Nutritional and trace metal dynamics shaped by sexual maturity in the multidimensional niche of a delphinid

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INTRODUCTION

- While progress has been made to understand different food pathways for the ingestion of metals and their physiological effects on individuals (e.g., Fossi et al., 2018; Harley & O'Hara, 2015; O'Shea, 1999; Ramos & González-Solís, 2012), our current knowledge of their nutritional linkages remains largely unexplored (Bignert et al., 1993).
- This knowledge gap hampers current understanding on how marine mammals fulfil their nutritional and energetic needs, while balancing their intake of trace metals during different life history stages (Machovsky-Capuska & Raubenheimer, 2020; Malinowski & Herzing, 2015).
- We explore (i) influence of sexual maturity on prey consumption, diet, and the nutritional niche breadth in common dolphins; ii) trace metal accumulation (Hg, Cd, Se, and Zn) in relation to age, sex, and/or sexual maturity status; iii) first insights to the roles of Se and Zn in the detoxification mechanisms of Hg and Cd; and iv) linkages between protein (P) and lipid (L) intake with metal accumulation within a multidimensional niche.

METHODS

- Stomach content analyses (SCA), proximate composition analysis (PCA), multidimensional nutritional niche framework (MNNF) with Bayesian multivariate ellipses, trace metal analysis and nicheROVER were applied to explore the nutritional and trace metal niche dynamics across sex, age, and sexual maturity status in common dolphins (*Delphinus delphis*).
- Common dolphins (n=20) which either live stranded and subsequently died or were found beachcast along the New Zealand coast between 2011-2013 were sampled post-mortem following Stockin et al., (2009).
- Sex, age, sexual maturity, body condition, stomach contents and trace element burden were determined for each animal (Stockin et al., 2007; Meynier et al 2008; Palmer et al., 2022).

