Feeding ecology analysis supports a marine diet in the extinct Chatham Island Duck (*Anas chathamica*)

Rodrigo B. Salvador, Karyne M. Rogers, Alan J. D. Tennyson & Barbara M. Tomotani

To cite this article: Rodrigo B. Salvador, Karyne M. Rogers, Alan J. D. Tennyson & Barbara M. Tomotani (2021) Feeding ecology analysis supports a marine diet in the extinct Chatham Island Duck (*Anas chathamica*), Emu - Austral Ornithology, 121:4, 314-322, DOI: 10.1080/01584197.2021.1939719

To link to this article: https://doi.org/10.1080/01584197.2021.1939719

Published online: 22 Jun 2021.
Feeding ecology analysis supports a marine diet in the extinct Chatham Island Duck (Anas chathamica)

Rodrigo B. Salvador, Karyne M. Rogers, Alan J. D. Tennyson and Barbara M. Tomotani

*Natural History Department, Museum of New Zealand Te Papa Tongarewa, Wellington, New Zealand; †GNS Science, National Isotope Centre, Lower Hutt, Wellington, New Zealand; ‡NIOO-KNAW, Netherlands Institute of Ecology, Wageningen, The Netherlands

ABSTRACT
The Chatham Island Duck, Anas chathamica, is one of many New Zealand bird species that became extinct after Polynesian arrival. The Chatham Island Duck was a large flightless bird, with salt glands on its skull, which led to the hypothesis that it lived in a marine habitat. We tested this hypothesis using a combination of stable isotope analysis (carbon and nitrogen) and analysis of morphoanatomical features. We also conducted a comparative analysis with other anatid species from the Chatham Islands and New Zealand. Furthermore, we trialled the non-destructive technique of portable X-ray fluorescence (elemental composition of bones) to assess whether it can be helpful for reconstructing the ecology and habitat of extinct species. We obtained data from museum specimens: 12 samples of A. chathamica and 55 of other anatid species for isotope analysis; and 23 samples of A. chathamica and 63 of other anatids for X-ray fluorescence. Results from isotope analysis, supported by anatomical features, show that A. chathamica had a more fully marine diet than previously hypothesised, mainly composed of invertebrates. The large body size of A. chathamica is possibly related to territoriality and combat, which is also supported by the presence of carpal weaponry. Our data demonstrate the importance that the marine environment likely played in the life of this extinct species, while highlighting the key role nature history collections can have in ecological studies.

Introduction
Recent technological and methodological advances allow us to explore a vast and still largely untapped wellspring of ecological information in natural history collections (Webster 2017; Meineke et al. 2018; Salvador and Cunha 2020). Besides the more usual studies focusing on current anthropogenic effects of environment and global change (Meineke et al. 2018; Schmitt et al. 2018), another important aspect of using museum specimens is the reconstruction of the ecology of species that became extinct in historical times due to anthropogenic activity. Given that typically very few specimens remain of such species, it is important that they are analysed in as much detail as possible, balancing destructive and non-destructive techniques (Webster 2017). Among the new methodologies now available to us are isotope analysis (destructive) and portable X-ray fluorescence (non-destructive).

Stable isotope analysis is an established methodology for acquiring environmental and ecological information. The ratio between the stable isotopes of carbon (13C/12C) and nitrogen (15N/14N) are particularly useful to reconstruct habits of extinct species by defining their feeding ecology (Peterson and Fry 1987; Kelly 2000; Inger and Bearhop 2008). The δ13C and δ15N values of organisms reflect those of their environment and, thus, can be used to infer diet and trophic relationships (Mizutani et al. 1992; Post 2002; Fox and Bearhop 2008; Bond and Jones 2009). Nitrogen isotopes are indicative of trophic level (e.g. DeNiro and Epstein 1981; Minagawa and Wada 1984; Peterson and Fry 1987; Post 2002), while carbon isotopes are related to sources of carbon from the animals’ feeding environment (e.g. marine versus freshwater; Kelly 2000; Fry 2006; Fox and Bearhop 2008; Inger and Bearhop 2008).

