.0	0.0	0.1	1.2	6.3	12.3	13.6	66.4	sM
	6-Aug-11	0.0	0.0	0.1	0.5	2.2	7.0	10.4	79.8	sM
	28-Aug-13	0.0	0.0	0.1	2.2	5.6	12.9	13.4	65.8	sM
	4-Apr-14	0.0	0.0	0.7	3.3	5.2	10.6	16.9	63.2	sM
	7-Aug-15	0.7	5.0	7.9	8.1	8.2	11.5	9.2	49.5	gM
	14-Aug-17	0.0	0.0	0.0	0.1	0.4	9.1	22.0	68.4	sM
	7-Aug-19	0.0	0.0	0.0	0.0	0.8	14.3	20.6	64.2	sM
	13-Mar-20	0.0	< 0.1	< 0.1	0.2	0.9	7.0	10.1	81.9	(g)sM
	24-Aug-20	0.0	< 0.1	< 0.1	0.1	0.3	1.8	5.3	92.4	(g)M
	16-Aug-21	< 0.1		< 0.1	0.2	0.9	10.6	9.2	79.1	(g)sM
Southside C	1-Oct-03	0.1	0.5	0.8	1.8	3.8	13.7	7.6	71.8	(g)sM
	26-Aug-05	0.0	3.6	4.8	7.1	7.2	10.4	7.9	58.8	(g)sM
	22-Aug-07	0.0	0.2	0.9	3.3	5.6	0.1	20.3	69.7	(g)sM
	26-Aug-09	0.0	0.0	0.3	1.5	6.2	10.5	9.0	72.5	sM
	6-Aug-11	0.0	0.0	0.2	1.4	4.2	16.0	10.5	67.7	sM
	28-Aug-13	0.0	0.2	0.6	5.7	7.0	11.2	10.6	64.7	(g)sM
	4-Apr-14	-	-	-	-	-	-	-	-	-
	7-Aug-15	0.8	8.5	5.2	5.6	9.0	19.9	12.5	38.5	gmS
	14-Aug-17	0.4	0.5	1.6	3.8	5.9	17.6	11.8	58.3	(g)sM
	7-Aug-19	0.1	0.3	0.6	1.7	3.8	19.0	16.0	58.4	(g)sM
	4-May-20	0.0	0.9	2.9	3.8	8.1	23.6	6.1	54.7	(g)sM
	24-Aug-20	-	-	-	-	-	-	-	-	-
	17-Aug-21	2.1		3.1	4.2	5.1	10.8	6.7	68.1	(g)sM
Control D	15-Sept-21	< 0.1		< 0.1	< 0.1	0.6	4.4	21.3	73.6	(g)sM

Appendix 2 Oyster Data

Table A2.1 Annual Biological Data for Oysters

Station	Year	Density (no. / 0.25 m²)		Length (mm)		Condition Index	
		mean	95% CI	mean	95% CI	mean	95% CI
N5	1985	38.60	7.20	49.57	3.30	8.51	1.15
	1986	42.33	8.28	49.71	2.36	5.16	0.51
	1987	72.60	18.19	47.28	2.96	3.87	0.55
	1988	52.17	13.61	50.69	2.13	6.78	0.81
	1989	60.67	13.86	48.39	2.79	5.27	0.83
	1990	78.57	20.28	49.15	2.42	4.95	0.73
	1991	56.00	16.38	45.10	2.51	5.22	0.77
	1992	57.77	15.60	46.72	2.14	7.69	0.52
	1993	29.53	9.81	48.08	1.83	5.35	0.36
	1994	31.33	10.57	46.24	1.97	5.43	0.51
	1995	12.13	4.33	50.96	2.15	6.93	0.54
	1996	17.50	5.06	45.51	2.38	5.41	0.63
	1997	41.13	18.60	44.80	4.51	3.71	0.43
	1998	26.52	8.60	46.78	1.96	5.29	0.67
	1999	22.83	6.98	47.51	3.00	5.78	0.39
	2000	22.97	8.43	47.35	3.09	4.88	0.58
	2001	17.63	6.93	48.00	2.32	5.84	0.99
	2002	14.97	6.66	52.32	2.53	4.44	0.47
	2003	19.07	11.79	44.54	3.31	3.09	0.47
	2004	12.70	5.36	47.34	2.91	4.45	0.26
	2005	16.40	6.77	46.71	2.42	5.17	0.98
	2006	14.20	7.86	44.46	1.85	4.30	0.48
	2007	13.77	6.15	43.19	2.28	4.45	0.50
	2008	16.50	7.00	44.81	2.43	3.26	0.49
	2009	10.43	6.60	46.05	2.44	4.29	0.38
	2010	4.73	2.21	47.77	2.15	4.97	0.57
	2011	3.97	2.74	44.68	2.24	6.46	1.02
	2012	3.50	3.08	45.13	2.59	4.75	0.82
	2013	2.27	1.67	43.97	1.95	6.73	0.77
	2014	0.77	0.73	45.74	4.05	9.26	2.91
	2015	1.27	1.34	44.51	4.80	5.80	0.88
	2016	2.23	2.27	47.93	2.37	5.39	0.88
	2017	2.77	4.11	39.02	2.32	7.16	0.96
	2018	3.90	3.88	49.70	2.26	5.32	0.76
	2019	0.63	0.62	54.53	8.61	5.70	0.33
	2020	0.93	0.78	51.00	5.30	6.86	0.90
	2021	0.70	0.90	53.00	6.29		

Station	Year	Density (no. / 0.25 m²)		Length (mm)		Condition Index	
		mean	95% CI	mean	95% CI	mean	95% CI
N6	1985	31.63	13.00	64.45	4.70	6.51	1.10
	1986	34.30	13.94	53.43	2.73	4.26	0.89
	1987	36.43	15.56	58.95	4.59	2.55	0.36
	1988	40.40	9.65	54.17	3.73	4.03	0.54
	1989	30.53	8.83	60.65	3.56	3.60	1.14
	1990	28.77	10.66	56.63	3.30	4.98	0.29
	1991	25.20	6.31	53.39	3.89	4.54	0.46
	1992	23.00	6.55	49.12	2.60	7.42	0.57
	1993	16.17	4.55	86.76	5.64	5.32	0.58
	1994	35.77	14.43	53.60	2.65	4.73	0.53
	1995	15.43	7.43	55.86	2.52	6.09	0.38
	1996	13.60	5.92	46.74	2.99	4.65	0.37
	1997	24.20	9.33	43.73	2.56	3.48	0.49
	1998	14.83	5.68	42.23	2.11	4.15	0.53
	1999	14.10	5.31	48.50	2.25	5.27	0.39
	2000	31.03	7.61	44.53	2.73	3.75	0.44
	2001	17.60	5.27	49.09	2.75	4.57	0.61
	2002	11.57	5.76	48.92	2.16	5.02	0.92
	2003	9.57	3.87	43.87	3.39	4.04	0.81
	2004	20.13	7.78	40.01	2.35	3.75	0.75
	2005	12.17	4.30	43.86	2.14	4.64	0.49
	2006	18.40	11.01	49.28	2.41	4.47	0.82
	2007	9.57	4.57	42.32	1.92	4.10	0.80
	2008	8.73	4.41	40.98	1.99	2.63	0.27
	2009	3.60	2.34	46.44	1.85	6.39	2.95
	2010	7.83	4.23	45.73	1.68	4.80	0.48
N6A	2010	15.43	7.13	38.63	2.34	3.86	0.52
	2011	12.73	7.58	42.15	1.79	4.53	0.62
	2012	21.70	10.26	30.86	2.54	4.50	0.73
	2013	13.37	5.45	39.53	1.92	5.16	0.63
	2014	12.23	7.44	41.51	2.47	5.71	0.62
	2015	9.50	7.14	42.96	2.06	4.62	0.43
	2016	28.83	15.03	38.88	2.84	4.74	0.60
	2017	26.27	10.61	32.88	2.00	6.14	0.69
	2018	16.60	8.36	49.42	1.93	5.23	1.37
	2019	28.53	14.21	45.67	2.03	5.15	0.48
	2020	23.17	12.09	43.01	2.16	5.63	0.65
	2021	37.07	18.36	47.83	2.38		

Station	Year	Density (no. / 0.25 m²)		Length (mm)		Condition Index	
		mean	95% CI	mean	95% CI	mean	95% CI
N10	1988	46.07	21.98	62.12	2.54	7.23	1.16
	1989	58.87	26.11	43.93	3.28	7.19	1.01
	1990	41.50	18.03	87.98	4.72	6.88	0.82
	1991	39.43	14.93	53.73	4.05	6.61	0.75
	1992	63.93	21.43	44.55	3.43	6.64	0.69
	1993	29.50	14.58	48.92	3.03	8.80	0.62
	1994	18.77	9.87	54.59	2.52	9.58	0.71
	1995	14.40	7.46	53.49	2.40	9.53	0.94
	1996	29.70	14.52	45.56	2.22	8.70	2.46
	1997	75.50	25.36	40.37	2.62	5.24	0.59
	1998	45.07	14.69	52.24	1.93	5.86	0.59
	1999	49.73	14.38	45.24	1.92	6.91	1.79
	2000	54.03	18.88	48.57	3.45	6.82	1.37
	2001	42.07	17.56	50.17	2.69	7.72	1.51
	2002	46.93	15.81	34.73	4.70	6.81	0.99
	2003	29.90	14.72	46.34	3.96	5.99	0.54
	2004	45.60	21.02	42.51	3.44	6.39	0.51
	2005	15.83	7.69	46.88	2.74	6.34	0.78
	2006	47.10	21.68	45.45	3.07	4.66	0.63
	2007	37.17	19.72	49.09	2.59	5.23	0.33
	2008	40.37	16.63	47.25	3.17	3.66	0.91
	2009	34.37	16.31	46.63	3.55	6.33	0.53
	2010	37.07	17.84	49.38	2.68	5.02	0.65
	2011	8.57	5.16	51.51	2.26	5.99	0.53
	2012	26.40	11.63	41.11	3.10	7.17	0.68
	2013	17.43	9.01	44.94	2.38	6.57	0.55
	2014	33.03	13.32	40.57	2.01	8.23	0.82
	2015	39.87	17.06	40.41	3.23	5.67	0.34
	2016	30.17	15.91	29.60	3.22	5.63	0.55
	2017	38.67	18.33	45.54	2.75	5.44	0.48
	2018	21.20	9.80	53.25	3.00	6.20	0.69
	2019	24.13	14.77	48.70	2.30	6.48	0.40
	2020	29.30	11.30	47.70	2.65	7.06	0.95
	2021	21.00	9.63	43.57	2.26		

Station	Year	Density (no. / 0.25 m²)		Length (mm)		Condition Index	
		mean	95% CI	mean	95% CI	mean	95% CI
S3	1985	14.50	3.70	52.44	3.30	7.82	0.57
	1986	19.23	4.08	46.99	2.52	5.57	0.63
	1987	35.90	10.25	44.15	2.57	4.85	0.44
	1988	30.47	8.36	48.43	2.05	4.93	0.70
	1989	26.63	8.45	53.95	2.43	4.41	0.32
	1990	36.73	11.31	51.04	3.19	4.92	0.28
	1991	27.87	9.35	53.37	2.96	4.91	0.48
	1992	27.83	7.40	52.02	2.66	6.11	0.72
	1993	23.23	7.77	51.91	2.85	6.32	1.96
	1994	19.83	6.64	45.52	1.86	4.48	0.62
	1995	17.97	6.03	56.99	2.46	5.59	0.53
	1996	16.80	4.62	44.99	2.59	4.74	0.34
	1997	21.77	5.68	37.37	3.09	3.21	0.36
	1998	20.40	4.68	38.61	2.32	4.13	0.50
	1999	20.70	4.75	35.06	2.41	5.58	0.58
	2000	17.90	5.75	49.03	2.41	5.10	0.68
	2001	15.07	4.24	44.57	2.32	4.48	0.65
	2002	23.93	6.08	45.40	2.45	4.50	0.29
	2003	20.52	6.12	46.44	2.85	3.72	0.46
	2004	20.40	5.74	35.88	2.79	5.07	0.57
	2005	16.73	5.48	37.67	2.69	6.06	1.47
	2006	15.70	5.28	41.68	2.18	5.78	0.58
	2007	17.37	4.07	37.49	1.92	3.91	0.17
	2008	17.17	6.42	36.21	2.23	2.82	0.34
	2009	16.10	6.09	41.22	2.37	3.87	0.35
	2010	12.37	6.23	41.46	2.31	4.06	0.63
S3a	2010	16.83	5.98	41.46	2.31	4.35	0.62
	2011	10.80	3.11	41.26	1.79	4.91	0.33
	2012	11.60	3.85	35.58	2.54	5.61	1.08
	2013	12.27	4.14	40.05	2.00	7.20	0.63
	2014	12.27	5.50	42.92	2.67	7.81	1.53
	2015	16.63	5.30	46.30	2.93	4.71	0.43
	2016	16.10	4.90	47.13	2.79	4.69	0.62
	2017	21.23	7.04	36.68	2.24	7.28	1.09
	2018	16.67	5.09	45.62	2.13	5.02	0.82
	2019	20.90	6.49	46.80	2.75	4.37	0.52
	2020	17.93	8.60	51.03	9.74	6.00	0.49
	2021	17.20	6.34	46.27	3.06		

