A merganser at Auckland Islands, New Zealand

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Dedicated to the late Janet Kear, a friend and colleague from afar, whose lifetime work enriched our knowledge and enjoyment of the world's waterfowl.

Abstract

The last population of the merganser *Mergus australis* persisted at Auckland Islands in New Zealand's Subantarctic until its extermination by specimen collectors in 1902. It is now represented by four duckling specimens, 23 skins of immatures and adults, three skeletons, and a partial cadaver stored in 11 museums. It was the smallest known *Mergus,* the males weighing *c.* 660 g and showing little plumage dimorphism from the smaller (*c.* 530 g) females. Only five published accounts report first-hand observations of its ecology, breeding or distribution. Most likely it occurred as year-round territorial pairs in the larger streams and along the coastal edge at the heads of Auckland Island's eastern inlets and in Carnley Harbour and fed on both marine and fresh water foods. Its population probably never exceeded 20–30 pairs. The scant records suggest it had a typical summer breeding season. Although its keel area and wing skeleton were reduced relative to its sternum length it was well capable of flapping flight.

Key words: Auckland Islands, Auckland Islands Merganser, *Mergus australis*.

A merganser (Family Anatidae, Tribe Mergini) once inhabited the Auckland Islands archipelago, 450 km south of New Zealand in the subantarctic Southern Ocean (Fig. 1). When Polynesians first settled New Zealand in the late 13th Century, mergansers were also present in New Zealand (North, South and Stewart Islands) and at Chatham Island 800 km to New Zealand's east (Holdaway *et al.* 2001; Worthy & Holdaway 2002). It was from Auckland Islands that the first specimen, in 1840 (Hombron & Jacquinot 1841), and the last, in 1902 (Alexander 1902; Ogilvie-Grant 1905) was obtained, Polynesians having earlier extirpated the New Zealand and Chatham Island populations. This biogeographic oddity, a merganser in New Zealand's waters, is today represented by 27 skins and bones thereof from Auckland Islands (Kear & Scarlett 1970; Kear 2005a) and a small but increasing collection of bones from midden and natural deposits from the other two populations (Worthy 1998a,b, 2004; Millener 1999).

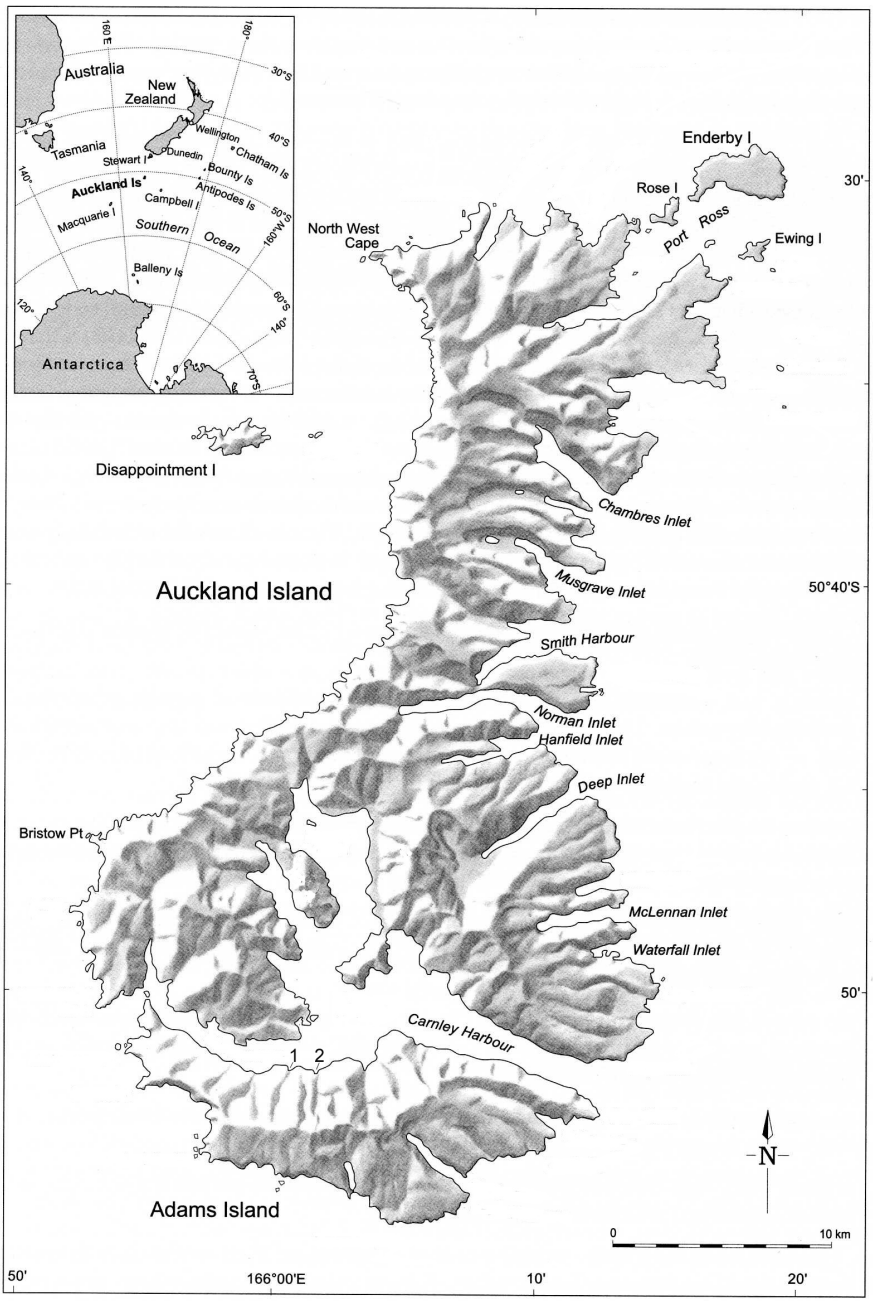


Figure 1. The Auckland Islands showing locations referred to in the text. 1= Magnetic Bay, 2 = Maclaren Bay.

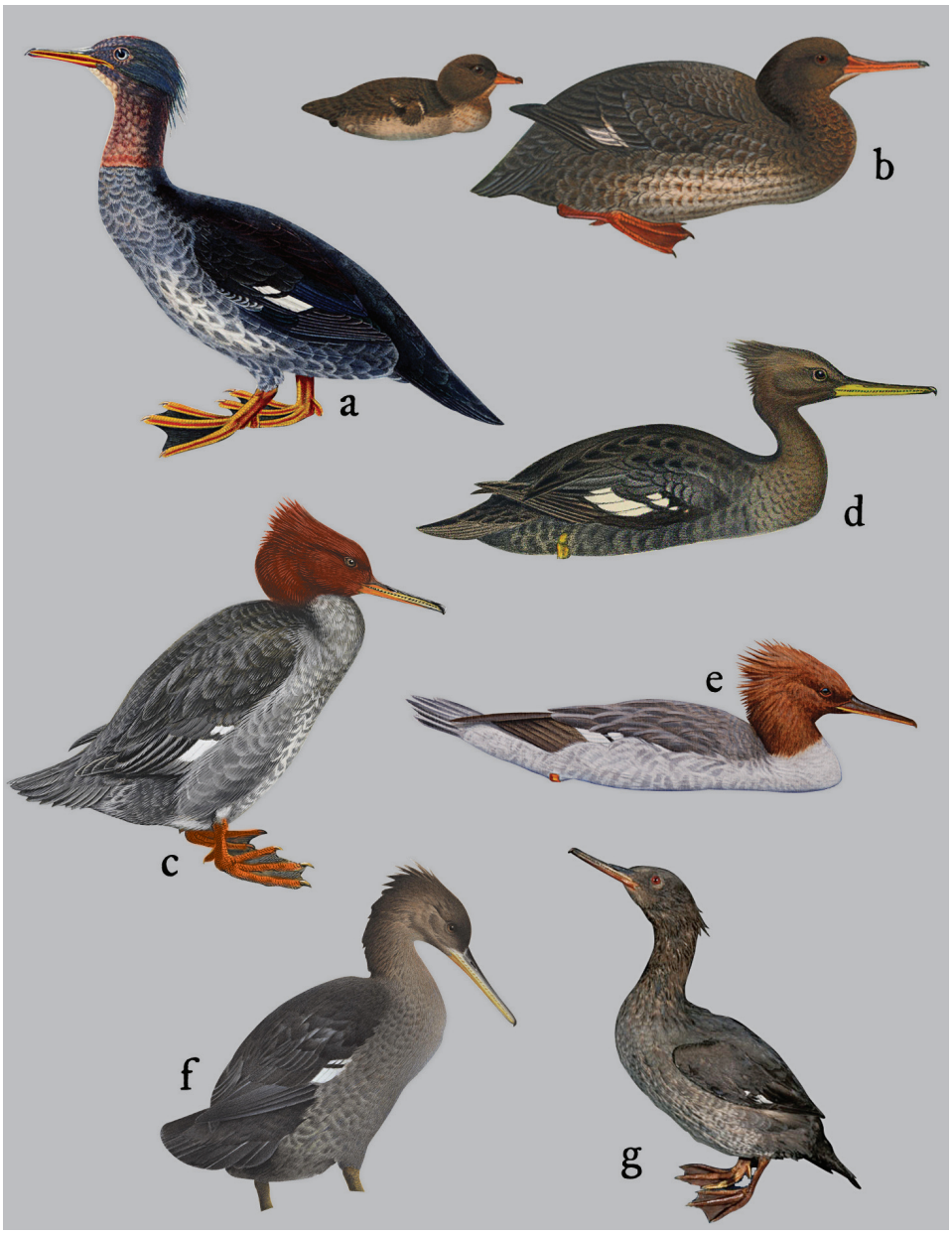
In this paper I review, and where appropriate reappraise, existing knowledge of *Mergus australis* at Auckland Islands, a bird commonly referred to as Auckland Island(s) Merganser (*e.g.* Buller 1882, 1905; Hutton & Drummond 1905; Kear & Scarlett 1970; Kear 2005a; Young & Kear 2006) but also as Southern Merganser (Tennyson & Martinson 2006) and New Zealand Merganser (Gill 2010). Scattered historical accounts and documentation of this merganser were assembled by Kear & Scarlett (1970) to provide a first synthesis. Livezey (1989) added an appraisal of its phylogenetic relationships and of its flightedness. These two publications provide the only substantive accounts of *M. australis* to date and have been the sources for all subsequent accounts (*e.g.* Marchant & Higgins 1990; Kear 2005a; Tennyson & Martinson 2006), much as Buller's (1905) account was the source for early treatises (*e.g.* Phillips 1926; Mathews 1936; Delacour 1959).

