Can management regime, vegetative, and morphological characteristics of drains in the Bay of Plenty explain the presence of mallards and their broods?

2 August 2018

MATTHEW MCDOUGALL[1],

BRIGITTA NIEUWBOER[2]

ANDY GARRICK[1]

1. Fish and Game New Zealand, Eastern Region, Private Bag 3010, Rotorua 3046
   mmcdougall@fishandgame.org.nz
2. 551 Hamurana Road, Rotorua

EXECUTIVE SUMMARY

Drainage networks in the Bay of Plenty (BOP) have been instrumental in the loss of over 98% of wetlands. These drains have now become important habitat for what remains of local waterfowl populations. Regional Councils have obligations under the RMA to manage natural habitat sustainably, and this includes drains. Given the paucity of wetland habitat we sought to establish if maintenance, management, and construction of drains could be approached in a way that enhances their habitat values for local and regional mallard populations. We conducted a randomised survey of mallard brood use of BOP drains during the 2015 breeding season. We used general linear models to investigate the association between mallard broods and drain morphology, associated vegetation, and maintenance practices. We modelled the average number of ducks (mallards not directly associated with broods), Class Ia (1–7 days old), and Class III (43–55 days old) against 58 drain characteristics (morphological, vegetative, and maintenance practices). We found that drain width explained the presence of ducks and broods better than any other factor while presence of floating vegetation in the drain, extent of grass cover on the banks, the presence of a small number of overhanging trees and shrubs, and no recent drain maintenance activity having been undertaken were all important in explaining the number of mallards and broods observed in the drains. Some characteristics such as bank profile which we suspected might play a role were similar amongst all drains so provided no insight to their importance. We recommend that drain maintenance be avoided during the breeding season wherever possible, that grass cover be retained on the banks of the drains, and that small copses of trees be planted at intervals along the drain margins. Where an option, construction of wider rather than narrower drains is also desirable.

1. Introduction

In the quest to develop agriculture and horticulture land most (>98%) of the wetlands in the Rangitaiki Plain, Bay of Plenty, have been drained (Irving and Beadel 1992). In addition, many natural rivers and streams have been straightened, channelized and in some instances, are now treated as floodways. There is increasing recognition that drains have ecological and environmental values (Hudson and Harding 2004), and that Regional Councils have obligations under the Resource Management Act 1990 (RMA) to sustainably manage all natural[1] habitats including drains (Schwarz and Snelder 1999, Hudson and Harding 2004).

Drains have become increasingly important for a variety of species following the loss of wetlands. For example, where preferred wetland habitat is scarce, or no longer present, species such as mudfish (*Neochana sp.*) seek refuge in drains (McDowall 1990) as do other native fish (Hudson and Harding 2004). Drains have also become important breeding habitat for game birds such as mallard (*Anas platyrhynchos*) and grey duck (*A. superciliosa*) (Sheppard 2017). Management of drains can have an impact on invertebrates (Hudson and Harding 2004) which are an important food source for waterfowl (Krapu and Reinecke 1992) and fish (McDowall 1990).

[1] Natural includes land, water, air, soil, minerals, and energy, all forms of plants and animals (whether native to New Zealand or introduced), and all structures.

Mallard make up the largest component of the hunter's bag in New Zealand (Fish & Game unpub. data) and are a key species for the c.3,500 hunters that hunt in the Eastern Fish and Game Region (which includes the Bay of Plenty). Mallard populations appear most sensitive to reproductive success (Hoekman et al. 2002, Sheppard 2017). A small increase in duckling survival may be the difference between the mallard population increasing and decreasing (Sheppard 2017). This being so, Fish & Game is keen to understand what ecological factors may affect duckling survival and habitat selection of breeding hens.

Eastern Region Fish & Game staff have conducted annual October counts of broods in ten drains within the Bay of Plenty for the last ten years and observed that some drains consistently hold more mallard and mallard broods than others (Fish & Game unpub. data). A previous Fish & Game study of drain management in the Bay of Plenty and Hawke's Bay concluded that waterfowl production (broods produced ha^{-1}) was significantly higher in unmanaged drains cf. managed drains (Maxwell 2006). Maxwell (2006) found lower numbers of broods in drains where there was mowing of berms and weed cutting.

We wish to know if there are other morphological characters, or vegetation associations, or management activities[2] influencing how many ducks/broods use the drains. This information would enable Fish & Game to advocate for management and maintenance regimes that enhance habitat for ducks, particularly brood rearing areas, while not compromising their primary purpose of draining surrounding farmland. In the case of drains managed by the Bay of Plenty Regional Council it would also mean that the Council could go some way towards meeting its obligations under the RMA to manage natural habitat sustainably, and comply with its Environmental Code of Practice (Crabbe 2001). Furthermore, a review of what drains and how they are managed might also result in cost savings to drain managers (Schwarz and Snelder 1999). Schwarz and Snelder (1999) suggest 70% of the Christchurch drainage network would benefit from less aquatic vegetation clearance and this would result in cost savings to the Council.

In this preliminary study we examined the relationship between morphological and vegetative characteristics and the presence of mallard duck and their broods in the Bay of Plenty. Between 27/8/15 – 24/9/15 Fish & Game conducted a survey of 81 randomly selected drains. Drain morphological and vegetative characteristics were measured and the number of ducks and their broods were recorded on up to 10 subsequent occasions.

2. Methods

2.1 Study Area

Drains in the Bay of Plenty (Lat-Long, -37 47 30.74,176 28 07.20; Figure 1) were mapped using GIS (ArcMap 10) and divided into 200m segments. One hundred of these segments were randomly selected and visited, and where possible (access was difficult at some sites so

[2] Bay of Plenty Regional Council and Waihi Drainage Board manage drains to expedite the removal of water from surrounding farmland. A number of management activities are undertaken to reduce hydraulic impedance (i.e. get the water away quicker), including spraying herbicide on the banks, aquatic weed clearance with a digger or weed cutter boat. Further, bank vegetation is often cleared to allow diggers better access to the drain. Some farmers also use the riparian strip as an additional paddock or they are mowed for hay.

were dropped leaving a sample of 81) morphological and vegetative characteristics were recorded.

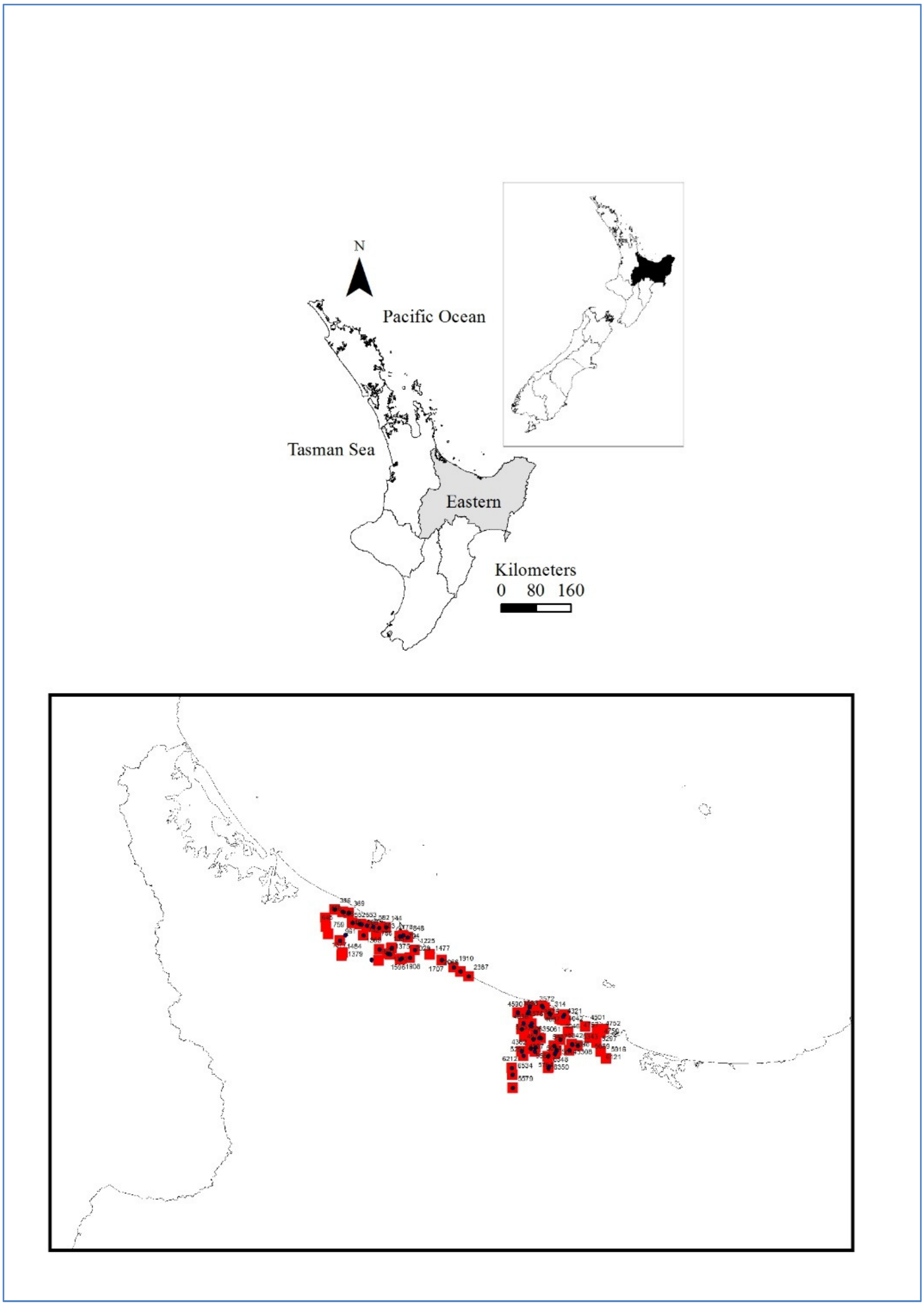

Figure 1. Bay of Plenty random drain sites (81). Mallard and brood counts and drain morphological and vegetative characteristics were recorded 100m either side of the random points.

