Waikato Regional Council Technical Report 2019/16

Use of West Coast Waikato estuaries by Canada geese and black swans

www.waikatoregion.govt.nz
ISSN 2230-4355 (Print)
ISSN 2230-4363 (Online)

Waikato
REGIONAL COUNCIL
Te Kaunihera ā Rohe o Waikato

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18 June 2019

Document #: 14530616

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Disclaimer

Acknowledgement

We would like to thank and acknowledge the help of the following people and organisations:

- David Klee and John Dyer from Fish & Game New Zealand who supplied information on estuarine surveys, swan and goose history in the Waikato and swan and goose diet;
- Birds New Zealand who provided Canada goose and black swan census data; and
- Andrew Styche from the Department of Conservation (DOC) who provided additional information on Birds New Zealand National Wader Census survey methodology.
- Hannah Jones, Michael Townsend and Alastair Fairweather from Waikato Regional Council provided valuable feedback on the initial draft of this report.

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Abstract

The exotic Canada goose and the native black swan are present in Waikato estuaries, and there are concerns that bird numbers are increasing. This report reviews available information on the use of estuaries on the west coast of the Waikato region by Canada geese and black swans, including the potential effects of these species on estuarine ecosystems. A systematic literature review was carried out using key search terms and survey data from Fish & Game New Zealand and Birds New Zealand were used to estimate bird populations in these areas.

Bird surveys show that Canada goose numbers are increasing in western Waikato lakes, wetlands and estuaries. Black swan numbers have declined in the western Waikato over the past three decades, though use of estuarine habitats may be increasing. Further surveys are required to understand whether black swan numbers are increasing in estuaries, and whether this is associated with declines in lake and wetland habitats.

These waterfowl have various potential ecological effects, the most significant of which is damage to seagrass, a key biogenic habitat provider that has been declining over the last 50 years. Both species feed on seagrass, and may damage seagrass beds, though it is not clear whether either species feeds preferentially on seagrass in Waikato estuaries. At high densities, waterfowl can also contribute to reductions in water quality. Waterfowl can contribute to eutrophication of waterbodies through the deposition of faecal matter. The nutrient contribution of swans and geese to Waikato estuaries is as yet undetermined, though it could be calculated based on parameters from relevant literature. Other potential ecological impacts of these birds include changes to other estuarine vegetation, disease transmission, propagule transport and aggression towards other birds.

Swans and geese should be managed via an integrated approach focused primarily on reducing the adult population. Given the mobile nature of these species, management would probably need to be nationally coordinated to ensure that vacated habitats are not recolonised.

1 Introduction

1.1 Context

There are concerns that Canada goose and black swan numbers are increasing in west coast Waikato estuaries, specifically Aotea Harbour, Whaingaroa (Raglan) Harbour[1] and Kawhia Harbour. These birds may be having negative ecological impacts, particularly on seagrass, which is a key biogenic habitat (Anderson et al., 2019) that has been declining over the last 50 years and is now At Risk – Declining (De Lange et al., 2018; Schwarz et al., 2004).

1.2 Overview of ecology

1.2.1 Canada geese

Canada geese (*Branta canadensis*)[2] are naturally occurring in North America but have been introduced elsewhere. Geese were introduced into New Zealand in 1876 and 1905 for recreational hunting purposes. They were originally introduced into both islands but died out in the North Island and were reintroduced in 1970. The hunting of geese was originally restricted by the Wildlife Act 1953 where it was part of the First Schedule (wildlife declared to be game); however in 2011 it was moved to the Fifth Schedule (wildlife not protected). This change was made following concerns that increasing numbers required more lenient conditions under which the species could be hunted (now at any time, by any method except poison); typically by farmers who wish to protect pasture. The change in status means that Fish & Game New Zealand (F&G) no longer have authority or responsibility to assist with any future management of geese; however, F&G can provide expertise regarding culls or management (Fish & Game New Zealand 2019, accessed 21 March).

In New Zealand, geese are found near high-country lakes and rivers and lowland lakes and estuaries. Some geese remain in either high- or low-country year-round, while others are highly mobile. Geese are herbivorous, feeding on grasses, clovers, legumes (Heather & Robertson, 1996) and submerged macrophytes, but are primarily grassland feeders (Williams et al., 2006). Breeding usually occurs in high country areas with some geese breeding in coastal areas in loose colonies (Spurr & Coleman, 2005). Estimates of average lifespan of geese in the wild vary between sources, ranging from less than four years (Allan et al., 1995; Spurr & Coleman, 2005), to six (Robinson, 2005) or even twelve years (Johnson, 2012). Breeding occurs from September to November when 4 to 5 eggs are laid and incubated by the female for about 28 days. Chicks fledge at about 80 days. Breeding geese and their young leave breeding areas in January/February to join non-breeders on coastal lakes and estuaries for the autumn moult. During the moult period, birds lose their wing feathers and become flightless for up to three weeks, thus they prefer to moult in secluded habitats.

1.2.2 Black swans

Black swans (*Cygnus atratus*)[3] are considered native to New Zealand, probably arriving from Australia at around the same time as they were introduced as an ornamental species in the late 1800s (Miers & Williams, 1969). There has been much debate of whether *C. atratus* is conspecific with the extinct endemic swan *C. sumnerensis*, but they are now considered separate species (Rawlence et al., 2018)

Swans are herbivorous, living in lakes and wetlands foraging preferentially on submerged species such as filamentous algae, sea lettuce and seagrass (Sagar et al., 1995). Swans will forage on grass when submerged macrophyte food supplies are reduced (Fish & Game New Zealand

[1] Hereafter referred to as Raglan Harbour.
[2] The reference to the word "geese" in this report relates to specifically to *Branta Canadensis*, unless otherwise specified.
[3] The reference to the word "swan" in this report relates to specifically to *Cygnus atratus*, unless otherwise specified.

2019, accessed 21 March). Swan numbers in New Zealand increased until the 1970s when siltation from farming affected macrophyte populations in some lakes, reducing food supply (Fish & Game New Zealand 2019, accessed 21 March). Culls were carried out to reduce the effects of swan grazing on farmland. Culls continue to be carried out regularly in some areas and most F&G regions still allow swan hunting opportunities.

Swans breed in a range of habitats in either solitary pairs or in a colony. Solitary nesting occurs in winter, whereas colonial nesting is highly variable, occurring in spring and summer (Sagar et al., 1995). Colonial nesting tends to occur in estuaries only. The mean clutch size of swans is 5-6 eggs, and these are incubated for approximately 36 days (Williams, 2013b). Chicks fledge after 120 days and may remain with their families for several months. When food is plentiful, a second brood may be raised in one breeding season.

Swans are highly mobile and the New Zealand population is described as a "single national mobile population unit" (Sagar et al. 1995). In summer swans congregate in shallow coastal areas to moult and, in some places, nest colonially. The biggest moulting site in New Zealand is located in the Tasman District where up to 14,000 birds were counted per year between 1977 and 2002 (Williams 1982, cited in Battley et al. 2005). Swans are unable to fly for approximately one month after moulting, thus they prefer to moult in secluded habitats.