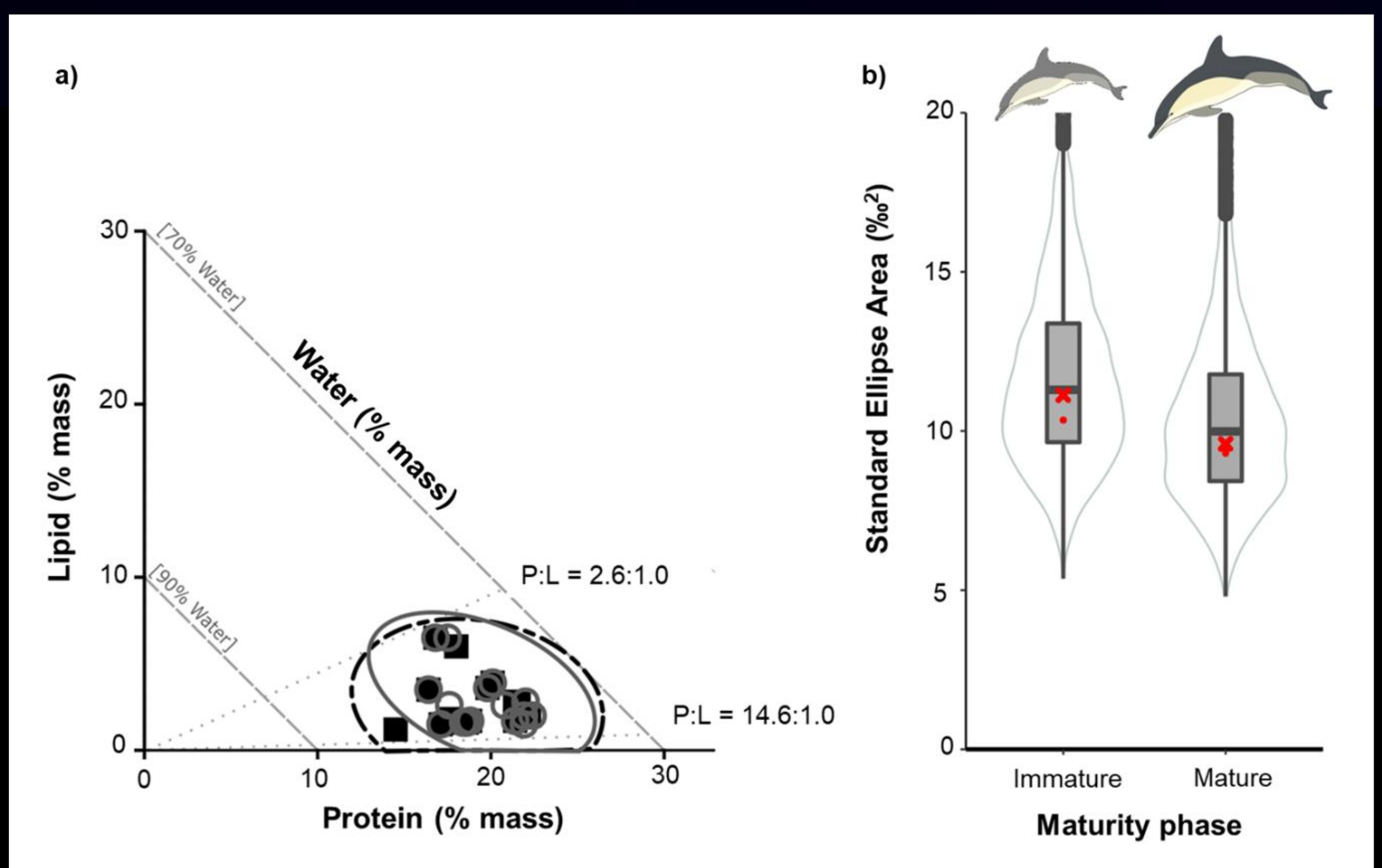

Fig 1. Prey range consumed by a species (prey composition niches, sensu Machovsky-Capuska et al., 2016a) for immature and mature common dolphins (*Delphinus delphis*) in New Zealand. **a)** Proportions Nutritional Geometry (PNG) showing the nutritional composition of prey consumed and the niche breadths measured as the small sample corrected standard ellipse areas (SEAc) for immature (black squares, SEAc: 11.9, black ellipse) and mature (grey hollow scircles, SEAc: 10.3, grey ellipse) dolphins. **b)** Box plots combined with mirrored kernel densities in the form of violins are used for comparing the Bayesian estimates (SEAb) for the realized nutritional niches of each maturity phases. Red crosses indicate the Maximum-likelihood estimated SEAc, and red dots the SEAb.

