Doctoral Dissertation

The Application of Discriminant Function Analysis to Atlas and Axis Vertebrae of Toothed Whales: Aiding Species Identification of Zooarchaeological Remains

（ハクジラ類第一・第二頸椎への判別分析の適用：
遺跡出土試料の種同定に向けて）

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ABSTRACT

Toothed whale remains are common finds from archeological sites across Japan from the Jomon to the Ainu Culture Period, suggesting a key marine resource of subsistence in this region. However, the actual state of whale exploitation at each archeological site remains unclear. The reason is that most assemblages consist of primarily postcranial bones that are similar in morphology and are difficult to identify. To date, zooarchaeological toothed whale bones have been identified by differences in morphological traits based on a small number of specimens. In this study, I attempted to establish taxonomic identification criteria for atlas and axis vertebrae of modern toothed whales using discriminant function analysis (DFA) and applied the criteria to atlas and axis vertebrae from Japanese archeological sites.

Canonical discriminant function analysis was effective at classifying the atlas and axis vertebrae of 18 modern toothed whale species in a hierarchical classification system, with a high successful classification rate at the superfamily (97.1%), family (89.6%), and subfamily (78.9%) levels. At the species level, six received the highest score (100.0%) for correct identification rate for each species, while four other species had sufficiently high correct identification rates (above 80.0%). The established canonical discriminant functions were applied to 44 zooarchaeological atlas and axis vertebrae from three archeological sites in Japan ranging from the early Jomon to the Okhotsk Culture periods. Twenty-seven of the zooarchaeological specimens (61.4%) were identified in a hierarchical taxonomic classification scheme without contradiction and six species

(Pacific white-sided dolphin (N=11), Striped dolphin (N=5), Risso's dolphin (N=5), short-beaked common dolphin (N=3), common bottlenose dolphin (N=2), and northern right whale dolphin (N=1)) including four species not found in the previous morphological analysis and three not distributed around the sites, were found.

Based on these results, DFA-based classification was suggested to be useful for taxonomic identification at the family level and higher, and thus, effective in improving the identification quality of zooarchaeological specimens. Adding more modern reference specimens in the dataset may further improve the certainty and accuracy of identification for future work. Furthermore, the presence of other species as unexpectedly revealed by DFA-based classification offers not only insight into the taxonomic diversity of species exploited by the early Jomon and Okhotsk people but also questions about the acquisition routes from archeological perspectives and temporal distribution changes of the species from zoogeographical perspectives.

บทคัดย่อ

การขุดค้นซากโครงกระดูกของวาฬมีฟันในชั้นทับถมทางวัฒนธรรมตามแหล่งโบราณคดีหลายแห่งทั่วทั้งประเทศญี่ปุ่นนับตั้งแต่สมัยโจมงเรื่อยมาจนถึงสมัยวัฒนธรรมไอนุนั้น บ่งบอกถึงความเป็นทรัพยากรชีวภาพทางทะเลที่มีบทบาทและความสำคัญต่อการยังชีพและดำรงอยู่ของผู้คนในภูมิภาคนี้ของสัตว์ทะเลเลี้ยงลูกด้วยนมกลุ่มดังกล่าวมาอย่างต่อเนื่องและยาวนานนับตั้งแต่สมัยก่อนประวัติศาสตร์ อย่างไรก็ตามแบบแผนในการยังชีพที่รวมทั้งรูปแบบและวิธีการให้ได้มาซึ่งสัตว์ทะเลเลี้ยงลูกด้วยนมในกลุ่มนี้ของแหล่งโบราณคดีแต่ละแห่งนั้นยังไม่เป็นที่ทราบแน่ชัด ทั้งนี้เนื่องมาจากซากโครงกระดูกของวาฬมีฟันที่ขุดพบนั้นประกอบด้วยกระดูกสันหลังและกระดูกอื่น ๆ ที่อยู่ถัดจากกะโหลกลงมา ซึ่งส่วนใหญ่มีลักษณะทางสัณฐานวิทยาที่คล้ายคลึงกันจนยากที่จะนำมาใช้ในการจัดจำแนกชนิดได้ ปัจจุบันนี้ การจำแนกชนิดวาฬมีฟันจากแหล่งโบราณคดีนั้น ยังคงมีข้อจำกัดในเรื่องของชนิดและจำนวนตัวอย่างอ้างอิงที่นำมาใช้เป็นดัชนีในการศึกษาทางสัณฐานวิทยาเชิงเปรียบเทียบ ด้วยเหตุดังกล่าว การศึกษานี้จึงได้พยายามสร้างเกณฑ์ในการจำแนกชนิดตามลำดับอนุกรมวิธานโดยใช้กระดูกสันหลังส่วนคอชิ้นที่ ๑ และชิ้นที่ ๒ ของตัวอย่างวาฬมีฟันปัจจุบันที่พบในน่านน้ำญี่ปุ่นด้วยวิธีการวิเคราะห์ทางสถิติแบบจำแนกประเภทเพื่อประยุกต์ใช้ในการจำแนกชนิดวาฬมีฟันจากหลักฐานกระดูกสันหลังส่วนคอชิ้นที่ ๑ และชิ้นที่ ๒ ที่พบจากแหล่งโบราณคดีของญี่ปุ่นในสมัยวัฒนธรรมโจมงตอนต้น (ประมาณ ๕,๐๐๐ ปีมาแล้ว) และวัฒนธรรมโอคอตสก์ (ระหว่างพุทธศตวรรษที่ ๑๐ – ๑๘ โดยประมาณ)

ผลการวิเคราะห์ทางสถิติแบบจำแนกประเภทนี้ พบว่าสามารถนำไปใช้ในการจำแนกความแตกต่างระหว่างวาฬมีฟันทั้ง ๑๘ ชนิดจากลักษณะของกระดูกสันหลังส่วนคอชิ้นที่ ๑ และชิ้นที่ ๒ ตามหลักอนุกรมวิธานอย่างได้ผลดี โดยมีค่าความน่าเชื่อถือของความถูกต้องในการจัดจำแนกสูงสุดที่ระดับวงศ์ใหญ่ (ร้อยละ ๙๗.๑) ระดับวงศ์ (ร้อยละ ๘๙.๖) และระดับวงศ์ย่อย (ร้อยละ ๗๘.๙) ตามลำดับ สำหรับการจำแนกในระดับชนิดนั้น พบว่ามีอยู่หกชนิดด้วยกันที่แสดงค่าความน่าเชื่อถือของความถูกต้องในการจัดจำแนกสูงสุด (ร้อยละ ๑๐๐.๐) ขณะที่อีกสี่ชนิดนั้นพบว่ามีค่าความน่าเชื่อถือของความถูกต้องในการจัดจำแนกที่สูงเช่นกัน

(เกินร้อยละ ๘๐.๐) โดยสมการการจำแนกกลุ่มที่สร้างขึ้นนี้ ได้นำไปใช้ในการพยากรณ์สมาชิกกลุ่มของกระดูกสันหลังส่วนคอชิ้นที่ ๑ และชิ้นที่ ๒ ของวาฬมีฟัน จำนวน ๔๔ ชิ้น ที่ได้จากขุดค้นทางโบราณคดีจากแหล่งโบราณคดี ๓ แห่งในญี่ปุ่น ซึ่งมีอายุอยู่ในช่วงสมัยวัฒนธรรมโจมงตอนต้นและในสมัยวัฒนธรรมโอคอตสก์ ผลการวิเคราะห์ทางสถิติแสดงให้เห็นว่ามีกระดูกสันหลังส่วนคอชิ้นที่ ๑ และชิ้นที่ ๒ จำนวน ๒๗ ชิ้น (ร้อยละ ๖๑.๔) ที่สามารถจำแนกถึงระดับชนิดตามอนุกรมวิธานแบบลำดับขั้น รวม ๖ ชนิด ได้แก่ โลมาลายเส้นแปซิฟิก (๑๑), โลมาแถบ (๕), โลมาริสโซ (๕), โลมาปากสั้น (๓), โลมาปากขวดธรรมดา (๒), และโลมาวาฬเผือกเหนือ (๑) โดยในจำนวนนี้ พบว่ามีอยู่ด้วยกันสี่ชนิดที่ไม่ยังไม่เคยมีรายงานพบมาก่อนในแหล่งโบราณคดีจากทั้งสองวัฒนธรรม นอกจากนี้ ยังมีอีกสามชนิดที่ไม่มีขอบเขตการแพร่กระจายพันธุ์ในปัจจุบัน

จากผลการศึกษานี้ แสดงให้เห็นว่าการประยุกต์ใช้การวิเคราะห์ทางสถิติแบบจำแนกประเภทนี้ ได้ผลดีในการจำแนกชนิดตามลำดับขั้นอนุกรมวิธานตั้งแต่ระดับวงศ์ขึ้นไป ทั้งนี้หากในอนาคตสามารถเพิ่มจำนวนของตัวอย่างอ้างอิงสัตว์ปัจจุบันที่ใช้เป็นฐานข้อมูลในการเปรียบเทียบทางสถิติคาดว่าจะช่วยเพิ่มพูนประสิทธิภาพและความแม่นยำในการจำแนกได้ดียิ่งขึ้น นอกเหนือไปจากนี้ การค้นพบวาฬมีฟันชนิดอื่นเพิ่มเติมนอกเหนือไปจากชนิดที่เคยมีในรายงานการศึกษาก่อนหน้านี้ ไม่เพียงแต่จะช่วยเพิ่มพูนองค์ความรู้ในด้านความหลากชนิดของวาฬมีฟันที่กลุ่มคนในสมัยวัฒธรรมโจมงและโอคอตสก์รู้จักนำมาใช้ประโยชน์ หากยังชวนตั้งคำถามถึงเรื่องของรูปแบบและวิธีการให้ได้มาซึ่งวาฬมีฟันชนิดนั้น ๆ ที่กลุ่มคนสมัยก่อนประวัติศาสตร์ในช่วงเวลาดังกล่าวนำมาใช้เพื่อการยังชีพในมุมมองและบริบททางด้านโบราณคดี ตลอดจนถึงเรื่องของขอบเขตการแพร่กระจายของชนิดพันธุ์ของวาฬมีฟันชนิดนั้น ๆ ในอดีตเมื่อเทียบกับปัจจุบันในมุมมองและบริบททางด้านสัตวภูมิศาสตร์

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CHAPTER 1

GENERAL INTRODUCTION

In this chapter, an overview of prehistoric exploitation and cultural significance of cetaceans (baleen and toothed whales), with a focusing on odontocetes (toothed whales) in particular, as a key marine resource are explored. Furthermore, a problem of research in archaeological remains of cetaceans is addressed and discussed along with the proposed method of the discriminant function analysis (DFA) with the aiming to facilitate the identification of toothed whale species in zooarchaeological specimens.

1.1 Prehistoric exploitation and cultural significance of odontocetes (toothed whale) in archaeological context

Cetaceans have long been exploited as a key marine resource for subsistence by coastal communities in many parts of the world since prehistoric times (Savelle & Ishigami, 2013; Bernal-Casasola et al., 2016; Rodrigues et al., 2016; Evans & Mulville, 2018). The archaeological oldest evidence dates back to a late Middle Pleistocene cave site in South Africa by the presence of an isolated whale barnacle compartment that regarded as the indirect evidence of human consumption of a baleen whale (Marean et al., 2007; Collareta et al., 2017) whereas studies on Neanderthals at different sites across Gibraltar providing the earliest direct evidences of marine mammals exploitation (i.e. Stringer et al., 2008).

Evidence of the use of cetaceans by coastal communities on all inhabited continents and archipelagos has been derived from the accumulation of cetacean remains in excavated archaeofaunal assemblages (e.g. Higham & Thosarat, 1998; Sawada et al., 2011; Gruwier, 2017) or the presence of parasitic whale barnacles in archaeological sites, implying meat-processing and blubber rendering at inland locations (Jerardino & Parkington, 1993; Smith, 1993; Kendell & Conrad, 2003). Symbolic representations of cetacean imagery also exist in the form of figurines and effigies (e.g. Yamaura, 1998; Cameron, 2000) or natural rocks bearing resemblance to cetaceans, known as manuports (Koerper et al., 2014). Cetaceans and whaling scenes are also depicted as petroglyphs and pictographs (e.g. Khemnak, 1996; Yamaura, 1998; Lee & Robineau, 2004; Ballestre, 2018), as well as engravings on various household items, such as needle cases, spoon handles, spindle whorls, and pendants (Yamaura, 1998; Kasuya, 2017). These artifacts provide evidence of the strong human–cetacean relationship, in terms of economy and symbolic value in time and space.

Cetaceans provided communities with bone, meat, and oil including blubber, for food and biofuel resources (Monks, 2001; Higgs et al., 2011). Furthermore, they also provided sources of raw material for carvings, ornamentation, and the manufacture of architectural elements (e.g. Savelle, 1997; Mulville, 2002; Schuhmacher et al., 2013). Ideologies related to whaling ceremonialism and whale cults also existed (e.g. Ohba & Ohyi, 1976; Yamaura, 1998), as well as mortuary elements associated with burial practices (Guia-Ramirez, 2014; Roca & Inglesia, 2014). The human exploitation of cetaceans has encompassed the scavenging of naturally stranded dead or live individuals, low-level opportunistic hunting, organized whaling (Whitridge, 2000; Savelle, 2005; Savelle & Kishigami, 2013; Rodrigues et al., 2016), or even a combination of different strategies (Wellman et al., 2017). These different forms of exploitation undeniably contributed to both primary and supplementary subsistence and the lifestyle of prehistoric coastal communities. As a result, cetacean remains have accumulated to varying degrees in archaeological sites.

1.2 Research in archaeological remains of cetaceans

Cetacean bones found in archaeological deposits tend to be highly fragmented, beyond visual recognition, due to excessive processing, modification, and their friability. However, it is possible to distinguish them from other terrestrial and marine mammals based on their unique cancellous texture (Porcasi & Fujita, 2000). This cancellous structure characterized by a thin cortical layer and moderate to low overall density, is the result of their adaptation to a fully aquatic lifestyle (Cozzi et al., 2017; Gray et al., 2007).

However, the remains of cetaceans in archaeological sites are sometimes difficult to identify at the species level due to the very similar morphology of some different species and the significant sexual dimorphism within some species (Murray, 2008; Evans & Mulville, 2018). Remains fragmented beyond visual recognition are often subjected to molecular techniques (Buckley et al., 2014; Evans et al., 2016; Speller et al., 2016; Wellman et al., 2017). It is possible to identify some long bones, mandibles, and skull in some baleen whale, (Murray, 2008: S42), while teeth, tympanic bones, and skull are well suited for identifying toothed whale species (Evans & Mulville, 2018). These bones have been successfully used to identify cetacean species from archaeological sites (Castilho, 2008; Castilho & Lopes, 2008; Colten, 2015; McMillan, 2015; Cooke et al., 2016; Kasuya, 2017).

Previous studies on the morphometrics of the thoracic, lumbar, and caudal vertebrae have also provided insights into species identification (Wang, 1984; Buchholtz and Schur, 2004; Cooke et al., 2016; Evans & Mulville, 2018). However, the cervical vertebrae, especially the first two cervical vertebrae (atlas and axis), are less frequently used. Unlike that of other mammals, the atlas vertebra of cetaceans does not have a massive centrum but forms a ring that rotates around an odontoid process on the axis vertebra (Marx et al., 2016). The centrum of the atlas and axis usually fuses together in most cetaceans (balaenids, neobalaenids, and odontocetes), with some exceptions (e.g. Rommel, 1990; Berta et al., 2015; Cozzi et al., 2017). Although comparative morphological descriptions and illustrations of the atlas and axis vertebrae of different taxa of cetaceans have been provided (e.g. Gray 1864a, 1864b) and the atlas and axis vertebrae have a species-specific morphology in baleen whales (Murray, 2008), their potential for distinguishing toothed whale species (dolphins and porpoises) has rarely been explored (but see also Pilleri and Gihr,1974; Kongthaworn, 2007).

1.3 A summary of thesis structure

This thesis comprises of four main chapters and is summarized as followed:

Chapter One provides an overview of prehistoric exploitation and cultural significance of toothed whale species and addresses the problem of research in archaeological remains of cetaceans along with proposed method of the discriminant function analysis (DFA) approach and the scope of the study.

Chapter Two presents the results and discussion on the taxonomic identification criteria based on the atlas and axis vertebrae of modern toothed whale species, using DFA.

Chapter Three presents the results and discussion on the species classification of archaeological atlas and axis vertebrae applying the established taxonomic identification criteria.

Chapter Four provides discussion over the species exploitation and distribution in the past based on the overall results and discussion further on application of DFA-based identification in zooarchaeological toothed whale atlas and axis vertebrae: contribution to researches, limitation, and implication for future studies.

CHAPTER 2

APPLYING DFA-BASED CLASSIFICATION TO MODERN REFERENCE ATLAS AND AXIS VERTEBRAE OF TOOTHED WHALE SPECIES

2.1 INTRODUCTION

This study aims in attempt to investigate the atlas and axis vertebrae of toothed whale for species identification of zooarchaeological specimens using canonical DFA in order to understand the species exploitation and distribution in the past.

It should be noted that at the beginning of this study, it was primary focused on the analysis of atlas and axis vertebrae of toothed whale recovered from Okhotsk Kafukai-1 site. Thus, the specimens were chosen to include those species that were expected to be found in the seas around Hokkaido, based on Ohdachi et al. (2015) and Matsuishi (*pers. comm.*). Except for sperm whale (*Physeter macrocephalus*) as none of the zooarchaeological specimens used in this study showed any comparative size to those of this species. However, these selected specimens were already included those species that had been previously identified from early Jomon Mawaki and Mibiki sites. Moreover, finless porpoises (*Neophocaena phocaenoides*) were also added, with the aim of covering a range of species within the family Phocoenidae.

The content of Chapter 2 is already published in Thongcharoenchaikit and Eda (2020).

2.2 MATERIALS AND METHODS

2.2.1 Modern reference samples

To establish identification criteria for atlas and axis vertebrae of toothed whales at different taxonomic levels, modern specimens of known species from the National Museum of Nature and Science (NMNS), Tsukuba, Ibaraki, and the Hokkaido University Museum (HOUM), Sapporo, Hokkaido, were measured (Table 2.1 and Figure 2.1). Specimens were preferably physically mature, regardless of whether sex was known. At least 10 specimens of each species were intended to be measured, but availability of specimens was limited to that in the museum collections. In total, 173 modern toothed whale specimens were measured.

2.2.2 Morphometric discrimination of the atlas and axis vertebrae of modern toothed whales

A set of 13 linear measurements (Figure 2.2) was applied to the vertebral specimens. Of these, five measurements were based on those described by Perrin (1975), with eight new measurements being included for the partially preserved archaeological specimen (Table 2.2). All measurements were taken once and recorded to the nearest 0.01 mm using a digital caliper.

Statistical analyses were conducted using the statistical software SPSS Statistics version 26 (IBM, U.S.A.) to assess variation in the hierarchical system of taxonomic classification. All data were log transformed before conducting the analyses. DFA was used to discriminate the shape and size of the atlas and axis vertebrae at different taxonomic levels for the modern specimens. Before the DFA, homogeneity of covariance matrices of each group was measured, using Box's M test. Because the Box's M test found significant differences among covariance matrices in each group, or could not be performed due to fewer than two non-singular group covariance matrices, canonical DFA was conducted for all of the group discriminations. The relative contributions of each of the 13 measurements to each canonical DFA are presented in each case. To check the robustness of the data, cross-validation was conducted for each case in the dataset, and the percentage of total cases correctly assigned to a known group and individual was reported as the 'correct classification rate'.

Modern specimens were classified following the systematics of Perrin (1989), with some current amendments in nomenclature as referred to in the Society for Marine Mammalogy (https://marinemammalscience.org/) (Figure 2.3): superfamily level (Delphinoidea, Hyperoodontidae, Physeteroidea), family level (Phocoenidae, Delphinidae, Hyperoodontidae, Kogiidae), and subfamily level (Lissodelphinae, Globicephalinae, Delphininae, Phocoeninae, Phocoenoidinae). Specimens were classified separately at the subfamily level for each family (Delphinidae, Phocoenidae). Moreover, specimens were also classified separately at the species level for each family (Kogiidae, Phocoenidae, Hyperoodontidae) and subfamily (Globicephalinae, Delphininae, Phocoeninae).

2.3 RESULTS

2.3.1 SUPERFAMILY CLASSIFICATION: Delphinoidea, Physeteroidea, and Ziphioidea

At the superfamily level, Box's M test showed significant differences between the covariance matrices (Box's M = 1412.09, F ≅ 5.53, df1 = 182, df2 = 6008.24, P < 0.001). In the canonical DFA (Wilk's lambda = 0.005, Chi-square = 734.45, P < 0.001), the correct classification rate was 97.1% (Table 2.3), and 98.0% of the variation in the data was explained by the first canonical discriminant function (Table 2.4). The classification functions are presented in Table 2.5. The correct classification rate for Delphinoidea and Physeteroidea was 100.0% and for Ziphioidea was 81.5% (Table 2.3). A canonical discriminant function plot showed that Delphinoidea was clearly separated from Physeteroidea and Ziphioidea (Figure 2.4). There was some overlap between Physeteroidea and Ziphioidea for both functions; however, Physeteroidea was the most tightly clustered group.

2.3.2 FAMILY CLASSIFICATION: Delphinidae, Phocoenidae, Kogiidae, and Hyperoodontidae

At the family level, Box's M test showed significant differences between the covariance matrices (Box's M = 1624.68, F ≅ 4.41, df1 = 273, df2 = 10786.87, *P* < 0.001). In the canonical DFA (Wilk's lambda = 0.002, Chi-square = 829.08, P < 0.001), the overall correct classification rate was 89.6% (Table 2.6), and the first two canonical discriminant functions described 96.6% and 2.5% of variance, respectively (Table 2.7). The classification functions are presented in Table 2.8. The correct classification rate for Kogiidae was 100.0% (Table 2.6). A canonical discriminant function plot showed that Delphinidae and Phocoenidae overlapped considerably, while being clearly separated from Hyperoodontidae and Kogiidae, which had a small overlap along the first function (Figure 2.5).

2.3.3 SUBFAMILY CLASSIFICATION: Lissodelphinae, Globicephalinae, Delphininae, Phocoeninae, and Phocoenoidinae

At the subfamily level, BOX'S M showed significant differences between the covariance matrices (Box's M = 737.524, F ≅ 2.72, df1 = 182, df2 = 5547.19, $P < 0.001$). In the canonical DFA (Wilk's lambda = 0.021, Chi-squared = 380.69, P < 0.001), the overall correct classification rate was 78.9% (Table 2.9), and the first two canonical discriminant functions described 67.3% and 22.5% of the variance, respectively (Table 2.10). The classification functions are presented in Table 2.11. With the exception of Phocoeninae (59.3%) and Phocoenoidinae (60.0%), the correct classification rate for each subfamily was high, especially for Globicephalinae (94.7%) and Lissodelphinae (90.0%), followed by Delphininae (86.0%) (Table 2.9). A canonical discriminant function plot showed that Lissodelphinae was clearly discriminated from the other subfamilies along the first function (Figure 2.6). Globicephalinae overlapped the least with all other groups, which showed considerable overlap with one another.

2.3.4 SUBFAMILY CLASSIFICATION

2.3.4.1 FAMILY DELPHINIDAE: Lissodelphinae, Delphininae, and Globicephalinae

At the subfamily level within Family Delphinidae, Box's M showed significant differences between the covariance matrices (Box's M = 365.353, F ≅ 2.69, df1 = 91, df2 = 2894.83, df = 26, $P < 0.001$). In the canonical DFA (Wilk's lambda = 0.052, Chi-squared = 215.22, P < 0.001), an overall correct classification rate of 91.9% was obtained (Table 2.12). The first two discriminant functions described most of the variance, with 77.9% and 22.1%, respectively (Table 2.13). The classification functions are presented in Table 2.14. The correct classification rate for each subfamily group within Delphinidae was considerably high, especially for Lissodelphinae (100.0%), whereas Delphininae was also high (94.7%), and Globicephalinae had the lowest correct classification (89.5%; Table 2.12). The combined-groups plot of the canonical discriminant functions showed that Delphininae and Globicephalinae were clearly separated along the first function, whereas Lissodelphinae slightly overlapped with the other two along the second canonical discriminant function (Figure 2.7).

2.3.4.2 FAMILY PHOCOENIDAE: Phocoeninae and Phocoenoidinae

No Box's M test could be performed for the subfamily within Family Phocoenidae. In the canonical DFA (Wilk's lambda = 0.110, Chi-squared = 40.82, df=13, P < 0.001), an overall correct classification rate of 85.7% was achieved (Table 2.15). The percentage of variance accounted for was 100.0% (Table 2.16). The classification function is presented in Table 2.17. Phocoenoidinae had the highest rate of correct classification (86.7%), while Phocoeninae was also usually correctly classified (85.2%; Table 2.15). The separate-groups plot of the canonical discriminant function showed no overlap, and these two groups were clearly separated (Figure 2.8).

2.3.5 SPECIES LEVEL CLASSIFICATION

2.3.5.1 WITHIN SUBFAMILY DELPHININAE

No Box's M test could be performed at the species-level within the subfamily Delphininae. In the canonical DFA (Wilk's lambda = 0.006, Chi-squared = 229.34, df = 52, P < 0.001), an overall correct classification rate of 84.2% was achieved (Table 2.18). The first four canonical discriminant functions explained most of the between-species variance, with 66.8%, 19.6%, 10.4%, and 3.2%, respectively (Table 2.19). The classification functions are presented in Table 2.20. The correct classification rate for individual species was 100.0% for the striped dolphin (*Stenella coeruleoalba*), 92.9% for the Pacific white-sided dolphin (Latin name), and 80.0% for Risso's dolphin (*Grampus griseus*), whereas the common bottlenose dolphin (*Tursiops truncatus*) and the short-beaked common dolphin (*Delphinus delphis*) had the lowest rate (72.7%; Table 2.18). A canonical discriminant function plot showed that Risso's dolphin was clearly discriminated from others along the first canonical discriminant function (Figure 2.9).

2.3.5.2 WITHIN SUBFAMILY GLOBICEPHALINAE

No Box's M test could be performed at the species-level within the subfamily Globicephalinae. The canonical DFA (Wilk's lambda = 0.001, Chi-squared = 60.28, df = 24, P < 0.001) produced the lowest percentage of correct classification (68.4%; Table 2.21). The first canonical discriminant function of all three species described 93.9% of the variation in the data (Table 2.22). The classification functions are presented in Table 2.23. The correct identification rate for individual species was highest in the killer whale (*Orcinus orca*) (100.0%), lowest in the false killer whale (*Pseudorca crassidens*) (66.7%), and negligible for the short-finned pilot whale (*Globicephalas macrorhynchus*) (Table 2.21). A canonical discriminant function plot showed that all three species overlapped along the first canonical discriminant function (Figure 2.10).

2.3.5.3 WITHIN SUBFAMILY PHOCOENINAE

No Box's M test could be performed at the species level within subfamily Phocoeninae. The canonical DFA (Wilk's lambda = 0.005, Chi-squared = 45.77, df = 13, $P < 0.001$) produced a correct classification rate of 96.3% (Table 2.24). The percentage of variance was 100.0% (Table 2.25). The classification function is presented in Table 2.26. The finless porpoise had a correct classification rate of 100.0%, with the harbor porpoise (*Phocoena phocoena*) at 93.6% (Table 2.24). These two species overlapped slightly (Figure 2.11).

2.3.5.4 WITHIN FAMILY PHOCOENIDAE

No Box's M test could be performed at the species level within family Phocoenidae. The canonical DFA (Wilk's lambda = 0.006, Chi-squared = 90.69, df = 26, $P < 0.001$) gave an overall correct classification rate of 85.7% (Table 2.27). The first canonical discriminant function explained most of the between-species variance (89.6%; Table 2.28). The classification functions are presented in Table 2.29. The correct identification rate for individual species was 100.0% for finless porpoise, and lowest for harbor porpoise at 85.7% (Table 2.27). Dall's porpoise (*Phocoenoides dalli*) and finless porpoise were clearly separated along the first canonical variate, but both overlapped with harbor porpoises, as shown by the canonical discriminant function plot (Figure 2.2).

2.3.5.5 WITHIN FAMILY HYPEROODONTIDAE

No Box's M test could be performed at the species level within family Hyperoodontidae. In the canonical DFA (Wilk's lambda = 0.001, Chi-squared = 82.24, df = 39, $P < 0.001$), an overall correct classification rate of 74.1% (Table 2.30) was obtained. The first canonical discriminant function explained most of the between-species variance (93.6%; Table 2.31). The classification functions are presented in Table 2.32. The correct identification rate for individual species was the highest for Cuvier's beaked whale (*Ziphius cavirostris*) at 91.7%, was lowest for Hubbs' beaked whale (*Mesoplodon carlhubbsi*) at 66.7%, and negligible for Baird's beaked whale (*Berardius bairdii*) (Table 2.30). Baird's beaked whale and Cuvier's beaked whale were clearly separated from both Hubbs' beaked whale and Stejneger's beaked whale (*Mesoplodon stejnegeri*) which overlapped, as shown by the combined-group plot of the canonical discriminant functions in Figure 2.13.

2.3.5.6 WITHIN FAMILY KOGIIDAE

At present, there are only two extant species in family Kogiidae. Both belong to the genus *Kogia,* namely, the dwarf sperm whale (*Kogia sima*) and the pygmy sperm whale (*Kogia breviceps*). Although no Box's M test could be performed, the canonical DFA gave a correct classification rate of 100.0% (Table 2.33). Moreover, there was also 100.0% variance accounted for (Table 2.34). The classification function is presented in Table

2.35. Species were clearly discriminated (Figure 2.14).

2.4 DISCUSSION

2.4.1 Morphological differences of the atlas and axis vertebrae of toothed whales

The DFA approach revealed morphological differences in the atlas and axis vertebrae of modern toothed whales in a hierarchical classification system, and the successful classification rate was 97.1% at the superfamily level, 86.9% at the family level, and 78.9% at the subfamily level. The most successful classification (100.0%) at the superfamily level was that of the superfamily Delphinoidea and superfamily Physeteroidea. At the family level, 100.0% DFA classification was obtained for family Kogiidae, with the classification of the other families also being high (over 80.0%), except for Phocoenidae (73.8%). Canonical DFA classification at the subfamily level was also high for the subfamilies Globicephalinae (97.7%) and Lissodelphinidae (90.0%). Three subfamilies in the family Delphinidae (91.2%) and two subfamilies in the family Phocoenidae (85.7%) also had high correct classification rates. These results suggest that using DFA on the measurements of the atlas and axis of toothed whales is useful for taxonomic identification at the family level and higher.

At the species level, this approach was particularly successful (100.0% correct identification) at predicting the taxonomic affiliation for the following species: striped dolphin, killer whale, finless porpoise, dwarf sperm whale, and pygmy sperm whale. In addition, at the subfamily level within family Delphinidae, Lissodephinae, represented by the northern right whale dolphin (*Lissodelphis borealis*), also showed the highest success rate (100.0%). High correct identification rates (80.0–99.0%) were also obtained for the Pacific white-sided dolphin (92.9%), Cuvier's beaked whale (91.7%), Dall's porpoise (86.5%), and Risso's dolphin (80.0%). This suggests that DFA is also effective for species level identification in these 10 species. Lower identification (less than 80.0%) was obtained for harbor porpoises (75.0%), common bottlenose dolphins (72.7%), short-beaked common dolphins (72.7%), Stejneger's beaked whale (70.0%), Hubbs' beaked whale (66.7%), and false killer whales (66.7%). The lowest rates were obtained for the short-finned pilot whale and Baird's beaked whale, which were misclassified as other species. These low identification rates are attributed to the morphological similarity of the atlas and axis vertebrae of the short-finned pilot whale and false killer whale, and of Baird's beaked whale and Cuvier's beaked whale, making differentiation difficult. The small sample sizes of the short-finned pilot whale (n = 3) and Baird's beaked whale (n = 2) might have contributed to the low identification success. Future studies with larger sample sizes and more measurement points are required to increase the correct classification rate for the identification of these species.

2.4.2 Archaeological implication of DFA-based identification to zooarchaeological specimens

Cooke et al. (2016) attempted to identify delphinid thoracic, lumbar, and caudal vertebrae from archaeofaunal remains using a combination of morphological and morphometric analyses. However, the study failed to distinguish between *Stenella* spp. and Pacific white-sided dolphin vertebrae owing to their morphological similarities. The

DFA-based approach developed here clearly distinguished the Pacific white-sided dolphin from the striped dolphin (*Stenella coeruleoalba*). This suggests the possibility that the atlas and axis vertebrae are more useful for distinguishing different species of toothed whales in comparison with other vertebrae of cetaceans. So far, taxonomic variation in the atlas and axis vertebrate has been found in some of the toothed whale genera: Pilleri and Gihr (1974) showed morphological differences between the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) and common bottlenose dolphin (*Tursiops truncatus*), while Kongthaworn (2007) detected morphological differences in three *Stenella* species. These results demonstrate that there are sufficient morphological variations in the atlas and axis vertebrae of a wider range of toothed whales, and that the DFA approach is useful for distinguishing between higher taxonomic groups and, in some cases, even between closely related species.

CHAPTER 3

APPLYING DFA-BASED CLASSIFICATION TO ZOOARCHAEOLOGICAL ATLAS AND AXIS VERTEBRAE OF TOOTHED WHALE SPECIES

3.1 INTRODUCTION

Cetacean bones have been excavated from many coastal archaeological sites throughout Japan, in particularly from Jomon period. These sites ranging from north to south; Higashi-kushiro (Kushiro, Hokkaido), Irie (Abuta, Hokkaido), Natagiri (Tateyama, Kanagawa), Idokawa (Ito, Shizuoka), Asahi (Himi, Toyama), and Mawaki (Noto, Ishikawa) (Kasuya, 2017). Of those, numerous harbor porpoises were identified from bone fragments of cetaceans at Higashi-kushiro site, whereas numerous Pacific white-sided dolphins and a false-killer whale were identified at Irie site. Furthermore, some finless porpoises and a harbor porpoise were identified at Miyashita site, whereas numerous common dolphins and pilot whales were identified at Natagiri site. Moreover, Pacific white-sided dolphins, common bottlenose dolphins, common dolphins, and bottlenose dolphins were identified at Shomyoji site, and skulls of six common dolphins was found along with other terrestrial mammals were found at Idokawa site (Kasuya, 2017).

Here, atlas and axis vertebral elements identified from cetacean bone assemblages of three archaeological sites were examined. Two sites were from early Jomon period, whereas the other was from Okhotsk period.

Early Jomon Mawaki site is located on the east coast of the Noto Peninsula in central Japan (Figure 3.1). Excavation in 1983 and 1984 yielded a large number of toothed whale remains, accounting for at least 286 individuals in one stratum associated with a village and a ceremonial complex occurring within the late early to earliest middle sequence of the Jomon period, dated to approximately 5,000 years BP (Sevelle and Ishikami, 2013; Takada and Takemura, 2016). The samples are currently curated by Mawaki Ruins Jomon Museum (MRJM).

Six species of toothed whale has been identified from the site, namely Pacific white-sided dolphin, short-beaked common dolphin, common bottlenose dolphin, false killer whale, short-finned pilot whale, and Risso's dolphin (Takada and Takemura, 2016) with an addition of unknown species of ziphiids (beaked whale) and balaenopterid (Miyazaki, 1986). Based on the morphological observation of cervical vertebrae, Pacific white-sided dolphin and short-beaked common dolphin were common (accounted for 143 individuals), followed by bottlenose dolphins, a pilot whale, and a Risso's dolphin (Kasuya, 2017) only the results are shown without any identification criteria. Similar result was obtained from species identification results on skull and mandible and the number of Pacific white-sided dolphins and short-beaked common dolphins were the highest, followed by a smaller number of bottlenose dolphins (Kasuya, 2017). Most of identified species are distributed around the Noto Peninsula, except for short-beaked common dolphin that occurs mainly off the Pacific coast of Japan north of the Izu Peninsula (Ohdachi et al., 2015).

In the absence of detachable harpoon head or barbed lance in the archaeological assemblage led to the assumption that the people of the early Jomon Mawaki site probably drove the toothed whale into the bay and slaughtered them using the stone lances (Kasuya, 2017; Takada and Takemura, 2016), as some of which were inserted in the bone. In addition, a partially preserved symbol carved wooden pole (2.52 m in length; 45 cm in max. dia.) was associated with a large number of toothed whale remains (http://mawakiiseki.jp/sculpture.html) suggesting evidence of ritual treatment of toothed whale remains (Savelle & Kishigami, 2013) in the way that similar to Iyomante (bear-spirit-sending ritual/bear festival) in the Ainu Culture (http://mawakiiseki.jp/sculpture.html).

Early Jomon Mibiki site is also located on the east coast of the Noto Peninsula in central Japan (Figure 3.2). Archaeological excavation during 1995 and 1999 yielded 1,542 whale remains (Hiraguchi, 2004; 2005). Four species of toothed whale has been identified from the archaeofaunal assemblage based on traditional morphological analysis, with short-beaked common dolphin (N=100) was commonly identified, followed by common bottlenose dolphin (N=59), Pacific white-sided dolphin (N=41), and false killer whale (N=2) (Hiraguchi, 2004; 2005). Most of identified species coincided with the modern distribution around the Noto Peninsula, except for short-beaked common dolphin (Ohdachi et al., 2015). Considering that the excavation area of the Mibiki site was relatively large and the layers that containing faunal remains was thick, it is unlikely that dolphins were frequently hunted in the sea nearby the site, although more than 1,500 dolphin bones were recovered from the Mibiki site (Hiraguchi, 2004). Rather, it seems likely that the people of the Mibiki site in the early Jomon Period occasionally captured a small number of stranded toothed whale into the nearby (not the closest) sea and brought disarticulated toothed whale to the site (Hiraguchi, 2005). The samples are currently curated by Ishikawa Archaeological Foundation (IAF).

Okhotsk Kafukai-1 site is located at the mouth of the Kafukai River on the east coast of Rebun Island of northern Hokkaido (Figure 3.3). The samples are currently curated by The Hokkaido University Museum (HOUM). The island is located in the northeastern Sea of Japan near the southwest opening of the Okhotsk Sea. The Okhotsk Culture flourished in Sakhalin, Hokkaido, and the Kuril Islands of Northeast Asia during the 5^{th} and 13^{th} centuries AD (Amano, 2003). Analysis of faunal assemblage excavated from the site demonstrated that subsistence activities tended to rely on marine rather than land resources and that fishing was more relatively important than sea mammal exploitation and sea-urchin fishery in subsistence (Ohba and Ohyi, 1976). Although the fur seal (*Callorhinus ursinus*) was the most commonly identified of all marine mammal remains from the site, eleven species of cetacean have also been identified. Seven of these are toothed whale, namely Pacific white-sided dolphin (N=11), harbor porpoise (N=4), Dall's porpoise (N=5), pilot whale (*Globicephala melas;* N=25), false killer whale (N=5), sperm whale (N=2), and ziphiids (N=1). Four species of baleen whale was also identified, namely sei whale (N=1), humpback whale (N=6), minke whale (N=1), and North Pacific right whale (N=2) ((Ohba and Ohyi, 1976; Kasuya, 2017). Many of these were found in almost every strata, particularly Pacific white-sided dolphin and pilot whale in which the latter was the commonly identified. Although most identified species coincided with the modern distribution in the seas around Rebun Island, some rarely occur in both the Sea of Japan and the Sea of Okhotsk such as sei whale and sperm whale. The distribution of false killer whale is northern limit at Hokkaido, this species is more commonly found in the south (Ohdachi et al. 2015). Whereas pilot whale has been local extinct from the western North Pacific (Kasuya, 1975).