Since Kear & Scarlett's synthesis, a further skin has been reported in a museum collection (Sigwart *et al.* 2004, 2005), a partial skeleton reported (but erroneously identified; see Appendix 1) from Lyon, France (Wood *et al.* 1982), bones attributed to mergansers have been located at further sites on New Zealand's main islands (Worthy 1998a,b, 2004; Worthy & Holdaway 2002), and the smaller sizes of bones found in abundance in a cave on Chatham Island prompted Millener (1999) to suggest they may constitute a separate taxon. Morphometric distinctions between the three New Zealand Merganser populations await appraisal.

Description of plumage and soft parts

Kear & Scarlett (1970) described the plumages and soft-parts of the adult, immature and duckling. The adult description was compiled from the authors' examinations of three skins in Canterbury Museum, Christchurch, New Zealand (CM) (see Appendix 1), six skins in the (British) Natural History Museum, Tring, England (NHM), and one skin in the Cambridge University Museum, Cambridge, England (J. Kear pers. comm.).

Their description was warranted because the original description (Hombron & Jacquinot 1841) had not been referred to in any publication other than in passing by von Hugel (1875), and most subsequent descriptions, commencing with Buller (1882, 1905), have been incremental modifications and abbreviations either of von Hugel's or of Buller's and have ignored Mathews' (1936) substantive re-description (based on specimens NHM 1901.10.21.57 and NHM 1901.10.21.58). Similarly, minor changes from the initial depiction (Hombron & Jacquinot 1853) have resulted in portrayals with plumage and soft part colourations that differ from original descriptions (*e.g.* Mathews 1936; Shirihai & Jarrett 2002; del Hoyo *et al.* 2002; Tennyson & Martinson 2006), and in the idiom of merganser species familiar to the artists (*e.g.* Fleming 1982). Some are more fanciful (*e.g.* Flannery & Schouten 2001). Depictions based on freshly collected specimens (*e.g.* Hombron & Jacquinot 1853; Buller 1905; Fleming 1982) best capture soft part and head colouration. A composite of some historic and contemporary illustrations is presented in Colour Plate 1.



Colour plate 1. Historic and contemporary depictions of *Mergus australis* from: a) Hombron & Jacquinot 1853; b) Buller 1905; c) Fleming 1982; d) Mathews 1936; e) Shirihai & Jarrett 2002; f) Tennyson & Martinson 2006; g) photograph of Otago Museum mount AV1110 (Rod Morris).

Kear & Scarlett (1970) did not discriminate the ages of the specimens they examined and, because some were newly-fledged young, their account is amended in the descriptions below.

Adult

Sexes alike but males are larger and have a longer head crest. Head, crest and neck dark brown, chin and throat a lighter brown. Crown and throat more rust-brown in male. Mantle, scapulars, back, rump and tail very dark brownish-black. Rust colouration of throat may descend onto upper breast (further in the male than female; Hutton 1901a). Entire ventral surface a dull grey liberally streaked brown to present an overall browny-mottled appearance (males paler on abdomen; Hutton 1901a); flanks are uniform dark brown. Wing coverts slate grey, like the sides of the breast, with the lower row darker and banded white. Middle secondaries white on the outer web and black on the inner web and tips. Primaries and inner secondaries blackish. Males have white sub-terminally on the outer web of 3–4 greater coverts to give the impression they have two white wing bars (Falla 1970). Underwing mottled and axillaries white.

Iris dark brown, culmen and tip of lower mandible black; cutting edge of upper mandible and rest of lower mandible yellowish-orange; legs and feet orange; webs, joints and soles dusky. This description of eye and soft parts is as written in F.W. Hutton's hand on the label of an adult female specimen (NHM 1901.10.21.58) and it is repeated on the label of the companion male specimen NHM 1901.10.21.57 (Appendix 1). The label to specimen NHM 1904.8.4.1, a female collected in July 1901 (mid winter), reads "Iris brown. Bill black on top, red underneath. Legs and feet light red".

Immature

This description is of birds newly-fledged and identified as such by a terminal notch in the rectrices or the persistence of the down feather stalk extending from the tip of the rachis (Larson & Taber 1980).

Sexes alike. Uniformly dark brownish-black on head, neck and throat. Entire dorsal surface, including rump and upper wing, dark grey. Entire ventral surface heavily mottled grey-brown. Developing head crest apparent.

Two specimens collected in July 1901 (NHM 1904.8.4.1; NHM 1902.8.6.1) whose rectrices have terminal notches, show a much darker dorsal surface, obvious rufous on head and throat and conspicuously elongated crest feathers. I interpret these as having undergone a post-juvenile body moult.

The dried legs of immature specimens indicate they were a reddish colour.

Duckling

Description taken from specimen CM AV1581 (Appendix 1). Dark brown-black above with only a trace of pale wing, scapular and dorsal rump spots. Chin, throat and upper breast rusty brown with a spot of chestnut beneath the eye (this chestnut may represent fading of a darker plumage). Remaining underparts yellowish-white. Bill, legs and feet dark olive-brown.

These descriptions indicate that *M. australis,* like the Brazilian Merganser *Mergus*

octosetaceus, had little sexual dimorphism in plumage and the adult nuptial plumage was only a slight enhancement of the juvenile plumage. The patterns of the downy young were similar to all other mergansers but the uniformly dark appearance was most similar to *M. octosetaceus*.

Variation in body size

A size disparity between males and females occurs in all extant mergansers (Appendix 2). In general, female bills are approximately 10% shorter, their wings 6–10% shorter, and their weights approximately 15–20% less than males and these disparities are greatest in the three larger mergansers (Red-breasted Merganser *Mergus serrator,* Goosander *Mergus merganser,* Scaly-sided Merganser *Mergus squamatus*).

Two sets of standard measurements of *M. australis* skins have been compiled, by Livezey (1989) and this study. Neither set includes all skins. Livezey's 15 specimens included those in Otago, Museum of New Zealand(MNZ), Carnegie, American Museum of Natural History (AMNH), NHM and Dresden museums, and comprised seven adult, one juvenile males and four adult, three juvenile females (one of his males is now considered a female) although he did not discriminate between adults and juveniles. Table 1 below summarises measurements from 18 specimens measured by the author (thus excluding only Carnegie and AMNH museum specimens for which measurements are provided in Appendix 1) and comprises six adult, two juvenile males and five adult, five juvenile females.

Discriminating sex and age by measurement

Using measurements of culmen and wing there was a clear separation between birds labelled as males and females which helped indicate the likely sex of four unlabelled skins (Appendix 1). Culmen lengths and wing lengths of males did not overlap those of females and the widths of their nails at the bill-tips were wider; in combination any two of these three metrics separated the specimens into two groupings (Table 1, Fig. 2). Nares to bill tip measurements were also longer in males.

The wing lengths of juveniles were generally shorter than adults (Appendix 1) but all other standard measurements overlapped those of adults.

Four specimens whose sex was not recorded can be sexed by these measurements. The most problematic unsexed specimen was NHM 1875.11.6.14 (Appendix 1). It was collected in late November and has a short bill for a putative male but wing length and nail width both fall well within the male range; its well-developed head crest and rufous head and neck colouration suggest this bird was an adult, and a male.

Weight

No field weights of *M. australis* were recorded. Livezey (1989) regressed body weights of three merganser species (*M. serrator*, *M. merganser,* Hooded Merganser *Lophodytes culcullatus*) against the "body length" (skin length minus culmen and tail) of their museum skins. From the derived regression equation and inserting "body

Table 1. Measurements (mm) from all known *Mergus australis* skins except those at Carnegie Museum and AMNH (mean ± s.d., range). * Tarsus and mid toe & claw measurements are problematic on dried specimens; these were measured to nearest mm and the value recorded below is the mean of four separate measurements, presented to the nearest mm.

	Exposed culmen	**Width at nail**	**Nares to tip**	**Tarsus***	**MT&Cl***	**Tail**	**Wing**
Adult males (n = 6)	60.6 ± 0.5	6.6 ± 0.5	44.4 ± 1.5	42 ± 2	66 ± 5.1	73 ± 4	194 ± 6
All males (n = 8)	60.3 ± 0.9 (58.4–61.3)	6.6 ± 0.5 (5.8–7.1)	43.8 ± 1.7 (41.6–45.9)	41 ± 2.2 (39–45)	66 ± 4.2 (57–70)	72 ± 4 (68–78)	194 ± 6 (185–202)
Adult females (n = 5)	54.5 ± 1.3	5.7 ± 0.2	39.4 ± 0.9	41 ± 1.6	63 ± 2.9	67 ± 4	180 ± 3
All females (n = 10)	54.6 ± 1.1 (53.1–56.8)	5.8 ± 0.2 (5.4–6.0)	39.3 ± 0.7 (38.3–40.4)	40 ± 2.2 (37–44)	61 ± 3.9 (55–67)	66 ± 4 (63–72)	179 ± 4 (172–185)

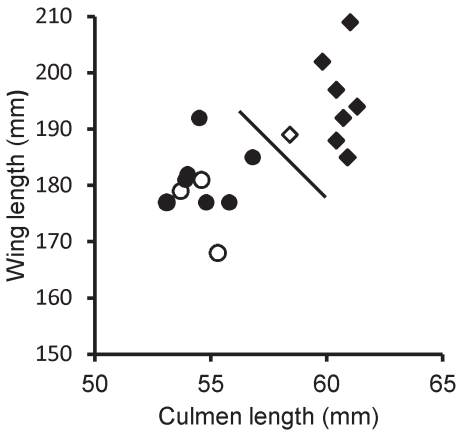


Figure 2. Scatterplot of wing and culmen lengths of *Mergus australis* museum specimens. Specimens labelled as males (◆), as females (●) and those unsexed (unfilled symbols) and indicating the sex now assigned to them.

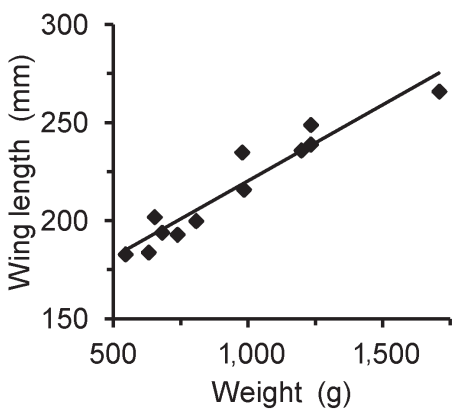


Figure 3. Relationship between mean wing lengths and mean weights for males and females of all extant merganser species. Data from Appendix 2. Regression equation is y = 0.095x + 133 (R^2 = 0.95, n = 12).

lengths" of *M. australis* and *M. octosetaceus* skins, he deduced a weight of 898 g for *M. australis* and 983 g for *M. octosetaceus*. Field weights for *M. octosetaceus* are now known (Appendix 2) and Livezey's estimated weight was approximately 20% too high (assuming it was for a male). Furthermore, 898 g for *M. australis* seems especially generous for what is undoubtedly a small merganser.