Station	Year	Density (no. / 0.25 m²)		Length (mm)		Condition Index	
		mean	95% CI	mean	95% CI	mean	95% CI
S5	1985	26.70	7.00	49.87	2.50	6.21	1.11
	1986	30.00	7.05	47.06	2.26	4.43	0.58
	1987	57.67	13.33	38.95	2.49	4.82	0.45
	1988	41.00	10.70	44.14	2.09	4.49	0.55
	1989	47.00	8.66	46.99	2.18	5.07	0.55
	1990	40.83	8.86	43.87	2.77	5.37	0.64
	1991	37.60	8.24	40.40	2.28	5.88	0.51
	1992	30.97	7.98	44.93	2.25	5.93	0.71
	1993	43.50	11.73	46.10	1.81	5.72	0.58
	1994	40.23	6.89	44.65	2.30	5.75	0.57
	1995	32.60	6.89	43.84	2.05	6.30	0.45
	1996	37.60	5.90	40.94	2.83	5.04	0.71
	1997	33.67	5.87	39.12	2.97	4.04	0.29
	1998	25.63	5.99	46.42	1.91	5.44	0.54
	1999	33.90	6.39	40.17	2.81	5.76	0.90
	2000	23.17	5.09	46.29	2.87	5.26	0.52
	2001	25.33	5.30	43.30	2.62	5.84	1.62
	2002	22.17	4.22	50.95	2.55	4.59	0.54
	2003	16.07	3.93	47.10	2.83	3.71	0.32
	2004	14.33	3.04	50.28	2.70	4.38	0.47
	2005	10.80	2.70	43.18	2.10	5.19	0.74
	2006	10.17	3.18	42.66	1.86	6.30	1.00
	2007	14.83	4.19	39.13	2.53	3.75	0.39
	2008	5.47	2.07	50.99	3.47	3.06	0.29
	2009	4.83	3.24	42.89	2.46	3.91	0.43
	2010	2.30	1.76	46.71	4.07	3.30	0.43
S5a	2010	7.57	3.81	41.37	2.76	5.99	1.01
	2011	1.80	1.45	7.73	1.14	5.16	0.76
	2012	2.87	1.23	33.08	2.72	5.87	0.63
	2013	1.90	1.32	44.38	2.16	7.44	0.43
	2014	2.27	1.04	45.00	2.89	9.07	1.19
	2015	0.50	0.31	43.33	6.07	-	-
	2016	0.33	0.33	38.50	10.72	-	-
	2017	4.80	3.74	41.40	1.99	7.11	0.94
	2018	5.40	3.30	36.92	2.93	5.81	0.61
	2019	5.30	3.55	43.96	1.87	6.99	0.47
	2020	2.00	2.34	46.13	3.25	7.13	1.09
	2021	0.07	0.09	43.50	133.42		

Station	Year	Density (no. / 0.25 m²)		Length (mm)		Condition Index	
		mean	95% CI	mean	95% CI	mean	95% CI
TC	1985	45.97	15.50	36.70	2.40	11.24	1.05
	1986	79.90	25.28	46.20	2.26	6.23	0.89
	1987	94.50	35.30	45.86	2.87	4.59	2.87
	1988	65.43	22.68	58.75	3.96	5.16	1.04
	1989	28.80	14.57	59.90	3.58	6.71	0.63
	1990	44.80	18.74	60.92	3.34	8.69	1.47
	1991	39.43	13.55	57.47	4.63	7.82	1.00
	1992	22.37	12.28	42.20	3.67	6.42	0.64
	1993	5.77	2.71	52.92	4.03	7.45	0.56
	1994	10.67	7.69	60.51	4.04	8.58	0.79
	1995	17.77	8.40	54.00	2.87	8.44	0.91
	1996	16.50	11.18	47.24	3.85	7.15	1.30
	1997	15.77	9.96	43.20	2.93	6.17	0.89
	1998	12.67	8.11	42.61	2.94	6.77	0.65
	1999	10.23	8.15	57.21	4.43	7.28	0.80
	2000	33.33	15.57	53.69	3.22	5.14	0.44
	2001	17.63	10.85	61.86	3.14	6.98	0.68
	2002	15.50	8.05	53.77	4.96	5.61	0.66
	2003	-	-	-	-	-	-
	2004	-	-	-	-	-	-
	2005	26.87	13.11	60.37	4.91	7.48	1.36
	2006	8.27	9.65	48.73	2.56	7.30	0.64
	2007	2.73	2.47	50.51	2.48	7.88	0.67
	2008	1.03	1.84	52.65	6.68	8.01	0.45
	2009	-	-	-	-	-	-
TCa	2010	33.20	17.19	32.90	3.59	5.32	1.21
	2011	4.27	3.34	50.91	2.74	7.11	1.02
	2012	4.67	4.18	41.72	2.68	5.33	0.75
	2013	12.30	10.84	31.86	3.20	6.98	1.14
	2014	14.10	11.73	36.45	3.85	6.24	1.52
	2015	7.20	8.10	36.65	3.60	4.86	0.99
	2016	6.23	4.84	14.31	1.29	4.96	0.42
	2017	4.37	4.32	39.46	1.74	4.70	0.84
	2018	7.03	5.30	34.91	3.57	5.45	1.01
	2019	4.37	5.92	44.34	2.59	4.91	0.51
	2020	1.90	2.61	46.70	3.42	4.51	0.66
	2021	4.70	3.88	47.90	4.01		

Table A2.2 Raw Data for Oysters August 2021

SITE	Sample ID	Wet Weight	% Moisture	Dry Weight Zinc	Dry Weight Copper	Wet Weight Zinc	Wet Weight Copper	Condition Index
Northside NS5 16 August 2021	1	47.08	92.0	4,100.0	380.0	328.00	30.40	5.09
	2	44.19	91.1	2,800.0	340.0	249.20	30.26	6.45
	3	44.21	92.3	3,500.0	280.0	269.50	21.56	4.79
	4	46.16	92.0	3,600.0	360.0	288.00	28.80	5.20
	5	46.17	91.5	2,700.0	310.0	229.50	26.35	6.54
	6	41.29	90.8	2,600.0	300.0	239.20	27.60	6.33
	7	41.84	91.4	3,200.0	330.0	275.20	28.38	5.45
	8	41.90	91.2	2,600.0	270.0	228.80	23.76	4.10
	9	48.85	90.7	3,300.0	400.0	306.90	37.20	6.06
	10	44.21	89.9	3,000.0	310.0	303.00	31.31	6.20
	11	44.93	91.6	3,100.0	270.0	260.40	22.68	5.72
	12	48.82	92.4	2,600.0	250.0	197.60	19.00	5.46
Mean		**44.97**	**91.4**	**3,091.7**	**316.7**	**264.61**	**27.28**	**5.62**
Standard Deviation		**2.55**	**0.7**	**473.8**	**46.8**	**37.98**	**4.98**	**0.74**

SITE	Sample ID	Wet Weight	% Moisture	Dry Weight Zinc	Dry Weight Copper	Wet Weight Zinc	Wet Weight Copper	Condition Index
Northside NS6A 16 August 2021	1	41.28	92.0	6,900.0	410.0	552.00	32.80	4.93
	2	63.85	92.1	6,200.0	370.0	489.80	29.23	4.99
	3	44.23	92.6	6,100.0	290.0	451.40	21.46	4.48
	4	35.60	91.3	6,200.0	310.0	539.40	26.97	4.92
	5	40.68	93.0	7,400.0	390.0	518.00	27.30	4.91
	6	35.48	91.8	8,800.0	470.0	721.60	38.54	4.22
	7	39.91	91.3	7,800.0	330.0	678.60	28.71	4.76
	8	46.53	91.1	8,000.0	300.0	712.00	26.70	5.75
	9	55.85	89.9	6,600.0	210.0	666.60	21.21	6.72
	10	58.32	90.7	6,500.0	260.0	604.50	24.18	6.38
	11	46.85	92.6	6,000.0	290.0	444.00	21.46	4.28
	12	36.87	92.4	7,900.0	440.0	600.40	33.44	4.52
Mean		**45.45**	**91.7**	**7,033.3**	**339.2**	**581.53**	**27.67**	**5.07**
Standard Deviation		**9.33**	**0.9**	**921.8**	**77.5**	**97.76**	**5.34**	**0.80**

SITE	Sample ID	Wet Weight	% Moisture	Dry Weight Zinc	Dry Weight Copper	Wet Weight Zinc	Wet Weight Copper	Condition Index
Northside NS10 16 August 2021	1	52.82	89.5	3,300.0	330.0	346.50	34.65	5.84
	2	35.96	88.8	2,400.0	280.0	268.80	31.36	7.19
	3	44.96	89.6	2,700.0	340.0	280.80	35.36	6.32
	4	33.46	88.8	2,400.0	280.0	268.80	31.36	5.95
	5	43.91	90.1	1,700.0	190.0	168.30	18.81	5.87
	6	44.35	88.0	2,100.0	270.0	252.00	32.40	6.82
	7	43.17	88.8	2,100.0	230.0	235.20	25.76	6.53
	8	63.34	90.1	1,900.0	200.0	188.10	19.80	6.53
	9	48.59	89.1	2,300.0	260.0	250.70	28.34	8.28
	10	46.13	88.8	2,400.0	300.0	268.80	33.60	7.95
	11	42.24	89.5	2,200.0	270.0	231.00	28.35	6.43
	12	56.97	88.8	2,000.0	190.0	224.00	21.28	7.42
Mean		**46.33**	**89.2**	**2,291.7**	**261.7**	**248.58**	**28.42**	**6.76**
Standard Deviation		**8.32**	**0.6**	**414.4**	**50.6**	**45.79**	**5.81**	**0.80**

SITE	Sample ID	Wet Weight	% Moisture	Dry Weight		Wet Weight		Condition Index
				Zinc	Copper	Zinc	Copper	
Southside SS3A 17 August 2021	1	34.22	92.9	3,100.0	410.0	220.10	29.11	4.19
	2	49.53	90.6	3,000.0	360.0	282.00	33.84	6.29
	3	42.86	90.5	2,600.0	340.0	247.00	32.30	5.90
	4	35.90	90.3	2,600.0	350.0	252.20	33.95	5.90
	5	44.00	91.9	2,800.0	340.0	226.80	27.54	4.51
	6	48.26	88.9	2,400.0	260.0	266.40	28.86	7.76
	7	50.49	90.9	2,000.0	300.0	182.00	27.30	6.13
	8	49.18	90.3	2,200.0	300.0	213.40	29.10	6.20
	9	42.28	90.5	2,900.0	390.0	275.50	37.05	6.09
	10	45.92	90.1	2,500.0	330.0	247.50	32.67	6.49
	11	41.06	90.9	3,500.0	400.0	318.50	36.40	5.42
	12	43.16	89.6	1,700.0	230.0	176.80	23.92	6.32
Mean		**43.91**	**90.6**	**2,608.3**	**334.2**	**242.35**	**31.00**	**5.93**
Standard Deviation		**5.19**	**1.0**	**498.1**	**54.7**	**41.24**	**3.98**	**0.92**

SITE	Sample ID	Wet Weight	% Moisture	Dry Weight		Wet Weight		Condition Index
				Zinc	Copper	Zinc	Copper	
Southside SS5A 17 August 2021	1	60.34	89.6	2200.0	240.0	228.80	24.96	8.05
	2	51.55	87.6	1800.0	230.0	223.20	28.52	10.65
	3	35.52	89.6	2400.0	330.0	249.60	34.32	13.19
	4	62.35	89.0	2600.0	290.0	286.00	31.90	6.86
	5	59.09	87.5	2100.0	250.0	262.50	31.25	8.79
	6	46.36	88.7	3400.0	370.0	384.20	41.81	13.10
	7	59.74	88.2	2000.0	220.0	236.00	25.96	8.81
	8	42.83	87.8	2000.0	240.0	244.00	29.28	8.71
	9	67.62	89.8	2900.0	350.0	295.80	35.70	5.90
	10	46.41	87.2	1800.0	190.0	230.40	24.32	9.14
	11	61.11	87.4	2100.0	230.0	264.60	28.98	9.51
	12	62.13	88.7	2100.0	230.0	237.30	25.99	6.75
Mean		**54.59**	**88.4**	**2,283.3**	**264.2**	**261.87**	**30.25**	**9.12**
Standard Deviation		**9.79**	**0.9**	**474.5**	**57.1**	**44.75**	**5.12**	**2.29**