2.2 Morphological and vegetative characteristics

A 200m section of the drain (100m either side of the random point) was divided into 10 evenly spaced transects perpendicular to the drain. Drain morphological and vegetative characteristics (Table 1) were recorded at each transect and for both banks (57 characteristics). The transect characteristics were then averaged for each site (40 characteristics, except for trees which were summed.

Table 1. Drain characteristics, index description and hypothesis (+β = the mallard index increases with the variable; - β = mallard index decreases with the variable; E= exploratory variable, we were unsure how mallard numbers would respond to this variable).

Index	Description	Units	Hypothesis (β)
Bank_Batter	Bank Batter	degrees	- β
Berm_Height	Berm Height	m	+ β
Blackberry	Blackberry	%	+ β
Bottom_cover	Bottom cover (macrophytes)	%	+ β
Bridges	Bridges	count	+ β
Buildings	Buildings	distance	- β
Connecting_waterways	Connecting waterways	count	+ β
Culverts	Culverts	count	+ β
Digger	Digger	presence/ absence	- β
Dist_to_road	Distance to road	m	+ β
Drain_depth	Drain depth (1<d<1)	m	E
Drain_shape	Drain shape (U or V)	U=0, V=1	+ β
Drain_Width	Drain Width	m	+ β
Emergent_Veg	Emergent vegetation	%	+ β
Fine_leaf	Fine leaf macrophytes (e.g. *Myriophyllum*)	%	+ β
Floating_veg	Floating vegetation	%	+ β
Flow_rate	Flow rate	m/sec	- β
Forbs	Forbs	%	E
Glyceria	*Glyceria*	%	- β
Gorse	Gorse	%	E
Grass	Grass	%	+ β
Loafing	Loafing sites	count	+ β
Mid_size	Mid-size macrophytes (e.g *Potamogeton*)	%	+ β
Mowed	Mowed	Not/one bank/both banks	- β
Percentage_no_macrophytes visible	Aquatic macrophytes visible from the bank	%	+ β
Raupo	Raupo	%	+ β

Riparian_width	Riparian width	m	+ β
Sedge	Sedge	%	+ β
Small_leaf	Small leaf macrophytes (e.g. *Egeria*)	%	+ β
Sprayed	Sprayed	Not/one bank/both banks	- β
Stock_access	Stock access to drain	High-None (High, Moderate, Low, None)	- β
Surrounding_landuse[(a)]			
Toetoe.Pampas	Toetoe/Pampas	%	- β
Tree_overhang_L1_andG1 above_water	Tree overhang <1m out into drain and > 1m above water	count	+ β
Tree_overhangG1and_G1above_water	Tree overhang >1m out into drain and >1m above water	count	+ β
Tree_overhangG1and_L1above_water	Tree overhang >1m out into drain and <1m above water	count	+ β
Trees_overhangL1m_andL1m_above water	Tree overhang <1m out into drain and <1m above water	count	+ β
Trees_G5	Trees >5m high	count	+ β
Trees_L5	Trees <5m high	count	+ β
Trees_shrubs	Trees & shrubs	count	+ β
Unmanaged	No obvious signs of management	One bank/ both banks	+ β
Weed_cutter	Weed cutter boat	Presence/ absence	- β

(a): we recorded surrounding land use but decided not to include it in the final analysis.

2.3 Count surveys

Following the recording of characteristics each random site was visited 6 – 10 times (except one dry, grass, flood diversion structure which was counted twice) to count ducks. Mallards were variously recorded as broods (number and class), waiting males, hens, hens with broods, and ducks (i.e. not associated with a brood). Broods were classified on size and feather development (7 stages; Ia=recently hatched all down, Ib, Ic, IIa, IIb, IIc, III=fledging; Gollop and Marshall 1954).

Other factors were also recorded such as date and time, weather, predators observed, and any disturbance (e.g. whitebaiters, diggers).

2.4 Analysis

The data was standardised in Program R (R Development Core Team 2005). We used Principal Component Analysis[3] to examine drain characteristics. Program R (3.4.1) package MuMIn (Bartoń 2013), FactoMinR (Lê et al. 2008) and ggbiplot (Vu 2011) were used to analyse and graph the data respectively. We created GLM's (family= Gaussian; link= Identity) in package Rcmdr (Fox et al. 2009) where the response variable was either the average number of ducks (mallards not obviously associated with a brood), or class Ia, or class III ducklings.

We used "dredge" (package MuMIn; Program R) on the global model (most parameterised) to run all permutations of this model and ranked them on their AICc (Burnham and Anderson 2002) where the lowest AICc has the greatest support[4]. Models are reported where delta AICc ≤2 (the difference between the top model and models with less support).

3. Results

3.1 Characteristics

A high proportion of the drains were quite similar. The first two principal components only explained 18% of the cumulative variance in the drain characteristics and it took 25 of the 43 dimensions to explain 90% of the cumulative data variance (Figure 2).

[3] Principal component analysis (PCA) fits perpendicular lines to the data along the axes that have the greatest variability in the data. For example PCA is used to differentiate species of animal where bone measurements of different body parts are known. Some bones will vary more markedly between species and these bones will be the best ones to use to differentiate the species (they will also be the principal or main axes). PCA was used to compare drains with ducks vs. drains without ducks. In the graphs all the components fit in a circle with a radius of 1 so the longer the arrow the better the correlation with the principal component.

[4] AICc is a function of the model likelihood and the number of parameters – the greater the likelihood the better the support however this support is devalued by the number of parameters – so the more parameters the poorer the support.