Most of cetacean bones were largely modified into bone tools, with an exception of the seven skulls of pilot whales and a skull of Pacific white-sided dolphin, including the lower jaw of false killer whale and some vertebrae of cetaceans arranging inside at the base of the stone piling structure suggesting some ritual ceremony for pilot whales caught (Ohba and Ohyi, 1976). Although some of cetacean remains may represent stranded animals, the people of the Okhotsk Culture at the site undoubtedly hunted cetaceans by hand harpoons as supported by bone artefacts found as well as the depiction of whaling scene and probably net engraved on the needle cases from the site.

In this chapter, established species classification criteria based on canonical DFA is applied to archaeological samples from three archaeological sites. The zooarchaeological specimens were identified using the classification functions of those modern reference species and archaeological implications of the results are discussed.

3.2 MATERIALS AND METHODS

3.2.1 Zooarchaeological samples

Cetacean bones identified as atlas and axis vertebrae of toothed whale were sorted out with preferably physically mature (see Pilleri and Gihr, 1974 for additional description of immature bone) and complete. However, as it is common in archaeofaunal assemblages consist of mostly broken bone fragments. Nearly complete specimens were taken into account. Thus, partially broken element which allowed, for at least any 5 out of

13 measurements could be taken were also included in the dataset. Thus, a total of 44 zooarchaeological samples were measured and included into the dataset (Table 3.1).

3.2.1.1 Samples from early Jomon Mawaki site (N=28)

A total number of 191 atlas and axis vertebrae of toothed whale were recovered from the site. Some of these were put out for display in the gallery of permanent exhibition of the museum. Thus, allowing four complete (M-3, M-20, M-28, and M-69) specimens and other twenty nearly complete atlas and axis vertebrae of mature toothed whale to be sorted out, measured, and included in the data set (Figure 3.4).

3.2.1.2 Samples from early Jomon Mibiki site (N=7)

A total number of 16 atlas and axis vertebrae of toothed whale was recovered from the site. Mostly broken bone fragments with only one was an exceptionally complete specimen (No. 159) including other six nearly complete atlas and axis vertebrae of mature toothed whale that allowing the samples to be sorted out, measured, and included in the data set (Figure 3.5).

3.2.1.3 Samples from Okhotsk Kafukai-1 site (N=9)

A total number of 15 atlas and axis vertebrae of toothed whale was recovered from the site. Among these, only one was a complete (RKA18142) atlas and axis vertebrae of mature toothed whale whereas other eight were nearly complete specimens which were sorted out, measured, and included in the data set (Figure 3.6).

3.2.2 Sample measurements

Following the modern reference specimens, a set of 13 linear measurements (Table 2.2 and Figure 2.2) were applied to the selected zooarchaeological samples and taken on the right side in case of bilateral measurement (except for LLeftLtPA) with antimeres substituted in the case of missing data. All measurements were taken once and recorded to the nearest 0.01 mm using a digital caliper. All measuring data was presented in Table 3.2

3.2.3 Data analysis

To identify the species of toothed whale from complete zooarchaeological specimens, all the modern atlas and axis vertebrae measurements were included in the analysis in order to establish discriminant functions and classification functions. On the other hand, for partially broken zooarchaeological specimens, any measurements that could not be taken on each sample were also excluded from the data set of modern reference specimens. Box's M test was used to measure homogeneity of covariance matrices of each group. Because the homogeneity of covariance matrices of each group was rejected or Box's M test could not be performed due to fewer than two non-singular group covariance matrices, canonical DFA was conducted for all of the group discriminations. All data were log transformed before conducting the analyses. Box's M test and DFA were conducted using the statistical software SPSS Statistics version 26 (IBM, U.S.A.).

Samples were classified following the systematics of Perrin (1989) as shown in the Chapter 2: superfamily level (Delphinoidea, Hyperoodontidae, Physeteroidea), family level (Phocoenidae, Delphinidae, Hyperoodontidae, Kogiidae), subfamily level (Lissodelphinae, Globicephalinae, Delphininae, Phocoeninae, Phocoenoidinae), and species level. Thus, DFA-based classification proved to be robust, if each sample was correctly clustered with each known group at each taxonomic level. To check the robustness of the data, cross-validation was conducted for each case in the dataset, and the percentage of total cases correctly assigned to a known group and individual was reported as the 'correct classification rate', and these were summarized and presented in Table 3.3. Thus, DFA-based classification proved to be robust, with sample being correctly clustered with each known group at each taxonomic level.

3.3 RESULTS

Summary of DFA-based classification results of zooarchaeological samples are presented and divided by site. Details were described as followed:

3.3.1 Early Jomon Mawaki zooarchaeological samples

At the species level classification, seven species of toothed whale were identified in the atlas and axis vertebrae of the early Jomon Mawaki site: Pacific white-sided dolphin (N=8), striped dolphin (N=6), northern right whale dolphin (N=4), Dall's porpoise (N=3), Risso's dolphin (N=3), short-beaked common dolphin (N=2), and common bottlenose dolphin (N=2). Following the hierarchical classification scheme, the canonical DFA of the zooarchaeological sample revealed correct taxonomic affiliation at every level for 20 of the 28 samples (Table 3.3). M-54 (assigned to common bottlenose dolphin with seven measurements) had the highest correct classification rate (72.3%) at species level whereas M-21 (assigned to Pacific white-sided dolphin with nine measurements) had the lowest (59.0%). More than 70% correct classification rate at species level were also obtained in 14 samples whereas correct classification rate between 60.0 – 70.0% were obtained in 12 samples.

3.3.2 Early Jomon Mibiki site zooarchaeological samples

At the species level classification, four species of toothed whale were identified in the atlas and axis vertebrae of the early Jomon Mawaki site: Pacific white-sided dolphin (N=2), striped dolphin (N=1), Risso's dolphin (N=2), and Dall's porpoise (N=2).

Following the hierarchical classification scheme, canonical DFA of the zooarchaeological sample revealed correct taxonomic affiliation at every level for most of the samples (N=5). While No.159 (assigned to Pacific white-sided dolphin with 13 measurements) had the highest rate for species-level classification, No. 495 (assigned to striped dolphin with six measurements) obtained the lowest rate (52.0%). Five other samples obtained high correct identification rate at species level ranging between 60.0 – 70.0%.

3.3.3 Okhotsk Kafukai-1 site zooarchaeological samples

At the species level classification, five species of toothed whale were identified in the atlas and axis vertebrae of the Okhotsk Kafukai-1 site: Pacific white-sided dolphin

(N=3), short-finned pilot whale (N=2), false killer whale (N=1), short-beaked common dolphin (N=1), and harbor porpoise (N=2).

Following the hierarchical classification scheme, the canonical DFA of the zooarchaeological sample revealed correct taxonomic affiliation at every level for most of the samples (N=6). Among these, the highest rate (71.10%) for species-level classification was obtained for RKA17138 (assigned to pacific white-sided dolphin with eight measurements) and RKA3690 (assigned to harbor porpoise with eight measurements). While most of samples obtained the rate between 60 – 70% (N=5), the classification rate for both RKA2047 (assigned to short-finned pilot whale with six measurements) and RKA2804 (assigned to false killer whale with six measurements) were lower than 60.0%.

3.4 DISCUSSION

3.4.1 Toothed whales exploited at early Jomon Mawaki

At the species level classification, seven species of toothed whale were identified based on the atlas and axis vertebrae recovered from the site. Following the hierarchical classification scheme, the canonical DFA of the zooarchaeological sample revealed correct taxonomic affiliation at every level for 20 out of the 28 samples in total.

However, group membership classification for eight samples showed contradictions (Table 3.3). M-20 (Figure 3.4) and M-109 (Figure 3.5) were assigned to Dall's porpoise at species level. However, they were classified into Delphininae at subfamily level, Delphinidae at family level, and Delphinoidea at superfamily level, showing consistency for oceanic dolphin. M-111 (Figure 3.6) was assigned to Dall's porpoise at species level and showed consistency in classification at family (Phocoenidae) and superfamily level (Delphinoidea), but was assigned to Delphininae at subfamily level. M-106 (Figure 3.7), M-91 (Figure 3.8), and M-5 (Figure 3.9) were assigned to northern right whale dolphin at species level and showed consistency in classification at family (Delphinidae) and superfamily level (Delphinoidea), but were assigned to Delphininae at subfamily level. M-3 (Figure 3.10) was assigned to short-beaked common dolphin and showed consistency in classification at subfamily (Delphininae) and superfamily level (Delphinoidea), but was assigned to Phcoenidae at family level. M-90 (Figure 3.11) was assigned to striped dolphin at species level and showed consistency in classification at subfamily (Delphininae) and superfamily level (Delphinoidea), but was assigned to Phocoenidae at family level.

These contradictions seem to be attribute to mensural overlap between Dall's porpoise and pacific white-sided dolphin in case of both M-20 and M-109, between subfamily Delphininae and Phocoenoidinae in case of M-111 and between subfamily Delphininae and Lissodelphinae in case of M-106, M-91, and M-5, and between family Delphinidae and Phocoenidae in case of both M-3 and M-90. Based on these data, M-20 and M-109 should be classified into Delphininae (subfamily-level); M-111 into Phocoenidae (family-level); and M-106, M-91, and M-5 into Delphinidae (family-level). Furthermore, due to the lowest rate of species-level classification in assigning to striped dolphin (59.0%), M-21 would be classified into Delphininae (subfamily-level).

In comparison to previous study of 28 zooarchaeological samples (Miyazaki, 1986), DFA-based classification and morphological-based identification were in accordance with Pacific white-sided dolphin (N=3), short-beaked common dolphin (N=2), and common bottlenose dolphin (N=1) (Table 3.6). This discrepancy between DFA-based classification and morphological-based identification highlights the difficulty in comparisons to be based on the morphological traits of a few individuals rather than multiple specimens of the same species with correct taxonomic affiliation at every level based on correct classification rate.

Moreover, DFA-based classification unexpectedly revealed the presence of three other species; striped dolphin, Dall's porpoise, and northern bottlenose dolphin, providing new evidence for range of toothed whale species exploited by early Jomon People at Mawaki archaeological site. Although Dall's porpoise is endemic and more common than striped dolphin in modern distribution around Noto Peninsula, the presence of only a single Dall's porpoise was more likely a result from stranding or by chance. As Kasuya (2017) noted that large-strong swimming Dall's porpoise could only be caught by hand harpoon method, not by drive-in fishery as commonly practiced by early Jomon People at Mawaki site due to its swimming in unpredictable way. Further analysis should ascertain whether one or multiple individuals were present at the site.

In addition, northern right whale dolphin is another rare species with no record of sightings and stranding from the Sea of Japan or the Sea of Okhotsk (Ohdachi et al., 2015). However, this highly gregarious species are often found in large schools and occasionally in association with many other species including commonly identified from archaeological sites across Japan, including Pacific white-sided dolphins, Dall's porpoises, pilot whales and bottlenose dolphins (Ohdachi et al., 2015; Kasuya, 2017).

3.4.2 Toothed whales exploited at early Jomon Mibiki

At the species level classification, four species of toothed whale were identified based on the atlas and axis vertebrae recovered from the site. Following the hierarchical classification scheme, the canonical DFA of the zooarchaeological sample revealed correct taxonomic affiliation at every level for four out of the seven samples in total.

In comparison to previous study of seven zooarchaeological samples (add reference), DFA-based classification and morphological-based identification were in accordance with only Pacific white-sided dolphin (N=1) (Table 3.6). Whereas DFA-based classification unexpectedly revealed the presence of another species; Risso's dolphin and a possibly Dall's porpoise providing new evidence for range of toothed whale species exploited by early Jomon People at Mibiki archaeological site apart from short-beaked common dolphin, common bottlenose dolphin, Pacific white-sided dolphin, and false killer whale.

However, group membership classification for No. 749 and No. 748 showed contradictions. No. 749 (Figure 3.12) was assigned to Dall's porpoise at species level but assigned to Delphininae (subfamily-level), Delphinidae (family-level), and Delphinoidea (superfamily-level), showing consistency for oceanic dolphin. No. 748 (Figure 3.13) was assigned to Dall's porpoise at species level, Phocoenidae (family-level), and Delphinoidea (superfamily-level) and showed consistency in classification for porpoise, but was assigned to Delphininae at subfamily level.

These contradictions seem to be attribute to mensural overlap between Dall's porpoise and pacific white-sided dolphin in case of No. 749, and between subfamily Delphininae and Phocoenoidinae in case of No. 748.

In regarding to these, DFA-based classification on zooarchaeological samples would be best at subfamily-level classification for Delphininae, in case of No. 749. This should also be the same for No. 495, due to the lowest rate (52.0%) of species level classification in assigning to striped dolphin at species level. In case of No. 748, it would be best at family-level classification for Phocoenidae.

Based on results of canonical DFA, three species were assigned to early Jomon Mibiki zooarchaeological samples: Risso's dolphin, Pacific white-sided dolphin, and possibly porpoise.

3.4.3 Toothed whales exploited at Okhotsk Kafukai-1

At the species level classification, five species of toothed whale were identified based on the atlas and axis vertebrae recovered from the site. All species (except for short-beaked common dolphin) were in accordance with previous analysis based on skull and ear bone elements (Ohba and Ohyi, 1976). Following the hierarchical classification scheme, the canonical DFA of the zooarchaeological sample revealed correct taxonomic affiliation at every level for six out of the nine samples in total.

However, group membership classification for three samples showed contradictions: RKA3690 (Figure 3.14) showed consistency in classification at subfamily level (Phocoenoidinae), at family level (Phocoenidae), and at superfamily level (Delphinoidea) for Dall's porpoise, but was assigned to harbor porpoise at specie level. RKA15283 (Figure 3.15) was assigned to harbor porpoise at species level and showed consistency in classification at family level (Phocoenidae) and at superfamily level (Delphinoidea), but was assigned to Delphininae at subfamily level. RKA5918 (Figure 3.16) was assigned to Pacific white-sided dolphin at species level and showed consistency in classification at subfamily level (Delphininae) and at superfamily level (Delphinoidea) for oceanic dolphin, but was assigned to Phocoenidae at subfamily level.

These contradictions seem to be attribute to mensural overlap between Dall's porpoise and harbor porpoise in case of RKA3690, between subfamily Delphininae and Phocoeninae in case of RKA15283, and between family Delphinidae and Phocoenidae in case of RKA5918.

In regarding to the low classification rate that produced at species-level classification for RKA2047 and RKA2804, DFA-based classification on zooarchaeological samples would be best at subfamily-level classification for Globicephalinae. Although there is more likely that short-finned pilot whale was present at the site due to its higher classification rate obtained for RKA3882 (68.80%), there is a need to increase the sample size by including more atlas and axis vertebral specimens of short-finned pilot whale into modern reference dataset.

Furthermore, there is also a need to include the atlas and axis vertebrae of long-finned pilot whale into the dataset. This species was previously identified based on the skulls from the Okhotsk Kafukai-1 site (Kasuya, 1975). However, it is regarded as locally extinct from Japan Waters and thus no modern specimens available for study in Japan. Therefore, regarding these, RKA3882 should be best assigned to Globicephalinae at subspecies level.

DFA-based classification confirmed that in addition to the skulls, the atlas and axis vertebrae of Pacific white-sided dolphin, harbor porpoise, and possibly pilot whale and/or false killer whale were brought to the Kafukai villages for some reason as well. In addition, another species assigned to short-beaked common dolphin was also detected. This species is known from the Pacific coast of Shikoku to Hokkaido in modern distribution (Kasuya, 2017). However, the presence of only a single short-beaked common dolphin was more likely known from stranding or by chance. Further analysis should ascertain whether one or multiple individuals were present at the site.

Based on results of canonical DFA, two species were assigned to Okhotsk Kafukai-1 site zooarchaeological samples: Pacific white-sided dolphin and short-beaked common dolphin along with possibly porpoise (Phocoenid), and Globicephalinids.

In sum, the analysis of zooarchaeological samples from three different archaeological sites reveals the relative strength of DFA-based classification approach in distinguishing the morphological variation of atlas and axis vertebrae among many toothed whale species. This method shed light on cetacean exploitation, the taxonomic diversity of exploited species and the past occurrence of the species.

CHAPTER 4

DISCUSSION

The application of DFA-based identification to zooarchaeological atlas and axis vertebrae to determine the taxonomic affiliation highlights the relatively advantages and limitation of the technique.

Canonical discriminant function analysis was effective at classifying the atlas and axis vertebrae of 18 modern toothed whale species in a hierarchical classification system, with a high successful classification rate at the superfamily (97.1%), family (89.6%), and subfamily (78.9%) levels. At the species level, six received the highest score (100.0%) for correct identification rate for each species, while four other species had sufficiently high correct identification rates (above 80.0%). The established canonical discriminant functions were applied to 44 zooarchaeological atlas and axis vertebrae from three archeological sites in Japan ranging from the early Jomon to the Okhotsk Culture periods. Twenty-seven of the zooarchaeological specimens (61.4%) were identified in a hierarchical taxonomic classification scheme without contradiction and six species (Pacific white-sided dolphin (N=11), Striped dolphin (N=5), Risso's dolphin (N=5), short-beaked common dolphin (N=3), common bottlenose dolphin (N=2), and northern right whale dolphin (N=1)) including four species not found in the previous morphological analysis and three not distributed around the sites, were found.

The presence of other species as unexpectedly revealed by DFA-based classification offers not only insight into the taxonomic diversity of species exploited by the early Jomon and Okhotsk People but also questions about the acquisition routes from archeological perspectives and temporal distribution changes of the species from zoogeographical perspectives.

Furthermore, the presence of locally extinct long-finned pilot whale at the Okhotsk Kafukai-1 site is affirmed by the presence of skulls found at the site, but the identification of short-finned pilot whale as well as false killer whale is required for further investigation due to the morphological similarity of the atlas and axis vertebrae by including more sample of short-finned pilot whale as well as long-fined pilot whale which could not be included in this study due to the availability of the specimens.

It should also mention about the presence of short-beaked common dolphin. This species has been previously identified based on skull, mandible, and atlas and axis vertebrae at both early Jomon Mawaki site (Miyazaki, 1986) and early Jomon Mibiki site (Hiraguchi 2004; 2005) including in this study based on DFA-based identification at the Okhotsk Kafukai-1 site. However, Kasuya (2017) in summary of cetacean remains found at Mawaki site, proposed *Delphinus* sp. (cf. *D. capensis*) or long-beaked common dolphin. Previously both were considered to be one species, but in 1994 (Heyning and Perrin, 1994) the common dolphin was separated into short and long beaked varieties (but see e.g. Cunha et al. 2015). The distribution ranges of these two species are also different, as for short-beaked common dolphin usually occurs in offshore waters and less commonly in coastal waters, compared with long-beaked common dolphin (Ohdachi et al. 2015). Thus, long-beaked pilot whale could have presented at the site, or perhaps both species. Further study, should include the atlas and axis vertebrae of long-beaked dolphin into the dataset as well.

Based on these results, DFA-based classification was suggested to be useful for taxonomic identification at the family level and higher, and thus, effective in improving the identification quality of zooarchaeological specimens. Adding more modern reference specimens in the dataset may further improve the certainty and accuracy of identification for future work. Furthermore, the presence of other species as unexpectedly revealed by DFA-based classification also shed light on the taxonomic diversity of species exploited by the early Jomon and Okhotsk People and questions about the acquisition routes from archeological perspectives, including temporal distribution changes of the species from zoogeographical perspectives.

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Table 2.1 Details of modern toothed whales used as standards in this study, listing the source and common, family, genus, and species names, along with the number of specimens. Classification followed Perrin (1989).

Common name	**Classification**					**n**	**Sources**
	Superfamily	**Family**	**Subfamily**	**Genus**	**Species**		
killer whale	Delphinoidea	Delphinidae	Globicephalinae	*Orcinus*	*orca*	7	NMNS
short-finned pilot whale	Delphinoidea	Delphinidae	Globicephalinae	*Globicephala*	*macrorhynchus*	3	NMNS
false killer whale	Delphinoidea	Delphinidae	Globicephalinae	*Pseudorca*	*crassidens*	9	NMNS
northern right whale dolphin	Delphinoidea	Delphinidae	Lissodelphinae	*Lissodelphis*	*borealis*	10	NMNS
Risso's dolphin	Delphinoidea	Delphinidae	Delphininae	*Grampus*	*griseus*	10	NMNS
Pacific white-sided dolphin	Delphinoidea	Delphinidae	Delphininae	*Lagenorhynchus*	*obliquidens*	14	NMNS & HOUM
striped dolphin	Delphinoidea	Delphinidae	Delphininae	*Stenella*	*coeruleoalba*	11	NMNS
short-beaked common dolphin	Delphinoidea	Delphinidae	Delphininae	*Delphinus*	*delphis*	11	NMNS
common bottlenose dolphin	Delphinoidea	Delphinidae	Delphininae	*Tursiops*	*truncatus*	11	NMNS
harbor porpoise	Delphinoidea	Phocoenidae	Phocoeninae	*Phocoena*	*phocoena*	16	NMNS & HOUM
finless porpoise	Delphinoidea	Phocoenidae	Phocoeninae	*Neophocaena*	*phocaenoides*	11	NMNS
Dall's porpoise	Delphinoidea	Phocoenidae	Phocoenoidinae	*Phocoenoides*	*dalli*	15	NMNS
pygmy sperm whale	Physeteroidea	Kogiidae		*Kogia*	*breviceps*	10	NMNS
dwarf sperm whale	Physeteroidea	Kogiidae		*Kogia*	*sima*	8	NMNS
Baird's beaked whale	Ziphioidea	Hyperoodontidae		*Berardius*	*bairdii*	2	NMNS
Hubbs' beaked whale	Ziphioidea	Hyperoodontidae		*Mesoplodon*	*carlhubbsi*	3	NMNS
Stejneger's beaked whale	Ziphioidea	Hyperoodontidae		*Mesoplodon*	*stejnegeri*	10	NMNS
Cuvier's beaked whale	Ziphioidea	Hyperoodontidae		*Ziphius*	*cavirostris*	12	NMNS

NMNS: National Museum of Nature and Science, Tsukuba, Ibaraki, Japan; **HOUM**: The Hokkaido University Museum, Sapporo, Hokkaido, Japan

Table 2.2 List of measurements used in this study.

Abbreviation	Measurements	Sources
GWASA	greatest width of articulating surface of atlas	Perrin, 1975
HA	height of atlas	Perrin, 1975
LLPA	length of lateral process of atlas	Perrin, 1975
GLNSA	greatest length of neural spine of atlas	Perrin, 1975
LLeftLtPA	length of left lateral process of Axis from margin of posterior articulating surface to distal end of process	Perrin, 1975
GLCAF	greatest length of cranial articular facet	This study
GWCAF	greatest width of cranial articular facet	This study
BNA	breadth of neural canal	This study
HNA	height of neural canal	This study
GBNSA	greatest breadth of neural spine of atlas	This study
ThLPA	thickness of lateral process of atlas	This study
BLPA	breath of lateral process of atlas	This study
ThNSA	thickness of neural spine of atlas	This study

Table 2.3 Results from canonical Discriminant Function Analysis (DFA) to classify the atlas and axis vertebrae of 18 toothed whale species from three superfamilies (Delphinoidea, Physeteroidea, and Ziphioidea). The overall accuracy rate in classification after cross-validation was 97.1%.

Classification Results[a,c]

		SUPERFAMILY	Predicted Group Membership: DELPHINOIDEA	PHYSETEROIDEA	ZIPHIOIDEA	Total
Original	Count	DELPHINOIDEA	128	0	0	128
		PHYSETEROIDEA	0	18	0	18
		ZIPHIIOIDEA	0	1	26	27
	%	DELPHINOIDEA	100.0	.0	.0	100.0
		PHYSETEROIDEA	.0	100.0	.0	100.0
		ZIPHIIOIDEA	.0	3.7	96.3	100.0
Cross-validated[b]	Count	DELPHINOIDEA	128	0	0	128
		PHYSETEROIDEA	0	18	0	18
		ZIPHIIOIDEA	0	5	22	27
	%	DELPHINOIDEA	100.0	.0	.0	100.0
		PHYSETEROIDEA	.0	100.0	.0	100.0
		ZIPHIIOIDEA	.0	18.5	81.5	100.0

a. 99.4% of original grouped cases correctly classified.

b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

c. 97.1% of cross-validated grouped cases correctly classified.

Table 2.4 Percentage of variance explained by each canonical discriminant function of 18 toothed whale species from three superfamilies (Delphinoidea, Physeteroidea, and Ziphioidea).

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	78.570[a]	98.0	98.0	.994
2	1.574[a]	2.0	100.0	.782

a. First 2 canonical discriminant functions were used in the analysis.

Table 2.5 Classification functions out of three superfamilies (Delphinoidea, Physeteroidea, and Ziphioidea) of toothed whale.

	Function	
	1	2
GWASA	-1.396	9.489
HA	3.684	2.391
LLPA	-2.045	-.038
GLNSA	2.474	2.347
LLefLtPA	9.076	-7.979
BLPA	-7.598	.483
ThLPA	-8.702	-2.705
GBNSA	-.446	-.231
ThBNSA	-.790	-2.440
GLCAF	5.052	7.384
GWCAF	-1.819	3.220
BNA	2.069	-8.068
HNA	1.468	-1.866
(Constant)	-6.585	-9.499

Unstandardized coefficients

Table 2.6 Results from canonical DFA to classify the atlas and axis of 18 toothed whale species from four families (Delphinidae, Phocoenidae, Kogiidae, and Hyperoodontidae). The overall accuracy rate in classification after cross-validation was 89.6%.

Classification Results[a,c]

		FAMILY	Predicted Group Membership: DELPHINIDAE	PHOCOENIDAE	KOGIIDAE	HYPEROODONTIDAE	Total
Original	Count	DELPHINIDAE	83	3	0	0	86
		PHOCOENIDAE	7	35	0	0	42
		KOGIIDAE	0	0	18	0	18
		HYPEROODONTIDAE	0	0	1	26	27
	%	DELPHINIDAE	96.5	3.5	.0	.0	100.0
		PHOCOENIDAE	16.7	83.3	.0	.0	100.0
		KOGIIDAE	.0	.0	100.0	.0	100.0
		HYPEROODONTIDAE	.0	.0	3.7	96.3	100.0
Cross-validated[b]	Count	DELPHINIDAE	82	4	0	0	86
		PHOCOENIDAE	11	31	0	0	42
		KOGIIDAE	0	0	18	0	18
		HYPEROODONTIDAE	0	0	3	24	27
	%	DELPHINIDAE	95.3	4.7	.0	.0	100.0
		PHOCOENIDAE	26.2	73.8	.0	.0	100.0
		KOGIIDAE	.0	.0	100.0	.0	100.0
		HYPEROODONTIDAE	.0	.0	11.1	88.9	100.0

a. 93.6% of original grouped cases correctly classified.

b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

c. 89.6% of cross-validated grouped cases correctly classified.

Table 2.7 Percentage of variance explained by each discriminant function in four families of toothed whale (Delphinidae, Phocoenidae, Kogiidae, and Hyperoodontidae).

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	78.571[a]	96.6	96.6	.994
2	2.066[a]	2.5	99.1	.821
3	.704[a]	.9	100.0	.643

a. First 3 canonical discriminant functions were used in the analysis.

Table 2.8 Classification functions of 18 toothed whale species from four families (Delphinidae, Phocoenidae, Kogiidae, and Hyperoodontidae).

	Function		
	1	2	3
GWASA	-1.406	13.031	2.999
HA	3.670	2.199	-1.090
LLPA	-2.038	-.050	-.007
GLNSA	2.463	2.559	-.387
LLefLtPA	9.049	-8.032	2.451
BLPA	-7.571	.034	-.917
ThLPA	-8.673	-1.575	2.782
GBNSA	-.435	-3.875	-6.123
ThBNSA	-.791	-.489	4.095
GLCAF	5.034	5.443	-5.654
GWCAF	-1.816	3.693	-.221
BNA	2.065	-7.161	4.114
HNA	1.463	-1.457	1.289
(Constant)	-6.544	-14.427	-5.352

Unstandardized coefficients

Table 2.9 Results from canonical DFA to classify the atlas and axis vertebrae of 12 toothed whale species from five subfamilies (Lissodelphinae, Globicephalinae, Delphininae, Phocoeninae, and Phocoenoidinae) within the superfamily Delphinoidea. The overall accuracy rate in classification after cross-validation was 78.9%.

Classification Results[a,c]

			Predicted Group Membership					
		SUBFAMILY	LISSODELPHINAE	GLOBICEPHALINAE	DELPHININAE	PHOCOENINAE	PHOCOENOIDINAE	Total
Original	Count	LISSODELPHINAE	10	0	0	0	0	10
		GLOBICEPHALINAE	0	19	0	0	0	19
		DELPHININAE	1	1	53	2	0	57
		PHOCOENINAE	0	0	2	22	3	27
		PHOCOENOIDINAE	0	0	5	0	10	15
	%	LISSODELPHINAE	100.0	.0	.0	.0	.0	100.0
		GLOBICEPHALINAE	.0	100.0	.0	.0	.0	100.0
		DELPHININAE	1.8	1.8	93.0	3.5	.0	100.0
		PHOCOENINAE	.0	.0	7.4	81.5	11.1	100.0
		PHOCOENOIDINAE	.0	.0	33.3	.0	66.7	100.0
Cross-validated[b]	Count	LISSODELPHINAE	9	0	1	0	0	10
		GLOBICEPHALINAE	0	18	1	0	0	19
		DELPHININAE	3	2	49	2	1	57
		PHOCOENINAE	1	0	1	16	9	27
		PHOCOENOIDINAE	0	0	6	0	9	15
	%	LISSODELPHINAE	90.0	.0	10.0	.0	.0	100.0
		GLOBICEPHALINAE	.0	94.7	5.3	.0	.0	100.0
		DELPHININAE	5.3	3.5	86.0	3.5	1.8	100.0
		PHOCOENINAE	3.7	.0	3.7	59.3	33.3	100.0
		PHOCOENOIDINAE	.0	.0	40.0	.0	60.0	100.0

a. 89.1% of original grouped cases correctly classified.

b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

c. 78.9% of cross-validated grouped cases correctly classified.

Table 2.10 Percentage of variance explained by each canonical discriminant function in five subfamilies of toothed whale within the superfamily Delphinoidea (Lissodelphinae, Globicephalinae, Delphininae, Phocoeninae, and Phocoenoidinae).

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	6.169[a]	67.3	67.3	.928
2	2.058[a]	22.5	89.7	.820
3	.638[a]	7.0	96.7	.624
4	.303[a]	3.3	100.0	.482

a. First 4 canonical discriminant functions were used in the analysis.

Table 2.11 Classification functions of five subfamilies of toothed whale within the superfamily Delphinoidea (Lissodelphinae, Globicephalinae, Delphininae, Phocoeninae, and Phocoenoidinae).

	Function			
	1	2	3	4
GWASA	2.083	7.060	15.333	-12.105
HA	-.195	11.907	-5.306	5.513
LLPA	.417	-.226	1.930	-.787
GLNSA	-.080	2.055	5.056	-3.981
LLefLtPA	1.314	-5.179	-5.119	19.761
BLPA	-1.873	-.426	.369	1.838
ThLPA	-1.937	-.126	7.262	-.850
GBNSA	-4.216	7.015	-.406	2.160
ThBNSA	.531	-5.892	.376	1.925
GLCAF	3.109	-11.553	-18.447	-10.453
GWCAF	4.241	.425	4.737	-4.734
BNA	12.874	.913	-1.698	5.136
HNA	2.440	-2.923	-4.222	1.136
(Constant)	-34.659	-8.345	2.827	-3.783

Unstandardized coefficients

Table 2.12 Results from canonical DFA to classify the atlas and axis vertebrae of three toothed whale species into three subfamilies within the family Delphinidae (Lissodelphinae, Delphininae, and Globicephalinae). The overall accuracy rate in classification after cross-validation was 91.9%.

Classification Results[a,c]

			Predicted Group Membership			
		SUBFAMILY	LISSODELPHINAE	GLOBICEPHALINAE	DELPHININAE	Total
Original	Count	LISSODELPHINAE	10	0	0	10
		GLOBICEPHALINAE	0	19	0	19
		DELPHININAE	2	1	54	57
	%	LISSODELPHINAE	100.0	.0	.0	100.0
		GLOBICEPHALINAE	.0	100.0	.0	100.0
		DELPHININAE	3.5	1.8	94.7	100.0
Cross-validated[b]	Count	LISSODELPHINAE	10	0	0	10
		GLOBICEPHALINAE	0	18	1	19
		DELPHININAE	3	3	51	57
	%	LISSODELPHINAE	100.0	.0	.0	100.0
		GLOBICEPHALINAE	.0	94.7	5.3	100.0
		DELPHININAE	5.3	5.3	89.5	100.0

a. 96.5% of original grouped cases correctly classified.

b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

c. 91.9% of cross-validated grouped cases correctly classified.

Table 2.13 Percentage of variance explained by each canonical discriminant function in three subfamilies of toothed whale within the family Delphinidae (Lissodelphinae, Delphininae, and Globicephalinae).

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	6.030[a]	77.9	77.9	.926
2	1.713[a]	22.1	100.0	.795

a. First 2 canonical discriminant functions were used in the analysis.

Table 2.14 Classification functions of three subfamilies of toothed whale within the family Delphinidae (Lissodelphinae, Delphininae, and Globicephalinae).

	Function	
	1	2
GWASA	-1.994	14.311
HA	6.468	2.005
LLPA	.007	1.418
GLNSA	1.135	5.995
LLefLtPA	-1.154	-12.810
BLPA	-1.976	-.712
ThLPA	-2.454	4.703
GBNSA	-.798	6.361
ThBNSA	-4.523	-5.973
GLCAF	-1.600	-14.950
GWCAF	7.910	4.150
BNA	13.627	-5.280
HNA	3.056	-3.366
(Constant)	-33.695	7.402

Unstandardized coefficients

Table 2.15 Results from canonical DFA to classify the atlas and axis vertebrae of two toothed whale species in two subfamilies within the family Phocoenidae (Phocoeninae and Phocoenoidinae). The overall accuracy rate in classification after cross-validation was 85.7%.

Classification Results[a,c]

			Predicted Group Membership		
		SUBFAMILY	PHOCOENINAE	PHOCOENOIDINAE	Total
Original	Count	PHOCOENINAE	27	0	27
		PHOCOENOIDINAE	0	15	15
	%	PHOCOENINAE	100.0	.0	100.0
		PHOCOENOIDINAE	.0	100.0	100.0
Cross-validated[b]	Count	PHOCOENINAE	23	4	27
		PHOCOENOIDINAE	2	13	15
	%	PHOCOENINAE	85.2	14.8	100.0
		PHOCOENOIDINAE	13.3	86.7	100.0

a. 100.0% of original grouped cases correctly classified.

b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

c. 85.7% of cross-validated grouped cases correctly classified.

Table 2.16 Percentage of variance explained by a canonical discriminant function between two subfamilies of toothed whale within the family Phocoenidae (Phocoeninae and Phocoenoidinae).

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	8.082[a]	100.0	100.0	.943

a. First 1 canonical discriminant functions were used in the analysis.

Table 2.17 Classification function of two subfamilies of toothed whale within the family Phocoenidae (Phocoeninae and Phocoenoidinae).

	Function
	1
GWASA	6.667
HA	6.642
LLPA	3.322
GLNSA	-1.249
LLefLtPA	4.802
BLPA	3.622
ThLPA	5.982
GBNSA	-6.667
ThBNSA	6.635
GLCAF	-17.441
GWCAF	.522
BNA	18.154
HNA	17.333
(Constant)	-67.340

Unstandardized coefficients

Table 2.18 Results from canonical DFA to classify the atlas and axis vertebrate of five species within the subfamily Delphininae (Risso's dolphin, common bottlenose dolphin, Pacific white-sided dolphin, striped dolphin, and short-beaked common dolphin). The overall accuracy rate in classification after cross-validation was 84.2%.

Classification Results[a,c]

			Predicted Group Membership					
		SPECIES	Risso's dolphin	common bottlenose dolphin	Pacific white-sided dolphin	striped dophin	short-beaked common dolphin	Total
Original	Count	Risso's dolphin	10	0	0	0	0	10
		common bottlenose dolphin	0	9	2	0	0	11
		Pacific white-sided dolphin	0	0	14	0	0	14
		striped dolphin	0	0	0	11	0	11
		short-beaked common dolphin	0	0	0	0	11	11
	%	Risso's dolphin	100.0	.0	.0	.0	.0	100.0
		common bottlenose dolphin	.0	81.8	18.2	.0	.0	100.0
		Pacific white-sided dolphin	.0	.0	100.0	.0	.0	100.0
		striped dolphin	.0	.0	.0	100.0	.0	100.0
		short-beaked common dolphin	.0	.0	.0	.0	100.0	100.0
Cross-validated[b]	Count	Risso's dolphin	8	2	0	0	0	10
		common bottlenose dolphin	1	8	2	0	0	11
		Pacific white-sided dolphin	0	1	13	0	0	14
		striped dolphin	0	0	0	11	0	11
		short-beaked common dolphin	0	0	2	1	8	11
	%	Risso's dolphin	80.0	20.0	.0	.0	.0	100.0
		common bottlenose dolphin	9.1	72.7	18.2	.0	.0	100.0
		Pacific white-sided dolphin	.0	7.1	92.9	.0	.0	100.0
		striped dolphin	.0	.0	.0	100.0	.0	100.0
		short-beaked common dolphin	.0	.0	18.2	9.1	72.7	100.0

a. 96.5% of original grouped cases correctly classified.

b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

c. 84.2% of cross-validated grouped cases correctly classified.

Table 2.19 Percentage of variance explained by each canonical discriminant function among five toothed whale species within the subfamily Delphininae (Risso's dolphin, common bottlenose dolphin, Pacific white-sided dolphin, striped dolphin, and short-beaked common dolphin).

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	9.980[a]	66.8	66.8	.953
2	2.922[a]	19.6	86.3	.863
3	1.558[a]	10.4	96.8	.780
4	.484[a]	3.2	100.0	.571

a. First 4 canonical discriminant functions were used in the analysis.