SITE	Sample ID	Wet Weight	% Moisture	Dry Weight		Wet Weight		Condition Index
				Zinc	Copper	Zinc	Copper	
Taihiki Control 27 September 2021	1	34.80	89.3	1,400.0	160.0	149.80	17.12	5.82
	2	32.75	89.2	1,500.0	190.0	162.00	20.52	5.13
	3	28.75	89.4	1,800.0	230.0	190.80	24.38	4.76
	4	24.98	90.7	3,100.0	370.0	288.30	34.41	3.87
	5	24.60	89.5	1,600.0	230.0	168.00	24.15	5.17
	6	31.29	90.5	2,100.0	270.0	199.50	25.65	4.19
	7	28.79	90.5	2,600.0	350.0	247.00	33.25	3.34
	8	26.56	88.4	2,200.0	250.0	255.20	29.00	4.40
	9	29.72	88.4	2,000.0	260.0	232.00	30.16	4.79
	10	32.02	88.8	2,400.0	300.0	268.80	33.60	4.48
	11	27.89	89.9	1,800.0	240.0	181.80	24.24	5.63
	12	26.99	89.8	1,700.0	280.0	173.40	28.56	5.86
Mean		**29.10**	**89.5**	**2,016.7**	**260.8**	**209.72**	**27.09**	**4.79**
Standard Deviation		**3.15**	**0.8**	**497.0**	**59.9**	**46.50**	**5.38**	**0.78**

Table A2.3 Copper in Oysters - Comparison of Annual Results 1985 – 2021 mg/kg dry weight (sample size = 12)

Year	Northside Sites						Taihiki Control		Southside Sites			
	5		6		10				3		5	
	Mean	CI	Mean	CI	Mean	CI	Mean	CI	Mean	CI	Mean	CI
1985	295.4	80.5	307.8	65.6			162.2	24.6	250.1	41.4	251.3	45.1
1986	318.0	47.1	420.9	69.4			195.8	41.2	375.9	37.5	366.1	22.1
1987	499.3	75.5	515.3	61.3			246.9	24.0	526.9	76.7	528.7	68.9
1988	435.5	108.9	436.1	44.6	237.0	21.7	294.0	27.8	493.0	64.4	445.3	53.0
1989	480.5	60.4	461.7	53.4	317.0	37.5	253.5	22.9	533.7	37.9	437.5	61.6
1990	699.8	64.1	411.0	45.7	301.7	52.9	273.2	41.2	653.8	39.6	558.3	69.6
1991	600.3	77.2	441.8	69.2	365.1	51.3	221.6	34.9	624.9	51.8	476.5	66.1
1992	834.4	92.1	623.1	55.7	473.3	47.6	265.5	44.6	774.1	120.3	526.9	54.5
1993	1150.8	231.9	647.5	98.4	410.0	51.3	430.0	148.2	780.8	98.5	647.5	90.4
1994	715.8	74.4	487.5	59.1	312.5	39.3	200.8	21.9	767.5	88.1	495.0	79.5
1995	541.7	49.7	381.7	34.5	323.0	78.4	154.2	46.2	595.0	65.5	458.3	42.9
1996	714.2	67.9	514.2	38.6	349.2	70.7	180.0	19.5	723.3	99.7	566.7	54.3
1997	871.7	97.5	643.3	83.1	412.5	75.1	255.8	24.8	842.5	84.6	724.2	113.2
1998	735.8	85.1	582.5	69.4	320.0	42.7	205.8	33.1	817.5	101.5	616.7	70.6
1999	534.2	114.4	409.2	63.0	335.8	67.6	245.0	32.8	600.8	90.0	570.8	57.8
2000	590.0	127.0	625.8	80.6	365.0	52.1	184.2	33.9	482.5	52.5	579.2	80.0
2001	537.5	76.6	555.0	77.3	306.7	42.1	182.5	23.9	692.5	122.7	532.5	104.2
2002	595.0	94.1	438.3	68.2	297.5	54.0	214.2	21.9	484.2	58.6	455.0	45.8
2003	1011.2	207.3	639.3	96.6	407.3	87.9	240.8	28.2	771.3	99.1	768.8	100.8
2004	670.0	54.4	549.2	62.7	334.2	55.0	165.0	19.4	570.0	64.9	548.3	77.1
2005	599.2	66.2	478.1	71.9	258.3	26.4	252.0	46.3	521.4	72.3	492.5	74.5
2006	463.1	81.8	431.8	64.1	257.3	38.6	174.8	20.9	406.3	70.8	386.2	65.4
2007	524.2	64.3	424.2	57.0	325.0	38.8	161.7	23.4	614.2	49.5	536.7	79.9
2008	586.7	76.2	585.0	60.9	478.3	59.2	167.5	18.8	562.5	62.1	450.0	37.1
2009	455.0	55.4	458.3	55.5	316.7	30.5	-	-	455.0	37.4	365.7	39.2
2010	466.7	62.9	359.2	40.0	405.8	44.3	228.2	56.7	463.3	42.7	399.2	35.4
2011	406.7	52.2	388.3	53.3	318.3	51.5	250.0	35.2	494.2	53.9	397.5	58.8
2012	375.8	46.4	317.5	34.0	216.7	24.9	184.8	63.0	393.3	70.5	314.2	29.6
2013	490.0	283.1	343.3	47.4	286.7	67.7	325.8	88.0	383.3	53.9	265.8	52.6
2014	281.7	33.9	291.7	26.0	246.7	34.5	290.0	45.9	334.2	45.3	216.7	63.2
2015	475.0	95.4	415.0	69.9	320.8	39.2	377.5	131.9	393.3	53.3	0.0	0.0
2016	378.3	29.4	329.2	26.6	298.3	25.2	259.2	51.5	362.5	49.3	0.0	0.0
2017	363.3	26.3	351.7	29.4	260.0	54.2	246.7	39.7	338.3	38.9	133.3	11.6
2018	331.7	37.2	266.7	33.5	215.8	48.0	158.3	18.9	273.3	59.3	166.7	22.1
2019	291.7	37.7	305.0	42.8	245.8	21.6	242.3	39.2	339.2	40.0	197.5	22.8
2020	320.8	45.7	321.7	50.8	293.3	34.5	277.5	34.2	308.3	37.1	202.5	35.1
2021	316.7	29.7	339.2	49.2	261.7	32.2	260.8	38.1	334.2	34.7	264.2	36.3

Table A2.4 Multiple Comparison of mean Copper Concentrations (mg/kg dry weight) in Oysters from the Northside and Southside Outfalls

NORTHSIDE

Normality Test (Shapiro-Wilk): Passed (P = 0.935)
Equal Variance Test (Brown-Forsythe): Passed (P = 0.309)

One Way Analysis of Variance

Site	N	Mean	Standard Deviation	SEM
N5	12	316.667	46.775	13.503
N6A	12	339.167	77.513	22.376
N10	12	261.667	50.602	14.608
TC	12	260.833	59.918	17.297

Source of Variation	DF	SS	MS	F	P
Between Groups	3	56375.000	18791.667	5.239	0.004
Residual	44	157816.667	3586.742		
Total	47	214191.667			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.004).

Power of performed test with alpha = 0.050: 0.828

Tukey Multiple Comparison Matrix

	TC	N10	N6A
N5	NSD	NSD	NSD
N6A	*	*	
N10	NSD		

SOUTHSIDE

Normality Test (Shapiro-Wilk): Passed (P = 0.326)
Equal Variance Test (Brown-Forsythe): Passed (P = 0.973)

One Way Analysis of Variance

Group Name	N	Mean	Standard Deviation	SEM
S3A	12	334.167	54.682	15.785
S5A	12	264.167	57.122	16.490
TC	12	260.833	59.918	17.297

Source of Variation	DF	SS	MS	F	P
Between Groups	2	41155.556	20577.778	6.272	0.005
Residual	33	108275.000	3281.061		
Total	35	149430.556			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.005).

Power of performed test with alpha = 0.050: 0.799

Tukey Multiple Comparison Matrix

	TC	S5a
S3a	*	*
S5a	NSD	

Table A2.5 Zinc in Oysters - Comparison of Annual Results 1985 - 2020 mg/kg dry weight (sample size = 12)

Year	Northside Sites						Taihiki Control		Southside Sites			
	5		6		10				3		5	
	Mean	CI	Mean	CI	Mean	CI	Mean	CI	Mean	CI	Mean	CI
1985	4346.3	1002.2	6869.5	1174.1			1493.0	155.9	2886.1	453.6	2816.6	542.9
1986	3998.3	565.4	7673.8	1143.6			1366.0	254.9	5155.2	438.5	4547.2	278.0
1987	5821.2	852.2	8886.0	921.4			1547.1	152.6	6289.1	760.0	5238.5	713.4
1988	4486.1	623.2	9490.3	917.0	2583.8	287.8	1920.2	183.3	5774.7	802.6	4048.7	414.5
1989	4833.2	676.1	7971.2	636.7	3149.4	537.3	1594.3	142.2	5408.8	340.7	3766.1	475.7
1990	6340.1	568.2	8255.9	690.8	3039.2	602.3	1830.8	287.6	6087.7	775.7	4446.6	469.8
1991	5352.9	712.8	6781.8	649.7	3271.2	502.7	1583.9	301.8	5316.8	449.1	3788.3	481.8
1992	7793.3	744.9	10108.6	1137.6	4580.6	500.9	2119.3	277.4	6910.6	1147.9	4515.7	549.2
1993	6657.5	741.2	9040.0	747.4	3109.2	296.1	2101.7	436.8	5601.7	475.9	4138.3	386.3
1994	6954.2	693.9	9783.3	2005.7	3253.3	433.5	1526.7	140.2	6249.2	652.6	3850.0	512.1
1995	4819.2	439.1	8235.8	1132.1	3528.0	631.9	1300.0	363.1	4932.5	569.1	3809.2	277.6
1996	5617.5	582.7	11086.7	2175.8	3134.2	754.5	1265.0	113.8	5169.2	719.7	4149.2	397.2
1997	7493.3	943.5	8919.2	881.5	4138.3	786.0	1960.8	176.1	6546.7	521.3	5967.5	533.9
1998	6048.3	363.6	8635.8	817.0	3225.0	451.6	1550.0	212.4	6198.3	689.4	4626.7	431.4
1999	4125.8	770.3	6084.2	884.1	3179.2	728.4	1718.3	257.3	4375.0	567.8	3953.3	337.0
2000	4570.8	645.6	7864.2	989.7	3270.8	416.5	1351.7	252.7	3560.0	383.7	4110.0	490.9
2001	3805.8	454.5	6325.8	1317.0	2511.7	402.6	1089.2	84.5	4573.3	763.9	3442.5	665.9
2002	3932.5	726.4	5242.5	893.1	2397.5	586.8	1220.0	128.9	2805.8	407.7	2520.0	393.2
2003	8601.9	1795.9	11210.3	1834.3	3753.8	821.7	1674.2	175.8	6354.4	843.1	5138.4	910.8
2004	5072.5	294.9	7644.2	1173.2	3010.0	499.6	1325.8	156.5	4304.2	522.3	3640.0	366.3
2005	4833.3	410.5	7474.2	891.2	2286.7	177.5	1675.6	316.9	3965.8	439.3	3671.7	606.0
2006	4086.7	607.5	6418.3	858.2	2065.8	258.4	1254.1	150.0	3595.8	594.2	3073.3	433.2
2007	4383.3	530.1	9133.3	1587.9	3075.0	656.5	1205.0	161.3	4775.0	388.0	4033.3	512.8
2008	5358.3	550.9	9550.0	1133.5	4600.0	741.0	1433.3	172.1	5191.7	582.0	3675.0	392.7
2009	4333.3	571.1	6966.7	888.8	2766.7	297.2			3741.7	278.2	2728.6	398.6
2010	4458.3	571.2	7308.3	833.5	3650.0	505.0	1690.0	305.6	3883.3	347.8	3050.0	229.1
2011	3225.0	461.5	6200.0	1938.6	2366.7	311.7	1422.5	207.1	3241.7	595.7	2891.7	499.2
2012	3425.0	460.7	6483.3	637.6	1958.3	254.8	1513.3	424.1	3333.3	1229.4	2866.7	254.6
2013	2916.7	234.4	6391.7	640.2	1991.7	208.9	1735.8	308.8	2583.3	224.8	1716.7	360.3
2014	2408.3	349.5	5941.7	652.2	1950.0	222.6	1908.3	229.0	2233.3	201.5	1583.3	447.3
2015	3691.7	601.8	8291.7	664.4	2700.0	239.3	2425.0	610.1	2891.7	410.4		
2016	3491.7	284.7	7716.7	699.1	2700.0	240.8	1991.7	308.3	3208.3	569.9		
2017	3141.7	230.6	7058.3	505.7	2308.3	501.4	1825.0	255.8	2641.7	388.3	1170.8	85.9
2018	2891.7	279.5	5500.0	830.6	1916.7	412.5	1173.3	125.7	2083.3	389.6	1458.3	188.6
2019	2600.0	298.0	6308.3	585.1	2225.0	199.3	2033.3	282.0	2450.0	252.0	1658.3	159.0
2020	2908.3	427.9	8016.7	1187.1	2858.3	333.4	2150.0	170.3	2416.7	308.7	1716.7	240.5
2021	3091.7	301.0	7033.3	585.7	2291.7	263.3	2016.7	315.8	2608.3	316.5	2283.3	301.5