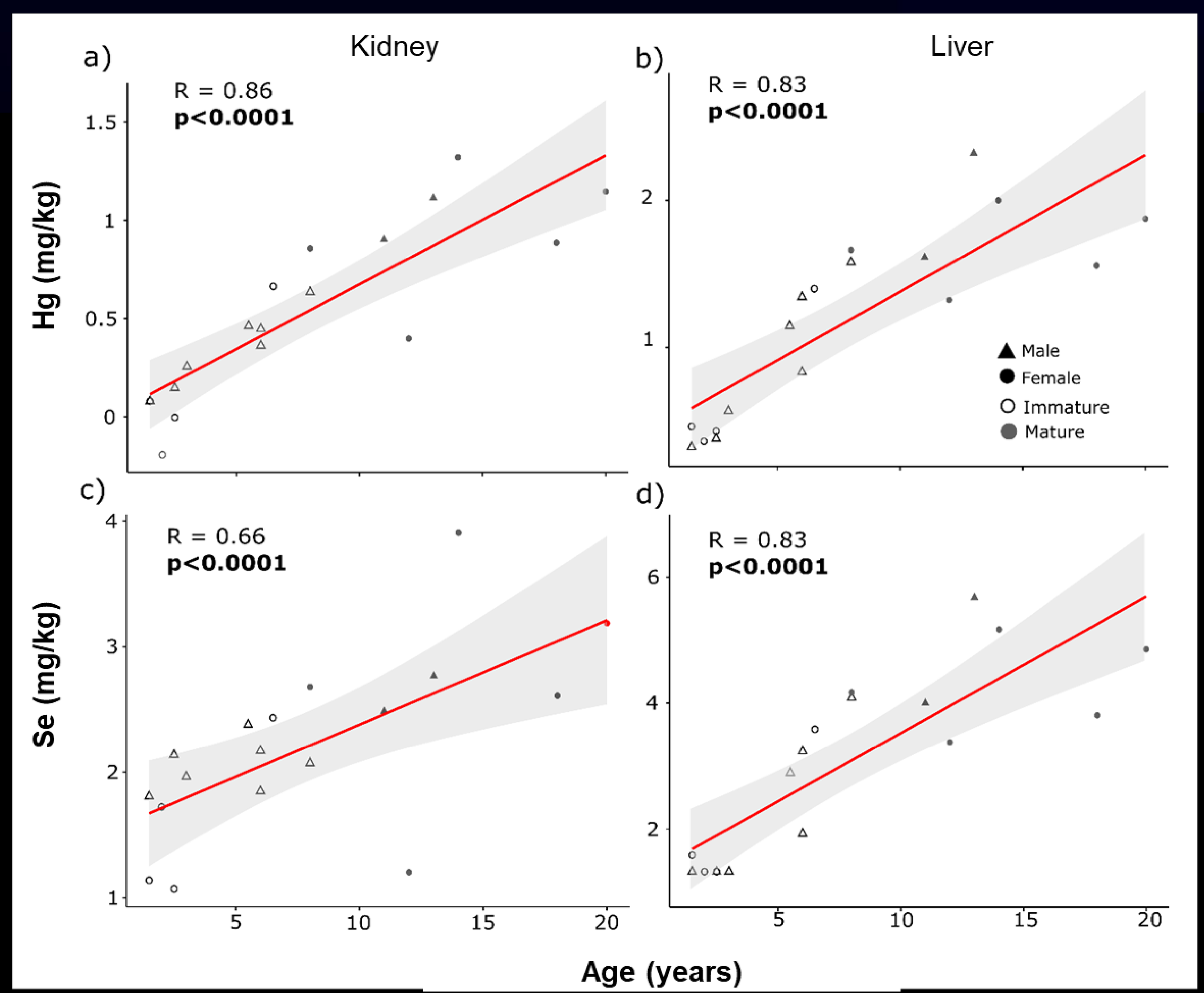

Fig 2. Linear regressions of Hg concentrations (a, b) and Se (c, d) in kidney and liver in relation to age (years) in common dolphins (*Delphinus delphis*). The grey shade represents the confidence interval of regression. Only chemicals demonstrated statistically significant correction ($p < 0.05$) with age are shown.