Portable X-ray fluorescence (pXRF) provides the elemental composition of a sample, determining the abundance of major and trace elements assimilated from the bird’s habitat and diet (Plummer et al. 1994; Rogers 2019). This method is widely used in archaeology to determine the provenance of human bones and artefacts (e.g. LaBrecque et al. 1998; Adan-Bayewitz et al. 2007; Byrnes and Bush 2016), but can also be used to investigate bones of other species, including fossils (e.g. Plummer et al. 1994; Rogers 2019). However, besides its use for detection of pollutants (e.g. Radu and Diamond 2009;
Peinado et al. 2010), the use of pXRF in zoo-ecological analyses has not been thoroughly explored yet.

New Zealand’s avifauna, although not particularly rich, is among the most recognisable in the world due to its numerous flightless ‘oddities’. Unfortunately, the country also ranks high in the number of extinct species during the Holocene as more than a third of its breeding bird diversity has been extirpated, including several waterfowl species (Holdaway 1989; Young et al. 1996; Tennyson and Martinson 2007). The Chatham Islands (located ca. 800 km east of mainland New Zealand), despite its limited size, had a reasonably diverse waterfowl fauna comprising nine species, four of which became entirely extinct via anthropic action, with another four species locally extinct in the Chathams but surviving elsewhere in New Zealand (Holdaway 1989; Millener 1999; Tennyson and Martinson 2007; Miskelly 2008). One such casualty was the endemic Chatham Island Duck, Anas chathamica (Oliver 1955), extinguished through hunting by early Polynesian settlers (Williams 1964; Tennyson and Martinson 2007).

Anas chathamica had some unique and unusual features, including its size (largest in genus), flightlessness, carpal weaponry (proportionally the largest in Anseriformes) and the presence of large salt glands on the skull (Figure 1; Williams 2015a, 2015b; Watanabe 2017). Very few bones of this duck have been collected so far, either from natural settings or middens (Marshall et al. 1987; Williams 2015b), and this lack of physical material makes it difficult to study the species in more detail. Previous authors proposed that A. chathamica had a marine-based diet due to the physiological presence of salt glands (Williams 2015a), but that hypothesis has not been tested so far.

Herein we use a combination of independent lines of evidence to assess whether A. chathamica lived primarily in a marine environment. Namely, we analyse morpho-anatomical features that are potentially related to marine habits and use stable isotope data to gain information about diet, and thus habitat. To provide better support to our analyses of A. chathamica, we also supply comparative data on other anatid species that inhabit the Chatham Islands, as well as other oceanic islands around New Zealand. Finally, we test whether pXRF can offer useful information for ecological studies of extinct species through the retention and accumulation of dietary or environmentally specific elements in bones. Being a portable and non-destructive procedure, it is worthwhile exploring its potential uses for cases where only few precious museum specimens are available.

**Material and methods**

Our comparative analyses included specimens of A. chathamica, as well as other Anas spp. present in New Zealand: Brown Teal, A. chlorotis G.R. Gray, 1845; Grey Duck, A. superciliosa Gmelin, 1789; Auckland Island Teal, A. aucklandica (G.R. Gray, 1849); Campbell Island Teal, A. nesiotis (J.H. Fleming, 1935). The former two were present both on the Chatham Islands and on New Zealand’s mainland (we analysed specimens from both settings), and the latter two inhabit other archipelagos south of the New Zealand mainland and are flightless like A. chathamica. We also included the extinct endemic Chatham Island Merganser, Mergus milleneri Williams & Tennyson, 2014, for comparison, which likely had a marine-based diet.

The isotope dataset stems from a joint project of Murray J. Williams and Richard N. Holdaway that took place in 2000–2005, to which we have been granted access. Part of the dataset has already been published by Holdaway et al. (2013: A. chlorotis) and Williams et al. (2012: M. milleneri), but the remaining values are reported here for the first time.

Samples for stable isotope analysis were largely obtained from bone specimens housed at the Museum of New Zealand Te Papa Tongarewa (NMNZ, Wellington) and Canterbury Museum (CM, Christchurch) (Supplementary Material: Table S1). Furthermore, stable isotope values reported here include samples taken from bones during fieldwork by Murray J. Williams (MJW), of which no voucher specimens remain (Table S1). The bones were prepared and analysed at the Stable Isotope Laboratory of GNS Science (Lower Hutt, New Zealand). Bone collagen extraction followed the protocol of Holdaway and Beavan (1999). Stable isotope values acquired from

**Figure 1.** Skull of A. chathamica (NMNZ S.029475), from Maunganui Beach, Chatham Island, showing the impression of the salt glands above each orbital cavity (arrow). Photograph by Jean-Claude Stahl, Te Papa. Credit: NMNZ, CC BY-NC-ND 4.0.
bone collagen represent an averaged diet history throughout the life of the bird (Hobson and Clark 1992).

