ENVIRONMENT BAY OF PLENTY

FIRST ORDER ESTIMATION OF THE NUTRIENT AND BACTERIAL INPUT FROM AQUATIC BIRDS TO TWELVE ROTORUA LAKES

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Environment Bay of Plenty

First Order Estimation of the Nutrient And Bacterial Input from Aquatic Birds to Twelve Rotorua Lakes

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FOR: **ENVIRONMENT BOP**
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C O N T E N T S

1. INTRODUCTION

In response to concerns expressed about the potential effects of waterfowl on the water quality of lakes in the Rotorua area, Environment Bay of Plenty commissioned Bioresearches to assess the contribution of waterfowl to the nutrient and bacterial input to twelve of the Rotorua lakes. These lakes, the location of which is shown in Figure 1, include Rotorua, Tarawera, Rotoiti, Okataina, Rotomahana, Rotoma, Rotoehu, Rerewhakaaitu, Rotokakahi, Okareka, Tikitapu and Okaro.

A literature search was undertaken to retrieve data concerning the impact of waterfowl and other lake dwelling species on nutrients and pathogen concentrations.

The overall impression gained from this search was that the quantity of information directly relevant to these aspects was low, but sufficient to enable a determination of whether or not lake-dwelling birds represented a significant source of both nutrients and pathogens. The nature of the available data restricts the following analysis to an approximate assessment with a moderate degree of error, rather than the final numbers providing a precise and definitive answer. Throughout the analysis the information sources, derivations of various estimations and data calculations have been presented in full to ensure that the basis for the final conclusion for each lake is transparent.

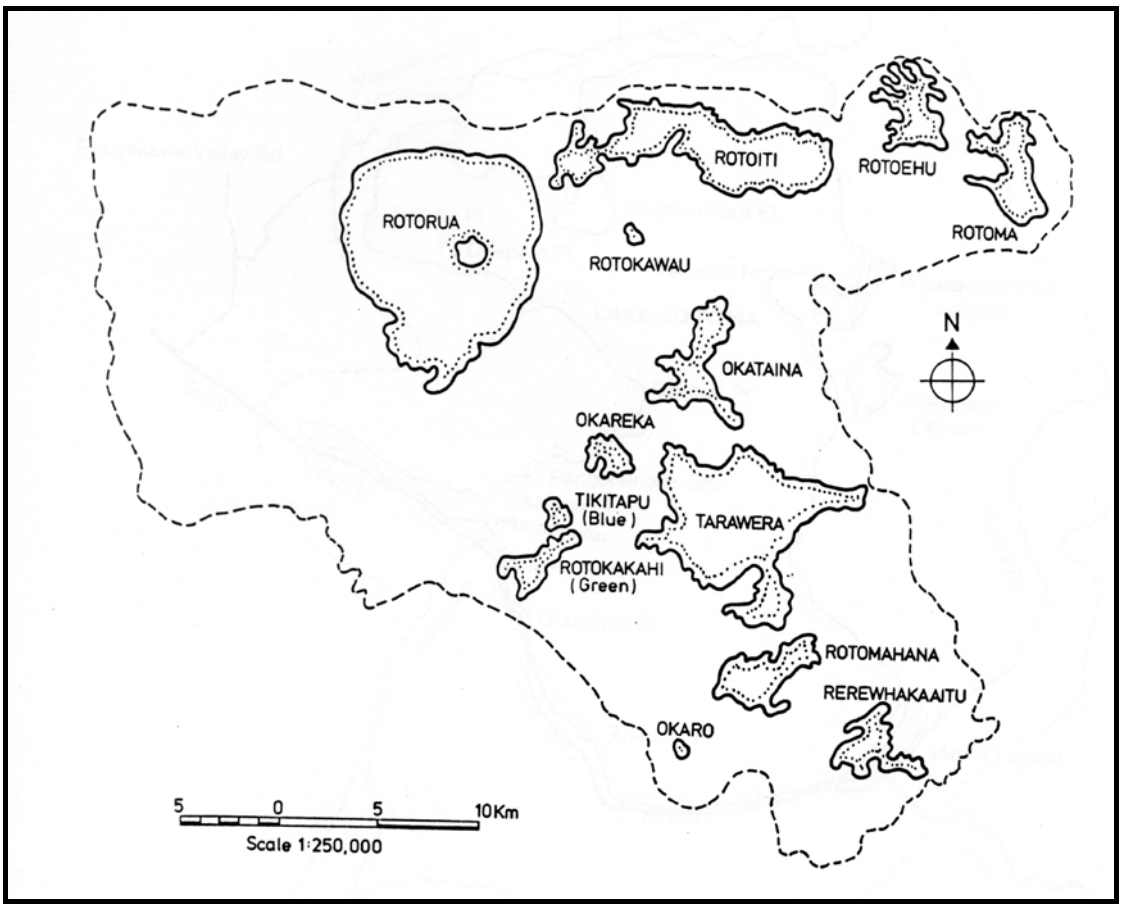

FIGURE 1 Rotorua Lakes

2. RELATIVE MANURE PRODUCTION RATES

The total quantity of waste material produced per day is related to animal type and size. For example the percentage of waste production relative to body weight varies as follows:

dairy cow	8.7%
beef	6.1%
sheep	4.0%
duck	10.7%

(Source Reference 1)

A study that addressed the impacts of mixed wild waterfowl, however, based its calculations for the average quantity of guano produced per day at 3.2% of body weight (Reference 2) which is the estimate which has been used in the following calculations.

The 10% of body weight for duck (above) applies to domestic ducks only whereas the 3.2% of body weight applies to mixed wild waterfowl and for the purposes of this evaluation has been selected as the more appropriate estimate.

Table 1 summarises bird weights for the species occurring on the twelve lakes under consideration (Reference 3). The species present and their total numbers have been taken from a 1996 census by the Ornithological Society of New Zealand (Reference 4).

TABLE 1 BIRD WEIGHTS (kg)

black swan	male female	6.0 5.0
canada goose	male female	5.4 4.5
feral goose		3.0
black shag		2.2
paradise shelduck	male female	1.7 1.4
mallard	male female	1.3 1.1
grey duck	male female	1.1 1.0
black-backed gull	male female	1.05 0.85
little black shag		0.80
little shag		0.70
caspian tern		0.70
shoveler	male female	0.65 0.60
scaup		0.65
coot	male female	0.57 0.52
white-faced heron		0.55
grey teal	male female	0.525 0.425
red-billed gull	male female	0.30 0.26
black-billed gull	male female	0.30 0.25
dabchick		0.25
pied stilt		0.19

That publication notes that the overall waterbird community had changed little over the previous decade, both in terms of total numbers of all species combined and species composition. Some changes, however, were noted, especially an increase in the range (number of lakes utilised) of canada geese and an apparent decrease in the numbers of little shags and little black shags.

As this appraisal aims at an order of magnitude of effect assessment, the most recent bird census data are not critical, provided the 1996 information is representative which appears to be the case. If larger birds, such as black swan and canada geese, have increased in numbers significantly, then this evaluation probably underestimates overall effects.

Table 2 lists the mean bird weights (a); an average has been taken where male and female weights differ.

TABLE 2 GUANO PRODUCTION PER INDIVIDUAL BIRD

	(a)	(b)	(c)	(d)	(e)
	mean wt (kg)	**guano per day 3.2% body wt (a) (g)**	**guano per annum (kg)**	**time on lake % (b)**	**guano input to lake per bird per annum (kg)**
black swan	5.5	176.0	64.2	90	57.8
canada goose	4.95	158.4	57.8	70	40.5
feral goose	3.0	96.0	35.0	70	24.5
black shag	2.2	70.4	25.7	50	12.9
paradise shelduck	1.55	49.6	18.1	40	7.2
mallard	1.2	38.4	14.0	50	7.0
grey duck	1.05	33.6	12.3	50	6.2
black-backed gull	0.95	30.4	11.1	40	4.4
little black shag	0.80	25.6	9.3	50	4.7
little shag	0.70	22.4	8.2	50	4.1
caspian tern	0.70	22.4	8.2	50	4.1
scaup	0.65	20.8	7.6	90	6.8
shoveler	0.625	20.0	7.3	50	3.7
white-faced heron	0.55	17.6	6.4	50	3.2
coot	0.545	17.4	6.4	90	5.8
grey teal	0.475	15.2	5.5	50	2.8
red-billed gull	0.28	8.9	3.2	40	1.3
black-billed gull	0.275	8.8	3.2	40	1.3
dabchick	0.25	8.0	2.9	90	2.6
pied stilt	0.19	6.1	2.2	40	0.9

(a) dry weight
(b) water surface and riparian areas

The guano production per day has been calculated (b) on the basis of 3.2% body weight per day. Again this percentage may be conservative based on other information from commercial duck rearing facilities.

The "guano per annum" data (c) have then been adjusted according to the estimated time various species utilise the lake surface and its immediate edge and riparian zones (d). There are no suitable New Zealand data and clearly the allocated percentages are debatable and would vary amongst individual birds (eg. breeding versus non-breeding). The highest percentage use of the lake environment (90% of the time) has been assigned to black swan, scaup, coot and dabchick as "obligate lake species." Black-billed gull may utilise the lake

environment more, but has been reported as also moving to the east coast at times (Reference 4) and is not a relatively major guano producer.

Column (e) of Table 2 provides the final estimate of guano production per species per annum based on body weight and the percentage utilisation of the lake habitat.

The dominant guano producers are black swan, canada goose and feral goose, followed by black shag, which has about half the guano production rate of feral goose. An intermediate group consists of paradise shelduck, mallard, grey duck, scaup and coot with the remainder contributing less than 5 kg per annum per bird.

Although dabchick is estimated to utilise the lake habitat for 90% of the time its input is, relatively, very low.

Table 3 amalgamates the Table 2 (e) data with the 1996 bird census data to derive potential guano deposition quantities for each species and each of the twelve lakes. The total number of birds involved and the total guano deposition per lake is also shown. The comparative summary is shown in Table 4 in decreasing order of guano input.

Lake Rotorua receives the highest input 105932 kg (c.106 tonnes) of guano per year and has the highest percentage of the waterbird population, followed by Rotoehu (c.92 tonnes), Rotoiti (c.72 tonnes) and Rotomahana (c.31 tonnes). The remainder receive less than 20 tonnes per annum and have 50% or less of the bird population.