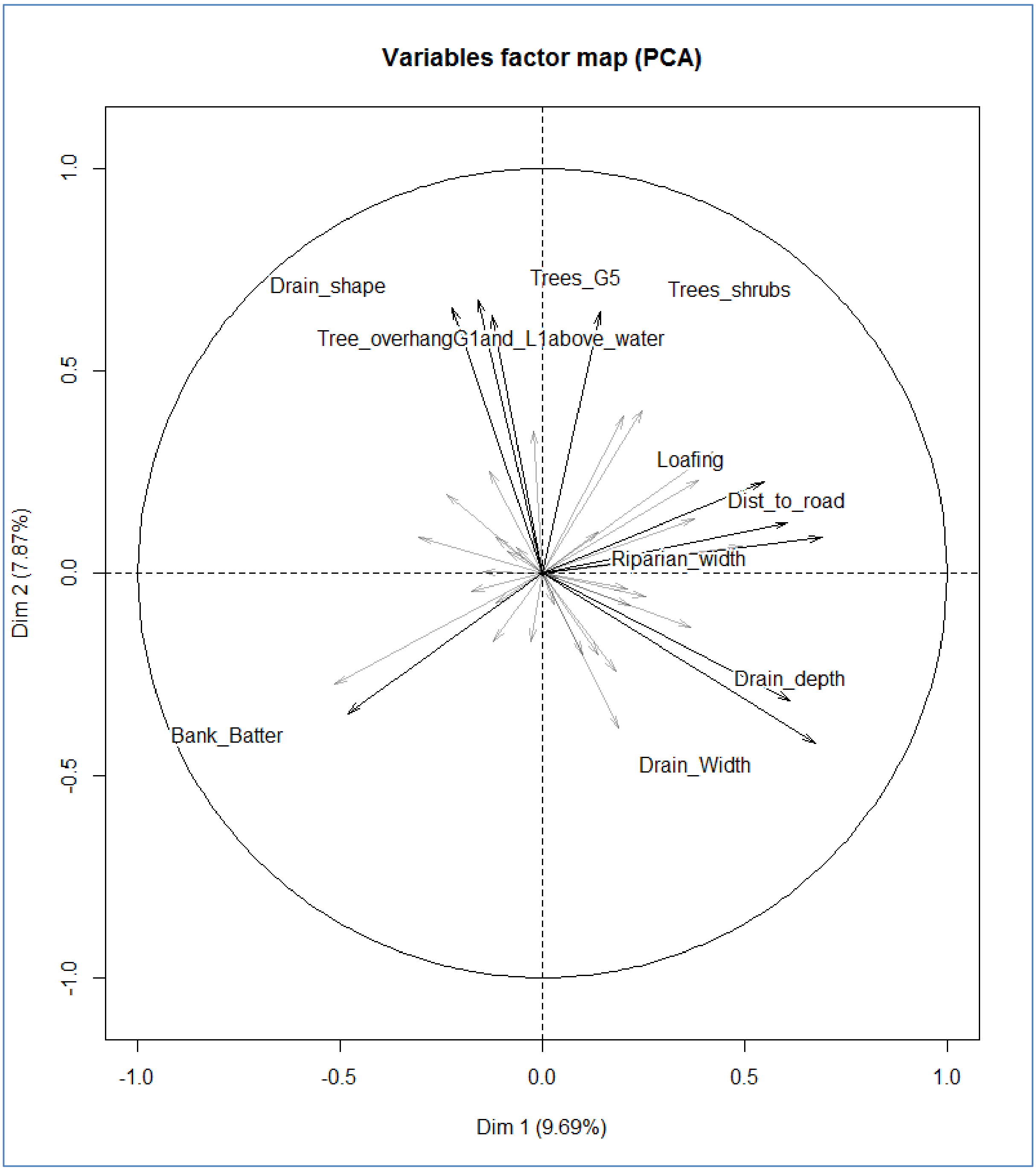

Figure 2. Principal component analysis showing the 10 characteristics that explain the greatest variability in the data over the first two principal components.

3.2 Mallards

Mallards were encountered at 58 of the 81 sites (72%). Of the sites with mallards, 43 (74%) had at least one brood present when visited. There was a large amount of overlap between habitat with ducks, broods, and no ducks (Figure 3).

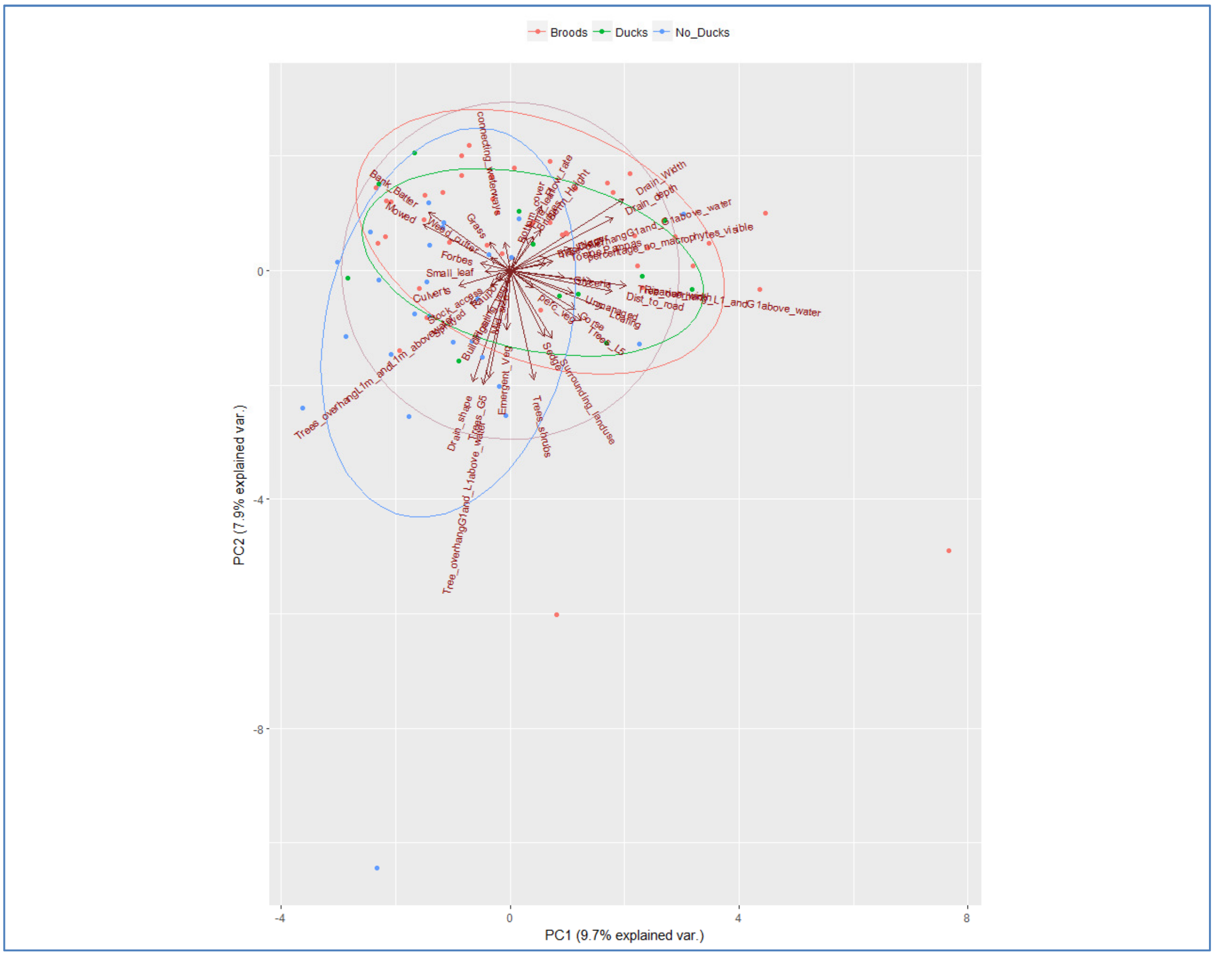

Figure 3. The first two Principal components of the standardised drain characteristics (morphology, habitat and management) with Ducks (green points), Broods (red points) and No Ducks (blue points) superimposed.

3.3 Ducks

Congregations of mallard ducks that did not appear to be associated with a brood were observed at 46 of 81 sites. It is likely that these were predominantly males that had finished breeding, or non-breeders. These mallards were recoded as "Ducks". There were 36 models (Table 2) with delta AICc ≤2, that explained the average number of Ducks we encountered. None of these models however exhibited overwhelming support (top ranked model w_i=0.0008; total weight for the top 36 models was 0.015).

Four covariates explained the presence of ducks in the top model; drain width, flow rate, grass, and unmanaged. Drain width was a common covariate in all 36 top models and exhibited the greatest influence on whether or not ducks were encountered. The wider the drain the more ducks were observed. The presence of grass and drains that were unmanaged (at the time of survey) had a positive influence on duck numbers while flow rate was negatively associated with duck numbers (Table 3).

Table 2. GLM models where the dependant variable is the average number of ducks encountered ranked on AICc.