Table A2.6 Multiple Comparison of mean Zinc Concentrations (mg/kg dry weight) in Oysters from the Northside and Southside Outfalls

NORTHSIDE

Normality Test (Shapiro-Wilk):	Passed	(P = 0.094)
Equal Variance Test (Brown-Forsythe):	Failed	(P < 0.050)

Kruskal-Wallis One Way Analysis of Variance on Ranks

Site	N	Mean	Standard Deviation	Median	25%	75%
N5	12	3091.67	473.78	3050.0	2625.0	3450.0
N6A	12	7033.33	921.79	6750.0	6200.0	7875.0
N10	12	2291.67	414.42	2250.0	2025.0	2400.0
TC	12	2016.67	496.96	1900.0	1625.0	2350.0

H = 37.085 with 3 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

Tukey Multiple Comparison Matrix

	TC	N10	N6a
N5	*	NSD	NSD
N6a	***	***	
N10	NSD		

SOUTHSIDE

Normality Test (Shapiro-Wilk):	Passed	(P = 0.229)
Equal Variance Test (Brown-Forsythe):	Passed	(P = 0.873)

One Way Analysis of Variance

Group Name	N	Mean	Standard Deviation	SEM
S3A	12	2608.333	498.102	143.790
S5A	12	2283.333	474.501	136.977
TC	12	2016.667	496.960	143.460

Source of Variation	DF	SS	MS	F	P
Between Groups	2	2107222.222	1053611.111	4.389	0.020
Residual	33	7922500.000	240075.758		
Total	35	10029722.222			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.020).

Power of performed test with alpha = 0.050: 0.598

Tukey Multiple Comparison Matrix

	TC	S5a
S3a	*	NSD
S5a	NSD	

Appendix 3 Coastal Vegetation Species List

Species name	Common names
Coastal Intertidal Area	
Avicennia marina var resinifera	mangrove, manawa
Rush marsh and coastal grass	
Apodasmia similis	jointed wire rush, oioi
Juncus kraussii	sea rush, wiwi
Ficinia nodosa	knobby clubrush, wiwi
Austrostipa stipoides	bugger grass
Plagianthus divaricatus	saltmarsh ribbonwood, makaka
Salt marsh meadow	
Isolepis cernua var. cernua	slender club rush
Apium prostratum	sea celery, tuae koau
Samolus repens	sea primrose, maakoako
Selliera radicans	selliera, remuremu
Sarcocornia quinqueflora	glasswort, ureure
Exotic Species	
Atriplex prostrata	orache
Coastal Terrestrial/Freshwater Area	
Astelia banksii	coastal astelia, kowharawhara
Brachyglottis repanda	rangiora
Coprosma repens	taupata
Coprosma robusta	karamu
Cordyline australis	cabbage tree, tı kōuka
Corynocarpus laevigatus	karaka
Cyathea dealbata	silver fern, ponga
Cyathea medullaris	black tree fern, mamaku
Dicksonia squarrosa	wheki
Geniostoma ligustrifolium var. ligustrifolium	hangehange
Leptospermum scoparium var. scoparium	manuka
Leucopogon fasciculatus	mingimingi
Melicytus ramiflorus	whitey wood, mahoe
Metrosideros excelsa	pohutukawa
Myrsine australis	mapou
Phormium tenax	flax, harakeke
Piper excelsum	kawakawa
Pneumatopteris pennigera	gully fern, pakauroharoha
Pseudopanax lessonii	coastal five finger, houpara
Pseudopanax lessonii X crassifolius	Pseudopanax lessonii hybrid with P. crassifolius.
Pteridium esculentum	bracken
Sophora microphylla	kowhai
Veronica (Hebe) stricta	koromiko
Vitex lucens	puruti
Exotic Species	
Cortaderia selloana, C. jubata.	pampas
Ligustrum lucidum	tree privet
Solanum mauritianum	woolly nightshade
Ulex europaeus	gorse
Acacia sophorae	coastal wattle
Lycium ferocissimum	boxthorn
Pinus radiata	radiata pine
Cupressus macrocarpa	macrocarpa
Wetland	
Typha orientalis	bullrush, raupo
Cyperus ustulatus	giant umbrella sedge,
Machaerina articulata	jointed twig rush
Bolboschoenus fluviatilis	marsh club-rush
Exotic Species	
Glyceria maxima	reed sweet-grass

Appendix 4 Bird Survey – Site Conditions

Northside/Southside and Ruakohua areas

18 May 2020

Counts were undertaken over the tidal period High Water + 1 hour (i.e. 1 hour after high tide) to Low Water inclusive, a total of 6 counts – 0900hrs, 1000, 1100, 1200, 1300, 1400. Conditions were ideal with a light SE wind (average = 2.8 kts; range 1.5-4.0 kts); average air temperature = 17.3 °C; average barometric pressure = 1021.5 hPa; fine, sunny with scattered cloud. Raw data are presented in Table A4.1.

High Water (HW) 0731 hrs 3.5m tidal height

Low Water (LW) 1347 hrs 1.2m tidal height

14 August 2020

Counts were undertaken from High Water + 3 hours (c. half tide falling) to Low Water + 2 hours (rising tide) inclusive and at 0900, 1000, 1100, 1200, 1300 and 1400 hours. Conditions during the counts were as follows – easterly wind (i.e. offshore) averaging 7.3 kts (range 3 – 12 kts); average air temperature = 13.1 °C; average barometric pressure = 1016.8 hPa; dry, 80% cloud cover to 1000hrs then dry, sunny, 60% cloud. Raw data are presented in Table A4.1.

HW 0538 hrs 3.3m

LW 1201 hrs 1.5m

14 October 2020

Counts were undertaken from High Water +1 hour (1 hour after high water) to Low Water inclusive, and at 1030hrs, 1130, 1230, 1330, 1430 and 1530. Conditions during the survey were as follows - south/south west wind to 9 kts, average 6.7 kts; average air temperature = 19.7 °C; average barometric pressure = 1014.7 hPa; dry, sunny with variable cloud. Raw data are presented in Table A4.1.

HW 0910 hrs 3.8m

LW 1522 hrs 0.9m

22 January 2021

Counts were undertaken from High Water +4 hours (c. 1 hour after half tide falling) to Low Water + 3 hours (c. half tide rising), and every hour from 1000 to 1500. Conditions during the survey were as follows – west/south west wind to 13 kts, average 9.0 kts; average air temperature = 22.3°C; average barometric pressure = 1008 hPa; dry, sunny with cloud clearing. Raw data are presented in Table A4.1.

HW 0548 hrs 3.3m

LW 1158 hrs 1.6m

Table A4.1 Hourly weather parameters at the observation site overlooking the Northside-Southside Outfall and Ruakohua spillway.

TIME (hrs)	Air temperature (C)	Barometric pressure (hPa)	Wind (kts)	General weather conditions
18-May-20				
900	14.1	1022	SE to 1.5	fine, sunny, scattered cloud
1000	15.3	1022	SE to 4	fine, sunny, scattered cloud
1100	17.1	1022	SE to 2	fine, sunny, scattered cloud
1200	18.9	1021	SE to 5	fine, sunny, scattered cloud
1300	18.9	1021	SE to 2	fine, sunny, scattered cloud
1400	9.3	1021	SE to 2	fine, sunny, scattered cloud
Mean	*17.3*	*1021.5*	*2.8*	
SD	*2.2*	*0.5*	*1.4*	
14-Aug-20				
900	10.8	1016	E to 3	dry; 80% cloud cover
1000	12.2	1017	E to 5	dry; 80% cloud cover
1100	14.3	1017	E to 7	dry; sunny;60% cloud cover
1200	13.9	1017	E to 12	dry; sunny;60% cloud cover
1300	14.2	1017	E to 11	dry; sunny;60% cloud cover
1400	13.2	1017	E to 6	dry; sunny;60% cloud cover
Mean	*13.1*	*1016.8*	*7.3*	
SD	*1.4*	*0.4*	*3.5*	
14-Oct-20				
1030	18.4	1015	S to 5	dry; sunny with cloud
1130	17.6	1015	S to 6	dry; sunny with cloud
1230	20.2	1015	S to 6	dry; sunny, clear
1330	19	1015	SW to 9	dry; sunny, clear
1430	21.5	1014	SW to 7	dry; sunny with cloud
1530	21.4	1014	SW to 7	dry; sunny with cloud
Mean	*19.7*	*1014.7*	*6.7*	
SD	*1.6*	*0.5*	*1.4*	
22-Jan-21				
1000	21.1	1007	SW to 4	dry; sunny; occ. cloud
1100	20.8	1008	SW to 6	dry; sunny; occ. cloud
1200	21.5	1008	SW to 10	dry; sunny; occ. cloud
1300	24.6	1008	SW to 11	sunny; cloud clearing
1400	21.9	1008	W to 13	sunny; cloud clearing
1500	23.9	1008	W to 10	sunny; cloud clearing
Mean	*22.3*	*1007.8*	*9*	
SD	*1.6*	*0.4*	*3.3*	

Kahawai to North streams area

19 May 2020

Counts of birds in the intertidal habitat were undertaken from High Water + 2.5 hours (i.e. 2.5 hours after high water) to Low Water, a total of six counts to parallel the Outfall – Spillway surveys – 1100 hours, 1130, 1200, 1230, 1330, 1430. In addition, a significant high tide roost on raised rock platforms was inspected off the end of Higgins Road about two hours after high water and prior to birds moving from it. Conditions were also ideal with a SE wind (average 5.3 kts offshore; range 2-8 kts); average air temperature = 15.9 °C; average barometric pressure = 1025.9 hPa; fine, dry and sunny. Raw data are presented in Table A4.2.

High Water (HW) 0819 hrs 3.7m tidal height

Low Water (LW) 1434 hrs 1.1m tidal height

28 August 2020

Six counts covered the period from High Water + 3 hours (i.e. c. half tide falling) to Low Water + 2 hours (i.e. tide rising) inclusive – 0900 hours, 1000, 1100, 1200, 1300 and 1400. Weather conditions consisted of an average air temperature of 14.9 °C and an average barometric pressure of 1018.7 hPa. The wind was westerly at an average of 3.8 kts (range 0 – 7 kts) and the general weather dry, sunny with cloud. Raw data are presented in Table A4.2.

HW 0558 hrs 3.5m

LW 1214 hrs 1.3m

27 October 2020

Six counts were completed of the habitat from High Water + 1.5 hrs to Low Water inclusive – 1000hrs, 1030, 1130, 1230, 1330 and 1430. Weather conditions consisted of an average air temperature of 21.2 °C and an average barometric pressure of 1021.5 hPa. The wind was north westerly to 5 kts until 1030hrs then changing to south west to 5 kts; overall the average wind speed was 3.2 kts. General weather conditions were dry, cloudy with sunny intervals. Raw data are presented in Table A4.2.

HW 0834 hrs 3.4m

LW 1439 hrs 1.3m

25 January 2021

Counts were undertaken from High Water +1 hour to Low Water inclusive, and each hour from 1000 to 1500 inclusive. Conditions during the survey were as follows – south west wind to 10 kts, average 8.2 kts; average air temperature = 22.6°C; average barometric pressure = 1011.3 hPa; fine, sunny with scattered cloud. Raw data are presented in Table A4.2.

HW 0904 hrs 3.4m

LW 1516 hrs 1.4m

Table A4.2 Hourly weather parameters at the observation site overlooking the Kahawai – North Streams.