TABLE 3 INDIVIDUAL SPECIES NUMBERS (1996) AND GUANO PRODUCTION PER LAKE

	ROTORUA		TARAWERA		ROTOITI		OKATAINA		ROTOMAHANA		ROTOMA		ROTOEHU		REREWHAKAAITU		ROTOKAKAHI		OKAREKA		TIKITAPU		OKARO	
	No.	**kg/yr**	**No.**	**kg/yr**	**No.**	**kg/yr**	**No.**	**kg/yr**	**No.**	**kg/yr**	**No.**	**kg/yr**	**No.**	**kg/yr**	**No.**	**kg/yr**	**No.**	**kg/yr**	**No.**	**kg/yr**	**No.**	**kg/yr**	**No.**	**kg/yr**
dabchick	24	62.4	52	135.2	221	574.6	2	5.2	3	7.8	13	33.8	11	28.6	9	23.4	6	15.6	46	119.6	0	0	0	0
black shag	140	1,806.0	12	154.8	6	77.4	2	25.8	1	12.9	0	0	13	167.7	9	116.1	1	12.9	4	51.6	0	0	2	25.8
little black shag	509	2,392.3	9	42.3	37	173.9	1	4.7	48	225.6	10	47.0	188	883.6	28	131.6	6	28.2	1	4.7	1	4.7	1	4.7
little shag	683	2,800.0	86	352.6	260	1,066.0	35	143.5	57	233.7	25	102.5	166	680.6	53	217.3	34	139.4	20	82.0	1	4.1	3	12.3
white-faced heron	6	19.2	24	76.8	11	35.2	12	38.4	20	64.0	3	9.6	46	147.2	26	83.2	1	3.2	0	0	1	3.2	1	3.2
black swan	1,483	85,717.4	193	11,155.4	1026	59,302.8	23	1,329.4	228	13,178.4	2	115.6	1,182	60,319.6	73	4,219.4	29	1,676.2	204	11,791.2	0	0	0	0
canada goose	0	0	2	81.0	0	0	0	0	22	891.0	120	4,860.0	124	5,022.0	159	6,439.5	0	0	0	0	0	0	0	0
feral goose	0	0	45	1,102.5	0	0	0	0	130	3,185.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
paradise shelduck	76	547.2	3	21.6	15	108.0	0	0	690	4,968.0	125	900.00	2,822	20,318.4	74	532.8	150	1,080.00	4	28.8	0	0	31	223.2
mallard/grey duck	306	2,019.6	231	1,524.6	214	1,412.4	33	217.8	822	5,425.2	15	99.0	526	3,471.6	164	1,082.4	61	402.6	113	745.8	30	198.0	62	409.2
grey teal	9	25.2	0	0	0	0	0	0	21	58.8	0	0	31	86.8	97	271.6	8	22.4	0	0	0	0	2	5.6
shoveler	1	3.7	0	0	0	0	0	0	35	129.5	0	0	0	0	9	33.3	0	0	0	0	0	0	0	0
scaup	989	6,725.2	340	2,312.0	1,073	7,296.4	110	748.0	210	1,428.0	83	564.4	28	190.4	138	938.4	17	115.6	167	1,135.6	0	0	0	0
coot	0	0	86	498.8	170	986.0	0	0	16	92.8	2	11.6	17	98.6	0	0	8	46.4	56	324.8	0	0	1	5.8
pied stilt	34	30.6	0	0	5	4.5	0	0	25	22.5	12	10.8	118	106.2	192	172.8	0	0	9	8.1	0	0	4	3.6
black-backed gull	284	1,249.6	23	101.2	9	39.6	12	52.8	216	950.4	11	48.4	3	13.2	55	242.0	6	26.4	3	13.2	0	0	2	8.8
red-billed gull	1,836	2,386.8	0	0	318	413.4	0	0	5	6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
black-billed gull	72	93.6	41	53.3	61	79.3	0	0	82	106.6	0	0	454	590.2	2	2.6	1	1.3	0	0	0	0	1	1.3
caspian tern	13	53.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**6,465**	**105,932.1**	**1,147**	**17,612.1**	**3,426**	**71,569.5**	**230**	**2,565.6**	**2,631**	**30,986.7**	**421**	**6,802.7**	**5,729**	**92,124.7**	**1,088**	**14,506.4**	**328**	**3,570.2**	**627**	**14,305.4**	**33**	**210.0**	**110**	**703.50**

NOTES
(i) juveniles excluded.
(ii) mallard-grey input per annum average; not separated in census data.

TABLE 4 SUMMARY OF TOTAL AND PERCENTAGE OF GUANO PRODUCTION AND BIRD NUMBERS PER LAKE

LAKE	TOTAL ANNUAL GUANO INPUT (kg)	% TOTAL	TOTAL NO. BIRDS – 1996	% TOTAL
Rotorua	105,932.1	29.35	6,465	29.08
Rotoehu	92,124.7	25.54	5,729	25.77
Rotoiti	71,569.5	19.84	3,426	15.41
Rotomahana	30,986.7	8.60	2,631	11.83
Tarawera	17,612.1	4.81	1,147	5.16
Rerewhakaaitu	14,506.4	4.03	1,088	4.89
Okareka	14,305.4	3.97	627	2.82
Rotoma	6,802.7	1.89	421	1.89
Rotokakahi	3,570.2	1.00	328	1.48
Okataina	2,565.6	0.72	230	1.03
Okaro	703.5	0.19	110	0.49
Tikitapu	210.0	0.06	33	0.15
TOTAL	**360,888.9**	–	**22,235**	–

TABLE 5 SUMMARY OF TOTAL BIRD NUMBERS FOR ALL TWELVE LAKES AND GUANO PRODUCTION

	TOTAL NO. INDIVIDUALS	% TOTAL	TOTAL GUANO POTENTIAL (kg/annum)	% TOTAL
black swan	4,443	19.98	248,805.4	68.94
paradise shelduck	3,990	17.94	28,728.00	7.96
scaup	3,155	14.19	21,454.0	5.94
canada goose	427	1.92	17,293.5	4.79
mallard/grey	2,577	11.60	17,008.02	4.71
little shag	1,423	6.40	5,834.0	1.62
feral goose	175	0.79	4,287.5	1.19
little black shag	839	3.77	3,943.3	1.10
red-billed gull	2,159	9.71	2,806.7	0.78
black-backed gull	624	2.81	2,745.6	0.76
black shag	190	0.85	2,451.0	0.68
coot	356	1.60	2,064.8	0.57
dabchick	387	1.74	1,006.2	0.28
black-billed gull	714	3.21	928.2	0.26
white-faced heron	151	0.68	483.2	0.13
grey teal	168	0.76	470.4	0.13
pied stilt	399	1.79	359.1	0.10
shoveler	45	0.20	166.5	0.05
caspian tern	13	0.06	53.3	0.01
TOTAL	**22,235**	–	**360,888.9**	–

The reason for the high input at Lakes Rotorua, Rotoehu and Rotoiti is clear from Tables 3 and 5. Those lakes contain respectively 1483, 1182, and 1026 black swan (83% of population) and from Table 5 black swans contribute about 70% of the guano entering the lakes. The contributions of paradise shelduck and scaup are low by comparison, however, note the low numbers of canada geese and the relatively high guano input.

While 4443 black swan contribute c.249 tonnes per annum, a combined total of 9722 paradise shelduck, scaup and mallard/grey duck only contribute c.67 tonnes.

Although a total estimated guano load from waterbirds of c.361 tonnes per annum is deposited, and although that deposition is generally direct, that needs to be placed into perspective.

Using data provided by Reference 7 the manure production per animal unit per annum for dairy cows is as follows:

	manure per day (kg)	**manure per annum (tonnes)**
lactating 454 kg cow	48.1	17.6
lactating 635 kg cow	67.1	24.5
dry 454 kg cow	37.2	13.6
dry 635 kg cow	52.2	19.0

Therefore from these data the total input in terms of quantity from waterbirds per annum is equivalent to that from c.15-27 dairy cows depending on several variables. While clearly the greatest contribution is from 4443 black swans, their level of guano input is equivalent to about 10 to 18 dairy cows assuming direct animal to lake addition. Similarly, the additions from all waterfowl to Lake Rotorua in isolation would be equivalent to direct input from 4 to 8 dairy cows. Note that this applies to the quantities of manure and not the relative input of nutrients and pathogens.

While that analogy assists with perspective, it is important to note that (a) equivalent direct animal to lake discharge is assumed and, (b) that weight for weight, duck manure contains higher levels of BOD, COD, total kjeldahl nitrogen, total ammonia, total phosphorus, faecal coliform and faecal streptococci bacteria than dairy cow manure (Reference 1). Therefore,

while an equivalence in manure weight can be defined there is not an equivalence regarding the effects.

3. NUTRIENTS

Livestock manure characteristics are shown in Tables 6 and 7. Note that the animal weights are stated in Table 6; the figures in Table 7 relate to a standard live animal mass of 1000 kg. As noted, duck manure contains higher nutrient concentrations and bacterial levels than an equivalent weight of dairy, beef or sheep manure.

TABLE 6 LIVESTOCK FRESH MANURE CHARACTERISTICS

MANURE SOURCE	AVERAGE ANIMAL WT	FAECES & URINE PRODUCTION		NH_3–N	PHOSPHORUS P_2O_5
	(kg)	g/day	kg/yr	kg/tonne	kg/tonne
dairy	635	55,475	20,248	0.85	2.28
beef	362	22,000	8,030	1.74	3.26
sheep	27	1,089	398	2.59	4.19
duck	1.4	150	55	3.66	10.45

(Source : Ref. 1)

An estimate of nutrient output as voided has been calculated using the mean outputs of total kjeldahl nitrogen (TKN) and total phosphorus for ducks in Table 7 i.e. TKN = 1.5 kg per 1000 kg live animal mass and TP = 0.54 kg per 1000 kg live animal mass.

The bird biomass has been adjusted to reflect the time spent (estimated) by each species on and immediately adjacent to the lake habitat eg. the average black swan weight is 5.5 kg, it is estimated to spend 90% of its time within the lake habitat and therefore its effective biomass in terms of nutrient input is 4.95 kg. A similar answer is provided if the bird weights remain the same and the census number is adjusted to reflect the "effective" number of birds.

The results for each lake are shown in Appendix 8.1. The total biomass of birds is determined in tonnes; for each "bird tonne" 1.5 kg/day TKN and 0.54 kg/day TP is produced – for the Lake Rotorua example 9.1 tonnes x 1.5 kg TKN per day per tonne equals 13.65 kg TKN per day or 4982.3 kg per annum.

