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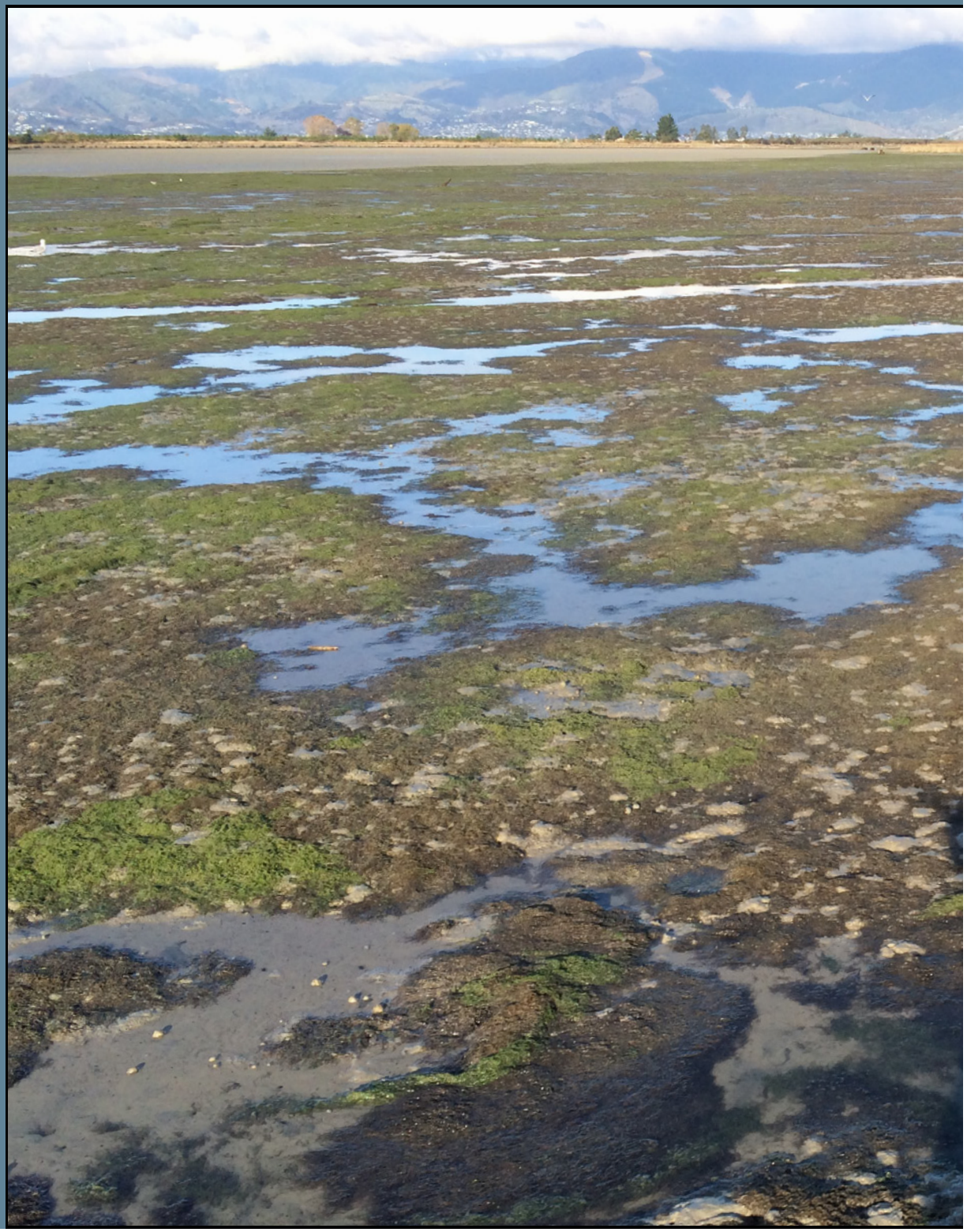
Summary of the Eutrophication Susceptibility and Trophic State of Estuaries in the Tasman Region



Prepared for

Tasman District Council

June 2018

Summary of the Eutrophication Susceptibility and Trophic State of Estuaries in the Tasman Region

Prepared for
Tasman District Council

by

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Cover Photo: Waimea Inlet - nuisance macroalgal growths of *Gracilaria* and *Ulva*, 2014.

EXECUTIVE SUMMARY

The recently released NZ Estuary Trophic Index (ETI) (Robertson2016a,b) was developed to help regional councils effectively monitor and manage estuaries. It provides a nationally consistent approach to assessing the susceptibility of estuaries to eutrophication/nutrient enrichment (Tool 1) and to characterise estuary trophic state (Tool 2). Wriggle Coastal Management was asked by Tasman District Council (TDC) to provide a preliminary summary and short report for estuaries in the Tasman district by entering existing data into the Tool 1 and Tool 2 online calculators developed as part of the ETI work. Outputs are provided which:

- Estimate estuary physical and nutrient load susceptibility (primarily based on catchment nutrient loads combined with mixing and dilution in the estuary)
- Rate trophic state based on the expression measured by key estuary indicators

The results show that the majority of estuaries in the Tasman region are currently rated as very good or good in terms of trophic state, indicating nutrient enrichment is not causing significant estuary degradation in most areas. The estuaries with the greatest eutrophication degradation were the larger SIDE estuaries, e.g. Waimea Inlet and Moutere Inlet (Moderate). The very good ecological status on the West Coast reflects smaller sized well-flushed SSRTRE type estuaries with a predominantly native forest catchment. Abel Tasman estuaries are in good condition but specific data are currently unavailable for their assessment. It is recommended that:

- Estuaries with moderate or high susceptibility, or with ETI status bands of moderate to poor, should be assessed at least every 5 years.
- Estuaries with low susceptibility, or with ETI status bands of good or very good, should be assessed 5-10 yearly.
- As new information becomes available it should be integrated into the regional data sets and used to update ETI scores and bands as necessary.
- The ETI tools should be re-run using existing data following any updates to the ETI tools or underpinning rating criteria.

INTRODUCTION

The recently released NZ ETI (Robertson2016a,b) provides a nationally consistent approach to assessing the susceptibility of estuaries to eutrophication/nutrient enrichment (Tool 1) and to characterise estuary trophic state (Tool 2). The ETI tools are summarised below:

- **Screening Tool 1. Physical and Nutrient Susceptibility**
  This tool is designed to enable robust yet cost effective prioritisation of estuaries potentially at risk from nutrient enrichment degradation for more rigorous monitoring and management. It applies a desktop susceptibility approach based on estuary physical characteristics and nutrient input load/estuary response relationships for key NZ estuary types. The tool produces a susceptibility rating based on either ***physical susceptibility***, or when combined with nutrient load data, a ***combined physical and nutrient load susceptibility*** rating (i.e. very high, high, moderate, low). Nutrient areal load/trophic state bands for each estuary eutrophication type provide an indication of the expected trophic state based on estimated nutrient inputs which can be used within simple load/response models and guide approaches for setting load limits.
- **Screening Tool 2. Trophic Condition Assessment**
  This tool uses monitoring data to characterise the ecological gradient of estuary trophic condition for relevant ecological response indicators (e.g. macroalgal biomass, dissolved oxygen), and provides a means of translating these ratings into ecological status bands for each estuary (A=Very Good, B=Good, C=Moderate, D=Poor). The status bands are derived from calculated ETI scores that define where an estuary fits along an ecological condition gradient from *zero* "oligotrophic" (natural/undegraded) to *one* "highly eutrophic" (significantly adversely impacted). The tool provides guidance on which condition indicators to use for monitoring various estuary types (and why they have been chosen), and involves measurement of the expression of primary (direct) eutrophication symptoms as well as supporting indicators for secondary (indirect) symptoms of trophic state. The ETI score becomes more robust as more indicators are included.