TIME (hrs)	Air temperature (C)	Barometric pressure (hPa)	Wind (kts)	General weather conditions
19-May-20				
1100	15.2	1026	SE to 5	fine; dry; sunny
1130	14.6	1026	SE to 8	fine; dry; sunny
1200	15.7	1026	SE to 6	fine; dry; sunny
1230	16	1026	SE to 5	fine; dry; sunny
1330	16.6	1025	SE to 8	fine; dry; sunny
1430	16.6	1025	SE to 4	fine; dry; sunny
Mean	15.8	1025.7	6	
SD	0.8	0.5	1.7	
28-Aug-20				
900	12.8	1018	nil	dry; sunny with cloud
1000	13.3	1019	nil	dry; sunny with cloud
1100	14.8	1019	W to 5	dry; sunny with cloud
1200	15.4	1019	W to 7	dry; sunny with cloud
1300	16.6	1019	W to 6	dry; sunny with cloud
1400	16.6	1018	W to 5	dry; sunny with cloud
Mean	*14.9*	*1018.7*	*3.8*	
SD	*1.6*	*0.5*	*3.1*	
27-Oct-20				
1000	19.1	1022	NW to 3	dry; sunny with cloud
1030	19.8	1022	NW to 5	cloudy; sunny intervals
1130	20.6	1022	SW to 1	cloudy; sunny intervals
1230	22.4	1021	SW to 2	cloudy; sunny intervals
1330	22.6	1021	SW to 3	cloudy; sunny intervals
1430	22.8	1021	SW to 5	cloudy; sunny intervals
Mean	*21.6*	*1021.5*	*3.2*	
SD	*1.6*	*0.5*	*1.6*	
25-Jan-21				
1000	21.1	1012	SW to 10	dry; sunny with cloud
1100	23	1012	SW to 10	dry; sunny with cloud
1200	21.9	1011	SW to 10	dry; sunny with cloud
1300	22.2	1011	SW to 6	dry; sunny with cloud
1400	23.9	1011	SW to 5	dry; sunny with cloud
1500	23.3	1011	SW to 8	dry; sunny with cloud
Mean	*22.6*	*1011.3*	*8.2*	
SD	*1*	*0.5*	*2.2*	

Appendix G Biodiversity Compensation Model – Coastal Birds

REPORT

Tonkin+Taylor

Biodiversity Compensation Model

Coastal Birds

Prepared for
New Zealand Steel

Prepared by
Tonkin & Taylor Ltd

Date
April 2024

Job Number
1010577.2000R v2

Together we create and sustain a better world
www.tonkintaylor.co.nz

Document control

Title: Biodiversity Compensation Model					
Date	**Version**	**Description**	**Prepared by:**	**Reviewed by:**	**Authorised by:**
July 2022	1	Draft Biodiversity Compensation Models to inform Resource Consent application and Coastal Bird Management Plan	S Jackson S Heggie-Gracie	M Baber	J Simpson
April 2024	2	Indicative Draft Biodiversity Compensation Models to inform Resource Consent application and Coastal Bird Management Plan –EAF and NPSIB updates	S Jackson S Heggie-Gracie	M Baber	J Simpson

Distribution:

New Zealand Steel	1 electronic copy
Tonkin & Taylor Ltd (FILE)	1 electronic copy

Table of contents

1 Introduction

1.1 Background

New Zealand Steel (NZ Steel) owns and operates the Glenbrook Steel Mill near Waiuku, Auckland (Site). NZ Steel holds resource consents (Existing Permits) that authorise the discharge of stormwater and process water from the Steel Mill to surface water and the Coastal Marine Area (CMA). The North Drain, the Ruakohua Stream and the Kahawai Stream all receive discharges from the Steel Mill and in turn discharge to the CMA of the Waiuku Estuary. Further, there are two direct discharges to the CMA, the Northside and Southside Outfalls, which discharge treated stormwater and process water from the Steel Mill (refer to consent application documents).

In June 2021, NZ Steel applied for Resource Consents to replace the discharge permits that authorise the stormwater and process water discharges from the Steel Mill to freshwater and the CMA.

NZ Steel has secured co-funding from the NZ Government to enable the installation of an electric arc furnace (EAF) at the Site. If the EAF goes ahead, it is anticipated that the EAF will be fully operational by 2027. The EAF will enable reduced use of virgin steelmaking materials (including iron sand and coal) and instead the recycling of externally sourced scrap. Once the EAF is fully operational, only one of the current two ironmaking streams will operate at any one time.

Based on initial information it is expected that effects on the Receiving Environment will be reduced from those detailed in the Marine Ecological Effects Assessment (T+T, 2024a) once the EAF is fully operational. However, to remain conservative, any potential improvement in discharge quality was not factored into the assessment. The assessment therefore presents a 'worst case scenario' based on the current operations.

1.2 Purpose and scope

NZ Steel has requested that Tonkin & Taylor Ltd (T+T) prepare this report to support the assessment of marine ecological effects associated with the proposed discharge consent application, and the assessment of the scale and nature of the compensation proposed in relation to those effects. This has been undertaken through the application of preliminary Biodiversity Compensation Models (BCM)[1].

The preliminary BCMs are used as decision support tools to help determine the type and magnitude of biodiversity compensation that is likely needed to achieve positive effects that outweigh the adverse effects for residual effects on coastal avifauna values associated with discharges from the Site.

This BCM sits within the appendices of the Marine Ecological Effects Assessment (T+T, 2024a). The outcomes of the BCM will inform the Coastal Birds Management Plan, required by proposed Resource Consent Condition 17, and have informed the draft Coastal Birds Management Plan (T+T, 2024b) that accompanies this report.

[1] These BCMs are considered preliminary and would not typically be considered finalised until feedback and inputs on the approach and data inputs by ecologists representing regulatory authorities and submitters has been included.

2 The Biodiversity Compensation Modelling (BCM) approach

2.1 Overview

The BCMs are used instead of biodiversity offset models when quantitative data is not available or lacks adequate precision to determine if adverse effects can be demonstrably offset[2] (Baber et al., 2021a,b,c). This is almost always the case for plan change and resource consent applications that are based on future predictions rather than on real data that has been collected after compensation has been undertaken (Baber et al., 2021a,b).

The BCMs include the determination of a biodiversity value score (herein "value score") for habitats and/or species, both before and after impacts ("losses") and before and after implementation of proposed compensation action(s) ("gains"). These value scores are derived from the NZ Steel assessments of ecological effects on coastal birds. Specifically, the assessments of ecological value (before impacts) and magnitude of effect are as set out in the respective marine ecological effects assessment report (T+T, 2022a; Section 6.10). To this end, the value scores are based on a combination of site-specific field assessments, scientific literature and the professional judgement of project ecologists.

The BCM approach and methods are described in detail in the User Guide developed by Tonkin & Taylor Ltd (T+T) (Baber et al., 2021a).

2.2 Advantages of BCMs

To date, biodiversity compensation requirements for plan change or resource consent applications have been determined based solely on professional opinion compensation ratios or 'multipliers'.

The key advantages of BCMs in comparison to these previous approaches are that BCMs provide greater transparency and scientific rigour to the process of developing measures to address residual adverse effects on biodiversity through compensation actions at proposed compensation site(s). In doing so, the BCMs operate at the 'as close to offset as possible' end of the compensation continuum. This is termed 'biodiversity compensation' in the National Policy Statement for Indigenous Biodiversity (NPSIB) (Ministry for the Environment [MfE], 2023).

2.3 Model limitations

In applying any biodiversity offset or compensation model, it is important to acknowledge the limitations, constraints and uncertainties associated with such models (Maseyk et al., 2018). Notably for BCMs, these limitations, constraints and uncertainties have the potential to generate false positives, i.e. instances where the models generate Net Gain (or positive) outcomes when the converse is true (Baber et al., 2021b). To address this risk, model inputs are deliberately conservative, and Net Gain (or positive) target outcomes are also conservative, equating to a target of 10% exceedance is necessary to reach a conclusion of No Net Loss.

It is also important to recognise that as described in Section 2.2 above, this approach is robust, provides transparency for determining compensation requirements to address residual adverse effects.

[2] A biodiversity offset is a 'measurable conservation outcome' that meets certain principles and balances adverse residual effects that cannot reasonably be avoided, minimised, remedied and/ or mitigated, to a no net loss / net gain standard. While offsetting requires a measurable outcome that has been quantified through a robust and transparent process, biodiversity compensation does not necessarily need to be quantified and measurable.

3 Coastal bird biodiversity compensation

3.1 Overview of residual effects

The discharges from the Steel Mill to the CMA have an impact on benthic ecology and shellfish, primarily from: elevated metal concentrations in the water column and in sediment, increased sedimentation rates, and increased water temperature and decreased salinity in the modelled mixing zone.

These effects are considerably more pronounced in the immediate vicinity of the Northside and Southside Outfalls (i.e., within the modelled mixing zone), with effects progressively lessening towards the subtidal channels and across the wider ZOI. However, the DHI (2021) modelling shows that proposed discharges do have a small and measurable effect on sedimentation rates and sediment metal levels across a relatively large area of intertidal habitat in the ZOI outside the modelled mixing zone. The identified sediment load coming from proposed discharges contributes to this effect as one, albeit relatively minor, source of sediment to the Waiuku Estuary. Approximately 1.3% of the total annual average sediment load and 6.4% of the very fine sediment load to the Waiuku Estuary is derived from the proposed discharges.

These effects can result in reduced diversity and condition of benthic invertebrate prey for foraging coastal birds. In addition, within the modelled mixing zone, the proposed discharges have resulted in elevated zinc and copper concentrations in oysters, a food resource for coastal bird species. The greatest effect is for zinc at site N6a, closest to the Northside Outfall.

Other potential effects on coastal birds as a result of the Steel Mill discharges include suspended sediment in the water column (impacting the visual foraging ability of birds) and potential impacts on saline vegetation (such as mangroves, saltmarsh and large roost trees) that provide habitat for cryptic coastal wetland birds such as banded rail and marsh crake as well as nesting / roosting coastal birds. These potential effects were assessed as low or very low.

NZ Steel's existing water management systems are already effective at removing the majority of contaminants and sediment from the existing Northside and Southside Outfall discharges. In addition, the quality of the discharges can be expected to improve over the term of the consent due to NZ Steel's continual improvement programme which is embedded in its Environmental Management System. It is also expected that effects on the Receiving Environment will be reduced from those detailed in the Marine Ecological Effects Assessment once the EAF is fully operational (T+T, 2024a).

However, despite the adverse effects of the existing and proposed discharges being avoided, remedied, minimised and /or mitigated to the greatest practicable extent, the proposed discharges will have residual adverse effects on coastal birds. Specifically, the proposed discharges are expected to result in a **moderate** level of ecological effect on coastal bird biodiversity values.

Considering the above, the Marine Ecological Effects Assessment (T+T, 2024a) identifies an overall **moderate** level of effect on coastal birds.

3.2 Proposed coastal bird compensation

Proposed compensation measures are outlined below and shown in **Figure 3.1** and will be fine-tuned through the resource consenting process and following further consultation. The quantum of each measure will also be determined through the application of this preliminary BCM, with proposed implementation, monitoring, and review to be outlined in the CBMP. Proposed compensation measures include:

[**Drafting note:** The below are **indicative** compensation actions that may each individually or collectively be proposed and outlined in the final BCM. They are included in this preliminary BCM as a guide to illustrate the nature and type of compensation measures that NZ Steel is likely to propose in the final Coastal Bird Management Plan (CBMP) but alternative proposals may be included to the extent their impact is sufficient having applied the BCM.]

1 **Kahawai roost complex enhancement: Enhancement of the mid-high tide roost sites in the vicinity of the Kahawai Stream discharge to the CMA (referred to as the Kahawai roost complex).**

Mangroves are encroaching on these locally important roost sites, compromising the line of sight (to predators) rendering roost sites less favourable for roosting. Mangrove removal on the Kahawai roost complex would help to restore the roosts and increase available space for roosting birds; an area of 0.25 ha is proposed. A limited amount of pest plant control along the landward edge of the Kahawai Roost complex could further improve line of sight and enhance the site for roosting bird species. In addition to the roost-site enhancement proposed above, an elevated sheltered area of approximately 0.15 ha sits immediately above a rock platform on the coastal margin and offers potential as a king tide roost site. However, this location is currently covered in mature pine trees and is unsuitable for roosting in its current form. This site will be restored to a functioning high value roost site through the removal of the pine trees, levelling of the elevated coastal margin, deposition of shell materials and planting of appropriate species to maintain line of sight.

Mangrove management: Selective mangrove removal and ongoing mangrove seedling control

Where recent historical aerials show intertidal foraging areas to be mangrove-free in the vicinity of the Kahawai roost (between the Lower North Stream and Kahawai Stream mouths), selective mangrove removal (~6 ha) (enhancement) and ongoing mangrove seedling removal (maintenance) of ~60 ha is proposed. These actions will assist with enhancing and maintaining the quality and availability of intertidal feeding habitat for almost all of the coastal bird species present in the ZOI; refer to **Figure 3.1** for the proposed mangrove removal and maintenance zone.