TABLE 7 FRESH MANURE PRODUCTION AND CHARACTERISTICS PER 1000 kg LIVE ANIMAL MASS PER DAY (standard deviation in brackets)

	TOTAL MANURE (kg)	BOD (kg)	COD (kg)	TKN (kg)	NH_4-N (kg)	TP (kg)	FC cfu x 10^{10}	FS cfu x 10^{10}
dairy	86 (17)	1.6 (0.48)	11 (2.4)	0.45 (0.096)	0.079 (0.083)	0.094 (0.024)	16 (28)	92 (140)
beef	58 (17)	1.6 (0.75)	7.8 (2.7)	0.34 (0.073)	0.086 (0.052)	0.092 (0.027)	28 (27)	31 (45)
sheep	40 (11)	1.2 (0.47)	11 (2.5)	0.42 (0.11)	n/a	0.087 (0.030)	45 (27)	62 (73)
duck	110 (n/a)	4.5 (n/a)	27 (n/a)	1.5 (0.54)	n/a	0.54 (0.21)	180 (180)	590 (n/a)

Source References . 5 & 10

BOD : biochemical oxygen demand
COD : chemical oxygen demand
TKN : total kjeldahl nitrogen
n/a : not available
NH_4-N : total ammonia
TP : total phosphorus
FC : faecal coliforms
FS : faecal streptococci

The Appendix 8.1. calculations are summarised in Table 8. The total estimated wet weight of TKN produced is 17.34 tonnes per annum while 6.27 tonnes of TP are produced by 31.66 tonnes of birds.

TABLE 8 NUTRIENT (TKN; TP) INPUT SUMMARY (kg per annum); BASED ON WET WEIGHT DATA

LAKE	TKN (kg/annum)	TP (kg/annum)	TOTAL WATERBIRI BIOMASS (kg)
Rotorua	4,982.3	1,792.2	9.100.6
Rotoehu	4,701.2	1,693.6	8,586.2
Rotoiti	3,361.7	1,208.2	6,138.0
Rotomahana	1,456.4	525.6	2,662.0
Tarawera	828.6	299.3	1,511.8
Rerewhakaaitu	682.6	244.6	1,245.6
Okareka	671.6	240.9	1,226.8
Rotoma	321.2	116.8	583.8
Rotokakahi	167.9	62.1	306.7
Okataina	120.5	76.7	221.0
Okaro	32.9	10.9	60.7
Tikitapu	10.9	3.3	18.2
TOTAL	**17,337.8**	**6,274.2**	**31,661.4**

TABLE 9 TOTAL NITROGEN AND TOTAL PHOSPHORUS INPUT SUMMARY – DRY WEIGHT (kg per annum)

LAKE	TN (kg/annum)	TP (kg/annum)	EFFECTIVE BIRD NO (ζ) (rounded)
Rotorua	1,433.9	1,375.2	4,001
Rotoehu	1,574.2	775.7	3,045
Rotoiti	880.8	545.6	2,668
Rotomahana	453.9	232.4	1,427
Tarawera	290.5	186.1	845
Rerewhakaaitu	252.5	175.4	632
Okareka	184.7	87.7	501
Rotoma	107.3	62.8	260
Rotokakahi	80.9	54.3	172
Okataina	47.4	45.4	168
Okaro	27.0	13.3	52
Tikitapu	11.4	5.3	21
TOTAL	**5,344.5**	**3,559.2**	**13,792**

(ζcensus number adjusted for the time each species estimated to spend on lake)

To place this into perspective, using the dairy cow figures from Table 7, the following comparison can be made.

31.661 tonnes dairy cow animal mass:

		kg/day	kg/annum
TKN	31.661 x 0.45	14.25	5201.25
TP	31.661 x 0.094	2.98	1087.70

Therefore the same weight of birds is estimated to produce 12.1 tonnes more TKN and 5.2 tonnes more TP; the total biomass of birds is equivalent to about 72 dairy cows at 440 kg average weight from the perspective of nutrient input.

The second method which has been used to estimate nutrient loadings from birds uses rates from Reference 9 as outlined below, which themselves were taken from References 8 and 13. Those rates accommodate differences in the guano composition of birds according to their diet. For example herbivorous species (geese, black swans) produce relatively higher quantities of nitrogen than phosphorus, whereas the converse applies to fish-eating birds such as shags and herons. In the lakes analysis, pied stilt has been assigned the dabchick (grebes) figure as it is similarly insectivorous. In Reference 9 the nutrient production rate for dabbling ducks has been modified from the rate for geese. In the original reference (Reference 8) however, the rate for ducks has been assumed to be the same as geese. In this assessment the goose rate has been applied to dabbling ducks but the Reference 9 rate to diving ducks (i.e. scaup). Caspian tern has been assigned the cormorant rate as it is similarly a fish-eater.

Appendix 8.2. presents the results of calculations based on the above rates (dry weight) for each of the twelve lakes. The numbers of birds counted in the 1996 census have been adjusted to reflect the total estimated time each species spends within the lake habitat i.e. effective number. That number is multiplied by the Table 10 rate to provide the quantity of TN and TP per day per species and the subsequent load per annum.

The total dry weight nutrient production of birds per lake is summarised in Table 9. The overall total nitrogen produced by an "effective bird population" of 13792 individuals is 5.34 tonnes while the total phosphorus production is 3.56 tonnes. The decreasing order of nutrient

input in Table 9 is the same as that in Table 8 with Lake Rotorua having the highest overall input followed by Lakes Rotoehu and Rotoiti.

TABLE 10 TOTAL NITROGEN AND TOTAL PHOSPHORUS PRODUCTION RATES (g/per day dry weight)

Reference 6 Category	NZ species assigned	TN (g/day)	TP (g/day)
geese	feral goose, black swan, canada goose, paradise shelduck, mallard/grey, grey teal, shoveler	1.57	0.49
dabbling ducks	nil (refer text)	0.72	0.22
diving ducks	Scaup	0.61	0.19
cormorants	black shag, little black shag, little shag, caspian tern	0.89	3.87
gulls	black-backed gull, red-billed gull, black-billed gull	0.44	0.24
egrets and herons	white-faced heron	0.97	2.64
coots	Coot	0.28	0.09
muscovy ducks	Nil	0.97	0.30
grebes	dabchick, pied stilt	0.20	0.89

Notes (1) nutrient rates apply to dry weight
(2) nitrogen is total nitrogen
TN (total nitrogen) = organic N + ammonia + nitrate + nitrite
TKN (total kjeldahl nitrogen) = organic N + ammonia

Clearly there are differences between the Table 8 and 9 estimates. In Table 8 the nitrogen is TKN while that in Table 9 is TN. The estimates in Table 8 are wet weight as voided, while those in Table 9 are on a dry weight basis. A direct relationship between the wet weight TKN and dry weight TN is further complicated by the varying nitrogenous outputs of the species involved and the proportions of herbivorous, insectivorous and fish-eating birds on the different lakes. Further, birds excrete uric acid (white, barely soluble in water) as a nitrogenous waste in urine, which can be as high as 20%. Uric acid breaks down to ammonia and carbon dioxide in contact with water and oxygen.

The difference between the Table 8 and 9 total outputs are as follows:

wet weight as voided		dry weight	
TKN	TP	TN	TP
17337.8	6274.2	5344.5	3559.2

The wet weight - dry weight ratios are:

TKN wet/TN dry – c. 3:1
TP wet/TP dry – c. 2:1

The average wet weight to dry weight ratios per canada geese droppings reported in References 8 and 15 were about 5:1.

The relationship between the nitrogen and phosphorus total load is as follows:

wet weight TKN/TP – 2.8:1
dry weight TN/TP – 1.5:1
average – c.2:1

This relationship, however, varies between lakes depending on the proportion of species, particularly shags, for example the Lake Rotorua ratio is 1:1 while that for Lake Rotoehu is 2:1 which is the more typical situation.

For the purposes of this evaluation the dry weight totals for TN and TP should be included in the overall catchment assessment for each lake. Those figures accommodate the varying nitrogen and phosphorus outputs per species and include all forms of nitrogen.

The analogy of dairy cows has been calculated simply to place the relative significance of potential waterfowl impacts into a layperson's perspective. Clearly in terms of an overall nutrient budget a proportion of the nutrients contributed via waterfowl faeces is part of the internal nutrient load of the lakes and represents recycling only. The precise proportion of new nutrients contributed to the lakes versus the proportion re-cycled, of the total waterfowl nutrient input is not known and would be difficult to estimate. In this regard this analysis presents a worst-case situation for nutrient input, however, similar logic does not apply to the bacterial contribution.

4. BACTERIA

A similar evaluation can be undertaken for the impact of waterbirds on the input of pathogens, but limited to bacteria, however the data accessed had an even larger level of uncertainty than the nutrient data.

From Reference 10 gulls are considered to have high faecal coliform concentrations per weight of faeces excreted. Estimated loading rates of 1.1 x 10^6 to 16.0 x 10^6 coliforms per g per hour per bird were estimated. Information (Reference 10) suggests that weight for weight, gull faeces carries a greater quantity of *E. coli* than other waterfowl and that up to 99% of the bacteria can consist of *E. coli.*

Reference 16 cites the average faecal coliform level in ring-billed gull faeces as 368 x 10^6 per g and as 0.0153 x 10^6 per g for canada geese.

On Lake Rotorua, gulls and black swans are numerous and if the faecal coliform level recorded in canada geese can be applied to black swans, the contributions from these birds could be as follows using the guano production rates of Table 3.

	gulls	black swan
guano production (g/day)	1022	234841
faecal coliforms (cfu per g)	368 x 10^6	0.0153x10^6
faecal coliforms (cfu per day)	376096 x 10^6	3593 x 10^6

The Reference 16 study also identified that sun-dried faeces can contain viable faecal coliform bacteria (up to 300,000 cfu per g).

While there are a moderate number of studies of pathogen levels in bird faeces, a literature summary was not the primary purpose of this appraisal that aimed at estimating the order of magnitude of potential water quality effects as a result of waterbird activity.

To arrive at ballpark figures for faecal coliform bacteria the guano input per bird per day (in grams) has been calculated from Table 3 (e). That figure has been adjusted for estimated time spent within the lake habitat.