Table 2.20 The classification functions among five toothed whale species within the subfamily Delphininae (Risso's dolphin, common bottlenose dolphin, Pacific white-sided dolphin, striped dolphin, and short-beaked common dolphin).

	Function			
	1	2	3	4
GWASA	12.795	-15.905	-24.279	-10.613
HA	10.858	16.453	10.752	2.815
LLPA	-2.167	6.389	-.065	1.121
GLNSA	.328	.061	7.295	2.805
LLefLtPA	-6.897	-18.411	-21.981	15.651
BLPA	-1.382	-3.517	-1.882	-6.139
ThLPA	1.845	-1.383	-1.710	1.745
GBNSA	2.829	3.339	1.925	1.529
ThBNSA	2.767	-3.418	2.295	1.604
GLCAF	-18.198	-19.144	-9.262	-13.922
GWCAF	3.629	18.034	18.880	-6.354
BNA	13.988	-.846	.946	-3.963
HNA	15.539	6.583	1.304	7.237
(Constant)	-54.816	27.170	39.174	14.604

Unstandardized coefficients

Table 2.21 Results from canonical DFA to classify the atlas and axis vertebrae of three toothed whale species within subfamily Globicephalinae (false killer whale, killer whale, and short-finned pilot whale). The overall accuracy rate in classification after cross-validation using a jackknifed model was 68.4%.

Classification Results[a,c]

		SPECIES	Predicted Group Membership: false killer whale	killer whale	short-finned pilot whale	Total
Original	Count	false killer whale	8	1	0	9
		killer whale	1	6	0	7
		short finned-pilot whale	0	0	3	3
	%	false killer whale	88.9	11.1	.0	100.0
		killer whale	14.3	85.7	.0	100.0
		short finned-pilot whale	.0	.0	100.0	100.0
Cross-validated[b]	Count	false killer whale	6	0	3	9
		killer whale	0	7	0	7
		short finned-pilot whale	3	0	0	3
	%	false killer whale	66.7	.0	33.3	100.0
		killer whale	.0	100.0	.0	100.0
		short finned-pilot whale	100.0	.0	.0	100.0

a. 89.5% of original grouped cases correctly classified.

b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

c. 68.4% of cross-validated grouped cases correctly classified.

Table 2.22 Percentage of variance explained by each canonical discriminant function in three toothed whale species within the subfamily Globicephalinae (false killer whale, killer whale, and short-finned pilot whale).

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	127.653[a]	93.9	93.9	.996
2	8.341[a]	6.1	100.0	.945

a. First 2 canonical discriminant functions were used in the analysis.

Table 2.23 The classification functions in five toothed whale species within the subfamily Globicephalinae (false killer whale, killer whale, and short-finned pilot whale).

	Function	
	1	2
GWASA	184.809	-3.757
HA	-14.571	-13.118
LLPA	-170.040	-21.636
GLNSA	78.975	7.205
LLefLtPA	-116.699	5.046
BLPA	71.111	4.370
ThLPA	-10.223	38.663
GBNSA	35.203	-3.709
ThBNSA	99.056	9.831
GLCAF	-126.171	-16.972
GWCAF	-89.945	-16.192
HNA	-62.217	-6.118
(Constant)	300.577	62.361

Unstandardized coefficients

Table 2.24 Results from canonical DFA to classify the atlas and axis vertebrae of two toothed whale species within the subfamily Phocoeninae (harbor porpoise and finless porpoise). The overall accuracy rate in classification after cross-validation was 96.3%.

Classification Results[a,c]

			Predicted Group Membership		
		SPECIES	harbor porpoise	finless porpoise	Total
Original	Count	harbor porpoise	13	3	16
		finless porpoise	0	11	11
	%	harbor porpoise	81.3	18.8	100.0
		finless porpoise	.0	100.0	100.0
Cross-validated[b]	Count	harbor porpoise	15	1	16
		finless porpoise	0	11	11
	%	harbor porpoise	93.8	6.3	100.0
		finless porpoise	.0	100.0	100.0

a. 88.9% of original grouped cases correctly classified.

b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

c. 96.3% of cross-validated grouped cases correctly classified.

Table 2.25 Percentage of variance explained by a canonical discriminant function in two toothed whale species within the subfamily Phocoeninae (harbor porpoise and finless porpoise).

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	217.075[a]	100.0	100.0	.998

a. First 1 canonical discriminant functions were used in the analysis.

Table 2.26 The classification functions of two toothed whale species within the subfamily Phocoeninae (harbor porpoise and finless porpoise).

	Function
	1
GWASA	-568.473
HA	-521.442
LLPA	108.680
GLNSA	42.902
LLefLtPA	243.827
BLPA	-78.616
ThLPA	25.837
GBNSA	32.167
ThBNSA	17.916
GLCAF	-754.600
GWCAF	582.012
BNA	333.353
HNA	14.706
(Constant)	1212.406

Unstandardized coefficients

Table 2.27 Results from canonical DFA to classify the atlas/axis vertebra of three species within the family Phocoenidae (Dall's porpoise, harbor porpoise, and finless porpoise). The overall accuracy rate in classification after cross-validation was 85.7%.

Classification Results[a,c]

		SPECIES	Predicted Group Membership: Dall's porpoise	harbor porpoise	finless porpoise	Total
Original	Count	Dall's porpoise	15	0	0	15
		harbor poprpoise	0	15	1	16
		finless porpoise	0	0	11	11
	%	Dall's porpoise	100.0	.0	.0	100.0
		harbor poprpoise	.0	93.8	6.3	100.0
		finless porpoise	.0	.0	100.0	100.0
Cross-validated[b]	Count	Dall's porpoise	13	2	0	15
		harbor poprpoise	4	12	0	16
		finless porpoise	0	0	11	11
	%	Dall's porpoise	86.7	13.3	.0	100.0
		harbor poprpoise	25.0	75.0	.0	100.0
		finless porpoise	.0	.0	100.0	100.0

a. 97.6% of original grouped cases correctly classified.

b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

c. 85.7% of cross-validated grouped cases correctly classified.

Table 2.28 Percentage of variance explained by each canonical discriminant function for three toothed whale species within the family Phocoenidae (Dall's porpoise, harbor porpoise, and finless porpoise).

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	31.907[a]	89.6	89.6	.985
2	3.687[a]	10.4	100.0	.887

a. First 2 canonical discriminant functions were used in the analysis.

Table 2.29 The classification functions of three species within the family Phocoenidae (Dall's porpoise, harbor porpoise, and finless porpoise).

	Function 1	Function 2
GWASA	-19.512	16.865
HA	6.237	4.559
LLPA	5.367	1.208
GLNSA	2.120	-2.428
LLefLtPA	43.305	-15.203
BLPA	-4.648	6.324
ThLPA	4.184	4.789
GBNSA	-8.858	-3.338
ThBNSA	4.182	5.532
GLCAF	-47.491	2.865
GWCAF	14.151	-6.155
BNA	15.799	13.056
HNA	-6.993	22.993
(Constant)	-7.404	-72.844

Unstandardized coefficients

Table 2.30 Results from canonical DFA to classify the atlas and axis vertebrae of four toothed whale species within the family Hyperoodontidae (Baird's beaked whale, Cuvier's beaked whale, Hubbs' beaked whale, and Stejneger's beaked whale). The overall accuracy rate in classification after cross-validation was 74.1%.

Classification Results[a,c]

		SPECIES	Predicted Group Membership: Baird's beaked whale	Cuvier's beaked whale	Hubbs' beaked whale	Stejneger's beaked whale	Total
Original	Count	Baird's beaked whale	2	0	0	0	2
		Cuvier's beaked whale	1	11	0	0	12
		Hubbs' beaked whale	0	0	3	0	3
		Stejneger's beaked whale	0	0	1	9	10
	%	Baird's beaked whale	100.0	.0	.0	.0	100.0
		Cuvier's beaked whale	8.3	91.7	.0	.0	100.0
		Hubbs' beaked whale	.0	.0	100.0	.0	100.0
		Stejneger's beaked whale	.0	.0	10.0	90.0	100.0
Cross-validated[b]	Count	Baird's beaked whale	0	2	0	0	2
		Cuvier's beaked whale	1	11	0	0	12
		Hubbs' beaked whale	0	0	2	1	3
		Stejneger's beaked whale	0	0	3	7	10
	%	Baird's beaked whale	.0	100.0	.0	.0	100.0
		Cuvier's beaked whale	8.3	91.7	.0	.0	100.0
		Hubbs' beaked whale	.0	.0	66.7	33.3	100.0
		Stejneger's beaked whale	.0	.0	30.0	70.0	100.0

a. 92.6% of original grouped cases correctly classified.

b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

c. 74.1% of cross-validated grouped cases correctly classified.

Table 2.31 Percentage of variance explained by each canonical discriminant function among four toothed whale species within the family Hyperoodontidae (Baird's beaked whale, Cuvier's beaked whale, Hubbs' beaked whale, and Stejneger's beaked whale).

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	88.979[a]	93.6	93.6	.994
2	4.514[a]	4.7	98.3	.905
3	1.571[a]	1.7	100.0	.782

a. First 3 canonical discriminant functions were used in the analysis.

Table 2.32 The classification functions of four species within the family Hyperoodontidae (Baird's beaked whale, Cuvier's beaked whale, Hubbs' beaked whale, and Stejneger's beaked whale).

	Function		
	1	2	3
GWASA	.112	-16.445	-9.603
HA	84.258	-19.366	-24.905
LLPA	-21.974	-24.674	-4.426
GLNSA	-5.988	25.799	3.933
LLefLtPA	39.306	11.439	-6.542
BLPA	13.739	19.115	4.822
ThLPA	2.594	-23.696	3.872
GBNSA	-10.706	-7.351	3.580
ThBNSA	8.253	2.926	-1.883
GLCAF	61.157	31.196	32.504
GWCAF	-10.093	8.138	13.206
BNA	8.146	-5.384	1.214
HNA	-50.747	-8.243	-12.013
(Constant)	-245.016	16.171	3.484

Unstandardized coefficients

Table 2.33 Results from canonical DFA to classify the atlas and axis vertebrae of two species within the family Kogiidae (pygmy sperm whale and dwarf sperm whale). The overall accuracy rate in classification after cross-validation was 100.0%.

Classification Results[a,c]

		SPECIES	Predicted Group Membership: pygmy sperm whale	Predicted Group Membership: dwarf sperm whale	Total
Original	Count	pygmy sperm whale	10	0	10
		dwarf sperm whale	0	8	8
	%	pygmy sperm whale	100.0	.0	100.0
		dwarf sperm whale	.0	100.0	100.0
Cross-validated[b]	Count	pygmy sperm whale	10	0	10
		dwarf sperm whale	0	8	8
	%	pygmy sperm whale	100.0	.0	100.0
		dwarf sperm whale	.0	100.0	100.0

a. 100.0% of original grouped cases correctly classified.

b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

c. 100.0% of cross-validated grouped cases correctly classified.

Table 2.34 Percentage of variance explained by a canonical discriminant function of two toothed whale species within the family Kogiidae (pygmy sperm whale and dwarf sperm whale).

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	1252.363[a]	100.0	100.0	1.000

a. First 1 canonical discriminant functions were used in the analysis.

Table 2.35 The classification functions of two species within the family Kogiidae (pygmy sperm whale and dwarf sperm whale).

	Function 1
GWASA	-168.240
HA	-6.010
LLPA	74.199
GLNSA	-72.606
LLefLtPA	81.623
BLPA	37.707
ThLPA	-92.306
GBNSA	-21.183
ThBNSA	69.290
GLCAF	155.134
GWCAF	51.519
BNA	-197.614
HNA	259.243
(Constant)	-246.409

Unstandardized coefficients

Table 3.1 Summary of specimens measured in this study along with identification information for archaeological specimens.

Specimens	Field No.	Period	Preservation	Morphological ID	References	Collection
M-1	CA-1	early Jomon	Incomplete	short-beaked common dolphin (♂)	(Miyazaki, 1986)	MRJM
M-2	CA-2	early Jomon	Incomplete	short-beaked common dolphin (♂)	(Miyazaki, 1986)	MRJM
M-3	CA-3	early Jomon	Complete	short-beaked common dolphin (♂)	(Miyazaki, 1986)	MRJM
M-5	CA-5	early Jomon	Incomplete	*Dolphin*	(Miyazaki, 1986)	MRJM
M-8	CA-8	early Jomon	Incomplete	short-beaked common dolphin (♂)	(Miyazaki, 1986)	MRJM
M-12	CA-12	early Jomon	Incomplete	short-beaked common dolphin (♂)	(Miyazaki, 1986)	MRJM
M-20	CA-20	early Jomon	Complete	short-beaked common dolphin (♂)	(Miyazaki, 1986)	MRJM
M-21	CA-21	early Jomon	Incomplete	short-beaked common dolphin (♂)	(Miyazaki, 1986)	MRJM
M-23	CA-23	early Jomon	Incomplete	short-beaked common dolphin (♂)	(Miyazaki, 1986)	MRJM
M-28	CA-29	early Jomon	Complete	Pacific white-sided dolphin (♀)	(Miyazaki, 1986)	MRJM
M-29	CA-30	early Jomon	Incomplete	Pacific white-sided dolphin (♂)	(Miyazaki, 1986)	MRJM
M-36	CA-45	early Jomon	Incomplete	short-beaked common dolphin?	(Miyazaki, 1986)	MRJM
M-39	CA-48	early Jomon	Incomplete	Pacific white-sided dolphin (♂)	(Miyazaki, 1986)	MRJM
M-40	CA-59	early Jomon	Incomplete	*Dolphin*	(Miyazaki, 1986)	MRJM
M-43	CA-58	early Jomon	Incomplete	*Dolphin*	(Miyazaki, 1986)	MRJM
M-45	CA-60	early Jomon	Incomplete	Pacific white-sided dolphin (♂)	(Miyazaki, 1986)	MRJM
M-49	CA-66	early Jomon	Incomplete	common bottlenose dolphin (♀?)	(Miyazaki, 1986)	MRJM
M-50	CA-67	early Jomon	Incomplete	common bottlenose dolphin	(Miyazaki, 1986)	MRJM
M-54	-	early Jomon	Incomplete	*Dolphin*	(Miyazaki, 1986)	MRJM
M-58	CA-84	early Jomon	Incomplete	short-beaked common dolphin	(Miyazaki, 1986)	MRJM
M-61	CA-88	early Jomon	Incomplete	*Dolphin*	(Miyazaki, 1986)	MRJM
M-69	CA-109	early Jomon	Complete	*Dolphin*	(Miyazaki, 1986)	MRJM
M-87	CA-131	early Jomon	Incomplete	Pacific white-sided dolphin (♂) ?	(Miyazaki, 1986)	MRJM
M-90	CA-149	early Jomon	Incomplete	short-beaked common dolphin (♂)	(Miyazaki, 1986)	MRJM

MRJM: Mawaki Ruins Jomon Museum

Table 3.2 (*continued*)

Specimens	Field No.	Period	Preservation	Morphological ID	References	Collection
M-91	CA-150	early Jomon	Incomplete	Pacific white-sided dolphin (♂)?	(Miyazaki, 1986)	MRJM
M-106	CA-184	early Jomon	Incomplete	common bottlenose dolphin or Pacific white-sided dolphin ?	(Miyazaki, 1986)	MRJM
M-109	CA-221	early Jomon	Incomplete	*Dolphin*	(Miyazaki, 1986)	MRJM
M-111	CA-285	early Jomon	Incomplete	*Dolphin*	(Miyazaki, 1986)	MRJM
159	-	early Jomon	Complete	short-beaked common dolphin	Hiraguchi (2004; 2005)	IAF
161	-	early Jomon	Incomplete	Pacific white-sided dolphin	Hiraguchi (2004; 2005)	IAF
483	-	early Jomon	Incomplete	Pacific white-sided dolphin	Hiraguchi (2004; 2005)	IAF
494	-	early Jomon	Incomplete	*Dolphin*	Hiraguchi (2004; 2005)	IAF
495	-	early Jomon	Incomplete	*Dolphin*	Hiraguchi (2004; 2005)	IAF
748	-	early Jomon	Incomplete	Pacific white-sided dolphin	Hiraguchi (2004; 2005)	IAF
749	-	early Jomon	Incomplete	*Dolphin*	Hiraguchi (2004; 2005)	IAF
RKA2047	-	Okhotsk	Incomplete	*Dolphin*	-	HOUM
RKA2804	-	Okhotsk	Incomplete	*Dolphin*	-	HOUM
RKA3690	-	Okhotsk	Incomplete	*Dolphin*	-	HOUM
RKA3982	-	Okhotsk	Incomplete	*Dolphin*	-	HOUM
RKA5918	-	Okhotsk	Incomplete	*Dolphin*	-	HOUM
RKA15283	-	Okhotsk	Incomplete	*Dolphin*	-	HOUM
RKA15547	-	Okhotsk	Incomplete	*Dolphin*	-	HOUM
RKA17138	-	Okhotsk	Incomplete	*Dolphin*	-	HOUM
RKA18142	-	Okhotsk	Complete	*Dolphin*	-	HOUM

MRJM: Mawaki Ruins Jomon Museum; **IAF**: Ishikawa Archaeological Foundation; **HOUM**: The Hokkaido University Museum.

Table 3.2 Detailed list of specimens and measurements data

Site	Specimens	Measurement (mm)												
		GWASA	HA	GLNSA	LLPA	LLeftLtPA	GLCAF	GWCAF	BNA	HNA	GBNSA	THLPA	BLPA	THNSA
Mawaki	**M-1**	88.41	55.41	35.02		59.71	46.68	28.13	38.86	25.41	10.65	9.10	17.23	6.10
Mawaki	**M-2**	89.78			28.34	58.21	49.21	31.69	38.18			10.97	17.49	
Mawaki	**M-3**	83.49	56.32	24.38	51.95	55.92	49.96	29.87	40.46	23.12	14.09	8.32	11.19	7.43
Mawaki	**M-5**	83.74					46.06	28.71	38.97			8.76	17.49	
Mawaki	**M-8**	83.67	61.95		27.22	57.27		29.41	40.79	27.23		10.75	19.33	
Mawaki	**M-12**	85.73			31.37	61.13	48.69	27.44	37.15			9.50	18.04	
Mawaki	**M-20**	89.47	60.94	31.18	46.52	52.00	49.26	33.67	37.58	26.87	12.89	10.07	24.02	10.68
Mawaki	**M-21**	87.76	56.90				51.36	32.45	39.98	25.62		9.46	21.76	11.30
Mawaki	**M-23**	86.72						34.64	38.96			11.74	21.49	
Mawaki	**M-28**	78.43	55.42	26.26	36.74	44.84	47.94	30.75	36.54	27.76	6.26	8.58	14.65	11.22
Mawaki	**M-29**	92.10			32.05	54.44	49.30	34.39	41.77			10.23	18.32	
Mawaki	**M-36**	85.96	55.35				46.82	30.06	39.90	22.54	9.52	10.23	11.98	6.51
Mawaki	**M-39**	92.79			30.15	54.06	46.37	32.32	38.28			10.81	20.01	
Mawaki	**M-40**	90.16					53.08	29.55	39.37			13.23	23.78	
Mawaki	**M-43**	90.57					44.68	31.76	39.27			9.80	18.92	
Mawaki	**M-45**	85.32		29.87	23.66	51.72	52.04	31.15	36.80			10.93	21.46	
Mawaki	**M-49**	107.44			39.81	63.29	64.59	40.09	47.47			10.34	22.30	
Mawaki	**M-50**	108.90					58.70	36.72	52.50			13.64	30.62	
Mawaki	**M-54**	113.65			36.81	73.55	63.25	40.44				17.59	24.25	
Mawaki	**M-58**	81.58	53.29				49.18	26.93	35.01	23.91	8.98	9.99	15.14	9.20
Mawaki	**M-61**	105.78					51.62	41.18	50.65			12.85	30.56	
Mawaki	**M-69**	112.09	73.97	27.13	50.31	64.05	54.97	38.87	50.15	29.20	18.20	10.62	17.07	12.01
Mawaki	**M-87**	82.45			27.44	53.67	47.43	29.11	39.22			10.82	18.02	
Mawaki	**M-90**	82.20	61.56	26.63		54.19	51.98	28.67	39.58	31.79	14.12	9.30	21.49	11.03

Table 3.2 (*continued*)

Site	Specimens	Measurement (mm)												
		GWASA	**HA**	**GLNSA**	**LLPA**	**LLeftLtPA**	**GLCAF**	**GWCAF**	**BNA**	**HNA**	**GBNSA**	**THLPA**	**BLPA**	**THNSA**
Mawaki	**M-91**	89.93	59.08	27.22		55.97	50.42	31.15	34.92	24.98		8.74	21.07	
Mawaki	**M-106**	88.43			29.64	56.91	49.81	32.95	42.07			10.14	16.47	
Mawaki	**M-109**	77.11	51.96				47.05	25.78	36.35	22.16	11.50	7.80	14.97	9.60
Mawaki	**M-111**	85.72	60.60	25.94		54.65	51.64	28.50	40.42	28.62	14.14	9.82	18.56	8.93
Mibiki	**159**	82.24	55.89	46.95	24.19	47.56	46.81	27.78	37.43	22.94	7.29	9.59	15.08	10.05
Mibiki	**161**	90.42	59.86				51.95	32.44	39.69	24.45		8.29	21.17	
Mibiki	**483**	89.21	60.93	50.88			50.28	33.04	35.82	26.4	10.52	11.34	22.22	11.66
Mibiki	**494**	83.10	58.44				52.35	29.19	39.48	26.48		11.04	18.42	
Mibiki	**495**		74.03				65.38	30.03	46.2	33.09			25.53	
Mibiki	**748**	88.16	*60.22*				47.12	31.43	36.81	26.88	15.38	11.66	17.79	7.45
Mibiki	**749**	86.00	57.69				46.60	27.63	39.36	25.16	12.09	9.29	17.87	7.42
Kafukai-1	**RKA2047**			64.42		25.36			31.03	62.89	87.57			56.39
Kafukai-1	**RKA2804**		18.11		109.11		64.59			82.64	83.72			48.96
Kafukai-1	**RKA3690**	71.68			20.81	51.18	38.59	26.21	32.24			11.08	13.08	
Kafukai-1	**RKA3982**	175.92	118.9	80.00	50.19	83.26	99.93	62.90	85.10	57.43	30.73		23.12	27.12
Kafukai-1	**RKA5918**	82.44	56.37	36.39	22.38		46.04	27.66	41.68	27.09	19.74	12.05	16.15	12.30
Kafukai-1	**RKA15283**	70.64	44.91		22.24	46.85	37.98	23.3	35.4	22.85		8.86	13.24	
Kafukai-1	**RKA15547**					47.84	46.49	30.70				9.10	15.28	
Kafukai-1	**RKA17138**	78.32			20.3	43.65	42.27	29.21	37.27			12.05	12.8	
Kafukai-1	**RKA18142**	88.96	58.55	49.41	28.00	47.29	46.78	34.92	39.79	22.09	16.89	13.46	10.42	18.00

Table 3.3 Summary results of DFA-based identification of early Jomon Mawaki zooarchaeological samples for correct classification rate, following taxonomic hierarchical classification system

SPECIMENS	**Taxonomic hierarchical classification**							
	SPECIES	**%CORRECT**	**SUBFAMILY**	**%CORRECT**	**FAMILY**	**%CORRECT**	**SUPERFAMILY**	**%CORRECT**
M-3	*D. delphis*	*70.50*	DELPHININAE	*78.90*	PHOCOENIDAE	*86.90*	DELPHINOIDEA	*97.10*
M-20	*P. dalli*	*70.50*	DELPHININAE	*78.90*	DELPHINIDAE	*89.60*	DELPHINOIDEA	*97.10*
M-28	*L. borealis*	*70.50*	LISSODELPHINAE	*78.90*	DELPHINIDAE	*89.60*	DELPHINOIDEA	*97.10*
M-69	*G. griseus*	*70.50*	DELPHININAE	*78.90*	DELPHINIDAE	*89.60*	DELPHINOIDEA	*97.10*
M-1	*S. coeruleoalba*	*71.70*	DELPHININAE	*79.70*	DELPHINIDAE	*90.00*	DELPHINOIDEA	*98.10*
M-2	*L. obliquidens*	*71.10*	DELPHININAE	*75.80*	DELPHINIDAE	*78.80*	DELPHINOIDEA	*97.50*
M-5	*L. borealis*	*61.80*	DELPHININAE	*72.70*	DELPHINIDAE	*82.50*	DELPHINOIDEA	*96.90*
M-8	*S. coeruleoalba*	*67.60*	DELPHININAE	*70.30*	DELPHINIDAE	*78.80*	DELPHINOIDEA	*96.90*
M-12	*S. coeruleoalba*	*71.10*	DELPHININAE	*75.80*	DELPHINIDAE	*78.80*	DELPHINOIDEA	*97.50*
M-21	*L. obliquidens*	*59.00*	DELPHININAE	*74.20*	DELPHINIDAE	*76.30*	DELPHINOIDEA	*96.90*
M-23	*L. obliquidens*	*60.70*	DELPHININAE	*70.30*	DELPHINIDAE	*81.90*	DELPHINOIDEA	*96.90*
M-29	*L. obliquidens*	*71.10*	DELPHININAE	*75.80*	DELPHINIDAE	*78.80*	DELPHINOIDEA	*97.50*
M-36	*D. delphis*	*64.20*	DELPHININAE	*78.90*	DELPHINIDAE	*86.90*	DELPHINOIDEA	*96.90*
M-39	*L. obliquidens*	*71.10*	DELPHININAE	*75.00*	DELPHINIDAE	*78.80*	DELPHINOIDEA	*97.50*

striped dolphin (*S. coeruleoalba*); Pacific white-sided dolphin (*L. obliquidens*); common bottlenose dolphin (*T. truncatus*); Risso's dolphin (*G. griseus*); northern right whale dolphin (*L. borealis*); and Dall's porpoise (*P. dalli*).

Table 3.3 (*continued*)

SPECIMENS	Taxonomic hierachical classification							
	SPECIES	**%CORRECT**	**SUBFAMILY**	**%CORRECT**	**FAMILY**	**%CORRECT**	**SUPERFAMILY**	**%CORRECT**
M-40	*S. coeruleoalba*	*61.80*	DELPHININAE	*72.70*	DELPHINIDAE	*82.50*	DELPHINOIDEA	*96.90*
M-43	*L. obliquidens*	*61.80*	DELPHININAE	*72.70*	DELPHINIDAE	*82.50*	DELPHINOIDEA	*96.90*
M-45	*L. obliquidens*	*69.40*	DELPHININAE	*78.10*	DELPHINIDAE	*80.00*	DELPHINOIDEA	*97.50*
M-49	*T. truncatus*	*71.10*	DELPHININAE	*75.80*	DELPHINIDAE	*78.80*	DELPHINOIDEA	*97.50*
M-50	*G. griseus*	*61.80*	DELPHININAE	*72.70*	DELPHINIDAE	*82.50*	DELPHINOIDEA	*96.90*
M-54	*T. truncatus*	*72.30*	DELPHININAE	*76.60*	DELPHINIDAE	*78.80*	DELPHINOIDEA	*96.30*
M-58	*L. obliquidens*	*64.20*	DELPHININAE	*78.90*	DELPHINIDAE	*86.90*	DELPHINOIDEA	*96.90*
M-61	*G. griseus*	*61.80*	DELPHININAE	*72.70*	DELPHINIDAE	*82.50*	DELPHINOIDEA	*96.90*
M-87	*S. coeruleoalba*	*71.10*	DELPHININAE	*75.80*	DELPHINIDAE	*78.80*	DELPHINOIDEA	*97.50*
M-90	*S. coeruleoalba*	*71.10*	DELPHININAE	*79.70*	PHOCOENIDAE	*90.00*	DELPHINOIDEA	*98.10*
M-91	*L. borealis*	*66.50*	DELPHININAE	*78.90*	DELPHINIDAE	*81.90*	DELPHINOIDEA	*97.50*
M-106	*L. borealis*	*71.10*	DELPHININAE	*75.80*	DELPHINIDAE	*78.80*	DELPHINOIDEA	*97.50*
M-109	*P. dalli*	*64.20*	DELPHININAE	*78.90*	DELPHINIDAE	*86.90*	DELPHINOIDEA	*96.90*
M-111	*P. dalli*	*71.70*	DELPHININAE	*75.80*	PHOCOENIDAE	*90.00*	DELPHINOIDEA	*98.10*

striped dolphin (*S. coeruleoalba*); Pacific white-sided dolphin (*L. obliquidens*); common bottlenose dolphin (*T. truncatus*); Risso's dolphin (*G. griseus*); northern right whale dolphin (*L. borealis*); and Dall's porpoise (*P. dalli*).

Table 3.4 Summary results of DFA-based identification of early Jomon Mibiki zooarchaeological samples for correct classification rate, following taxonomic hierarchical classification system

SPECIMENS	Taxonomic hierarchical classification							
	SPECIES	**%CORRECT**	**SUBFAMILY**	**%CORRECT**	**FAMILY**	**%CORRECT**	**SUPERFAMILY**	**%CORRECT**
159	*L. obliquidens*	*70.50*	DELPHININAE	*78.90*	DELPHINIDAE	*89.60*	DELPHINOIDEA	*97.10*
161	*L. obliquidens*	*60.70*	DELPHININAE	*75.00*	DELPHINIDAE	*81.30*	DELPHINOIDEA	*96.90*
483	*G. griseus*	*68.20*	DELPHININAE	*78.10*	DELPHINIDAE	*86.90*	DELPHINOIDEA	*94.80*
494	*G. griseus*	*68.20*	DELPHININAE	*75.00*	DELPHINIDAE	*81.30*	DELPHINOIDEA	*96.90*
495	*S. coeruleoalba*	*52.00*	DELPHININAE	*73.40*	DELPHINIDAE	*81.90*	DELPHINOIDEA	*95.60*
748	*P. dalli*	*64.20*	DELPHININAE	*78.90*	PHOCOENIDAE	*86.90*	DELPHINOIDEA	*96.90*
749	*P. dalli*	*64.20*	DELPHININAE	*78.90*	DELPHINIDAE	*86.90*	DELPHINOIDEA	*96.90*

Pacific white-sided dolphin (*L. obliquidens*); Risso's dolphin (*G. griseus*); striped dolphin (*S. coeruleoalba*); and Dall's porpoise (*P. dalli*).

Table 3.5 Summary results of DFA-based identification of Okhotsk Kafukai-1 zooarchaeological samples for correct classification rate, following taxonomic hierarchical classification system

SPECIMENS	Taxonomic hierarchical classification							
	SPECIES	**%CORRECT**	**SUBFAMILY**	**%CORRECT**	**FAMILY**	**%CORRECT**	**SUPERFAMILY**	**%CORRECT**
RKA18142	*L. obliquidens*	*70.50*	DELPHININAE	*78.90*	DELPHINIDAE	*89.60*	DELPHINOIDEA	*97.10*
RKA2047	*G. macrorhynchus*	*59.90*	GLOBICEPHALINAE	*74.20*	DELPHINIDAE	*81.90*	DELPHINOIDEA	*96.90*
RKA2804	*P. crassidens*	*56.90*	GLOBICEPHALINAE	*71.70*	DELPHINIDAE	*76.90*	DELPHINOIDEA	*96.90*
RKA3690	*P. phocoena*	*71.10*	PHOCOENOIDINAE	*75.80*	PHOCOENIDAE	*78.80*	DELPHINOIDEA	*97.50*
RKA3982	*G. macrorhynchus*	*68.80*	GLOBICEPHALINAE	*80.50*	DELPHINIDAE	*89.40*	DELPHINOIDEA	*98.10*
RKA5918	*L. obliquidens*	*67.60*	DELPHININAE	*78.90*	PHOCOENIDAE	*87.50*	DELPHINOIDEA	*97.50*
RKA15283	*P. phocoena*	*69.40*	DELPHININAE	*78.10*	PHOCOENIDAE	*80.00*	DELPHINOIDEA	*96.90*
RKA15547	*D. delphis*	*65.90*	DELPHININAE	*76.60*	DELPHINIDAE	*81.90*	DELPHINOIDEA	*96.30*
RKA17138	*L. obliquidens*	*71.10*	DELPHININAE	*75.80*	DELPHINIDAE	*78.80*	DELPHINOIDEA	*97.50*

Pacific white-sided dolphin (*L. obliquidens*); short-finned pilot whale (*G. macrorhynchus*); false killer whale (*P. crassidens*); harbor porpoise (*P. phocoena*); and short-beaked common dolphin (*D. delphis*)

Table 3.6 Summary of DFA-based identification (this study) results in comparison with previous morphological comparative analysis (Red color denoted result that were in accordance).

Site	Specimens	Morphological ID	DFA-based ID
Mawaki	**M-1**	short-beaked common dolphin	striped dolphin
Mawaki	**M-2**	short-beaked common dolphin	Pacific white-sided dolphin
Mawaki	**M-3**	short-beaked common dolphin	short-beaked common dolphin
Mawaki	**M-5**	*Dolphin*	nothern right whale dolphin
Mawaki	**M-8**	short-beaked common dolphin	striped dolphin
Mawaki	**M-12**	short-beaked common dolphin	striped dolphin
Mawaki	**M-20**	short-beaked common dolphin	DELPHININAE
Mawaki	**M-21**	short-beaked common dolphin	DELPHININAE
Mawaki	**M-23**	short-beaked common dolphin	Pacific white-sided dolphin
Mawaki	**M-28**	Pacific white-sided dolphin	nothern right whale dolphin
Mawaki	**M-29**	Pacific white-sided dolphin	Pacific white-sided dolphin
Mawaki	**M-36**	short-beaked common dolphin?	short-beaked common dolphin
Mawaki	**M-39**	Pacific white-sided dolphin	Pacific white-sided dolphin
Mawaki	**M-40**	*Dolphin*	striped dolphin
Mawaki	**M-43**	*Dolphin*	Pacific white-sided dolphin
Mawaki	**M-45**	Pacific white-sided dolphin	Pacific white-sided dolphin
Mawaki	**M-49**	common bottlenose dolphin?	common bottlenose dolphin
Mawaki	**M-50**	common bottlenose dolphin	Risso's dolphin
Mawaki	**M-54**	*Dolphin*	common bottlenose dolphin
Mawaki	**M-58**	short-beaked common dolphin	Pacific white-sided dolphin
Mawaki	**M-61**	*Dolphin*	Risso's dolphin
Mawaki	**M-69**	*Dolphin*	Risso's dolphin
Mawaki	**M-87**	Pacific white-sided dolphin?	striped dolphin
Mawaki	**M-90**	short-beaked common dolphin	striped dolphin

Table 3.6 (*continued*)

Site	Specimens	Morphological ID	DFA-based ID
Mawaki	**M-91**	Pacific white-sided dolphin?	northern right whale dolphin
Mawaki	**M-106**	common bottlenose dolphin or Pacific white-sided dolphin?	northern right whale dolphin
Mawaki	**M-109**	*Dolphin*	DELPHININAE
Mawaki	**M-111**	*Dolphin*	Dall's porpoise
Mibiki	**159**	short-beaked common dolphin	Pacific white-sided dolphin
Mibiki	**161**	Pacific white-sided dolphin	Pacific white-sided dolphin
Mibiki	**483**	Pacific white-sided dolphin	Risso's dolphin
Mibiki	**494**	*Dolphin*	Risso's dolphin
Mibiki	**495**	*Dolphin*	DELPHININAE
Mibiki	**748**	Pacific white-sided dolphin	PHOCOENIDAE
Mibiki	**749**	*Dolphin*	DELPHININAE
Kafukai-1	**RKA2047**	*Dolphin*	GLOBICEPHALINAE
Kafukai-1	**RKA2804**	*Dolphin*	GLOBICEPHALINAE
Kafukai-1	**RKA3690**	*Dolphin*	PHOCOENIDAE
Kafukai-1	**RKA3982**	*Dolphin*	GLOBICEPHALINAE
Kafukai-1	**RKA5918**	*Dolphin*	Pacific white-sided dolphin
Kafukai-1	**RKA15283**	*Dolphin*	Harbor porpoise
Kafukai-1	**RKA15547**	*Dolphin*	short-beaked common dolphin
Kafukai-1	**RKA17138**	*Dolphin*	Pacific white-sided dolphin
Kafukai-1	**RKA18142**	*Dolphin*	Pacific white-sided dolphin

Figure 2.1 Representative atlas and axis vertebrae specimens of 18 toothed whale species from the National Museum of Nature and Science, Tsukuba, Ibaraki, Japan used in this study.

Figure 2.2 Thirteen linear measurements used in this study. The details are described in Table 2.2

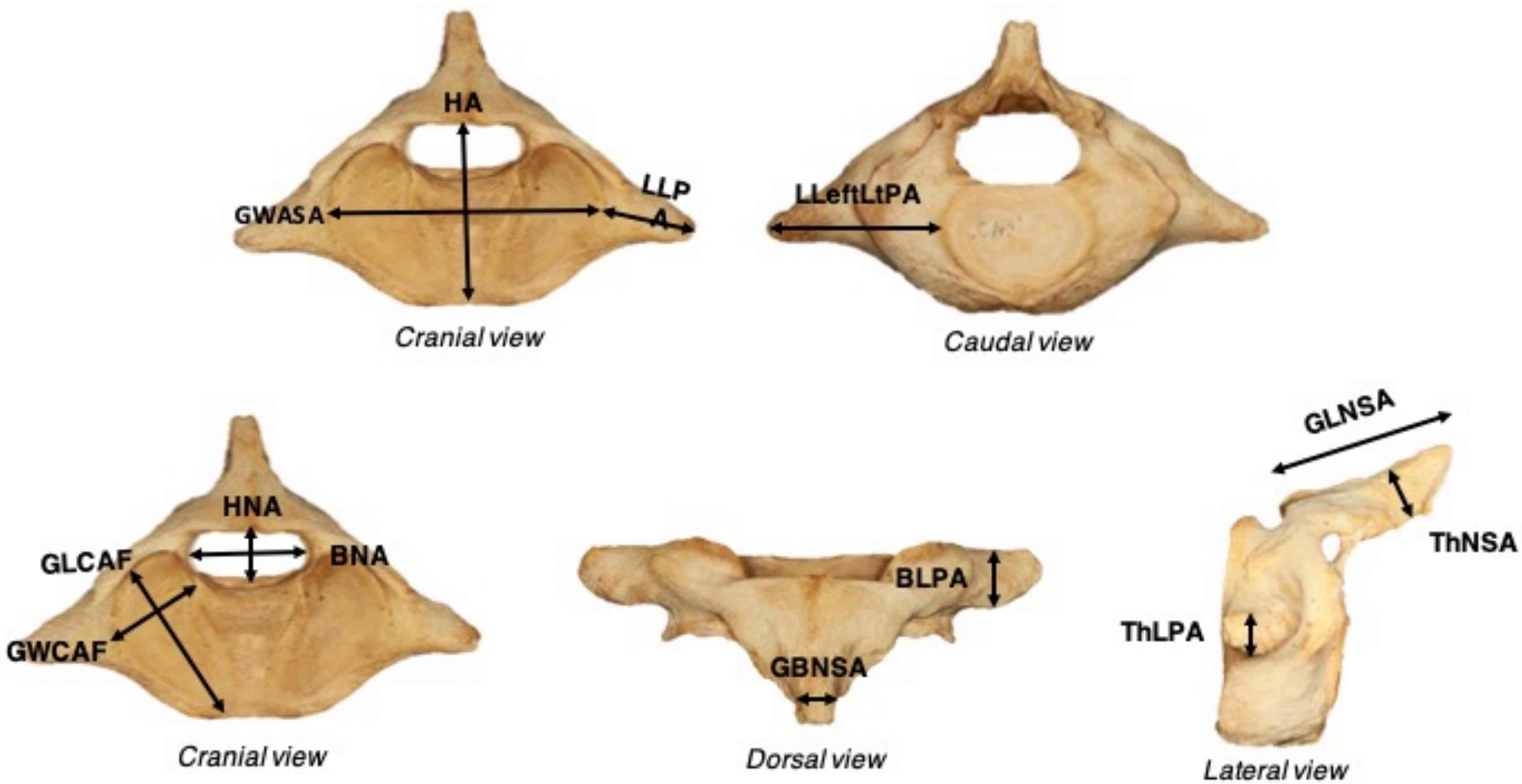


Figure 2.3 Classification scheme used in this study following Perrin (1989).