An overview of the status bands and predicted ecological changes across the eutrophication gradient is presented in Table 1. The common response to increasing nutrient inputs is a change in the type and relative abundance of primary producer communities (i.e. macroalgae and phytoplankton), commonly causing increases in the production of organic matter and subsequent microbial decomposition.

Introduction (continued...)

The negative ecological effects of increasing eutrophication result from a combination of both direct effects of nuisance algal growth (e.g. algal toxins, shading, smothering) as well as often more ecologically stressful indirect effects (e.g. deoxygenation and/or increased sulphide concentrations). These indirect effects have an inhibitory effect on macrophytes, macrofauna, and on some biogeochemical processes such as coupled nitrification/denitrification. Where this is extreme it leads to a shift towards high organic enrichment with elevated sediment nutrient release to the water column, and a negative feedback loop promoting accelerating eutrophication. The management of such effects is based around ensuring nutrient inputs remain below thresholds where significant adverse effects occur.

The following summary and short report for estuaries in the Tasman district was based on the addition of existing data to Tool 1 and Tool 2 online calculators developed as part of the ETI work. These are available at:

https://shiny.niwa.co.nz/Estuaries-Screening-Tool-1/ & https://shiny.niwa.co.nz/Estuaries-Screening-Tool-2/.

The purpose was to:

- Estimate estuary physical and nutrient load susceptibility (primarily based on catchment nutrient loads combined with mixing and dilution in the estuary).
- Rate trophic state based on the expression measured by key estuary indicators.

The online Tool 1 calculator contains underpinning physical data on the larger Tasman estuaries derived from NIWA's Coastal Explorer data base. These data were screened and updated to reflect more accurate local knowledge of each estuary based on a recent regional assessment of estuaries undertaken by TDC (see Robertson and Stevens 2012) - primarily estuary area and depth, and to incorporate many of the smaller estuaries not included in the Coastal Explorer data set.

Table 1. A generalised summary of narrative ecological thresholds that exist along the eutrophication gradient.

Nutrient Load →

Ecological Status - Very Good ETI Band 'A' ETI score 0 to <0.25	Ecological Status - Good ETI Band 'B' ETI score 0.25 to <0.5	Ecological Status - Moderate ETI Band 'C' ETI score 0.5 to <0.75	Ecological Status - Poor ETI Band 'D' ETI score 0.75 to 1.0
Ecological communities are healthy and resilient. *Primary Producers: dominated by seagrasses and microalgae. **Primary Producers: dominated by phytoplankton (diverse, low biomass). Water Column: high clarity, well-oxygenated. Sediment: well oxygenated, low organic matter, low sulphides and ammonia, diverse macrofaunal community with low abundance of enrichment tolerant species.	Ecological communities are slightly impacted by additional algal growth arising from nutrient levels that are elevated. *Primary Producers: seagrass/microalgae still present but increasing biomass opportunistic macroalgae. **Primary Producers: dominated by phytoplankton (moderate diversity and biomass). Water Column: moderate clarity, mod-poor DO esp at depth. Sediment: moderate oxygenation, organic matter, and sulphides, diverse macrofaunal community with increasing abundance of enrichment tolerant species.	*Ecological communities are highly impacted by macroalgal or phytoplankton biomass elevated well above natural conditions. Reduced water clarity likely to affect habitat available for native macrophytes. **Ecological communities are highly impacted by phytoplankton biomass elevated well above natural conditions. Reduced water clarity may affect deep seagrass beds. *Primary Producers: opportunistic macroalgal biomass high, seagrass cover low. Increasing phytoplankton where residence time long e.g. ICOLLs. **Primary Producers: dominated by phytoplankton (low diversity and high biomass). Water Column: low-moderate clarity, low DO, especially at depth. Sediment: poor oxygenation, high organic matter, and sulphides, macrofauna dominated by high abundance of enrichment tolerant species.	*Excessive algal growth making ecological communities at high risk of undergoing a regime shift to a persistent, degraded state without macrophyte/seagrass cover. **Excessive algal growth making ecological communities at high risk of undergoing a regime shift to a nuisance algal bloom situation (often toxic). *Primary Producers: opportunistic macroalgal biomass very high or high/low cycles in response to toxicity, no seagrass. At very high nutrient loads, cyanobacterial mats may be present. Phytoplankton only high where residence time is long. **Primary Producers: dominated by nuisance phytoplankton (e.g cyanobacteria, picoplankton). Water Column: low clarity, deoxygenated at depth. Sediment: anoxic, very high organic matter, and sulphides, subsurface macrofauna very limited or absent. Eventually the sediments are devoid of macrofauna and are covered in mats of sulfur-oxidizing bacteria (i.e. *Beggiatoa*).

* shallow estuaries, often intertidal dominated, including ICOEs

** Open, moderate to deep subtidal dominated estuaries

Introduction (continued...)

The outputs provide a summary of input data and a rating for each estuary in terms of the likelihood of problems being expressed based on current land use. Input values are summarised in Appendix 1. An accompanying spreadsheet provided to TDC presents the original Coastal Explorer data base values alongside modified data to show where the NIWA data have been modified. These changes relate primarily to estuary classification, depth, area, mouth closure or constriction, and freshwater inflow.

Available monitoring data from the estuaries were then used in Tool 2 to assess current trophic state. One limitation was that no direct assessment work has been undertaken for many of the West Coast estuaries other than in Westhaven/Whanganui, while many of the region's smaller estuaries lack empirical data for key indicators used in the ETI e.g measures of chl-a, sediment oxygenation, nitrogen, organic content and macrofauna. For estuaries lacking specific monitoring data, expert judgement was applied based on local knowledge and an assessment of estuaries using recent aerial photography.

ETI scores based on a small number of indicators (e.g. based only on macroalgal growth or sediment oxygenation), or which rely on expert opinion where data are lacking, have a relatively low level of certainty. Although the ETI status bands (A= Very Good, B=Good, C=Moderate, D=Poor) are likely to be accurate for the estuaries included, less weight should be given to the specific ETI scores derived due to the limited number of indicators available for many of the smaller estuaries. Input values used in Tool 2 are summarised in Appendix 2 and outputs in Table 2 and Figure 3.

ESTUARY TYPES. The estuaries in the Tasman region fall into two categories (see Figure 1):

1. Shallow Intertidal Dominated Estuaries (SIDEs) and
2. Shallow, Short Residence time Tidal River Estuaries (SSRTREs).

SIDEs are the dominant estuary type in NZ and are characterised as shallow (mean depth <3m), short residence time (<3 days, and often <1 day), and predominantly intertidal (>40%) tidal lagoon estuaries. In estuaries with permanently open mouths, flushing is generally too strong for significant retention of dissolved nutrients meaning sustained phytoplankton blooms are uncommon. However tidal lagoon estuaries with settlement basins retain sediment and sediment-bound nutrients, particularly in the upper estuary tidal flats where salinity driven flocculation and hydrodynamic deposition is promoted. If catchment nutrient inputs are elevated, and suitable growing conditions exist, nuisance opportunistic macroalgae (especially *Ulva* spp. and *Gracilaria* spp.) can establish. Because of their capacity to retain fine sediment and sediment bound nutrients, the susceptibility of this estuary type to nutrient loads is moderate to high.

Local examples are the Waimea, Moutere, Motupipi and Westhaven Inlets. SIDEs are also present as a subcomponent of larger estuary types where extensive tidal flats exist (e.g. Firth of Thames, Kaipara Harbour, Marlborough Sounds).