TABLE 11 ESTIMATED POTENTIAL FAECAL COLIFORM INPUT BY WATERBIRDS PER DAY (cfu x 10^6 per day)

LAKE	guano input (g/day) (% use adjusted)	No. birds	Total guano input (g/day)	Faecal coliforms (cfu x 10^6 per g)	Faecal coliforms (cfu x 10^6 per day)	Total faecal coliform (input per day x 10^6)
ROTORUA						
gulls; tern	30.41	2,205	67,054.1	368	24,675,890.4	
others	522.47	4,260	2,225,722.2	0.0153	34,053.5	24,709,943.9
TARAWERA						
gulls; tern	30.41	64	1,946.2	368	716,201.6	
others	522.47	1,083	565,835.0	0.0153	8,657.3	724,858.9
ROTOITI						
gulls; tern	30.41	388	11,799.1	368	4,342,068.8	
others	522.47	3,038	1,587,263.9	0.0153	24,285.1	4,366,353.9
OKATAINA						
gulls; tern	30.41	12	364.9	368	134,283.2	
others	522.47	218	113,898.5	0.0153	1,742.6	136,025.8
ROTOMAHANA						
gulls; tern	30.41	303	9,214.2	368	3,390,825.6	
others	522.47	2,328	1,216,310.2	0.0153	18,609.5	3,409,435.1
ROTOMA						
gulls; tern	30.41	11	334.5	368	123,099.7	
others	522.47	410	214,212.7	0.0153	3,277.5	126,377.2
ROTOEHU						
gulls; tern	30.41	457	13,897.4	368	5,114,232.2	
others	522.47	5,272	2,754,461.8	0.0153	42,143.3	5,156,375.5
REREWHAKAAITU						
gulls; tern	30.41	57	1,733.4	368	637,891.2	
others	522.47	1,031	538,666.6	0.0153	8,241.6	646,132.8
ROTOKAKAHI						
gulls; tern	30.41	7	212.9	368	78,347.2	
others	522.47	321	167,712.9	0.0153	2,566.0	80,913.2
OKAREKA						
gulls; tern	30.41	3	91.2	368	33,561.6	
others	522.47	624	326,021.3	0.0153	4,988.1	38,549.7
TIKITAPU						
gulls; tern	30.41	0	0	368	0	
others	522.47	33	17,241.5	0.0153	263.8	263.8
OKARO						
gulls; tern	30.41	3	91.2	368	33,561.6	
others	522.47	107	55,904.3	0.0153	855.3	34,416.9

To estimate the faecal coliform load, the bacterial concentrations reported in Reference 16 have been used as these were the result of testing faecal samples from 249 ring-billed gulls and 236 canada geese over a two year period and therefore represented relatively robust data.

The average concentrations of faecal coliform bacteria per gram for canada geese stated above have been applied to all species except gulls and caspian tern for which the average Reference 16 level has been used.

Table 11 outlines the derivation of the Table 12 summary of the numbers of faecal coliform bacteria x 10^6 potentially entering the lakes from waterbirds per day. Note that the guano input for gulls/terns and others has been adjusted for the percentage use of the lake habitat.

TABLE 12 ESTIMATED POTENTIAL FAECAL COLIFORM INPUT SUMMARY (cfc x 10^6 per day)

Lake	cfu x 10^6 per day
Rotorua	24,709,944
Rotoehu	5,156,376
Rotoiti	4,366,354
Rotomahana	3,409,435
Tarawera	724,859
Rerewhakaaitu	646,133
Okataina	136,026
Rotoma	126,377
Rotokakahi	80,913
Okareka	38,550
Okaro	34,417
Tikitapu	264

Clearly Lake Rotorua has a high potential waterbird-derived faecal input at 24, 709, 944 x 10^6 faecal coliform bacteria per day, but also has the highest number of birds (6465) and a large gull population (2205).

Lakes Rotoehu, Rotoiti and Rotomahana have a similar potential while the lowest is Lake Tikitapu at 264 million cfu per day.

While these estimates would represent a significant and probably adverse input from a point source, the input from waterbirds is diffuse with a large proportion entering the lakes directly. Note that from Table 7, however, the relative weight for weight input of faecal coliform

bacteria from ducks is about 11 times higher than that for dairy cows; the faecal streptococci input from ducks is about 6 times higher.

Clearly there is the potential for waterbirds to adversely effect the sanitary quality of quiescent waterbodies when large concentrations of individuals are present, for example in specific areas around lake edges. That potential is clearly exacerbated in situations such as Lake Rotorua that have relatively large populations of both waterfowl and gulls, the latter of which are the greater source of bacterial contamination.

As was the case for nutrients, perspective can be placed on the results by comparison with dairy cows using the data provided in Table 7. The total biomass of waterbirds on all the lakes is estimated at 31.661 tonnes. If that biomass was represented by dairy cows the following would apply.

Faecal coliforms per day

$$31.661 \text{ tonnes } @ 160{,}000 \times 10^6 \text{ per tonne} = 5{,}065{,}760 \times 10^6 \text{ cfu per day}$$

31.661 tonnes of dairy cows equates with about 72 animals at 440 kg each with each animal contributing about 70358 cfu per day. If the daily input from waterbirds is divided by the daily dairy cow production, a dairy cow-equivalent can be estimated for the lakes.

The daily input of faecal coliforms from waterbirds to Lake Rotorua therefore equates with that from c.351 dairy cows. That to Lakes Rotoehu, Rotoiti and Rotomahana equates with about 73, 62 and 48 dairy cows respectively, that to Lakes Tarawera and Rerewhakaaitu equates with c.9 to 10 animals, and that to Lake Okataina with 2. The remainder of the lakes have equivalent bacterial inputs of less than 2 dairy cows.

From this preliminary estimation of bacterial inputs from waterbirds it is evident that the waterbody most likely to be adversely affected by bird-derived faecal coliform bacteria, and by inference pathogens in general, is Lake Rotorua.

5. LAKE NUTRIENT BUDGETS

The nutrient budgets for the twelve lakes are shown in Appendix 8.3. and the summary in Table 13.

Water column nutrient concentrations in lakes are the product of both external loading (eg. land runoff) and internal loading where nutrients are released from storage in lake sediments via stratification and lake turnover.

It is probable that the majority of the nutrient load contributed by lake-dwelling birds is re-cycled and can be considered part of the internal load in terms of a strict lake catchment nutrient budget. (Clearly this does not apply to the bacterial input of lake birds). The addition of re-cycled nutrients as bird faeces, however, increases their availability to lake organisms such as algae and that has implications regarding colour, clarity and aesthetics, especially in shallow lake edge habitats.

Therefore for this evaluation the addition of nutrients from lake birds has been considered to be a nutrient budget factor in terms of lake management.

With respect to nitrogen inputs to the lakes, in nine out of the twelve lakes, it is estimated that the wildfowl contributed less than 1% of the total loading (Table 13). Of the remaining three lakes the maximum wildfowl contribution was estimated at 4.4% of the total nitrogen input for Lake Rotoehu. The maximum phosphorus input from wildfowl (15.9% of total input) was also recorded for Lake Rotoehu. For most of the remaining lakes (nine out of twelve) the phosphorus input from wildfowl was estimated to be less than 4% of the total input.

TABLE 13. SUMMARY OF NUTRIENT INPUTS FROM WILDFOWL TO ROTORUA LAKES

SOURCE	NUTRIENTS					
	NITROGEN			PHOSPHORUS		
	Total (a)	Wildfowl		Total (a)	Wildfowl	
	tonnes per year		%	tonnes per year		%
Rotorua	474.5	1.4	0.3	67.0	1.4	2.0
Tarawera	64.4	0.29	0.4	5.5	0.19	3.4
Rotoiti	415.3	0.9	0.2	31	0.5	1.6
Okataina	22.6	0.05	0.2	1.3	0.04	3.1
Rotomahana	59.0	0.45	0.8	7.0	0.23	3.3
Rotoehu	36.0	1.6	4.4	5.0	0.8	15.9
Rotoma	19.4	0.1	0.5	2.0	0.06	2.9
Rerewhakaaitu	33.1	0.25	0.7	4.3	0.17	4.0
Rotokakahi	5.8	0.08	1.4	0.60	0.05	8.3
Okareka	15.4	0.18	1.2	1.75	0.09	5.1
Tikitapu	2.7	0.01	0.4	0.155	0.005	3.2
Okaro	3.8	0.03	0.8	0.52	0.01	1.9

Note:

(a) Totals based on Bioresearches data presented in "Report on Rural Land Use Practices in the Rotorua District" (Sigma Consultants, 1993).

6. RECOMMENDATIONS

6.1. From the viewpoint of lake management, information should be obtained on the distributions of lake birds to identify the most critical areas of aggregation of the dominant manure-producing species.

6.2. Bacterial and nutrient data should be collected from the areas with the most significant aggregations to determine whether or not a significant change in water quality occurs as a result of intensive bird use, and whether or not this has implications regarding bacterial guidelines for contact recreation.

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8. APPENDICES

Appendix 8.1.

Wet weight nutrient input

LAKE: ROTORUA

	Corrected bird biomass (kg) ψ	No. individuals	Total biomass (kg)
dabchick	0.23	24	5.5
black shag	1.1	140	154
little black shag	0.4	509	203.6
little shag	0.35	683	239.1
white-faced heron	0.28	6	1.7
black swan	4.95	1,483	7,340.9
canada goose	3.47	0	0
feral goose	2.1	0	0
paradise shelduck	0.62	76	47.1
mallard/grey	0.57	306	174.4
grey teal	0.24	9	2.16
shoveler	0.31	1	0.3
scaup	0.59	989	583.5
coot	0.49	0	0
pied stilt	0.08	34	2.7
black-backed gull	0.38	284	107.9
red-billed gull	0.11	1,836	201.9
black-billed gull	0.11	72	31.2
caspian tern	0.35	13	4.6
		TOTAL (kg)	**9,100.6**
		TOTAL (tonnes)	**9.1006**

	kg/day	kg/annum
TOTAL KJELDAHL NITROGEN (x1.5)	13.65	4,982.25
TOTAL PHOSPHORUS (x0.54)	4.91	1,792.15

ψ corrected biomass is weight corrected for time on lake (Table 2(a) and (d))

LAKE: TARAWERA

	Corrected bird biomass (kg) ψ	No. individuals	Total biomass (kg)
dabchick	0.23	52	11.9
black shag	1.1	12	13.2
little black shag	0.4	9	3.6
little shag	0.35	86	30.1
white-faced heron	0.28	24	6.7
black swan	4.95	193	955.4
canada goose	3.47	2	6.9
feral goose	2.1	45	94.5
paradise shelduck	0.62	3	1.9
mallard/grey	0.57	231	131.7
grey teal	0.24	0	0
shoveler	0.31	0	0
scaup	0.59	340	200.6
coot	0.49	86	42.1
pied stilt	0.08	0	0
black-backed gull	0.38	23	8.7
red-billed gull	0.11	0	0
black-billed gull	0.11	41	4.5
caspian tern	0.35	0	0
		TOTAL (kg)	**1,511.80**
		TOTAL (tonnes)	**1.5118**

	kg/day	kg/annum
TOTAL KJELDAHL NITROGEN (x1.5)	2.27	828.55
TOTAL PHOSPHORUS (x0.54)	0.82	299.30