1.3 Literature review objectives and outline

This literature review has been prepared for Waikato Regional Council to describe available information on the use of west coast estuaries in the Waikato region by geese and swans, including the potential effects of these species on estuarine ecosystems. The focus of this review is on swans and geese:

- Population estimates, trends and distribution in the Waikato;
- Habitat utilisation, diet and feeding within Waikato estuaries; and
- Population management.

2 Literature review methodology

A systematic approach was used to search the relevant literature regarding geese and swans using Google Scholar and Google. The search included the key terms listed in 0. Results included peer-reviewed articles, technical reports, client reports, theses and websites (government, restoration groups, and press). The following databases were also accessed: New Zealand Birds Online, iNaturalist, and Ebird.

Fish & Game (F&G) supplied information on its annual goose and swan surveys in lakes, wetlands and estuaries of the western Waikato. F&G survey locations are listed in 0. These counts are carried out at known moult sites[4] during moult season and take place in the second or third week of January to coincide with a high tide event (David Klee 2019, pers. comm., 8 March). From a small aircraft two observers count all the birds within a given lake or estuary and the average of their counts is recorded. If necessary, photos are taken and birds are counted later from the photos. These counts have taken place annually since 1986, though geese are no longer a game bird, so will no longer be monitored.

Birds New Zealand (BNZ) provided information on the National Wader Censuses (2012-2017), which are carried out at key sites in both November-December and May-June annually. Raglan, Aotea and Kawhia estuaries are all surveyed as part of this census. The National Wader Census survey is carried out by volunteers working at ground level, repeatedly returning to the same

[4] Note that the term "moult site" refers to an entire lake or harbour, and does not describe a particular location within a given harbour.

high tide roosts (Andrew Styche 2019, pers. comm., 21 March). Other species are counted on the way to and from these roosts.

3 Findings

3.1 Population estimates

3.1.1 Geese

Goose numbers have increased rapidly in the North Island since they were reintroduced in 1970 and in 1997 there were estimated to be 8,000 geese in the North Island (Holloway et al. 1997). Williams (2013a) estimated that the total New Zealand population numbered 60,000, with most birds found in the South Island. F&G aerial counts of geese in western Waikato lakes, wetlands and estuaries began in 1986 when a total of 460 geese were counted, increasing to more than 10,000 in 2018 (**Figure 2.1**).

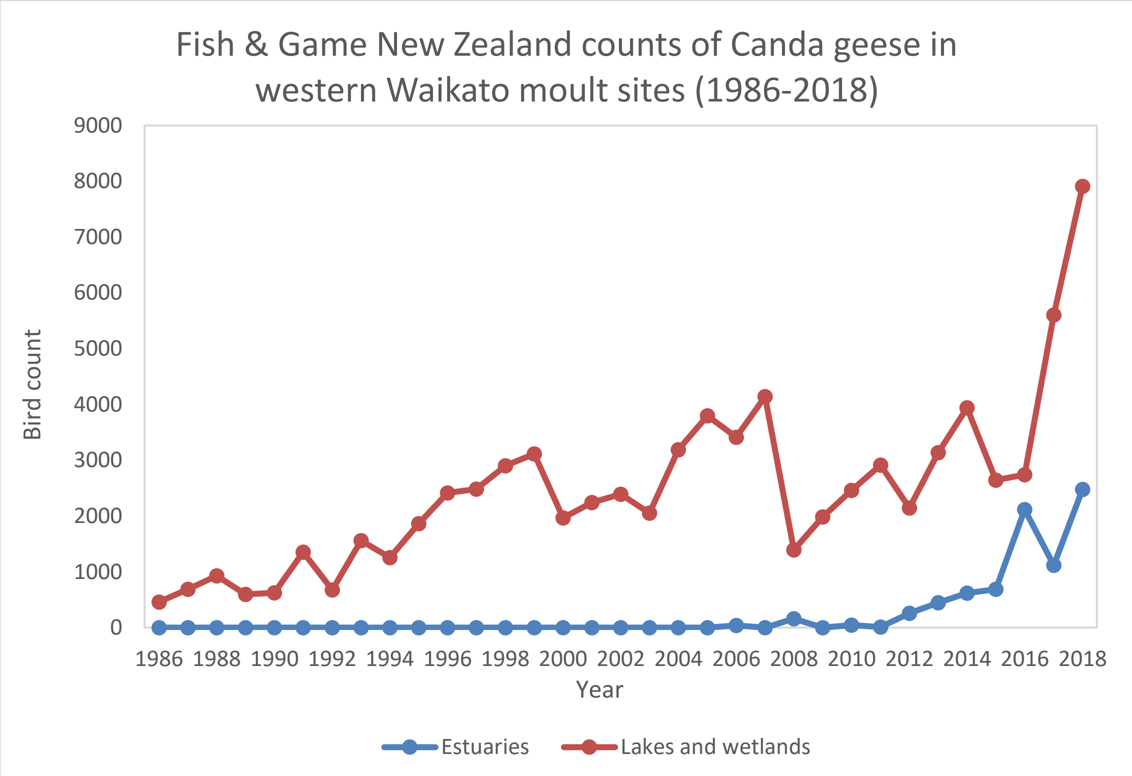

Figure 2.1: Fish & Game New Zealand counts of geese at moult sites in western Waikato harbours (Kawhia, Raglan and Aotea estuaries), lakes, and wetlands in January. Zero counts reflect an absence of birds. Data supplied by Fish & Game New Zealand. Survey locations are listed in 0 and survey methodology is described in Section 2.

Geese were not observed in estuaries during moult season until 2006 when 40 geese were observed in Kawhia Harbour. Geese were first detected in Raglan harbour in 2008 and Aotea in 2010. Since then, numbers have increased overall, although no geese were recorded at the moult site in Kawhia Harbour in January 2017 (Figure 2.2), despite an overall increase of geese in the western Waikato (see Figure 2.1). This absence may have been due to the extreme tide reported that day (David Klee and John Dyer 2019, pers. comm., 14 March) or due to weather conditions, for example geese are widely dispersed in wet years (Spurr & Coleman, 2005). However, geese do vary their laying dates depending on spring phenology (Clermont et al., 2018), which may limit the usefulness of these surveys.