SSRTREs are shallow (mean depth <3m), short residence time (<3 days and often <1 day) often subtidal dominated tidal river estuaries, but include those that exit via a very well-flushed small lagoon or a coastal delta. They have such strong flushing that the majority of fine sediment and nutrients are exported directly to the sea. In general, these estuary types have extremely low susceptibilities and can often tolerate nutrient loads an order of magnitude greater than SIDEs. Where nutrient concentrations are high, and rivers are long (e.g. Manawatu River), phytoplankton can reach high concentrations but little growth occurs in the estuary itself unless there are deep poorly flushed holes and/or stratified basins/channels. Macroalgae can establish where there is stable substrate for attachment or where significant areas of tidal flats or shallow channel margins allow muds to settle. In such cases eutrophic symptoms of macroalgal growth can develop, particularly under stable low-flow conditions, but are generally removed by flood flows.

Local examples of larger SSRTREs are the Paturau, Ruataniwha, Takaka, and Moutere River estuaries. Smaller SSRTREs are present throughout the region e.g. Sandhills Creek, Taupata, Parewhakaoho.

SIDEs or SSRTREs with Intermittently Constricted/closed or Open Entrances (ICOEs) have the highest susceptibility to nutrient retention and eutrophication, with the most susceptible being those with closure periods of months (e.g. Waituna Lagoon, Southland) rather than days (e.g. Lake Onoke, Wellington). In general, tidal river ICOEs have shorter periods of mouth closure (unless they are very small) than the more buffered tidal lagoon ICOEs. The high susceptibility arises from reduced dilution (absence of tidal exchange at times) and increased nutrient retention (through both enhanced plant uptake and sediment deposition). Excessive phytoplankton and macroalgal growths and reduced macrophyte growth are characteristic symptoms of ICOE eutrophication. In ICOEs in which salinities vary between marine and close to freshwater, a co-limiting situation between N and P is expected, and as a consequence nutrient load/estuary response relationships should consider both N and P. Local examples of SSRTREs with ICOEs are Big River Estuary, Lagoon Creek and Grants Road. There are no SIDEs with ICOEs in the Tasman district.

Healthy *Gracilaria* growing in the entrance channel of Ruataniwha Estuary, Golden Bay: ETI Band B - Good.

Localised nuisance macroalgal growth of *Gracilaria* and *Ulva* in Waimea Inlet, Tasman Bay: ETI Band C - Moderate.

RESULTS

Figure 1 shows the ETI classes of Tasman estuaries. Relatively small SSRTREs dominate on the exposed West Coast, many of which have ICOEs. In the more sheltered Golden Bay there are a mix of predominantly small open SSRTREs and moderate sized open SIDEs, and two large open delta SSRTREs (Aorere and Takaka). Tasman Bay is dominated by open SIDEs. It is noted that most of the estuaries in the Abel Tasman region are poorly classified by Coastal Explorer and data require validation.

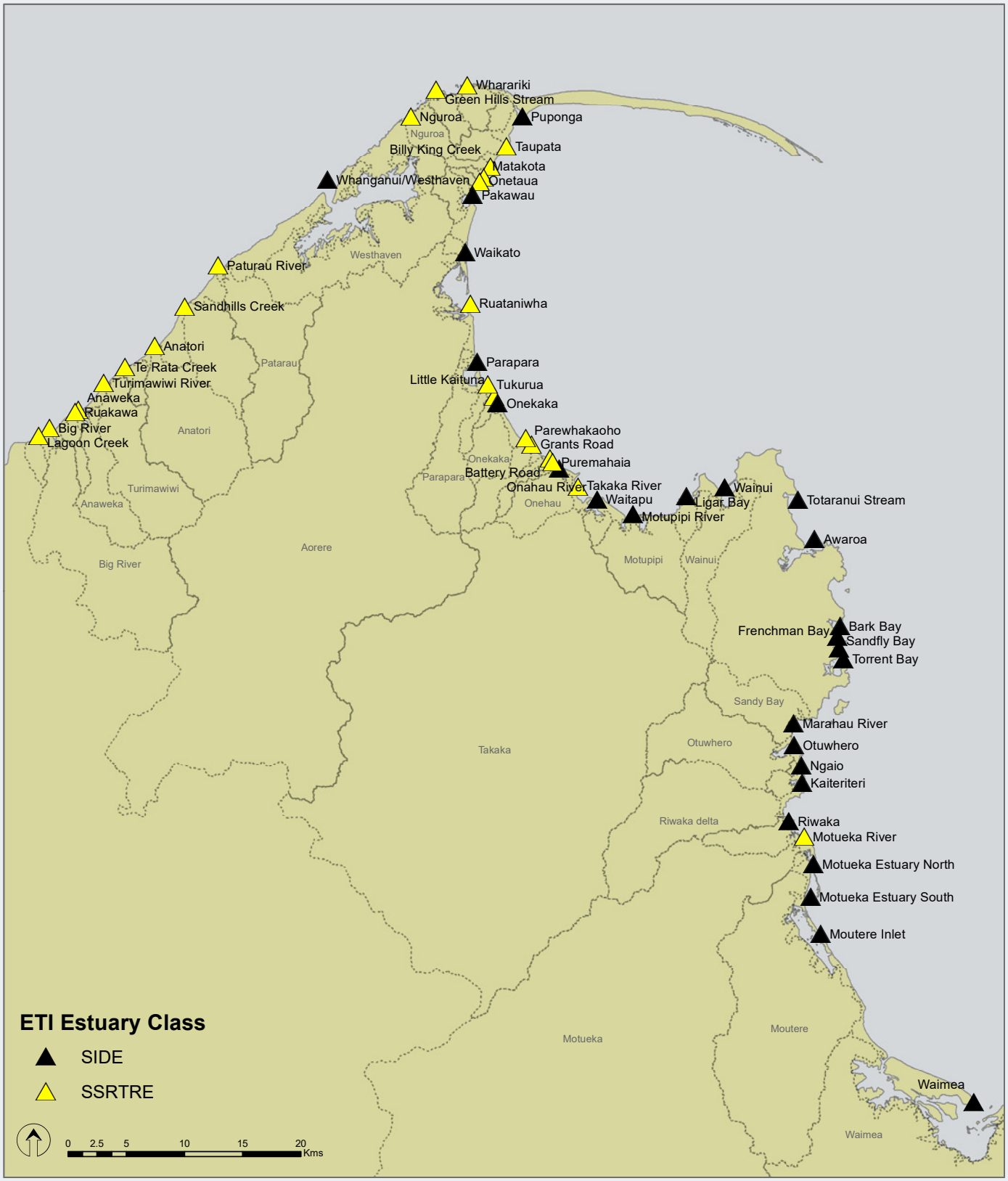

Figure 1. ETI Class of Estuaries in the Tasman Region.

Results (continued...)

Figure 2 shows the physical and nutrient susceptibility ratings of Tasman estuaries. The estuaries on the West Coast are all rated low or moderate reflecting the relatively small size of the estuaries, high flushing, and low nutrient inputs due to the native forest dominated catchments. The very low rating for the much larger Westhaven/Whanganui Inlet reflects its larger assimilative capacity. In Golden and Tasman Bays the susceptibility ratings generally increase with increased catchment development (reflecting higher nutrient inputs).