ψ corrected biomass is weight corrected for time on lake (Table 2(a) and (d))

LAKE: ROTOITI

	Corrected bird biomass (kg) ψ	No. individuals	Total biomass (kg)
dabchick	0.23	221	50.8
black shag	1.1	6	6.6
little black shag	0.4	37	14.8
little shag	0.35	260	91.0
white-faced heron	0.28	11	3.1
black swan	4.95	1,026	5,078.7
canada goose	3.47	0	0
feral goose	2.1	0	0
paradise shelduck	0.62	15	9.3
mallard/grey	0.57	214	121.9
grey teal	0.24	0	0
shoveler	0.31	0	0
scaup	0.59	1,073	633.1
coot	0.49	170	83.3
pied stilt	0.08	5	0.4
black-backed gull	0.38	9	3.4
red-billed gull	0.11	318	34.9
black-billed gull	0.11	61	6.7
caspian tern	0.35	0	0
		TOTAL (kg)	**6,138.0**
		TOTAL (tonnes)	**6.138**

	kg/day	kg/annum
TOTAL KJELDAHL NITROGEN (x1.5)	9.21	3,361.65
TOTAL PHOSPHORUS (x0.54)	3.31	1,208.15

ψ corrected biomass is weight corrected for time on lake (Table 2(a) and (d))

LAKE: OKATAINA

	Corrected bird biomass (kg) ψ	No. individuals	Total biomass (kg)
dabchick	0.23	2	0.5
black shag	1.1	2	2.2
little black shag	0.4	1	0.4
little shag	0.35	35	12.3
white-faced heron	0.28	12	3.4
black swan	4.95	23	113.9
canada goose	3.47	0	0
feral goose	2.1	0	0
paradise shelduck	0.62	0	0
mallard/grey	0.57	33	18.8
grey teal	0.24	0	0
shoveler	0.31	0	0
scaup	0.59	110	64.9
coot	0.49	0	0
pied stilt	0.08	0	0
black-backed gull	0.38	12	4.6
red-billed gull	0.11	0	0
black-billed gull	0.11	0	0
caspian tern	0.35	0	0
		TOTAL (kg)	**221.0**
		TOTAL (tonnes)	**0.221**

	kg/day	kg/annum
TOTAL KJELDAHL NITROGEN (x1.5)	0.33	120.45
TOTAL PHOSPHORUS (x0.54)	0.12	76.65

ψ corrected biomass is weight corrected for time on lake (Table 2(a) and (d))

LAKE: ROTOMAHANA

	Corrected bird biomass (kg) ψ	No. individuals	Total biomass (kg)
dabchick	0.23	3	0.7
black shag	1.1	1	1.1
little black shag	0.4	48	19.2
little shag	0.35	57	19.9
white-faced heron	0.28	20	5.6
black swan	4.95	228	1,128.6
canada goose	3.47	22	76.3
feral goose	2.1	130	273
paradise shelduck	0.62	690	427.8
mallard/grey	0.57	822	468.5
grey teal	0.24	21	5
shoveler	0.31	35	10.9
scaup	0.59	210	123.9
coot	0.49	16	7.8
pied stilt	0.08	25	2
black-backed gull	0.38	216	82.1
red-billed gull	0.11	5	0.6
black-billed gull	0.11	82	9
caspian tern	0.35	0	0
		TOTAL (kg)	**2,662.0**
		TOTAL (tonnes)	**2.662**

	kg/day	kg/annum
TOTAL KJELDAHL NITROGEN (x1.5)	3.99	1,456.35
TOTAL PHOSPHORUS (x0.54)	1.44	525.60

ψ corrected biomass is weight corrected for time on lake (Table 2(a) and (d))

LAKE: ROTOMA

	Corrected bird biomass (kg) ψ	No. individuals	Total biomass (kg)
dabchick	0.23	13	2.9
black shag	1.1	0	0
little black shag	0.4	10	4
little shag	0.35	25	8.8
white-faced heron	0.28	3	0.8
black swan	4.95	2	9.9
canada goose	3.47	120	416.4
feral goose	2.1	0	0
paradise shelduck	0.62	125	77.5
mallard/grey	0.57	15	8.6
grey teal	0.24	0	0
shoveler	0.31	0	0
scaup	0.59	83	48.9
coot	0.49	2	0.9
pied stilt	0.08	12	0.9
black-backed gull	0.38	11	4.2
red-billed gull	0.11	0	0
black-billed gull	0.11	0	0
caspian tern	0.35	0	0
		TOTAL (kg)	**583.8**
		TOTAL (tonnes)	**0.5838**

	kg/day	kg/annum
TOTAL KJELDAHL NITROGEN (x1.5)	0.88	321.20
TOTAL PHOSPHORUS (x0.54)	0.32	116.80

ψ corrected biomass is weight corrected for time on lake (Table 2(a) and (d))

LAKE: ROTOEHU

	Corrected bird biomass (kg) ψ	No. individuals	Total biomass (kg)
dabchick	0.23	11	2.5
black shag	1.1	13	14.3
little black shag	0.4	188	75.2
little shag	0.35	166	58.1
white-faced heron	0.28	46	12.9
black swan	4.95	1,182	5,850.9
canada goose	3.47	124	430.3
feral goose	2.1	0	0
paradise shelduck	0.62	2,822	1,749.64
mallard/grey	0.57	526	299.8
grey teal	0.24	31	7.4
shoveler	0.31	0	0
scaup	0.59	28	16.5
coot	0.49	17	8.3
pied stilt	0.08	118	9.4
black-backed gull	0.38	3	1.1
red-billed gull	0.11	0	0
black-billed gull	0.11	454	49.9
caspian tern	0.35	0	0
		TOTAL (kg)	**8,586.24**
		TOTAL (tonnes)	**8.5862**

	kg/day	kg/annum
TOTAL KJELDAHL NITROGEN (x1.5)	12.88	4,701.20
TOTAL PHOSPHORUS (x0.54)	4.64	1,693.60

ψ corrected biomass is weight corrected for time on lake (Table 2(a) and (d))

LAKE: REREWHAKAAITU

	Corrected bird biomass (kg) ψ	No. individuals	Total biomass (kg)
dabchick	0.23	9	2.1
black shag	1.1	9	9.9
little black shag	0.4	28	11.2
little shag	0.35	53	18.6
white-faced heron	0.28	26	7.3
black swan	4.95	73	361.4
canada goose	3.47	159	551.7
feral goose	2.1	0	0
paradise shelduck	0.62	74	45.9
mallard/grey	0.57	164	93.5
grey teal	0.24	97	23.3
shoveler	0.31	9	2.8
scaup	0.59	138	81.4
coot	0.49	0	0
pied stilt	0.08	192	15.4
black-backed gull	0.38	55	20.9
red-billed gull	0.11	0	0
black-billed gull	0.11	2	0.2
caspian tern	0.35	0	0
		TOTAL (kg)	**1,245.6**
		TOTAL (tonnes)	**1.2456**

	kg/day	kg/annum
TOTAL KJELDAHL NITROGEN (x1.5)	1.87	682.55
TOTAL PHOSPHORUS (x0.54)	0.67	244.55

ψ corrected biomass is weight corrected for time on lake
(Table 2(a) and (d))

LAKE: ROTOKAHAHI

	Corrected bird biomass (kg) ψ	No. individuals	Total biomass (kg)
dabchick	0.23	6	1.4
black shag	1.1	1	1.1
little black shag	0.4	6	2.4
little shag	0.35	34	11.9
white-faced heron	0.28	1	0.3
black swan	4.95	29	143.6
canada goose	3.47	0	0
feral goose	2.1	0	0
paradise shelduck	0.62	150	93
mallard/grey	0.57	61	34.8
grey teal	0.24	8	1.9
shoveler	0.31	0	0
scaup	0.59	17	10
coot	0.49	8	3.9
pied stilt	0.08	0	0
black-backed gull	0.38	6	2.3
red-billed gull	0.11	0	0
black-billed gull	0.11	1	0.1
caspian tern	0.35	0	0
		TOTAL (kg)	**306.7**
		TOTAL (tonnes)	**0.3067**

	kg/day	kg/annum
TOTAL KJELDAHL NITROGEN (x1.5)	0.46	167.90
TOTAL PHOSPHORUS (x0.54)	0.17	62.05

ψ corrected biomass is weight corrected for time on lake (Table 2(a) and (d))

LAKE: OKAREKA

	Corrected bird biomass (kg) ψ	No. individuals	Total biomass (kg)
dabchick	0.23	46	10.6
black shag	1.1	4	4.4
little black shag	0.4	1	0.4
little shag	0.35	20	7
white-faced heron	0.28	0	0
black swan	4.95	204	1,009.8
canada goose	3.47	0	0
feral goose	2.1	0	0
paradise shelduck	0.62	4	2.5
mallard/grey	0.57	113	64.4
grey teal	0.24	0	0
shoveler	0.31	0	0
scaup	0.59	167	98.5
coot	0.49	56	27.4
pied stilt	0.08	9	0.7
black-backed gull	0.38	3	1.1
red-billed gull	0.11	0	0
black-billed gull	0.11	0	0
caspian tern	0.35	0	0
		TOTAL (kg)	**1,226.8**
		TOTAL (tonnes)	**1.2268**

	kg/day	kg/annum
TOTAL KJELDAHL NITROGEN (x1.5)	1.84	671.60
TOTAL PHOSPHORUS (x0.54)	0.66	240.90

ψ corrected biomass is weight corrected for time on lake (Table 2(a) and (d))

LAKE: TIKITAPU

	Corrected bird biomass (kg) ψ	No. individuals	Total biomass (kg)
dabchick	0.23	0	0
black shag	1.1	0	0
little black shag	0.4	1	0.4
little shag	0.35	1	0.4
white-faced heron	0.28	1	0.3
black swan	4.95	0	0
canada goose	3.47	0	0
feral goose	2.1	0	0
paradise shelduck	0.62	0	0
mallard/grey	0.57	30	17.1
grey teal	0.24	0	0
shoveler	0.31	0	0
scaup	0.59	0	0
coot	0.49	0	0
pied stilt	0.08	0	0
black-backed gull	0.38	0	0
red-billed gull	0.11	0	0
black-billed gull	0.11	0	0
caspian tern	0.35	0	0
		TOTAL (kg)	**18.2**
		TOTAL (tonnes)	**0.0182**

	kg/day	kg/annum
TOTAL KJELDAHL NITROGEN (x1.5)	0.03	10.95
TOTAL PHOSPHORUS (x0.54)	0.009	3.29