Carbon and nitrogen content and stable isotopic composition were analysed using an Isoprime isotope ratio mass spectrometer (VG Micromass, UK) interfaced to a EuroEA elemental analyser (UK) in continuous-flow mode (EA-IRMS). Bone collagen was weighed in duplicate into 4 × 6 mm tin capsules for \( \delta^{13}C \) and \( \delta^{15}N \). The EA oxidation and reduction furnace temperatures were set at 920°C and 600°C, respectively, with high-purity (>99.99%) CO₂ and N₂ as reference gases. Helium was used as the carrier gas and with a flow rate of 60 mL/min. Stable isotope ratios were calculated referring to the equation \( \delta(\%) = R_{\text{sam}}/R_{\text{ref}} -1 \) (Coplen 2011), where \( \delta \) represents either \( \delta^{13}C \) or \( \delta^{15}N \), \( R_{\text{sam}} \) denotes the abundance ratio of heavy isotope against light isotope (\( ^{13}C/^{12}C \) or \( ^{15}N/^{14}N \)), \( R_{\text{ref}} \) is the isotope ratio of reference standard versus primary standards, i.e. Vienna Pee Dee Belemnite (VPDB) for carbon, Air gas (AIR) for nitrogen. Working reference standards (leucine, EDTA, caffeine, and sucrose) were calibrated against international reference materials (IAEAN1, IAEA-N2, IAEA-CH6 and IAEA-CH7) and blanks were included during each run for calibration. Analytical precision of the measurements is ±0.1 ‰, and reproducibility of the results is within ±0.1 ‰ for carbon and ±0.2 ‰ for nitrogen (1σ).

There is a global change in the ratio of atmospheric carbon isotopes, which is caused by the large amount of \( ^{13}C \)-depleted CO₂ released by the burning of fossil fuels (Keeling 1979). This phenomenon is known as the Suess effect and requires the correction of carbon isotope measurements from samples subsequent to the Industrial Revolution (Verburg 2007). Thus, we used equation #4 of Verburg (2007) to correct our bulk carbon measurements of freshly collected specimens, according to the year they were collected (Table S1). Subfossil specimens predate the Industrial Revolution and did not require correction (Table S1).

The specimens analysed using non-destructive pXRF were likewise obtained from the NMNZ collection (Table S1). A portable handheld X-Ray Fluorescence analyser gun (Olympus Innov-X 50 KV) was used in 'Geochemistry mode'. Samples were placed over the detector window of the pXRF mounted in a test stand provided by the manufacturer, which enclosed the X-rays within a metal case. Objects were scanned for 90 s with beam settings at 50 kV for 60 s and 15 kV for 30 s. Calibration checks (using a Stainless-Steel Calibration Check Reference Coin provided by Olympus) and reference materials (NIST2710a, NIST2711a) were taken every 20 samples. Contents of major and trace elements were recorded by Innov-X Delta Advanced PC software. Elemental abundance was measured in ppm (1 ppm = 1 mg/kg) or percentage (where 1% = 10,000 ppm). Limits of detection (LoDs) for elements analysed by pXRF are in the ppm range. Elemental abundance was not linearity corrected and was used for comparative purposes only.

We tested if species and specimen location (islands versus mainland) explained differences in bulk isotopic values of carbon and nitrogen using multiple regression analysis in R 4.0.2 (R Core Team 2020). To define the minimal model, we used backward model selection, dropping non-significant terms in each step. We then did a post hoc pairwise t-test comparison between each pair of species, accounting for multiple testing via Bonferroni adjustment.

To evaluate chemical elements in relation to habitat and species differences determined by pXRF, we used an orthogonal partial least squares discriminant analysis (OPLS-DA) with the pXRF results using SIMCA-p software (v.13.0, Umetrics, Germany). OPLS-DA is widely used as a supervised recognition tool, which decomposes the raw sample-variable matrix by partial least squares (PLS) and extracts characteristic information from all variables and fits them into the first few latent variables (LVs) to realise dimensionality reduction of data. Score matrices of samples projected on the first few latent variables generate a new variable matrix summarising raw data (e.g. t1 and t2) and present the classification of observations (samples) and outliers. The first component (t1) explains the largest variation of the X space, followed by t2. In addition, key characteristic variables used to discriminate the origin of samples can be identified according to variable loadings plot and importance for the projection values (VIPs >1 indicates importance).