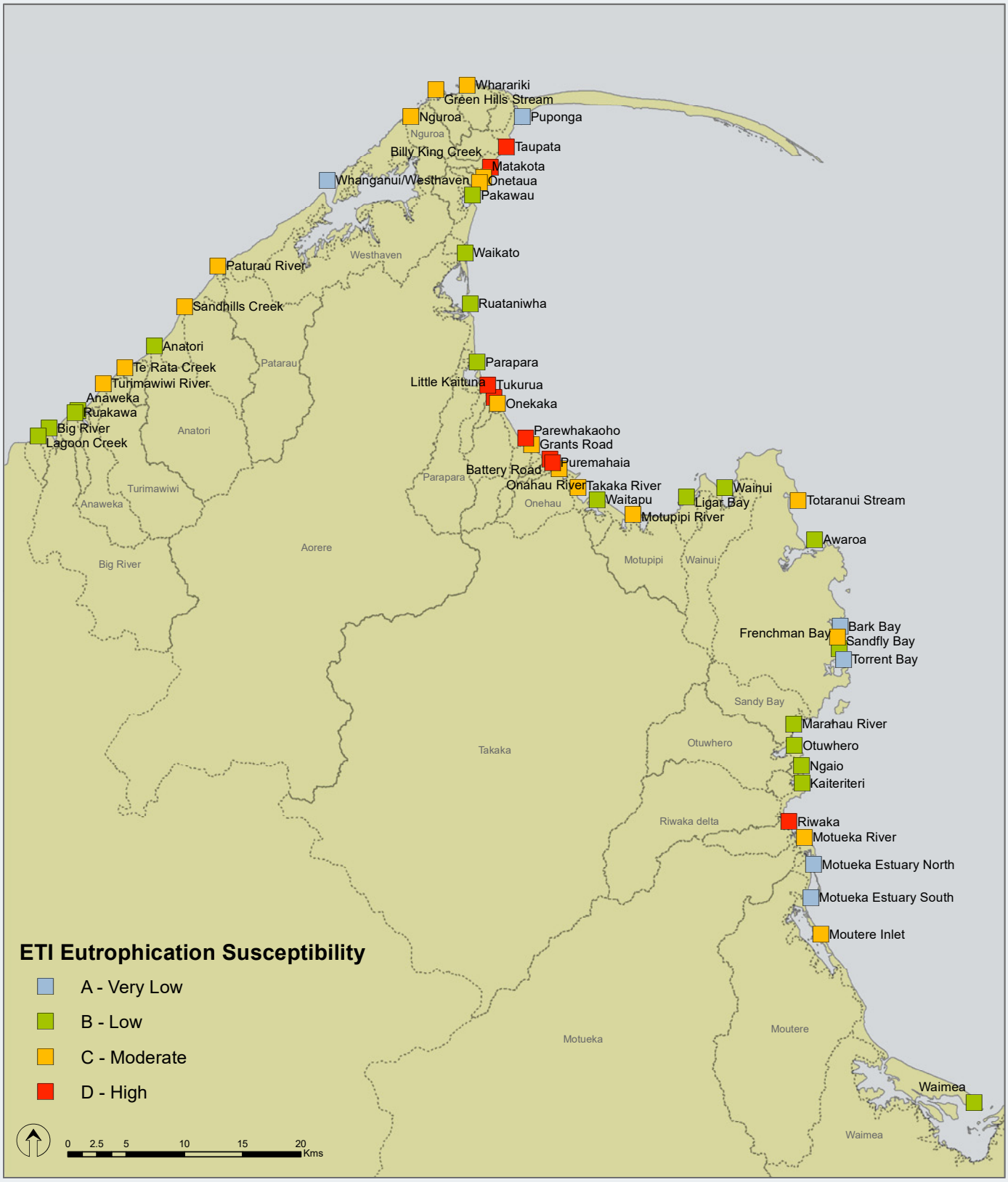

Figure 2. Physical and Nutrient Susceptibility of Estuaries in the Tasman Region.

Results (continued...)

Figure 3 shows the ETI status bands of each estuary where sufficient data were available to assess trophic state. The overall pattern is strongly correlated with estuary type and size, larger SIDE estuaries having the lowest status bands. The estuaries with the lowest status bands are currently a core part of the current TDC estuary monitoring programme, providing strong support for the focus on these estuaries as priorities for monitoring and management. Note values for many estuaries are estimated where data are lacking.

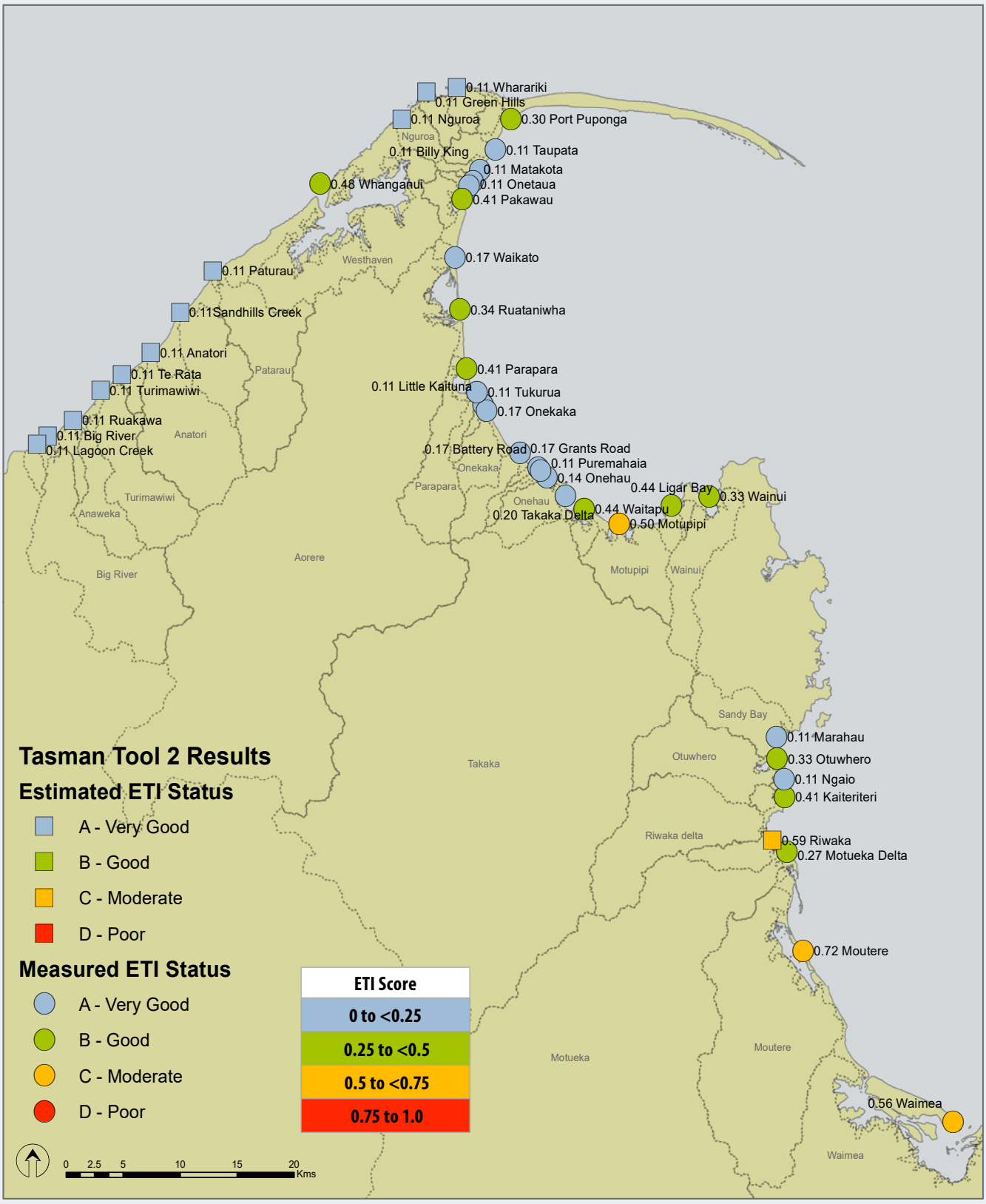

Figure 3. ETI Status Bands of Estuaries in the Tasman Region.