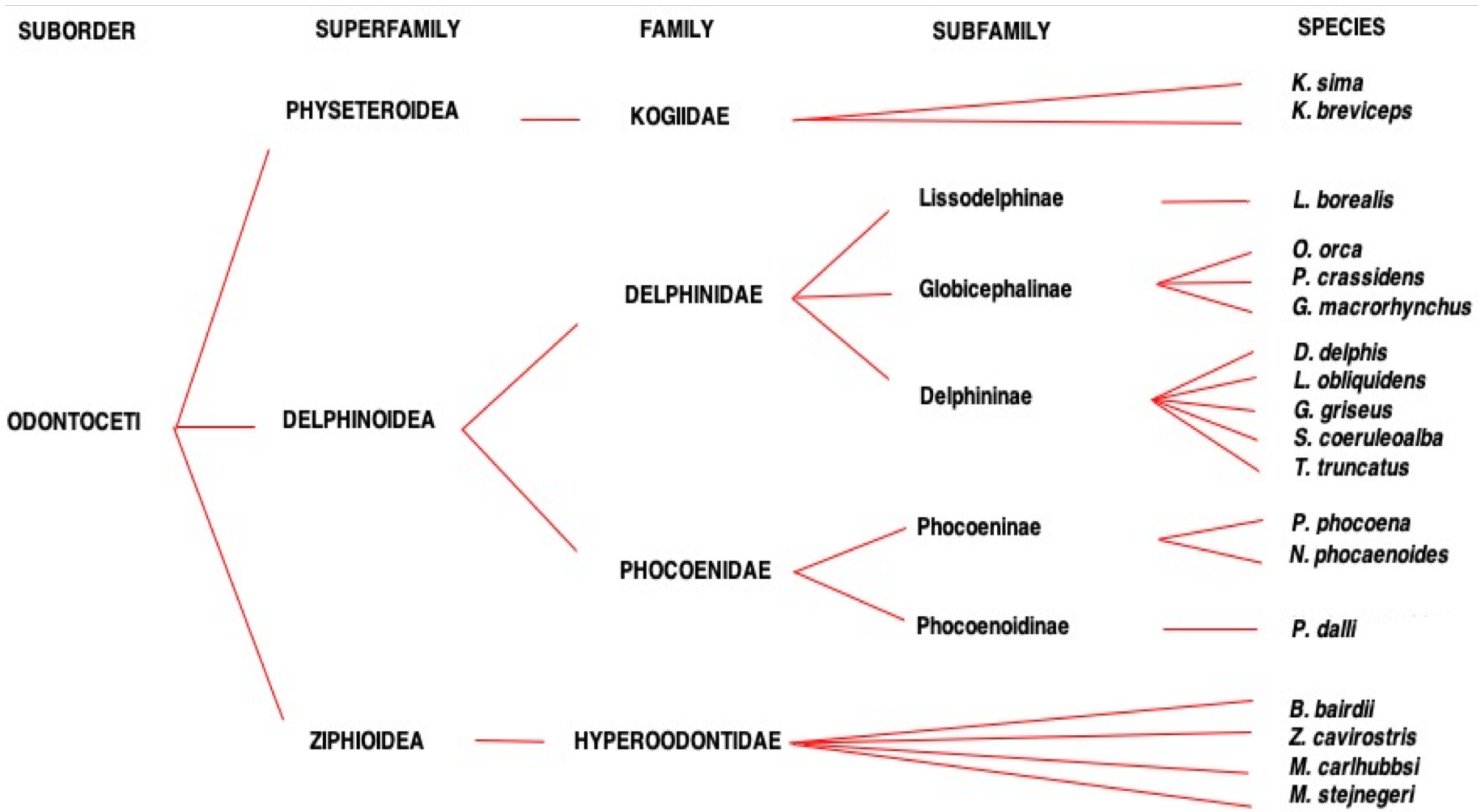


Figure 2.4 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily level classification of 18 toothed whale species.

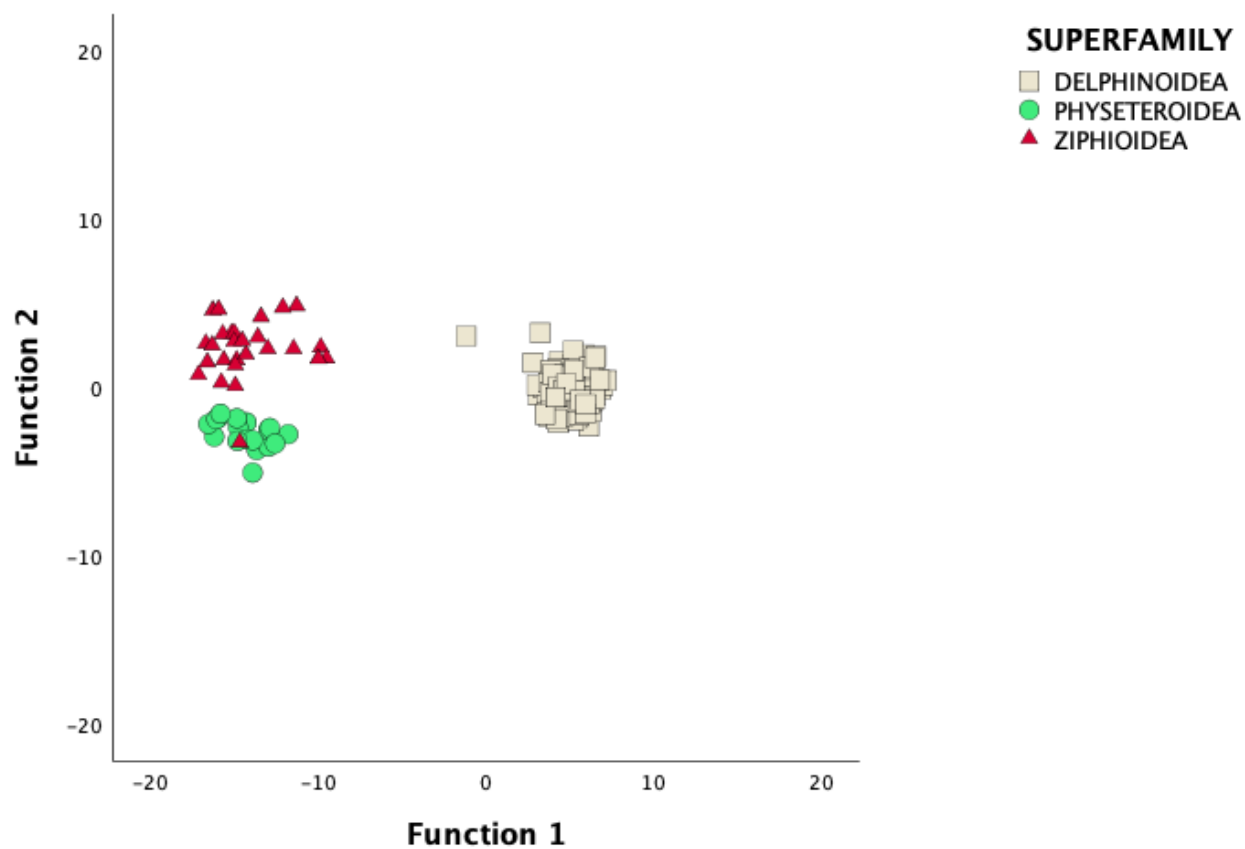


Figure 2.5 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the family level classification of 18 toothed whale species.

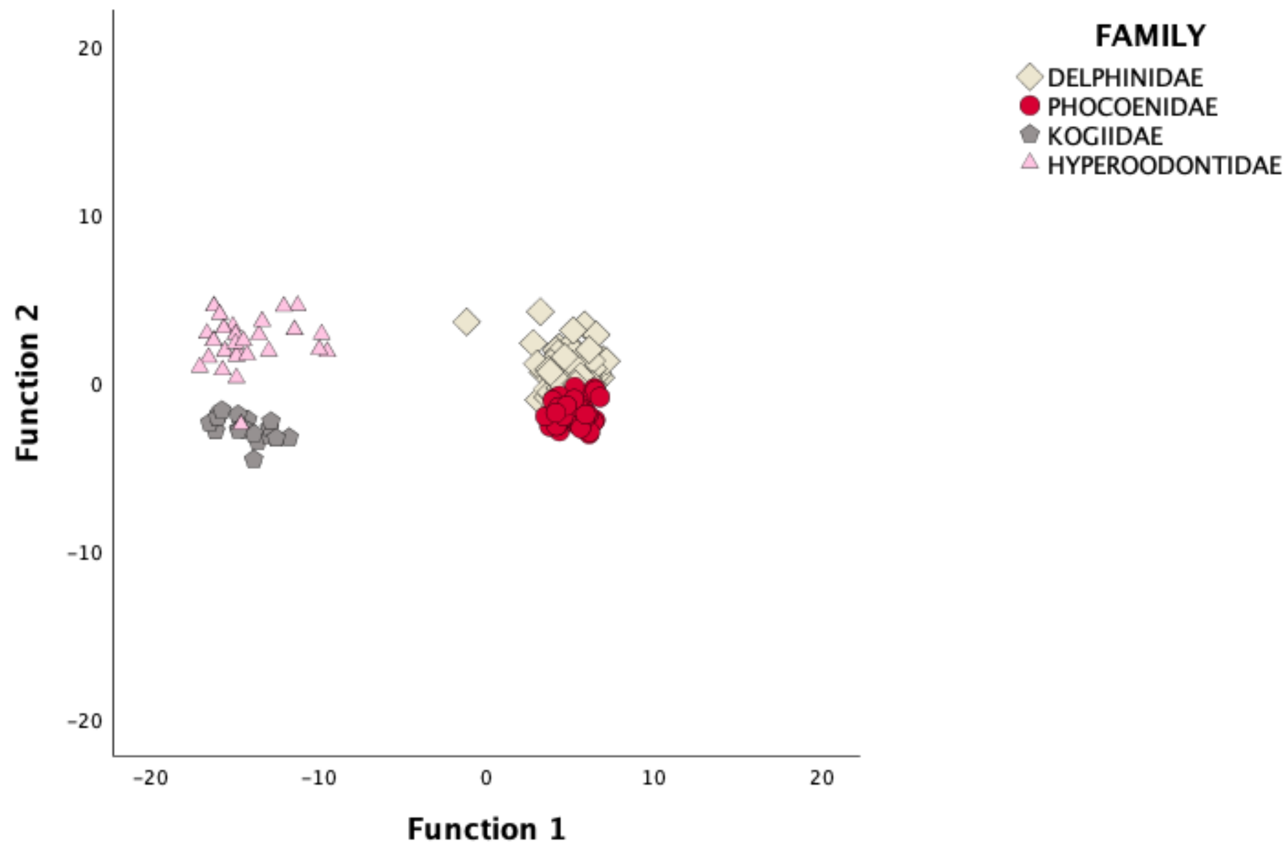


Figure 2.6 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the subfamily level classification of 12 toothed whale species.

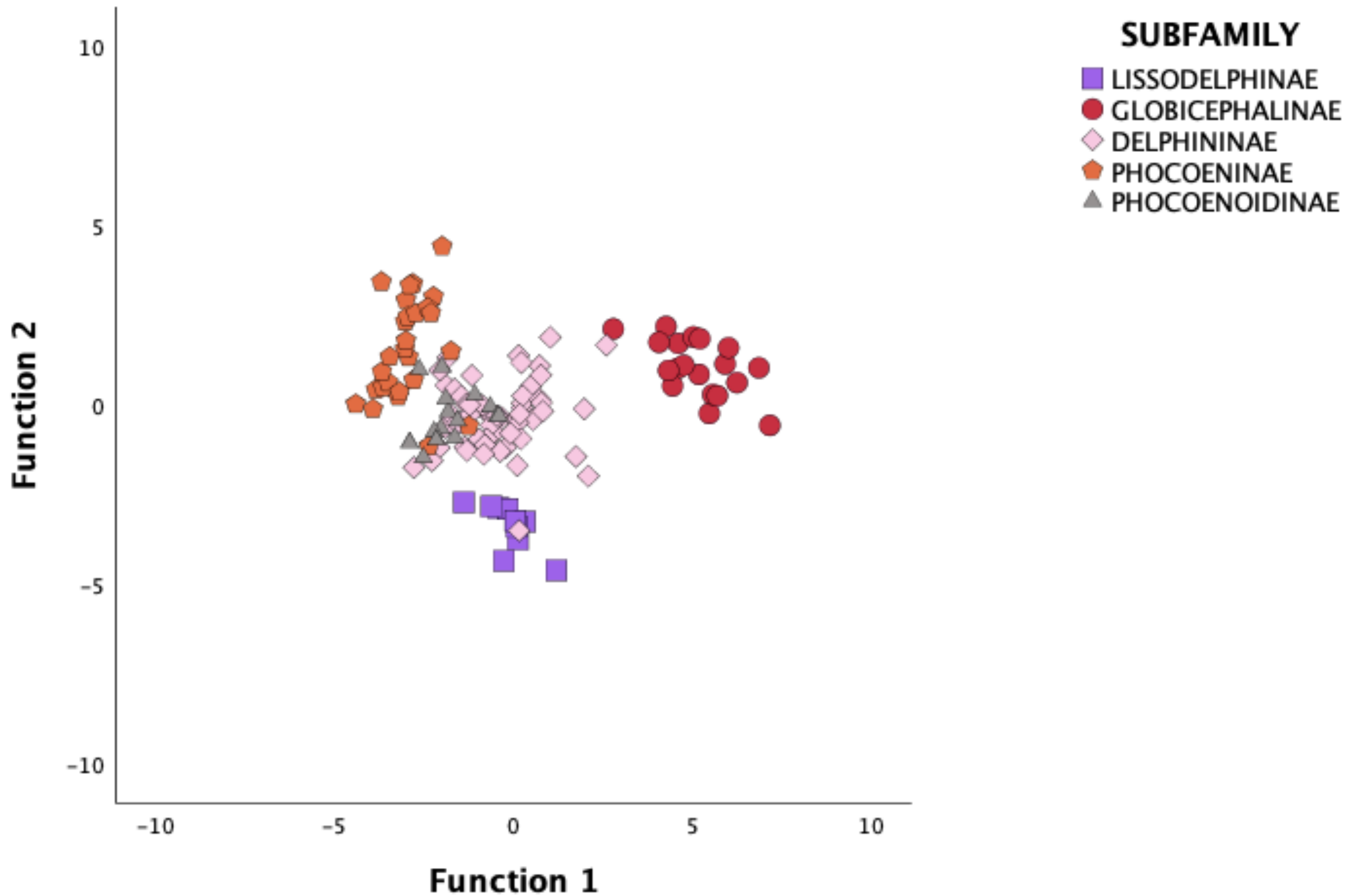


Figure 2.7 Combined-groups plot of canonical discriminant functions of the atlas and axis vertebrae for subfamily level classification within the family Delphinidae of nine toothed whale species (Lissodelphinae, Delphininae, and Globicephalinae).

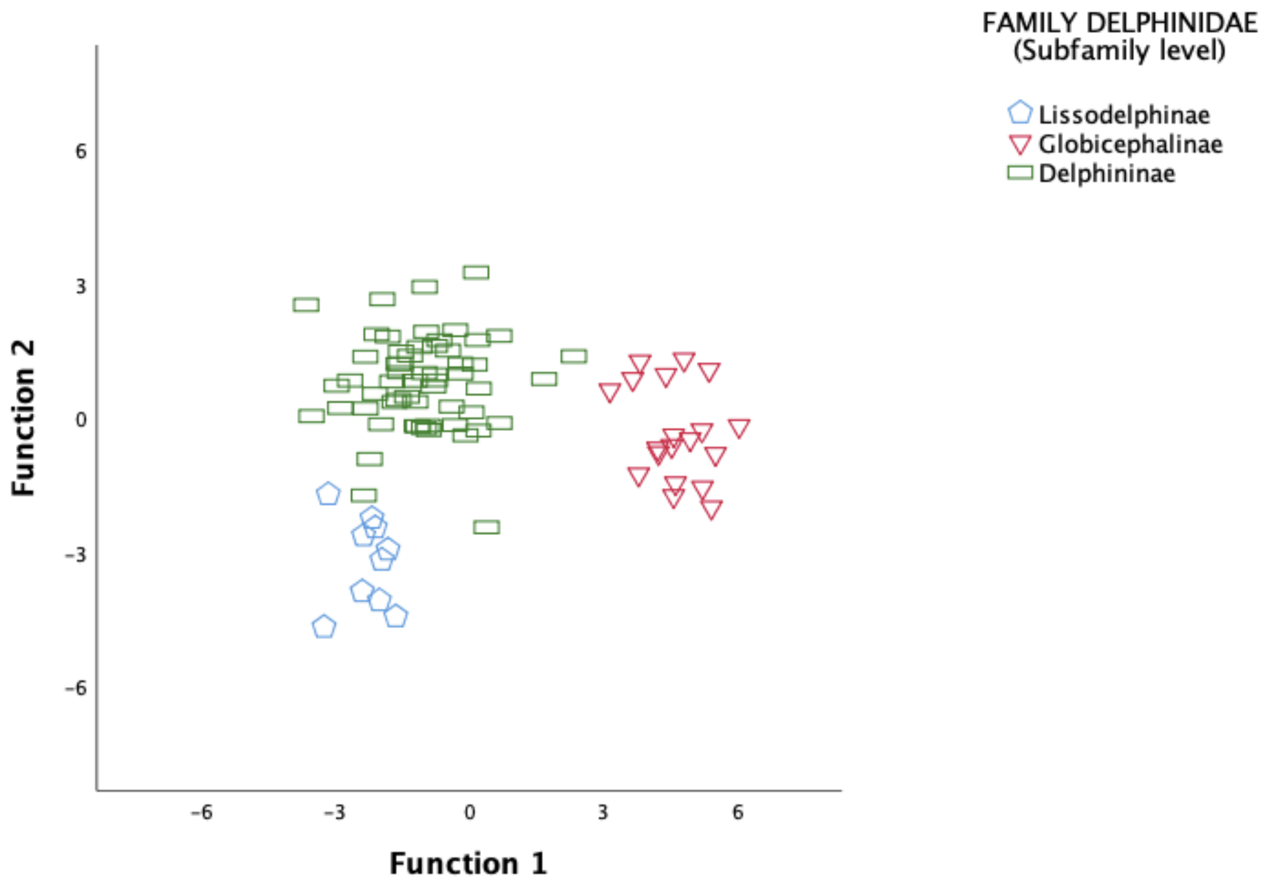


Figure 2.8 Histogram of the canonical discriminant functions of the atlas and axis vertebrae for subfamily level classification within the Family Phocoenidae of three toothed whale species (Phocoeninae and Phocoenoidinae).

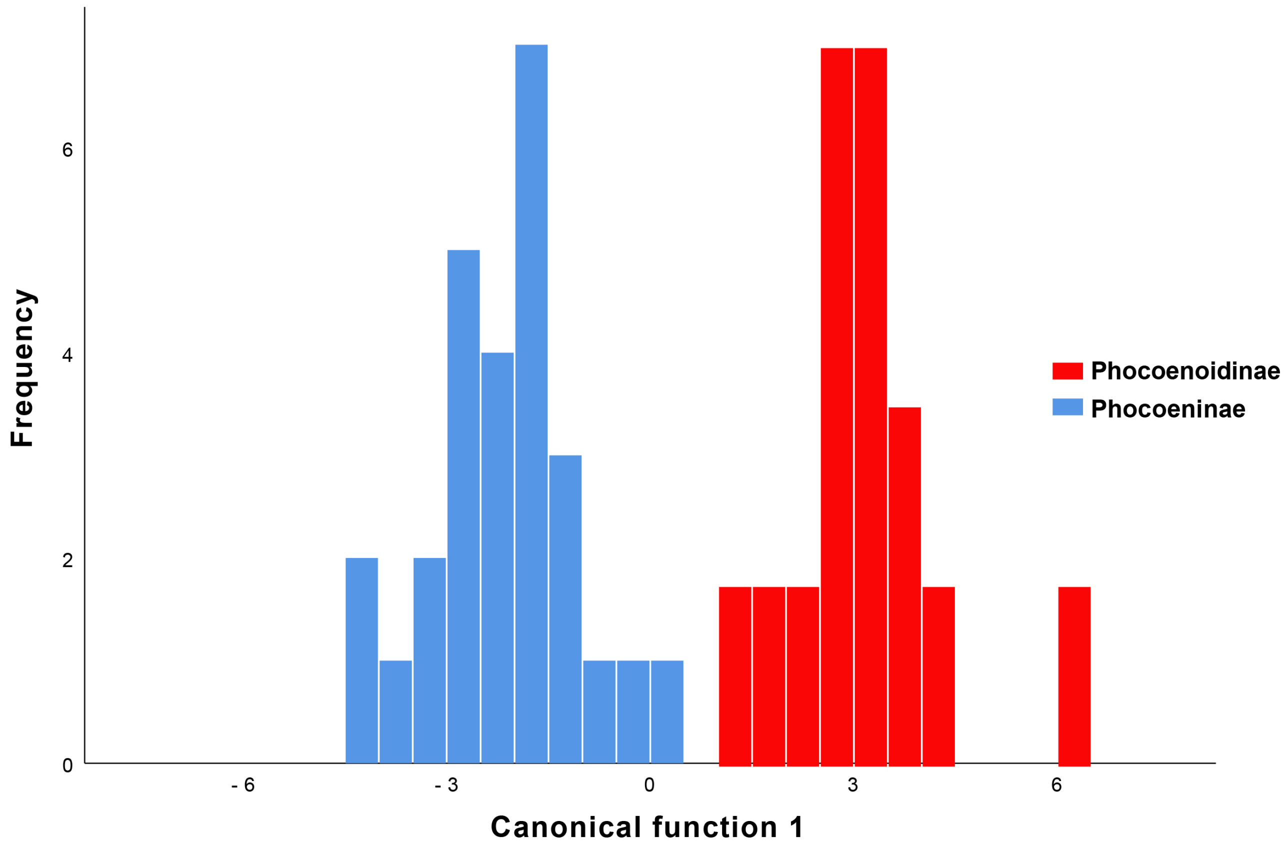


Figure 2.9 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for species-level classification within the subfamily Delphininae with 5 toothed whale (Risso's dolphin, common bottlenose dolphin, Pacific white-sided dolphin, striped dolphin, and short-beaked common dolphin).

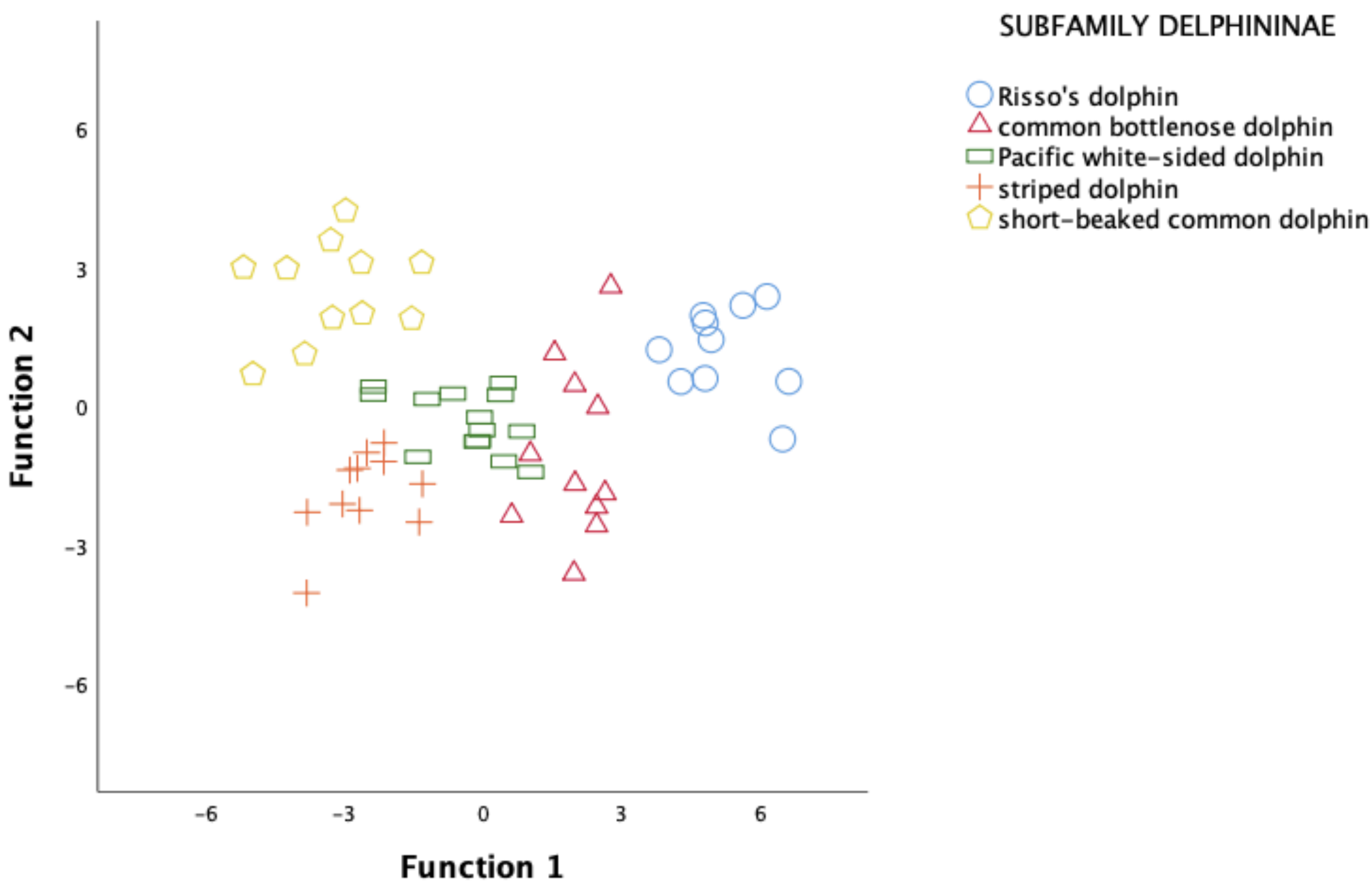


Figure 2.10 Combined-groups plot of canonical discriminant functions of the atlas and axis vertebrae for species-level classification within the subfamily Globicephalinae of three toothed whale species (false killer whale, killer whale, and short-finned pilot whale).

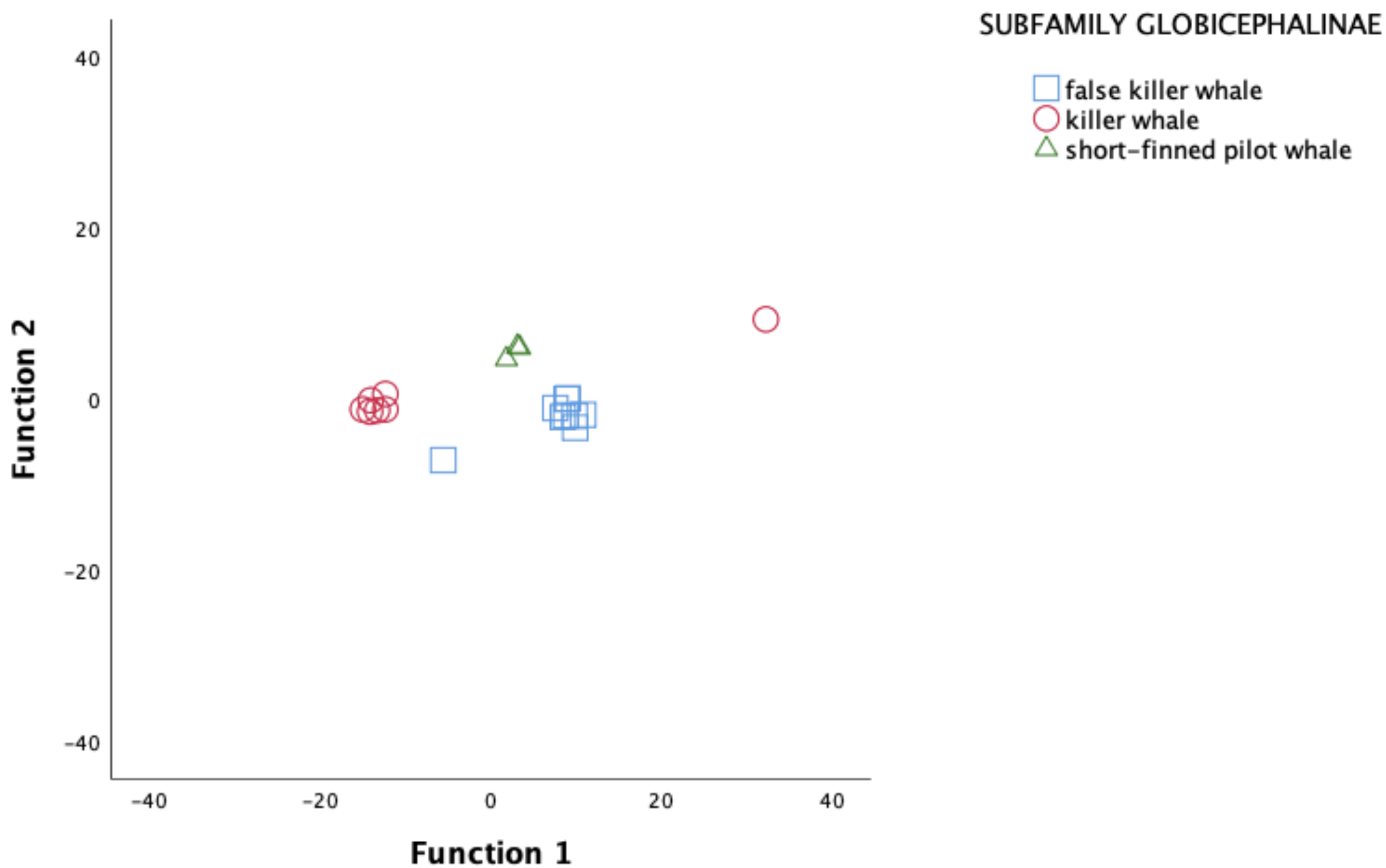


Figure 2.11 Histogram of canonical discriminant functions of the atlas and axis vertebrae for species-level classification within the subfamily Phocoeninae of two toothed whale species (harbor porpoise and finless porpoise).

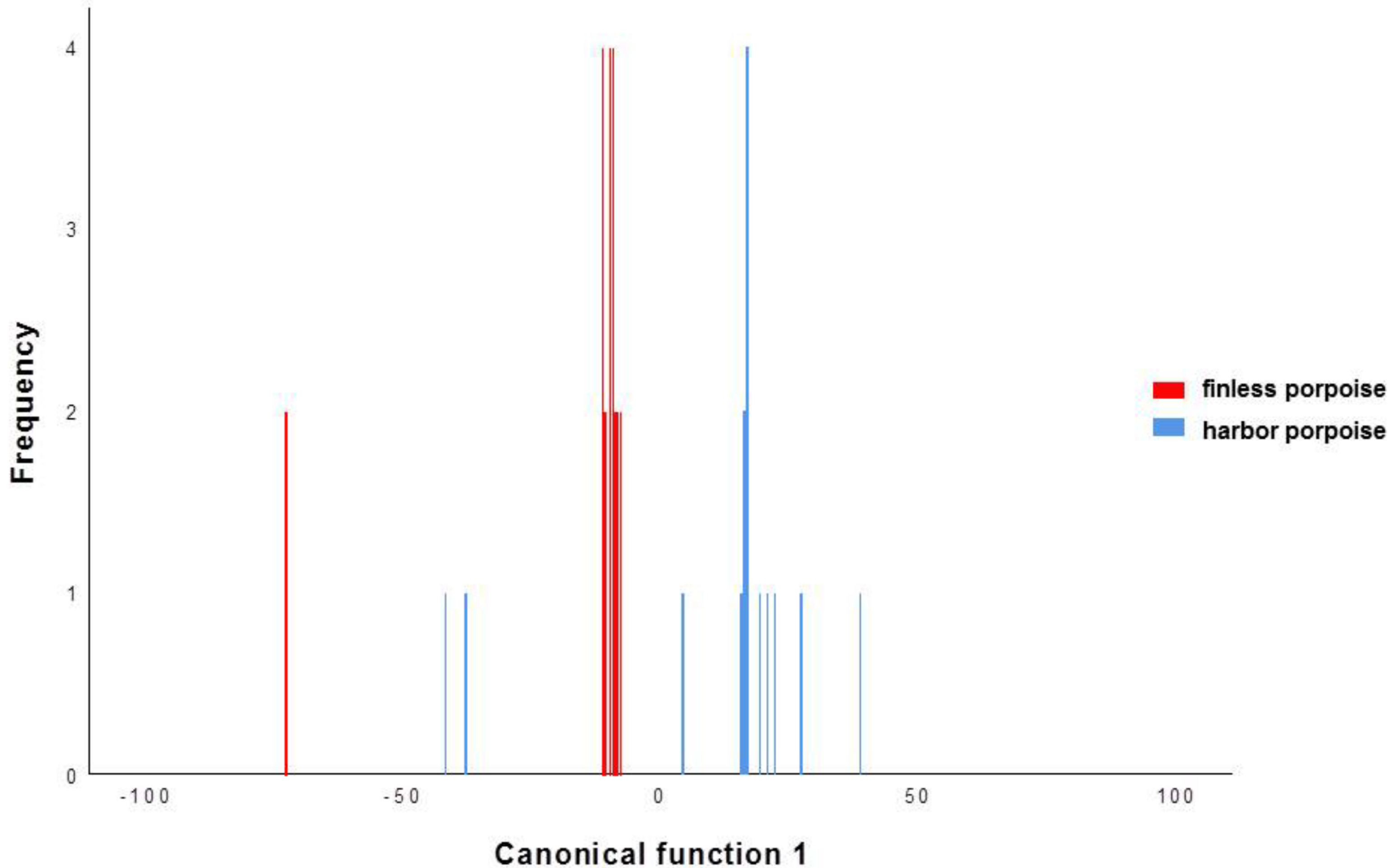


Figure 2.12 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebrae for species-level classification within the Family Phocoenidae with three toothed whale species (Dall's porpoise, harbor porpoise, and finless porpoise).

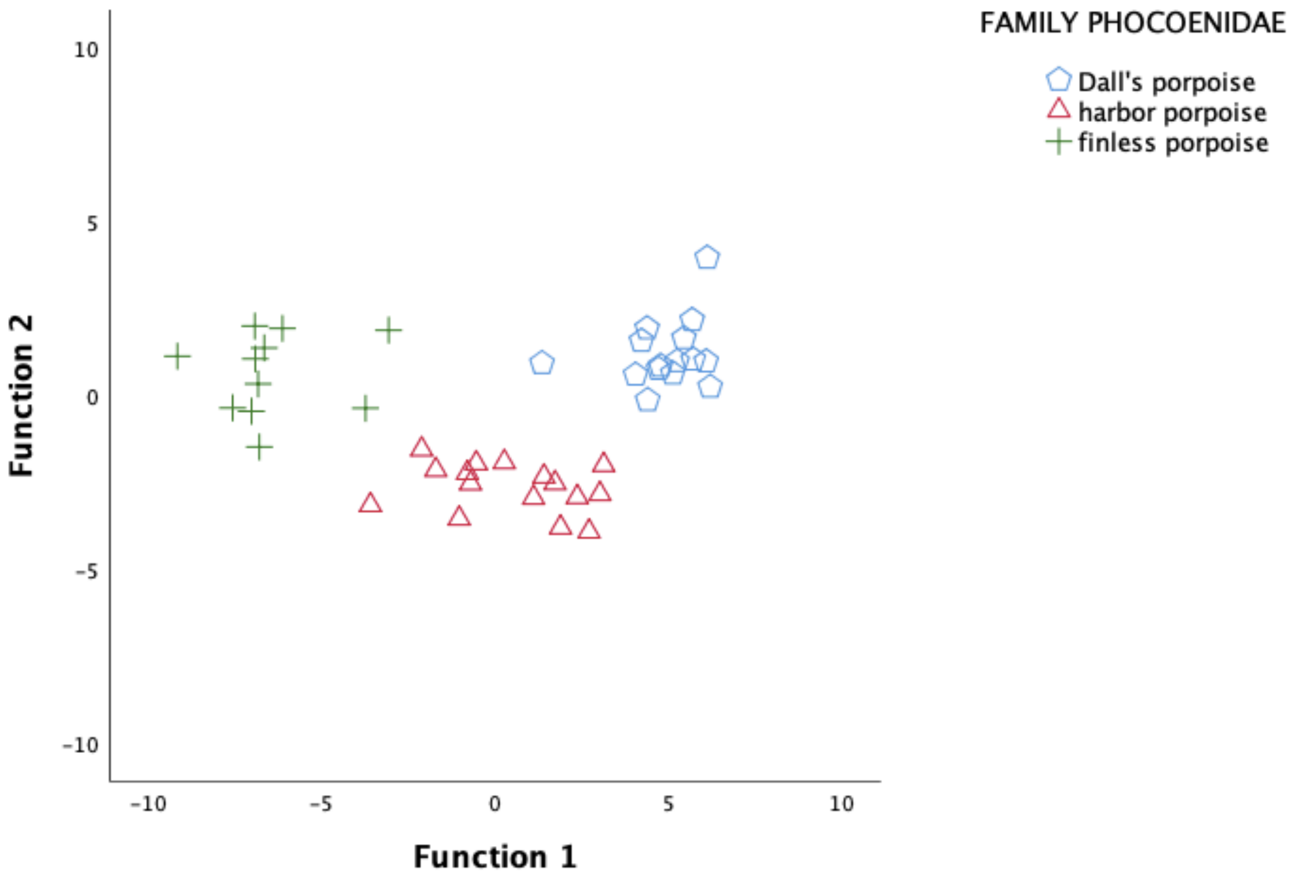


Figure 2.13 Combined-groups plot of canonical discriminant functions of the atlas and axis vertebrae for species-level classification within the family Hyperoodontidae (Baird's beaked whale, Cuvier's beaked whale, Hubbs' beaked whale, and Stejneger's beaked whale).