**Results**

The carbon and nitrogen isotope values, as well as the major and trace elemental abundance obtained by pXRF are listed in Table S1.

\( \delta^{15}N \) values were significantly different between species \( (F = 22.51; p < 0.01) \), but there was no difference between island and mainland specimens of each species \( (F = 1.17; p = 0.28) \) (Figure 2(a,c)). The post hoc comparison revealed significantly higher \( \delta^{15}N \) values for *A. chathamica* (mean ± s.e.: +14.4 ± 0.8 ‰) than *A. chlorotis* (+8.1 ± 0.3 ‰) and *A. superciliosa* (+9.6 ± 1.4 ‰), but no significant difference between *A. chathamica* and *A. auklandica* (+15.2 ± 1.2 ‰), *A. nesiotes* (+17.6 ± 2.7 ‰) or *M. milleneri* (+19.3 ± 1.1 ‰). For a full comparison, see Supplementary Material (Tables S2, S3).

\( \delta^{13}C \) values were also significantly different between species \( (F = 38.80; p < 0.01) \) and were generally more
negative in the mainland specimens, the latter reflecting a terrestrially influenced basal food web ($F = 4.75; p < 0.01$) (Figure 2(b,c)). The post hoc comparison revealed significantly less negative $\delta^{13}C$ values for *A. chathamica* ($−13.2 ± 0.9 \%$) than mainland *A. chlorotis* ($−20.9 ± 0.6 \%$), mainland *A. superciliosa* ($−22.6 ± 0.4 \%$) and *A. nesiotis* ($−22.6 ± 0.7 \%$), but no difference between *A. chathamica* and *A. aucklandica* ($−14.0 ± 0.9 \%$), island
A. chlorotis (−16.2 ± 0.7 %), island A. superciliosa (−14.0 ± 2.9 %) or M. milleneri (−14.1 ± 0.8 %). For a full comparison, see Supplementary Material (Tables S2, S4).

The OPLS-DA analysis of pXRF data clustered different species and their associated habitat (island or mainland) into different regions based on their elemental composition. The clustering accuracy, which combined two latent variables (t1 and t2), accounts for 48% of the species separation, respectively highlighting that some species overlap and do not cluster well into their classes (Figure 2(d)); total classification accuracy R2X(cum) = 63.9%). The classification performance of the OPLS-DA model was evaluated by the cumulative contribution of latent variables (R2Y; only 24.1% for t1 and t2) and goodness of fit (Q2 = 15.1%); this suggests that there are too many scattered outliers to cluster each species according to a predictive model.

The significant chemical elements (VIP > 1.0) contributing to t1 (Figure S1) were magnesium, calcium, aluminium; iron was borderline (0.98). In t2 (Figure S2), the elements were iron, silica, magnesium, zinc, calcium, aluminium; strontium was borderline (0.99). With very few exceptions, samples lying in the negative region for t1 are related to islands, while positive values are more indicative of the mainland. No clear relation between species and environment could be established based on t2, although most samples clustering in the upper left quadrant (negative t1 and positive t2) are from the Chatham Islands. Figure S3 shows the loadings scatter plot resulting from the pXRF displaying the relationship between the elements, the species and their habitat. In this plot, elements close to the centre of the quadrant have lower discriminatory powers. Anas chathamica plots closely to the island representatives of A. superciliosa and A. chlorotis, which is expected given that the latter are almost exclusively from the Chatham Islands (Table S1). Mergus milleneri, A. nesiotis and A. aucklandica plot close to one another, forming a second cluster. Mainland samples of A. superciliosa and A. chlorotis plot the farthest away from the other species.

**Trophic level and diet**

Holdaway (1989) posited a diet entirely made up of crustaceans and molluscs for Anas chathamica. On the other hand, Mitchell et al. (2014) proposed a mostly herbivorous diet, which was later questioned by Williams (2015b) based on the brackish and marine environment predominant in the Chathams. Our results are consistent with a carnivorous diet based on invertebrates.