Across all extant mergansers, mean wing length and mean weight (of both sexes; Appendix 2) are strongly correlated (R^2 = 0.95, P < 0.001; Fig. 3). Using the regression equation (length = 0.095 * weight + 133) and the mean values of wing lengths of adult *M. australis* (Table 1) males may have weighed *c.* 660 g and females *c.* 530 g. Using the extremes of the range of adult wing measurements, the range of male weights may have been 550–800 g and females 460–620 g. These estimates imply a sexual size dimorphism similar to most other mergansers (Appendix 2).

Livezey (1989) suggested the wing lengths of *M. australis* were disproportionately shorter than those of other mergansers relative to their "body length". If so, estimated weights above will be conservative. However, as demonstrated later (see Flight) wing length is correlated with keel area which in turn reflects pectoral muscle mass, a major determinant of body weight. *M. australis* was capable of flight and wing length should still reflect weight in a way similar to other mergansers.

Using Livezey's "body length" for five merganser species (his Table 2) and relating them to the mean weights given in Appendix 2 produced a weaker correlation (R^2 = 0.74, P = 0.05) than the wing length : weight relationship above. Nevertheless, inserting Livezey's "body lengths" for *M. australis* into the equation describing the

average relationship (length = 0.168 * weight + 348.5) derives a mean weight of 835 g for males and 757 g for females. Such a mean estimate remains too high, especially relative to known weights of *M. octocetaseus*, and indicates that "body length" of museum specimens is an unreliable measure of merganser size.

The estimated weights for *M. australis* seem appropriate when specimen skins and mounts are compared with the two smallest mergansers (Hooded Merganser and Smew *Mergellus albellus*) and with other New Zealand waterbirds of 500–700 g weight (*e.g.* Auckland Island Teal *Anas aucklandica*, Brown Teal *A. chlorotis*), Little Shag *Phalacrocorax melanoleucos*; see Marchant & Higgins (1990). Worthy (2004) noted that humerus, ulna and tarsometatarsus bones of *M. australis* were similar in size to, and readily confused with, those of Brown Teal, and that their carpometacarpi and scapulae approximated those of New Zealand Scaup *Aythya novaeseelandiae,* both species in the 500–700 g weight range.

Distribution and possible population size

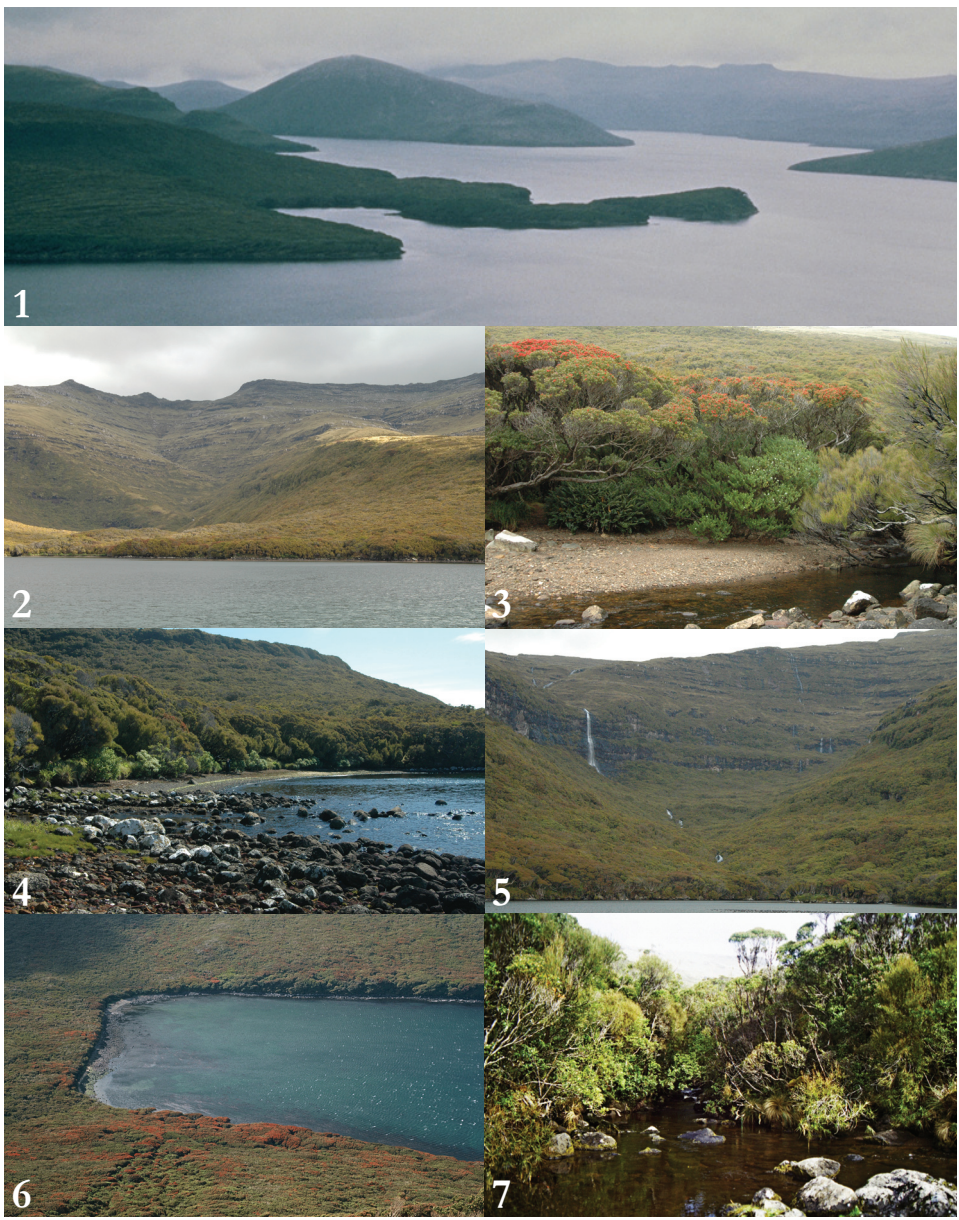
Specimens were collected in Waterfall Inlet (Reischek 1889; Wilson 1959), McLennan Inlet (specimen NHM1901.10.21.57 label), Norman Inlet (Hutton 1901a) and Carnley Harbour (Maclaren or Magnetic Bay, Adams Island ; Chapman 1891), possibly in Port Ross (Hombron & Jacquinot 1841), and at unspecified locations in Carnley Harbour (Alexander 1902, Fig. 1, Colour plate 2, Appendix 1). McCormick (1884) reported merganser present in Laurie Harbour at the head of Port Ross in 1840.

The absence of records from Auckland Island's other eastern inlets does not imply that suitable habitat elsewhere was lacking. The short and steep streams flowing into Waterfall, McLennan and Norman Inlets are replicated elsewhere (*e.g.* Hanfield Inlet and bays within Carnley Harbour) while at the heads of other inlets are larger streams flowing along flat valley floors (*e.g.* Deep and Chambers Inlets) and in two of which (Musgrave and Granger Inlets) are small lakes.

On riverine breeding habitat, other merganser species are generally dispersed at very low densities (< 0.2 pairs/km; species accounts in Kear 2005b). Most observations of their feeding are as pursuit feeders, chasing small fish prey underwater but they also grovel among stones and rocks in shallow water where snails and benthic invertebrates are captured (Hughes & Green 2005).

Auckland Island would have offered mergansers sheltered habitat only on its protected eastern side where, along its 42 km length, are 13 deep inlets (Fig. 1, Colour plate 2). At its southern end the drowned caldera of Carnley Harbour is flanked by Adams Island and within these confined waters lie 12–14 smaller bays into which short streams tumble from the steep surrounding hillsides (Fig 1, Colour plate 2); at least one, Maclaren or Magnetic Bay, provided habitat for a merganser pair and young (Chapman 1891).

A likely year-round territorial habit akin to *M. octosetaceus* suggests the head of each inlet or bay would probably have been occupied by just a single pair. Although in some larger inlets (*e.g.* Deep, Chambres



Colour plate 2. Auckland Island landscapes and locations (2, 4) from which mergansers were collected. 1 = Carnley Harbour viewed from Adams Island; 2 = Maclaren Bay on Adams Island; 3 = Stream at head of Magnetic Bay and typical of other streams on Adams Island; 4 = Shoreline at head of Waterfall Inlet; 5 = Hanfield Inlet south branch; 6 = Head of Musgrave Inlet. 7 = Stream at head of Norman Inlet and typical of streams in most eastern inlets. (Photographs: K. Walker and G. Walls).

Inlets) two or more well-separated large streams emerge in close proximity, most likely these would have been occupied and defended by a single pair. Unpaired or juvenile birds may have been forced to live a more transitory life in smaller and more exposed bays or coves.

By this reasoning, a population of just 20–30 pairs, and a non-breeding component of perhaps 10 seems likely. Possibly mergansers persisted at the Auckland Islands in such low numbers because of the paucity of suitable feeding habitat in low gradient segments of streams at the heads of the inlets and bays. Their wider exploitation of more exposed marine environments may have been constrained by the high abundance of the coastal feeding Auckland Island Shag *Phalacrocorax colensoi*.

The paucity of merganser sightings remarked upon in the early writings (*e.g.* von Hugel 1875; Chapman 1891) suggests that, from the time of interest in collecting specimens, very few mergansers remained at the Auckland Islands. Contributing to this scarcity would have been early human depredation; from the time of the island's initial discovery (1806; Fraser 1986) to the collection of the first (and type) specimen (1840; Hombron & Jacquinot 1841) the heads of many inlets were occupied by sealers (Dingwall *et al.* 2007), and tame resident waterfowl would have provided ready fare. Furthermore predatory mammals, pigs *Sus scrofa* and cats *Felis catus*, had been introduced to Auckland Island. No historic account from prior to von Hugel obtaining the second specimen in 1874 (von Hugel 1875), either by shipwrecked mariners (*e.g.* Musgrave 1866; Smith 1866; Raynal 1874; Allen 2003), or settlers (*e.g.* Dingwall *et al.* 1999) refer to mergansers. Musgrave's and Raynal's accounts cover 20 month's life as castaways in Carnley Harbour and although Raynal, a Frenchman, recognisably described many birds including the flightless Auckland Island Teal ("young duck"), Auckland Island Shags ("widgeon") and Grey Duck *Anas superciliosa* ("canards sauvage"), he does not mention mergansers ("harle"). This lack of mention could suggest mergansers were already uncommon in the harbour and did not occur in bays near the castaway's camp. However, Krone (1900, pp. 26, 154), in an account commenting on fauna observed during his 140 days in Port Ross as a member of the German 1874 Transit of Venus expedition, refers to their presence in the harbour, and their possible capture "along the cliff- filled coast" (p. 26).