BNZ data are highly variable, which may be an artefact of the methodology that only targets known roosts sites and birds seen on the way to and from these roosts. In this dataset "zero" records are ambiguous (Andrew Styche 2019, pers. Comm., March 21). However, high goose numbers are frequently present in Kawhia and Raglan in winter (**Figure 2.3**). Some observations of the BNZ data are as follows:

- In Raglan, high number of geese have been recorded at the Ponganui Estuary during winter counts with more than 400 recorded in the winters of 2012 and 2016, but fewer than 20 in summers, likely due to the migration of geese inland to breed. In Raglan during spring or summer counts there have generally been few goose observations (40 or fewer), except for 2016 when 114 geese were observed.
- Winter counts in Kawhia have been carried out at Oparau River and Ellis Point with 700 in winter 2012, 41 in winter 2014, 380 in winter 2016 (**Figure 2.3**), indicative of an overall drop in numbers. Numbers counted at Opeope Rocks in November have been few and stable between 2013 and 2017 with fewer than 20 birds counted each year. There has been an overall increase in swans counted on Te Motu Island in summer, although numbers have been declining since 2015. The maximum count at any site in Kawhia Harbour was 700 in winter 2012 and 696 in summer 2015.
- Few geese have been recorded at Aotea Harbour.

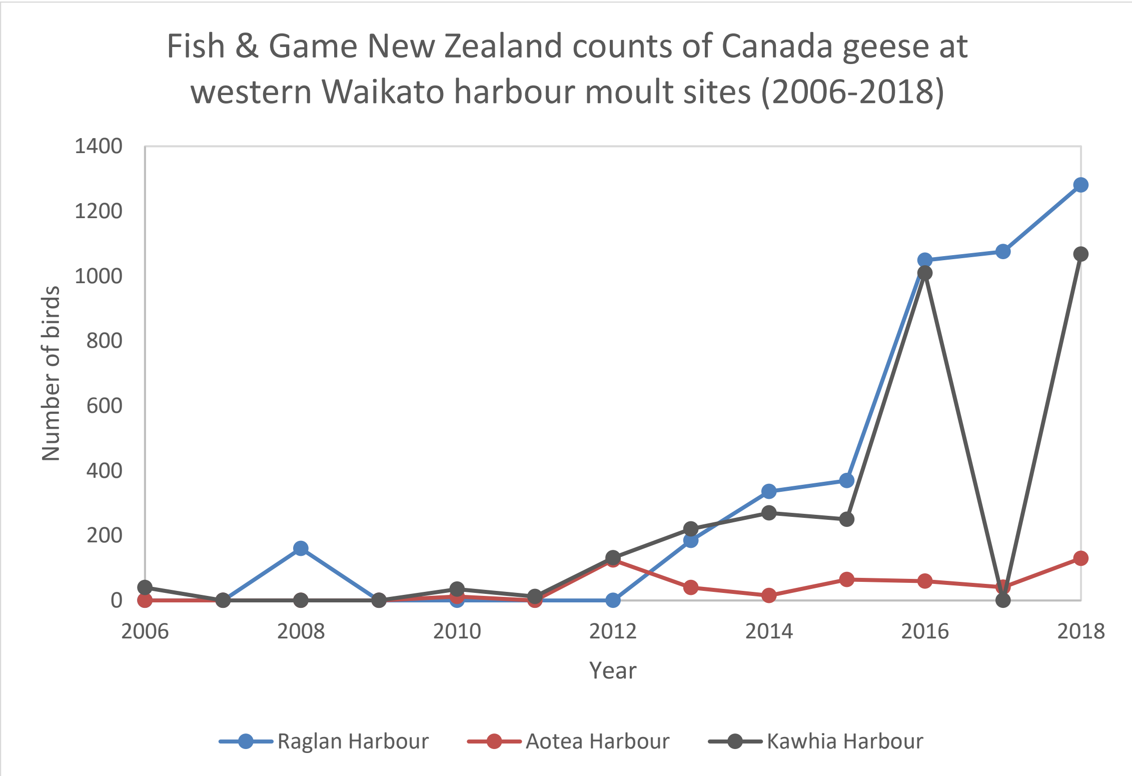

Figure 2.2: Fish & Game New Zealand counts of geese at western Waikato harbour moult sites in January. Note that surveys began in 1989 but no geese were detected until 2006. Zero counts reflect an absence of birds. Data supplied by Fish & Game New Zealand. Survey locations are listed in 0 and survey methodology is described in Section 2.

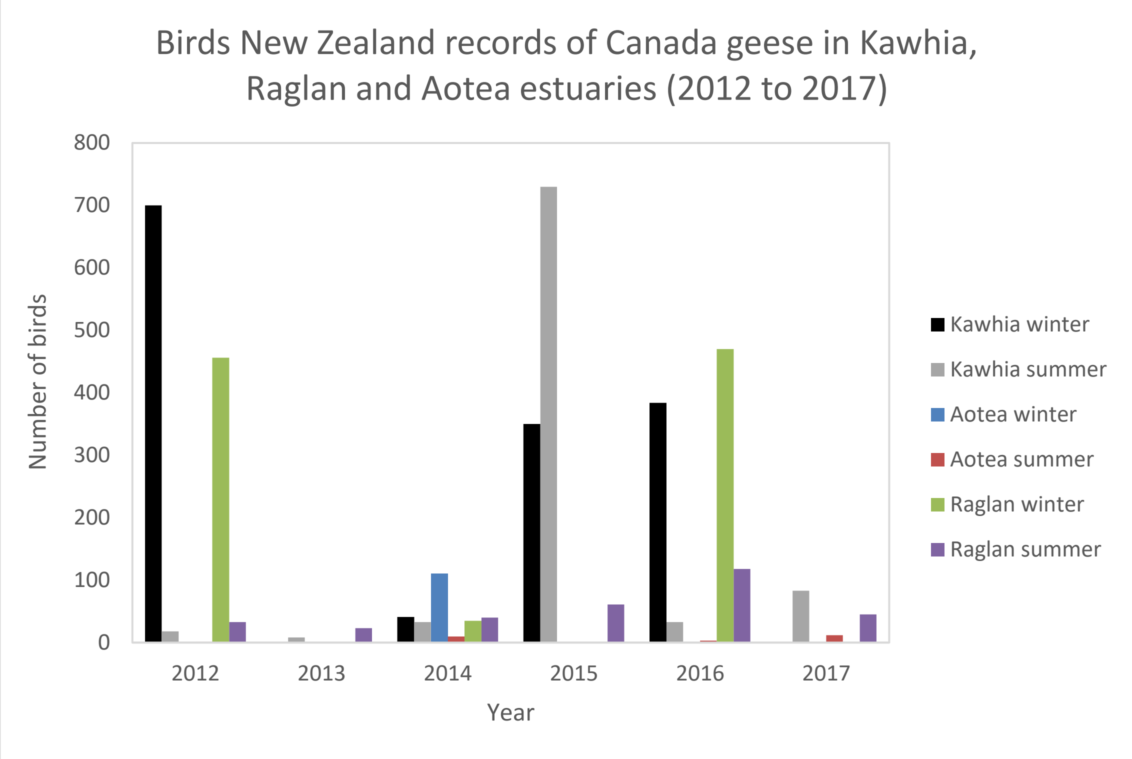

Figure 2.3: Birds New Zealand total goose counts in Kawhia, Raglan and Aotea estuaries in winter (June-July) and spring-summer (November-December). Zero counts are ambiguous and may indicate either a true count or the absence of a count. Data supplied by Birds New Zealand. Survey methodology is described in Section 2.