2 **Expansion of mangrove management at the Waipipi Roost: Expansion of mangrove management being undertaken at the Waipipi Roost to improve the quality of this high tide roost through maintenance of line of sight for roosting birds.**

Auckland Council has acquired resource consent to undertake initial mangrove clearance on Waipipi Roost (2.88 ha), as shown in **Figure 3.1**. Mangrove clearance proposed as part of this compensation package (4.8 ha) is over and above what is currently proposed by Auckland Council (i.e. this is not considered to be 'additionality' under biodiversity offsetting guidance).

Mangrove removal is proposed for all trees within the area delineated in **Figure 3.1** as 'Additional proposed Waipipi mangrove clearance'.

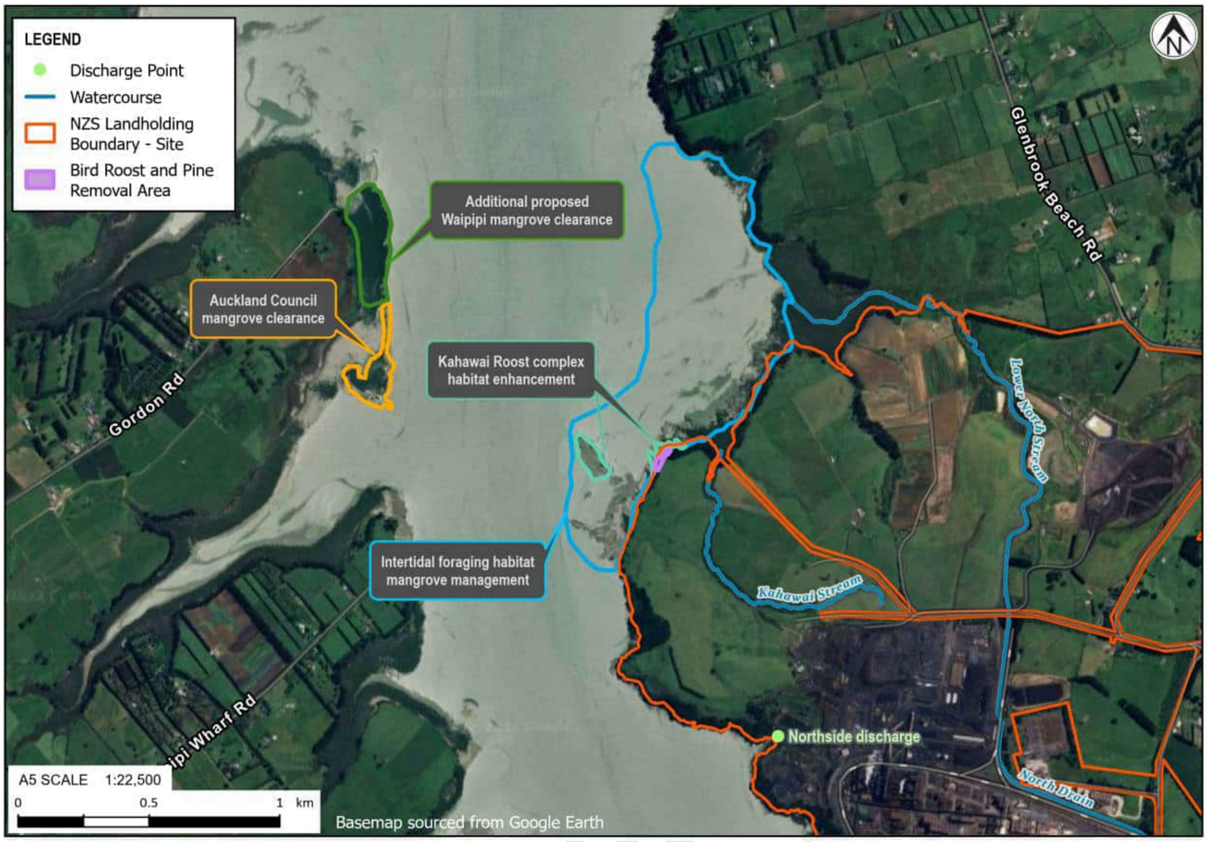

Figure 3.1: Location of proposed compensation actions and the NZS Landholding Boundary in the Waiuku Estuary

3.3 Coastal bird Biodiversity Compensation Model

A preliminary coastal birds-specific BCM has been developed for the Resource Consent applications to determine the type and magnitude of effort that is expected to achieve positive biodiversity outcomes for coastal birds.

3.3.1 BCM inputs

Table 3.1 below describes the data inputs into the BCM. **Table 3.2** below provides the data input and output summary. **Table 3.1** sets out the explanation and justification for each data input into the BCM; input descriptors and score ranges for each of the BCM inputs are included in **Appendix A**. Definitions and terminology associated with each model input (for example, the term “benchmark” or “Net Gain target”) are described in **Appendix A**, noting that as per the NPSIB, Appendix 4 (MFE, 2023) compensation principles identify ‘positive effects that outweigh adverse effects’ as opposed to the term ‘Net Gain’ which applies to biodiversity offsetting.

Table 3.1: BCM data inputs

General model descriptor inputs	
Model inputs	**Explanation**
Biodiversity type	Coastal avifauna in the Zone of Influence (ZOI)
Technical expert input(s)	Susan Jackson, Matt Baber, Sam Heggie-Gracie

Benchmark	A benchmark of 5 equates to a pre-human impact state of intertidal feeding flats, fringed with saline vegetation with unimpeded shell barrier beaches and sandstone reef habitats that perform high-tide roost functions.
How many habitat types OR sites are impacted	1 – which includes the ZOI as defined in the marine ecological assessment, and which is used by an assemblage of coastal birds.
Number of proposed compensation measures	3 – under this BCM we are considering how compensation measures (mangrove management for intertidal foraging, maintenance of mid-high tide roosts (Kahawai and Waipipi)) benefit the same coastal bird assemblage that is affected by project activities within the ZOI.
Net Gain target	10% (i.e. the compensation score needs to be at least 10% higher than the impact score). In general terms, the greater the assigned Net Gain outcome target, the greater the likelihood that No Net Loss or preferably Net Gain outcomes will be achieved. As noted above, 10% is agreed to be generally appropriate and provides a margin of error in terms of data inputs into the model.
Impact model inputs and descriptions	
Habitat/site impacted	Coastal avifauna that uses the Zone of Influence (ZOI)
Impact contingency (risk)	4 – Very High risk/value (calculated biodiversity impact score is multiplied by 1.2 (+20%)) This score is based on the threat status of birds foraging and roosting in the ZOI, as well as species diversity and abundance (described further in the EcIA). The higher the value or threat status of the biodiversity feature being modelled, the higher risk of irreversible biodiversity loss associated with project activities (irrespective of the level of effect).
Impact contingency (uncertainty)	3 – High uncertainty (calculate biodiversity impact score is multiplied by 1.2 (+20%) A high uncertainty has been assigned based on: • The lack of literature on the impact of sedimentation and associated contaminants on coastal birds. A recent literature review (lukies et al., 2021) draws on international literature and all known NZ knowledge on this topic, however it is still difficult to draw quantitative links between impact and effect. • The lack of knowledge on how vulnerable individual birds are, which is largely dependent on the proportion of time individual birds spend foraging in the zoi or modelled mixing zone.
Areal extent of impact (ha)	1911 ha – this includes the intertidal areas of the modelled mixing zone and the ZOI.
Value score <u>prior to</u> impact	4 – A value of 4 (relatively high value habitat) relative to the benchmark of 5 as per the characterisation and assessment of coastal bird values in the Marine Ecological Effects Assessment. This score reflects the fact that the ecosystem is degraded but the coastal bird species assemblage remains diverse and abundant.
Value score <u>after</u> impact	3.75 – A value of 3.75 reflects that the intertidal habitat will be further impacted by NZ Steel discharges to the CMA (as opposed to general degradation associated with discharges from the wider catchment). The value score after impact assumes a potential 5% drop from the benchmark (5) and is associated with the impact that the proposed discharge has on the quantity and quality of the benthic fauna assemblage within the modelled mixing zone and

	wider ZOI. The impact on benthic infauna is driven by small increasing concentrations of zinc, and to a lesser degree copper, suspended sedimentation and sedimentation deposition. The impact on the quality and quantity of benthic infauna assemblages is linked to a reduction in foraging habitat quality for coastal birds. Sediment deposition is linked to mangrove expansion and encroachment onto high tide roosts and into intertidal foraging areas. A 5% drop from the benchmark considers that 5% of the coastal bird assemblage is potentially impacted by the effects associated with the discharge to the degree that they preferentially choose to forage or roost elsewhere. However, the 5% drop from baseline also takes into account the existing degraded state of intertidal foraging habitat benthic infauna assemblages, and the fact that they continue to support high value coastal bird species.
Compensation model inputs	
Compensation type 1	Kahawai Roost complex enhancement (1.52 ha)
Discount rate	+3% (the default discount score as per Maseyk et al. (2015); Baber et al. (2021a)). The discount rate addresses the temporal time lag between the impact occurring and the biodiversity gains being generated by the conservation action(s).
Finite end-point	2 years - this is the assessed timeframe to achieve mangrove clearance extents. Subsequent mangrove management to keep intended extents clear.
Compensation contingency (confidence)	3 – Moderate confidence in success of compensation actions (50%-75%). Given the existing knowledge that well maintained high tide roosts (i.e. Ambury Foreshore) successfully provide roosting habitat for large numbers and a wide variety of coastal birds we can be moderately confident that any improvements to the Kahawai Roost complex will further enhance the availability of habitat for birds that can roost at this location.
Areal extent (ha) of compensation type	1911 ha (ZOI). Areal extent needs to be consistent with ZOI for impact; compensation outcomes apply to coastal avifauna assemblage in the ZOI.
Value score <u>prior to</u> compensation measure (relative to benchmark)	3.75 – this is the value score before the impact as described above.
Value score <u>after</u> compensation measure (relative to benchmark)	**4** – We have assigned a score of 4, based on a 5% Improvement of the benchmark (0.25) of 5. This figure has been assigned on the basis that the compensation action will contribute to increasing high tide roost capacity in the Waiuku Estuary (the ZOI). The Waiuku Estuary contains a number of significant high tide roost sites; the carrying capacity of intertidal areas for shorebirds is linked to the proximity of good high tide roosts. If roosts are degraded or lost, the number of shorebirds using the adjacent intertidal feeding areas may decline (pers obs, Dr Tim Lovegrove (Lee, 2019)). Mangrove removal on the Kahawai roost complex would help to restore the roosts and increase available space for roosting birds. A limited amount of pest plant control along the landward edge of the Kahawai Roost complex could further improve line of sight and enhance the site for roosting bird species.

	The removal of pine along the elevated coastal margin comprising approximately 0.15 ha will further benefit coastal birds by providing a king tide roosting site. The assigned value score after impact was considered suitable (i.e. not higher or lower) on the basis that although the quantum of habitat for compensation is relatively small, the benefits are expected to be substantial to roosting birds. To assign a higher score, we would expect the area for compensation to be larger and / or more intensive compensation actions that would have beneficial outcomes for the coastal bird species assemblage.
Compensation type 2	Mangrove management for intertidal foraging (60.9 ha)
Discount rate	+3% (the default discount score as per Maseyk et al. (2015); Baber et al. (2021a). The discount rate addresses the temporal time lag between the impact occurring and the biodiversity gains being generated by the conservation action(s).
Finite end-point	2 years - this is the assessed timeframe to achieve mangrove clearance extents. Subsequent mangrove management to keep intended extents clear.
Compensation contingency (confidence)	2 – High confidence in success of compensation actions (75%-90%). Given the existing knowledge that mangrove encroachment onto intertidal foraging grounds decreases the availability of foraging habitat, we can be confident that maintenance of the intertidal foraging area as mangrove free will enhance foraging quality and quantity.
Areal extent (ha) of compensation type	1911 ha (ZOI). Areal extent needs to be consistent with ZOI for impact; compensation outcomes apply to coastal avifauna assemblage in the ZOI.
Value score <u>prior to</u> compensation measure (relative to benchmark)	3.75 – this is the value score before the impact as described above.
Value score <u>after</u> compensation measure (relative to benchmark)	**3.9** – We have assigned a score of 3.9, based on a 3% improvement of the benchmark (0.15) of 5. We have calculated that an area of 60.9 ha of mangrove management equates to 3% of the intertidal foraging area of the ZOI. Mangrove management of 60.9 ha improves the quality of and ensures continuation of availability of intertidal foraging habitat for coastal birds in a proportion of the ZOI. Where recent historical aerials show intertidal foraging areas to be mangrove-free in the vicinity of the Kahawai roost (between the Lower North Stream and Kahawai Stream mouths), selective mangrove removal (enhancement) and ongoing mangrove seedling removal (maintenance) of ~60 ha is proposed. ~60 ha is proposed based on historical mangrove extents which demonstrate mangrove encroachment in the Kahawai embayment in recent years. These actions will assist with enhancing and maintaining the quality and availability of intertidal feeding habitat for almost all of the coastal birds present in the ZOI.
Compensation type 3	Waipipi Roost (3.88 ha)
Discount rate	+3% (the default discount score as per Maseyk et al. (2015); Baber et al. (2021a). The discount rate addresses the temporal time lag between the impact occurring and the biodiversity gains being generated by the conservation action(s).
Finite end-point	2 years - this is the assessed timeframe to achieve mangrove clearance extents. Subsequent mangrove management to keep intended extents clear.