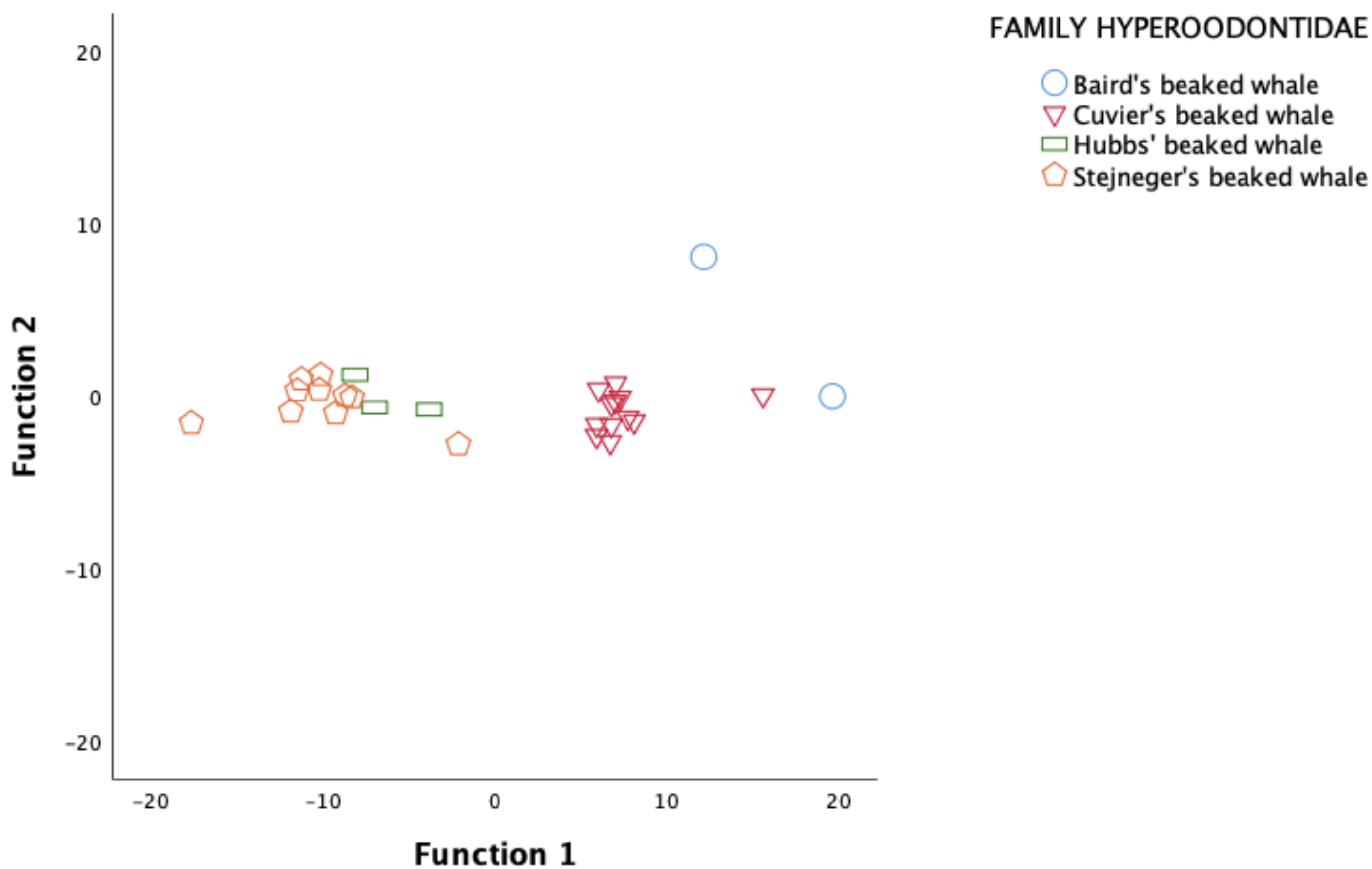


Figure 2.14 Separate-group plot showed no overlap and clearly discriminated the atlas and axis vertebra for species level classification in the Family Kogiidae of two toothed whale species (pygmy sperm whale and dwarf sperm whale).

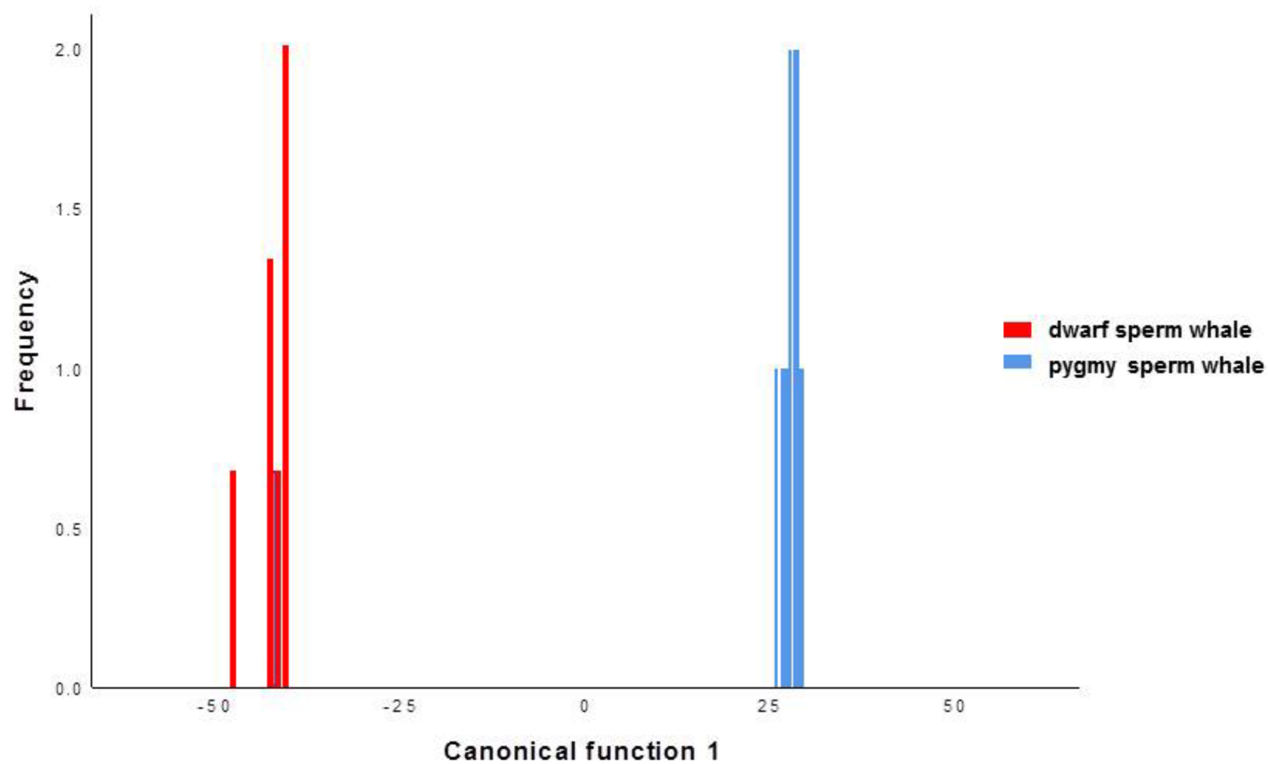


Figure 3.1 Map showing location of early Jomon Mawaki site of Noto Peninsula, central Japan (Source: Nakamura & Takada, 2016)

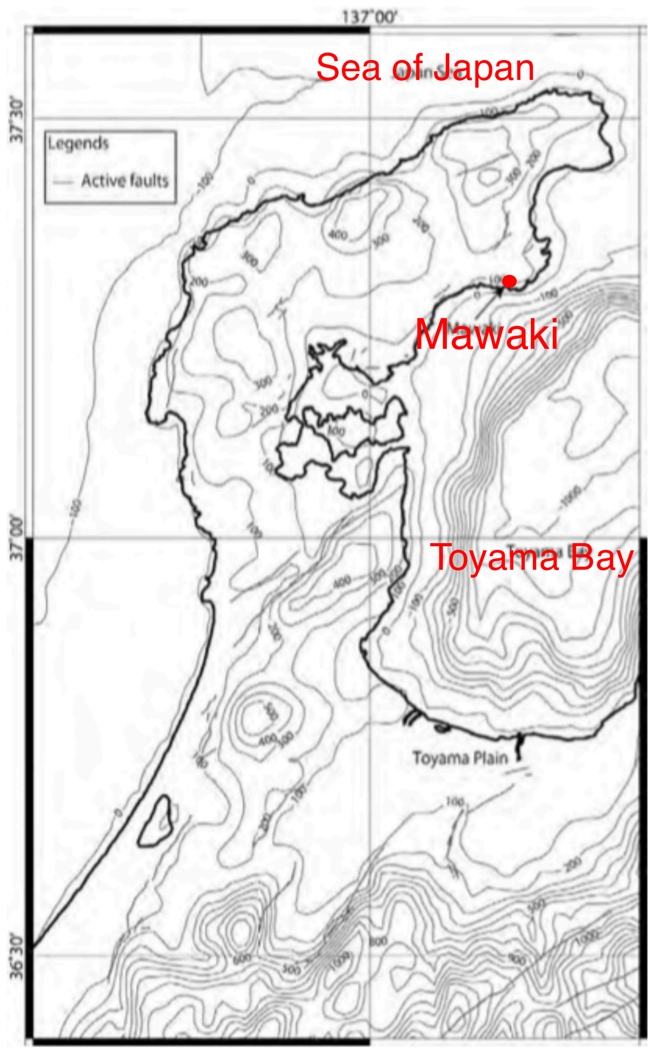


Figure 3.2 Map showing location of early Jomon Mibiki site of Noto Peninsula, central Japan

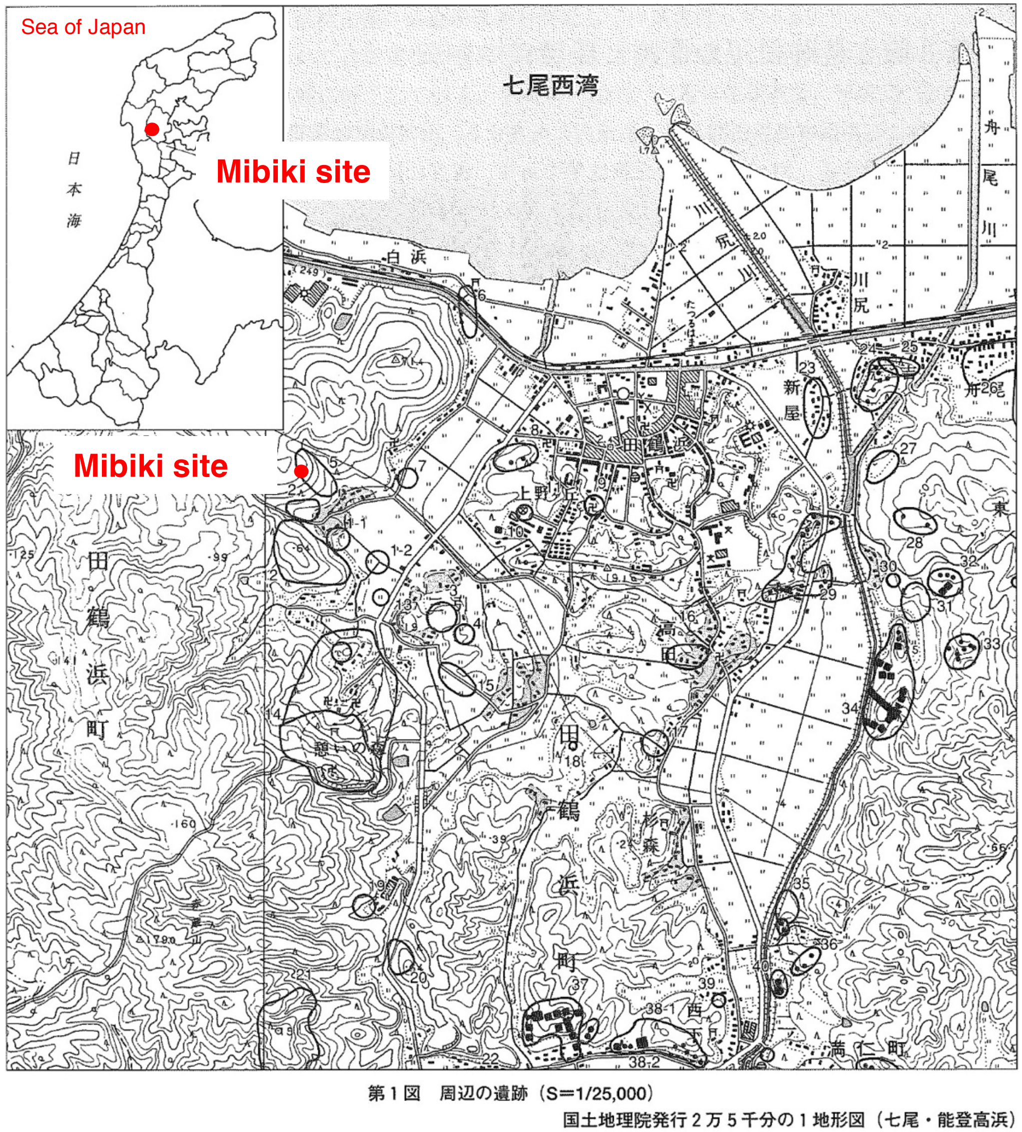


Figure 3.3 Map showing location of Okhotsk Kafukai-1site on Rebun Island, Hokkiado, northern Japan (Source: Ohba & Ohyi, 1976)

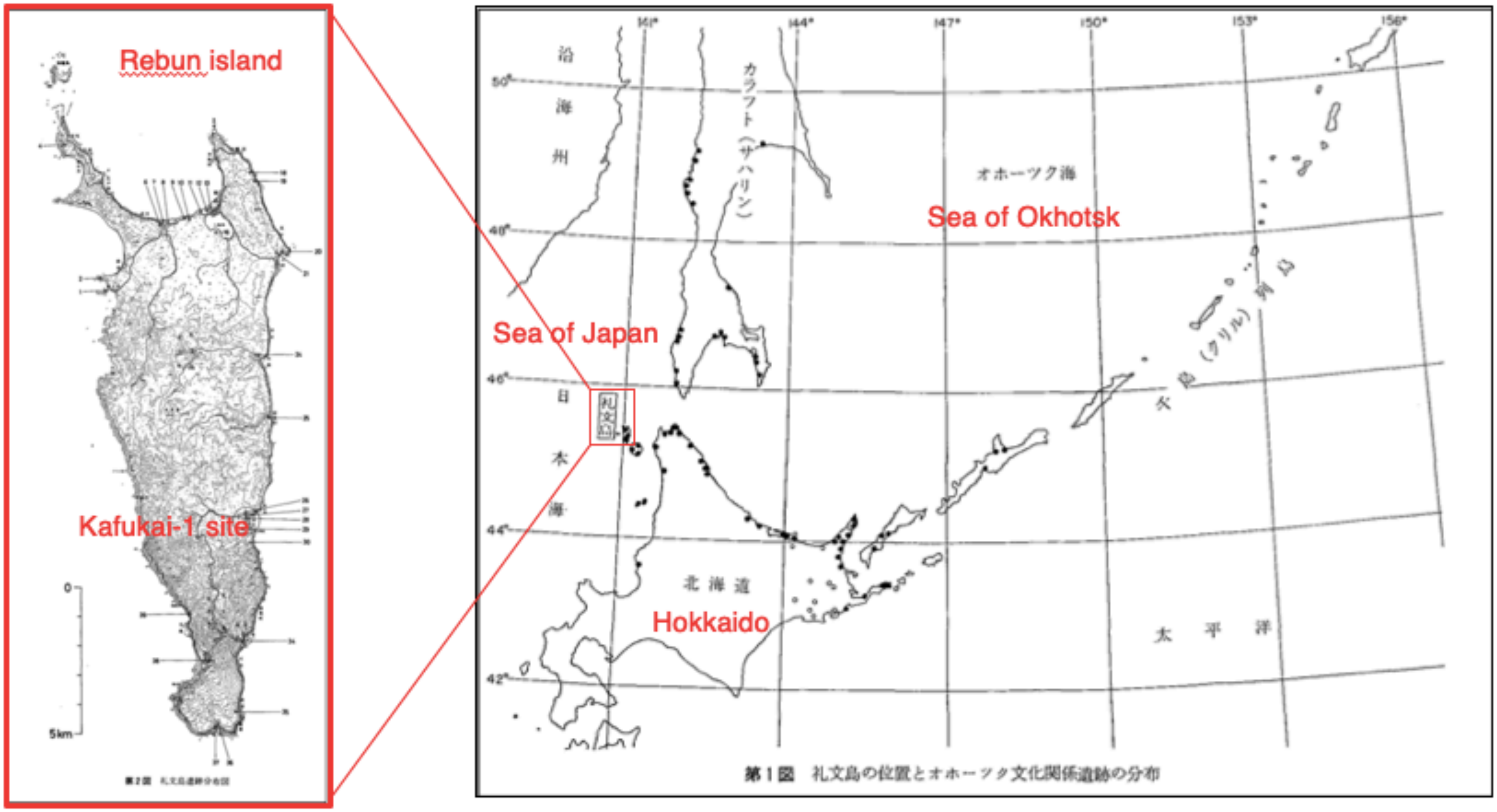


Figure 3.4 Representatives early Jomon Mawaki zooarchaeological samples examined in this study (4/28 samples)

Figure 3.5 early Jomon Mibiki zooarchaeological samples examined in this study (n=7)

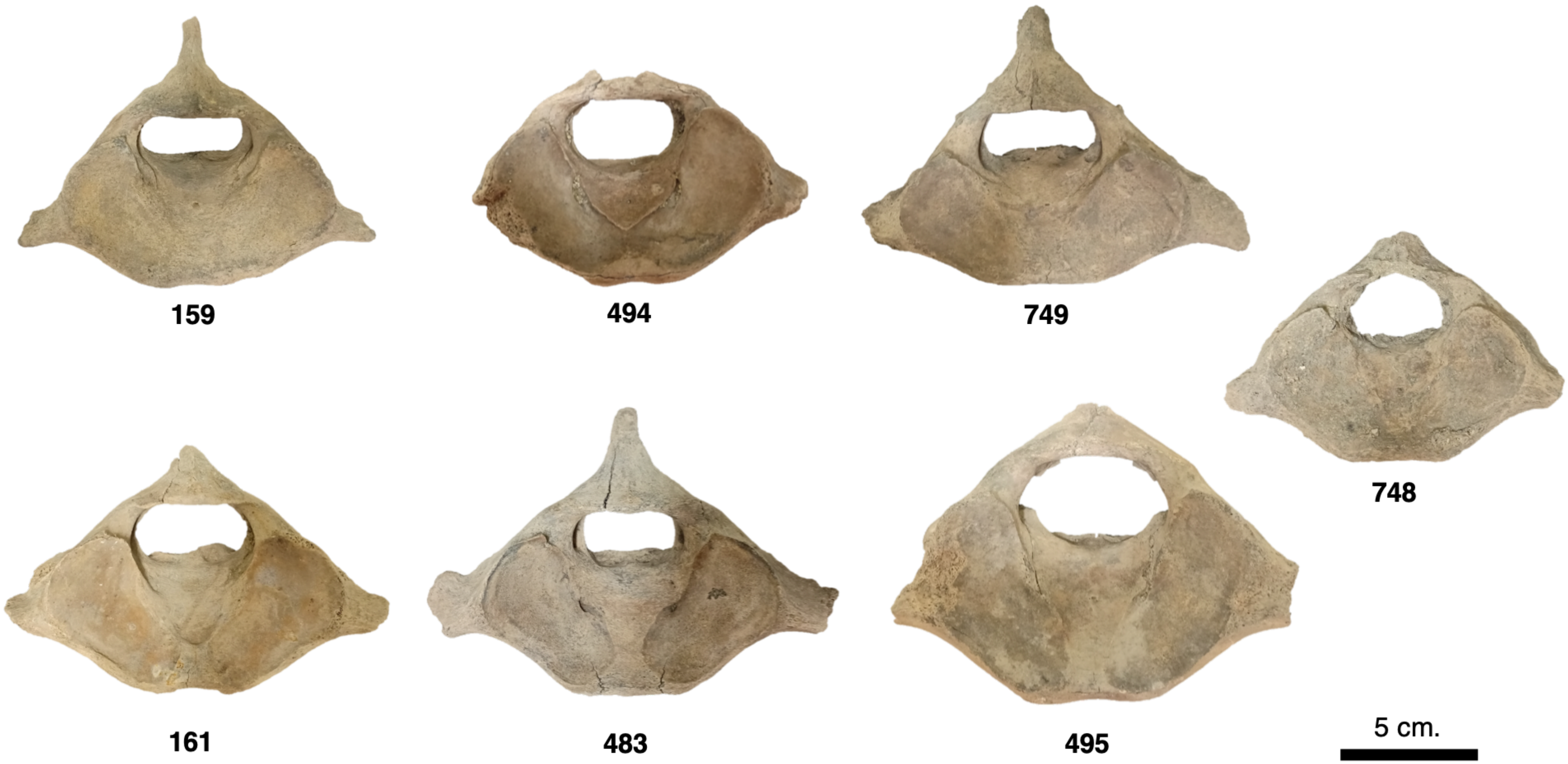


Figure 3.6 Okhotsk Kafukai-1zooarchaeological samples examined in this study (n=9). Greyscale denoted samples (n=8) that were excluded from this analysis due to their physical maturity and state of preservation.

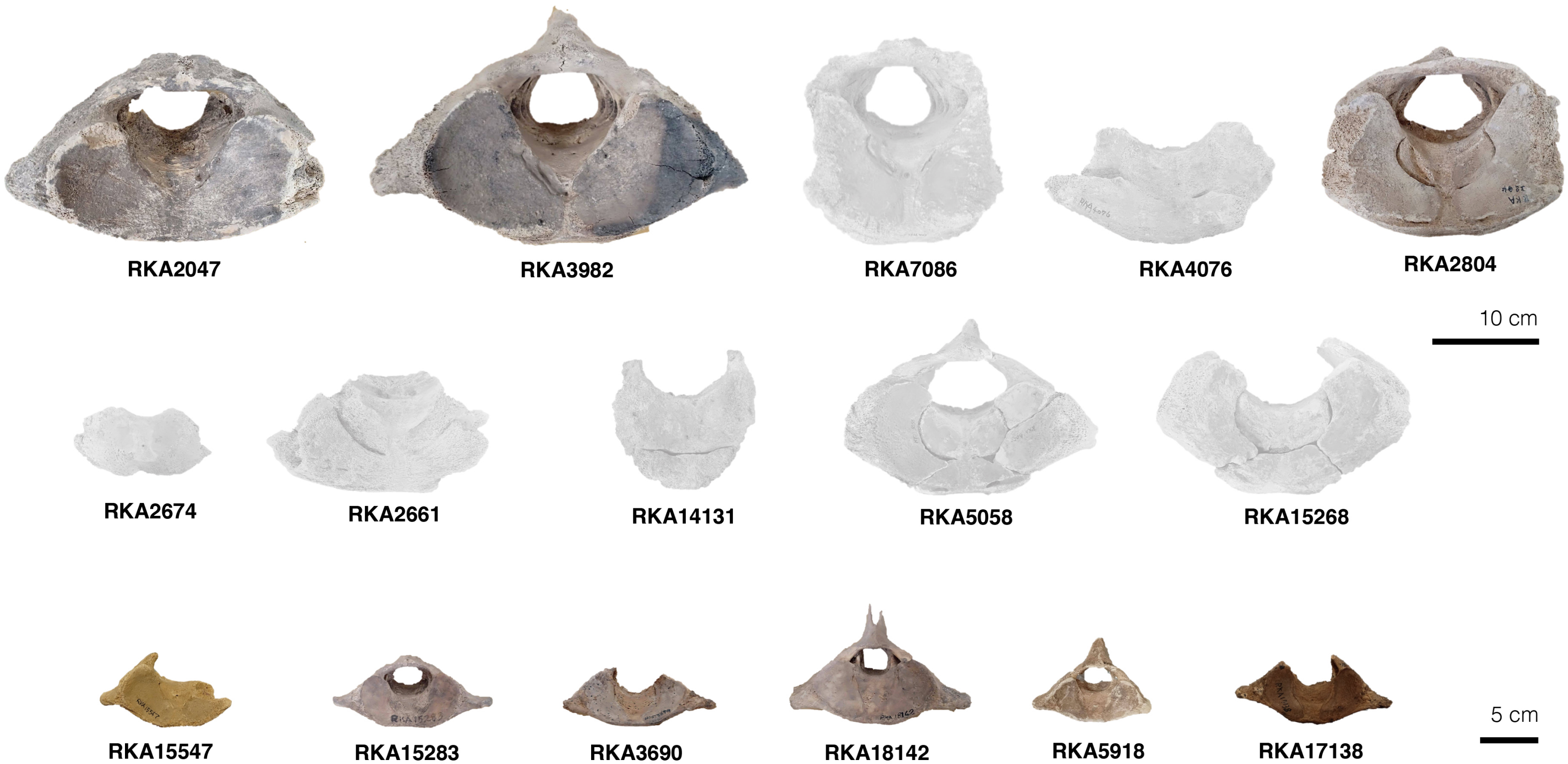


Figure 3.4 Combined-groups plot of the first two canonical DFA for prediction of group membership of M-20 at species-level classification. Note that the sample (M-20) was assigned to Dall's porpoise (*P. dalli*).

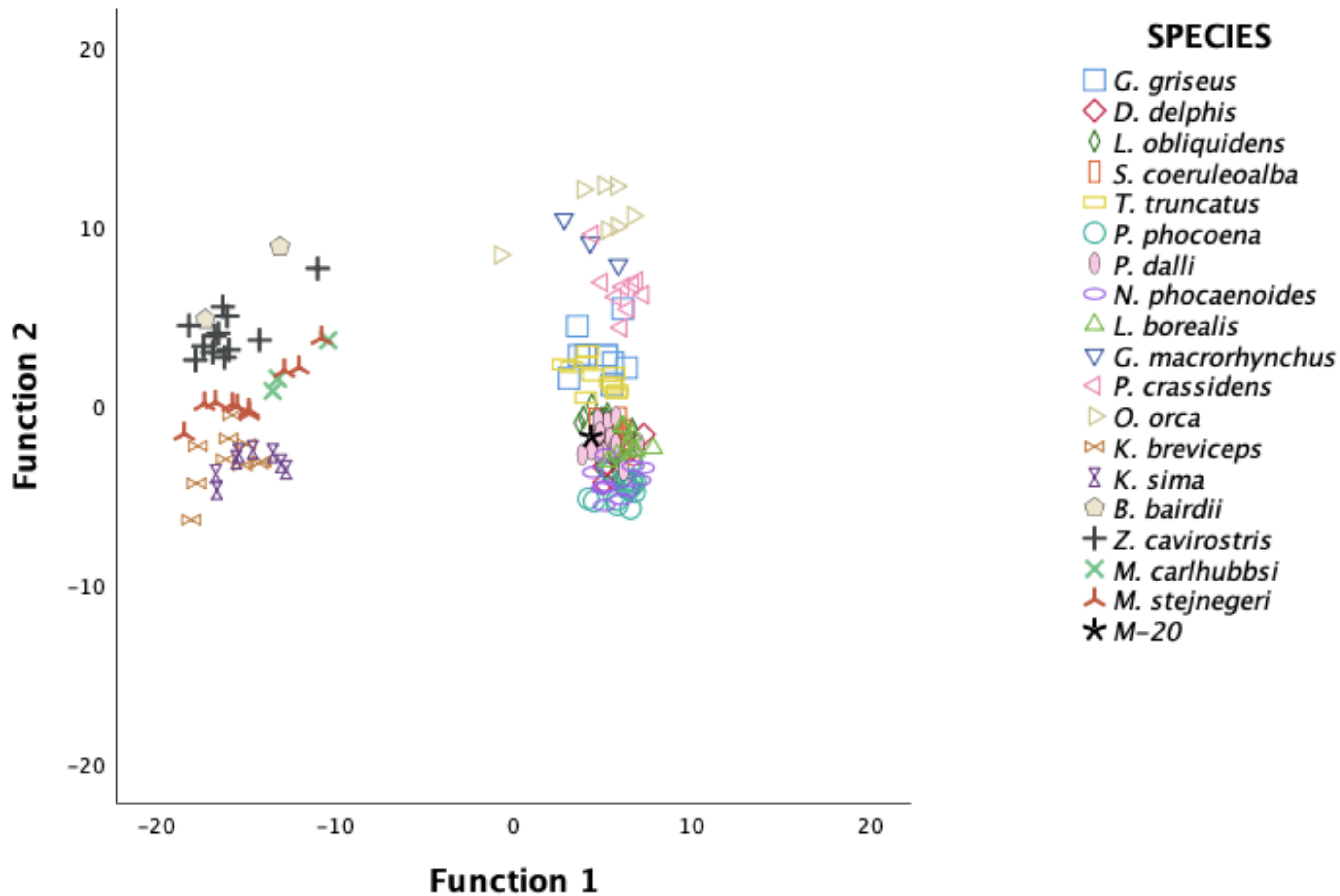


Figure 3.5 Combined-groups plot of the first two canonical DFA for prediction of group membership of M-109 at species-level classification. Note that the sample (M-109) was assigned to Dall's porpoise (*P. dalli*).

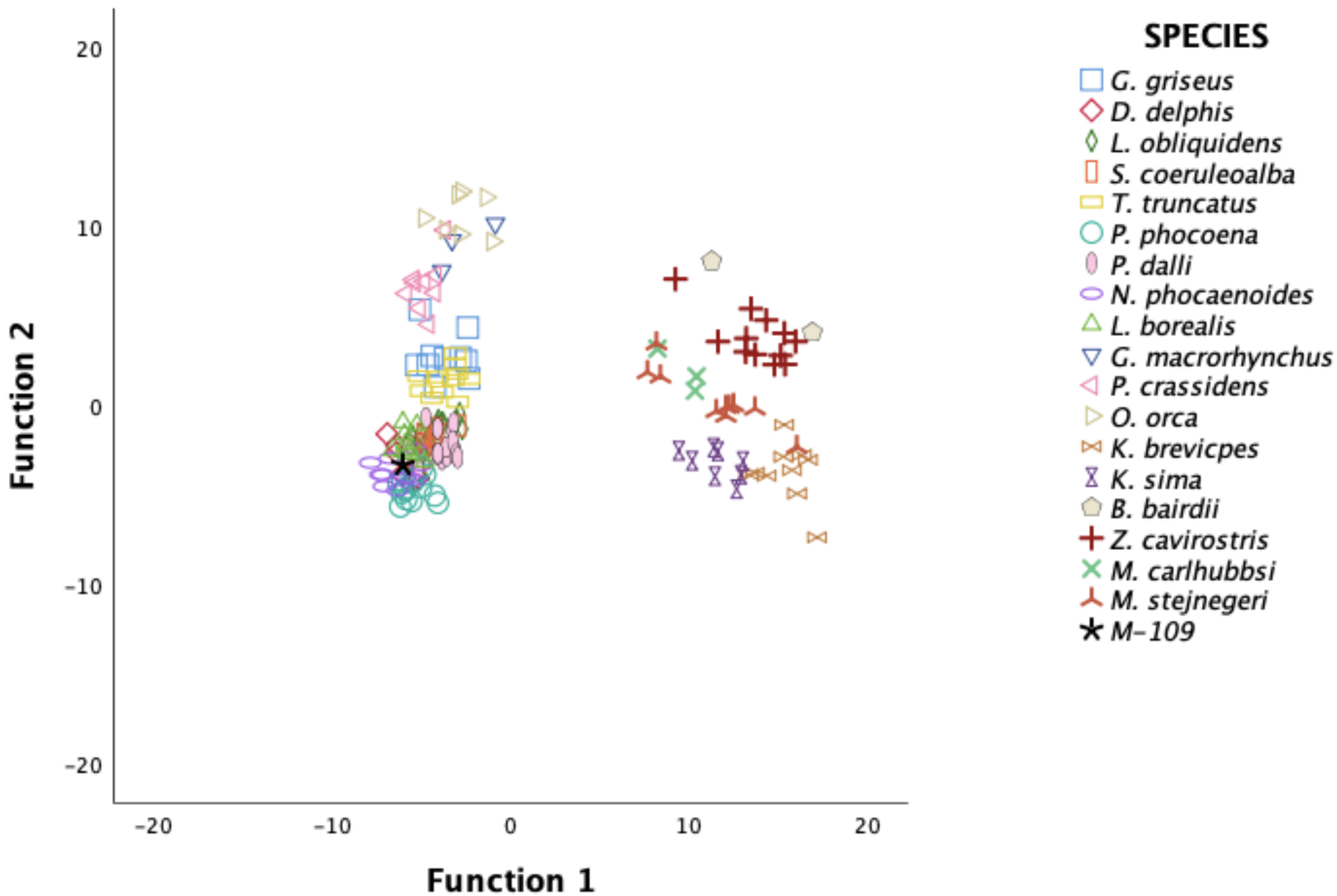


Figure 3.6 Combined-groups plot of the first two canonical DFA for prediction of group membership of M-111 at subfamily-level classification. Note that the sample (M-111) was assigned to Delphininae.

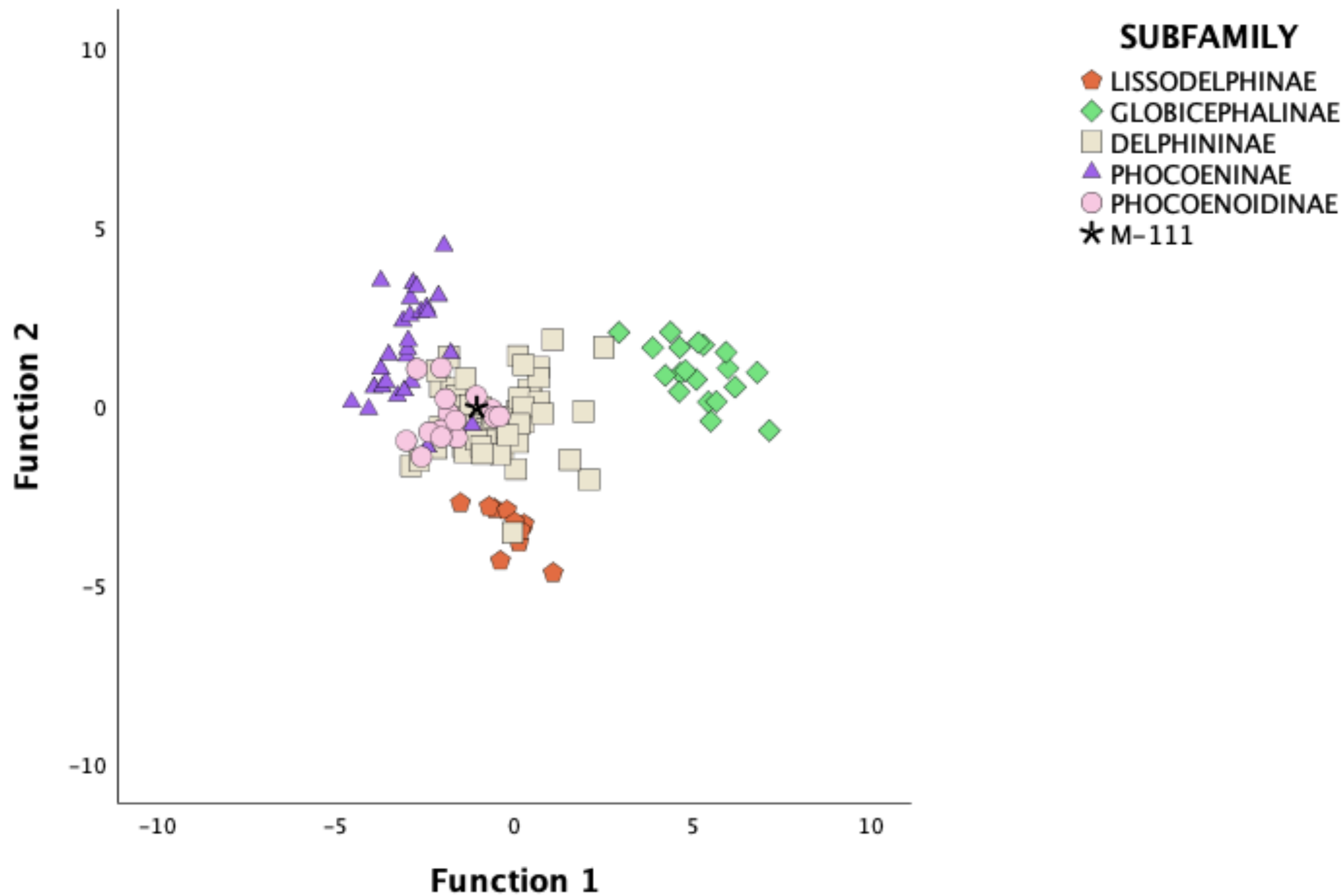


Figure 3.7 Combined-groups plot of the first two canonical DFA for prediction of group membership of M-106 at subfamily-level classification. Note that the sample (M-106) was assigned to Delphininae.