3.1.2 Swans

In 2006 the New Zealand swan population was estimated to be 60,000 (Fish & Game New Zealand, unpubl. data, cited in Williams et al., 2006) decreasing to 50,000 in 2011 (Williams, 2013b). Sagar et al., (1995) reported declines in swan numbers in the Waikato and other areas by 1995, which may have been the result of reduced food supply. For example, at Lake Whangape macrophyte collapse in the summer of 1978-1979 led to an almost complete exodus of swan from one year to the next (Ward et al., 1987). Swans continued to decline in western Waikato lakes and wetlands from a total of nearly 16,000 birds in 1986, to approximately 1,000 birds in 2009 when the population appears to have stabilised (**Figure 2.4**). In contrast, there has been a slight increase in swan numbers in Waikato estuaries (**Figure 2.4**), possibly due to migration from lake and wetland habitats into estuaries.

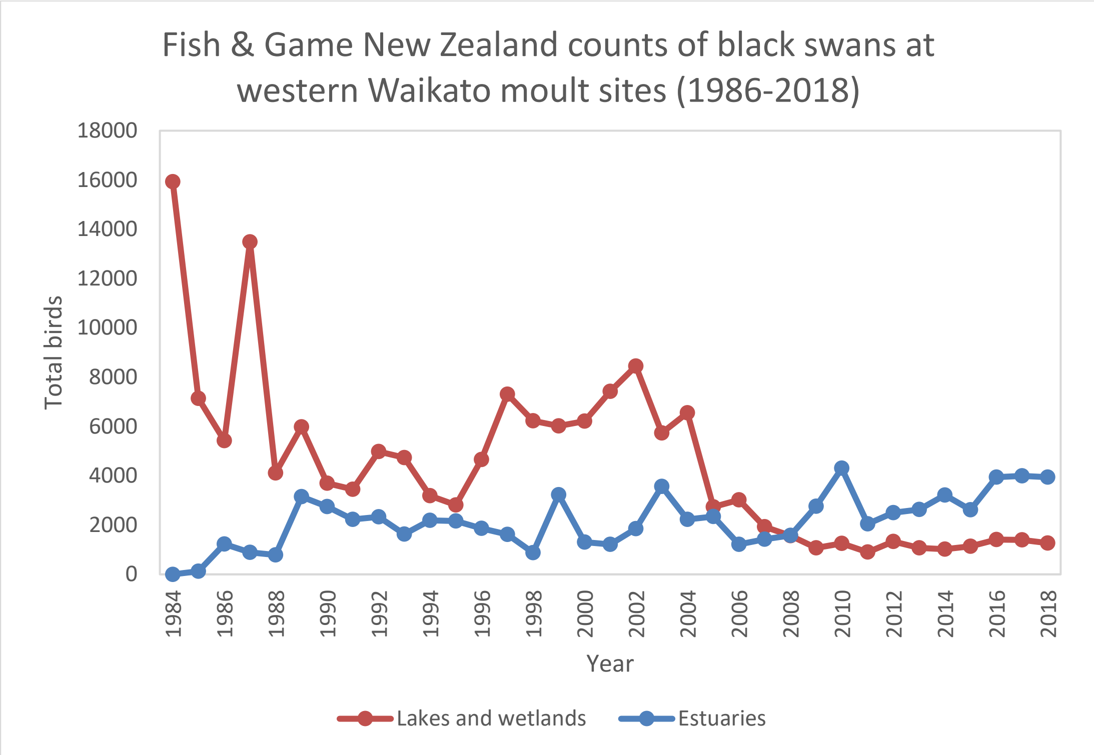

Figure 2.4: Fish & Game New Zealand counts of swans in western Waikato estuaries (Kawhia, Raglan and Aotea estuaries), lakes, and wetlands in January. Zero counts reflect an absence of birds. Data supplied by Fish & Game New Zealand. Survey locations are listed in 0 and survey methodology is described in Section 2.

Historical banding data has shown that swans are highly mobile at certain times of year and will move between different areas largely depending on food availability, and data suggests that swans at Kawhia and Aotea, along with Taharoa Lakes to the south, should be treated as a single population (David Klee 2019, pers. comm., 8 March). F&G aerial counts of swans in western Waikato lakes and estuaries began in 1984, and swans were first observed during moult season in estuaries in 1985 when 75 birds were observed in Kawhia Harbour and 53 in Aotea Harbour. The Kawhia-Aotea-Taharoa Lakes swan population has remained stable between 1985 and 2019, with an average size of approximately 3600 individuals (**Figure 2.5**). Swans were not detected in Raglan until 2002, and since then, count numbers have been relatively low (< 50), with no swans observed in approximately 50% of years (**Figure 2.6**). BNZ counts also show variable numbers of swans in Aotea and Kawhia in spring and summer, and few in winter (**Figure 2.7**), suggesting that swans use alternative habitats in winter and may move to smaller waterbodies for solitary winter nesting. BNZ results suggest that swans are uncommon in Raglan Harbour with four swans recorded in May 2012 at Okete, but none recorded during subsequent surveys.