ψ corrected biomass is weight corrected for time on lake
(Table 2(a) and (d))

LAKE: OKARO

	Corrected bird biomass (kg) ψ	No. individuals	Total biomass (kg)
dabchick	0.23	0	0
black shag	1.1	2	2.2
little black shag	0.4	1	0.4
little shag	0.35	3	1.1
white-faced heron	0.28	1	0.3
black swan	4.95	0	0
canada goose	3.47	0	0
feral goose	2.1	0	0
paradise shelduck	0.62	31	19.2
mallard/grey	0.57	62	35.3
grey teal	0.24	2	0.5
shoveler	0.31	0	0
scaup	0.59	0	0
coot	0.49	1	0.5
pied stilt	0.08	4	0.3
black-backed gull	0.38	2	0.8
red-billed gull	0.11	0	0
black-billed gull	0.11	1	0.1
caspian tern	0.35	0	0
		TOTAL (kg)	**60.7**
		TOTAL (tonnes)	**0.0607**

	kg/day	kg/annum
TOTAL KJELDAHL NITROGEN (x1.5)	0.09	32.85
TOTAL PHOSPHORUS (x0.54)	0.03	10.95

ψ corrected biomass is weight corrected for time on lake (Table 2(a) and (d))

Appendix 8.2.

Dry weight nutrient input

LAKE : ROTORUA

	CENSUS NO	EFFECTIVE NOω	INPUT PER BIRD PER DAY (g)		g/day		kg/annum	
			TN	TP	TN	TP	TN	TP
dabchick	24	21.6	0.20	0.89	4.32	19.22	1.58	7.02
black shag	140	70	0.89	3.87	62.3	270.90	22.74	98.88
little black shag	509	254.5	0.89	3.87	226.5	984.92	82.67	359.49
little shag	683	341.5	0.89	3.87	303.9	1,321.61	110.92	482.39
white-faced heron	6	3	0.97	2.64	2.91	7.92	1.06	2.89
black swan	1,483	1,334.7	1.57	0.49	2,095.5	654.00	764.86	238.71
canada goose	0	0	1.57	0.49	0	0	0	0
feral goose	0	0	1.57	0.49	0	0	0	0
paradise shelduck	76	30.4	1.57	0.49	47.73	14.89	17.42	5.43
mallard/grey	306	153	1.57	0.49	240.21	74.97	87.68	27.36
grey teal	9	4.5	1.57	0.49	7.07	2.21	2.58	0.81
shoveler	1	0.5	1.57	0.49	0.79	0.25	0.29	0.09
scaup	989	890.1	0.61	0.19	542.9	169.12	198.16	61.73
coot	0	0	0.28	0.09	0	0	0	0
pied stilt	34	13.6	0.20	0.89	2.72	12.10	0.99	4.42
black-backed gull	284	113.6	0.44	0.24	49.9	27.26	18.21	9.95
red-billed gull	1,836	734.4	0.44	0.24	323.1	176.26	117.93	64.33
black-billed gull	72	28.8	0.44	0.24	12.7	6.91	4.64	2.52
caspian tern	13	6.5	0.89	3.87	5.8	25.16	2.12	9.18
			TOTAL kg/annum				**1433.85**	**1375.20**

ω corrected for percentage time on lake – refer Table 2; Column d.

LAKE : TARAWERA

	CENSUS NO	EFFECTIVE NOω	INPUT PER BIRD PER DAY (g)		g/day		kg/annum	
			TN	TP	TN	TP	TN	TP
dabchick	52	46.8	0.20	0.89	9.4	41.7	3.43	15.22
black shag	12	6	0.89	3.87	5.3	23.2	1.93	8.47
little black shag	9	4.5	0.89	3.87	4.0	17.4	1.46	6.35
little shag	86	43	0.89	3.87	38.3	166.4	13.98	60.74
white-faced heron	24	12	0.97	2.64	11.6	31.7	4.23	11.57
black swan	193	173.7	1.57	0.49	272.7	85.1	99.54	31.06
canada goose	2	1.4	1.57	0.49	2.2	0.7	0.80	0.26
feral goose	45	31.5	1.57	0.49	49.5	15.4	18.07	5.62
paradise shelduck	3	1.2	1.57	0.49	1.88	0.59	0.69	0.21
mallard/grey	231	115.5	1.57	0.49	181.34	56.59	66.19	20.66
grey teal	0	0	1.57	0.49	0	0	0	0
shoveler	0	0	1.57	0.49	0	0	0	0
scaup	340	306	0.61	0.19	186.7	58.1	68.15	21.21
coot	86	77.4	0.28	0.09	21.7	6.9	7.92	2.52
pied stilt	0	0	0.20	0.89	0	0	0	0
black-backed gull	23	9.2	0.44	0.24	4.0	2.2	1.46	0.80
red-billed gull	0	0	0.44	0.24	0	0	0	0
black-billed gull	41	16.4	0.44	0.24	7.2	3.9	2.63	1.42
caspian tern	0	0	0.89	3.87	0	0	0	0
			TOTAL kg/annum				**290.48**	**186.11**

ω corrected for percentage time on lake – refer Table 2; Column d.

LAKE : ROTOITI

	CENSUS NO	EFFECTIVE NOω	INPUT PER BIRD PER DAY (g)		g/day		kg/annum	
			TN	TP	TN	TP	TN	TP
dabchick	221	198.9	0.20	0.89	39.78	177.02	14.52	64.61
black shag	6	3	0.89	3.87	2.67	11.61	0.97	4.24
little black shag	37	18.5	0.89	3.87	16.47	71.59	6.01	26.13
little shag	260	130	0.89	3.87	115.7	503.10	42.23	183.63
white-faced heron	11	5.5	0.97	2.64	5.34	14.52	1.95	5.29
black swan	1,026	923.4	1.57	0.49	1,449.74	452.47	529.16	165.15
canada goose	0	0	1.57	0.49	0	0	0	0
feral goose	0	0	1.57	0.49	0	0	0	0
paradise shelduck	15	6	1.57	0.49	4.32	1.32	1.58	0.48
mallard/grey	214	107	1.57	0.49	77.04	23.54	28.12	8.59
grey teal	0	0	1.57	0.49	0	0	0	0
shoveler	0	0	1.57	0.49	0	0	0	0
scaup	1,073	965.7	0.61	0.19	589.08	183.48	215.01	66.97
coot	170	153	0.28	0.09	42.84	13.77	15.64	5.03
pied stilt	5	2	0.20	0.89	1.94	5.28	0.71	1.93
black-backed gull	9	3.6	0.44	0.24	1.58	0.86	0.58	0.31
red-billed gull	318	127.2	0.44	0.24	55.96	30.53	20.43	11.14
black-billed gull	61	24.4	0.44	0.24	10.74	5.86	3.92	2.14
caspian tern	0	0	0.89	3.87	0	0	0	0
			TOTAL kg/annum				**880.83**	**545.64**

ω corrected for percentage time on lake – refer Table 2; Column d.

LAKE : OKATAINA

	CENSUS NO	EFFECTIVE NO*	INPUT PER BIRD PER DAY (g)		g/day		kg/annum	
			TN	TP	TN	TP	TN	TP
dabchick	2	1.8	0.20	0.89	0.36	1.60	0.13	0.58
black shag	2	1	0.89	3.87	0.89	3.87	0.32	1.41
little black shag	1	0.5	0.89	3.87	0.45	1.94	0.16	0.71
little shag	35	17.5	0.89	3.87	15.58	67.73	5.69	24.72
white-faced heron	12	6	0.97	2.64	5.82	15.84	2.12	5.78
black swan	23	20.7	1.57	0.49	32.49	10.14	11.86	3.7
canada goose	0	0	1.57	0.49	0	0	0	0
feral goose	0	0	1.57	0.49	0	0	0	0
paradise shelduck	0	0	1.57	0.49	0	0	0	0
mallard/grey	33	16.5	1.57	0.49	11.88	3.63	4.34	1.32
grey teal	0	0	1.57	0.49	0	0	0	0
shoveler	0	0	1.57	0.49	0	0	0	0
scaup	110	99	0.61	0.19	60.39	18.81	22.04	6.87
coot	0	0	0.28	0.09	0	0	0	0
pied stilt	0	0	0.20	0.89	0	0	0	0
black-backed gull	12	4.8	0.44	0.24	2.11	1.15	0.77	0.42
red-billed gull	0	0	0.44	0.24	0	0	0	0
black-billed gull	0	0	0.44	0.24	0	0	0	0
caspian tern	0	0	0.89	3.87	0	0	0	0
			TOTAL kg/annum				**47.43**	**45.41**

ω corrected for percentage time on lake – refer Table 2; Column d.

LAKE : ROTOMAHANA

	CENSUS NO	EFFECTIVE NOω	INPUT PER BIRD PER DAY (g)		g/day		kg/annum	
			TN	TP	TN	TP	TN	TP
dabchick	3	2.7	0.20	0.89	0.54	2.40	0.19	0.88
black shag	1	0.5	0.89	3.87	0.45	1.94	0.16	0.71
little black shag	48	24	0.89	3.87	21.36	92.88	7.79	33.9
little shag	57	28.5	0.89	3.87	25.37	110.29	9.26	40.26
white-faced heron	20	10	0.97	2.64	9.70	26.4	3.54	9.64
black swan	228	205.2	1.57	0.49	322.16	100.55	117.59	36.7
canada goose	22	15.4	1.57	0.49	24.18	7.55	8.83	2.76
feral goose	130	91.0	1.57	0.49	142.87	44.59	52.15	16.28
paradise shelduck	690	276	1.57	0.49	198.72	60.72	72.53	22.16
mallard/grey	822	411	1.57	0.49	295.92	90.42	108.01	33.00
grey teal	21	10.5	1.57	0.49	7.56	2.31	2.76	0.84
shoveler	35	17.5	1.57	0.49	12.6	3.85	4.59	1.41
scaup	210	189	0.61	0.19	115.29	35.91	42.08	13.11
coot	16	14.4	0.28	0.09	4.03	1.29	1.47	0.47
pied stilt	25	10	0.20	0.89	9.7	26.4	3.54	9.64
black-backed gull	216	86.4	0.44	0.24	38.02	20.74	13.88	7.57
red-billed gull	5	2	0.44	0.24	0.88	0.48	0.32	0.18
black-billed gull	82	32.8	0.44	0.24	14.43	7.87	5.27	2.87
caspian tern	0	0	0.89	3.87	0	0	0	0
			TOTAL kg/annum				**453.96**	**232.38**

ω corrected for percentage time on lake – refer Table 2; Column d.