Model	AICc	df	Delta AICc	weight
Drain_Width+Flow_rate+Grass+Unmanaged	373.6757	6	0	0.001
Dist_to_road+Drain_Width+Flow_rate+Grass+Unmanaged	373.7431	7	0.067405	0.001
Blackberry+Drain_Width+Flow_rate+Unmanaged	373.977	6	0.301306	0.001
Buildings+Dist_to_road+Drain_Width+Flow_rate+Grass+Unmanaged	374.1042	8	0.428493	0.001
Blackberry+Drain_Width+Flow_rate+Grass+Unmanaged	374.2241	7	0.548407	0.001
Blackberry+Dist_to_road+Drain_Width+Flow_rate+Unmanaged	374.5634	7	0.887661	0.001
Dist_to_road+Drain_Width+Flow_rate+Unmanaged	374.6184	6	0.942669	0.001
Dist_to_road+Drain_Width+Fine_leaf+Flow_rate+Grass+Unmanaged	374.6436	8	0.967926	0.001
Drain_Width+Grass+Unmanaged	374.8242	5	1.14846	0.000
Drain_Width+Fine_leaf+Flow_rate+Grass+Unmanaged	374.8785	7	1.202757	0.000
Drain_Width+Flow_rate+Unmanaged	374.8951	5	1.219361	0.000
Blackberry+Dist_to_road+Drain_Width+Flow_rate+Grass+Unmanaged	374.9037	8	1.228007	0.000
Drain_Width+Flow_rate+Grass+Riparian_width+Unmanaged	374.9832	7	1.3075	0.000
connecting_waterways+Drain_Width+Flow_rate+Grass+Unmanaged	375.055	7	1.379312	0.000
Drain_Width+Flow_rate+Grass+Sprayed	375.1575	6	1.481838	0.000
connecting_waterways+Dist_to_road+Drain_Width+Flow_rate+Grass+Unmanaged+	375.1675	8	1.491799	0.000
Blackberry+connecting_waterways+Drain_Width+Flow_rate+Unmanaged	375.1953	7	1.519589	0.000
Buildings+Drain_Width+Flow_rate+Grass+Unmanaged	375.1966	7	1.520875	0.000
Blackberry+Drain_Width+Fine_leaf+Flow_rate+Grass+Unmanaged	375.3135	8	1.63784	0.000
Blackberry+Drain_Width+Grass+Unmanaged	375.3449	6	1.669221	0.000
Dist_to_road+Drain_Width+Grass+Unmanaged	375.3639	6	1.688161	0.000
connecting_waterways+Dist_to_road+Drain_Width+Fine_leaf+Flow_rate+Grass+Unmanaged	375.3667	9	1.690962	0.000
Blackberry+connecting_waterways+Drain_Width+Flow_rate+Grass+Unmanaged	375.3786	8	1.702952	0.000
Blackberry+Drain_Width+Fine_leaf+Flow_rate+Unmanaged	375.4051	7	1.729374	0.000
Buildings+Dist_to_road+Drain_Width+Fine_leaf+Flow_rate+Grass+Unmanaged	375.4159	9	1.740229	0.000
Blackberry+Drain_Width+Flow_rate+Riparian_width+Unmanaged	375.4228	7	1.747095	0.000
Drain_Width+Fine_leaf+Flow_rate+Grass+Sprayed	375.4296	7	1.753901	0.000
Dist_to_road+Drain_Width+Flow_rate+Grass+Raupo+Unmanaged	375.4642	8	1.788528	0.000
Drain_Width+Flow_rate+Grass+Unmanaged	375.4869	7	1.811201	0.000
Drain_Width+Flow_rate+Grass+Raupo+Unmanaged	375.5306	7	1.854944	0.000
Drain_Width+Flow_rate+Grass	375.5644	5	1.888743	0.000
Drain_Width+Flow_rate+Grass+Mowed+Unmanaged	375.5852	7	1.909503	0.000
Blackberry+Buildings+Dist_to_road+Drain_Width+Flow_rate+Grass+Unmanaged	375.6275	9	1.951816	0.000
Drain_Width+Floating_veg+Flow_rate+Grass+Unmanaged	375.6471	7	1.971434	0.000
connecting_waterways+Drain_Width+Fine_leaf+Flow_rate+Grass+Unmanaged	375.6668	8	1.991061	0.000
Drain_Width+Flow_rate+Grass+Sprayed+Unmanaged	375.6737	7	1.998018	0.000

Table 3. Parameter estimates from top ranked GLM (standardised data) explaining the presence of ducks as a function of drain morphology, vegetation, and management.

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	1.3822	0.2486	5.561	3.72E-07	***
Drain_Width	1.2685	0.2562	4.951	4.25E-06	***
Flow_rate	-0.4665	0.2554	-1.827	0.0716	.
Grass	0.4713	0.2553	1.846	0.0688	.
Unmanaged	0.5204	0.2581	2.016	0.0472	*

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

3.4 Class Ia broods (1–7 days old)

Class Ia broods were encountered at 13 of 81 sites. There were 17 models where delta AICc was ≤2 (Table 4), none of which received overwhelming support (w_i≤0.004). The best supported model show that class Ia broods were positively associated with drain width and floating vegetation and negatively associated with distance to road, riparian width and if it had been mowed recently. The strongest influence was drain width (Table 5).

Table 4. GLM models where the dependant variable is the average number of class Ia ducklings encountered ranked on AICc.

	AICc	df	Delta AICc	weight
Dist_to_road+Drain_Width+Floating_veg+Mowed+Riparian_width	410.3317	7	0.000	0.004
Dist_to_road+Drain_Width+Floating_veg+Mowed+Riparian_width+Stock_access	410.6393	8	0.308	0.003
Dist_to_road+Drain_Width+Floating_veg+Riparian_width	410.8937	6	0.562	0.003
Drain_Width+Floating_veg+Riparian_width	411.025	5	0.693	0.003
Dist_to_road+Drain_Width+Floating_veg+Riparian_width+Stock_access	411.0304	7	0.699	0.003
Dist_to_road+Drain_Width+Floating_veg+Mowed+Riparian_width+Unmanaged	411.2457	8	0.914	0.002
Dist_to_road+Drain_Width+Floating_veg+Stock_access	411.4718	6	1.140	0.002
Drain_Width+Floating_veg+Riparian_width+Stock_access	411.4816	6	1.150	0.002
Dist_to_road+Drain_Width+Floating_veg+Mowed+Riparian_width+Stock_access+Unmanaged	411.4841	9	1.152	0.002
Drain_Width+Floating_veg+Mowed+Riparian_width	411.5589	6	1.227	0.002
Dist_to_road+Drain_Width+Floating_veg	411.6242	5	1.293	0.002
Dist_to_road+Drain_Width+Floating_veg+Mowed+Stock_access	411.8691	7	1.537	0.002
Dist_to_road+Drain_Width+Floating_veg+Mowed	411.8941	6	1.562	0.002
Drain_depth+Drain_Width+Floating_veg+Riparian_width	412.1919	6	1.860	0.002
Drain_Width+Floating_veg+Mowed+Riparian_width+Stock_access	412.2135	7	1.882	0.002
Dist_to_road+Drain_Width+Floating_veg+Mowed+Stock_access+Unmanaged	412.264	8	1.932	0.001
Bridges+Dist_to_road+Drain_Width+Floating_veg+Mowed+Riparian_width+	412.3144	8	1.983	0.001

Table 5. Parameter estimates from top ranked GLM (standardised data) explaining the presence of class Ia broods as a function of drain morphology, vegetation, and management.

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	1.264	0.3083	4.1	0.000103	***
Dist_to_road	-0.6485	0.3501	-1.852	0.067867	.
Drain_Width	0.9783	0.3477	2.814	0.006231	**
Floating_veg	0.7555	0.3127	2.416	0.018102	*
Mowed	-0.5595	0.335	-1.67	0.099011	.
Riparian_width	-0.6709	0.3462	-1.938	0.056321	.

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

As with drains with ducks cf. without ducks, there was no clear separation between drains with broods and without broods (Figure 4). Class Ia ducklings however appear to occupy a smaller subset of the data spread (Figure 5).

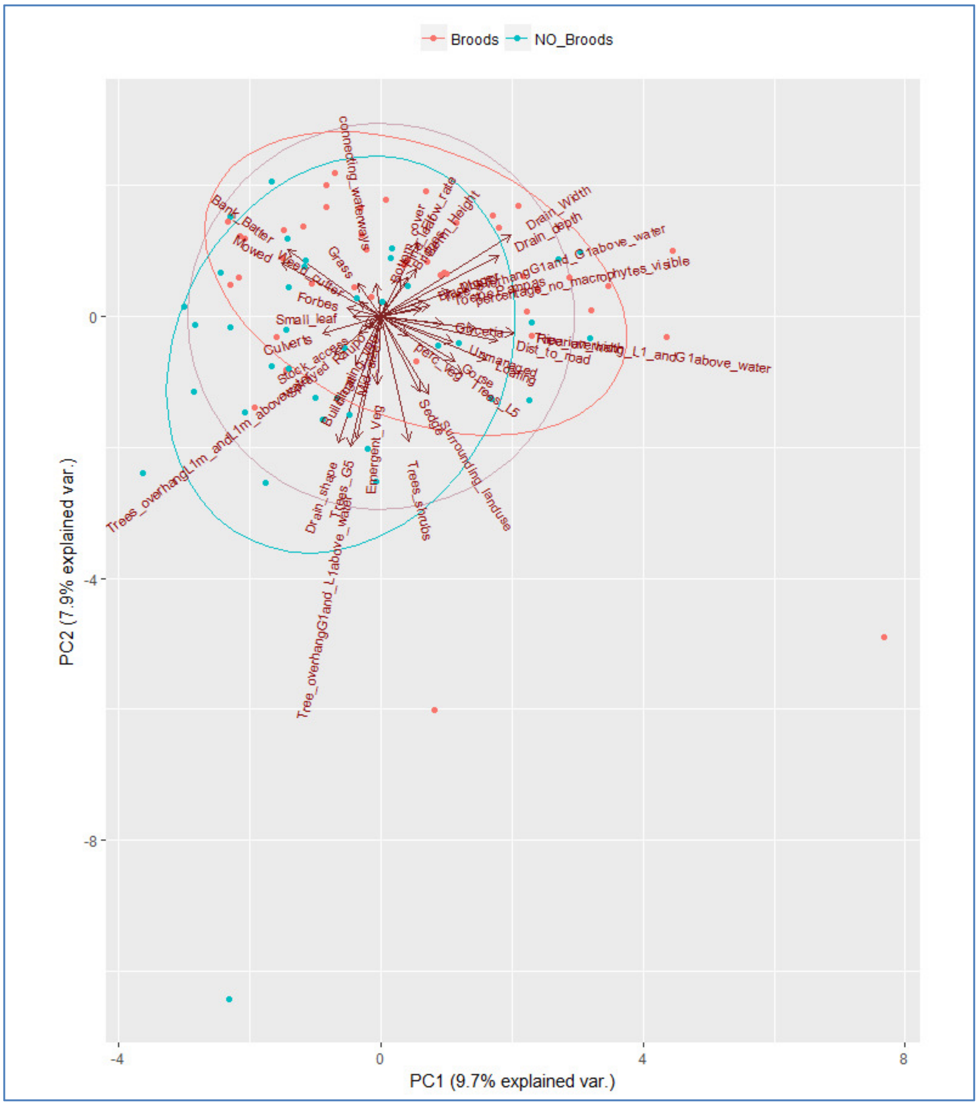

Figure 4. Drains that had broods vs. drains that did not have broods overlaid on the first two Principal Components of drain characteristics.