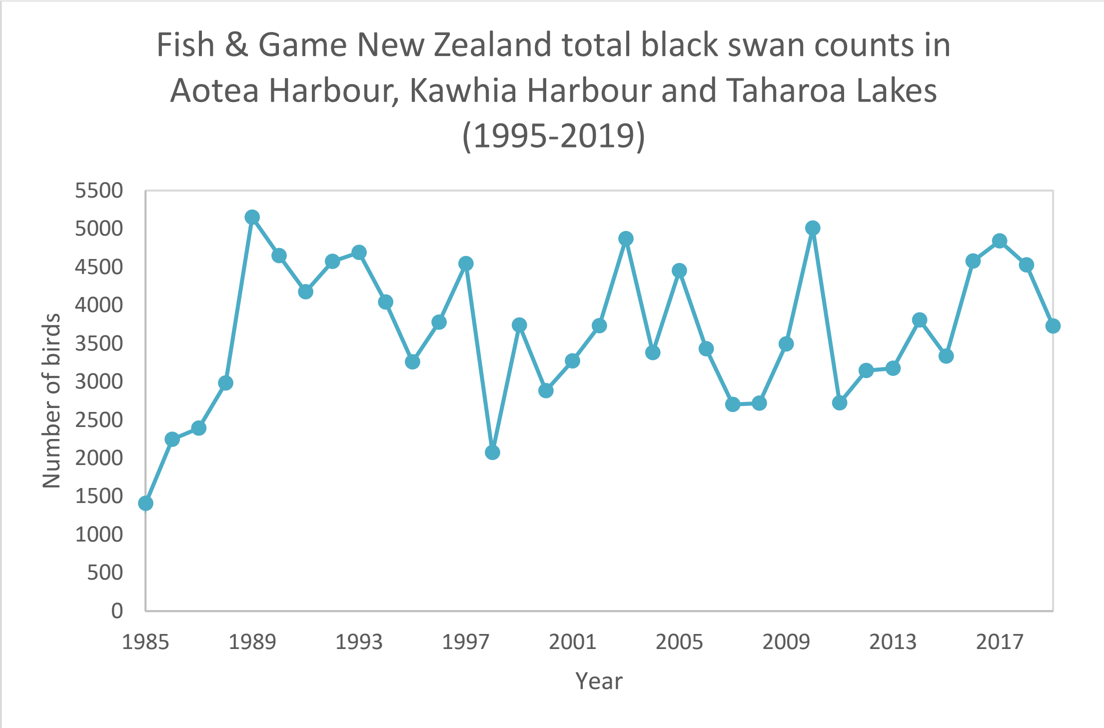

Figure 2.5: Combined counts of swans in Aotea Harbour, Kawhia Harbour and Taharoa Lakes between 1985 and 2019. Zero counts reflect an absence of birds. Data supplied by Fish & Game New Zealand. Survey locations are listed in 0 and survey methodology is described in Section 2.

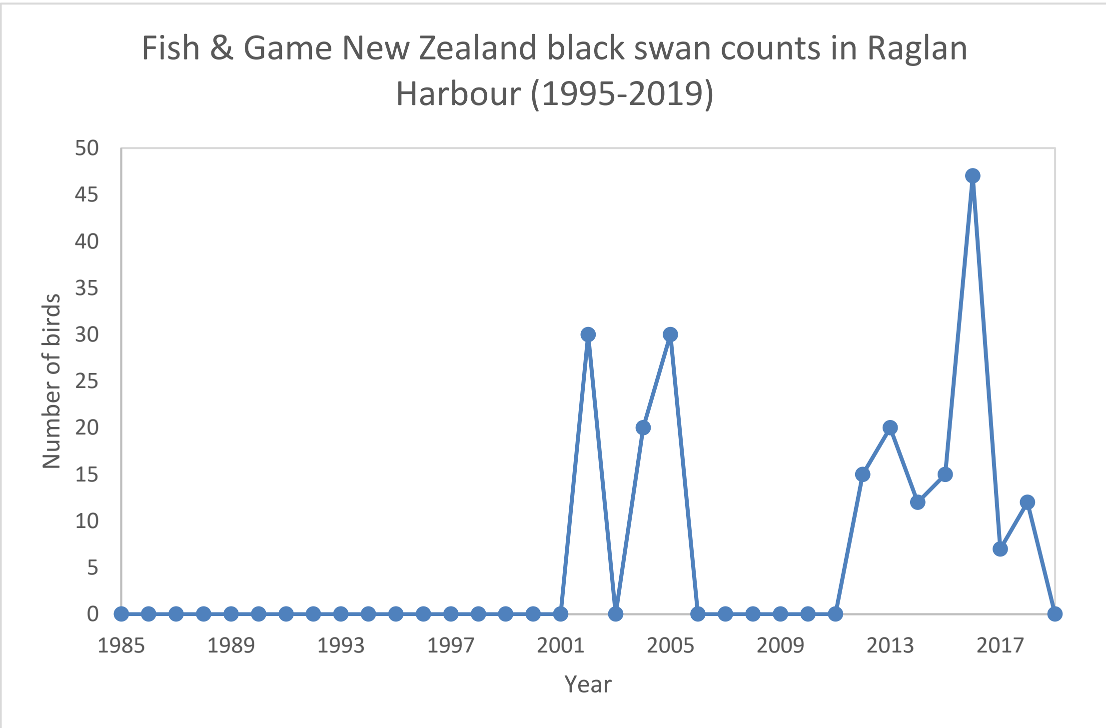

Figure 2.6: Counts of swans in Raglan Harbour between 1985 and 2019. Zero counts reflect an absence of birds. Data supplied by Fish & Game New Zealand. Survey locations are listed in 0 and survey methodology is described in Section 2.

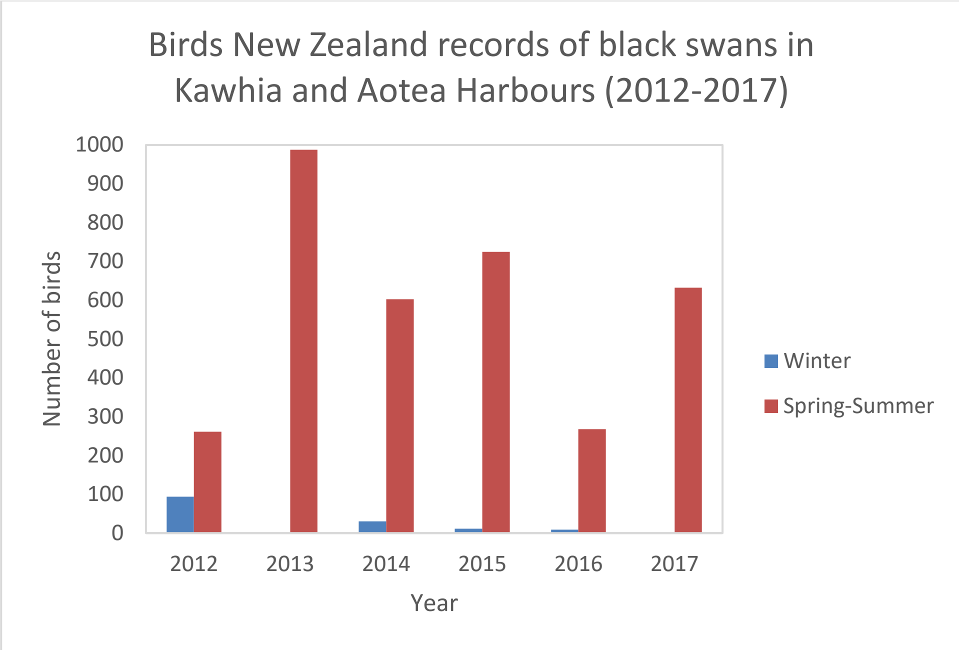

Figure 2.7: Total swans counted in Kawhia and Aotea estuaries in winter (June-July) and spring-summer (November-December). Zero counts are ambiguous a may indicate either a true count or the absence of a count. Data supplied by Birds New Zealand. Survey methodology is described in Section 2.

3.2 Habitat, diet and feeding

3.2.1 Geese

Geese are primarily grassland grazers (Williams et al., 2006). In North American estuaries they will consume a range of estuarine vegetation including marsh grasses (*Spartina*), rushes (*Juncus*), seagrass (*Zostera*), *Carex*, *Puccinella*, *Triglochin*, *Paspalum* and green algae, though the latter forms a small part of their diet (Dawe et al., 2011; Dawe et al., 2015; Buchsbaum & Valiela, 1987; Zacheis et al., 2001; Glazener, 1946). They are selective feeders and will avoid certain foods even if highly abundant (Buchsbaum & Valiela, 1987). They are known to affect both the biomass and composition of estuarine vegetation (Zacheis et al., 2001). On the Mersey Estuary in North West England, at the end of the moult season geese will spread widely throughout the marshes and travel several kilometres to find food, including nearby crops (Mersey Estuary Conservation Group 2019, accessed 8 March).