Breeding

The collection of four downy ducklings, approximately one week old, on 14 or 15 January 1890 in Maclaren or Magnetic Bay on Adams Island (Chapman 1891) is the single definitive record of the merganser's time of breeding. However, there are two other records that can be interpreted as indicating breeding.

Reischek (1889) reported that on 27 January (1888) in Waterfall Inlet (Colour plate 2) he "saw six mergansers, and shot two of them; the others concealed themselves among the rocks". Six mergansers together suggest a family group, and concealment among rocks is a likely response of unfledged young if caught on an exposed shoreline. Reischek's specimens

were both adults (now in Vienna Museum, Austria; Appendix 1) and, because he did not indicate the others to have been conspicuously different, most likely they were near-fledged young.

New Zealand's then Governor-General, Lord Ranfurly, obtained four merganser specimens in early January 1901 (Alexander 1901). Two adult specimens, now in the Natural History Museum at Tring, were obtained on 5 January 1901 and two other specimens were probably collected on that or the following day – AV2944 (now in Canterbury Museum, Christchurch) and NMINH 1904.559.1 (now in National Museum of Ireland, Natural History, Dublin; Appendix 1). Both latter specimens have identical characteristics of newly-fledged birds, their tail feathers carrying down stalks, their primaries unfrayed and unworn compared to those of adult birds, and they have immature plumage and colouration. Possibly they were newly-fledged siblings and collected together although there are no records to confirm this.

These observations, of newly-hatched and almost-fledged young in January, imply a late October–November laying period. Other merganser species, none of which breed in their first year, lay eggs at 1.5–2 day intervals mostly in hole nests, incubate for about four weeks, and take 60–70 days to fledge their young (Cramp & Simmons 1977; species accounts in Kear 2005b).

That nesting sometimes was more protracted is indicated by a letter (dated 16 May 1895) from S.V. Dannefaerd (a New Zealand specimen collector/dealer) to Walter Rothschild at Tring (O'Rourke 1997) in which he referred to a female specimen collected in February containing an egg (specimen AMNH 734365; Appendix 1). Perhaps the merganser had a similar breeding period to Auckland Island Teal whose late re-nesting attempts can extend into January and February and whose ducklings can sometimes be observed in March and early April (Williams 1995).

Both Chapman (1891) and Reischek (1889) provide evidence of brood size, one soon after hatching and the other near fledging, and both are of four young. Neither can be interpreted as clutch size other than as a minimum. Other mergansers lay clutches of 8–10 eggs (species accounts in Kear 2005b).

Krone (1900, p. 154) provides an enigmatic reference to the merganser's choice of nesting site. Translated from his account, which was presented in poetic form …." *We liked the meat of the hunted cormorants, tasting just like geese and ducks, with lemon yellow fat, also the rare Sage taucher (merganser), also called Entensager, with serrated duck beak, which is on the side sharply notched, to hold the fish which they catch while diving – those nest, always rare, on top of the steep cliff, facing north or north east, above the wild surf, around the big cliff gate (cave?), where they live together with the cormorants and also with the penguins, related through kinship."*

Social structure

Observations of mergansers at Auckland Islands have been reported from October (Wilson 1959), late November (McCormick 1884) and January–February (Chapman 1891; Reischek 1889; Alexander 1901, 1902; Hutton 1901a,b). Specimens were collected

at other times (November, March, July; Appendix 1) but I have not found notes associated with these that shed light on the birds' habits at these times.

There are no records of mergansers having been encountered other than as singles, as pairs, or as pairs with young; Reischek's (1889) encounter with six mergansers is interpreted as a family group. Wilson's encounter, when he shot a pair in a stream away from the coast (Falla 1970), is the only one that immediately precedes the assumed breeding period, and has the pair together.

All northern hemisphere mergansers are gregarious during winter and during migration and form monogamous pair bonds on breeding habitat. The females of some species have been recorded at the same breeding sites in consecutive years (species accounts in Kear 2005b). Brazilian Mergansers are dispersed as pairs on well-defended river territories year round (Silveira & Bartmann 2001) and a similar social dispersion seems likely for *M. australis*.

Foods and feeding habitat

There are two records of food taken by Auckland Island's mergansers.

A specimen shot in 1901 (NHM 1901.21.57) at Adams Island's Maclaren/Magnetic Bay had a 90mm ("3.5 in") Koaro *Galaxias brevipinnis* in its bill (Hutton 1901b). Although described by Hutton as a marine species, this is, like all *Galaxias* spp., a freshwater inhabitant and most likely the merganser would have caught it in the lower reaches of the bay's stream to which there would have been easy access from the shoreline for Hutton and his hunters.

Kear and Scarlett (1970) reported the gut contents of a preserved cadaver (NHM A/1999.1.124) as containing "macerated fish bones, mandibles of an errant polychaete and an unidentified gastropod". They added that "the presence of the polychaete tends to suggest a brackish water environment".

Some treatises (*e.g.* Phillips 1926; Delacour 1959; Greenway 1967) have reported *M. australis* taking freshwater shrimps, an observation attributed to Waite (1909) but Waite says no such thing.

There are no accounts of mergansers feeding at the Auckland Islands and few accounts from which their feeding habitat can be discerned with certainty. Reischek (1889) observed his group of six feeding among rocks on the shoreline of Waterfall Inlet (Colour plate 2); Waite (1909) quotes Capt. J. Bollons, master of the government ships regularly visiting the Subantarctic islands, as not having seen the bird on the coasts, but having found it at the heads of estuaries and especially on the island's watercourses "picking about in the creeks"; and Falla (1970) reports R.A. Wilson, the collector of two specimens in 1891, as having encountered his quarry up the stream bed some distance from the coast and in a deep pool where the stream was partly dammed on a rocky terrace.

Despite many streams on Auckland and Adams Islands being short and steep, *Galaxias brevipinnis* is common in all, and especially so where the streams' gradients flatten prior to flowing into the sea (M. Williams pers. obs.). These lower reaches would have offered suitable, albeit limited, feeding sites for mergansers in fresh water. However, given that human access up

streams from the coastline is extremely difficult, it is not surprising that the merganser specimens were mostly seen and taken at the head of the bays, either in a stream's lower reaches or at the coastal edge (Colour plate 2).

Williams *et al.* (2012) examined stable isotopes of C and N in feathers and claws of some museum specimens. They concluded some of the birds sampled were feeding mostly on marine-sourced prey at the time of growing their feathers while others had included fresh water-sourced prey. However, they found no evidence of an exclusively fresh water feeding habit; feathers from one of Wilson's specimens collected from a stream provided evidence of a mixed-source diet.

Flight

M. australis was not flightless despite its depictions with short wings suggesting otherwise (*e.g.* Buller 1905; Fleming 1982). Ogilvie-Grant (1905) quotes F. W. Hutton's comment that the merganser "flies well". Elsewhere, Hutton reported that "an old drake merganser flew out from the shore to the steamer where it was anchored close in for the evening. It settled on the water within a few yards of the vessel and swam calmly about quacking like a duck" (Hutton & Drummond 1905).

Livezey (1989) suggested *M. australis* approached the threshold of flightlessness, a conclusion derived from his estimates of both body weight and wing area and the assumption that wing loading (wing area/weight) is a measure of flying ability. The latter is not so for flapping flight (Pennycuick 2008).

Livezey (1989) also identified *M. australis* as having a "weakly keeled" sternum and "disproportionately short mid-wing elements". The latter conclusion arose from his observation that the length of the wing skeleton was similar to that of Hooded Merganser, which he concluded was a smaller bird.

Relative to its sternum length, *M. australis* had a reduced keel. The keel area of all five specimens examined lie beyond the 50% prediction interval of a regression equation describing the average relationship between keel area and sternum length for four extant merganser species combined (see Fig. 4 in Appendix 3). On average, the keel area was 79% (75–84%; geometric mean and range) of that predicted by the regression equation. This implies a relative reduction in pectoral muscle mass, and of weight.

Similarly, relative to its sternum length, *M. australis* had shortened wing bones (humerus + ulna). The wing bone lengths of all three specimens examined lie beyond the 50% prediction interval of the regression equation describing the average relationship between wing bone length and sternum length for four extant merganser species combined (see Fig. 5 in Appendix 3). The combined lengths of the two wing bones of *M. australis* were 91% (89–93%; geometric mean and range) of that predicted by the regression equation.

Does having a reduced keel (and thus reduced pectoral muscle mass) and reduced wing bone length necessarily mean reduced flying ability? Pennycuick (2008) provides a model (PROGRAM *Flight 1.22*) for determining the merganser's likely flight characteristics (Table 2).

In simulations of *M. australis,* pectoral muscle mass as a percentage of total body mass was varied between the default value of 17% and 12% (to reflect the reduction in keel area), and body weight and wing span were also varied within the range of estimates and measurements obtained. Even when the most extreme values of maximum calculated weight (from Fig. 3), shortest wing length (Table 1) and 12% pectoral muscle mass were included together in a simulation the results suggest *M. australis* had similar flight characteristics to many other waterfowl (Table 2) and flew with the rapid wing beat typical of the two smaller mergansers (Hooded Merganser, Smew). The work required to maintain level flight at minimum power speed was about the same per unit weight of muscle as for a Mallard *Anas platyrhynchos* (Williamson *et al.* 2001; Pennycuick 2008).

Extinction

The merganser is the only bird known to have become extinct at the Auckland Islands following the islands' discovery by Europeans in 1806, after which people, predators and specimen collectors arrived.

Human occupation of the islands was brief and localised. Sealers were the earliest residents, establishing camps at the heads of several bays and inlets (Dingwall *et al.* 2007); tame waterfowl would almost certainly have been included in their fare. Maori and European settlement persisted for about a decade (1842–1854) in the Port Ross area (Fraser 1986) and presumably local waterfowl would have supplemented the residents' diets also.