LAKE : ROTOMA

	CENSUS NO	EFFECTIVE NOω	INPUT PER BIRD PER DAY (g)		g/day		kg/annum	
			TN	TP	TN	TP	TN	TP
dabchick	13	11.7	0.20	0.89	2.34	10.41	0.85	3.79
black shag	0	0	0.89	3.87	0	0	0	0
little black shag	10	5	0.89	3.87	4.45	19.35	1.62	7.06
little shag	25	12.5	0.89	3.87	11.13	48.38	4.06	17.66
white-faced heron	3	1.5	0.97	2.64	1.46	3.96	0.53	1.45
black swan	2	2.2	1.57	0.49	3.45	1.08	1.26	0.39
canada goose	120	84	1.57	0.49	131.88	41.16	48.14	15.02
feral goose	0	0	1.57	0.49	0	0	0	0
paradise shelduck	125	50	1.57	0.49	78.5	24.50	28.65	8.94
mallard/grey	15	7.5	1.57	0.49	11.78	3.68	4.29	1.34
grey teal	0	0	1.57	0.49	0	0	0	0
shoveler	0	0	1.57	0.49	0	0	0	0
scaup	83	74.7	0.61	0.19	45.57	14.19	16.63	5.18
coot	2	1.8	0.28	0.09	0.50	0.16	0.18	0.06
pied stilt	12	4.8	0.20	0.89	0.96	4.27	0.35	1.56
black-backed gull	11	4.4	0.44	0.24	1.94	1.06	0.71	0.39
red-billed gull	0	0	0.44	0.24	0	0	0	0
black-billed gull	0	0	0.44	0.24	0	0	0	0
caspian tern	0	0	0.89	3.87	0	0	0	0
			TOTAL kg/annum				**107.27**	**62.84**

ω corrected for percentage time on lake – refer Table 2; Column d.

LAKE : ROTOEHU

	CENSUS NO	EFFECTIVE NOω	INPUT PER BIRD PER DAY (g)		g/day		kg/annum	
			TN	TP	TN	TP	TN	TP
dabchick	11	9.9	0.20	0.89	1.98	8.81	0.72	3.22
black shag	13	6.5	0.89	3.87	5.79	25.16	2.11	9.18
little black shag	188	94	0.89	3.87	83.66	363.78	30.54	132.78
little shag	166	83	0.89	3.87	73.87	321.21	26.96	117.24
white-faced heron	46	23	0.97	2.64	22.31	60.72	8.14	22.16
black swan	1,182	1,063.8	1.57	0.49	1,670.17	521.26	609.61	190.26
canada goose	124	86.8	1.57	0.49	136.28	42.53	49.74	15.52
feral goose	0	0	1.57	0.49	0	0	0	0
paradise shelduck	2,822	1,128.8	1.57	0.49	1,772.22	553.11	646.86	201.89
mallard/grey	526	263	1.57	0.49	412.91	128.87	150.71	47.04
grey teal	31	15.5	1.57	0.49	24.34	7.59	8.88	2.77
shoveler	0	0	1.57	0.49	0	0	0	0
scaup	28	25.2	0.61	0.19	15.37	4.79	5.61	1.75
coot	17	15.3	0.28	0.09	4.28	1.38	1.56	0.50
pied stilt	118	47.2	0.20	0.89	9.44	42.01	3.45	15.33
black-backed gull	3	1.2	0.44	0.24	0.53	0.29	0.19	0.11
red-billed gull	0	0	0.44	0.24	0	0	0	0
black-billed gull	454	181.6	0.44	0.24	79.9	43.58	29.16	15.91
caspian tern	0	0	0.89	3.87	0	0	0	0
			TOTAL kg/annum				**1,574.24**	**775.66**

ω corrected for percentage time on lake – refer Table 2; Column d.

LAKE : REREWHAKAAITU

	CENSUS NO	EFFECTIVE NOω	INPUT PER BIRD PER DAY (g)		g/day		kg/annum	
			TN	TP	TN	TP	TN	TP
dabchick	9	8.1	0.20	0.89	1.62	7.21	0.59	2.63
black shag	9	4.5	0.89	3.87	4.01	17.42	1.46	6.36
little black shag	28	14	0.89	3.87	12.46	54.18	4.55	19.78
little shag	53	26.5	0.89	3.87	23.59	102.56	8.61	32.43
white-faced heron	26	13	0.97	2.64	12.61	34.32	4.60	12.53
black swan	73	65.7	1.57	0.49	103.15	32.19	37.65	11.75
canada goose	159	111.3	1.57	0.49	174.74	54.54	63.78	19.91
feral goose	0	0	1.57	0.49	0	0	0	0
paradise shelduck	74	29.6	1.57	0.49	46.47	14.50	16.96	5.29
mallard/grey	164	82	1.57	0.49	128.74	40.18	46.99	14.67
grey teal	97	48.5	1.57	0.49	76.15	23.77	27.79	8.68
shoveler	9	4.5	1.57	0.49	7.07	2.21	2.58	0.81
scaup	138	124.2	0.61	0.19	75.76	23.59	27.65	8.61
coot	0	0	0.28	0.09	0	0	0	0
pied stilt	192	76.8	0.20	0.89	15.36	68.35	5.61	24.95
black-backed gull	55	22	0.44	0.24	9.68	5.28	3.53	1.93
red-billed gull	0	0	0.44	0.24	0	0	0	0
black-billed gull	2	0.8	0.44	0.24	0.35	0.19	0.13	0.07
caspian tern	0	0	0.89	3.87	0	0	0	0
			TOTAL kg/annum				**252.48**	**175.40**

ω corrected for percentage time on lake – refer Table 2; Column d.

LAKE : ROTOKAKAHI

	CENSUS NO	EFFECTIVE NOω	INPUT PER BIRD PER DAY (g)		g/day		kg/annum	
			TN	TP	TN	TP	TN	TP
dabchick	6	5.4	0.20	0.89	1.08	4.81	0.39	1.76
black shag	1	0.5	0.89	3.87	0.45	1.94	0.16	0.71
little black shag	6	3	0.89	3.87	2.67	11.61	0.97	4.24
little shag	34	17	0.89	3.87	15.13	65.79	5.52	24.01
white-faced heron	1	0.5	0.97	2.64	0.49	1.32	0.18	0.48
black swan	29	26.1	1.57	0.49	40.98	12.79	14.96	4.67
canada goose	0	0	1.57	0.49	0	0	0	0
feral goose	0	0	1.57	0.49	0	0	0	0
paradise shelduck	150	60	1.57	0.49	94.20	29.40	34.38	10.73
mallard/grey	61	30.5	1.57	0.49	47.89	14.95	17.48	5.46
grey teal	8	4	1.57	0.49	6.28	1.96	2.29	0.72
shoveler	0	0	1.57	0.49	0	0	0	0
scaup	17	15.3	0.61	0.19	9.33	2.91	3.41	1.06
coot	8	7.2	0.28	0.09	2.02	0.65	0.74	0.24
pied stilt	0	0	0.20	0.89	0	0	0	0
black-backed gull	6	2.4	0.44	0.24	1.06	0.58	0.39	0.21
red-billed gull	0	0	0.44	0.24	0	0	0	0
black-billed gull	1	0.4	0.44	0.24	0.18	0.09	0.07	0.03
caspian tern	0	0	0.89	3.87	0	0	0	0
			TOTAL kg/annum				**80.94**	**54.32**

ω corrected for percentage time on lake – refer Table 2; Column d.

LAKE : OKAREKA

	CENSUS NO	EFFECTIVE NOω	INPUT PER BIRD PER DAY (g)		g/day		kg/annum	
			TN	TP	TN	TP	TN	TP
dabchick	46	41.4	0.20	0.89	8.28	36.85	3.02	13.45
black shag	4	2	0.89	3.87	1.78	7.74	0.65	2.83
little black shag	1	0.5	0.89	3.87	0.45	1.94	0.16	0.71
little shag	20	10	0.89	3.87	8.90	38.70	3.25	14.13
white-faced heron	0	0	0.97	2.64	0	0	0	0
black swan	204	183.6	1.57	0.49	288.25	89.96	105.21	32.84
canada goose	0	0	1.57	0.49	0	0	0	0
feral goose	0	0	1.57	0.49	0	0	0	0
paradise shelduck	4	1.6	1.57	0.49	2.51	0.78	0.92	0.28
mallard/grey	113	56.5	1.57	0.49	88.71	27.69	32.38	10.11
grey teal	0	0	1.57	0.49	0	0	0	0
shoveler	0	0	1.57	0.49	0	0	0	0
scaup	167	150.3	0.61	0.19	91.68	28.56	33.46	10.42
coot	56	50.4	0.28	0.09	14.11	4.54	5.15	1.66
pied stilt	9	3.6	0.20	0.89	0.72	3.20	0.26	1.17
black-backed gull	3	1.2	0.44	0.24	0.53	0.29	0.19	0.11
red-billed gull	0	0	0.44	0.24	0	0	0	0
black-billed gull	0	0	0.44	0.24	0	0	0	0
caspian tern	0	0	0.89	3.87	0	0	0	0
			TOTAL kg/annum				**184.65**	**87.71**

ω corrected for percentage time on lake – refer Table 2; Column d.

LAKE : TIKITAPU

	CENSUS NO	EFFECTIVE NOω	INPUT PER BIRD PER DAY (g)		g/day		kg/annum	
			TN	TP	TN	TP	TN	TP
dabchick	0	0	0.20	0.89	0	0	0	0
black shag	0	0	0.89	3.87	0	0	0	0
little black shag	1	0.5	0.89	3.87	0.45	1.94	0.16	0.71
little shag	1	0.5	0.89	3.87	0.45	1.94	0.16	0.71
white-faced heron	1	0.5	0.97	2.64	0.49	1.32	0.18	0.48
black swan	0	0	1.57	0.49	0	0	0	0
canada goose	0	0	1.57	0.49	0	0	0	0
feral goose	0	0	1.57	0.49	0	0	0	0
paradise shelduck	0	0	1.57	0.49	0	0	0	0
mallard/grey	30	19	1.57	0.49	29.83	9.31	10.89	3.39
grey teal	0	0	1.57	0.49	0	0	0	0
shoveler	0	0	1.57	0.49	0	0	0	0
scaup	0	0	0.61	0.19	0	0	0	0
coot	0	0	0.28	0.09	0	0	0	0
pied stilt	0	0	0.20	0.89	0	0	0	0
black-backed gull	0	0	0.44	0.24	0	0	0	0
red-billed gull	0	0	0.44	0.24	0	0	0	0
black-billed gull	0	0	0.44	0.24	0	0	0	0
caspian tern	0	0	0.89	3.87	0	0	0	0
			TOTAL kg/annum				**11.39**	**5.29**

ω corrected for percentage time on lake – refer Table 2; Column d.