In some coastal areas in Europe and North America where there is little grassland or crops to feed on, Canada geese and other goose species (including brent geese, *Branta bernicla*) are dependent on seagrass beds, particularly in autumn and winter (Ganter 2000; Erskine 1997). This dependence is reflected in the fact that in various instances, the collapse of goose populations have coincided with seagrass collapse (Seymour et al., 2002). In New Zealand, geese have been observed feeding on seagrass in estuaries (Cade, 2016), but it is unknown what other estuarine vegetation is consumed by geese in New Zealand. In Kawhia Harbour, many geese were observed in the open areas of the harbour which coincides with the distribution of seagrass (see Figure 14 and 15 in Hillock & Rohan, 2011).

Little information is available on the feeding behaviour of geese in estuaries, but there are observations of brent geese behaviour, which like Canada geese also forage on seagrass (Jacobs et al., 1981; Erskine, 1997). In estuaries, brent geese are attracted to seagrass growing in high densities, particularly patches “situated in small depressions with some standing water, so that the leaves floated on the water surface” (Jacobs et al., 1981). Brent geese fed primarily through pecking at leaves in high density beds, and grubbing to remove whole plants, but were not observed digging for rhizomes (Jacobs et al., 1981; Fox, 1996). Observations by Jacob et al. (1981) of brent geese feeding on seagrass beds in the Netherlands showed that they arrived at seagrass beds approximately 50 min before the bed became completely exposed, or at first and last light when low water coincided with sunrise or sunset. Similarly, Canada geese forage during daylight hours and return to roost sites around the estuary margin in the evening, though they may continue to forage on moonlit nights (Mersey Estuary Conservation Group 2019, accessed 8 March). Brent geese prefer younger leaves so may leave some areas ungrazed (Thayer et al 1984).

3.2.2 Swans

Estuarine plants, such as sea lettuce and sea grass beds, are now an important year-round food source for swans given that many lowland lakes that formerly supported these birds are become eutrophic and no longer support aquatic macrophyte beds (Williams et al., 2006). Swans are now observed in most estuaries year round (Williams et al., 2006), although BNZ data suggests that few swans are present in western Waikato estuaries in winter (**Figure 2.7**). Swans forage across tidal flats and flock to seagrass beds to graze, particularly in summer and autumn (Matheson et al., 2009).

Swans are selective grazers. In estuaries, they forage on tidal flats feeding preferentially on dense patches of submerged species such as filamentous algae, sea lettuce and seagrass (Sagar et al., 1995; Dixon 2009). They are the only native shorebird species known to graze on seagrass (Matheson et al., 2009) and at various locations in the Tasman District, they are known to feed primarily on seagrass (Byrom & Davidson, 1992). Sagar et al. (1995) provide a list of aquatic plants eaten by swans in NZ (see their Table 1). In Kawhia Harbour, many swans were observed in the open areas of the harbour which coincides with the distribution of seagrass (see Figure 14 and 15 in Hillock & Rohan, 2011).

Swans graze mostly on seagrass in summer-autumn (Matheson et al., 2009). They feed in shallow water in a tide-dependent manner (Battley et al. 2005; Dos Santos et al., 2012), preferring to feed when their food plants and the birds are floating, and less so when it is exposed and they have to pick it off the substrate (Williams et al., 2006). Thus they tend to actively forage during the intertidal period and roost during high and low tides, and, unlike geese, they continue this pattern through the night (Dixon, 2009). Swans create devegetated patches averaging 0.3m^2 in size (Dos Santos et al., 2012).

Swans feed on all parts of seagrass by cropping leaves, uprooting plants and grubbing for rhizomes (Byrom & Davidson, 1992; Turner & Schwarz 2006; Dixon, 2009). They remove nearly all the shoots and rhizomes but only about a quarter of the roots (Dos Santos et al., 2012). The feeding rate of swans is approximately 0.25kg fresh plant per kg swan body weight per day (Sagar et al., 1995). Swans may have a greater impact on estuarine vegetation than geese as their longer necks allow access more deeply submerged vegetation.

Swans are exclusively herbivorous, though they do accidentally eat small animals while foraging (Sagar et al., 1995). In Kawhia Harbour, locals have suggested that swans are eating juvenile fish, with media reporting that a swan from Kawhia Harbour was found to contain more than 80 juvenile flounder (Calder, 2018). F&G suspect that the ‘juvenile flounder’ have been misidentified are actually liver flukes observed from disembowelled carcasses, as these are common in swans. F&G is interested in carrying out swan dietary studies to determine the identity of these organisms (David Klee 2019, pers. comm., 8 March).

3.3 Ecological effects of swans and geese

3.3.1 Water quality

Eutrophication of estuaries can result in the proliferation of phytoplankton, macroalgae or algal epiphytes. This can lead to a reduction in the amount of photosynthetically available radiation available to seagrass (Turner & Schwarz 2006). Waterfowl contribute to eutrophication of waterbodies through the deposition of faecal matter (see Rönicke et al., 2008). Modelling by

Bowen and Valiela (2004) showed that unless waterfowl are present in estuaries year-round at very high densities, they are unlikely to be a significant source of nutrients.. Raffaelli (1999) calculated that daily nitrogen and phosphorus inputs from grey geese were extremely low and of limited availability to primary producers. Furthermore, goose faecal material settles quickly to the sediment, making the nutrients unavailable unless disturbed by seasonal or man-made mixing (Unckless & Makarewicz, 2007).

The extent of nutrient enrichment depends on many factors, such as bird size and flush time of waterbody, and in some cases there may be no adverse effect. Nutrient inputs from swans and geese may have a greater impact on parts of Kawhia and Raglan esutaries (i.e. the tidal creeks in the upper parts of these estuaries) as they have longer flushing times than Aotea Harbour (Greer et al., 2016). Waterfowl may also contribute to reductions in water quality through increased turbidity associated with feeding behaviour (Turner & Schwarz 2006).

3.3.2 Changes to estuarine vegetation through feeding behaviour

Grazing waterfowl can have a big impact on estuarine vegetation structure and biomass. Geese have significant negative impacts on intertidal marshes through selective grazing and trampling (Dawe 2015), resulting in vegetation homogeneity and the disappearance of above-ground parts of plants (Jacobs et al. 1981). Studies on migratory geese in the Northern hemisphere have shown that they can remove up to 98 percent of seagrass biomass, which recovers slowly or cannot fully recover, depending on the damage (Rivers & Short 2007). A decline in estuarine vegetation may leave areas vulnerable to weed invasion, which may then be exacerbated by selective feeding (Sagar et al., 1995).