The scale of successful alien animal introductions to Auckland Islands is modest by comparison to other islands in the New Zealand region (King 2006). While no rat colonised any of the Auckland Islands and no alien mammals were released onto Adams Island, mice *Mus musculus*, goats *Capra hircus*, cats and pigs became well established on Auckland Island. Pigs, already numerous about Port Ross by 1840 (McCormick 1884), and cats have impacted many seabird colonies on Auckland Island and now restrict some petrel species to breeding only on the smaller and predator-free islands (Taylor 2000), just as they have Auckland Island Teal. Undoubtedly cats and pigs would have preyed upon any merganser nesting in an exposed site.

A third and final influence on the merganser's extinction was specimen collecting (see Appendix 1). Eighteen of the 23 skins of adults and fledglings now in the world's museums were collected during the 14 year period 1888–1902. More were undoubtedly collected but have subsequently disappeared, *e.g.* one of Wilson's pair from 1891, the 1882 Colonial Museum specimen (Appendix 1), and others that were collected for private dealers and collectors (including S.V. Dannefaerd, H.H. Travers and W.L. Buller) by crew of the government vessels *Hinemoa* and *Tutanekai* during twice-yearly visits to the islands.

Buller's (1892) insistence that "specimens of this interesting form in the adult stage should be obtained for our museums before it is too late" clearly found willing listeners and established willing buyers. For example, Ogilvie-Grant (1905) chronicles how, when at port in Bluff prior to Ranfurly's 1901

Table 2. Results of simulations using PROGRAM *Flight 1.22* (Pennycuick 2008) examining the flight characteristics of *M. australis* and selected other mergansers and waterfowl.

Species (sex)	Weight (kg)	Wing span (m)	[1]V_{mp} = minimum power speed (m/s)	[2]Specific work at V_{mp} (J/kg)	[3]Wingbeat frequency (Hz)	Source; notes
M. serrator (F)	0.908	0.86	14.8	10.6	7.61	Pennycuick 2008: *Program Flight 1.22*
M. australis (M)[4]	0.70	0.700	15.0	10.41	9.43	17% pectoral muscle mass
M. australis (M)	0.70	0.700	15.0	15.5	9.43	12% pectoral muscle mass
M. australis (M)	0.76	0.678	15.7	10.8	10.1	Maximum calculated weight, shortest male wing, 17% muscle mass
M. australis (M)	0.76	0.678	15.7	16.2	10.1	Maximum calculated weight, shortest male wing, 12% muscle mass
M. australis (F)[5]	0.55	0.658	14.3	9.46	9.53	17% pectoral muscle mass
M. australis (F)	0.55	0.658	14.3	14.1	9.53	12% pectoral muscle mass
M. australis (F)	0.63	0.652	15.0	9.97	10.2	Maximum calculated weight, shortest female wing, 17% muscle mass
M. australis (F)	0.63	0.652	15.0	14.9	10.2	Maximum calculated weight, shortest female wing, 12% muscle mass

L. cucullatus (JM)[6]	0.59	0.61	15.2	9.94	11.0	captive
L. cucullatus (M)	0.68	0.63	15.7	10.9	10.4	Mean male wt, mid range of wingspan from Cramp & Simmons (1977)
M. albellus (JM)[6]	0.58	0.57	15.6	12.1	11.4	captive
M. albellus (M)	0.65	0.62	15.6	10.9	10.4	Mean male wt, mid range of wingspan from Cramp & Simmons (1977)
Anas platyrhynchos	1.09	0.885	15.5	14.3	7.14	Pennycuick 2008: *Program Flight 1.22*
A. penelope	0.81	0.842	14.4	11.7	7.16	Pennycuick 2008: *Program Flight 1.22*

[1] V_{mp} = minimum power speed, the velocity at which the power required to fly is less than at either slower or faster speeds. If the muscles cannot produce this level of power, then the bird cannot fly horizontally, and if the heart and lungs cannot sustain the minimum power aerobically, then it can only fly in short bursts, if at all (from Pennycuick 2008: Chapter 1).

[2] Specific work at V_{mp} = the work done in each contraction by unit mass of muscle when flying level at V_{mp}.

[3] Wingbeat frequency = wingbeat frequency expected in level flight at V_{mp}.

[4] All *M. australis* male simulations based on estimated body weight (Fig. 3), and wingspan (distance between glenoid fossae (54 mm) from NHM A/1999.1.124, humerus + ulna length (128 mm) from NHM 1904.8.4.3, mean adult wing length (194 mm), aspect ratio 9).

[5] All *M. australis* female simulations based on estimated body weight (Fig. 3), and wingspan (estimated distance between glenoid fossae (50 mm), humerus + ulna length (124 mm) from NHM 1904.8.4.4, mean adult wing length (180 mm), aspect ratio 9).

[6] Fledged juvenile male in captivity, Wildfowl & Wetlands Trust, Slimbridge, UK.

collecting trip on *Hinemoa*, a bystander offered the ship's crew £3 10s for any merganser skin from the island. Ranfurly's very deliberate pursuit of mergansers in every inlet of Auckland Island for the British Museum (Alexander 1901, 1902; Ogilvie-Grant 1905) yielded the last nine specimens in 1901–1902. None was seen subsequently despite a determined search by members of a 1907 scientific expedition to the islands (Waite 1909). It is hard not to conclude that a naturally small merganser population, already depleted by early human occupants and under pressure from two new mammalian predators, was tipped into premature extinction by rapacious collecting.

Overview

The persistence of a small and isolated population of mergansers at Auckland Islands at the time of European arrival in New Zealand provided a brief glimpse of a species that had already disappeared everywhere else.

This small fish-eating duck, the smallest *Mergus*, might be expected to show hints of the 'islandisation' conspicuous among waterfowl, and especially *Anas* ducks, on remote islands (Lack 1970; Weller 1980). These effects include reduction in body size, lower clutch sizes, larger eggs relative to body size, reduced flight capability, year-round territoriality, increased terrestrial habit, enhanced sexual size dimorphism and reduced plumage dimorphism, most of which may be viewed as energetic responses to limited but spatially predictable food on small islands (McNabb 1994a,b).

Breeding characteristics of mergansers at Auckland Islands may never be resolved but if mergansers had been long-established residents of Auckland Island a smaller clutch size than other merganser species is almost certain (Lack 1970; Weller 1980; Rohwer 1988). Perhaps Chapman's (1891) observation of four new hatchlings is indicative. A reduction of body mass relative to its New Zealand progenitor is also possible if the founders responded to their isolation in a manner similar to the antecedents of Auckland Island Teal (Williams *et al.* 1991). The reduction in pectoral muscle mass which a reduced keel area implies and the apparent shortening of wing bones are indicators of this response. Still to be resolved, however, is whether Auckland Islands' mergansers were smaller 'island' derivatives of those on mainland New Zealand or whether all mergansers in the New Zealand region were small derivatives of a larger common founder.

The Auckland Islands archipelago is such a small and restricted locality that it is difficult to interpret many of the snippets of merganser ecology assembled by Kear & Scarlett (1970) and in this presentation. This was a more widely distributed bird whose bones have been recovered in natural deposits and middens on New Zealand's main islands (from northern North Island to Stewart Island) and on Chatham Island (Millener 1999; Worthy 1998b; Worthy & Holdaway 2002). Although eight of the present nine sites at which *Mergus* bones have been found on New Zealand are coastal this does not necessarily imply the merganser was a marine or coastal species. To date, only two inland lacustrine sites have yielded Holocene avifaunal remains –

Pyramid Valley in North Canterbury from which no fish-eating birds were recovered (Holdaway & Worthy 1997), and Lake Poukawa in inland Hawkes Bay where *Mergus* and almost all other Holocene waterfowl and water-dependent birds were present (Worthy 2004). *M. australis* may have had a wider distribution which the few fossil sites under-represents and plausibly may have been a bird of New Zealand lakes and rivers, a habitat like that of most extant mergansers. The coastal edge habitat of mergansers at Auckland Islands may be more an example of a broader island niche than one confirming a ubiquitous habitat choice.

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Appendix 1. *Mergus australis* specimens from Auckland Islands in museum collections.

The late 19th century was a period of assiduous collecting of New Zealand's avifauna and specimens from its remote islands, like the Auckland Islands, were especially prized. This demand was driven by competition between Imperial museums in Europe to assemble premier collections of fauna, flora and anthropology from their nation's colonies, by New Zealand's new Colonial Museum and provincial museums in Auckland, Christchurch and Dunedin to do likewise, and by private collectors, most notably Walter Rothschild of Tring, England.

Baron Anatole von Hugel (1875), a travelling UK-based aristocrat returned the first mergansers to England having purchased his specimens from collectors in Invercargill. He placed one specimen each in the British Museum of Natural History and the Zoological Museum at Cambridge University. Hermann Krone, following participation in the German Transit of Venus expedition to Auckland Island in 1874

(Dawson & Duerbeck 2008) returned home with a pair of mergansers which he presented to the Dresden Museum. Between 1877–1889 Andreas Reischek assembled a prodigious collection of New Zealand's birds for the K.k. Naturhistorisches Hofmuseum (later Naturhistorisches Museum Wien) in Vienna (Reischek 1889, 1930) and was the first major collector to visit the Auckland Islands (in 1888) determined to secure a pair of mergansers.

Crew of government ships visiting the island twice yearly returned to port with bird specimens for sale and some of their merganser specimens are included among the existing museum specimens. Sir Walter Buller was a determined acquirer of these for both his own collection and for sale to Walter Rothschild (Bartle & Tennyson 2009). Although Rothschild acquired many bird specimens from other New Zealand collectors (*e.g.* Dannefaerd, Travers) he received all of his mergansers from Buller. Those specimens are now in the AMNH collection (Bartle & Tennyson 2009).

A last and most determined field collector was Lord Ranfurly, Governor-General of New Zealand 1897–1904, who collected a large number of New Zealand and Pacific birds at the request of the British Museum (Ogilvie-Grant 1905). He visited Auckland Islands in January 1901 (on NZGS *Hinemoa*) and January 1902 (on NZGS *Tutanekai*) (Alexander 1901, 1902), collecting four mergansers in 1901 (an adult pair going to the British Museum and a recent fledgling each to Dublin and Canterbury Museums) and another two birds in 1902 (the fates of which remain uncertain). At Ranfurly's request crew of the British naval vessel HMS *Archer* visiting Auckland Islands in July 1901 collected at least three other merganser specimens which were eventually lodged in the British Museum (Ogilvie-Grant 1905). Following Ranfurly's 1902 collecting no live mergansers were seen again despite earnest (Waite 1909) and forlorn (Williams & Weller 1978) searches.