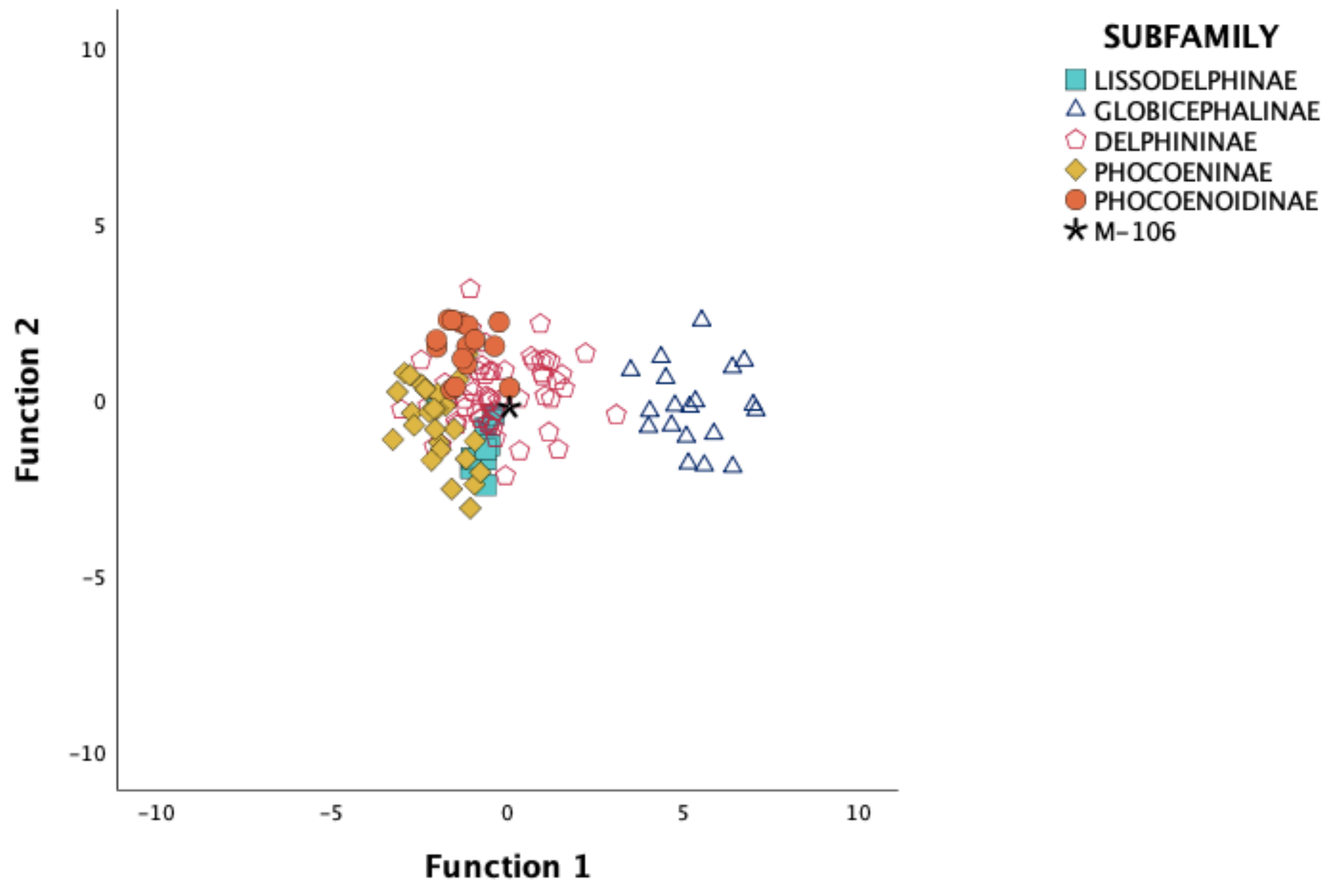


Figure 3.8 Combined-groups plot of the first two canonical DFA for prediction of group membership of M-91 at family-level classification. Note that the sample (M-91) was assigned to Delphininae.

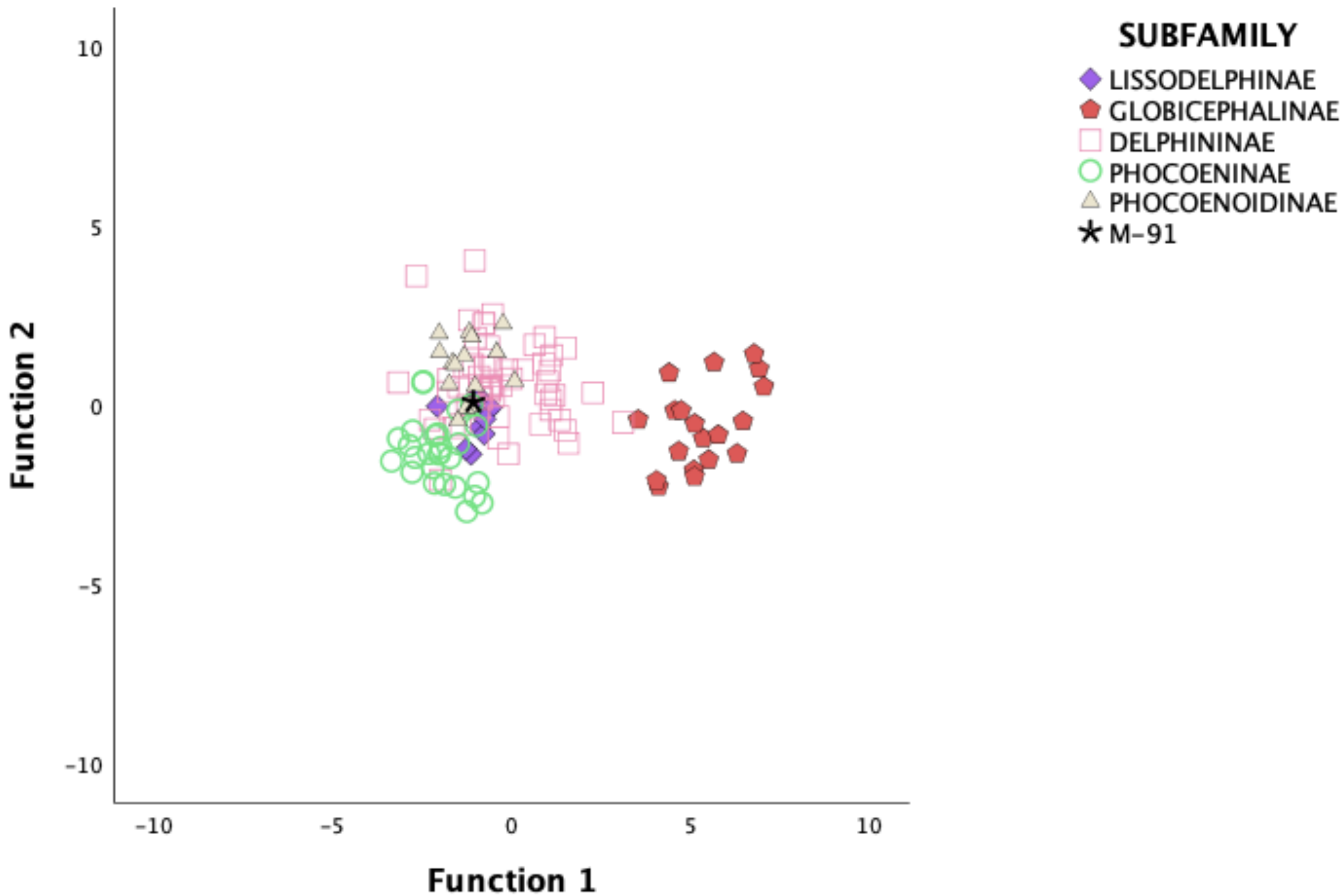


Figure 3.9 Combined-groups plot of the first two canonical DFA for prediction of group membership of M-5 at subfamily-level classification. Note that the sample (M-5) was assigned to Delphininae

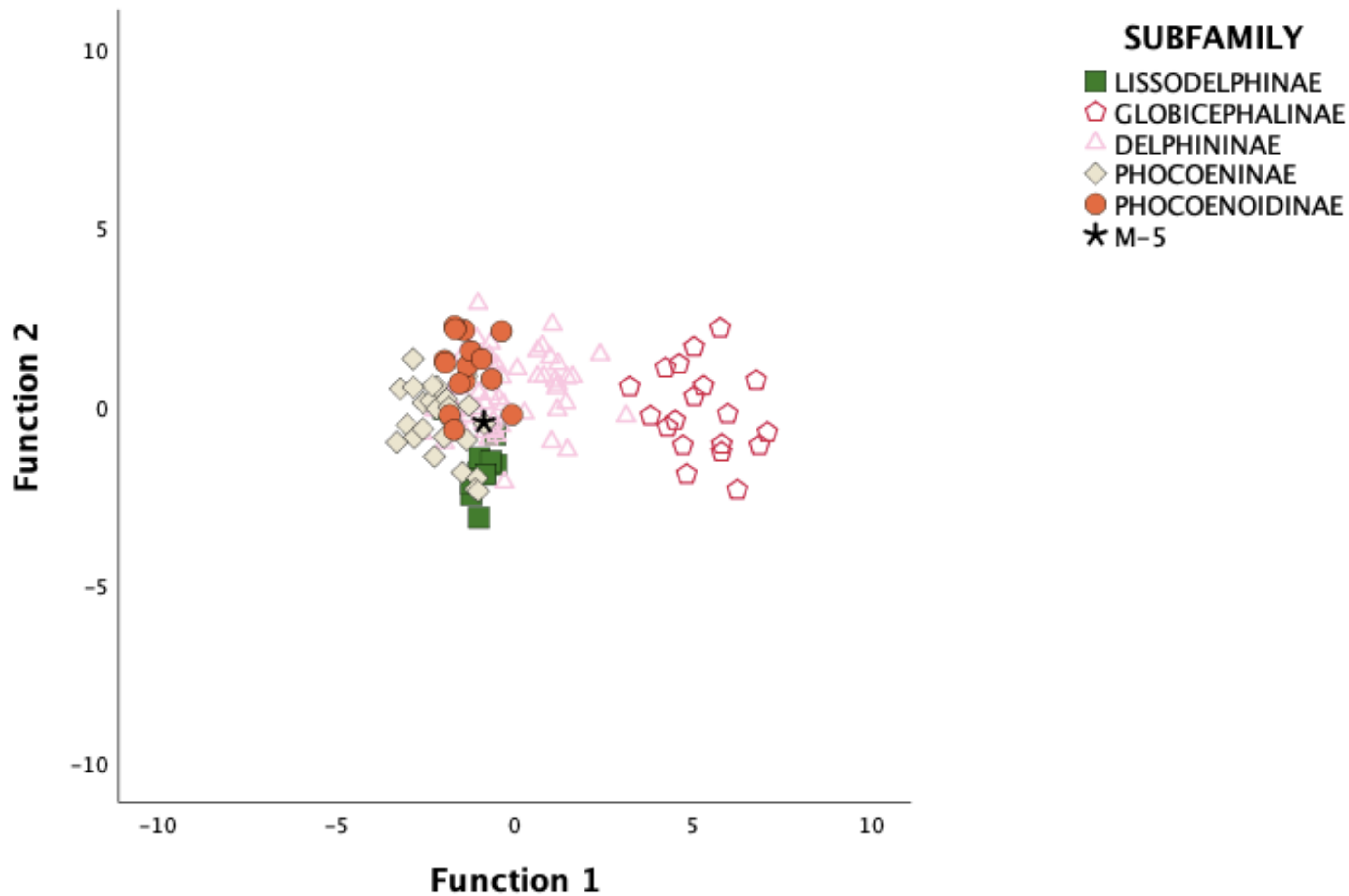


Figure 3.10 Combined-groups plot of the first two canonical DFA for prediction of group membership of M-3 at family-level classification. Note that the sample (M-3) was assigned to Phocoenidae

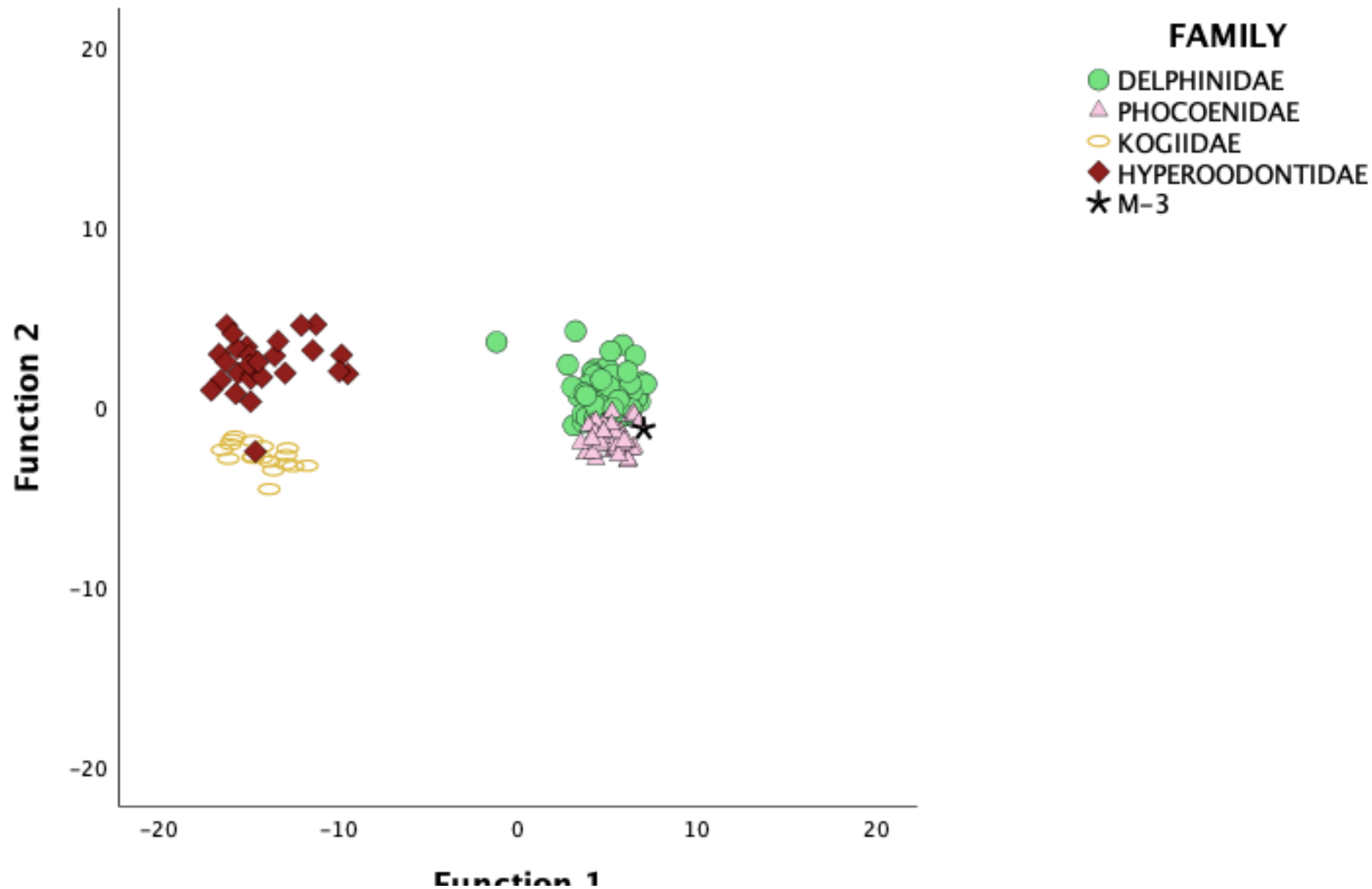


Figure 3.11 Combined-groups plot of the first two canonical DFA for prediction of group membership of M-90 at family-level classification. Note that the sample (M-90) was assigned to Delphininae

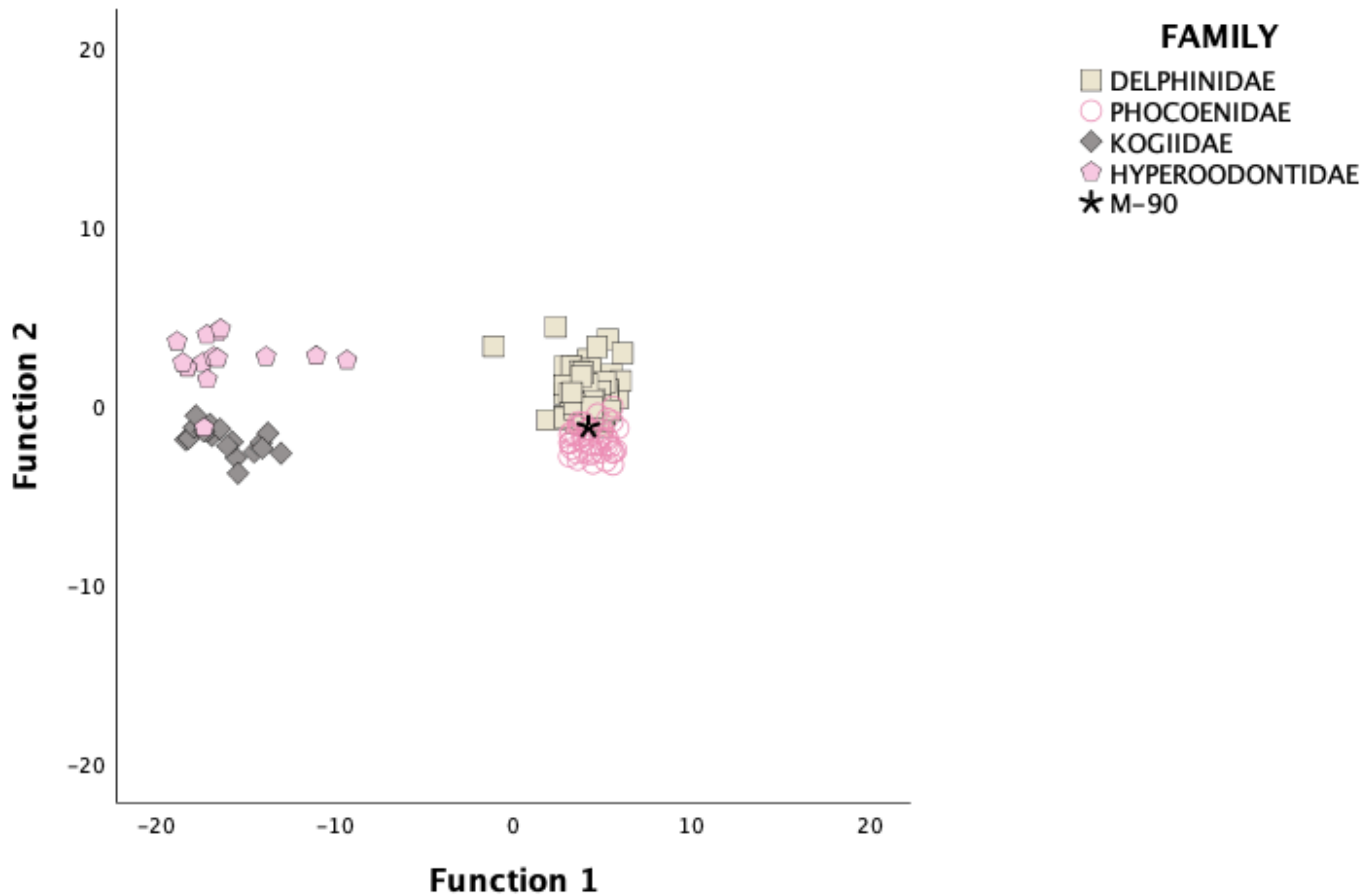


Figure 3.12 Combined-groups plot of the first two canonical DFA for prediction of group membership of 748 at subfamily-level classification. Note that the sample (748) was assigned to Delphininae.

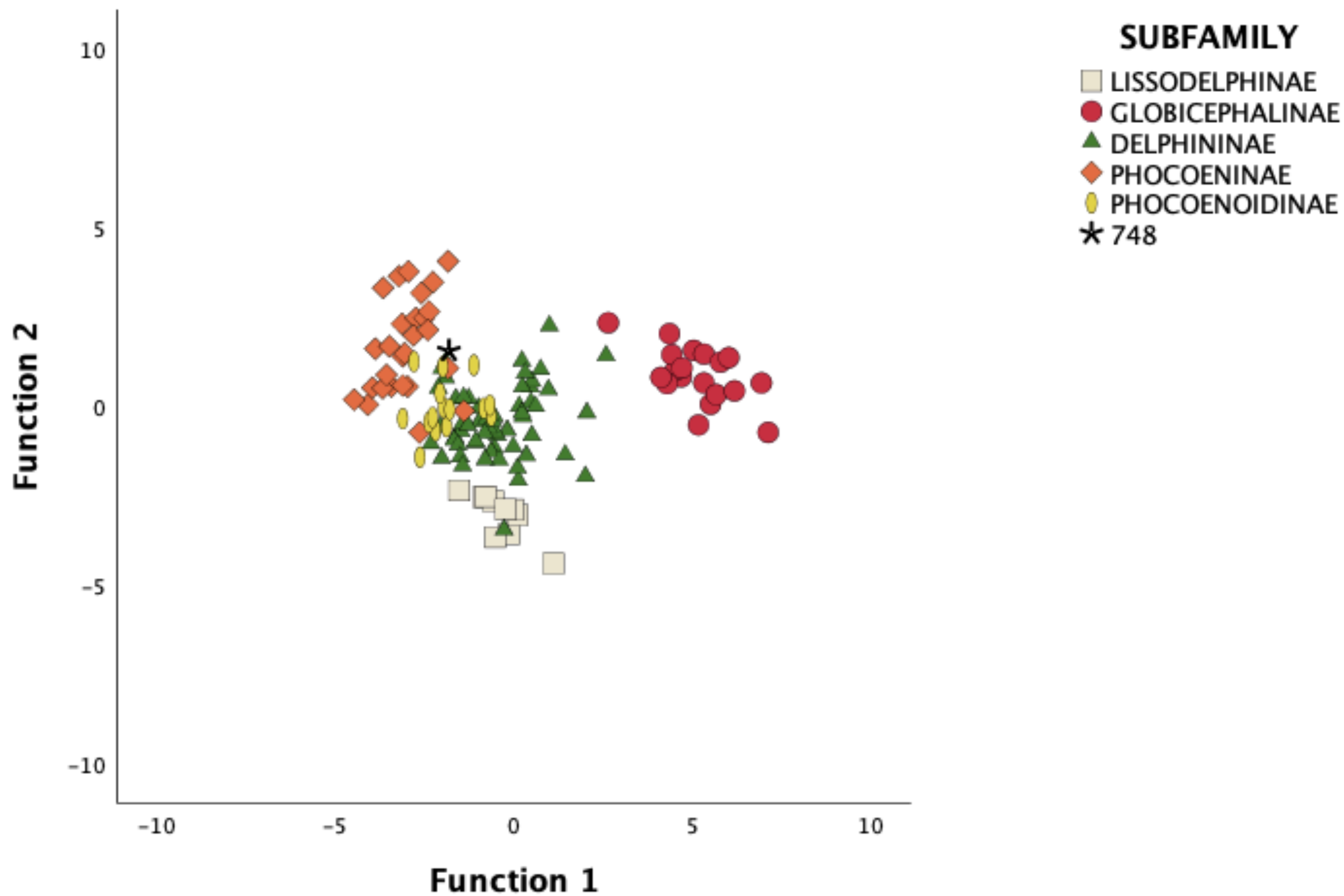


Figure 3.13 Combined-groups plot of the first two canonical DFA for prediction of group membership of 749 at species-level classification. Note that the sample (749) was assigned to Dall's porpoise (*P. dalli*).

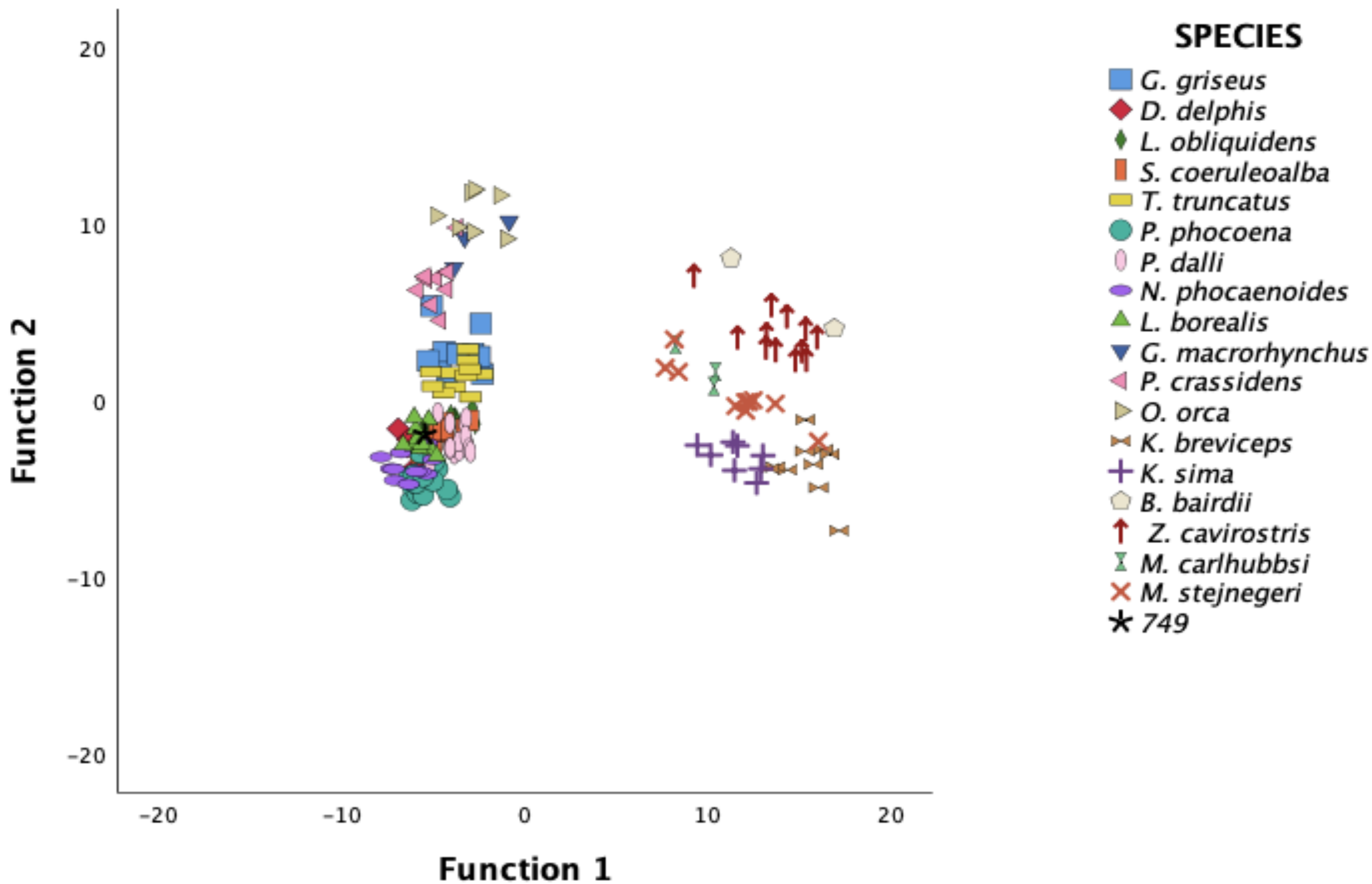


Figure 3.14 Combined-groups plot of the first two canonical DFA for prediction of group membership of RKA3690 at subfamily-level classification. Note that the sample (RKA3690) was assigned to Phocoenoidinae.

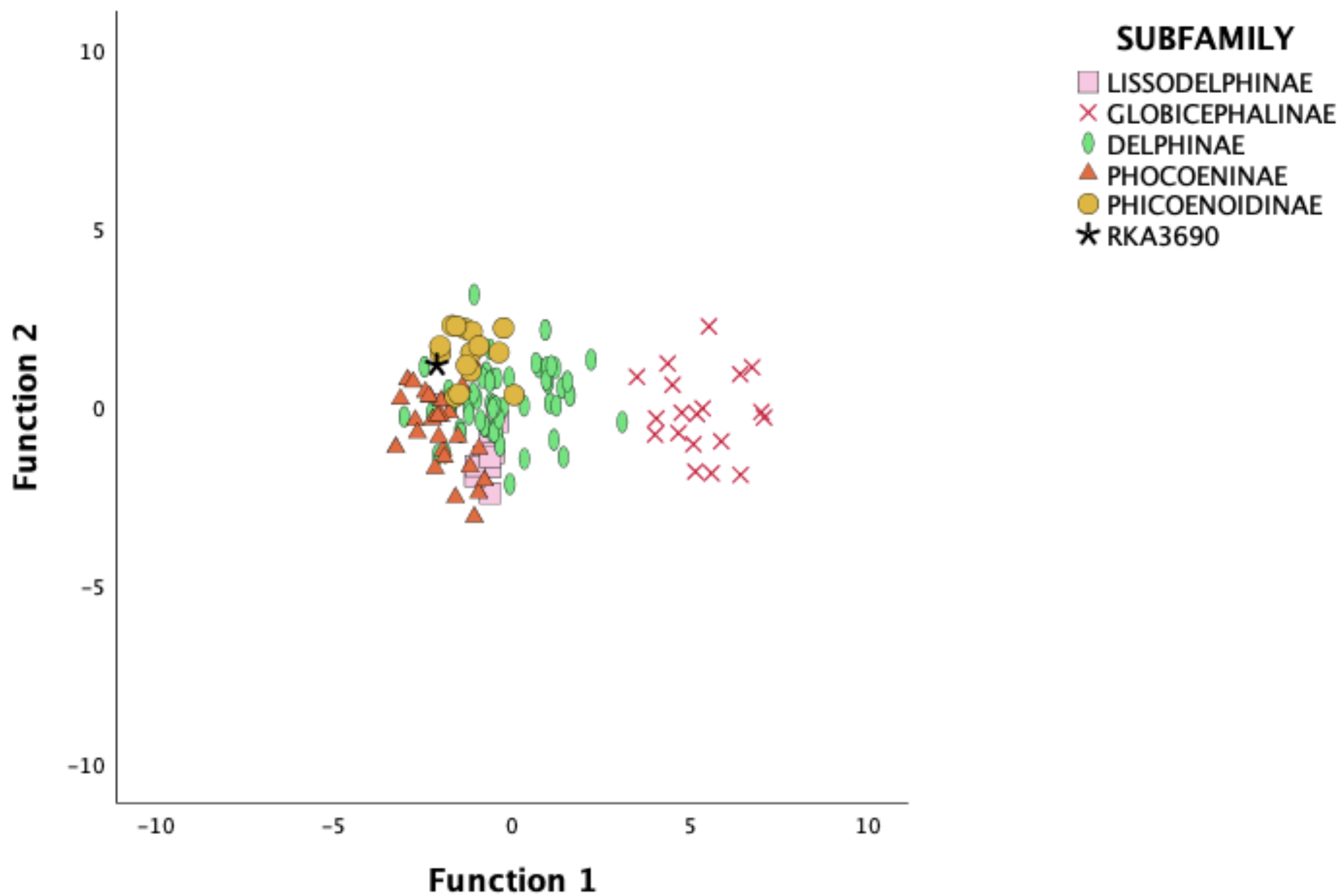


Figure 3.15 Combined-groups plot of the first two canonical DFA for prediction of group membership of RKA5918 at family-level classification. Note that the sample (RKA5918) was assigned to Phocoenidae

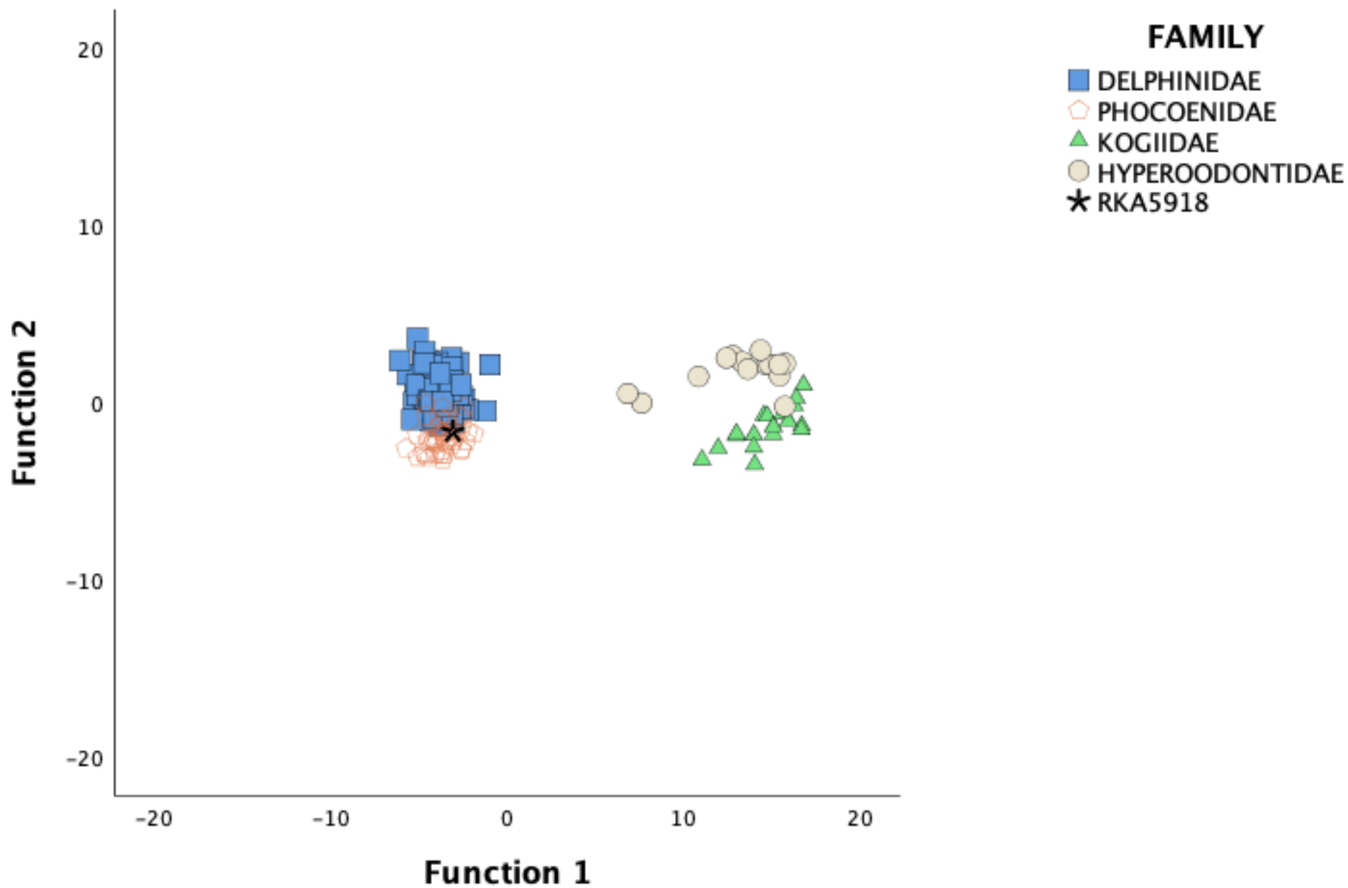
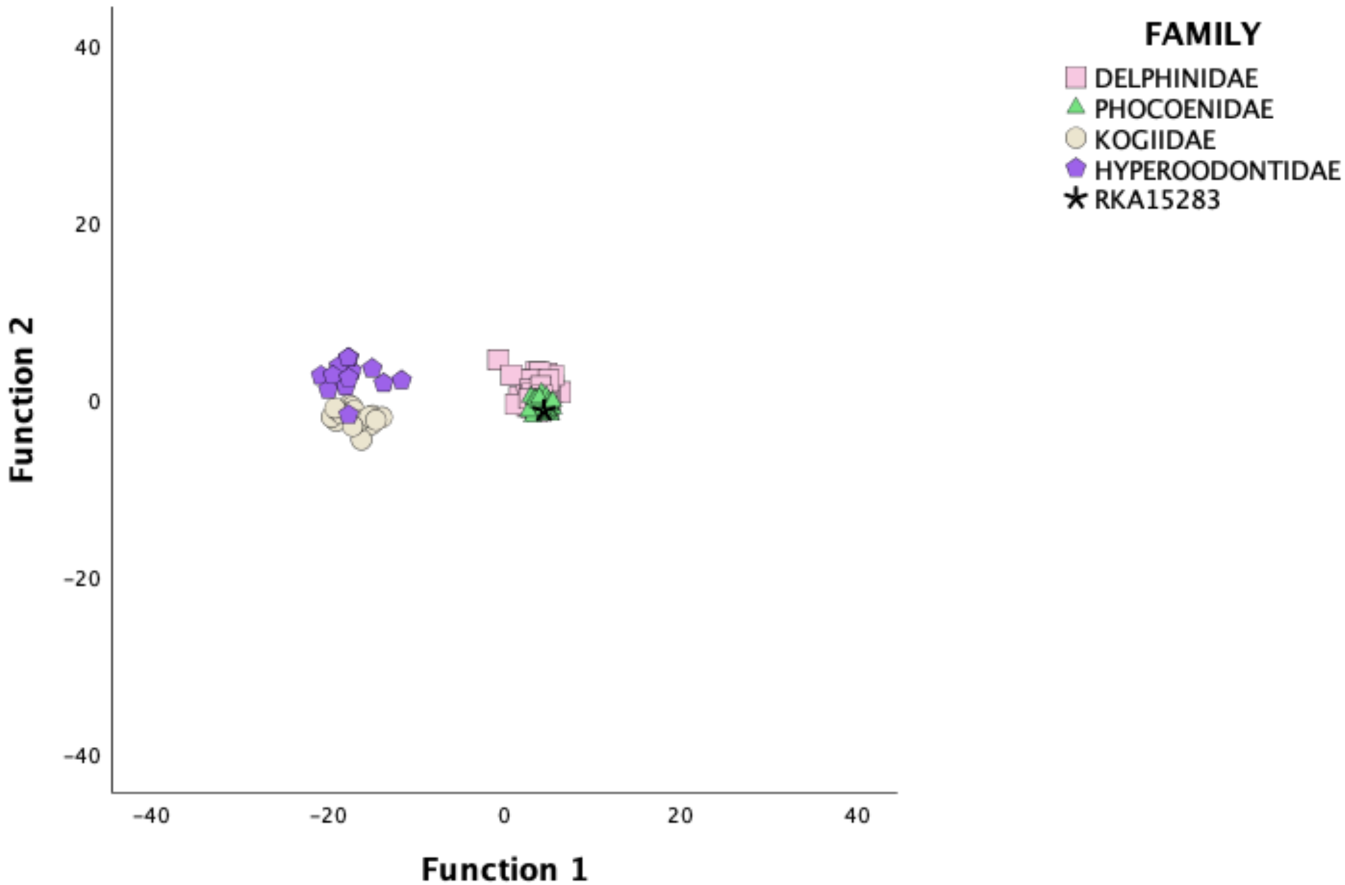


Figure 3.16 Combined-groups plot of the first two canonical DFA for prediction of group membership of RKA15283 at subfamily-level classification. Note that the sample (RKA15283) was assigned to Delphininae



APPENDIX A

Detailed list of modern reference samples and measurements data

Table S1 Detailed list of modern samples and measurements data (N = 173)