Results (continued...)

Table 2 shows the output data for Tasman Bay, Golden Bay and West Coast estuaries that Figure 3 is based on. Trophic condition is determined by the ETI scores and estuaries are placed in an ETI band reflecting ecological status (refer to Table 1). The table also shows the number of qualifying primary and secondary indicators for each estuary. Primary variables include macroalgae or phytoplankton biomass, and secondary variables, which can assist in measurement but have an ambiguous relationship with eutrophication, include sediment oxygenation, total nitrogen, total organic content, and macrofauna (at least one required), as well as optional indicators including dissolved oxygen, sediment mud content, area of soft mud, and sedimentation rate (Zeldis et al. 2017). There is greater confidence in the ETI scoring as the number of relevant indicators available increases.

Table 2. Summary of ETI Tool 2 results (see Appendix 2 for metadata).

Estuary Name	Assessed	Estuary Type	isICOE	Qualifying Primaries	Qualifying Secondaries	Max Primaries	Mean Secondaries	ETIscore	ETIband
Waimea Inlet	2014	SIDE	FALSE	3	4	9	8.8	0.56	C
Moutere Inlet	2013	SIDE	FALSE	2	4	14	9.2	0.72	C
Motueka Delta	2003	SSRTRE	FALSE	1	1	1	4	0.16	A
Motueka Delta	2012	SSRTRE	FALSE	1	1	1	7.5	0.27	B
Riwaka	2003	SIDE	FALSE	1	1	3	16	0.59	C
Kaiteriteri	2012	SIDE	FALSE	2	1	2	11	0.41	B
Ngaio	2012	SIDE	FALSE	1	1	1	2.5	0.11	A
Otuwhero	2012	SIDE	FALSE	2	1	2	8.5	0.33	B
Marahau	2012	SIDE	FALSE	1	1	1	2.5	0.11	A
Wainui Inlet	2012	SIDE	FALSE	2	1	2	8.5	0.33	B
Ligar Bay	2012	SIDE	FALSE	2	1	2	12	0.44	B
Motupipi	2015	SIDE	FALSE	3	1	4	12	0.5	C
Waitapu	2012	SIDE	FALSE	1	1	1	13	0.44	B
Takaka Delta	2012	SSRTRE	FALSE	1	1	1	5.5	0.2	A
Onahau	2014	SIDE	FALSE	3	1	2	2.5	0.14	A
Puremahaia	2012	SSRTRE	FALSE	1	1	1	2.5	0.11	A
Battery Road	2012	SSRTRE	FALSE	1	1	1	4.5	0.17	A
Grants Road	2012	SSRTRE	TRUE	1	1	1	4.5	0.17	A
Onekaka	2012	SIDE	FALSE	1	1	1	4.5	0.17	A
Little Kaituna	2012	SSRTRE	FALSE	1	1	1	2.5	0.11	A
Tukurua	2012	SSRTRE	FALSE	1	1	1	2.5	0.11	A
Parapara Inlet	2012	SIDE	FALSE	2	1	2	11	0.41	B
Ruataniwha	2016	SSRTRE	FALSE	2	4	2	9	0.34	B
Waikato	2012	SIDE	FALSE	2	1	2	3.5	0.17	A
Pakawau	2012	SIDE	FALSE	2	1	2	11	0.41	B
Onetaua	2012	SSRTRE	FALSE	1	1	1	2.5	0.11	A
Matakota	2012	SSRTRE	FALSE	1	1	1	2.5	0.11	A
Billy King Creek	2012	SSRTRE	FALSE	1	1	1	2.5	0.11	A
Taupata	2012	SSRTRE	FALSE	1	1	1	2.5	0.11	A
Port Puponga	2012	SIDE	FALSE	2	1	1	8.5	0.3	B
Whararikiki*	2012	SSRTRE	FALSE	1	1	1	2.5	0.11	A
Green Hills*	2012	SSRTRE	FALSE	1	1	1	2.5	0.11	A
Nguroa*	2012	SSRTRE	FALSE	1	1	1	2.5	0.11	A
Paturau*	2012	SSRTRE	FALSE	1	1	1	2.5	0.11	A
Whanganui/Westhaven	2016	SIDE	FALSE	2	4	7	8.2	0.48	B
Sandhills Creek*	2012	SSRTRE	FALSE	1	1	1	2.5	0.11	A
Anatori*	2012	SSRTRE	FALSE	1	1	1	2.5	0.11	A
Te Rata Creek*	2012	SSRTRE	TRUE	1	1	1	2.5	0.11	A
Turimawiwi*	2012	SSRTRE	TRUE	1	1	1	2.5	0.11	A
Ruakawa*	2012	SSRTRE	TRUE	1	1	1	2.5	0.11	A
Big River*	2012	SSRTRE	TRUE	1	1	1	2.5	0.11	A
Lagoon Creek*	2012	SSRTRE	TRUE	1	1	1	2.5	0.11	A

*Desktop assessment

CONCLUSION AND RECOMMENDATIONS

The results show that the majority of estuaries in the Tasman region are currently rated as very good or good in terms of trophic state, indicating nutrient enrichment is not causing significant estuary degradation in most areas.

The estuaries with the greatest eutrophication degradation were the larger SIDE estuaries, e.g. Waimea Inlet, Moutere Inlet, Motupipi Inlet (Moderate). The very good ecological status on the West Coast reflects smaller sized well-flushed SSRTRE type estuaries with a predominantly native forest catchment. Abel Tasman estuaries are in good condition but data are currently unavailable for specific assessment of the ETI.

Confidence in the overall status bands is high, but because of limitations with both underpinning information within the NIWA Coastal Explorer data set, and in the availability of monitoring data for specific indicators relevant to the ETI, there is less confidence in numerical ETI scores for many of the smaller estuaries that have received little monitoring attention.

Overall, the current ETI scores should be considered indicative, rather than definitive and this should be reflected in any future assessment of changes in ETI scores.

It is recommended that:

- Estuaries with moderate or high susceptibility, or with ETI status bands of moderate to poor, should be assessed at least every 5 years.
- Estuaries with low susceptibility, or with ETI status bands of good or very good, should be assessed 5-10 yearly.
- As new information becomes available it should be integrated into the regional data sets and used to update ETI scores and bands as necessary.
- The ETI tools should be re-run using existing data following any updates to the ETI tools or underpinning rating criteria.

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APPENDIX 1 - TOOL 1 INPUT DATA

Table 3 shows the input data for Tool 1 used to estimate the estuary physical and nutrient load susceptibility of Tasman estuaries. Metadata describing the variables included are included at the end of the table on page 15 - further information is available in the online resources. Data have been grouped into Tasman Bay, Abel Tasman, Golden Bay and West Coast estuaries. The output of these data have been summarised in Figure 2.

Table 3. Input data used in ETI Tool 1 - Tasman Bay.