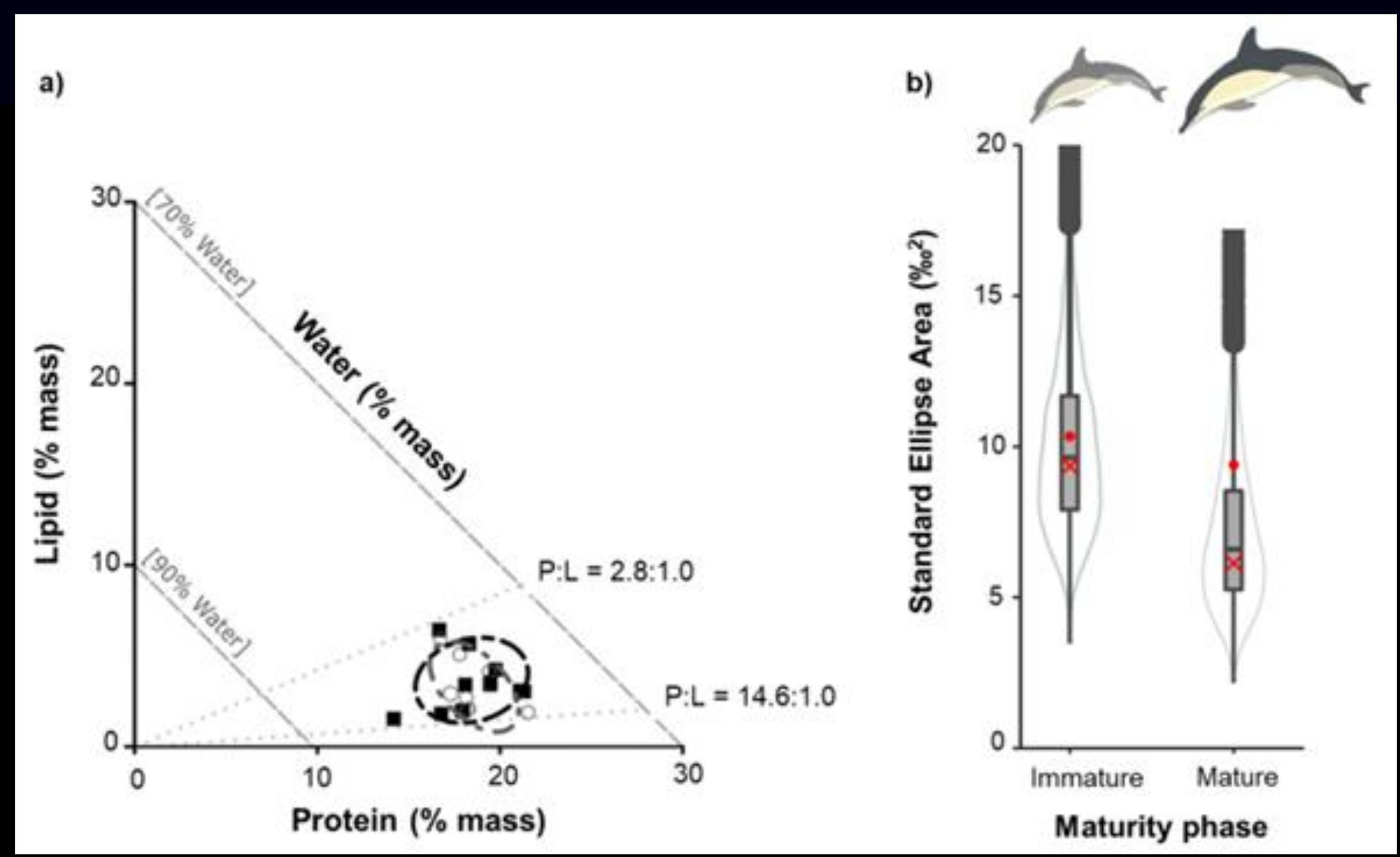

Fig 3. Diet range i.e. product of eating diverse prey (realized nutritional niches, sensu Machovsky-Capuska et al., 2016a) for immature and mature common dolphins (*Delphinus delphis*) in New Zealand. a) Proportions Nutritional Geometry (PNG) showing the nutritional composition of individual diets and the niche breadths estimated as the small sample corrected standard ellipse areas (SEAc) for immature dolphins (black squares and SEAc: 10.3, black ellipse) and mature dolphins (grey hollow circles, SEAc: 7.2, grey ellipse). b) Box plots combined with mirrored kernel densities in the form of violins are used for comparing the Bayesian estimates (SEAb) for the realized nutritional niches of each maturity phases. Red crosses indicate the Maximum-likelihood estimated SEAc, and red dots the SEAb

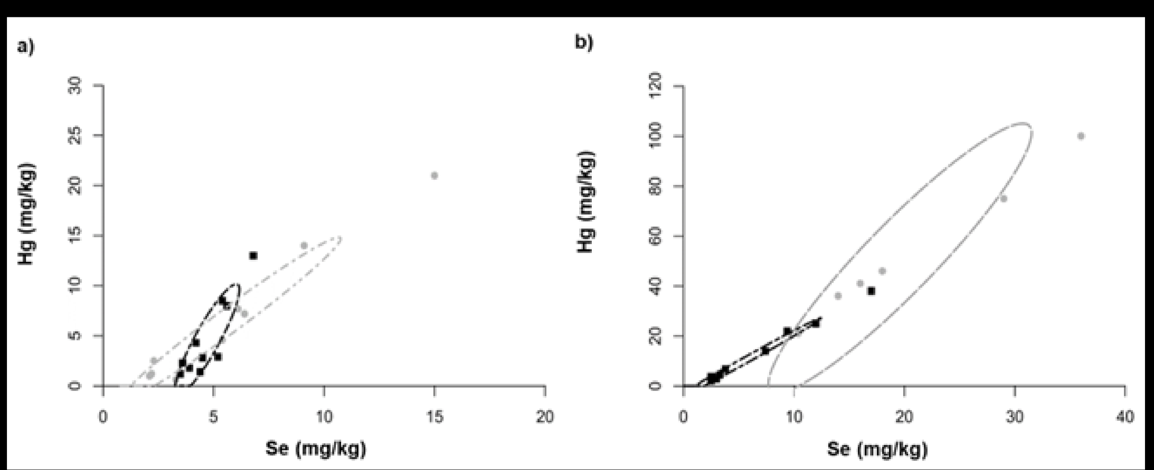

Fig 4. Bayesian ellipse analysis showing the range of Hg and Se concentrations in the kidney of (**a**) immature (black ellipse, SEAc = 6.22 $(mg.Kg^{-1})^2$) and mature dolphins ((grey ellipse, SEAc = 19.35 $(mg.Kg^{-1})^2$); and in the livers of (**b**) immature (black ellipse, SEAc= 16.35 $(mg.Kg^{-1})^2$) and mature dolphins (grey ellipse, SEAc = 867.94 $(mg.Kg^{-1})^2$).