Compensation contingency (confidence)	2 – High confidence in success of compensation actions. Given the existing knowledge that well maintained high tide roosts (i.e. Ambury Foreshore) successfully provide roosting habitat for large numbers and a wide variety of coastal birds we can be confident that any improvements to the Waipipi Roost will further enhance the availability of habitat for birds that can roost at this location.
Areal extent (ha) of compensation type	1911 ha (ZOI). Areal extent needs to be consistent with ZOI for impact; compensation outcomes apply to coastal avifauna assemblage in the ZOI.
Value score prior to compensation measure (relative to benchmark)	3.75 – this is the value score before the impact as described above.
Value score after compensation measure (relative to benchmark)	**4** – We have assigned a score of 4, based on a 5% improvement of the benchmark (0.25) of 5. This compensation action contributes to increasing high tide roost capacity in the Waiuku Estuary (the ZOI). High tide roost capacity and proximity is linked to the carrying capacity of an estuary. If suitable high tide roosts are degraded or lost, the number of coastal birds using adjacent intertidal foraging areas may decline. The Waipipi Roost is designated an SEA-M1 on the basis of provision of high tide roost services for coastal birds. Existing shell banks can be seen on historical aerials in this location that have been encroached by mangroves over a period of 20-30 years; restoration of these shell banks is expected to have a significant benefit to roosting coastal birds in the ZOI. An area of 4.8 ha proposed for mangrove removal on the Waipipi Roost, which is over and above what is currently proposed by Auckland Council (2.88 ha); this is not considered to be 'additionality' under biodiversity offsetting guidance.

3.3.2 BCM outputs

The BCM model output indicates a Net Gain outcome of 27.3% based on the compensation score being 27.3% higher than the absolute[3] impact score; refer to Table 3.2 . While the 27.3% compensation score implies a precise quantum of Net Gain, this is not the case because there is a degree of uncertainty in the model. However, the higher the Net Gain percentage, the more likely that the stated NG target of 10% will eventuate.

[3] Absolute disregards the negative e.g. the absolute impact score in this case is 137.59 rather than -137.59

Table 3.2: Coastal avifauna BCM input and output summary table

Model Inputs			
Input descriptors	**Input data**		
Project/reference name	NZ Steel Discharge Consent Application		
Biodiversity type	Coastal avifauna		
Technical expert(s) input	S Jackson, M Baber, S Heggie-gracie		
Benchmark	5		
How many habitat types OR sites are impacted	1		
Number of proposed compensation actions	3		
Net gain target	10%		
Habitat/Site Impact(s)	**Avifauna**		
Impact risk contingency:	4		
Impact uncertainty contingency:	3		
Areal extent of impact (ha):	1911		
Value score prior to impact:	4		
Value score after impact:	3.75		
Compensation Action(s)	**Kahawai Roost complex enhancement**	**Mangrove management - intertidal feeding**	**Waipipi Roost enhancement**
Discount rate:	3.0%	3.0%	3.0%
Finite end point (years):	2	2	2
Compensation confidence contingency:	3	2	2
Areal extent (ha) of compensation type:	1911	1911	1911
Value score prior to compensation:	3.75	3.75	3.75
Value score after compensation:	4	3.9	4

Model outputs

	Total impact score	**Avifauna**		
Impact score	**-137.59200**	-137.59200		
	Total compensation score	**Kahawai Roost complex enhancement**	**Mangrove management - intertidal feeding**	**Waipipi Roost enhancement**
Compensation score	**175.17650**	56.29065	44.58219	74.30366
Net gain outcome	**27.3%**			

4 Applicability

This report has been prepared for the exclusive use of our client New Zealand Steel, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that our client will submit this report as part of an application for resource consent and that Auckland Council as the consenting authority will use this report for the purpose of assessing that application.

Tonkin & Taylor Ltd

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
....	....
Susan Jackson	Jenny Simpson
Senior Ecologist	Project Director

Sam Heggie-Gracie

Ecologist

Technical review by Dr Matt Baber, Consultant Ecologist

SUJA
\\ttgroup.local\corporate\auckland\projects\1010577\1010577.2000\issueddocuments\20240411.coastal birds bcm update_eaf and npsib_indicative draft v2.docx

5 References

Baber, M, Dickson, J, Quinn, J, Markham, J, Ussher, G, Heggie-Gracie, S, and Jackson, S. (2021a). *A Biodiversity Compensation Model for New Zealand* – A User Guide (*Version 1*). Prepared by Tonkin & Taylor Limited. Project number 1017287.0000P.

Baber, M, Christensen, M, Quinn, J, Markham, J, Ussher, G and Signal-Ross, R. 2021b): The use of modelling for terrestrial biodiversity offsets and compensation: a suggested way forward. Resource Management Journal, Resource Management Law Association (April 2021).

Baber, M, Dickson, J, Quinn, J, Markham, J, Ussher, G, Heggie-Gracie, S, and Jackson, S. (2021c). Biodiversity Compensation Model for New Zealand– Excel Calculator Tool (*Version 1*). Prepared by Tonkin & Taylor Limited. Project number 1017287.0000P.

Lee, S. (2019) Reversing the decline of the shorebirds of the Tāmake Estuary. Prepared for the Maungakiekie-Tāmaki & Ōrākei Local Boards.

Lukies, K.A.; Gaskin C.P.; Whitehead, E.A. (2021): The effects of sediment on birds foraging in intertidal and nearshore habitats in Aotearoa New Zealand: A literature review and recommendations for future work. Prepared for the Department of Conservation by the Northern New Zealand Seabird Trust, Auckland. 77 p.

Maseyk, F., G.T. Ussher, G. Kessels, M. Christensen and M. Brown (2018). Biodiversity Offsetting under the Resource Management Act: A guidance document September 2018. Prepared for the Biodiversity Working Group on behalf of the BioManagers' Group.

Maseyk, F., M. Maron, R. Seaton, and G. Dutson (2015). A Biodiversity Offsets Accounting Model for New Zealand. Contract Report No: 2014-008, prepared for Department of Conservation Hamilton Service Centre Private Bag 3072 Hamilton New Zealand.

Ministry for the Environment. (2023). National Policy Statement for Indigenous Biodiversity.

Roper-Lindsay, J., Fuller S.A., Hooson, S., Sanders, M.D., Ussher, G.T. (2018). Ecological impact assessment. EIANZ guidelines for use in New Zealand: terrestrial and freshwater ecosystems. 2nd edition. Prepared by the Environment Institute of Australia and New Zealand.

T+T (2024a). Glenbrook Steel Mill Discharges. Marine Ecological Effects Assessment. Prepared for New Zealand Steel Ltd.

T+T (2024b). Glenbrook Steel Mill Discharges. Draft Coastal Birds Management Plan. Prepared for New Zealand Steel Ltd.

Appendix A BCM input descriptors (From Table 3.1, Baber et al. 2021a)

Model inputs	Description
Project reference/ name	**Instruction** Manually type project reference as applicable.
Biodiversity type	**Instruction** Manually type in the biodiversity type to which the BCM relates, e.g., terrestrial vegetation, kahikatea swamp forest, raupō wetland, indigenous fauna assemblage, lizard assemblage, kānuka or Australasian bittern. **Explanation** Models can be applied to broad habitat types (e.g. forest habitat or wetland habitat) for which impact scores for several specific forest or wetland habitat types can be independently determined (e.g. exotic wetland versus a raupō wetland). This approach is often taken when the same compensation action or actions are proposed for different impacts on different habitat types. For example, for a long-tailed bat BCM, native revegetation may be proposed as a common compensation measure to address effects associated with the loss of three habitat types (exotic plantation forest, exotic scrub and pasture).
Technical expert input(s)	**Instruction** Manually type in the names of all technical experts involved in contributing to and agreeing data inputs. **Explanation** Determining data inputs with maximum accuracy requires the involvement of experts, likely a team, including those experienced in implementing, monitoring and reporting on management actions. Evaluating the outputs of the BCM will equally benefit from interpretation by a representative team of suitability qualified and experienced experts.
Benchmark	**Instruction** Manually type in **5** (the benchmark is always 5). **Explanation** The benchmark of 5 is a reference measure score which constitutes a hypothetical but realistic potential state. Typically, this would include a large, contiguous, native-dominated terrestrial or wetland ecosystem type that has been subject to intensive mammalian pest control over the long-term with the full suite of indigenous flora and fauna present at or near carrying capacity. This habitat would generally be of such high quality that compensation actions would provide negligible additional ecological gain. The benchmark is always 5 so that it aligns with the Ecological Impact Assessment Guidelines (EcIAG, Roper-Lindsay *et al.* 2018). In broad terms the following numerical scores for ecological value align with the following ecological value categories: 1 < 1 = Negligible 2 1 - < 2 = Low 3 2 - < 3 = Moderate 4 3 - < 4 = High

Model inputs	Description
	5 4 - < 5 = Very High 6 5 = Benchmark
How many habitat types OR sites are impacted	**Instruction** Select from the drop-down menu the number of different habitat type or sites/locations impacted. Up to 5 different habitat types or sites can be selected. **Explanation** When the affected biodiversity value constitutes a broad habitat type (e.g. native forest) there may be different habitat types that are impacted. For example, the biodiversity type 'native forest' may include pūriri forest, kānuka forest, and kauri forest. Each of these specific habitat types will likely require different impact contingencies and have different ecological value scores and should therefore be considered separately. When an affected biodiversity value includes a specific habitat type that is impacted at different sites or locations, considering these as separate may be warranted if the ecological value or the type of impacts differ across sites or locations. For example, a project may have different types and magnitude of impacts on a single 0.4 ha of kauri forest, (including 0.1 ha of total habitat loss through vegetation clearance and 0.3 ha of habitat degradation through edge effects and general disturbance associated with land use change). In this situation, the impacts on this kauri forest fragment could be separated out because the type and magnitude of effects differs. Equally though, the areas could be assessed as one, provided the impacts are appropriately captured in the assessment. If there are more than 5 habitat types or sites/locations impacted, a new BCM can be created, and the overall impact scores added.
Number of proposed compensation actions	**Instruction** Select from the drop-down menu the number of different compensation actions proposed. Up to 5 different compensation actions can be selected. **Explanation** Where compensation actions differ AND are undertaken in different locations or sites, or the spatial extent of the compensation action is different, then each action must be assessed independently. In some instances, different compensation actions in the same location can be lumped into a single compensation action (e.g. native revegetation and weed control), provided appropriate justification is given. Similarly, it may be appropriate to combine the same compensation action at different locations into a single compensation action, with appropriate explanation.
Net Gain target	**Instruction** Manually type in the desired Net Gain target as a percentage, e.g., if the number 20 is typed, this will be converted to 20%. **Explanation** In general terms, the greater the assigned Net Gain outcome target, the greater the likelihood that No Net Loss or preferably Net Gain outcomes will be achieved. For compensation a Net Gain outcome target of 10% is considered by the authors to be generally appropriate. This equates to a 10% exceedance of No Net Loss, i.e. the Compensation Score is 10% higher than the Impact Score. However, the selected Net Gain outcome target will need to be justified and should be assigned on a case-by-case basis.
Habitat/site impacts	**Instruction** Manually type the name of the habitat(s) or site(s) impacted. The number of named habitat(s) or site(s) will need to match the number of proposed compensation actions specified above.