Name	Waimea Inlet	Moutere Inlet	Motueka Estuary (N)	Motueka Estuary (S)	Motueka River
NZCHS Class	Shallow drowned valley	Shallow drowned valley	Tidal lagoon (Permanently open)	Tidal lagoon (Permanently open)	Freshwater River Mouth (deltaic)
ETI Class	SIDE	SIDE	SIDE	SIDE	SSRTRE
Latitude	-41.28737059	-41.1574773	-41.10359271	-41.12902613	-41.08234056
Longitude	173.1968529	173.0396767	173.0323791	173.0293619	173.0227211
Qf	21	1.5	0.0	0.027	58.1
TNriver	222.5	88.22	0.73	2.51	548.8
TPriver	38	6.76	0.04	0.09	126.1
V	66890200	10050000	1108642.54	3971052.89	15205800
P	63880200	9930000	955469.63	3363777.24	14448800
A	-0.81	0	-0.21	-1.53	-0.53
B	727.88	0	274.73	17.78	173.84
R NO3	0.76	0.82	0.91	0.94	0.79
R DRP	0.76	0.74	0.80	0.78	0.69
Ocean Salinity	34.47	34.49	34.52	34.50	34.53
NOcean	16.63	15.97	15.83	15.88	15.76
POcean	7.72	7.50	7.45	7.47	7.42
Intertidal	99	76.52	83.09	80.48	80.09
isICOE	FALSE	FALSE	FALSE	FALSE	FALSE
Closure Length	-	-	-	-	-
Est Area m2	33445100	10050000	452906.28	1555521.65	7602900
Mean Depth	2	1	2.45	2.55	2
Tidal Height	3.66	3.63	3.61	3.62	3.60

Name	Riwaka Estuary	KaiterIterl Estuary	Ngaio	Otuwhero Inlet	Marahau River
NZCHS Class	Tidal river mouth (barrier beach enclosed)	Tidal lagoon (Permanently open)	Tidal lagoon (Permanently open)	Tidal lagoon (Permanently open)	Tidal lagoon (Permanently open)
ETI Class	SIDE	SIDE	SIDE	SIDE	SIDE
Latitude	-41.07041283	-41.04070279	-41.027255	-41.01149405	-40.99492654
Longitude	173.0070834	173.0203357	173.019797	173.0125357	173.0119491
Qf	0.37171	0.08	0.033	2.049	0.945
TNriver	26.5003	0.73	0.2	14.224	6.361
TPriver	0.7395	0.29	0.089	3.005	2.058
V	413107.0097	136501.16	7001.360	713841.375	186146.942
P	390235.5829	133838.84	6928.796	698130.477	183078.354
A	-0.532945154	-0.51		-0.562	-0.501
B	148.2194788	164.12		147.273	188.083
R NO3	0.72567153	0.63		0.606	0.681
R DRP	0.729001444	0.68		0.678	0.701
Ocean Salinity	34.53019726	34.55	34.5503243	34.5646496	34.5731341
NOcean	15.69803641	15.67	15.666	15.582	15.508
POcean	7.400432809	7.38	7.384	7.353	7.340
Intertidal	94.42	92.20	95.854	91.196	93.406
isICOE	FALSE	FALSE	FALSE	FALSE	FALSE
Closure Length	-	-	-	-	-
Est Area m2	204941.1	182001.549	28005.441	951788.500	372293.884
Mean Depth	2.0157353	0.75	0.25	0.75	0.5
Tidal Height	3.607	3.59	3.5884	3.5834	3.5818

Appendix 1 (continued...)

Table 3 continued.... Input data used in ETI Tool 1 - Abel Tasman and eastern Golden Bay.

Name	Torrent Bay	Frenchman Bay	Sandfly Bay	Bark Bay	Awaroa Inlet
NZCHS Class	Tidal lagoon (Permanently open)	Tidal lagoon (permanently open)	Tidal lagoon (permanently open)	Tidal lagoon (Permanently open)	Tidal lagoon (Permanently open)
ETI Class	SIDE	SIDE	SIDE	SIDE	SIDE
Latitude	-40.9450036	-40.93675295	-40.92776844	-40.91967621	-40.85237259
Longitude	173.0627631	173.0583453	173.0566653	173.0591583	173.0332189
Qf	0.45	0.02	0.65	0.21	1.91
TNriver	4.71	0.43	7.56	2.35	26.77
TPriver	1.32	0.12	2.01	0.64	6.39
V	7062549.82	108745.37	169163.40	1988989.78	4258318.37
P	4999772.141	99021.63	147097.87	1567546.48	4175182.041
A	-0.41	-0.49	-0.42	-0.51	-0.59
B	206.22	176.44	198.45	150.35	138.22
R NO3	0.70	0.97	0.71	0.62	0.71
R DRP	0.77	0.74	0.79	0.80	0.79
Ocean Salinity	34.61	34.61	34.61	34.62	34.64
NOcean	15.16	15.07	14.98	14.91	14.22
POcean	7.35	7.35	7.34	7.34	7.29
Intertidal	28.44	90.52	84.78	26.05	98.23
isICOE	FALSE	FALSE	FALSE	FALSE	FALSE
Closure Length	-	-	-	-	-
Est Area m2	1650880.56	51285.57	72488.62	512394.23	2348483.95
Mean Depth	4.28	2.12	2.33	3.88	1.81
Tidal Height	3.53	3.53	3.52	3.52	3.49

Name	Totaranui Stream	Wainui Inlet	Ligar Bay	Motupipi River	Waitapu
NZCHS Class	Tidal lagoon (Permanently open)	Tidal lagoon (Permanently open)	Tidal lagoon (Permanently open)	Tidal lagoon (Permanently open)	Tidal lagoon (Permanently open)
ETI Class	SIDE	SIDE	SIDE	SIDE	SIDE
Latitude	-40.82203026	-40.8122352	-40.81906116	-40.83270928	-40.82145914
Longitude	173.0164107	172.9418942	172.9029893	172.8484131	172.8117669
Qf	0.21	0.99	0.03	0.91	0.11
TNriver	3.71	17.30	0.57	40.41	7.84
TPriver	0.82	3.9	0.20	4.62	0.60
V	232909.85	3230284.74	82904.56	1690900	1815284.85
P	232247.29	3143903.33	82904.56	1666150	1782150.10
A	-0.50	-0.51	-0.53	-0.52	-0.52
B	164.43	163.32	169.12	158.29	145.43
R NO3	0.80	0.82	0.86	0.79	0.83
R DRP	0.78	0.76	0.76	0.68	0.65
Ocean Salinity	34.65	34.65	34.64	34.64	34.64
NOcean	13.90	13.35	13.13	12.87	12.49
POcean	7.26	7.24	7.24	7.24	7.23
Intertidal	99.75	89	100	88.71	92.70
isICOE	FALSE	FALSE	FALSE	FALSE	FALSE
Closure	-	-	-	-	-
Est Area m2	132510.51	2153523.16	165809.12	1690900	1210189.903
Mean Depth	1.76	1.5	0.5	1	1.5
Tidal Height	3.50	3.57	3.59	3.61	3.62

Appendix 1 (continued...)

Table 3 continued.... Input data used in ETI Tool 1 - central Golden Bay.