Likewise, swans have large effects on seagrass biomass; Dos Santos et al. (2012) observed a substantial decline in seagrass biomass at sites intensely grazed by swans in the Tauranga Harbour. Seagrass recovery following swan grazing depends on grazing intensity: low grazing (40% removal) has little effect on biomass a year later, whereas high intensity (~100% removal) takes 2 to 4 years to recover (Dos Santos et al., 2013).

The feeding behaviour of waterfowl can cause bioturbation, which can may also impact seagrass by slowing down spread and colonisation by reducing light availability and by smothering beds (Turner & Schwarz 2006). However in some ecosystems, trampling and digging by geese appears to be important for the persistence of seagrass (Nacken and Reise 2000). Herbivorous birds can also significantly reduce invertebrate biomass in salt marshes and seagrass meadows through habitat changes (Bakker et al., 2016).

The effects of waterfowl on estuarine vegetation likely depends on bird densities, and may have no negative impact in some ecosystems (Beemster & Klop, 2013), for example grazing has been shown to have sometimes had positive effects on seagrass regeneration, with increased growth, density and biomass following grazing (e.g. Ferson 2007). There is likely to be more grazing pressure on seagrass if birds are remaining in the estuary year-round; however, the negative effects of salinity on goslings may help to regulate goose populations (Stolley et al., 1999)

3.3.3 Effects on indigenous birds

Geese and swans carry a number of pathogens including avian influenza, *Campylobacter*, *Escherichia coli*, *Salmonella,* toxoplasmosis, aspergillosis and botulism (Clark, 2003; Buij et al., 2017; Coleman, 2006; Moriarty et al., 2011; Verma et al., 2016; Harris et al., 2010). They also host various parasites and diseases of indigenous waterfowl (e.g. grey duck, paradise shelduck, shoveler, and scaup) and so may act as reservoirs of disease (Tompkins & Poulin, 2006).

Swans co-occur consistently and in large numbers with migrant waders; however their feeding activities are potentially temporally and spatially separated (Williams et al., 2006). Contact between swans and migratory waders may result in the spread of pathogens between estuarine and freshwater habitats. During breeding season, geese can be aggressive towards other animals and are known kill other birds (Krauss & Salame, 2012).

Although swans restrict habitat for wading birds (Coleman, 2006), they are unlikely to directly compete with indigenous New Zealand birds for food as swans are the only native birds that feed on aquatic estuarine plants such as seagrass (Matheson et al., 2009). They may, however, indirectly impact other birds by reducing seagrass density and thus reducing invertebrate abundance (Battley et al., 2005).

3.3.4 Dispersal of plants and invertebrates

Many plants and invertebrates are transported through ingestion by or attachment to waterfowl (Reynolds et al., 2015). Brent geese have been shown to carry seeds (with and without adhesive structures) on their feet or feathers (Vivian-Smith & Stiles, 1994). Geese species may be responsible for the dispersal of the pondweed *Potamogeton praelongus* in northern Europe (Bennike & Anderson, 1998); however, seeds of salt-marsh vegetation carried in the gut of brent geese are two orders of magnitude less likely to germinate than tide-dispersed undigested seeds (Chang et al. 2005). Experimental studies on seed dispersal by greylag geese (*Anser anser*) showed that the proportion of seeds retrieved intact varied significantly between plants, but was higher for plants with larger seeds (García-Álvarez et al,. 2015). Greylag geese have been shown to disperse bryozoans (Figuerola et al., 2004) and may be vectors of other zooplankton (Haileselasie et al., 2016).

In America, Canada Geese are known to graze on *Spartina* (e.g. Grosholz & Blake 2004), some species of which are invasive weeds of New Zealand harbours. While *Spartina* is much reduced in Waikato harbours (Alastair Fairweather 2019, pers. comm., May 21), geese feeding on *Spartina* could potentially uproot plants resulting in plants and rhizome fragments being spread by tidal action.

3.4 Population management

Various methods have been implemented to control swan and goose populations around the world. These methods focus on either killing adults, reducing reproductive success, or physically isolating birds from a given habitat or food source. Population control methods and their advantages/disadvantages, are summarised in **Table 2.1**.

Table 2.1: Methods for controlling swan and goose populations

Control type and method	Advantage	Disadvantage	References
• Reduce reproductive success through: • Egg destruction by smashing • Egg destruction by oiling, injecting or puncturing • Reproductive control by medical or surgical sterilisation	• Less controversial than killing birds • Smashing and puncturing can be carried out without specialist skills (i.e. need for firearms licence)	• If eggs are smashed, birds are likely to lay a new clutch • Does not reduce the adult population size • Labour intensive • Medical sterilisation can require the ongoing feeding of birds • Medical sterilisation may affect other birds if other species eat the medicated food source	Wood et al., 2013; Fox et al., 2017; Spurr & Coleman, 2005; Allan et al., 1995; Hindman et al., 2014
• Killing of adults through: • Hunting • Culls during moult season when birds are flightless • Shooting from helicopters • Baits to sedate then kill	• Targets adults so can reduce population size • Hunting and culling are relatively inexpensive • At the right dose, sedation is humane	• Hunting alone may be insufficient to control population size • Negative public perception • Learned aversion to helicopters and cull areas • Methods that leave birds mortally wounded are inhumane • Incorrect dose of sedative can lead to inhumane death or escape • Sedative can affect other birds through feeding, and secondary poisoning in cats and dogs • Sedative used near water can result in drowning	Hughes et al., 1999; Spurr & Coleman, 2005; Allan et al., 1995; Balkcom, 2010; Ellis & Elphick 2007; Woronecki et al., 1990; Neilson 1993; Soulsby 1993.
• Physical isolation of individuals from habitats/food sources through: • Scaring and harassment • Repellents • Sacrificial crops and diversionary feeding	• Can be carried out incidentally by the public • Less controversial than killing	• Birds can simply relocate • Birds can become habituated • Can be expensive • Does not reduce population size • Repellents are available for seedlings and non-food crops only • May create conflict with landowners	Spurr & Coleman, 2005; Sagar et al., 1995; Allan et al., 1995; Fox et al., 2017; Steen et al., 2014

3.4.1 Reducing reproductive success

In modelled and real world scenarios, reducing reproductive success of mute swans in Europe has failed to achieve desired reductions in population size (Wood et al., 2013, Fox et al., 2017). This has been attributed to the high survival probabilities of existing birds and immigration from other catchments. Modelling by Ellis & Elphick (2007) showed that for mute swans the most efficient control method in terms of effectiveness and cost was initial intensive adult culls. Likewise, the lethal control of adult geese, particularly of nesting females, was found to be the most effective way to reduce goose populations, and up to four times more effective than egg destruction (Coluccy et al. 2004; Hughes et al., 1999).