SPECIMENS	SPECIES	Measurement (mm)													SOURCES
		GWASA	HA	GLNSA	LLPA	LLefLtPA	GLCAF	GWCAF	BNA	HNA	GBNSA	ThLPA	BLPA	ThNSA	
M33075	*Grampus griseus*	102.49	73.78	36.29	45.95	66.61	53.75	39.25	45.98	39.47	17.15	12.39	19.43	13.85	NMNS
M29326	*Grampus griseus*	106.95	58.86	37.37	51.97	57.78	64.06	40.76	51.26	39.65	25.87	16.76	22.41	13.92	NMNS
M32618	*Grampus griseus*	129.50	102.28	57.16	63.32	78.13	78.12	50.79	58.00	37.90	19.82	21.93	31.98	24.20	NMNS
M36338	*Grampus griseus*	114.66	76.58	43.97	53.03	63.46	55.56	39.22	45.81	34.14	21.04	12.38	17.55	15.86	NMNS
M35066	*Grampus griseus*	112.27	80.74	34.71	47.66	67.09	56.33	45.43	46.49	35.69	18.38	18.69	17.41	17.23	NMNS
M42006	*Grampus griseus*	115.16	82.44	36.34	51.84	61.63	57.98	40.96	49.65	36.06	21.04	14.14	16.78	18.06	NMNS
M33736	*Grampus griseus*	111.79	80.83	26.53	41.91	68.30	59.50	38.06	50.28	34.94	15.80	14.07	15.81	6.97	NMNS
M33550	*Grampus griseus*	103.65	79.62	38.20	55.56	61.99	61.56	38.68	49.56	34.43	17.97	24.95	14.11	20.29	NMNS
M32712	*Grampus griseus*	139.67	97.94	46.46	62.71	71.54	74.91	45.40	59.78	38.16	18.55	16.82	17.65	12.73	NMNS
M37876	*Grampus griseus*	115.20	85.71	35.81	50.04	76.82	61.97	45.44	44.06	35.37	22.14	15.35	18.46	22.29	NMNS
M38056	*Pseudorca crassidens*	188.34	146.14	43.00	83.11	81.04	124.04	71.52	80.58	59.91	29.86	27.00	26.73	26.50	NMNS
M32610	*Pseudorca crassidens*	152.09	110.43	39.38	65.23	79.89	85.58	54.24	78.54	49.07	23.00	17.02	16.70	17.84	NMNS
M28370	*Pseudorca crassidens*	166.06	106.52	30.32	60.34	77.66	82.12	63.06	74.33	40.80	20.67	18.32	24.45	11.55	NMNS
M24616	*Pseudorca crassidens*	133.71	93.50	36.02	59.41	83.36	71.61	48.25	66.87	36.79	22.15	16.03	21.56	10.24	NMNS
M32743	*Pseudorca crassidens*	137.79	103.12	55.35	61.64	77.48	80.23	48.72	75.61	66.82	17.30	15.20	26.69	10.97	NMNS
M29893	*Pseudorca crassidens*	153.74	123.88	47.63	66.45	81.87	99.33	56.28	78.97	43.21	23.19	18.38	21.62	14.81	NMNS
PC-24	*Pseudorca crassidens*	144.20	97.08	30.68	46.96	72.98	75.23	53.82	74.42	40.35	10.42	15.08	15.01	12.14	NMNS
M29345	*Pseudorca crassidens*	160.57	106.01	36.84	N/A	80.76	83.22	64.42	84.23	44.75	22.85	15.12	24.98	13.90	NMNS
M26474	*Pseudorca crassidens*	154.25	102.91	34.58	65.41	87.68	87.64	65.85	73.84	41.83	22.43	15.84	26.03	16.95	NMNS
M28353	*Delphinus delphis*	85.93	56.73	21.22	37.49	45.40	46.80	31.93	38.87	24.65	8.30	7.59	10.97	7.31	NMNS
M28356	*Delphinus delphis*	77.64	47.24	5.81	25.94	33.09	37.44	23.36	33.51	21.11	7.21	9.82	7.86	3.50	NMNS
M27074	*Delphinus delphis*	73.58	46.04	24.33	42.03	50.16	40.02	25.37	35.83	21.25	6.86	8.35	17.61	5.44	NMNS
M27135	*Delphinus delphis*	83.36	55.09	26.29	43.82	51.77	48.65	31.53	37.44	25.33	9.35	10.41	15.31	5.70	NMNS
M29636	*Delphinus delphis*	84.64	52.70	25.13	44.52	51.93	46.62	32.22	37.63	21.25	7.10	8.55	15.15	6.64	NMNS
M29855	*Delphinus delphis*	73.70	49.79	17.85	38.96	40.58	43.48	27.74	32.22	20.54	7.40	8.50	15.58	5.28	NMNS
M27818	*Delphinus delphis*	84.25	51.37	22.35	40.90	51.25	42.91	31.92	22.76	36.55	7.98	7.25	17.74	7.22	NMNS
M29624	*Delphinus delphis*	85.18	53.85	25.87	50.51	51.00	43.78	28.50	40.83	24.96	9.72	6.94	16.89	7.84	NMNS
M26194	*Delphinus delphis*	79.34	52.39	23.21	43.07	52.00	43.21	27.15	35.84	22.91	10.46	9.78	13.37	5.48	NMNS
M27811	*Delphinus delphis*	77.92	50.91	18.96	44.21	41.84	39.41	26.81	35.84	20.85	7.82	8.94	14.12	5.45	NMNS
M27810	*Delphinus delphis*	77.94	51.71	23.43	36.77	46.10	41.69	28.92	34.97	20.29	9.90	7.03	17.22	4.39	NMNS
M24743	*Lissodelphis borealis*	81.75	55.70	25.43	21.05	54.13	51.89	29.56	34.43	22.98	4.75	7.39	15.65	9.20	NMNS
M27078	*Lissodelphis borealis*	91.64	58.84	19.03	36.60	49.98	53.30	31.38	36.71	26.22	3.51	8.51	19.51	9.65	NMNS
M28400	*Lissodelphis borealis*	79.77	51.96	23.68	44.77	53.03	51.31	30.60	36.79	22.32	7.25	9.30	17.03	9.13	NMNS
M26273	*Lissodelphis borealis*	79.58	50.89	29.04	40.55	55.21	45.75	29.16	37.88	24.68	7.46	7.70	15.52	11.44	NMNS
M27807	*Lissodelphis borealis*	80.60	57.85	25.75	41.41	51.14	49.15	30.94	33.24	29.83	8.07	7.40	15.77	12.81	NMNS
M27819	*Lissodelphis borealis*	80.49	55.54	27.52	35.55	55.89	53.62	21.12	38.14	28.45	5.78	9.97	18.78	11.49	NMNS
M26103	*Lissodelphis borealis*	87.11	53.61	22.69	32.19	52.28	48.77	30.77	36.93	25.43	5.75	7.98	16.01	10.04	NMNS
M24829	*Lissodelphis borealis*	90.87	58.28	20.19	24.14	58.23	50.04	33.08	37.06	25.56	6.94	8.83	18.55	13.77	NMNS
M25021	*Lissodelphis borealis*	82.91	53.67	25.21	42.80	54.77	51.35	29.92	38.09	25.73	6.88	7.89	20.15	10.20	NMNS
M26249	*Lissodelphis borealis*	76.55	52.29	22.08	33.95	49.31	42.67	28.01	31.73	23.49	6.16	9.48	16.10	9.77	NMNS

Table S1 (*continued*)

SPECIMENS	SPECIES	Measurement (mm)													SOURCES
		GWASA	HA	GLNSA	LLPA	LLefLtPA	GLCAF	GWCAF	BNA	HNA	GBNSA	ThLPA	BLPA	ThNSA	
M24911	*Globicephalus macrorhynchus*	195.42	181.10	111.12	124.84	120.45	129.82	91.35	85.70	46.97	29.14	44.63	48.77	27.31	NMNS
M24603	*Globicephalus macrorhynchus*	156.19	106.77	55.47	73.14	89.86	81.01	56.59	70.46	43.05	17.09	24.21	16.62	15.06	NMNS
M42129	*Globicephalus macrorhynchus*	173.80	126.78	35.55	60.61	78.27	103.09	65.12	81.57	48.64	16.24	31.85	20.60	17.13	NMNS
M21262	*Orcinus orca*	220.55	181.82	120.86	127.32	142.53	154.98	94.48	88.20	59.99	21.51	33.07	39.23	32.64	NMNS
M38056	*Orcinus orca*	186.52	144.17	45.49	87.70	96.62	119.74	76.35	80.01	60.65	25.38	27.01	24.25	24.87	NMNS
M36330	*Orcinus orca*	181.67	164.68	115.95	133.65	136.21	123.90	81.30	90.95	72.35	38.12	29.16	34.85	31.16	NMNS
M34166	*Orcinus orca*	196.49	169.28	70.03	91.73	106.89	136.76	69.76	84.10	53.41	20.55	27.32	25.33	21.47	NMNS
M33459	*Orcinus orca*	223.85	184.84	123.06	136.83	128.01	156.19	93.80	94.23	65.37	30.11	34.90	40.93	28.62	NMNS
M32458	*Orcinus orca*	180.05	157.94	N/A	66.16	N/A	123.27	76.87	78.33	58.64	29.52	40.85	46.45	24.93	NMNS
M4510	*Orcinus orca*	214.50	170.96	121.54	157.48	128.84	141.46	98.55	93.03	68.25	45.95	40.39	37.71	36.31	NMNS
M23631	*Lagenorhynchus obliquidens*	89.56	57.97	46.55	24.78	53.79	49.18	33.51	41.61	28.52	7.83	11.87	22.01	11.11	NMNS
M23636	*Lagenorhynchus obliquidens*	90.15	63.65	49.50	21.71	52.29	56.58	35.90	39.10	28.62	10.64	12.26	21.13	9.08	NMNS
M23638	*Lagenorhynchus obliquidens*	83.24	60.00	46.74	22.40	47.68	49.53	31.90	43.26	24.15	12.56	18.26	16.87	8.69	NMNS
M23640	*Lagenorhynchus obliquidens*	87.54	61.07	38.20	20.41	50.46	49.77	30.54	40.57	24.83	13.77	15.93	17.77	15.37	NMNS
M24914	*Lagenorhynchus obliquidens*	81.94	55.35	39.70	20.48	44.30	45.32	30.97	34.25	20.58	9.27	9.12	17.24	9.94	NMNS
M24962	*Lagenorhynchus obliquidens*	73.23	53.72	41.44	23.22	46.07	41.70	25.66	32.08	25.12	7.77	8.87	17.88	9.56	NMNS
M25185	*Lagenorhynchus obliquidens*	84.52	55.26	45.85	26.13	49.70	45.76	29.52	37.26	25.64	7.68	9.49	14.37	8.42	NMNS
M42082	*Lagenorhynchus obliquidens*	84.51	59.42	47.33	22.18	47.43	48.57	31.99	40.53	25.30	6.91	9.36	16.14	8.79	NMNS
M42582	*Lagenorhynchus obliquidens*	86.92	57.07	42.17	20.81	50.60	45.25	29.47	39.78	23.99	10.61	9.88	16.34	10.25	NMNS
M46805	*Lagenorhynchus obliquidens*	91.78	60.04	49.28	27.58	54.57	53.15	35.28	38.89	28.17	12.14	11.90	21.46	9.27	NMNS
HOUMVC1001	*Lagenorhynchus obliquidens*	89.40	64.22	49.90	31.32	54.79	53.31	34.36	41.11	27.41	11.45	13.02	18.30	11.15	HOUM
HOUMVC1002	*Lagenorhynchus obliquidens*	85.34	60.38	50.83	24.10	47.31	47.93	29.46	39.48	24.23	14.90	10.22	19.52	20.21	HOUM
HOUMVC1003	*Lagenorhynchus obliquidens*	86.65	52.26	51.09	24.20	51.11	49.63	31.12	38.85	23.37	13.36	10.18	16.56	9.95	HOUM
HOUMVC0026	*Lagenorhynchus obliquidens*	93.66	60.17	52.34	30.13	58.66	53.57	37.73	38.39	24.98	14.91	14.84	18.56	13.58	HOUM
M19772	*Stenella coeruleoalba*	78.65	48.23	38.85	25.72	50.44	44.51	26.67	37.09	23.06	8.83	9.50	16.45	8.55	NMNS
M19774	*Stenella coeruleoalba*	85.35	54.04	49.89	35.60	63.96	50.35	28.62	38.77	22.13	5.30	13.24	16.54	10.90	NMNS
M19775	*Stenella coeruleoalba*	87.24	60.76	42.08	25.59	58.59	52.07	30.85	39.78	25.85	10.15	10.43	19.78	8.69	NMNS
M23654	*Stenella coeruleoalba*	86.01	52.00	44.63	33.49	58.46	42.02	27.44	39.18	23.97	6.23	11.75	16.91	5.04	NMNS
M24838	*Stenella coeruleoalba*	88.88	58.45	49.96	31.07	67.07	53.67	33.24	40.11	27.73	10.39	15.41	23.91	8.25	NMNS
M25187	*Stenella coeruleoalba*	90.20	46.83	57.55	31.71	64.68	41.03	33.04	38.03	23.55	6.37	10.42	23.19	6.84	NMNS
M26235	*Stenella coeruleoalba*	86.86	60.77	38.85	37.09	62.49	52.11	29.97	39.12	24.00	13.02	11.11	18.92	8.75	NMNS
M26239	*Stenella coeruleoalba*	83.30	56.84	47.85	33.15	57.89	51.16	30.11	37.86	25.13	8.92	11.67	21.62	7.75	NMNS
M34531	*Stenella coeruleoalba*	78.00	47.43	42.21	17.16	45.51	39.00	20.05	36.57	19.37	7.41	9.75	12.84	4.45	NMNS
M41969	*Stenella coeruleoalba*	87.47	51.34	55.10	28.45	55.05	48.81	30.24	36.79	24.38	7.30	10.87	21.03	6.90	NMNS
M19789	*Stenella coeruleoalba*	87.33	58.79	31.51	53.13	59.63	53.37	30.84	40.35	24.59	12.19	10.97	22.44	11.67	NMNS
M26994	*Tursiops truncatus*	108.97	65.62	72.46	31.33	N/A	55.59	38.69	24.06	47.38	9.31	17.29	20.00	12.92	NMNS
M26995	*Tursiops truncatus*	114.35	79.68	58.82	35.78	64.95	68.4	39.45	50.20	32.13	13.27	19.04	28.53	8.98	NMNS
M29360	*Tursiops truncatus*	112.10	71.45	60.91	32.17	68.50	64.57	38.90	48.28	31.41	19.09	13.38	24.24	10.51	NMNS
M32427	*Tursiops truncatus*	105.26	67.03	62.75	32.81	61.22	57.60	33.30	50.68	28.05	14.32	17.09	22.17	12.86	NMNS
M32431	*Tursiops truncatus*	99.13	67.75	56.06	40.78	69.90	57.41	34.21	52.45	29.80	14.36	15.32	20.34	10.74	NMNS
M28346	*Tursiops truncatus*	97.91	65.22	35.83	N/A	41.71	54.74	35.86	47.55	27.37	9.15	24.46	10.24	9.45	NMNS
M29464	*Tursiops truncatus*	95.35	61.20	39.65	5.11	42.32	54.76	34.74	42.98	25.12	7.83	14.93	12.89	8.51	NMNS
M54842	*Tursiops truncatus*	97.61	72.95	61.69	33.23	61.51	60.98	35.28	44.76	27.11	11.14	16.47	29.25	13.53	NMNS
M29853	*Tursiops truncatus*	112.12	71.93	24.54	45.01	58.91	66.47	41.95	49.23	29.29	8.67	10.85	24.11	11.68	NMNS
080222-2	*Tursiops truncatus*	103.52	65.61	24.58	46.77	58.71	58.68	39.65	46.83	29.92	14.40	11.05	16.80	10.20	NMNS
M24702	*Tursiops truncatus*	115.43	73.65	32.47	63.94	66.23	64.88	45.76	50.38	29.17	12.03	18.61	17.89	15.92	NMNS

Table S1 (*continued*)

SPECIMENS	SPECIES	Measurement (mm)													SOURCES
		GWASA	HA	GLNSA	LLPA	LLefLtPA	GLCAF	GWCAF	BNA	HNA	GBNSA	ThLPA	BLPA	ThNSA	
M24958	*Phocoena phocoena*	68.04	49.68	24.16	22.04	45.52	34.57	20.87	32.04	22.99	N/A	8.61	10.00	N/A	NMNS
M24959	*Phocoena phocoena*	62.08	46.64	15.65	21.36	42.01	34.84	21.30	30.80	20.60	5.62	7.97	11.19	4.87	NMNS
M24960	*Phocoena phocoena*	69.54	50.72	25.23	17.08	40.33	35.64	24.76	35.70	21.07	7.21	8.15	11.52	3.80	NMNS
M24961	*Phocoena phocoena*	62.15	46.88	22.56	20.72	39.32	34.83	22.59	29.68	22.38	N/A	10.05	11.35	N/A	NMNS
M29356	*Phocoena phocoena*	67.97	49.46	29.31	23.49	44.31	39.91	21.94	33.41	23.48	N/A	8.10	11.95	5.08	NMNS
M29357	*Phocoena phocoena*	67.76	46.87	21.07	18.57	38.59	34.78	22.38	34.78	21.53	N/A	7.04	13.96	5.77	NMNS
M29358	*Phocoena phocoena*	67.37	50.98	30.55	20.93	43.62	36.76	19.24	30.13	20.55	N/A	8.03	11.23	N/A	NMNS
M29793	*Phocoena phocoena*	70.21	49.83	25.72	20.70	42.08	35.93	21.47	33.76	23.20	N/A	8.92	9.70	4.58	NMNS
M29794	*Phocoena phocoena*	66.54	49.14	22.10	22.29	39.36	34.39	22.91	32.11	20.27	N/A	9.05	14.91	N/A	NMNS
M29795	*Phocoena phocoena*	69.20	51.64	24.22	17.52	40.76	35.70	24.78	33.81	22.29	N/A	9.98	9.70	N/A	NMNS
M29796	*Phocoena phocoena*	63.93	47.51	24.26	19.39	38.56	35.80	19.01	27.61	21.71	N/A	8.21	10.42	N/A	NMNS
M29798	*Phocoena phocoena*	76.36	48.3	19.35	26.00	44.36	37.00	26.06	29.16	18.96	12.14	9.35	11.23	7.90	NMNS
M27024	*Phocoena phocoena*	70.55	48.83	29.82	35.36	56.86	41.37	23.70	29.76	22.21	13.92	9.65	13.86	5.18	NMNS
M27139	*Phocoena phocoena*	69.12	47.82	24.31	27.62	46.18	34.17	20.65	30.19	22.28	9.97	8.24	12.14	4.56	NMNS
M30121	*Phocoena phocoena*	81.13	52.59	26.33	31.97	58.21	39.84	25.43	37.71	23.82	13.97	8.89	15.81	3.19	NMNS
HOUMVC1004	*Phocoena phocoena*	72.76	49.51	26.06	31.57	59.11	41.60	22.83	36.89	22.53	16.69	9.28	15.41	2.92	HOUM
M26166	*Phocoenoides dalli*	87.02	59.51	59.77	37.21	70.78	50.31	29.12	42.12	26.42	21.21	12.66	21.47	22.81	NMNS
M27746	*Phocoenoides dalli*	79.66	51.35	39.71	27.11	57.11	41.63	26.37	39.74	24.15	N/A	12.57	18.65	N/A	NMNS
M27770	*Phocoenoides dalli*	78.75	48.24	49.04	31.28	54.94	40.62	25.04	33.94	21.76	11.32	10.13	18.83	14.81	NMNS
M27778	*Phocoenoides dalli*	90.76	53.34	41.41	29.97	62.22	44.92	32.54	43.53	23.83	N/A	12.28	18.97	N/A	NMNS
M28352	*Phocoenoides dalli*	78.58	53.08	38.77	29.49	55.81	41.08	23.06	38.97	25.98	5.43	10.51	14.39	4.02	NMNS
M28360	*Phocoenoides dalli*	78.60	53.66	40.19	29.60	55.52	41.07	28.54	36.73	25.40	10.91	12.52	18.89	5.59	NMNS
M29348	*Phocoenoides dalli*	81.46	51.17	50.85	27.00	58.47	42.22	30.75	36.20	24.69	15.33	10.66	16.36	15.80	NMNS
M29354	*Phocoenoides dalli*	83.43	53.37	42.77	45.25	64.23	44.12	29.18	37.76	25.19	N/A	12.33	18.18	N/A	NMNS
M31393	*Phocoenoides dalli*	76.37	53.44	45.76	31.64	57.61	42.85	23.80	39.79	24.74	16.43	15.38	17.75	8.41	NMNS
M32606	*Phocoenoides dalli*	77.08	59.58	41.86	30.09	58.80	43.43	27.21	36.75	25.45	N/A	11.60	15.71	N/A	NMNS
M32732	*Phocoenoides dalli*	75.88	52.21	42.35	27.99	55.35	44.14	25.49	33.35	31.06	N/A	11.89	12.65	N/A	NMNS
M46876	*Phocoenoides dalli*	78.41	58.27	35.01	44.73	64.41	46.46	26.30	34.92	23.37	12.81	7.91	24.79	11.59	NMNS
M46890	*Phocoenoides dalli*	88.93	60.27	18.31	38.80	63.33	47.72	31.75	37.11	25.73	9.41	13.40	18.35	4.67	NMNS
M37919	*Phocoenoides dalli*	78.28	51.87	29.00	57.96	57.83	42.91	30.04	32.38	24.98	17.08	11.86	17.74	15.52	NMNS
M46882	*Phocoenoides dalli*	94.54	62.40	25.78	57.80	62.20	49.99	40.20	38.65	24.34	13.52	9.73	16.39	11.45	NMNS
60712	*Neophocoena phocoenoides*	76.56	50.64	21.39	29.17	42.25	40.36	27.66	33.46	23.65	13.94	7.57	19.42	4.04	NMNS
90419	*Neophocoena phocoenoides*	77.60	45.99	15.78	31.44	35.70	40.23	26.76	35.00	26.28	18.46	4.61	18.34	4.62	NMNS
M41964	*Neophocoena phocoenoides*	78.35	51.55	22.46	29.69	39.19	42.95	29.08	36.93	28.57	15.94	5.97	14.34	2.15	NMNS
M35160	*Neophocoena phocoenoides*	80.15	52.63	21.92	31.77	39.14	43.39	29.93	36.69	26.67	20.85	8.48	18.22	4.68	NMNS
60616	*Neophocoena phocoenoides*	76.98	43.22	15.01	24.45	37.79	38.49	24.03	34.46	25.40	14.86	6.95	16.67	4.34	NMNS
M32688	*Neophocoena phocoenoides*	73.44	50.24	15.18	24.53	33.92	37.77	24.46	34.81	21.73	22.34	7.91	11.30	6.05	NMNS
M34047	*Neophocoena phocoenoides*	83.51	50.20	20.65	30.77	40.97	44.22	28.47	38.32	26.32	21.34	8.94	13.69	5.57	NMNS
M35048	*Neophocoena phocoenoides*	78.16	48.68	18.60	30.37	33.50	38.74	24.13	36.00	24.18	16.97	5.77	8.71	6.20	NMNS
M35049	*Neophocoena phocoenoides*	75.40	47.21	7.62	18.29	35.95	36.46	23.86	37.42	21.41	19.14	6.46	9.90	3.97	NMNS
M34168	*Neophocoena phocoenoides*	73.92	44.00	12.18	27.14	34.77	37.22	22.92	34.44	21.42	16.35	5.25	17.69	9.70	NMNS
M41963	*Neophocoena phocoenoides*	80.26	56.65	18.65	N/A	48.55	45.75	25.59	37.41	27.11	N/A	6.24	15.83	N/A	NMNS

Table S1 (*continued*)

SPECIMENS	SPECIES	Measurement (mm)													SOURCE
		GWASA	HA	GLNSA	LLPA	LLefLtPA	GLCAF	GWCAF	BNA	HNA	GBNSA	ThLPA	BLPA	ThNSA	
M24784	*Kogia breviceps*	93.28	75.66	25.63	51.14	49.05	64.20	33.34	47.86	45.78	7.50	21.16	43.89	12.50	NMNS
110127	*Kogia breviceps*	96.11	81.50	39.77	53.88	56.57	64.16	33.56	51.98	46.51	4.78	20.58	36.65	19.07	NMNS
K.b-7	*Kogia breviceps*	84.46	74.19	24.96	43.29	42.16	59.69	34.67	35.43	38.92	7.55	19.52	40.41	11.93	NMNS
10414	*Kogia breviceps*	89.47	80.56	36.14	71.99	42.87	66.66	33.47	51.28	39.90	6.30	18.43	37.21	21.50	NMNS
M29645	*Kogia breviceps*	80.74	60.86	12.82	51.36	40.20	54.80	26.56	42.66	28.11	7.81	11.25	27.40	22.91	NMNS
M26611	*Kogia breviceps*	73.54	61.05	18.23	40.31	30.56	55.40	26.97	37.50	33.39	3.35	9.12	27.55	8.81	NMNS
30811	*Kogia breviceps*	84.47	69.00	9.26	39.47	25.87	52.12	29.72	41.46	34.17	11.46	11.67	36.65	18.87	NMNS
90118	*Kogia breviceps*	99.17	72.38	18.02	48.55	44.55	62.18	30.51	56.68	41.46	6.34	11.11	33.53	14.86	NMNS
100725	*Kogia breviceps*	83.55	71.90	19.47	44.55	36.39	58.70	29.29	44.66	33.39	12.93	11.57	38.16	23.43	NMNS
130527	*Kogia breviceps*	105.83	89.47	31.41	68.01	47.26	62.14	41.04	52.22	45.98	6.63	25.72	36.77	25.55	NMNS
121126	*Kogia sima*	85.95	62.96	29.09	53.08	42.79	55.17	32.03	41.55	30.45	9.17	31.44	19.34	17.08	NMNS
M24613	*Kogia sima*	72.25	66.74	25.26	42.68	35.32	53.98	27.79	42.41	31.78	9.14	29.99	12.21	20.48	NMNS
M32612	*Kogia sima*	80.21	65.56	25.93	40.98	30.81	49.52	27.38	41.56	32.61	6.67	25.11	13.01	24.18	NMNS
141019	*Kogia sima*	81.80	67.12	24.05	39.94	28.28	48.85	29.80	46.21	29.99	11.04	17.05	32.24	20.07	NMNS
M26460	*Kogia sima*	83.40	66.85	21.23	47.20	35.85	50.72	33.36	44.66	29.80	13.99	34.19	17.59	32.58	NMNS
80815	*Kogia sima*	80.26	59.10	21.85	N/A	22.12	51.09	24.95	40.76	33.73	13.49	24.41	14.25	N/A	NMNS
M24612	*Kogia sima*	77.00	68.10	26.79	41.19	34.08	48.09	26.47	38.31	31.75	14.66	35.81	18.90	29.70	NMNS
110127	*Kogia sima*	81.38	74.21	17.99	33.00	35.28	54.63	28.32	44.01	34.72	13.17	32.63	14.61	20.81	NMNS
90628	*Beradius bairdii*	174.92	121.12	59.38	90.47	83.72	102.99	54.67	73.66	54.51	8.35	21.87	47.53	16.72	NMNS
M24755	*Beradius bairdii*	182.17	149.75	41.87	N/A	102.23	119.85	65.72	98.43	76.32	N/A	25.75	32.83	N/A	NMNS
M25078	*Ziphius cavirostris*	157.40	102.58	50.83	61.91	89.50	85.41	59.32	71.54	41.33	8.76	36.50	18.19	23.50	NMNS
M24290	*Ziphius cavirostris*	149.45	96.55	19.20	62.60	57.82	89.75	36.94	70.50	44.88	13.09	19.32	52.77	32.91	NMNS
M24296	*Ziphius cavirostris*	159.59	140.19	69.96	N/A	101.49	106.58	61.17	81.46	64.80	N/A	42.50	28.46	N/A	NMNS
M54843	*Ziphius cavirostris*	153.95	120.21	88.78	113.35	108.10	100.44	62.91	76.34	59.34	16.81	50.22	29.14	42.45	NMNS
M25298	*Ziphius cavirostris*	161.67	120.72	95.94	97.88	94.65	104.26	53.82	78.25	62.76	19.42	38.72	24.03	47.79	NMNS
M32497	*Ziphius cavirostris*	133.72	116.74	44.34	65.64	68.61	85.71	58.67	64.82	48.33	9.83	32.52	22.39	42.58	NMNS
M24291	*Ziphius cavirostris*	139.36	119.73	82.92	72.32	95.11	87.37	49.01	68.48	48.31	24.83	41.29	24.47	24.81	NMNS
M26258	*Ziphius cavirostris*	139.02	111.18	72.86	75.81	93.78	89.03	54.23	67.98	45.01	17.12	42.39	16.33	44.16	NMNS
M31331	*Ziphius cavirostris*	132.27	114.63	67.67	92.30	88.16	91.14	45.96	71.47	52.80	10.88	36.78	22.12	34.08	NMNS
M33616	*Ziphius cavirostris*	127.82	113.39	66.51	84.75	78.68	90.83	53.17	60.59	47.94	10.86	41.76	27.91	36.29	NMNS
140515	*Ziphius cavirostris*	142.79	120.58	90.72	97.99	107.49	93.80	51.35	58.28	46.35	17.33	36.38	20.60	17.62	NMNS
M24294	*Ziphius cavirostris*	130.13	113.60	62.40	87.03	75.17	88.53	49.19	56.01	42.36	18.00	37.25	22.78	51.76	NMNS
M46965	*Mesoplodon carlhabbsi*	119.45	96.15	50.20	N/A	71.59	79.09	48.14	60.74	43.98	N/A	31.03	25.10	N/A	NMNS
M346867	*Mesoplodon carlhabbsi*	119.18	94.39	72.13	76.40	72.46	83.44	43.33	61.28	42.40	32.97	36.75	26.20	18.86	NMNS
M36185	*Mesoplodon carlhabbsi*	119.34	97.05	75.21	75.56	71.38	76.10	46.87	53.63	37.05	29.69	28.18	23.70	13.47	NMNS
M33090	*Mesoplodon stejnegeri*	107.18	93.26	46.16	68.68	64.46	72.14	38.13	52.60	39.23	22.09	22.15	25.33	16.78	NMNS
M35186	*Mesoplodon stejnegeri*	113.05	87.15	49.58	65.41	63.85	67.24	36.45	54.81	38.11	17.88	20.01	19.44	23.29	NMNS
M35060	*Mesoplodon stejnegeri*	111.47	93.35	62.60	59.50	56.69	73.65	37.38	54.37	40.62	14.34	27.74	18.35	15.70	NMNS
M31328	*Mesoplodon stejnegeri*	103.99	81.04	24.36	41.18	55.92	62.77	41.92	49.89	37.74	5.67	17.71	18.50	8.91	NMNS
M42143	*Mesoplodon stejnegeri*	115.53	81.46	45.36	N/A	56.49	66.93	40.68	57.71	37.64	N/A	17.23	15.54	N/A	NMNS
M32410	*Mesoplodon stejnegeri*	122.59	98.35	46.40	N/A	69.27	78.02	41.16	55.48	40.99	N/A	30.62	23.79	N/A	NMNS
M29888	*Mesoplodon stejnegeri*	111.12	96.55	46.29	57.09	59.51	71.46	36.57	52.47	44.96	11.47	20.87	16.33	25.22	NMNS
M31324	*Mesoplodon stejnegeri*	116.72	94.18	52.55	67.65	57.98	73.03	44.08	60.71	37.83	17.50	17.02	16.72	21.71	NMNS
M30134	*Mesoplodon stejnegeri*	111.34	92.45	45.49	N/A	60.62	76.16	41.22	57.40	38.48	N/A	17.69	14.69	N/A	NMNS
M42578	*Mesoplodon stejnegeri*	108.82	92.07	51.77	62.05	66.20	72.66	38.86	52.95	42.78	22.75	25.09	20.95	13.06	NMNS

APPENDIX B

Summary of DFA statistical analyses of

all zooarchaeological specimens examined

Table S2.1 Summary of Box's M test for all zooarchaeological specimens examined (N = 44) at superfamily level

SITE	SPECIMENS	Box's M	*F*	df1	df2	*P*
MAWAKI	M-1[a]	1009.424	9.135	78	2557.310	0.000
MAWAKI	M-2	632.871	6.679	72	3054.764	0.000
MAWAKI	M-3	1412.093	5.530	182	6008.241	0.000
MAWAKI	M-5	439.398	8.609	42	3202.775	0.000
MAWAKI	M-8	785.390	6.348	90	3013.768	0.000
MAWAKI	M-12	632.871	6.679	72	3054.764	0.000
MAWAKI	M-20	1412.093	5.530	182	6008.241	0.000
MAWAKI	M-21	790.321	6.387	90	3023.617	0.000
MAWAKI	M-23	303.124	8.624	30	3363.679	0.000
MAWAKI	M-28	1412.093	5.530	182	6008.241	0.000
MAWAKI	M-29	632.871	6.679	72	3054.764	0.000
MAWAKI	M-36	885.381	5.587	110	2998.968	0.000
MAWAKI	M-39	632.871	6.679	72	3054.764	0.000
MAWAKI	M-40	439.398	8.609	42	3202.775	0.000
MAWAKI	M-43	439.398	8.609	42	3202.775	0.000
MAWAKI	M-45	724.009	5.852	90	3013.768	0.000
MAWAKI	M-49	632.871	6.679	72	3054.764	0.000
MAWAKI	M-50	439.398	8.609	42	3202.775	0.000
MAWAKI	M-54	501.202	7.085	56	3115.08	0.000
MAWAKI	M-58	885.381	5.587	110	2998.968	0.000
MAWAKI	M-61	439.398	8.609	42	3202.775	0.000
MAWAKI	M-69	1412.093	5.530	182	6008.241	0.000
MAWAKI	M-87	632.871	6.679	72	3054.764	0.000
MAWAKI	M-90[a]	1009.424	9.135	78	2557.310	0.000
MAWAKI	M-91	933.384	5.893	110	2980.845	0.000
MAWAKI	M-106	632.871	6.679	72	3054.764	0.000

Table S2.1 (*continued*)

SITE	SPECIMENS	Box's M	*F*	df1	df2	*P*
MAWAKI	M-109	885.381	5.587	110	2998.968	0.000
MAWAKI	M-111[a]	1009.424	9.135	78	2557.310	0.000
MIBIKI	No.159	1412.093	5.530	182	6008.241	0.000
MIBIKI	No.161	739.086	7.801	72	3048.475	0.000
MIBIKI	No. 483	1094.392	6.300	132	6052.042	0.000
MIBIKI	No. 494	739.086	7.801	72	3048.475	0.000
MIBIKI	No. 495	483.397	9.471	42	3202.775	0.000
MIBIKI	No. 748	885.381	5.587	110	2998.968	0.000
MIBIKI	No. 749	885.381	5.587	110	2998.968	0.000
KAFUKAI-1	RKA2047	390.240	7.646	42	3202.775	0.000
KAFUKAI-1	RKA2804	464.444	9.097	42	3221.860	0.000
KAFUKAI-1	RKA3690	632.871	6.679	72	3054.764	0.000
KAFUKAI-1	RKA3982[b]	1026.822	9.291	78	2562.338	0.000
KAFUKAI-1	RKA5918[c]	943.452	8.538	78	2559.793	0.000
KAFUKAI-1	RKA15283	967.072	6.105	110	2984.584	0.000
KAFUKAI-1	RKA15547	292.868	8.332	30	3366.459	0.000
KAFUKAI-1	RKA17138	632.871	6.679	72	3054.764	0.000
KAFUKAI-1	RKA18142	1412.093	5.530	182	6008.241	0.000

[a] *Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -57.772*

[b] *Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -57.109*

[c] *Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -56.560*

Table S2.3 Summary of Wilk's Lambda value for all zooarchaeological specimens examined (N = 44) at superfamily level

SITE	SPECIMENS	Wilk's Lambda	Chi-square	df	*P*
MAWAKI	M-1	0.006	668.027	24	0.000
MAWAKI	M-2	0.010	669.023	16	0.000
MAWAKI	M-3	0.005	734.465	26	0.000
MAWAKI	M-5	0.033	518.544	12	0.000
MAWAKI	M-8	0.009	679.387	18	0.000
MAWAKI	M-12	0.010	669.023	16	0.000
MAWAKI	M-20	0.005	734.465	26	0.000
MAWAKI	M-21	0.013	601.505	18	0.000
MAWAKI	M-23	0.050	455.155	10	0.000
MAWAKI	M-28	0.005	734.465	26	0.000
MAWAKI	M-29	0.010	669.023	16	0.000
MAWAKI	M-36	0.012	590.491	20	0.000
MAWAKI	M-39	0.010	669.023	16	0.000
MAWAKI	M-40	0.033	518.544	12	0.000
MAWAKI	M-43	0.033	518.544	12	0.000
MAWAKI	M-45	0.010	674.699	18	0.000
MAWAKI	M-49	0.010	669.023	16	0.000
MAWAKI	M-50	0.033	518.544	12	0.000
MAWAKI	M-54	0.013	634.654	14	0.000
MAWAKI	M-58	0.012	590.491	20	0.000
MAWAKI	M-61	0.033	518.544	12	0.000
MAWAKI	M-69	0.005	734.465	26	0.000
MAWAKI	M-87	0.010	669.023	16	0.000
MAWAKI	M-90	0.006	668.027	24	0.000
MAWAKI	M-91	0.008	717.553	20	0.000
MAWAKI	M-106	0.010	669.023	16	0.000

Table S2.3 (*continued*)

SITE	SPECIMENS	Wilk's Lambda	Chi-square	df	*P*
MAWAKI	M-109	0.012	590.491	20	0.000
MAWAKI	M-111	0.006	668.027	24	0.000
MIBIKI	No.159	0.005	734.465	26	0.000
MIBIKI	No.161	0.015	630.573	16	0.000
MIBIKI	No. 483	0.010	651.435	22	0.000
MIBIKI	No. 494	0.015	630.573	16	0.000
MIBIKI	No. 495	0.023	571.674	12	0.000
MIBIKI	No. 748	0.012	590.491	20	0.000
MIBIKI	No. 749	0.012	590.491	20	0.000
KAFUKAI-1	RKA2047	0.039	491.064	12	0.000
KAFUKAI-1	RKA2804	0.028	493.979	12	0.000
KAFUKAI-1	RKA3690	0.010	669.023	16	0.000
KAFUKAI-1	RKA3982	0.009	606.771	24	0.000
KAFUKAI-1	RKA5918	0.010	606.436	24	0.000
KAFUKAI-1	RKA15283	0.007	714.531	20	0.000
KAFUKAI-1	RKA15547	0.015	628.120	10	0.000
KAFUKAI-1	RKA17138	0.010	669.023	16	0.000
KAFUKAI-1	RKA18142	0.005	734.465	26	0.000

Table S2.4 Summary of percentage of variance explained by each canonical discriminant function of eighteen toothed whale species from three superfamilies for all zooarchaeological specimens examined (N = 44)