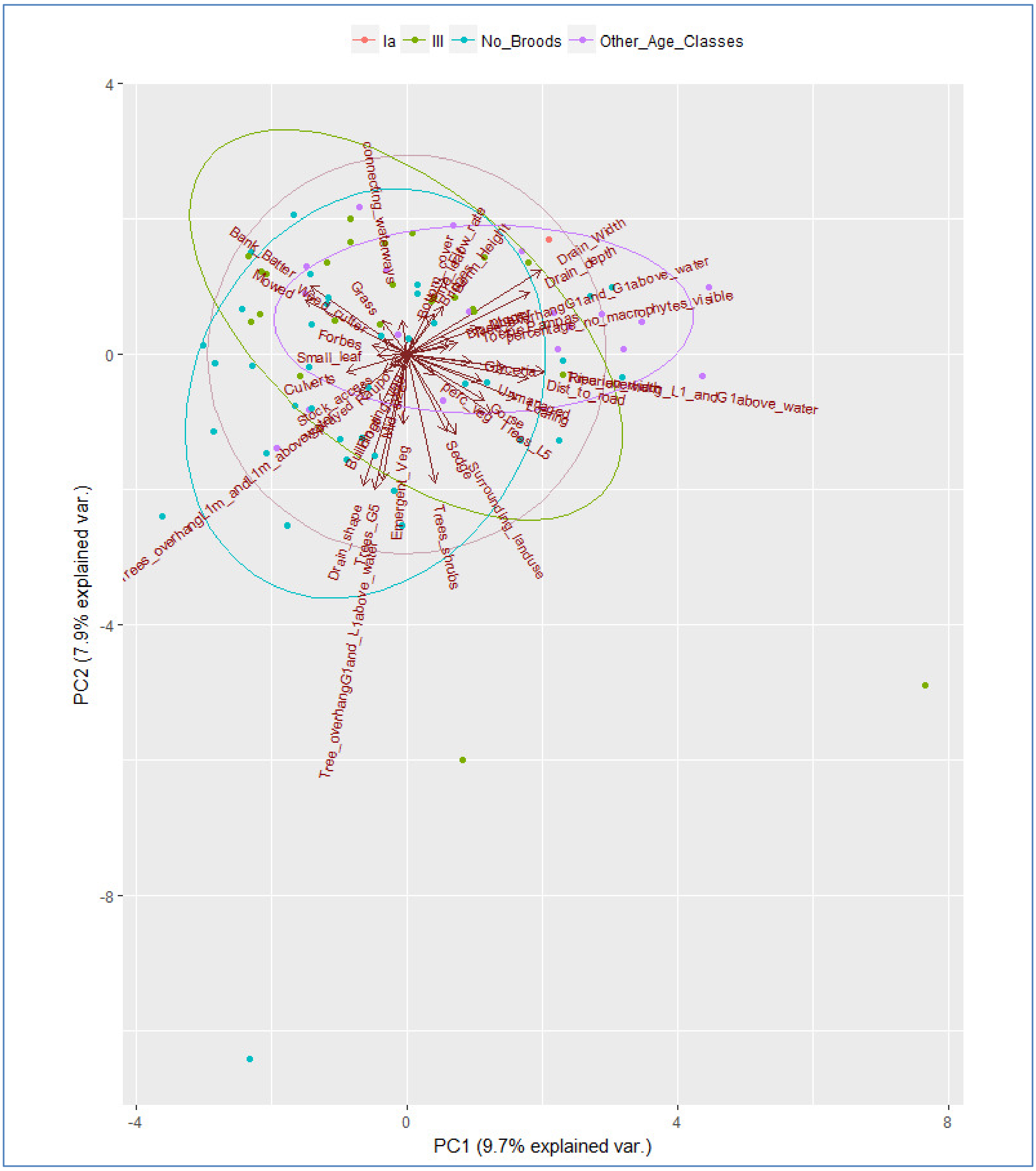

Figure 5. Drains with both Class Ia (Red points), III (green points), other age classes (purple points) no broods (teal points) overlaid on the first two Principal Components of drain characteristics.

3.5 Class III broods (43–55 days old)

There were 16 models where AICc≤2 (Table 6), but none received overwhelming support (w_i≤0.005). The top model indicates that class III broods are positively associated with drain width, floating vegetation, weed cutter, trees and shrubs and negatively associated with distance to road (Table 7).

Table 6. GLM models where the dependant variable is the average number of class III ducklings encountered ranked on AICc.

	AICc	df	delta	weight
Dist_to_road+Drain_Width+Floating_veg+Trees_shrubs+Weed_cutter	438.4054	7	0.000	0.005
Dist_to_road+Drain_Width+Floating_veg+Trees_shrubs	438.7032	6	0.298	0.005
Dist_to_road+Drain_Width+Floating_veg+Mowed+Trees_shrubs	439.2991	7	0.894	0.003
Dist_to_road+Drain_Width+Floating_veg+Weed_cutter	439.3732	6	0.968	0.003
Dist_to_road+Drain_Width+Floating_veg	439.4979	5	1.092	0.003
Dist_to_road+Drain_Width+Floating_veg+Mowed+Trees_shrubs+Weed_cutter	439.6189	8	1.214	0.003
Dist_to_road+Drain_Width+Floating_veg+Trees_shrubs+Unmanaged	439.7455	7	1.340	0.003
Dist_to_road+Drain_Width+Floating_veg+Riparian_width+Trees_shrubs+Weed_cutter	439.7664	8	1.361	0.003
Dist_to_road+Drain_Width+Floating_veg+Stock_access+Trees_shrubs+Weed_cutter	439.8771	8	1.472	0.003
Dist_to_road+Drain_Width+Floating_veg+Trees_shrubs+Unmanaged+Weed_cutter	440.0755	8	1.670	0.002
Dist_to_road+Drain_depth+Drain_Width+Floating_veg+Trees_shrubs+Weed_cutter	440.134	8	1.729	0.002
Berm_Height+Dist_to_road+Drain_Width+Floating_veg+Trees_shrubs	440.1553	7	1.750	0.002
Dist_to_road+Drain_Width+Floating_veg+Riparian_width+Trees_shrubs	440.1582	7	1.753	0.002
Dist_to_road+Drain_Width+Floating_veg+Mowed	440.271	6	1.866	0.002
Dist_to_road+Drain_Width+Floating_veg+Stock_access+Trees_shrubs	440.347	7	1.942	0.002
Berm_Height+Dist_to_road+Drain_Width+Floating_veg+Trees_shrubs+Weed_cutter	440.3905	8	1.985	0.002

Table 7. Parameter estimates from top ranked general linear model (standardised data) explaining the presence of class III broods.

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	2.1252	0.3658	5.809	1.38E-07	***
Dist_to_road	-0.9419	0.4039	-2.332	0.022337	*
Drain_Width	1.482	0.4052	3.658	0.000466	***
Floating_veg	0.9448	0.3704	2.551	0.012759	*
Trees_shrubs	0.6792	0.3809	1.783	0.078533	.
Weed_cutter	0.5905	0.3708	1.592	0.115442	

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

4. Discussion

Bay of Plenty drains are an important juvenile rearing area for mallards. Furthermore, given how important mallards are to a large number of Bay of Plenty hunters it was hoped that we may be able to utilise the findings of this study to influence drain management and maintenance.

We examined the influence of drain morphology, vegetation characteristics, and maintenance regimes (sprayed, mowed, weed cutter, digger, unmanaged) in Bay of Plenty drains on mallards and their broods. We expected to find that unmanaged drains, overhead cover (i.e. trees), loafing areas, aquatic vegetation (ducklings feed on invertebrates (Cox et al. 1998) which are often associated with aquatic vegetation), habitat size, drain shape, and flow rate would all be important. We found that habitat size (drain width) was the dominant factor in determining if mallard and their broods were encountered during our surveys.