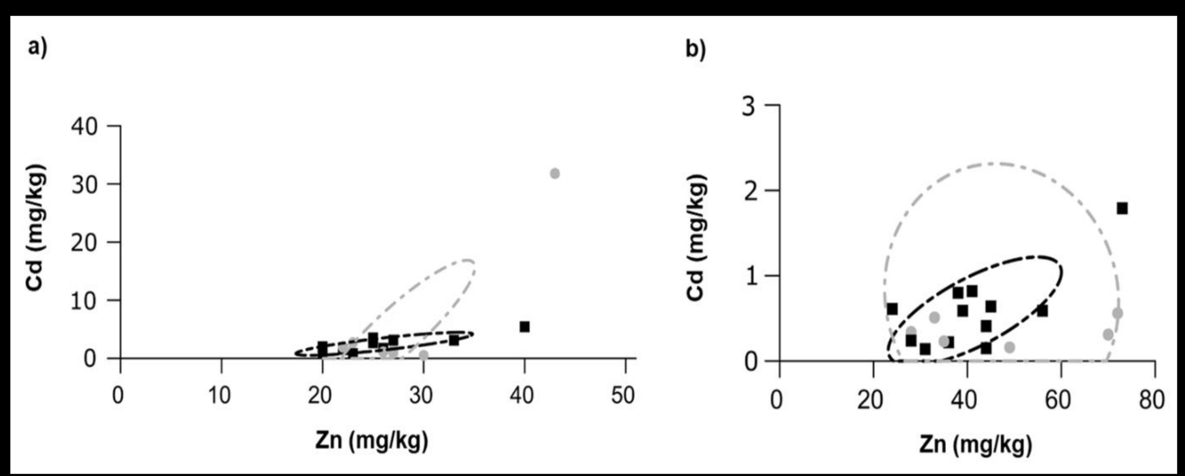

Fig 5. Bayesian ellipse analysis showing the range of Cd and Zn concentrations in the kidneys of (**a**) immature (black ellipse, SEAc = 16.16 $(mg.Kg^{-1})^2$) and mature dolphins (grey ellipse, SEAc = 101.37 $(mg.Kg^{-1})^2$); and in the livers of (**b**) immature (black ellipse, SEAc = 14.03 $(mg.Kg^{-1})^2$) and mature dolphins (grey ellipse, SEAc = 72.87 $(mg.Kg^{-1})^2$)