Our results show very similar high δ15N values between A. chathamica, A. aucklandica and A. nesiotis (Figure 2(a, c); Table S1) indicating a diet rich in marine invertebrates (marine invertebrates are enriched in 15N compared to freshwater ones; France 1994). Both teals inhabit islands (and thus are in comparable 15N-enriched habitats; see below) and are mostly carnivorous (Williams 1995; Williams and Robertson 1996). For A. nesiotis, higher δ15N values allied to more negative δ13C values (see below) support the hypothesis they are eating from a food web with a detrital base that may be affected by bird guano, or they are possibly insectivorous feeders. Less negative δ13C values support that A. aucklandica feed more on marine invertebrates (cf. Williams 1995; Williams and Robertson 1996). Anas chlorotis and A. superciliosa typically have lower δ15N and more negative δ13C values than the other species, in line with their omnivorous diet with a larger freshwater plant component (Moore et al. 2006).

Notably, the nitrogen isotope values obtained for A. chathamica were not significantly different from those of the piscivorous M. milleneri (Figure 2(a,c); Table S1). On average, both species had relatively high δ15N values with a non-significantly higher average δ15N value for M. milleneri. However, the low number of M. milleneri samples analysed may misrepresent the isotope variability of this species and bias the statistics, given that the average value for the species is much higher than that of A. chathamica. A difference of ca. 3–4% is typically considered a change of one trophic level (Mizutani et al. 1992; Post 2002; McCutchan et al. 2003), so we could expect the piscivorous M. milleneri to be on a trophic level above A. chathamica.

As alluded to above, islands (especially small oceanic ones) usually have a marked enrichment in 15N due to the presence of large numbers of seabirds (Hobson et al. 1994; Caut et al. 2012). That is due to 15N-enriched bird guano (coming from 15N-enriched marine prey) leaching into primary food (plants) and water sources (Hobson et al. 1994; Erskine et al. 1998; Ellis et al. 2006).
2006; Caut et al. 2012). The Chatham Islands are a global hotspot for seabirds, so heightened background levels of $^{15}$N could be expected there. This would affect nitrogen isotope values for animals feeding in terrestrial and freshwater environments on the islands (marine environments are already naturally enriched in $^{15}$N). For instance, enrichment in $^{15}$N has already been observed for the Chatham Island snipe Coenocorypha pusilla (Puller, 1869), which forages in the soil for invertebrates, as well as other snipes on oceanic islands around New Zealand (Hawke and Miskelly 2009). Nevertheless, an enrichment in $^{15}$N was not observed when comparing mainland New Zealand and island A. chlorotis and A. superciliosa (both almost exclusively from the Chathams; Figure 2(a), Table S1). However, the small sample size of island-dwelling A. superciliosa might have biased the results for this species, as their island average was much higher than that of their mainland counterparts, despite not being statistically significant.

Habitat

The carbon isotope values obtained for A. chathamica are in line with those of M. milleneri (Figure 2(b,c); Table S1), indicating a similar marine environment. They differ greatly from the $^{813}$C values of the freshwater-feeding A. chlorotis and A. nesiotis (Williams and Robertson 1996; Holdaway et al. 2013), but are similar to those of A. aucklandica, which feeds among kelp on protected shorelines (Williams 1995).

Williams (2015a) considered that A. chathamica would inhabit marine edges, sheltered reaches or coves, like A. aucklandica. The latter has very small salt glands and can spend a lot of time away from the sea in runnels and among tussock (Williams 2015b). The larger salt glands of A. chathamica (Figure 1) indicate more obligatory marine habits, including the island’s large brackish Te Whanga Lagoon, which would offer more sheltered habitats and has also been postulated as the prime habitat of M. milleneri (Williams et al. 2012, 2014). Furthermore, until a few millennia ago, the Chathams were a single large island, in all likelihood with a much more extensive shoreline (Campbell 2008) able to support a larger A. chathamica population.

From the OPLS-DA analysis of the pXRF values (Figures 2(d), S1–S3), it can be seen that habitat is a strong determinant of the bone’s elemental composition, given that A. chathamica plotted together with island-dwelling A. superciliosa, which are all from the Chathams, and island-dwelling A. chlorotis, mostly from the Chathams (Table S1). In the scatter plot (Figure S3), it can also be seen that the three values obtained for the three above-mentioned species cluster close to the elementa loading values of phosphorus and zircon. Phosphorus is elevated in island duck species due to concentrated and localised bird guano deposits from the marine diet ingested by these birds (e.g. Landis and Craw 2003; Irick et al. 2015). Mineralogy of the Chatham Island sediments has shown they are rich in detrital zircon from the Permian-Triassic Torlesse greywacke equivalent (and also in Sr, U, and Rb in basement rocks; Adams et al. 2008). Values from the mainland A. superciliosa and A. chlorotis plot far away from P and Zr (Figure S3) due to different regional geology, and higher geographical dispersal and mobility of the birds than on the Chathams.