Ducks were positively associated with unmanaged drains, consistent with a previous study in the Bay of Plenty and Hawke's Bay by (Maxwell 2006). It appears that one unmanaged bank is better than none and two may support more broods than one (Figure 6). Class Ia and Class III models including the "unmanaged" parameter received reasonable support (Delta AICc = 0.91 and 1.34 respectively) and observations of Class Ia were negatively associated with mowing (Figure 7). Mowing explain the number of Class Ia broods in 8 of the 17 models (Delta AIC<2) while the unmanaged parameter was only in 3 or the 17 models. Drain maintenance did not appear to be as important in explaining the presence of Class III broods. Nevertheless an examination of Figure 7 shows that broods are more common in drains that have not been sprayed on either bank, nor have had a digger through recently, or have been mowed.

As the flow rate of the drain increased duck numbers decreased. The relationship between flow rate and ducks however, was not strong, and this was due probably to the relatively slow flow in most of the drains (max flow = 0.8m sec^{-1}).

The percentage of grass on the banks was positively associated with mallards and their brood. Grass provides open habitat where ducks have a good view of approaching predators. Garrick et al. (2017) found brood survival was lower in areas of denser cover and when ducklings had to move long distances between nest and rearing sites. They postulate that narrow linear patches of dense cover could support a greater abundance of predators.

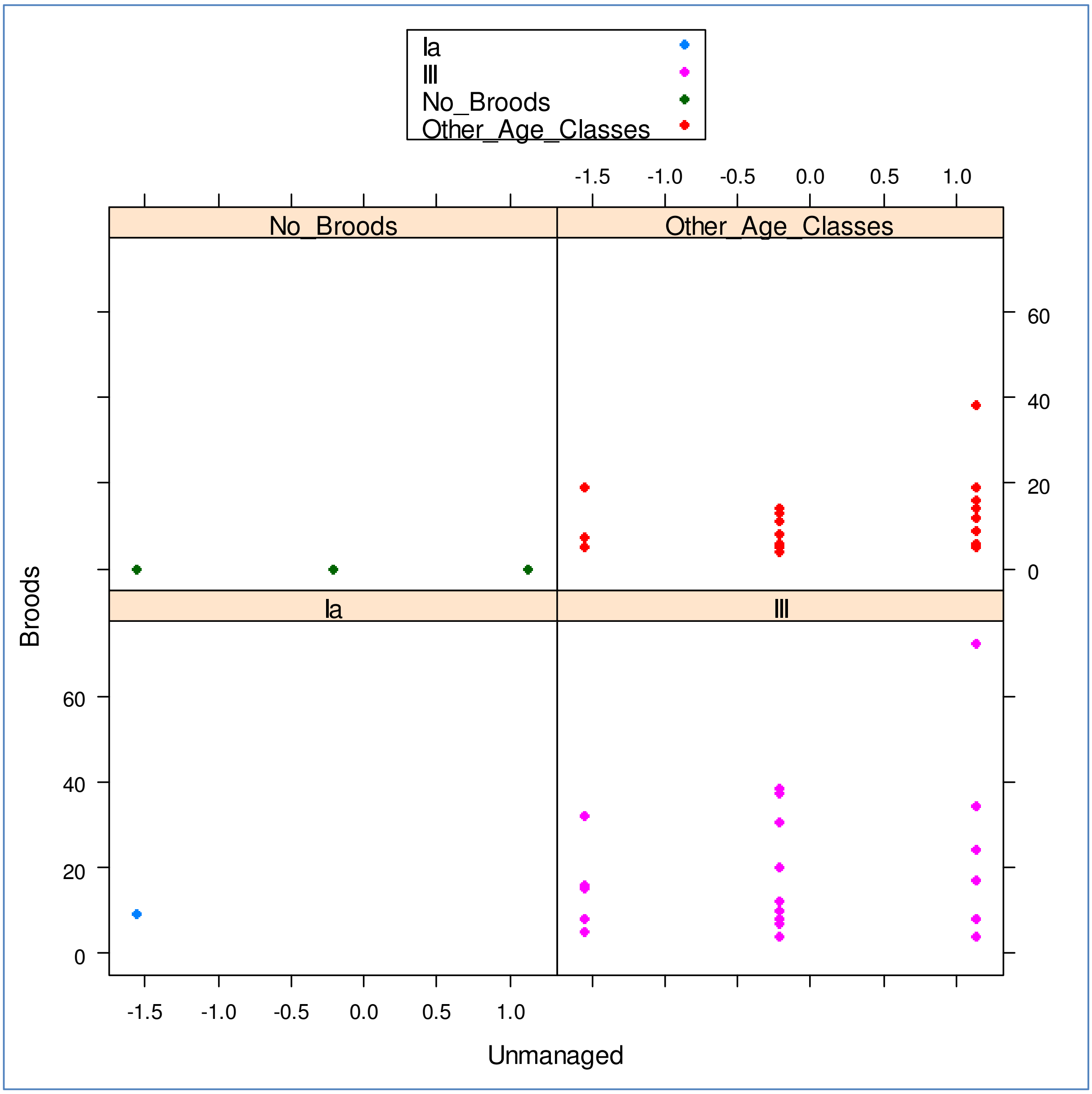

Figure 6. The number of broods observed in relation to unmanaged banks of drains (-1.55=0 unmanaged banks, -0.2=1 unmanaged bank and, 1.5 = 2 unmanaged banks). Most of the broods observed were either associated with one or two unmanaged banks. No_Brodds= No broods observed, Other_Age_Class=brood age clasess other than Ia and III, Ia=brood class Ia and III=brood age class III.

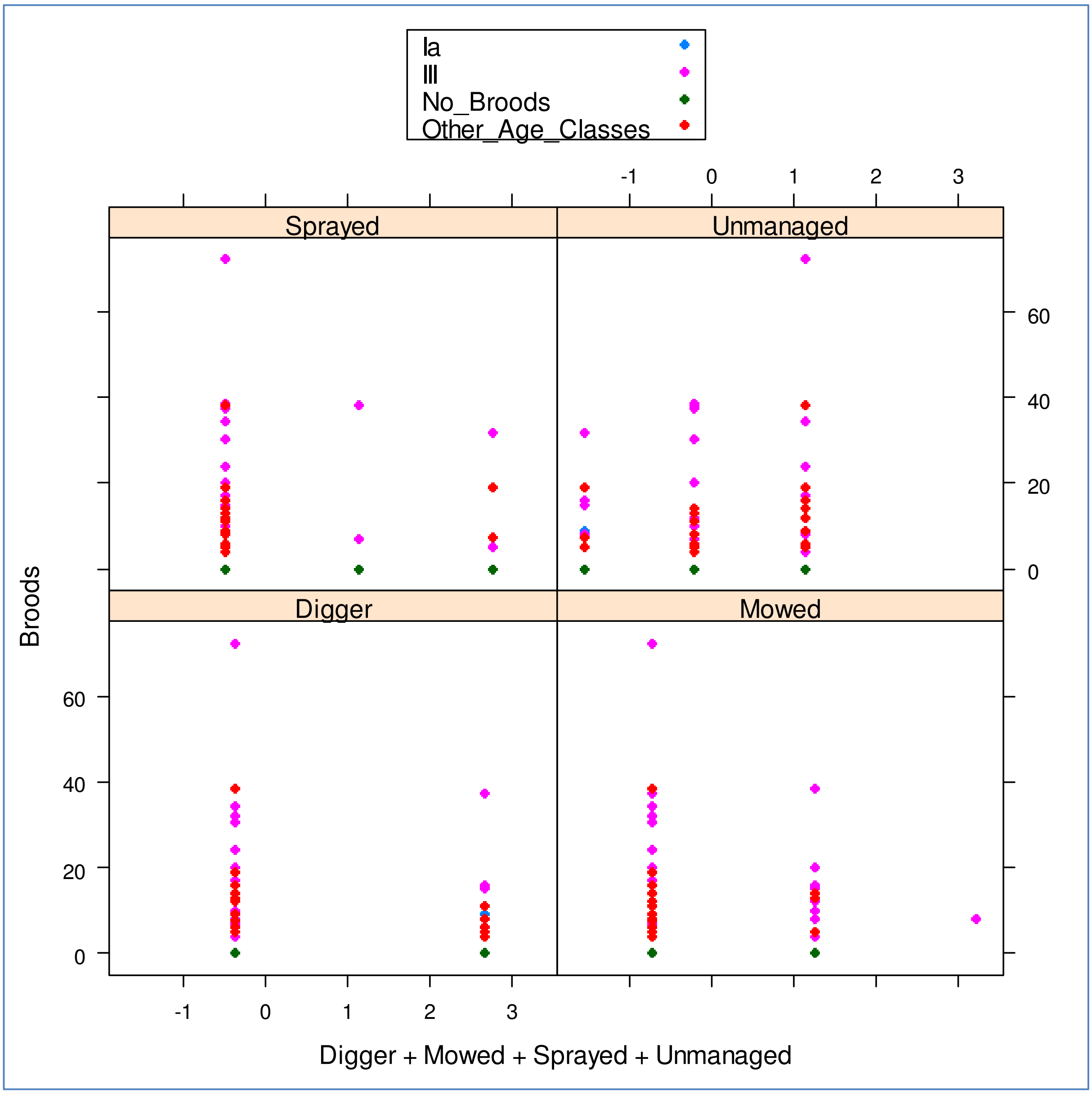

Figure 7. Drain maintenance methods and the number of broods of class Ia, III and other brood age classes counted. Sprayed (-.5=not spayed on either bank, 1=sprayed on one bank, 2.7=sprayed on both banks); Digger (-0.4=no digger observed, 2.7=digger observed); Unmanaged (-1.1=Both banks managed, -0.2=one bank unmanaged, 1.1=two banks unmanaged); Mowed (-0.7=neither bank mowed, 1.2=one bank mowed, 3.2=both banks mowed).