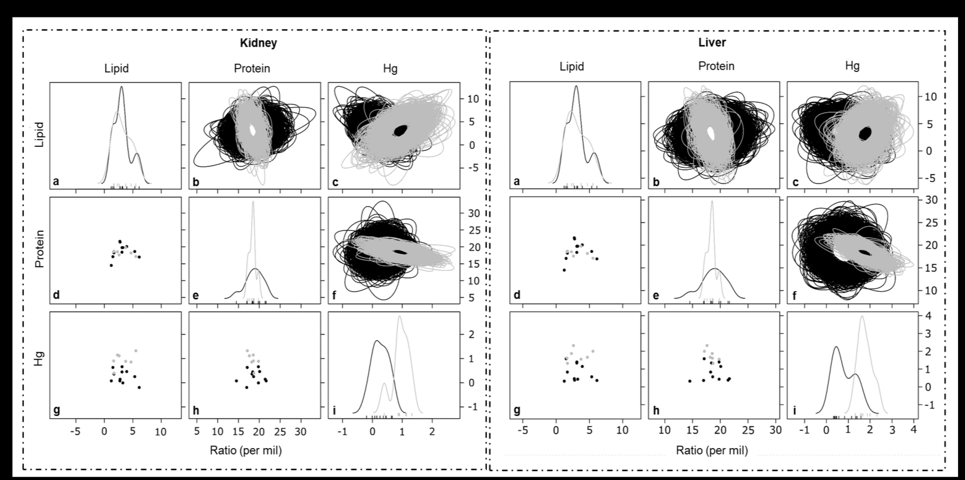

Fig 6. Density plots showing intake distribution of lipid (**a**), protein (**e**), Hg (**i**); Bayesian ellipse areas (1000 runs plotted) using posterior estimates of ellipses for lipid vs protein (**b**), lipid vs. Hg (**c**), and protein vs. Hg (**f**); and biplots for protein vs. lipid (**d**), Hg vs. lipid (**g**), and Hg vs. protein (**h**) in kidney and liver of immature (black) and mature (grey) dolphins.

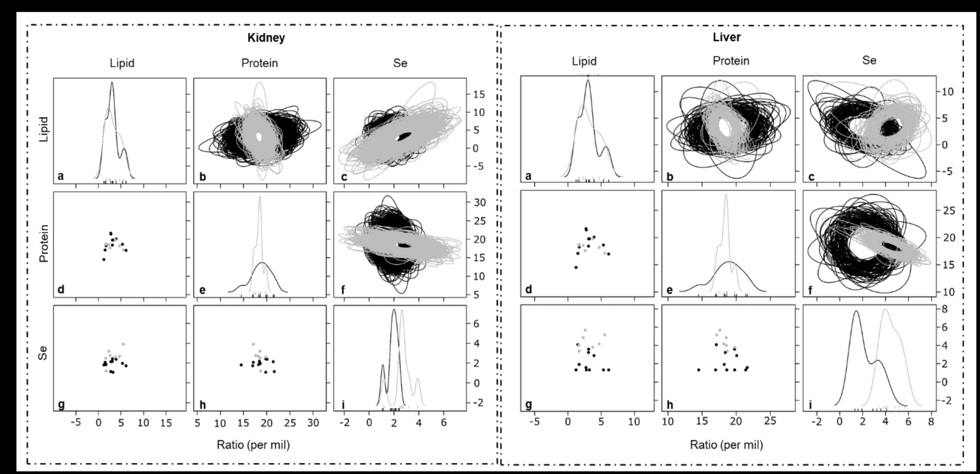

Fig 7. Density plots showing intake distribution of lipid (**a**), protein (**e**), Se (**i**); Bayesian ellipse areas (1000 runs plotted) using posterior estimates of ellipses for lipid vs protein (**b**), lipid vs. Se (**c**), and protein vs. Se (**f**); and biplots for protein vs. lipid (**d**), Se vs. lipid (**g**), and Se vs. protein (**h**) in kidney and liver of immature (black) and mature (grey) dolphins.

CONCLUSIONS

- A multidisciplinary approach is needed to explore interactions between nutrients and metals in the multidimensional niche of delphinids during different life stages.
- Nutritional and trace metal dynamics were shaped by sexual maturity, though not influenced by either sex or age.
- Mature dolphins demonstrated low niche overlap with their immature conspecifics, with wider Hg and Se niches characterized via higher hepatic and renal concentrations.
- Low niche overlap provides insight to the pathways and resources (e.g., foraging behaviour, prey and habitat) from which metals are incorporated.
- Our multidisciplinary assessment highlighted underlying intricacies on how nutritional requirements and foraging strategies are important to predict trace metal intake.

ACKNOWLEDGEMENTS

KAS was supported by a Royal Society Te Apārangi Rutherford Discovery Fellowship (2019-2024). Nutritional analyses were funded by a Massey University Strategic Research Excellence Fund (RM23810) grant awarded to KAS. Access to carcasses was kindly supported by Mana Whenua and facilitated via the New Zealand Department of Conservation permit 39239-MAR. Nutritional analyses were completed at the Nutritional Laboratory, Massey University, New Zealand. We thank Laureline Meynier (BioSciences) for published dietary data used in aspects of analyses presented here. We also thank Emma Betty, Sinead Murphy, Matthew Perrott, Odette Howarth, Emmanuelle Martinez, Sonja Clemens, and postgraduates of the Cetacean Ecology Research Group who assisted with various aspects of post-mortem sampling and life history assessment.