Eleven museums, three in New Zealand, two in USA, three in Europe, two in UK and one in Ireland, hold between them four duckling specimens and 23 skins of immatures and adults. Near-complete skeletal remains of three birds and a partial cadaver from another are held at the Natural History Museum, Tring, and sternum and pelvic bones from skins are in Otago and Canterbury Museums. No merganser bones have yet been collected from natural deposits at Auckland Islands. The documented presence of two *M. australis* skulls in the Universitie d'Lyon Anatomy Department collection, France (Wood *et al.* 1982) is a case of *M. serrator* skulls being misidentified and wrongly labelled (A. Previato pers. comm.).

Not all specimens apparently received by museums can now be accounted for. For example, Buller (1892) refers to the British Museum then containing "a pair" but the current collection contains only one specimen pre-dating 1892. Buller also refers to a specimen in both Otago and the Colonial (=National) Museum collections (the latter deposited in 1880–81; *Evening Post* 25 April 1882) but their current collections contain no mergansers of that vintage. Mystery also surrounds the fate of both birds collected by Ranfurly in 1902, and of the skins of 2 skeletons and cadaver in the NMH (see below).

Listed below are details for each specimen, as originally provided by Kear & Scarlett (1970), with added comment and measurements (in mm). Measurements of tarsus (especially) and mid toe & claw on the dried specimens proved extremely problematic and rarely repeatable to within 1 mm; the means of four measurements are provided for each simply to indicate their approximate magnitude. Length of exposed culmen, width of bill at tip (widest part of nail), and wing length proved the most repeatable of standard measurements, the latter being of unflattened wing feathers from the distal portion

of the carpus to the tip of the longest primary feather (usually the second). Rectrices of all specimens were examined for presence of terminal down stalks to indicate a recent fledgling (Larson & Taber 1980).

Canterbury Museum, Christchurch, New Zealand

Skin. AV1580. Collection date recorded as May 1894, collector not identified. Ex W L Buller collection. Original label has sex as male, changed (by R. M. Scarlett) to female. Measurements: culmen 54.5, bill width at tip 5.4, wing 178, tarsus 41, mid toe & claw 67, tail 63. Sex by measurement – female. Head crest poorly developed.

Skin. AV1583. Ex E. F. Stead collection. Collected by R. A. Wilson, 30 Oct 1891, probably at Waterfall Inlet (Wilson 1959). Unsexed. Measurements: culmen 61, bill width at tip 6.9, wing 199, tarsus 44, tail 73. Sex by measurement – male. Adult.

Skin (mount). AV2944. Collected by Lord Ranfurly's party 5 Jan 1901. Acquired by F.W. Hutton, Canterbury Museums' curator of the time who accompanied Ranfurly on *Hinemoa* and was later responsible for despatching Ranfurly's collection to the British Museum (Hutton 1901a; Ogilvie-Grant 1905). Labelled male. Measurements: culmen 55.8, bill width at tip 5.8, wing 177, tarsus 37, mid toe & claw 55, tail 62. Sex by measurement – female. Tips of its remiges and rectrices are unfrayed and the down stalk visible at tip of at least 3 rectrices. Recent fledgling. Identical in plumage to NMINH 1904.559.1 which was collected at the same time.

Skin. AV 1581. Duckling. Ex W.L. Buller collection. Downy, *c.* 1 week old. Kear & Scarlett (1970) suggest this to be one of the ducklings collected by crew of NZGS *Hinemoa* on or about 15 Jan. 1890 in Maclaren/Magnetic Bay, Adams island (Chapman 1891). Chapman collected 2 of these for Otago Museum (Chapman 1891) (see specimens A51.51) and another duckling from this brood is AMNH 744347, derived from Buller's collection (Buller 1892; Bartle & Tennyson 2009).

Bones. AV 1582. Head including part cranium, upper and lower mandibles and quadrate. Label states "from old skin skeletonised 23/10/53 R.J.Scarlett. Length of culmen 5.3 inches" Nares to tip 36.6 and comparable with females NHM 1904.8.4.2 and NHM 1904.8.4.4. No collection data or date recorded.

Bones AV 5176. Pelvis, sternum and 3 caudal vertebrae. Label reads "sternum and pelvis of male (O.1224.3) now AV 5176, Auckland Is, Jan 1901." Almost certainly from mounted specimen AV2944 in which case it is incorrectly sexed. Sternum + keel length (ventral) 85.7, sternum length (visceral/dorsal) 71.1, sternum anterior width 41.9, sternum posterior width 47.3, keel area 6.01 cm^2, pelvis acetabulum width 28.6, pelvis posterior width 48.0. Measurements comparable with those of females NHM 1904.8.4.2 and NHM 1904.8.4.4.

Bones. AV 7157. L. corocoid, length 44.8. L. scapula. Both bones labelled "merganser". No other data.

Otago Museum, Dunedin, New Zealand

Skin (mount). AV 1110 (formerly A51.50). Labelled as "collected 1890, ex F.R. Chapman collection, sex female". Kear & Scarlett (1970) suggest this specimen may have been collected in January 1890 on Chapman's journey on NZGS *Hinemoa* but Chapman (1891) makes no such claim and specifically says that the parents of the ducklings collected then escaped. Rectrices still carrying the down stalk. Recent fledgling.

Measurements: culmen 54.8, wing 177, tarsus 38, mid toe & claw 56, tail 69. Sex by measurement – female. Kear and Scarlett (1970) report that the female of the adult pair shot by R.A. Wilson in October 1891 (Wilson 1959) was presented by Wilson to the Otago Museum, and Buller (1905) refers to "a pair in Otago Museum." This specimen (AV 1110), because of its age, is not Wilson's female.

Spirit. AV 8511 and AV 8512 (formerly A51.51). Ducklings (2). Ex F. R. Chapman collection. Downy, *c.* 1 week old. Collected Maclaren or Magnetic Bay, Adams Island on 18 January 1890 (Chapman 1891). Siblings of AV 1581 (Canterbury Museum) and AMNH 744347.

Bones. AV1436. Sternum with articulated corocoids, scapulae, furcula and portions of ribs. Presumed to belong to AV 1110. Sternum + keel length (ventral) 85.8, sternum length (visceral/dorsal) 71.9, sternum anterior width 41.9, sternum posterior width 47.8, keel area 5.93 cm^2.

Museum of New Zealand Te Papa Tongarewa, Wellington, New Zealand

Skin (mount). OR 001357 (formerly DM1357). Labelled as 'collected June 1902, Auckland Islands, sex unknown, age unknown". No collector is identified. Measurements: culmen 53.7, bill width at tip 5.7, wing 179. Sex by measurement – female. This is a recent fledgling; a down stalk persists on several rectrices, the elongated nape feathers of the crest are barely discernible, the overall colouration is a dull brown (probably much darker in life) being only slightly lighter beneath than above, and no hint of rufous on head. Collection date (month) is clearly erroneous given the plumage characteristics of the specimen. Likewise the year and possible source is a matter of conjecture and confusion. Buller (1892, 1895, 1905) refers to a "good specimen" already in the Colonial Museum, presumably a reference to a specimen added to the museum's collection in 1880–81 (*Evening Post* 25 April 1882). The last known collection was of two specimens by Ranfurly on 9 January 1902 (Alexander 1902) but the fates of both are unknown; this specimen may be one of them.

National Museum of Ireland, Natural History, Dublin, Ireland

Skin (mount). NMINH 1904.559.1. Labelled as collected on 5 January 1901, Auckland Islands. Mounted by Rowland Ward, Piccadiliy, London. Lord Ranfurly collection. Unsexed. Measurements: culmen 54.6, bill width at tip 5.6, wing 181. Sex by measurement – female. This is a young bird with characteristics identical to those of Canterbury's AV 2944, its probable sibling. This specimen was not among those received by the British Museum (Ogilvie-Grant 1905).

Naturhistorisches Museum, Vienna, Austria

Skin. 50759. Collected 26 January 1886, Waterfall Inlet, Auckland Island. A. Reischek, collector (see Reischek 1889, 1930). Label sex- female. Measurements: culmen 56.8, bill width at tip 5.8, wing 185. Sex by measurement – female. Adult.

Skin. 50760. Collected 26 January 1886, Waterfall Inlet, Auckland Island. A. Reischek, collector (see Reischek 1889, 1930). Label sex – male. Measurements: culmen 59.8, bill width at tip 6.3, wing 202. Sex by measurement – male. Adult.

Museum Nationale d'Histoire Naturelle, Paris, France

Skin (Type). #28. Collected March 1840, M. Jacquinot, collector (Hombron & Jacquinot 1841, 1853). Label sex – male. Measurements: culmen 60.9, bill width at tip 5.8, wing 185.

Sex by measurement – male. Collected during Dumont D'Urville's expedition to Auckland Islands 10–20 March 1840. The collection locality is presumed to be Port Ross because D'Urville's two ships remained anchored there and later in the year McCormick (1884) saw them there. However D'Urville's expedition scientists visited several of the island's eastern inlets on a visiting Portugese whaler *Speculacao* (McNab 1913).

Staatliches Museum fur Tierkunde, Dresden, Germany

Skin. C5730. Carnley Harbour, Auckland Island. 1874. H. Krone presented. Label sex – male. Measurements: culmen 61.3, bill width at tip 7.1, wing 194. Sex by measurement – male. The date and location cannot be verified. Kear & Scarlet (1970) list the specimen's entry as "H. Krone bought and pres." implying either its purchase by Krone or its purchase from Krone. Hermann Krone was a member of the five-month long 1874–75 German Transit of Venus expedition based at Terror Cove in Port Ross. Although the expedition assembled a substantial natural history collection, it did not include birds. The expedition members are not known to have journeyed beyond Port Ross and they travelled to and from Auckland Island on the *Alexandrine* directly to Melbourne, without calling at any New Zealand port (Elliot Dawson *pers. com.*). However Krone (1900, pp. 24–26) lists seabirds at the island including small penguins in Carnley Harbour, perhaps indicative of an otherwise unrecorded visit.

Skin. C5731. Carnley Harbour, Auckland Island. 1874. Label sex – female. Measurements: culmen 54.1, bill width at tip 6.0, wing 182. Sex by measurement – female. Comments as above.

Zoology Museum, Cambridge University, Cambridge, England

Skin. 12/Ana/38/a/1. Von Hugel collection. Label sex – male. Measurements: culmen 60.7, bill width at tip 7.0, wing 192, tarsus 39, mid toe & claw 66, tail 73. Sex by measurement – male. Adult. Collection date on label given as 11 Dec. 1874; von Hugel (1875) indicates he purchased this and another specimen (BMNH 1875.11.6 14) in Invercargill, NZ and "the birds were killed the latter end of November..."