Distance to road was at odds with our predictions (Table 1). We had expected drains further from the road to hold more broods but this was not the case. We suspect that this was due to the larger (wider) drains following the roads whilst the ones further away tended to be small farm drains.

Also unexpectedly, Class Ia ducklings were negatively associated with riparian width (Figure 8). This negative relationship may be a function of the nest site location with young broods moving progressively from dense nesting habitat (small unmanaged drains with narrow riparian margins) to more open and larger drains as they age.

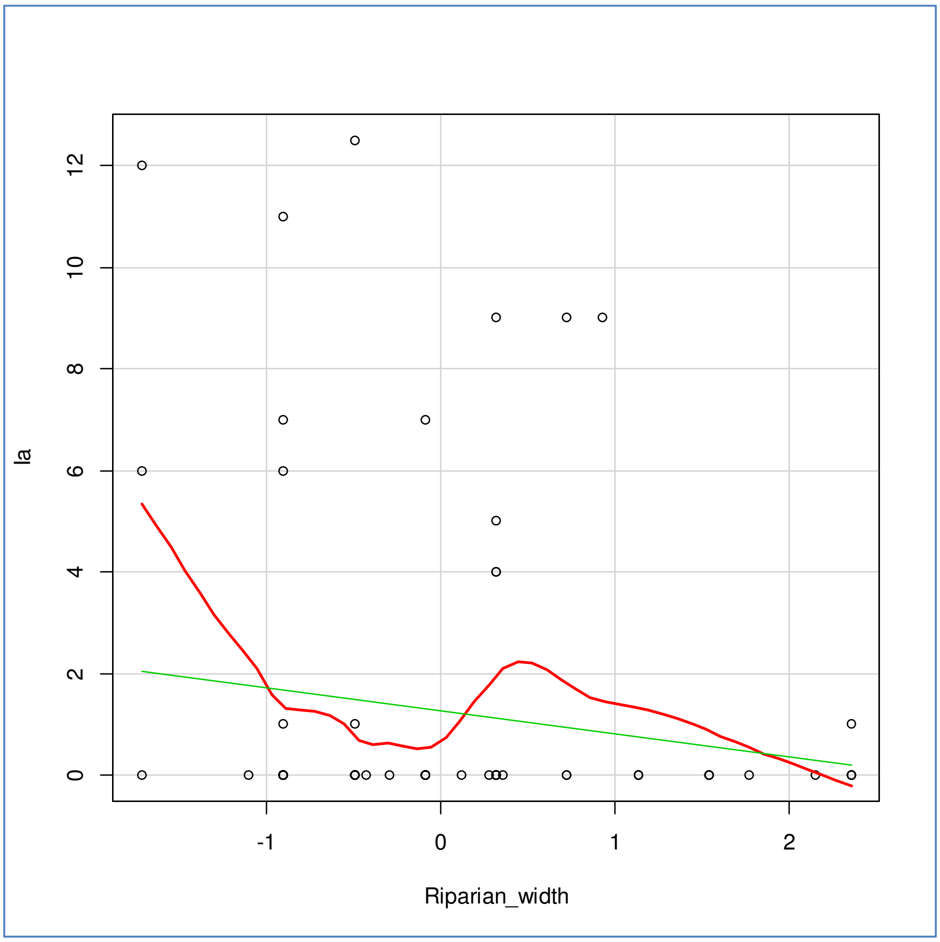

Figure 8. The relationship between Riparian width and Class Ia broods.

Overhead cover did not rank amongst the top variables but we suspect that this was, in part, a result of some sites with solid bamboo or macrocarpa hedges (i.e. numerous trees) which were not suitable for ducks. Figure 9 shows the relationship between the number of trees/shrubs and the number of ducks. Except for the many sites with no trees, most of the ducks were associated with a few trees/shrubs. A study on farm ponds in Central Hawke's Bay showed that as few as one or two trees overhanging the water's edge could make the difference between mallard use or otherwise of the pond (McDougall et al. 2010). More trees did not necessarily mean more ducks.

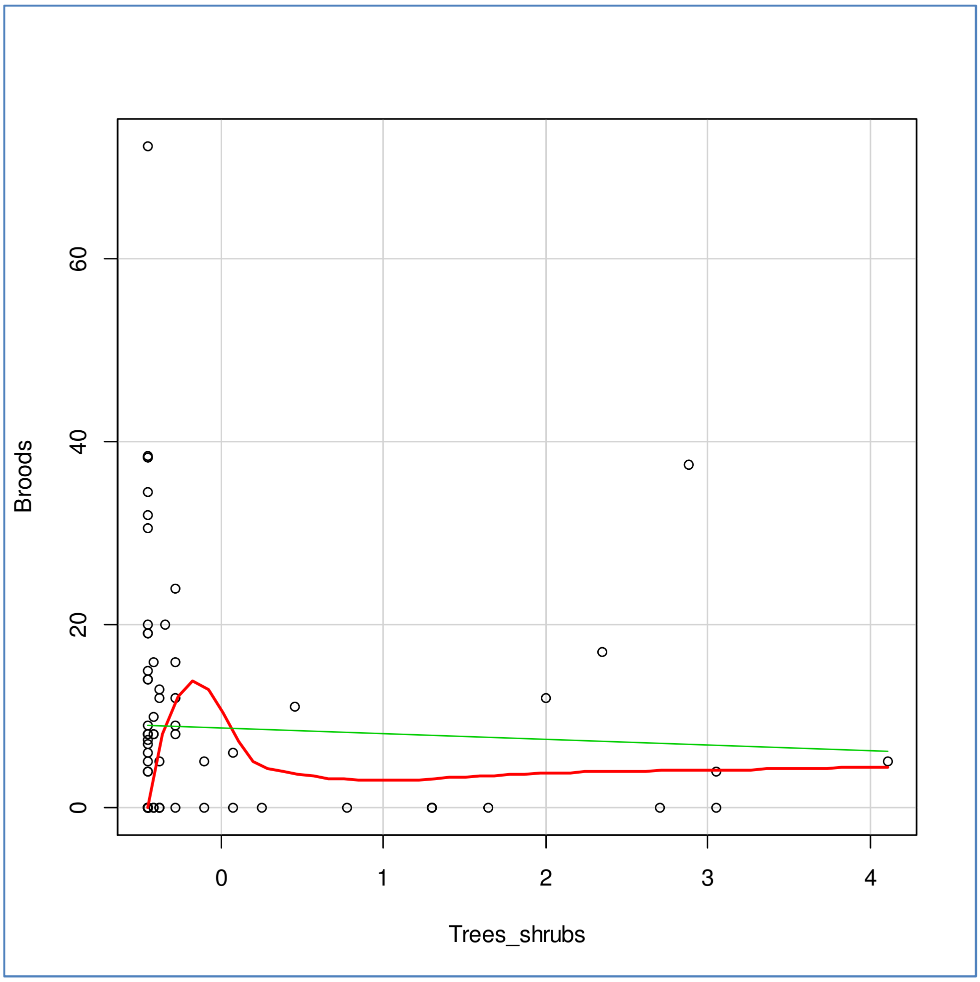

Figure 9. Scatter-plot of trees/shrubs (dots) against the number of ducks. The green line is the regression line and the red line the Loess fit line.

Loafing areas were probably not limiting at any site as the ducks were usually able to get out and onto the edges. We considered that ducklings in drains with large swaths of *Glyceria maxima* would have poor access to the banks for loafing, and the *Glyceria* may limit feeding opportunities, but there was no support for this hypothesis. Nevertheless, broods were negatively associated with the percent cover of *Glyceria*.

Mallards may select brood rearing habitat with high levels of invertebrates (Talent et al. 1982). We did not however, collect invertebrates as part of this study due to the difficulty of obtaining representative samples but instead noted substrate compatible with invertebrate abundance, such as aquatic vegetation. There was a strong positive relationship between drains with floating vegetation (such as *Lemna minor* and *Azolla rubra*) and Ducks, Classes I and Class III broods. We were not confident however that our assessment of macrophytes was robust. Water clarity and access often made this difficult to measure.