Model inputs	Description
Impact risk contingency	**Instruction** Select from the drop-down menu: 1 = Negligible or low risk/ Negligible or low value (calculated impact score is multiplied by 1.0 (+0%)) 2 = Moderate risk/Moderate value (calculated impact score is multiplied by 1.05 (+5%)) 3 = High risk/High value (calculated impact score is multiplied by 1.1 (+10%)) 4 = Very high risk/Very high value (calculated impact score is multiplied by 1.2 (+20%)) **Explanation** The impact risk contingency addresses the increased likelihood that adverse effects will result in the permanent and irreplaceable loss of significant biodiversity values when impacting on habitats or species that are of higher ecological value. The assigned ecological value is based on the EcIAG ecological value assessment. The risk contingency percentage multiplier is commensurate with the EcIAG assigned ecological value with the multiplier assigned to each ecological value category based on testing under a range of scenarios[4]. For avoidance of doubt, the impact risk contingency relates to the biodiversity type. For example: 1 If the model biodiversity type is 'long-tailed bat' then the impact risk contingency relates to the assigned ecological value for long-tailed bat and would therefore be the same across the different long-tailed bat habitat types that are impacted and included in the model (e.g. pasture versus shelterbelts, versus mature forest). 2 If the model biodiversity type is a broad habitat type, e.g. 'native forest', and the impacts relate to more specific habitat types that differ in their ecological value, then the impact risk contingency for each habitat type will be different (e.g. kauri forest versus young regenerating kānuka forest).
Impact uncertainty contingency	**Instruction** Select from the drop-down menu: 1 = Low uncertainty (calculated impact score is multiplied by 1.05 (+5%)) 2 = Moderate uncertainty (calculated impact score is multiplied by 1.1 (+10%)) 3 = High uncertainty (calculated impact score is multiplied by 1.2 (+20%)) 4 = Very high uncertainty (the model will not work if this option is selected) **Explanation** By providing for a greater margin of error, the impact uncertainty contingency addresses the increased risk of permanent or irreplaceable biodiversity loss when impacting on more complex habitats, or on species for which there is less information regarding species-specific impacts associated with an effect. The rationale for category selection will need to be justified on ecological grounds. Where very high uncertainty exists in relation to adverse effects, this constitutes a limit to the use of the BCM model; project redesign or avoidance of effects should instead be considered.

[4] In general terms, the application of higher percentage multipliers was difficult to justify and generated predicted Net Loss outcomes when the converse would be expected. Similarly, the use of lower multipliers undermined confidence that predicted Net Gain model outputs would be achieved.

Model inputs	Description
	The percentage multipliers used for the impact uncertainty contingency levels have been assigned based on testing different multipliers under a range of scenarios.[5]
Areal extent of impact (ha)	**Instruction** Manually type in the areal extent of impact in hectares with respect to the value being considered (incorporating both direct and indirect effects). **Explanation** If there is more than one habitat type or more than one site of the same habitat type, then impact (ha) will relate to that specific habitat or site. However, the total habitat loss (ha) will be automatically summed and factored into the impact score calculations.
Value <u>prior to</u> impact	**Instruction** Manually type in a numerical score between 0 and 5 that relates to the value score <u>prior to</u> impact relative to the benchmark value score of 5. **Explanation** The assigned value score in all instances must relate explicitly to the biodiversity type that the model relates to. Adequate detail must be provided to justify the assigned ecological value score based on desktop and field investigations. This enables an understanding of the adequacy and certainty surrounding the assessment and should include an explanation of why the value score was neither higher nor lower. **Habitat value scores:** For habitats, the ecological value prior to impact relates to the representativeness, rarity and distinctiveness, diversity and pattern, and ecological context associated with the habitats/vegetation types within a project footprint as assessed against the benchmark. Refer to Section 5.2 and Table 4 of the Ecological Impact Assessment Guidelines (EcIAG, Roper-Lindsay *et al.* 2018), the detail of which would be provided in the Assessment of Ecological Effects report for the Project. In broad terms: 1 < 1 = Negligible 2 1 - < 2 = Low 3 2 - < 3 = Moderate 4 3 - < 4 = High 5 4 - < 5 = Very High 6 5 = Benchmark NB: 1 In some instances, consideration of loss of 'potential value' may be required for impact values (e.g. for natural inland wetlands under the National Policy Statement for Freshwater Management 2020 (NPS FM)). This should be considered in the context of the value affected and the potential value if it were restored (using best practice, reasonable efforts). Ensure that the reporting outputs are clear as to whether the 'existing' or 'potential' values were used to quantify the compensation measures. 2 The EcIAG (Roper-Lindsay *et al.* 2018) assessment of ecological value does not assess the contribution that a particular habitat type may make to ecological

[5] In general terms, the application of higher percentage multipliers for each level of uncertainty category was difficult to justify and generated predicted Net Loss outcomes when the converse would be expected. Similarly, the use of lower percentage multipliers for each level of uncertainty category undermined confidence that predicted Net Gain model outputs would be achieved.

Model inputs	Description
	functioning or the provision of ecosystem services. We recommend that these factors are also considered when assessing the value of impacted habitats. **Species or species assemblage value scores:** The EcIAG (Roper-Lindsay *et al.* 2018) does not include criteria for determining habitat suitability for a given species. Since habitat suitability is a key component of a magnitude of effects assessment, this will ideally be addressed in subsequent versions of the EcIAG. In the interim we set out proposed criteria below: 1 0 = Habitat not suitable. 2 < 1 = Marginal habitat that may be used but is not important for any part of the species or species assemblage life-cycle(s). 3 1 - < 2 = Relatively low value habitat that provides some but not all of a species or species assemblages life-history requirements and/or the habitat is of low quality and the relative abundance within the habitat is low compared to other habitat types. 4 2 - < 3 = Relatively moderate value habitat that provides for most, if not all, of a species or species assemblage's life-history requirements and/or the habitat quality is of moderate quality and the relative abundance within the habitat is moderate compared to other habitat types. 5 3 - < 4 = Relatively high value habitat that would typically provide for all species or species assemblage life-history requirements and/or provides a critical resource or resource(s) for life-history requirements. The habitat quality is high and the relative abundance within the habitat is, or is likely to be, high compared to other habitat types. 6 4 - < 5 = Relatively very high value habitat that provides for all species or species assemblage life-history requirements and/or provides a critical resource or resource(s) needed for life-history requirements. The habitat quality is very high and the relative abundance within the habitat is or is likely to be very high compared to other habitat types. Likely to be a local hotspot for that species. 7 5 = Highest quality habitat and/or relative abundance for a given species or species assemblage, likely to be a regional hotspot or benchmark with the species or species assemblage at carrying capacity. As with habitat scores, adequate detail must be included from desktop and field investigations to provide transparent justification for each value score. The reader needs to understand the adequacy and certainty surrounding the assessment and requires an explanation of why the score was neither higher nor lower. The model assumes a static rather than temporally dynamic biodiversity baseline at the impact site. The predicted NNL/NG outcome is therefore relative to pre-impact values. In instances where population densities or relative abundance appear higher in seemingly less suitable habitats than in more suitable habitats, this will need to be addressed and reflected in the relative value scores.
Value after impact	**Instruction** Manually type in a numerical score between 0 and 5 that relates to the value score after the impact relative to the benchmark value score of 5. **Explanation** The explanation for determining the habitat or species scores after impact is the same as the method for determining these scores prior to impact except that the assessment value score relates to the impact site after the impact has occurred. NB:

<table>
<tr><th>Model inputs</th><th>Description</th></tr>
<tr><td></td><td>1 The drop in ecological value relates to the magnitude of impact based on the EcIAG, which is a function of the extent, intensity, frequency and permanence of the impact. It is important to factor in all types of impacts associated with the project which may range from earthworks, vegetation and sedimentation to increased exposure to artificial lighting or noise, or domestic mammalian predators.
2 The model does not accept a value score of 0 as the formula will not work, but it does allow for a score of 0.001 (virtually zero).</td></tr>
<tr><td>Compensation action(s)</td><td>Instruction
Manually enter the compensation action proposed. The number of different compensation measures (habitat(s) or site(s)) will need to match the number of proposed compensation actions specified above.

Explanation
The compensation action relates to each type of habitat creation, restoration, or enhancement activity that is proposed, e.g., native revegetation into existing pasture and/or weed and mammalian pest control in existing forest.

As long as it is explained, it is appropriate to lump different compensation types where they are applied as a total package within a particular habitat or site (e.g. bush retirement coupled with weed control and mammalian pest control).</td></tr>
<tr><td>Discount rate</td><td>Instruction
Manually enter a discount rate.

Explanation
The discount rate addresses the temporal time lag between the impact occurring and the biodiversity gains being generated by the conservation action(s).

A discount rate of 3% is recommended. This is the same as the discount rate recommended in the BOAM user guide (Maseyk et al. 2015), which is informed by research in Gibbons et al. 2015. That said, we note that a discount rate of 3% rewards benefits that deliver faster than those that take longer but provide greater ecological outcomes in the longer term, i.e. it punishes the tortoise and rewards the hare). For example, revegetation may deliver greater biodiversity gains in the long term for habitats than mammalian pest control, but all else being equal, a discount rate of 3% will favour mammalian pest control over revegetation because gains would be predicted to occur almost immediately after commencement of pest control operations.</td></tr>
<tr><td>Finite end-point</td><td>Instruction
Manually enter the number of years between impact and assessment of biodiversity gain at the compensation site(s) resulting from compensation actions.

Explanation
The finite end-point is the time period (years) over which to calculate Net Present Biodiversity Value. This equates to the time between the commencement of proposed compensation action(s) and an assessment of the associated benefits for the affected biodiversity value (e.g. native revegetation at 20 years).

For pest control this time period would be short because biodiversity gains occur almost immediately after commencement of pest control operations. However, these biodiversity gains will diminish once the pest control is terminated, and this needs to be addressed when applying the model.</td></tr>
</table>

Model inputs	Description
	The finite end-point should generally be tied to the duration of the biodiversity management and monitoring programmes that are used to verify that the benefits at compensation sites have been achieved. For instance, if the finite end point is set at 10 years from commencement of compensation, then the biodiversity management and monitoring programme should be undertaken for 10 years (but possibly longer if predicted biodiversity gains are not achieved and adaptive management or contingency measures are required).
Compensation confidence contingency	**Instruction** Select from the drop-down menu: 1 = Very high confidence (> 90%) 2 = High confidence (75% - 90%) 3 = Moderate confidence (50 – 75%) 4 = Low confidence (< 50%) (The model will not work if this option is selected). **Explanation** The approach used to assign compensation confidence contingency is aligned with the approached used in Maseyk *et al.* (2015) except that the term 'offset' has been changed to 'compensation'. The compensation confidence contingency relates to the level of confidence in the likely success of the proposed compensation measures and methodology (see above). This reflects that even well-established management methods sometimes fail to achieve targets for a multitude of reasons. The model does not consider confidence in the implementer of the proposed compensation. Nor does it consider likelihood of abandonment of the project post-impact but prior to the implementation of compensation actions. 1 Very high confidence: The proposed compensation measure uses methods that are well tested and repeatedly proven to achieve intended biodiversity gains; evidence-based expert opinion is that success is very likely. Likelihood of success is > 90%. Calculated biodiversity gain is multiplied by 0.925. 2 High confidence: The proposed compensation measure uses methods that are well known, often implemented, and which have been proven to succeed greater than 75% of the time. However, complicating factors and/or expert opinion precludes greater confidence in this compensation measure. Likelihood of success is greater than 75% but less than 90%. Calculated biodiversity gain is multiplied by 0.825. 3 Moderate confidence: The proposed compensation measure uses methods that have either been successfully implemented in New Zealand or in the situation and context relevant to the compensation site but infrequently, or the outcomes of the proposed compensation measures are not well proven or documented, or success rates elsewhere have been shown to be variable. Likelihood of success is > 50 % but < 75%. Calculated biodiversity gain is multiplied by 0.625. 4 Low confidence: Should not use the compensation measure and the model will not work if this option is selected on the basis that uncertainty is too high.
Areal extent (ha) of compensation action	**Instruction** Manually enter the areal extent (ha) of the proposed compensation action.
Value score prior to compensation action	**Instruction** Manually type in a numerical value score between 0 and 5 that relates to the value score at the compensation site(s) prior to implementation of compensation action(s).

Model inputs	Description
	Explanation Adequate detail must be provided to justify the assigned ecological value score based on desktop and field investigations and assessed using EcIAG (Roper-Lindsay *et al.* 2018 or an updated version). This enables an understanding of the adequacy and certainty surrounding the assessment and should include an explanation of why the value score prior to the implementation of the compensation action(s) was neither higher nor lower. The EcIAG (Roper-Lindsay *et al.* 2018) assessment of ecological value does not include an assessment of value in relation to ecological functioning or the provision of ecosystem services. We recommend that these factors are also considered when assessing the habitat value associated with a compensation action(s). Note that the model does not accept a value score of 0 as the formula will not work, but it does allow for a score of 0.001 (virtually 0).
Value score after compensation measure	**Instruction** Manually type in a numerical value score between 0 and 5 that relates to the value score at the compensation site(s) <u>after</u> implementation of compensation action(s) as assessed at the finite end point (years). **Explanation** Adequate detail must be provided to justify the assigned ecological value score after implementation of compensation actions based on desktop and field investigations and assessed using EcIAG (Roper-Lindsay *et al.* 2018 or an updated version). This enables an understanding of the adequacy and certainty surrounding the assessment and should include an explanation of why the compensation value score after implementation of the compensation action(s) was neither higher nor lower. The EcIAG (Roper-Lindsay *et al.* 2018) assessment of ecological value does not include an assessment of value in relation to ecological functioning or the provision of ecosystem services. We recommend that these factors are also considered when assessing the habitat value associated with a compensation action(s).

www.tonkintaylor.co.nz