Name	Takaka River	Onahau River	Puremahaia	Battery Rd	Grants Rd
NZCHS Class	Freshwater River Mouth (deltaic)	Tidal lagoon (Permanently open)	Tidal River Mouth (mostly open)	Tidal River Mouth (mostly open)	Tidal Lagoon (IWL)
ETI Class	SSRTRE	SIDE	SSRTRE	SSRTRE	SSRTRE
Latitude	-40.811475	-40.79765955	-40.792453	-40.789815	-40.778667
Longitude	172.792578	172.7731827	172.766523	172.76416	172.745366
Qf	57	0.62	0.20	0.06	0.01
TNriver	456.71	26.44	5.59	4.56	0.07
TPriver	48.72	2.74	0.43	0.34	0.05
V	8798048.67	555892.66	604.74	2799.03	377.71
P	8378488.55	546680.82	472.30	2481.60	289.53
A	-0.52	-0.55			
B	192.17	134.57			
R NO3	0.88	0.83			
R DRP	0.59	0.65			
Ocean Salinity	34.64	34.65	34.65	34.65	34.65
NOcean	12.35	11.97	11.97	11.97	11.97
POcean	7.23	7.22	7.22	7.22	7.22
Intertidal	80.92	93.37	12.40	54.64	6.62
isICOE	FALSE	FALSE	TRUE	TRUE	TRUE
Closure	-	-	days	days	months
Est Area m2	4399024.334	317652.95	806.3194643	2799.03	1510.84
Mean Depth	2	1.75	0.75	1	0.25
Tidal Height	3.62	3.63	3.63	3.63	3.63

Name	Parewhakaoho	Onekaka Inlet	Little Kaituna	Tukurua	Parapara Inlet
NZCHS Class	Tidal River Mouth (mostly open)	Tidal lagoon (Permanently open)	Tidal River Mouth (mostly open)	Tidal River Mouth (mostly open)	Tidal lagoon (Permanently open)
ETI Class	SSRTRE	SIDE	SSRTRE	SSRTRE	SIDE
Latitude	-40.773596	-40.746746	-40.741967	-40.732424	-40.71485809
Longitude	172.739369	172.710908	172.707355	172.700906	172.6903427
Qf	0.63	0.67	0.06	0.19	1.78
TNriver	11.76	17.66	2.41	2.30	14.80
TPriver	1.20	2.74	0.73	0.33	1.25
V	1167.85	350660.87	31455.72	179.24	3513627.254
P	1167.85	340882.25	30928.45	146.93	3448963.782
A					-0.56
B					154.22
R NO3					0.67
R DRP					0.68
Ocean Salinity	34.65	34.69	34.69	34.69	34.69
NOcean	11.97	10.48	10.48	10.48	10.48
POcean	7.22	7.20	7.20	7.20	7.20
Intertidal	100	88.85	93.30	27.90	92.64
isICOE	FALSE	FALSE	TRUE	FALSE	FALSE
Closure	-	-	days	-	-
Est Area m2	2335.69	233773.92	62911.43	358.4852474	1952015.141
Mean Depth	0.5	1.5	0.5	0.5	1.8
Tidal Height	3.63	3.65	3.65	3.65	3.65

Appendix 1 (continued...)

Table 3 continued.... Input data used in ETI Tool 1 - western Golden Bay.

Name	Ruataniwha Inlet	Waikato Estuary	Pakawau Inlet	Onetaua	Matakota
NZCHS Class	Tidal lagoon (Permanently open)	Tidal lagoon (Permanently open)	Tidal lagoon (Permanently open)	Tidal River Mouth (mostly open)	Tidal River Mouth (mostly open)
ETI Class	SSRTRE	SIDE	SIDE	SSRTRE	SSRTRE
Latitude	-40.66973996	-40.63005805	-40.58576874	-40.575965	-40.572184
Longitude	172.6835414	172.6785978	172.6863449	172.693502	172.697566
Qf	80	0.05	0.16	0.03	0.02
TNriver	482.67	1.01	3.31	0.89	0.25
TPriver	67.80	0.76	0.65	0.20	0.06
V	17388000	95760.02	780696.58	11744.14	12421.15
P	16859000	95760.02	780696.58	11705.98	12330.97
A	-0.62	-0.50	-0.51		
B	186.81	182.66	168.61		
R NO3	0.80	0.91	0.81		
R DRP	0.68	0.69	0.72		
Ocean Salinity	34.71	34.73	34.75	34.75	34.75
NOcean	9.95	9.49	9.09	9.09	9.09
POcean	7.19	7.19	7.18	7.18	7.18
Intertidal	87.83	100	100	98.70	97.10
isICOE	FALSE	FALSE	FALSE	FALSE	TRUE
Closure	-	-	-	-	days
Est Area m2	7560000	191520.05	650580.49	23488.29	24842.30
Mean Depth	2.3	0.5	1.2	0.5	0.5
Tidal Height	3.66	3.67	3.68	3.68	3.68

Name	Billy King Creek	Taupata	Puponga	Port Puponga
NZCHS Class	Tidal River Mouth (mostly closed)	Tidal River Mouth (mostly open)	Tidal lagoon (Permanently open)	Tidal lagoon (Permanently open)
ETI Class	SSRTRE	SSRTRE	SIDE	SIDE
Latitude	-40.564007	-40.54833	-40.525168	-40.52739188
Longitude	172.704577	172.720835	172.736935	172.7367226
Qf	0.05	0.14	0.09	0.09
TNriver	1.48	3.13	1.23	2.47
TPriver	0.27	0.39	0.16	0.31
V	2908	1803.55	489934.13	993507.15
P	2908	1707.31	487496.51	751378.20
A				-0.54
B				160.00
R NO3				0.79
R DRP				0.67
Ocean Salinity	34.75	34.75	34.75	34.78
NOcean	9.09	9.09	9.09	8.90
POcean	7.18	7.18	7.18	7.16
Intertidal	100	78.65	98.01	57.57
isICOE	TRUE	TRUE	FALSE	FALSE
Closure	days	days	-	-
Est Area m2	5815	3607.10	326622.76	285327.54
Mean Depth	0.5	0.5	1.5	3.48
Tidal Height	3.68	3.68	3.68	3.70

Table 3 continued.... Input data used in ETI Tool 1 - West Coast.

Name	Whaririki	Green Hills Stream	Nguroa	Paturau River
NZCHS Class	Tidal River Mouth (Mostly open)	Hapua Type Lagoon (small)	Tidal River Mouth (Mostly open)	Tidal River Mouth (spit enclosed)
ETI Class	SSRTRE	SSRTRE	SSRTRE	SSRTRE
Latitude	-40.500648	-40.50389154	-40.52477	-40.63933159
Longitude	172.681354	172.6496711	172.624065	172.4277796
Qf	0.17	0.15	0.21	5.11
TNriver	2.70	2.41	4.07	30.88
TPriver	0.55	0.35	1.77	5.90
V	42000	44000	22500	250250
P	39375	38250	18675	222687.5
A		-0.42		-0.49
B		327.12		215.67
R NO3		0.73		0.67
R DRP		0.69		0.68
Ocean Salinity	34.79	34.79	34.79	34.74
NOcean	7.91	7.91	7.91	7.54
POcean	7.18	7.18	7.18	7.22
Intertidal	75	47.73	32	55.94
isICOE	TRUE	TRUE	TRUE	FALSE
Closure	days	days	days	-
Est Area m2	28000	44000	15000	143000
Mean Depth	1.5	1	1.5	1.75
Tidal Height	3.16	3.16	3.16	3.09

Name	Whanganui	Sandhills creek	Anatori River	Te Rata Creek
NZCHS Class	Shallow Drowned Valley	Tidal River Mouth (Mostly open)	Hapua Type Lagoon (medium)	Tidal River Mouth (Mostly open)
ETI Class	SIDE	SSRTRE	SSRTRE	SSRTRE
Latitude	-40.57355368	-40.670688	-40.70105546	-40.71735
Longitude	172.5392578	172.393686	172.3628363	172.332546
Qf	2.72	1.77	5.00	0.22
TNriver	35.57	10.18	22.32	1.78
TPriver	5.27	1.47	3.12	1.54
V	32343800	49500	232000	17000
P	30355500	44250	207000	14750
A	-0.89		-0.53	
B	564.92		186.86	
R NO3	0.84		0.52	
R DRP	0.72		0.73	
Ocean Salinity	34.79	34.72	34.72	34.72
NOcean	7.91	7.50	7.50	7.50
POcean	7.18	7.23	7.23	7.23
Intertidal	75.41	57.58	56.90	47.06
isICOE	FALSE	TRUE	FALSE	TRUE
Closure	-	days	-	months
Est Area m2	27410000	33000	116000	17000
Mean Depth	1.18	1.5	2	1
Tidal Height	3.16	3.08	3.08	3.08

Appendix 1 (continued...)