We considered that steep sided drains (i.e. “u” shaped) would support fewer ducks than gradual sided drains (i.e. “v” shaped) but found little evidence for this. We suspect that this result was a function of the high proportion (91%) of drains in the study that were “u” shaped, coupled with most of the “v” shaped drains still being relatively steep sided.

As stock access increased so did duck numbers. We suspect this was due to the presence of grass in these areas (or open clear habitat) as grass and stock access are correlated (r^2= 0.25 ; t = -2.3154, df = 79, p-value = 0.02 .

Along with invertebrates, pest fish abundance was not measured. Waterfowl abundance in the Waikato has been shown to be negatively associated with pest fish (Garrett-Walker 2014). The Lake Tutira swan population collapsed after the introduction of grass carp resulted in a massive reduction in submerged aquatic weeds (Fish & Game unpub. data). There are high densities of *Gambusia* (mosquito fish) in many of the Bay of Plenty's waterways and it these may have a negative impact on hen condition and duckling growth rates, both of which impact on survival (Sheppard 2017). Grass carp are used by the Waihi Drainage Board to keep drains clear of weeds. We were aware of only one site in the study area that had grass carp so did not include this parameter, but a stratified survey including drains with grass carp is warranted as we suspect the presence of carp is likely to have a very negative influence on waterfowl.

We were unable to differentiate between Class Ia and Class III ducklings habitat associations. We had hoped that the associated habitats might provide insights into nesting habitat (assuming the newly hatched birds would be near nest habitat). Only one site was identified as having only Class Ia ducklings. At the other sites where Class Ia ducklings were observed we did not know if the broods had nested nearby or had commuted to these sites. Nest survival has been identified as the single most vital component of population growth in prairie habitat in the US (Howerter et al. 2014) and is also likely to be a key factor in NZ (Sheppard 2017). Although our study did not provide insight into nest habitat, common sense suggests timing of management actions such as digger disturbance, mowing, spraying and stock access would all be important in nest survival. What is not clear is to what extent habitat type dictates nest survival. There is some evidence from US studies that habitat structure is important for mallard brood rearing (Nummi et al. 2013). This warrants further investigation in the NZ context. Studies in the US have identified that mallard select nest sites away from edge habitat (Howerter et al. 2008); prefer taller vegetation (Hill 1984); and more commonly nest in woodland (Greenwood et al. 1995). Drain management often precludes many of these desirable attributes. Ducks will nest away from drains and travel with their brood to suitable rearing habitat but travel distance can negatively impact on brood survival (Rotella and Ratti 1992, Sayler and Willms 1997) so providing suitable nesting habitat close to good rearing habitat is desirable.

Developing a better understanding of successful nest habitat will improve Fish and Game's ability to advocate for its management.

5. Management Implications

This brief examination of the data highlights the importance of larger (wider) drains, small amounts of overhead cover, having grass cover present on the banks of drains and floating vegetation in the drains, and minimizing maintenance (cleaning/vegetation clearance) during the breeding season. Leaving drains unmanaged during the breeding season (August – November inclusive) is likely to benefit mallard productivity as would planting overhead cover (trees) in small copses at intervals along the drain banks. Keeping stock out prior to and during the nesting period would improve nest habitat and reduce nest loss through trampling.

Use of aquatic sprays (such as diquat) during periods when hens are consuming large numbers of aquatic invertebrates (late winter – spring) and brood rearing (spring – early summer) should be discouraged.

Acknowledgements

We would like to thank Nigel Simpson and Harri Condie for assistance with some of the field work and finally to the Royal Society of New Zealand Science Teaching and Leadership Programme that made it possible for Brigitta Nieuwboer to undertake this study.

References

Bartoń, K. 2013. MuMIn: Multi-model inference. R package version 1.9. 13. The Comprehensive R Archive Network (CRAN), Vienna, Austria.

Burnham, K. P. and D. R. Anderson. 2002. Model selection and multimodel inference. A practical information-theoretic Approach Second Ed. Springer-Verlag New York.

Cox, R. R., Jr., M. A. Hanson, C. C. Roy, N. H. Euliss, Jr., D. H. Johnson, and M. G. Butler. 1998. Mallard Duckling Growth and Survival in Relation to Aquatic Invertebrates. The Journal of Wildlife Management **62**:124-133.

Crabbe, B. 2001. Environmental code of practice for rivers and drainage activities.*in* E. BOP, editor., Whakatane, NZ.

Fox, J., M. Ash, T. Boye, S. Calza, A. Chang, P. Grosjean, R. Heiberger, G. Kerns, R. Lancelot, and M. Lesnoff. 2009. Rcmdr: R Commander. R package version 1.5-4. Available via dialog.

Garrett-Walker, J. 2014. The ecology of constructed ponds on the lower Waikato River floodplain: implications for waterfowl management. University of Waikato.

Garrick, E. J., C. L. Amundson, and P. J. Seddon. 2017. Duckling survival of mallards in Southland, New Zealand. The Journal of Wildlife Management.

Gollop, J. B. and W. H. Marshall. 1954. Guide for aging duck broods in the field. US Department of the Interior, Bureau of Sport Fisheries and Wildlife.

Greenwood, R. J., A. B. Sargeant, D. H. Johnson, L. M. Cowardin, and T. L. Shaffer. 1995. Factors associated with duck nest success in the prairie pothole region of Canada. Wildlife Monographs:3-57.

Hill, D. A. 1984. Factors affecting nest success in the mallard and tufted duck. Ornis Scandinavica:115-122.

Hoekman, S. T., L. S. Mills, D. W. Howerter, J. H. Devries, and I. J. Ball. 2002. Sensitivity Analyses of the Life Cycle of Midcontinent Mallards. The Journal of Wildlife Management **66**:883-900.

Howerter, D. W., M. G. Anderson, J. H. Devries, B. L. Joynt, L. M. Armstrong, R. B. Emery, and T. W. Arnold. 2014. Variation in mallard vital rates in Canadian Aspen Parklands: The Prairie Habitat Joint Venture assessment. Wildlife Monographs **188**:1-37.

Howerter, D. W., J. J. Rotella, M. G. Anderson, L. M. Armstrong, and J. H. Devries. 2008. Mallard Nest-Site Selection in an Altered Environment: Predictions and Patterns. Israel Journal of Ecology & Evolution **54**:435-457.

Hudson, H. R. and J. S. Harding. 2004. Drainage management in New Zealand: A review of existing activities and alternative management practices.*in* Conservation, editor., Wellington NZ.

Irving, R. M. and S. M. Beadel. 1992. Botanical surveys and assements of wildlife reserves in the Te Teko Ecological district. Department of Conservation, Rotorua.

Krapu, G. L. and K. J. Reinecke. 1992. Foraging ecology and nutrition. Ecology and management of breeding waterfowl:1-29.

Lê, S., J. Josse, and F. Husson. 2008. FactoMineR: an R package for multivariate analysis. Journal of statistical software **25**:1-18.

Maxwell, I. 2006. Some affects of drain management regimes on waterfowl populations in four drains in the Hawke's Bay and Eastern Fish and Game Regions.

McDougall, M., I. Maxwell, C. Cheyne, and T. Winlove. 2010. Mallard (Anas platyrhynchos) and Grey /Parera (A. superciliosa) presence at ponds in the East Coast Region: a pilot study to identify influential pond characteristics. Fish and Game New Zealand, Rotorua.

McDowall, R. M. 1990. New Zealand freshwater fishes: a natural history and guide.

Nummi, P., A. Paasivaara, S. Suhonen, and H. Pöysä. 2013. Wetland use by brood-rearing female ducks in a boreal forest landscape: the importance of food and habitat. Ibis **155**:68-79.

R Development Core Team. 2005. R: A language and environment for statistical computing, reference index version 2.15.2. R Foundation for Statistical Computing. Vienna, Austria.

Rotella, J. J. and J. T. Ratti. 1992. Mallard Brood Movements and Wetland Selection in Southwestern Manitoba. The Journal of Wildlife Management **56**:508-515.

Sayler, R. D. and M. A. Willms. 1997. Brood Ecology of Mallards and Gadwalls Nesting on Islands in Large Reservoirs. The Journal of Wildlife Management **61**:808-815.

Schwarz, A.-M. and T. Snelder. 1999. Integrated submerged aquatic vegetation management in an urban New Zealand river. Hydrobiologia **415**:235-241.

Sheppard, J. L. 2017. Breeding ecology and productivity of mallards and mallard-grey duck hybrids in New Zealand. University of Auckland, Auckland, NZ.

Talent, L. G., G. L. Krapu, and R. L. Jarvis. 1982. Habitat Use by Mallard Broods in South Central North Dakota. The Journal of Wildlife Management **46**:629-635.

Vu, V. Q. 2011. ggbiplot: A ggplot2 based biplot. R package version 0.55. There is no corresponding record for this reference.