3.4.2 Physical isolation of individuals from habitats/food sources

Scaring was carried out in New Zealand between the 1930s and 1960s to shift geese off farms, but is no longer used as it simply shifts birds to a new farm or results in habituation (Spurr & Coleman, 2005). Scaring, however, may be useful to divert waterfowl away from sensitive ecological areas and is used as part of integrated management strategies (e.g. Nichols, 2014). Other disturbance methods include the use of flags, lasers, pyrotechnics, strobe lights, sirens and recorded distress calls (Fox et al., 2017) and technology has been developed to allow specific and automatic scaring (e.g. Steen et al., 2014). A diversionary feeding trial of geese was attempted in New Zealand in order to lure geese away from farmland; however this method was not pursued due to costs (see Spurr & Coleman, 2005).

3.4.3 Lethal control of adults

In New Zealand, most control of swans and geese has been targeted killing of adults. Various geese culls have been carried out in New Zealand since the 1950s, with most taking place since the 1980s. These culls have involved culling moulting birds, shooting birds from helicopters and shooting nesting birds on the ground. Moult culls, which involve rounding up geese then killing them, are regularly carried out around the country, are approved by MPI and the SPCA (Spurr & Coleman, 2005). Swan culls began around 1970 when a reduction in food supply led to a higher presence of swans grazing on farmland (Sagar et al., 1995). Regular culls and organised hunts are now carried out around the country, including at Tauranga Harbour and Lake Wairarapa. These culls are controversial, particularly when birds are left mortally wounded (e.g. Cousins, 2013).

Humane culls are likely to have the greatest impact on population sizes of these birds (see Section 3.4.1), and may be more effective when applied in conjunction with other methods (Sagar et al. 1995; Nichols, 2014). For example, a ten year integrated damage management program to reduce goose herbivory in the Maurice River estuary in the USA resulted in a 70% decline in nests (Nichols, 2014). This approach, which combined shooting, puncturing eggs, harassing birds and euthanizing moulting geese, was initially intensive (200 per hours per season) but dropped dramatically in the fourth year (to 80 hours per season) and in the eight year down to 1 to 2 days each spring.

In the early 1990s, the Minister of Conservation recommended that Fish & Game Councils consider trialling the use of chemicals to control Canada Geese (Neilson 1993, unpublished report). A trial conducted in the Styx Basin in central Otago using barley laced with alphachloralose resulted in a number of non-target species being poisoned (Soulsby, 1993). This result, along with the availability of easier control tools and the potential for misuse by "persons wishing to illegally control waterfowl numbers" may have precluded further investigations into the use of chemical controls. Note that Spurr & Coleman (2005) report that using alphachloralose is an 'approved method of goose control'; however, alphachloralose has never been registered in NZ for the control of Canada geese.

3.4.4 Coordination

Clarey (2009) advises that effective control of geese will require national coordination. This recommendation is based on the extent, mobility, and wariness of the species, and thus likely also applies to swans, which are considered a “single national mobile population unit” (Sagar et al. 1995).

4 Conclusions and recommendations

Swans and geese are present in large numbers in the Waikato and may be having a negative impact on western Waikato estuaries.

Moult season surveys in the western Waikato show that swans have declined to approximately 5,000 birds, only a third of the 1984 swan population; however, approximately 80% of this population resides in estuarine habitats during moult season. The population now appears to be relatively stable, though numbers do fluctuate between years. Use of estuarine habitats by swans is variable between years, and it is not clear whether swan numbers are increasing, though swans may be preferentially using estuarine habitats as lake and wetland habitats decline. Further surveys are required to understand whether swan numbers are increasing in estuaries, and whether this is associated with declines in lake and wetland habitats.

Moulting season surveys in the western Waikato show that goose numbers have increased over the past 30 years by a factor of 20 to approximately 10,000 birds. Geese began appearing in estuaries in moult season in 2006 and numbers fluctuate between years but are increasing overall. Approximately 25% of the population was using Aotea, Raglan and Kawhia estuaries during the 2018 moult season survey.

These waterfowl have various potential ecological effects, the most significant of which is damage to seagrass, a key biogenic habitat provider that has been declining over the last 50 years. Swans are known to feed primarily on seagrass in some areas and have been shown to cause significant damage to seagrass beds. Geese also feed on seagrass and are known to cause significant damage to estuarine vegetation; however it is unknown whether geese feed primarily on seagrass in New Zealand estuaries. Goose feeding behaviour in estuaries is currently under investigation by Waikato Regional Council and the University of Waikato (Michael Townsend 2019, pers. comm., 24 May). Swans and geese may also negatively affect seagrass through trampling, increased turbidity and eutrophication via deposition of faecal matter; however, evidence to support this is currently lacking and further investigations are required.. To determine whether swans and geese are a significant source of nutrient enrichment, their nutrient contribution would need to be determined. This can be calculated based on parameters such as population size and estuary flushing times (see Raffealli 1999; Sagar et al. 1995). Other potential ecological impacts include changes to other estuarine vegetation, disease transmission, propagule transport and aggression towards other birds.

If further investigation confirms the negative ecological effects of swans and geese, then management options should to be considered. These birds can be managed via an integrated approach focused primarily on reducing the adult population. Humane moult season culls applied in conjunction with other methods, such as reproductive control and scaring techniques, are likely to have the greatest impact on population sizes of these birds. Given the mobile nature of these species, management would need to be nationally coordinated. Without effective coordination, vacated habitats would probably be quickly be recolonised by remaining populations.

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Appendix A: Key search terms

Canada geese estuary New Zealand
Black swan estuary New Zealand
Canada geese estuary Waikato
Black swan estuary Waikato
Canada geese ecology
Black swan ecology
Diet black swan
Diet Canada goose
Waterfowl grazing new Zealand
Waterfowl grazing
Seagrasses New Zealand grazing
Seagrass grazers New Zealand indigenous birds
Branta canadensis avian influenza
Cygnus atratus avian influenza
Cygnus atratus parasites
Branta canadensis parasites
Goose population management
Swan population management
Black swan behaviour
Canada goose behaviour
Miranda Canada goose bird
Canada goose avian botulism
Avian botulism New Zealand
Canada geese breeding Waikato
Canada goose diet salt marsh
Canada goose diet estuary
Geese estuary water quality
Canada geese cull
Black swan cull
Feeding behaviour Canada geese
Goose feeding bioturbation
Swan feeding bioturbation
Canada goose eutrophication
Canada goose water quality
Black swan eutrophication
Black swan water quality

Appendix B: Lakes and estuaries of the western Waikato surveyed annually for black swans and Canada geese by Fish & Game New Zealand

Lake Rotokauri
Horsham Down Lake E
Horsham Down Lake A
Horsham Down Lake B
Horsham Down Lake C
Horsham Down Lake D
Lake Areare
Lake Pikopiko
Lake Hotoananga
Lake Hakanoa
Lake Kimihia
Lake Ohinewai
Lake Rotokawau
Lake Rangiriri
Opuatia Lower Wetland
Lake Whangape
Lake Waikare
Lake Rotongaro
Lake Little Rotongaro
Lake Okowhao
Lake Waahi
Raglan Harbour
Aotea Harbour
Kawhia Harbour
Taharoa Lakes