Table 3 continued.... Input data used in ETI Tool 1 - West Coast cont..

Name	Turimawiwi River	Anaweka River	Ruakawa	Big River	Lagoon Creek
NZCHS Class	Hapua Type Lagoon (medium)	Freshwater River Mouth (BBE)	Tidal River Mouth (Mostly open)	Freshwater River Mouth (BBE)	Tidal River Mouth (Mostly open)
ETI Class	SSRTRE	SSRTRE	SSRTRE	SSRTRE	SSRTRE
Latitude	-40.72941274	-40.75035324	-40.751858	-40.7638704	-40.769782
Longitude	172.3104642	172.2845644	172.281424	172.2552235	172.243954
Qf	4.46	2.35	0.33	12.17	0.22
TNriver	19.66	9.90	1.96	47.60	1.35
TPriver	3.88	1.24	0.48	5.39	0.15
V	93000	969000	164250	600000	70000
P	85125	923250	153037.5	501000	65250
A	-0.48	-0.54		-0.52	
B	198.67	146.90		171.04	
R NO3	0.56	0.72		0.72	
R DRP	0.66	0.66		0.71	
Ocean Salinity	34.71	34.71	34.71	34.71	34.71
NOcean	7.18	7.05	7.05	6.81	6.81
POcean	7.24	7.24	7.24	7.25	7.25
Intertidal	66.13	81.11	72.69	34	72.86
isICOE	TRUE	FALSE	TRUE	FALSE	TRUE
Closure	months	-	days	-	days
Est Area m2	62000	646000	109500	300000	70000
Mean Depth	1.5	1.5	1.5	2	1
Tidal Height	3.06	3.06	3.06	3.05	3.05

Tool 1 Metadata	
ETI Class	Estuary type according to the Estuarine Trophic Index
NZCHS Class	New Zealand coastal hydrosystem classification from Hume 2016
Qf	Freshwater inflow per second
TNriver	Tonnes per year of total nitrogen from the catchment
Tpriver	Tonnes per year of total phosphorus from the catchment
V	Estuary volume at high tide
P	Tidal prism
A	Coefficient used to calculate ACExR model parameter
B	Coefficient used to calculate ACExR model parameter
R_NO3	Proportion of riverine total nitrogen in the form of nitrate. Ranges from 0 to 1.
R_DRP	Proportion of riverine total phosphorus in the form of disolved reactive phosphorus. Ranges from 0 to 1.
Ocean Salinity	Annual mean surface salinity of the ocean near the estuary
NOcean	Annual mean surface nitrate concentration of the ocean near the estuary
POcean	Annual mean surface DRP concentration of the ocean near the estuary
Intertidal	The percentage of the estuary that is intertidal. Ranges from 0 - 100.
isICOE	Whether an estuary is intermittently closed to the sea. If it is, the closure period is also required.
est_area_m2	Estuary water area at high tide MHW m2
mean_depth	Mean depth of estuary in m
tidal_height	Tidal range in m

APPENDIX 2 - TOOL 2 INPUT DATA

Table 4 shows the input data for Tool 2 used to calculate ETI scores and bands. Metadata describing the output variables are included at the end of the table with further information available in the online resources. Data have been grouped into Tasman Bay, Abel Tasman, Golden Bay and West Coast estuaries. The output of these data have been summarised in Figure 3.

Table 4. Input data used in ETI Tool 2 .

Estuary Name	Assessed	Chl-a	macroalgae GNA ha	macroalgae GNA %	macroalgae OMBT EQR	DO	REDOX mV@1cm	TOC %	TN mg/kg	macroinvert AMBI	soft mud proportion
Waimea Inlet	2014	NA	0.8	0.8	0.55	NA	-100	0.6	700	2.2	0.4
Moutere Inlet	2013	NA	60	7.8	NA	NA	-100	1	250	2.2	0.4
Motueka Delta	2003	NA	NA	0	NA	NA	50	NA	NA	NA	NA
Motueka Delta	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0.1
Riwaka	2003	NA	NA	0	NA		-100	NA	NA	NA	0.4
Kaiteriteri	2012	NA	NA	0	0.9*	NA	10	NA	NA	NA	0.2
Ngaio	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Otuwhero	2012	NA	NA	0	0.9*	NA	10	NA	NA	NA	0.1
Marahau	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Wainui Inlet	2012	NA	NA	0	0.9*	NA	10	NA	NA	NA	0.1
Ligar Bay	2012	NA	NA	0	0.9*	NA	-50	NA	NA	NA	0.4
Motupipi	2015	NA	0	0	0.84	NA	-50	NA	NA	NA	0.2
Waitapu	2012	NA	NA	0	NA	NA	-100	NA	NA	NA	0.3
Takaka Delta	2012	NA	NA	0	NA	NA	-100	NA	NA	NA	0
Onahau	2014	NA	0	0	0.9*	NA	50	NA	NA	NA	0
Puremahaia	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Battery Road	2012	NA	NA	0	NA	NA	-50	NA	NA	NA	0
Grants Road	2012	NA	NA	0	NA	NA	-50	NA	NA	NA	0
Onekaka	2012	NA	NA	0	NA	NA	-50	NA	NA	NA	0
Little Kaituna	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Tukurua	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Parapara Inlet	2012	NA	NA	0	0.9*	NA	10	NA	NA	NA	0.3
Ruataniwha	2016	NA	NA	0	0.91	NA	-220	0.8	567	3.2	0.1
Waikato	2012	NA	NA	0	0.9*	NA	10	NA	NA	NA	0
Pakawau	2012	NA	NA	0	0.9*	NA	10	NA	NA	NA	0.2
Onetaua	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Matakota	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Billy King Creek	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Taupata	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Port Puponga	2012	NA	NA	0	0.98	NA	10	NA	NA	NA	0.1
Whararikiki*	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Green Hills*	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Nguroa*	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Paturau*	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Whanganui/Westhaven	2016	NA	NA	0	0.67	NA	-100	0.49	600	1.314	0.54
Sandhills Creek*	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Anatori*	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Te Rata Creek*	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Turimawiwi*	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Ruakawa*	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Big River*	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0
Lagoon Creek*	2012	NA	NA	0	NA	NA	100	NA	NA	NA	0

*Desktop assessment *estimated value

Table 5. Meta data for ETI Tool 2 - results in Table 3.

Tool 2 Metadata		
Estuary type	Input	Estuaries classified into DSDE, SIDE, SSRTRE.
ICOE status	Input	Whether an estuary is intermittently closed or open
Qualifying primary indicators	Output	The number of qualifying primary indicators provided in the input data. At least one primary indicator is required to calculate the ETI score
Qualifying secondary Indicators	Output	The number of qualifying secondary indicators provided in the input data. At least one secondary indicator is required to calculate the ETI score
Max primaries	Output	Maximum of primary indicator values
Mean secondaries	Output	Average of secondary indicator values
ETI Calculation successful (ETIok)	Output	Was Tool 2 able to successfully calculate an ETI score? If FALSE, it is likely that there are insufficient primary or secondary indicators for the calculation
ETI Score	Output	ETI scores range from 0 to 1, with a value of 1 indicating poor trophic condition.
ETIband	Output	Ecological status band (A= Very Good, B= Good, C= Moderate, D= Poor) Scores: 0 to <0.25 = A, 0.25 to <0.5 = B, 0.5 to <0.75 = C, 0.75 to 1.0 = D