Morphology

Morpho-anatomical features observed in A. chathamica also offer ecological information to complement the results of the chemical analyses. First and foremost, the large impressions on the skull indicate the presence of well-developed salt glands (Figure 1; Williams 2015a), which is an important adaptation to marine life in birds (Schmidt-Nielsen 1960). Thus, this feature provides further evidence of a marine (or strongly marine-influenced) feeding environment for A. chathamica.

Anas chathamica was flightless (Williams 2015b; Watanabe 2017), indicating sessile habits in an environment which was productive and predictable, i.e. an island with food supply all year round (Williams 2015a, 2015b). In particular, A. chathamica is the largest species in the genus, which led Williams (2015a, 2015b) to propose that it became large-bodied after colonising the Chatham Islands. It is the only island-dwelling Anas species that has done so (though a similar scenario is known from the Hawaiian moa-nalos; Sorenson et al. 1999), and that author hypothesised it was due to higher predation risk in the more exposed and open shorelines environments of the Chathams. It is hard to ascertain the validity of that hypothesis based on current evidence, especially given that other explanations for large size are apparent in other anatid lineages.

A similar increase in size and flightlessness can be seen, for instance, in South American marine streamer ducks (Tachyeres spp.) and in the extinct coastal duck Chendytes lawi Miller, 1925 from California and the Channel Islands; all those species feed/fed on marine invertebrates (Miller et al. 1961; Fulton et al. 2012; Buckner et al. 2018). In C. lawi, the increase in size is hypothesised to be related
to locomotion, diving, and access to larger (possibly sessile) invertebrate prey (Miller et al. 1961; Buckner et al. 2018). In Tachyeres, the increase in size is hypothesised to be related to improved locomotion on the water, diving, thermore- gulation, defence and wing-assisted combat (Livezey and Humphrey 1986).

A strong territorialism is implied in A. chathamica by their carpal weaponry, which is proportionally the largest in Anseriformes (Williams 2015a). Thus, we suggest that a more likely explanation for their increase in size is related to territorialism, aggressive behaviour and wing-assisted combat, as proposed for streamer ducks (Livezey and Humphrey 1986). Similar cases of flightlessness accompanied by carpal weaponry are known from unrelated avian taxa, such as the Rodrigues solitaire Pezophaps solitaria (Gmelin, 1789) (Columbidae) and the Jamaican ibis Xenicibis xympithecus Olson & Steadman, 1977 (Threskiornithidae), both now extinct (Livezey 1993; Longrich and Olson 2011; Hume and Steel 2013).

Conclusion

The ability to investigate the ecology of extinct species is necessarily more limited than investigating living taxa, so using multiple lines of evidence helps to achieve stronger interpretations (Grimes et al. 2003; Rasser et al. 2019). Herein, we combined stable isotope analysis and morphoanatomical data to achieve a better understanding of the ecology of the extinct Anas chathamica. We show that it had a more fully marine diet than previously hypothesised, mainly composed of invertebrates but likely containing a minor plant component. The large body size of A. chathamica is possibly related to territoriality and combat, as suggested by the presence of carpal weaponry. Finally, we also highlight that, while non-destructive techniques such as pXRF are important in cases where few specimens exist, they are rather limited in what they can achieve. As such, destructive sampling (e.g. isotope analysis and DNA extraction) will remain necessary in most cases.

Acknowledgements

The isotope data set used here stems from a joint project of Murray J. Williams and Richard N. Holdaway that took place in 2000–2005; we are very grateful to them for inspiring us to take on this project and the discussions and encouragement along the way. We are likewise grateful to the two anonymous reviewers and the associate editor Kate Buchanan, whose comments and suggestions helped to improve this article.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Rodrigo B. Salvador http://orcid.org/0000-0002-4238-2276
Karyne M. Rogers http://orcid.org/0000-0001-8464-4337
Alan J. D. Tennyson http://orcid.org/0000-0001-6374-6924
Barbara M. Tomotani http://orcid.org/0000-0002-8855-4803

References