LAKE : OKARO

	CENSUS NO	EFFECTIVE NOω	INPUT PER BIRD PER DAY (g)		g/day		kg/annum	
			TN	TP	TN	TP	TN	TP
dabchick	0	0	0.20	0.89	0	0	0	0
black shag	2	1	0.89	3.87	0.89	3.87	0.32	1.41
little black shag	1	0.5	0.89	3.87	0.45	1.94	0.16	0.71
little shag	3	1.5	0.89	3.87	1.34	5.81	0.49	2.12
white-faced heron	1	0.5	0.97	2.64	0.49	1.32	0.18	0.48
black swan	0	0	1.57	0.49	0	0	0	0
canada goose	0	0	1.57	0.49	0	0	0	0
feral goose	0	0	1.57	0.49	0	0	0	0
paradise shelduck	31	12.4	1.57	0.49	19.47	6.08	7.11	2.22
mallard/grey	62	31	1.57	0.49	48.67	15.19	17.76	5.54
grey teal	2	1	1.57	0.49	1.57	0.49	0.57	0.18
shoveler	0	0	1.57	0.49	0	0	0	0
scaup	0	0	0.61	0.19	0	0	0	0
coot	1	0.9	0.28	0.09	0.25	0.08	0.09	0.03
pied stilt	4	1.6	0.20	0.89	0.32	1.42	0.12	0.52
black-backed gull	2	0.8	0.44	0.24	0.35	0.19	0.13	0.07
red-billed gull	0	0	0.44	0.24	0	0	0	0
black-billed gull	1	0.4	0.44	0.24	0.18	0.09	0.07	0.03
caspian tern	0	0	0.89	3.87	0	0	0	0
			TOTAL kg/annum				**27.00**	**13.31**

ω corrected for percentage time on lake – refer Table 2; Column d.

Appendix 8.3.

Lake nutrient budgets

LAKE: ROTORUA

Source	NUTRIENT INPUTS			
	NITROGEN		PHOSPHORUS	
	Tonnes per year	%	Tonnes per year	%
Pasture	253.00	53.3	35.40	52.8
Native forest	45.00	9.5	1.46	2.2
Exotic forest	4.40	0.9	0.32	0.5
Urban	64.76	13.6	14.83	22.1
Septic tanks	12.01	2.5	0.53	0.8
Ground water	-	-	-	-
Precipitation	18.9	4.0	1.90	2.8
Springs	45.0	9.5	8.2	12.2
Wastewater	30.0	6.3	3.0	4.5
Lake sediment	-	-	-	-
Wildfowl	1.43	0.3	1.37	2.0
TOTAL	**474.5**		**67.01**	

LAKE: TARAWERA

Source	NUTRIENT INPUTS			
	NITROGEN		PHOSPHORUS	
	Tonnes per year	%	Tonnes per year	%
Pasture	21.62	33.6	3.02	54.6
Native forest	28.15	43.7	0.92	16.6
Exotic forest	1.73	2.7	0.12	2.2
Urban	1.11	1.7	0.23	4.2
Septic tanks	1.80	2.8	0.08	1.4
Ground water	-	-	-	-
Precipitation	9.73	15.1	0.97	17.5
Lake sediment	-	-	-	-
Wildfowl	0.29	0.4	0.19	3.4
TOTAL	**64.43**		**5.53**	

LAKE: ROTOITI

Source	NUTRIENT INPUTS			
	NITROGEN		PHOSPHORUS	
	Tonnes per year	%	Tonnes per year	%
Pasture	47.1	11.3	6.5	21.0
Native forest	9.4	2.3	0.06	0.2
Exotic forest	2.5	0.6	0.23	0.7
Urban	4.4	1.1	0.9	2.9
Septic tanks	8.4	2.0	0.3	1.0
Ground water	0.01	-	-	-
Precipitation	10.0	2.4	1.34	4.3
Springs	41.6	10.0	0.13	0.4
Ohau Channel	291.0	70.1	21.0	67.8
Sediment	-	-	-	-
Wildfowl	0.9	0.2	0.5	1.6
TOTAL	**415.31**		**30.96**	

LAKE: OKATAINA

Source	NUTRIENT INPUTS			
	NITROGEN		PHOSPHORUS	
	Tonnes per year	%	Tonnes per year	%
Pasture	2.69	11.9	0.38	29.0
Native forest	16.60	73.1	0.54	41.2
Exotic forest	0.70	3.1	0.05	3.8
Urban	0	0	0	0
Septic tanks	0.03	0.1	-	-
Ground water	-	-	-	-
Precipitation	2.56	11.3	0.26	19.8
Sediment	-	-	-	-
Wildfowl	0.12	0.5	0.08	6.1
TOTAL	**22.7**		**1.31**	

LAKE: ROTOMAHANA

Source	NUTRIENT INPUTS			
	NITROGEN		PHOSPHORUS	
	Tonnes per year	%	Tonnes per year	%
Pasture	44.04	74.6	6.15	87.3
Native forest	10.92	18.5	0.36	5.1
Exotic forest	1.20	2.0	0.09	1.3
Urban	0	0	0	0
Septic tanks	0.52	0.9	0.02	0.3
Ground water	-	-	-	-
Precipitation	1.89	3.2	0.19	2.7
Sediment	-	-	-	-
Wildfowl	0.45	0.8	0.23	3.3
TOTAL	**59.02**		**7.04**	

LAKE: ROTOMA

Source	NUTRIENT INPUTS			
	NITROGEN		PHOSPHORUS	
	Tonnes per year	%	Tonnes per year	%
Pasture	10.4	53.6	1.4	68.6
Native forest	3.3	17.0	0.1	4.9
Exotic forest	0.6	3.1	0.04	2.0
Urban	0.6	3.1	0.1	4.9
Septic tanks	1.8	9.3	0.08	3.9
Ground water	-	-	-	-
Precipitation	2.6	13.4	0.26	12.7
Sediment	0	0	0	0
Wildfowl	0.1	0.5	0.06	2.9
TOTAL	**19.4**		**2.04**	

LAKE: ROTOEHU

Source	NUTRIENT INPUTS			
	NITROGEN		PHOSPHORUS	
	Tonnes per year	%	Tonnes per year	%
Pasture	22.0	61.1	3.0	59.5
Native forest	5.1	14.2	0.2	4.0
Exotic forest	0.4	1.1	0.03	0.6
Urban	0	0	0	0
Septic tanks	0.3	0.8	0.01	0.2
Ground water	-	-	-	-
Precipitation	1.9	5.3	0.2	4.0
Springs	4.7	13.0	0.8	15.9
Sediment	-	-	-	-
Wildfowl	1.6	4.4	0.8	15.9
TOTAL	**36.0**		**5.04**	

LAKE: REREWHAKAAITU

Source	NUTRIENT INPUTS			
	NITROGEN		PHOSPHORUS	
	Tonnes per year	%	Tonnes per year	%
Pasture	26.68	80.6	3.73	86.9
Native forest	1.15	3.5	0.04	0.9
Exotic forest	1.00	3.0	0.07	1.6
Urban	0	0	0	0
Septic tanks	2.25	6.8	0.1	2.3
Ground water	-	-	-	-
Precipitation	1.77	5.3	0.18	4.2
Sediment	-	-	-	-
Wildfowl	0.25	0.7	0.17	4.0
TOTAL	**33.1**		**4.29**	

LAKE ROTOKAKAHI

Source	NUTRIENT INPUTS			
	NITROGEN		PHOSPHORUS	
	Tonnes per year	%	Tonnes per year	%
Pasture	2.34	40.3	0.33	55.0
Native forest	1.36	23.4	0.04	6.7
Exotic forest	0.96	16.5	0.07	11.7
Urban	0	0	0	0
Septic tanks	0	0	0	0
Ground water	-	-	-	-
Precipitation	1.06	18.3	0.11	18.3
Sediment	-	-	-	-
Wildfowl	0.08	1.4	0.05	8.3
TOTAL	**5.80**		**0.60**	

LAKE: OKAREKA

Source	NUTRIENT INPUTS			
	NITROGEN		PHOSPHORUS	
	Tonnes per year	%	Tonnes per year	%
Pasture	9.3	60.4	1.3	74.3
Native forest	2.1	13.6	0.07	4.0
Exotic forest	0	0	0	0
Urban	0.5	3.2	0.1	5.7
Septic tanks	2.5	16.2	0.11	6.3
Ground water	-	-	-	-
Precipitation	0.82	5.3	0.08	4.6
Sediment	-	-	-	-
Wildfowl	0.18	1.2	0.09	5.1
TOTAL	**15.4**		**1.75**	

LAKE: TIKITAPU

Source	NUTRIENT INPUTS			
	NITROGEN		PHOSPHORUS	
	Tonnes per year	%	Tonnes per year	%
Pasture	0.42	15.8	0.06	38.7
Native forest	1.77	66.5	0.06	38.7
Exotic forest	0.10	3.7	-	-
Urban	0	0	0	0
Septic tanks	0.03	1.1	-	-
Ground water	-	-	-	-
Precipitation	0.33	12.4	0.03	19.3
Sediment	-	-	-	-
Wildfowl	0.01	0.4	0.005	3.2
TOTAL	**2.66**		**0.155**	

LAKE: OKARO

Source	NUTRIENT INPUTS			
	NITROGEN		PHOSPHORUS	
	Tonnes per year	%	Tonnes per year	%
Pasture	3.59	93.5	0.50	96.1
Native forest	0.09	2.3	-	-
Exotic forest	0	0	0	0
Urban	0	0	0	0
Septic tanks	0.05	1.3	-	-
Ground water	-	-	-	-
Precipitation	0.08	2.1	0.01	1.9
Sediment	-		-	-
Wildfowl	0.03	0.8	0.01	1.9
TOTAL	**3.84**		**0.52**	