Natural History Museum, Tring, England

Skin. 1875.11.6.14. Presented by von Hugel, one of pair purchased in Invercargill (von Hugel 1875). Label sex – unrecorded. Measurements: culmen 58.4, bill width at tip 6.3, wing 189, tarsus 38, mid toe & claw 67, tail 68. Sex by measurement – probably male. Measurements of bill and wing are smallest for any "male" measured. Its well-developed head crest and rufous colour of head and throat suggest it to be an adult.

Skin. 1901.10.21.57. McClennands (=McLennan) Inlet, Auckland Island. 4 January 1901. Presented by Earl of Ranfurly. Label sex – "male certain". Label contains description of soft parts in hand of F. W. Hutton. Measurements: culmen 60.4, bill width at tip 6.5, wing 188, tarsus 45, mid toe & claw 68, tail 70. Sex by measurement – male. Adult.

Skin. 1901.10.21.58. McClennands (=McLennan) Inlet, Auckland Island. 4 January 1901. Presented by Earl of Ranfurly. Label sex – "female certain". Measurements: culmen 53.9, bill width at tip 5.7, wing 181, tarsus 43, mid toe & claw 63mm, tail 72. Sex by measurement – female. Adult.

The collection dates for the above 2 specimens is incorrect by one day. On 4 January 1901,

Ranfurly's party aboard NZGS *Hinemoa* spent all day in the Port Ross area of Auckland Island (Alexander 1901; Hutton 1901a). They journeyed to Carnley Harbour on 5 January visiting many of the eastern inlets, including Norman and McLennan Inlets, along the way. Hutton (1901a) records one merganser being obtained in Norman Inlet but makes no reference to any being retrieved from McLennan Inlet. His notebook entry for 5 January 1901 records "visited sounds on east coast" followed by a description of a merganser's bill, feet and eye and a reference to its short wings and "quacks like a duck". His notebook entry for 6 January is without reference to location (but the party was then in Carnley Harbour; Alexander 1901) and contains a description of a male merganser. Later in his notebook he comments that "A full-grown male flew from the shore to the *Hinemoa* and settled in the water within gunshot of the vessel where it remained swimming about and quacking until shot from on board". The 4 January 1901 collection date appears to have arisen from Hutton's notebook listing of small bird specimens collected that day on Enderby Island and the Port Ross shoreline and placed in a numbered specimen jar, to which he later added (in different pencil) "merganser australis 1 in Normans Inlet". Two other mergansers (CM 2944 and NMINH 1904.559.1.) are labelled as collected on 5 January 1901.

Skin. 1904.8.4.1. Collector J P Rolleston, Carnley Harbour, Auckland Island, 9 July 1901 (Ogilvie-Grant 1905). Label records soft part colouration. Labelled sex – female. Measurements: culmen 53.1, bill width at tip 5.8, wing 177, tarsus (most removed from skin), mid toe & claw 60, tail 68. Sex by measurement – female. Rolleston, commanding officer of HMS *Archer* responded to Ranfurly's request and obtained a range of bird specimens when patrolling New Zealand's Subantarctic islands. Culmen measurements are not reliable because the rhampotheca has been soaked and lifted from the underlying bone, the entire skull removed from the skin and retained as part of skeleton NHM 1904.8.4.2.

Skin. 1902.8.6.1. Collector Lt. Kennett Dixon, R.N. Auckland Island. No collection date. Labelled as male. Measurements: culmen 60.4, bill width at tip 7.1, wing 197, tarsus 42, mid toe & claw 68, tail 78. Sex by measurement – male. Age uncertain. Collector was officer on HMS *Archer* which visited Auckland Island July 1901.

Skin. 1904.4.30.1. Collector Lt. A.J. Stewart, R.N. No further details. Presumed to have been collected July 1901 during HMS *Archer* visit to Auckland Island. Measurements: culmen 55.3, bill width at tip 6.0, wing 172, tarsus 41, mid toe & claw 63, tail 68. Sex by measurement – female. Falla (1970) considered this specimen to have "indeterminate" plumage and could be a young bird, which I confirm from the presence of down stalks at the tips of the rectrices.

Skeleton. 1904.8.4.2. Female. From skin 1904.8.4.1 (Ogilvie-Grant 1905). Total skull length 102.6, nares to bill tip 35.8, sternum + keel length (ventral) 87.4, sternum length (visceral) 71.7, sternum anterior width 42.5, keel area 5.45 cm^2, pelvis acetabulum width 28.7, pelvis posterior width 47.1, humerus 67.8, ulna 54.7, femur 42.6, tibiotarsus 76.9, tarsus 40.4.

Skeleton. 1904.8.4.3. Label sex – male. Associated note reads "belongs to mounted specimen standing up". No such specimen can be traced. Total skull length 109.9, nares to bill tip 40.2, sternum + keel length (ventral) 94.8, sternum length (visceral/dorsal) 77.1, sternum anterior width 47.7, keel area 6.28 cm^2, pelvis acetabulum width

31.2, pelvis posterior width 49.9, humerus 72.1, ulna 57.7, femur 45.4. Tibia and tarsus presumably retained in the mount.

Skeleton. 1904.8.4.4. Label sex – female. Associated note reads "belongs to lying mounted specimen". No such specimen can be traced. Total skull length 103.6, nares to bill tip 37.3, sternum + keel length (ventral) 88.5, sternum length (visceral/dorsal) 72.3, sternum anterior width 43.1, keel area 5.60 cm^2, pelvis acetabulum width 29.0, pelvis posterior width 47.0, humerus 68.9, ulna 55.0, femur 43.1, tibiotarsus 77.7, tarsus 41.2.

Ogilvie-Grant (1905) refers to skeletons "of an adult pair in the possession of Lord Ranfurly"; 1904.8.4.3 and 1904.8.4.4 are presumably these. Since both retain complete skulls the rhampothecae must have been removed from the bills, as for 1904.8.4.2. The whereabouts of the mounts are unknown.

Spirit. A/1999.1.124. Cadaver of a male (based on sternum-keel length) that was initially labelled as female but subsequently re-labelled as male. All musculature and entrails remain but the gizzard has been opened and food contents reported in Kear & Scarlett (1970). Associated original labels offer no indication of origin but one states "belongs to the one standing on/upright. Tibia and tarsus left with stuffed specimen". Body width at shoulder joint (glenoid fossae) 54mm.

Ogilvie-Grant (1905) refers to the museum receiving in the "ranfurly collection" 3 skins (1901.10.21.57, 1901.10.21.58, 1904.8.4.1) a skeleton (1904.8.4.2) derived from one of the skins (1904.8.4.1), plus another two skeletons of "an adult pair in the possession of Lord Ranfurly", which presumably are the two birds he collected in Carnley Harbour on 9 January 1902 (Alexander 1902). The museum later received a male specimen (1902.8.6.1) followed by a female specimen (1904.4.30.1). Of the birds presently in the NHM collection, the spirit specimen could be derived from either of the two male skins 1902.8.6.1 or 1901.10.21.57. The reference to a standing mount could be a confusion should one of these two birds have originally been mounted and later relaxed and turned into a skin, or it could indicate the cadaver is not from any specimen now in the museum. In the latter case it would represent another, presently unknown, male specimen.

Carnegie Museum, Pittsburgh, USA

Skin. 24509. Male. This was purchased in 1905 with the "third Buller collection" (Bartle & Tennyson 2009: Appendix 5) and is thought to be the adult male mentioned in Buller (1905). A separate tag bears Buller's no. 125. Bartle & Tennyson (2009) record collection date as 1894 and possibly supplied to Buller by the collector A.W. Bethune. Measurements (supplied by S. Rogers, Carnegie Museum): culmen 53.8, nares to tip 40.1, bill width at tip 5.3, wing 181. Sex by measurement – female.

American Museum of Natural History, New York, USA

Skin. 734364. Male. No other data. Original label in the handwriting of commercial collector S.V. Dannefaerd. Measurements (supplied by M. LeCroy, AMNH): culmen 61.5, bill width at tip 5, wing 187. Sex by measurement – probably male.

Skin. 734365. Female. No other data. Dannefaerd's label gives collection date as 2/1895. Measurements (supplied by M. LeCroy, AMNH): culmen 60, nares to tip 40, bill width at tip 5, wing 178. Sex by measurement – female.

Skin. 734366. Labelled as female but a note by R. A. Falla dated 5 Aug. 1966 says "this is clearly

a male". Falla (1970) adds this specimen is "bigger than 734364". Dannefaerd's label gives collection date as 2/1895. Measurements (supplied by M. LeCroy, AMNH) culmen 62, nares to tip 44, bill width at tip 5, wing 188. Sex by measurement – male.

Skin. 734367. Unsexed. December 1901 Travers collection. Falla (1970) writes "seems to be a male, wing 192mm, bill only 58mm but wide and deep like 734366". Measurements (supplied by M. LeCroy, AMNH) culmen 62, nares to tip 44, bill width at tip 5.5, wing 188. Sex by measurement – male.

Skin. 744347. Duckling. Presumably one of the brood of four collected by Chapman (1891). Others in Otago and Canterbury Museums.

These specimens were included in the AMNH's 1932 purchase of W.L. Rothschild's collection at Tring. According to Salvadori (1895) a male and female at Tring were immature birds in first plumage. Rothschild (1907) mentioned four specimens at Tring, one mounted and three skins.

Appendix 2. Comparative measurements (mm) and weights (g) of mergansers. Means are given ± s.d. with ranges in parentheses. Sources: 1 = Kear 2005b; 2 = Livezey 1989; 3 = Cramp & Simmons 1977; 4 = Kortright 1942; 5 = Solovieva & Shokhrin 2008; 6 = L. Lins (pers.comm.); 7 = this study.

Species	Sex	Culmen	Tarsus	Wing	Weight
Mergus australis	M	60.3 ± 0.9[7] 59.6 ± 3.8[2]	42 ± 2[7] 43.4 ± 1.7[2]	194 ± 6[7] 185 ± 5.2[2]	550–760[7] 898[2]
	F	54.6 ± 1.1[7] 55.0 ± 2.8[2] (91–93% of male size)	40 ± 2[7] 40.5 ± 1.2[2]	179 ± 4[7] 175 ± 3.5[2] (93–94% of male size)	440–630[7] (80–83% of male weight)
Mergellus albellus	M	29.6 (27–32)[3]	34.0 (31–36)[3]	202 (197–208)[3]	652 (540–825)[3]
	F	26.8 (25–29)[3] (90% of male size)	30.6 (29–32)[3]	184 (181–189)[3] (91% of male size)	568 (515–630)[3] (87% of male weight)
Lophodytes cucullatus	M	39.6 (37–41)[1] 40.7 ± 1.2[2]	32.4 (30–34)[1] 33.6 ± 1.6[2]	198 (191–207)[1] 193 ± 4.2[2]	680 (595–879)[4]
	F	38.3 (35–40)[1] 39.0 ± 2.1[2] (96% of male)	31.3 (30–33)[1] 32.2 ± 1.1[2]	185 (180–191)[1] 183 ± 3.4[2] (93% of male)	544 (453–652)[4] (= 80% of male weight) 617[2]
Mergus octosetaceus	M	51.6 ± 1.5[2]	44.4 ± 2.9[2]	200.2 ± 4.4[2]	828[6] 983 (calculated)[2]
	F	48.6 ± 0.9[2] (94% of male size)	40.8 ± 2.2[2]	193.0 ± 3.9[2] (96% of male size)	753[6] (91% of male weight)

Appendix 2 (*continued*)

Species	Sex	Culmen	Tarsus	Wing	Weight
M. serrator	M	59.2 (56–64)[3]	47.0 (44–50)[3]	247 (235–255)[3]	1197 (947–1,350)[3]
		58.1 ± 1.5[2]	46.6 ± 1.6[2]	236 ± 9.0[2]	984[2]
	F	52.1 (48–55)[3]	42.7(40–45)[3]	228 (216–239)[3]	984 (900–1,100)[3]
		54.4 ± 2.6[2]	45.1 ± 2.8[2]	216 ± 9.1[2]	(82% of male weight)
		(88–93% of male size)		(92% of male size)	
M. squamatus	M	52–57[1]	46–48[1]	250–265[1]	1,232(1,125–1,400)[1]
		55.6 ± 1.4[2]	46.8 ± 0.7[2]	249 ± 6.5[2]	1,234(calculated)[2]
	F	~45[1]	–	220–250[1]	977 (930–1,070)[5]
		50.5 ± 2.0[2]	45.7 ± 2.3[2]	235 ± 11.9[2]	(79% of male weight)
		(91% of male size)		(94% of male size)	
M. merganser	M	55.8 (52–60)[3]	51.7 (49–55)[3]	285 (275–295)[3]	1,709 (1,528–2,160)[3]
		55.5 ± 3.6[2]	51.9 ± 1.7[2]	267 ± 5.5[2]	1,382[2]
	F	48.7 (44–52)[3]	47.4 (44–51)[3]	262 (255–270)[3]	1,232 (1,050–1,362)[3]
		50.6 ± 2.3[2]	46.7 ± 1.3[2]	239 ± S 3.5[2]	
		(87–91% of male size)		(90–92% of male size)	(72% of male weight)

Appendix 3: Sternum lengths, keel areas and wing bone (humerus + ulna) lengths of mergansers.

Contributed by Stephen Hartley, School of Biological Sciences, Victoria University, P.O. Box 600, Wellington, New Zealand.

To examine whether the keel of *M. australis* was reduced and its wing short relative to its sternum length, linear regressions between $\log_e$(sternum length) and $\log_e$(keel area) and between $\log_e$(sternum length) and $\log_e$(wing bone length) were performed using data from four extant merganser species (Appendix 4). The results were back-transformed to the original scale for graphical display. In fitting the regressions, individuals were considered independent data points. 50% prediction intervals were constructed around the fitted regression lines; the area within the 50% prediction interval is expected to contain 50% of all future points following the same relationship used to build the model.

Data points for *M. australis* (Appendix 4) were then compared to the inter-specific relationship to determine whether they fell inside or outside the prediction interval more, or less, frequently than expected.

For the sternum – keel area relationship, all five points for *M. australis* fell below the 50% prediction interval (Fig. 4). The probability of this occurring if *M. australis* follows the same relationship as the other mergansers is $P = 0.0017$ ($0.5 * 0.25^4$). For a given sternum length, the keel area of *M. australis* was 0.792 (0.753–0.839) [geometric mean and range]

times that predicted by the inter-specific relationship.

For the sternum – wing bone length relationship, all three points for *M. australis* fell below the 50% prediction interval (Fig. 5). The probability of this occurring if *M. australis* follows the same relationship as the other mergansers is $P = 0.029$ ($0.5 * 0.25^2$). For a given sternum length, the wing bones of *M. australis* were 0.913 (0.892–0.925) [geometric mean and range] times the length predicted by the inter-specific relationship of the other species.

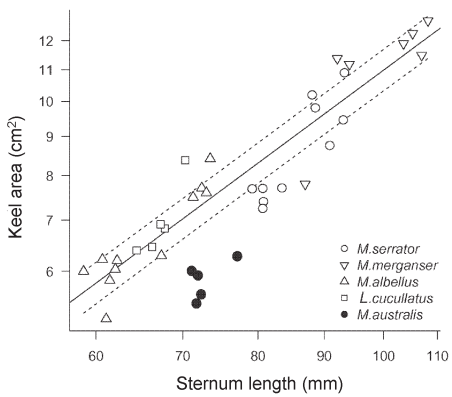

Figure 4. Interspecific allometric relationship (excluding *M. australis*) between sternum length and keel area for four species of merganser (open symbols) with 50% prediction interval (dashed line). $\log_e$(sternum) = –3.377 + 1.254*$\log_e$(keel area), R^2= 0.879, $F_{1,31}$ = 224.2, P = 9.7*10^{-16}. Species denoted *M. serrator* (open circle), *M. merganser* (inverted open triangle), *L. cucullatus* (open square), *M. albellus* (open triangle) and *M. australis* (filled circle). Data from Table 3.

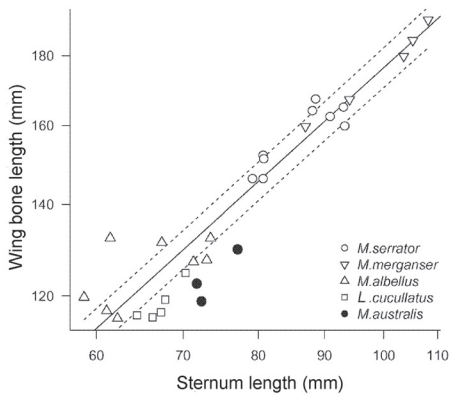

Figure 5. Interspecific allometric relationship (excluding *M. australis*) between sternum length and wing bone length for four species of merganser (open symbols) with 50% prediction interval (dashed line). $\log_e$(sternum) = 1.200 + 0.862*$\log_e$(wing bone), R^2= 0.920, $F_{1,25}$ = 288.5, P = 3.1*10^{-15}. Species denoted *M. serrator* (open circle), *M. merganser* (inverted open triangle), *L. cucullatus* (open square), *M. albellus* (open triangle) and *M. australis* (filled circle). Data from Table 3.

Appendix 4. Sternum lengths, keel areas and wing bone (humerus, ulna) lengths of four extant merganser species and *M. australis*. Specimens sourced from National Museum of Ireland, Dublin (NMINH), Natural History Museum, Tring (NHM), Naturhistorisches Museum, Wien (Vienna), Staatliches Museum fur Tierkunde, Dresden (Dresden), Museum Nationale d'Histoire Naturelle, Paris (Paris), Otago Museum, Dunedin (Otago), Canterbury Museum, Christchurch (CM).

Species & specimen identity	Sex	[1]Sternum length (mm)	[2]Keel area (cm^2)	Humerus length (mm)	Ulna length (mm)
M. serrator					
NMINH 1932.13.1	F	80.7	7.70	83.1	69.0
NHM1930.3.24.242	F	80.8	7.40	82.7	68.5
NHM 1997.78.1	F	79.2	7.69	81.5	64.7
NMINH 1927.6.1	M	88.6	9.81	91.1	76.2
NMINH 2004.79.26	M	93.3	10.90	87.6	72.2
NHM 1898.2.12.5	M	93.1	9.46	90.5	74.5
NHM 1930.3.24.633	M	88.1	10.20	90.3	73.7
Vienna 4456	F	83.5	7.71		
Vienna 4827	M	90.9	8.76	89.3	73.1
Paris 1996/39	?	80.7	7.25	80.2	66.0
M. merganser					
NHM 1955.5.10	F	94.1	11.18	93.9	73.2
NHM 1866.12.30.5	F(?)	87.0	7.80	87.2	72.5
Dresden 3092	F	92.1	11.38	94.0	
Dresden 3022	M	107.0	11.49		
NHM 1930.3.24.239	M	103.6	11.90	98.2	81.6
NHM 1930.3.24.238	M	105.3	12.27	100.1	84.6
Vienna 2733	M?	108.2	12.75	104.0	87.2
M. albellus					
NHM 1930.3.24.236	F	58.7	6.00	65.2	54.5
NHM s/1986.32.1	F	62.3	6.20	62.9	52.6
Dresden unnumbered	F	60.7	6.22		

Appendix 4 (*continued*)

Species & specimen identity	Sex	[1]Sternum length (mm)	[2]Keel area (cm^2)	Humerus length (mm)	Ulna length (mm)
NHM 1930.3.24.235	M	73.5	8.42	71.3	61.0
NHM 1930.3.24.237	M	71.3	7.50	68.9	58.2
Dresden barhmann 110	M	72.4	7.71	71.5	
Vienna 8645	F	61.5	5.84	72.1	60.2
Paris 1977/1200	?	73.0	7.60	69.4	58.1
Paris 1977/1199	?	67.4	6.29	72.0	59.3
Paris 1997/679	?	61.1	5.20	63.5	53.5
Paris 1921-203	?	62.1	6.04		
L. cucullatus					
NHM 1986.60.8	M	70.3	8.38	69.1	55.6
NHM 1997.35.1	F	64.5	6.39	64.1	52.0
Vienna 4865 captive	M	67.3	6.91	64.2	52.5
Vienna 2207 captive	F	67.8	6.83	66.6	52.6
Vienna 4598 captive	?	66.3	6.46	64.0	51.7
M. australis					
NHM1904.8.4.4	F	72.3	5.60	68.9	55.0
NHM1904.8.4.2	F	71.7	5.45	67.8	54.7
NHM 1904.8.4.3	M	77.1	6.18	72.1	57.7
CM 5176	F	71.1	6.01		
Otago 1110	F	71.9	5.93		

[1] Sternum length is measured along the midline of its visceral (dorsal) surface.

[2] Keel area measured from a thin plasticine impression of the keel scanned against 1 mm grid graph paper background.