SITE	SPECIMENS	Function 1[a]		Function 2[a]	
		Eigenvalue	% of Variance	Eigenvalue	% of Variance
MAWAKI	M-1	73.677	98.5	1.153	1.5
MAWAKI	M-2	52.307	98.4	0.863	1.6
MAWAKI	M-3	78.570	98.0	1.574	2.0
MAWAKI	M-5	19.698	97.6	0.481	2.4
MAWAKI	M-8	65.747	99.1	0.623	0.9
MAWAKI	M-12	52.307	98.4	0.863	1.6
MAWAKI	M-20	78.570	98.0	1.574	2.0
MAWAKI	M-21	44.814	98.4	0.706	1.6
MAWAKI	M-23	13.690	97.4	0.360	2.6
MAWAKI	M-28	78.570	98.0	1.574	2.0
MAWAKI	M-29	52.307	98.4	0.863	1.6
MAWAKI	M-36	45.942	98.5	0.718	1.5
MAWAKI	M-39	52.307	98.4	0.863	1.6
MAWAKI	M-40	19.698	97.6	0.481	2.4
MAWAKI	M-43	19.698	97.6	0.481	2.4
MAWAKI	M-45	54.117	98.4	0.903	1.6
MAWAKI	M-49	52.307	98.4	0.863	1.6
MAWAKI	M-50	19.698	97.6	0.481	2.4
MAWAKI	M-54	43.609	98.4	0.732	1.6
MAWAKI	M-58	45.942	98.5	0.718	1.5
MAWAKI	M-61	19.698	97.6	0.481	2.4
MAWAKI	M-69	78.570	98.0	1.574	2.0
MAWAKI	M-87	52.307	98.4	0.863	1.6

Table S2.4 (*continued*)

SITE	SPECIMENS	Function 1[a]		Function 2[a]	
		Eigenvalue	% of Variance	Eigenvalue	% of Variance
MAWAKI	M-90	73.677	98.5	1.153	1.5
MAWAKI	M-91	67.326	98.7	0.897	1.3
MAWAKI	M-106	52.307	98.4	0.863	1.6
MAWAKI	M-109	45.942	98.5	0.718	1.5
MAWAKI	M-111	73.677	98.5	1.153	1.5
MIBIKI	No.159	78.570	98.0	1.574	2.0
MIBIKI	No.161	41.825	98.7	0.541	1.3
MIBIKI	No. 483	51.267	98.3	0.880	1.7
MIBIKI	No. 494	41.825	98.7	0.541	1.3
MIBIKI	No. 495	28.666	98.4	0.467	1.6
MIBIKI	No. 748	45.942	98.5	0.718	1.5
MIBIKI	No. 749	45.942	98.5	0.718	1.5
KAFUKAI-1	RKA2047	16.854	97.5	0.432	2.5
KAFUKAI-1	RKA2804	20.566	97.0	0.641	3.0
KAFUKAI-1	RKA3690	52.307	98.4	0.863	1.6
KAFUKAI-1	RKA3982	50.766	97.9	1.093	2.1
KAFUKAI-1	RKA5918	57.222	98.6	0.791	1.4
KAFUKAI-1	RKA15283	73.684	98.8	0.881	1.2
KAFUKAI-1	RKA15547	38.293	98.3	0.676	1.7
KAFUKAI-1	RKA17138	52.307	98.4	0.863	1.6
KAFUKAI-1	RKA18142	78.570	98.0	1.574	2.0

[a] First 2 canonical functions were used in the analyses

Table S2.5 Summary of Box's M tests for all zooarchaeological specimens examined (N = 44) at family level

SITE	SPECIMENS	Box's M	*F*	df1	df2	*P*
MAWAKI	M-1[a]	1202.768	5.860	156	6904.757	0.000
MAWAKI	M-2	792.246	5.928	108	5297.998	0.000
MAWAKI	M-3	1624.679	4.413	273	10786.867	0.000
MAWAKI	M-5	530.558	7.236	63	5477.436	0.000
MAWAKI	M-8	975.047	5.648	135	5239.554	0.000
MAWAKI	M-12	792.246	5.928	108	5297.998	0.000
MAWAKI	M-20	1624.679	4.413	273	10786.867	0.000
MAWAKI	M-21	944.180	5.413	135	5416.126	0.000
MAWAKI	M-23	376.668	7.396	45	5702.059	0.000
MAWAKI	M-28	1624.679	4.413	273	10786.867	0.000
MAWAKI	M-29	792.246	5.928	108	5297.998	0.000
MAWAKI	M-36	1031.869	4.643	165	5417.801	0.000
MAWAKI	M-39	792.246	5.928	108	5297.998	0.000
MAWAKI	M-40	530.558	7.236	63	5477.436	0.000
MAWAKI	M-43	530.558	7.236	63	5477.436	0.000
MAWAKI	M-45	890.884	5.161	135	5239.554	0.000
MAWAKI	M-49	792.246	5.928	108	5297.998	0.000
MAWAKI	M-50	530.558	7.236	63	5477.436	0.000
MAWAKI	M-54	642.937	6.381	84	5383.756	0.000
MAWAKI	M-58	1031.869	4.643	165	5417.801	0.000
MAWAKI	M-61	530.558	7.236	63	5477.436	0.000
MAWAKI	M-69	1624.679	4.413	273	10786.867	0.000
MAWAKI	M-87	792.246	5.928	108	5297.998	0.000
MAWAKI	M-90 [a]	1202.768	5.860	156	6904.757	0.000
MAWAKI	M-91	1120.197	4.040	198	5390.149	0.000

Table S2.5 (*continued*)

SITE	SPECIMENS	Box's M	*F*	df1	df2	*P*
MAWAKI	M-106	792.246	5.928	108	5297.998	0.000
MAWAKI	M-109	1031.869	4.643	165	5417.801	0.000
MAWAKI	M-111[a]	1202.768	5.860	156	6904.757	0.000
MIBIKI	No.159	1624.679	4.413	273	10786.867	0.000
MIBIKI	No.161	907.549	6.797	108	5260.222	0.000
MIBIKI	No. 483	1120.197	4.040	198	5390.149	0.000
MIBIKI	No. 494	907.549	6.797	108	5260.222	0.000
MIBIKI	No. 495	633.632	8.642	63	5477.436	0.000
MIBIKI	No. 748	1031.869	4.643	165	5417.801	0.000
MIBIKI	No. 749	1031.869	4.643	165	5417.801	0.000
KAFUKAI-1	RKA2047	505.091	6.889	63	5477.436	0.000
KAFUKAI-1	RKA2804	595.670	8.064	63	5715.815	0.000
KAFUKAI-1	RKA3690	792.246	5.928	108	5297.998	0.000
KAFUKAI-1	RKA3982[b]	1238.424	6.031	156	6930.392	0.000
KAFUKAI-1	RKA5918[c]	1143.165	5.568	156	6917.398	0.000
KAFUKAI-1	RKA15283	1199.661	5.439	165	5197.870	0.000
KAFUKAI-1	RKA15547	397.748	7.810	45	5713.564	0.000
KAFUKAI-1	RKA17138	792.246	5.928	108	5297.998	0.000
KAFUKAI-1	RKA18142	1624.679	4.413	273	10786.867	0.000

[a] *Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -58.399*

[b] *Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -57.728*

[c] *Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -56.115*

Table S2.6 Summary of Wilk's Lambda value for all zooarchaeological specimens examined (N = 44) at family level

SITE	SPECIMENS	Wilk's Lambda	Chi-square	df	*P*
MAWAKI	M-1	0.003	760.179	36	0.000
MAWAKI	M-2	0.007	717.631	24	0.000
MAWAKI	M-3	0.002	829.082	39	0.000
MAWAKI	M-5	0.023	567.034	18	0.000
MAWAKI	M-8	0.006	727.718	27	0.000
MAWAKI	M-12	0.007	717.631	24	0.000
MAWAKI	M-20	0.002	829.082	39	0.000
MAWAKI	M-21	0.009	640.956	27	0.000
MAWAKI	M-23	0.036	503.430	15	0.000
MAWAKI	M-28	0.002	829.082	39	0.000
MAWAKI	M-29	0.007	717.631	24	0.000
MAWAKI	M-36	0.006	680.561	30	0.000
MAWAKI	M-39	0.007	717.631	24	0.000
MAWAKI	M-40	0.023	567.034	18	0.000
MAWAKI	M-43	0.023	567.034	18	0.000
MAWAKI	M-45	0.007	724.685	27	0.000
MAWAKI	M-49	0.007	717.631	24	0.000
MAWAKI	M-50	0.023	567.034	18	0.000
MAWAKI	M-54	0.009	681.732	21	0.000
MAWAKI	M-58	0.006	680.561	30	0.000
MAWAKI	M-61	0.023	567.034	18	0.000
MAWAKI	M-69	0.002	829.082	39	0.000
MAWAKI	M-87	0.007	717.631	24	0.000
MAWAKI	M-90	0.003	760.179	36	0.000
MAWAKI	M-91	0.005	769.158	30	0.000
MAWAKI	M-106	0.007	717.631	24	0.000

Table S2.6 (*continued*)

SITE	SPECIMENS	Wilk's Lambda	Chi-square	df	*P*
MAWAKI	M-109	0.006	680.561	30	0.000
MAWAKI	M-111	0.003	760.179	36	0.000
MIBIKI	No.159	0.002	829.082	39	0.000
MIBIKI	No.161	0.011	678.870	24	0.000
MIBIKI	No. 483	0.005	702.041	33	0.000
MIBIKI	No. 494	0.011	678.870	24	0.000
MIBIKI	No. 495	0.017	618.975	18	0.000
MIBIKI	No. 748	0.006	680.561	30	0.000
MIBIKI	No. 749	0.006	680.561	30	0.000
KAFUKAI-1	RKA2047	0.028	538.688	18	0.000
KAFUKAI-1	RKA2804	0.021	532.885	18	0.000
KAFUKAI-1	RKA3690	0.007	717.631	24	0.000
KAFUKAI-1	RKA3982	0.005	696.846	36	0.000
KAFUKAI-1	RKA5918	0.005	694.026	36	0.000
KAFUKAI-1	RKA15283	0.005	763.083	30	0.000
KAFUKAI-1	RKA15547	0.011	673.968	15	0.000
KAFUKAI-1	RKA17138	0.007	717.631	24	0.000
KAFUKAI-1	RKA18142	0.002	829.082	39	0.000

Table S2.7 Summary of percentage of variance explained by each canonical discriminant function of eighteen toothed whale species from four families for all zooarchaeological specimens examined (N = 44)

SITE	SPECIMENS	Function 1 [a]		Function 2 [a]		Function 3 [a]	
		Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance
MAWAKI	M-1	73.726	96.9	1.763	2.3	0.604	0.8
MAWAKI	M-2	52.720	97.3	1.287	2.4	0.148	0.3
MAWAKI	M-3	78.571	96.6	2.066	2.5	0.704	0.9
MAWAKI	M-5	19.775	95.3	0.902	4.3	0.082	0.4
MAWAKI	M-8	66.311	98.3	1.043	1.5	0.119	0.2
MAWAKI	M-12	52.720	97.3	1.287	2.4	0.148	0.3
MAWAKI	M-20	78.571	96.6	2.066	2.5	0.704	0.9
MAWAKI	M-21	45.087	97.6	0.873	1.9	0.226	0.5
MAWAKI	M-23	13.901	94.5	0.753	5.1	0.062	0.4
MAWAKI	M-28	78.571	96.6	2.066	2.5	0.704	0.9
MAWAKI	M-29	52.720	97.3	1.287	2.4	0.148	0.3
MAWAKI	M-36	46.007	96.3	1.267	2.7	0.507	1.1
MAWAKI	M-39	52.720	97.3	1.287	2.4	0.148	0.3
MAWAKI	M-40	19.775	95.3	0.902	4.3	0.082	0.4
MAWAKI	M-43	19.775	95.3	0.902	4.3	0.082	0.4
MAWAKI	M-45	54.368	97.3	1.370	2.5	0.148	0.3
MAWAKI	M-49	52.720	97.3	1.287	2.4	0.148	0.3
MAWAKI	M-50	19.775	95.3	0.902	4.3	0.082	0.4
MAWAKI	M-54	43.696	97.2	1.134	2.5	0.136	0.3
MAWAKI	M-58	46.007	96.3	1.267	2.7	0.507	1.1
MAWAKI	M-61	19.775	95.3	0.902	4.3	0.082	0.4
MAWAKI	M-69	78.571	96.6	2.066	2.5	0.704	0.9

Table S2.7 (*continued*)

SITE	SPECIMENS	Function 1 [a]		Function 2 [a]		Function 3 [a]	
		Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance
MAWAKI	M-87	52.720	97.3	1.287	2.4	0.148	0.3
MAWAKI	M-90	73.726	96.9	1.763	2.3	0.604	0.8
MAWAKI	M-91	67.905	97.8	1.344	1.9	0.163	0.2
MAWAKI	M-106	52.720	97.3	1.287	2.4	0.148	0.3
MAWAKI	M-109	46.007	96.3	1.267	2.7	0.507	1.1
MAWAKI	M-111	73.726	96.9	1.763	2.3	0.604	0.8
MIBIKI	No.159	78.571	96.6	2.066	2.5	0.704	0.9
MIBIKI	No.161	41.928	97.6	0.924	2.1	0.119	0.3
MIBIKI	No. 483	56.985	96.9	1.283	2.2	0.511	0.9
MIBIKI	No. 494	41.928	97.6	0.924	2.1	0.119	0.3
MIBIKI	No. 495	28.785	96.8	0.878	3.0	0.780	0.3
MIBIKI	No. 748	46.007	96.3	1.267	2.7	0.507	1.1
MIBIKI	No. 749	46.007	96.3	1.267	2.7	0.507	1.1
KAFUKAI-1	RKA2047	17.072	94.8	0.900	5.0	0.032	0.2
KAFUKAI-1	RKA2804	20.594	95.2	0.818	3.8	0.211	1.0
KAFUKAI-1	RKA3690	52.720	97.3	1.287	2.4	0.148	0.3
KAFUKAI-1	RKA3982	50.766	95.7	1.741	3.3	0.563	1.1
KAFUKAI-1	RKA5918	57.511	96.9	1.321	2.2	0.533	0.9
KAFUKAI-1	RKA15283	74.010	98.1	1.310	1.7	0.155	0.2
KAFUKAI-1	RKA15547	38.790	97.1	1.004	2.5	0.138	0.3
KAFUKAI-1	RKA17138	52.720	97.3	1.287	2.4	0.148	0.3
KAFUKAI-1	RKA18142	78.571	96.6	2.066	2.5	0.704	0.9

[a] First 3 canonical functions were used in the analyses

Table S2.8 Summary of Box's M test for all zooarchaeological specimens examined at subfamily level

SITE	SPECIMENS	Box's M	*F*	df1	df2	*P*
MAWAKI	M-1[b]	550.338	2.499	156	5911.574	0.000
MAWAKI	M-2	354.269	1.892	144	5796.824	0.000
MAWAKI	M-3[a]	737.524	2.723	182	5.547.187	0.000
MAWAKI	M-5	208.103	2.068	84	6095.442	0.000
MAWAKI	M-8	484.699	1.986	180	5736.102	0.000
MAWAKI	M-12	354.269	1.892	144	5796.824	0.000
MAWAKI	M-20[a]	737.524	2.723	182	5.547.187	0.000
MAWAKI	M-21	489.915	1.885	180	4307.032	0.000
MAWAKI	M-23	166.592	2.397	60	6334.337	0.000
MAWAKI	M-28[a]	737.524	2.723	182	5.547.187	0.000
MAWAKI	M-29	354.269	1.892	144	5796.824	0.000
MAWAKI	M-36[h]	421.179	2.933	110	6286.683	0.000
MAWAKI	M-39	354.269	1.892	144	5796.824	0.000
MAWAKI	M-40	208.103	2.068	84	6095.442	0.000
MAWAKI	M-43	208.103	2.068	84	6095.442	0.000
MAWAKI	M-45	488.863	2.003	180	5736.102	0.000
MAWAKI	M-49	354.269	1.892	144	5796.824	0.000
MAWAKI	M-50	208.103	2.068	84	6095.442	0.000
MAWAKI	M-54	283.342	2.023	112	5886.192	0.000
MAWAKI	M-58[h]	421.179	2.933	110	6286.683	0.000
MAWAKI	M-61	208.103	2.068	84	6095.442	0.000
MAWAKI	M-69[a]	737.524	2.723	182	5.547.187	0.000
MAWAKI	M-87	354.269	1.892	144	5796.824	0.000
MAWAKI	M-90[b]	550.338	2.499	156	5911.574	0.000
MAWAKI	M-91[f]	458.703	2.155	165	8613.470	0.000
MAWAKI	M-106	354.269	1.892	144	5796.824	0.000

Table S2.8 (*continued*)

SITE	SPECIMENS	Box's M	*F*	df1	df2	*P*
MAWAKI	M-109[h]	421.179	2.933	110	6286.683	0.000
MAWAKI	M-111[b]	550.338	2.499	156	5911.574	0.000
MIBIKI	No. 159[a]	737.524	2.723	182	5.547.187	0.000
MIBIKI	No. 161	373.297	2.010	144	5865.893	0.000
MIBIKI	No. 483[e]	469.543	2.612	132	5923.426	0.000
MIBIKI	No. 494	373.297	2.010	144	5865.893	0.000
MIBIKI	No. 495	259.508	2.578	84	6095.442	0.000
MIBIKI	No. 748[h]	421.179	2.933	110	6286.683	0.000
MIBIKI	No. 749[h]	421.179	2.933	110	6286.683	0.000
KAFUKAI-1	RKA2047	251.951	2.503	84	6095.442	0.000
KAFUKAI-1	RKA2804	324.176	3.087	84	4521.812	0.000
KAFUKAI-1	RKA3690	354.269	1.892	144	5796.824	0.000
KAFUKAI-1	RKA3982[c]	671.197	3.007	156	5572.621	0.000
KAFUKAI-1	RKA5918[d]	646.957	2.900	156	5550.984	0.000
KAFUKAI-1	RKA15283[g]	487.284	2.268	165	8237.825	0.000
KAFUKAI-1	RKA15547	176.143	2.530	60	6299.790	0.000
KAFUKAI-1	RKA17138	354.269	1.892	144	5796.824	0.000
KAFUKAI-1	RKA18142[a]	737.524	2.723	182	5547.187	0.000

[a] *Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -70.554*
[b] *Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -66.123*
[c] *Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -65.513*
[d] *Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -63.515*

Table S2.8 (*continued*)

[e] *Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -59.458*
[f] *Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -59.328*
[g] *Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -59.430*

Table S2.9 Summary of Wilk's Lambda for all zooarchaeological specimens examined (N = 44) at subfamily level

SITE	SPECIMENS	Wilk's Lambda	Chi-square	df	*P*
MAWAKI	M-1	0.021	391.313	48	0.000
MAWAKI	M-2	0.068	310.212	32	0.000
MAWAKI	M-3	0.021	380.689	52	0.000
MAWAKI	M-5	0.087	296.368	24	0.000
MAWAKI	M-8	0.070	305.683	36	0.000
MAWAKI	M-12	0.068	310.212	32	0.000
MAWAKI	M-20	0.021	380.689	52	0.000
MAWAKI	M-21	0.059	305.945	36	0.000
MAWAKI	M-23	0.111	268.262	20	0.000
MAWAKI	M-28	0.021	380.689	52	0.000
MAWAKI	M-29	0.068	310.212	32	0.000
MAWAKI	M-36	0.030	368.085	40	0.000
MAWAKI	M-39	0.068	310.212	32	0.000
MAWAKI	M-40	0.087	296.368	24	0.000
MAWAKI	M-43	0.087	296.368	24	0.000
MAWAKI	M-45	0.059	324.873	36	0.000
MAWAKI	M-49	0.068	310.212	32	0.000
MAWAKI	M-50	0.087	296.368	24	0.000
MAWAKI	M-54	0.081	292.207	28	0.000
MAWAKI	M-58	0.030	368.085	40	0.000
MAWAKI	M-61	0.087	296.368	24	0.000
MAWAKI	M-69	0.021	380.689	52	0.000
MAWAKI	M-87	0.068	310.212	32	0.000
MAWAKI	M-90	0.021	391.313	48	0.000

Table S2.9 (continued)

SITE	SPECIMENS	Wilk's Lambda	Chi-square	df	*P*
MAWAKI	M-91	0.046	361.775	40	0.000
MAWAKI	M-106	0.068	310.212	32	0.000
MAWAKI	M-109	0.030	368.085	40	0.000
MAWAKI	M-111	0.021	391.313	48	0.000
MIBIKI	No. 159	0.021	380.689	52	0.000
MIBIKI	No. 161	0.066	327.309	32	0.000
MIBIKI	No. 483	0.026	374.141	44	0.000
MIBIKI	No. 494	0.066	327.309	32	0.000
MIBIKI	No. 495	0.092	290.483	24	0.000
MIBIKI	No. 748	0.030	368.085	40	0.000
MIBIKI	No. 749	0.030	368.085	40	0.000
KAFUKAI-1	RKA2047	0.082	303.518	24	0.000
KAFUKAI-1	RKA2804	0.077	278.814	24	0.000
KAFUKAI-1	RKA3690	0.068	310.212	32	0.000
KAFUKAI-1	RKA3982	0.025	268.980	48	0.000
KAFUKAI-1	RKA5918	0.026	367.986	48	0.000
KAFUKAI-1	RKA15283	0.053	335.988	40	0.000
KAFUKAI-1	RKA15547	0.096	280.666	20	0.000
KAFUKAI-1	RKA17138	0.068	310.212	32	0.000
KAFUKAI-1	RKA18142	0.021	380.689	52	0.000

Table S2.10 Summary of percentage of variance explained by each canonical discriminant function of eighteen toothed whale species from five subfamilies for all zooarchaeological specimens examined (N = 44)

SITE	SPECIMENS	Function 1[a]		Function 2[a]		Function 3[a]		Function 4[a]	
		Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance
MAWAKI	M-1	6.368	68.2	2.063	22.1	0.615	6.6	0.296	3.2
MAWAKI	M-2	5.364	84.5	0.513	8.1	0.319	5.0	0.155	2.4
MAWAKI	M-3	6.169	67.3	2.058	22.5	0.638	7.0	0.303	3.3
MAWAKI	M-5	5.500	89.3	0.453	7.3	0.181	2.9	0.028	0.5
MAWAKI	M-8	5.318	84.3	0.644	10.2	0.226	3.6	0.120	1.9
MAWAKI	M-12	5.364	84.5	0.513	8.1	0.319	5.0	0.155	2.4
MAWAKI	M-20	6.169	67.3	2.058	22.5	0.638	7.0	0.303	3.3
MAWAKI	M-21	5.623	82.8	0.633	9.3	0.448	6.6	0.085	1.3
MAWAKI	M-23	5.454	93.7	0.253	4.3	0.087	1.5	0.026	0.4
MAWAKI	M-28	6.169	67.3	2.058	22.5	0.638	7.0	0.303	3.3
MAWAKI	M-29	5.364	84.5	0.513	8.1	0.319	5.0	0.155	2.4
MAWAKI	M-36	6.375	72.3	1.893	21.5	0.459	5.2	0.088	1.0
MAWAKI	M-39	5.364	84.5	0.513	8.1	0.319	5.0	0.155	2.4
MAWAKI	M-40	5.500	89.3	0.453	7.3	0.181	2.9	0.028	0.5
MAWAKI	M-43	5.500	89.3	0.453	7.3	0.181	2.9	0.028	0.5
MAWAKI	M-45	5.364	81.9	0.615	9.4	0.381	5.8	0.188	2.9
MAWAKI	M-49	5.364	84.5	0.513	8.1	0.319	5.0	0.155	2.4
MAWAKI	M-50	5.500	89.3	0.453	7.3	0.181	2.9	0.028	0.5
MAWAKI	M-54	4.806	84.2	0.513	9.0	0.293	5.1	0.093	1.6
MAWAKI	M-58	6.375	72.3	1.893	21.5	0.459	5.2	0.088	1.0
MAWAKI	M-61	5.500	89.3	0.453	7.3	0.181	2.9	0.028	0.5
MAWAKI	M-69	6.169	67.3	2.058	22.5	0.638	7.0	0.303	3.3

[a] First 4 canonical functions were used in the analyses

Table S2.10 (continued)

SITE	SPECIMENS	Function 1[a]		Function 2[a]		Function 3[a]		Function 4[a]	
		Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance
MAWAKI	M-87	5.364	84.5	0.513	8.1	0.319	5.0	0.155	2.4
MAWAKI	M-90	6.368	68.2	2.063	22.1	0.615	6.6	0.296	3.2
MAWAKI	M-91	5.503	78.4	0.731	10.4	0.471	6.7	0.312	4.5
MAWAKI	M-106	5.364	84.5	0.513	8.1	0.319	5.0	0.155	2.4
MAWAKI	M-109	6.375	72.3	1.893	21.5	0.459	5.2	0.088	1.0
MAWAKI	M-111	6.368	68.2	2.063	22.1	0.615	6.6	0.296	3.2
MIBIKI	No.159	6.169	67.3	2.058	22.5	0.638	7.0	0.303	3.3
MIBIKI	No.161	5.528	84.4	0.550	8.4	0.432	6.6	0.044	0.7
MIBIKI	No. 483	6.195	69.9	1.943	21.9	0.613	6.9	0.107	1.2
MIBIKI	No. 494	5.528	84.4	0.550	8.4	0.432	6.6	0.044	0.7
MIBIKI	No. 495	5.371	89.4	0.489	8.1	0.114	1.9	0.034	0.6
MIBIKI	No. 748	6.375	72.3	1.893	21.5	0.459	5.2	0.088	1.0
MIBIKI	No. 749	6.375	72.3	1.893	21.5	0.459	5.2	0.088	1.0
KAFUKAI-1	RKA2047	5.426	87.9	0.431	7.0	0.277	4.5	0.035	0.6
KAFUKAI-1	RKA2804	4.963	83.8	0.62	10.5	0.302	5.1	0.039	0.7
KAFUKAI-1	RKA3690	5.364	84.5	0.513	8.1	0.319	5.0	0.155	2.4
KAFUKAI-1	RKA3982	6.049	68.3	2.058	23.2	0.455	5.1	0.300	3.4
KAFUKAI-1	RKA5918	6.075	68.9	1.972	22.4	0.623	7.1	0.140	1.6
KAFUKAI-1	RKA15283	5.370	80.1	0.649	9.7	0.461	6.9	0.226	3.4
KAFUKAI-1	RKA15547	4.459	85.4	0.517	9.9	0.199	3.8	0.044	0.8
KAFUKAI-1	RKA17138	5.364	84.5	0.513	8.1	0.319	5.0	0.155	2.4
KAFUKAI-1	RKA18142	6.169	67.3	2.058	22.5	0.638	7.0	0.303	3.3

[a] First 4 canonical functions were used in the analyses

Table S2.11 Summary of Box's M test for all zooarchaeological specimens examined (N = 44) at species level

SITE	SPECIMENS	Box's M	*F*	df1	df2	*P*
MAWAKI	M-1[a]	-	-	-	-	-
MAWAKI	M-2[h]	1344.404	2.469	360	9453.311	0.000
MAWAKI	M-3[a]	-	-	-	-	-
MAWAKI	M-5[j]	933.534	2.273	294	9167.651	0.000
MAWAKI	M-8[f]	1762.581	2.718	405	9046.773	0.000
MAWAKI	M-12[h]	1344.404	2.469	360	9453.311	0.000
MAWAKI	M-20[a]	-	-	-	-	-
MAWAKI	M-21[g]	1875.956	2.482	450	9121.655	0.000
MAWAKI	M-23[o]	543.892	1.985	210	9482.513	0.000
MAWAKI	M-28[a]	-	-	-	-	-
MAWAKI	M-29[h]	1344.404	2.469	360	9453.311	0.000
MAWAKI	M-36[d]	1373.255	3.470	220	4707.821	0.000
MAWAKI	M-39[h]	1344.404	2.469	360	9453.311	0.000
MAWAKI	M-40[j]	933.534	2.273	294	9167.651	0.000
MAWAKI	M-43[j]	933.534	2.273	294	9167.651	0.000
MAWAKI	M-45[e]	1703.325	2.626	405	9046.773	0.000
MAWAKI	M-49[h]	1344.404	2.469	360	9453.311	0.000
MAWAKI	M-50[j]	933.534	2.273	294	9167.651	0.000
MAWAKI	M-54[i]	1095.681	2.472	308	9454.385	0.000
MAWAKI	M-58[d]	1373.255	3.470	220	4707.821	0.000
MAWAKI	M-61[j]	933.534	2.273	294	9167.651	0.000
MAWAKI	M-69[a]	-	-	-	-	-
MAWAKI	M-87[h]	1344.404	2.469	360	9453.311	0.000
MAWAKI	M-90[a]	-	-	-	-	-
MAWAKI	M-91[b]	1825.794	3.360	330	7473.908	0.000
MAWAKI	M-106[h]	1344.404	2.469	360	9453.311	0.000

Table S2.11 (*continued*)

SITE	SPECIMENS	Box's M	*F*	df1	df2	*P*
MAWAKI	M-109[d]	1373.255	3.470	220	4707.821	0.000
MAWAKI	M-111[a]	-	-	-	-	-
MIBIKI	No. 159[a]	-	-	-	-	-
MIBIKI	No. 161[g]	1627.891	2.740	396	10630.23	0.000
MIBIKI	No. 483[a]	-	-	-	-	-
MIBIKI	No. 494[g]	1627.891	2.740	396	10630.23	0.000
MIBIKI	No. 495[m]	1153.144	2.807	294	9167.651	0.000
MIBIKI	No. 748[d]	1373.255	3.470	220	4707.821	0.000
MIBIKI	No. 749[d]	1373.255	3.470	220	4707.821	0.000
KAFUKAI-1	RKA2047[k]	971.767	2.366	294	9167.651	0.000
KAFUKAI-1	RKA2804[l]	1160.675	3.018	273	9019.245	0.000
KAFUKAI-1	RKA3690[h]	1344.404	2.469	360	9453.311	0.000
KAFUKAI-1	RKA3982[a]	-	-	-	-	-
KAFUKAI-1	RKA5918[a]	-	-	-	-	-
KAFUKAI-1	RKA15283[c]	1641.383	3.644	275	6588.616	0.000
KAFUKAI-1	RKA15547[n]	678.237	2.449	210	8549.30	0.000
KAFUKAI-1	RKA17138[h]	1344.404	2.469	360	9453.311	0.000
KAFUKAI-1	RKA18142[a]	-	-	-	-	-

a No test can be performed with fewer than two nonsingular group covariance matrices
b Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -50.426
c Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -49.433
d Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -44.845
e Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -48.032

Table S2.11 (*continued*)

f Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -48.000

g Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -47.168

h Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -44.144

i Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -38.737

j Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -34.820

k Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -34.820

l Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -29.105

m Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -32.207

n Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -27.125

o Some covariances matrices are singular and the usual procedure will not work. The non-singular groups will be tested against their own pooled within-groups covariance matrix. The log of its determinant is -29.119

Table S2.12 Summary of Wilk's Lambda value for all zooarchaeological specimens examined at species level

SITE	SPECIMENS	Wilk's Lambda	Chi-square	df	*P*
MAWAKI	M-1	0.000	1789.107	204	0.000
MAWAKI	M-2	0.000	1573.581	136	0.000
MAWAKI	M-3	0.000	1826.003	221	0.000
MAWAKI	M-5	0.000	1288.711	102	0.000
MAWAKI	M-8	0.000	1679.246	153	0.000
MAWAKI	M-12	0.000	1573.581	136	0.000
MAWAKI	M-20	0.000	1826.003	221	0.000
MAWAKI	M-21	0.000	1427.058	153	0.000
MAWAKI	M-23	0.000	1198.135	85	0.000
MAWAKI	M-28	0.000	1826.003	221	0.000
MAWAKI	M-29	0.000	1573.581	136	0.000
MAWAKI	M-36	0.000	1543.276	170	0.000
MAWAKI	M-39	0.000	1573.581	136	0.000
MAWAKI	M-40	0.000	1288.711	102	0.000
MAWAKI	M-43	0.000	1288.711	102	0.000
MAWAKI	M-45	0.000	1644.926	153	0.000
MAWAKI	M-49	0.000	1573.581	136	0.000
MAWAKI	M-50	0.000	1288.711	102	0.000
MAWAKI	M-54	0.000	1095.681	119	0.000
MAWAKI	M-58	0.000	1543.276	170	0.000
MAWAKI	M-61	0.000	1288.711	102	0.000
MAWAKI	M-69	0.000	1826.003	221	0.000
MAWAKI	M-87	0.000	1573.581	136	0.000
MAWAKI	M-90	0.000	1789.107	204	0.000
MAWAKI	M-91	0.000	1767.933	170	0.000
MAWAKI	M-106	0.000	1573.581	136	0.000

Table S2.12 (*continued*)

SITE	SPECIMENS	Wilk's Lambda	Chi-square	df	*P*
MAWAKI	M-109	0.000	1543.276	170	0.000
MAWAKI	M-111	0.000	1789.107	204	0.000
MIBIKI	No. 159	0.000	1826.003	221	0.000
MIBIKI	No. 161	0.000	1483.233	136	0.000
MIBIKI	No. 483	0.000	1626.364	187	0.000
MIBIKI	No. 494	0.000	1483.233	136	0.000
MIBIKI	No. 495	0.000	1187.285	102	0.000
MIBIKI	No. 748	0.000	1543.276	170	0.000
MIBIKI	No. 749	0.000	1543.276	170	0.000
KAFUKAI-1	RKA2047	0.000	1219.805	102	0.000
KAFUKAI-1	RKA2804	0.000	1084.001	102	0.000
KAFUKAI-1	RKA3690	0.000	1573.581	136	0.000
KAFUKAI-1	RKA3982	0.000	1714.695	204	0.000
KAFUKAI-1	RKA5918	0.000	1668.104	204	0.000
KAFUKAI-1	RKA15283	0.000	1732.033	170	0.000
KAFUKAI-1	RKA15547	0.000	1254.599	85	0.000
KAFUKAI-1	RKA17138	0.000	1573.581	136	0.000
KAFUKAI-1	RKA18142	0.000	1826.003	221	0.000

Table S2.13 Summary of percentage of variance explained by each canonical discriminant function of eighteen toothed whale species for Early Jomon Mawaki zooarchaeological specimens examined (N = 28)

SPECIMENS	Function 1		Function 2		Function 3		Function 4		Function 5		Function 6	
	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance
M-1	98.855	77.0	18.541	14.4	4.310	3.4	2.292	1.8	1.849	1.4	1.146	0.9
M-2	79.515	77.8	17.088	16.7	2.494	2.4	1.496	1.5	0.880	0.9	0.354	0.3
M-3	100.646	77.0	18.225	13.9	4.313	3.3	2.267	1.7	1.866	1.4	1.332	1.0
M-5	46.701	71.0	16.817	25.6	1.296	2.0	0.448	0.7	0.357	0.5	0.187	0.3
M-8	87.499	77.9	18.129	16.1	2.953	2.6	1.347	1.2	1.049	0.9	0.823	0.7
M-12	79.515	77.8	17.088	16.7	2.494	2.4	1.496	1.5	0.880	0.9	0.354	0.3
M-20	100.646	77.0	18.225	13.9	4.313	3.3	2.267	1.7	1.866	1.4	1.332	1.0
M-21	73.071	76.1	18.620	19.4	1.873	2.0	1.107	1.2	0.540	0.6	0.411	0.4
M-23	41.176	69.5	16.520	27.9	0.973	1.6	0.398	0.7	0.204	0.3		
M-28	100.646	77.0	18.225	13.9	4.313	3.3	2.267	1.7	1.866	1.4	1.332	1.0
M-29	79.515	77.8	17.088	16.7	2.494	2.4	1.496	1.5	0.880	0.9	0.354	0.3
M-36	72.975	74.4	18.396	18.7	2.765	2.8	1.855	1.9	0.934	1.0	0.493	0.5
M-39	79.515	77.8	17.088	16.7	2.494	2.4	1.496	1.5	0.880	0.9	0.354	0.3
M-40	46.701	71.0	16.817	25.6	1.296	2.0	0.448	0.7	0.357	0.5	0.187	0.3
M-43	46.701	71.0	16.817	25.6	1.296	2.0	0.448	0.7	0.357	0.5	0.187	0.3
M-45	79.842	76.9	17.403	16.8	2.662	2.6	1.516	1.5	1.405	1.4	0.462	0.4
M-49	79.515	77.8	17.088	16.7	2.494	2.4	1.496	1.5	0.88	0.9	0.354	0.3
M-50	46.701	71.0	16.817	25.6	1.296	2.0	0.448	0.7	0.357	0.5	0.187	0.3
M-54	74.272	78.2	16.620	17.5	2.313	2.4	0.901	0.9	0.372	0.4	0.273	0.3
M-58	72.975	74.4	18.396	18.7	2.765	2.8	1.855	1.9	0.934	1.0	0.493	0.5
M-61	46.701	71.0	16.817	25.6	1.296	2.0	0.448	0.7	0.357	0.5	0.187	0.3
M-69	100.646	77.0	18.225	13.9	4.313	3.3	2.267	1.7	1.866	1.4	1.332	1.0
M-87	79.515	77.8	17.088	16.7	2.494	2.4	1.496	1.5	0.880	0.9	0.354	0.3
M-90	98.855	77.0	18.541	14.4	4.310	3.4	2.292	1.8	1.849	1.4	1.146	0.9
M-91	91.197	77.5	18.852	16.0	2.896	2.5	2.029	1.7	1.573	1.3	0.498	0.4
M-106	79.515	77.8	17.088	16.7	2.494	2.4	1.496	1.5	0.88	0.9	0.354	0.3
M-109	72.975	74.4	18.396	18.7	2.765	2.8	1.855	1.9	0.934	1.0	0.493	0.5
M-111	98.855	77.0	18.541	14.4	4.310	3.4	2.292	1.8	1.849	1.4	1.146	0.9

Remark:

1. First 13 canonical discriminant functions were used in the analyses for M-3, M-20, M-28, and M-69
2. First 12 canonical discriminant functions were used in the analyses for M-1, M-90, M-28, and M-111
3. First 10 canonical discriminant functions were used in the analyses for M-36, M-58, M-91, and M-109
4. First 9 canonical discriminant functions were used in the analyses for M-8, M-21, and M-45

Table S2.13 (*continued*)

SPECIMENS	Function 7		Function 8		Function 9		Function 10		Function 11		Function 12		Function 13	
	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance
M-1	0.545	0.4	0.415	0.3	0.234	0.2	0.144	0.1	0.060	0.0	0.019	0.0		
M-2	0.228	0.2	0.122	0.1										
M-3	0.870	0.7	0.473	0.4	0.366	0.3	0.159	0.1	0.137	0.1	0.045	0.0	0.015	0.0
M-5														
M-8	0.291	0.3	0.213	0.2	0.034	0.0								
M-12	0.228	0.2	0.122	0.1										
M-20	0.870	0.7	0.473	0.4	0.366	0.3	0.159	0.1	0.137	0.1	0.045	0.0	0.015	0.0
M-21	0.245	0.3	0.106	0.1	0.052	0.1								
M-23														
M-28	0.870	0.7	0.473	0.4	0.366	0.3	0.159	0.1	0.137	0.1	0.045	0.0	0.015	0.0
M-29	0.228	0.2	0.122	0.1										
M-36	0.378	0.4	0.215	0.2	0.086	0.1	0.046	0.0						
M-39	0.228	0.2	0.122	0.1										
M-40														
M-43														
M-45	0.231	0.2	0.136	0.1	0.166	0.1								
M-49	0.228	0.2	0.122	0.1										
M-50														
M-54	0.169	0.2												
M-58	0.378	0.4	0.215	0.2	0.086	0.1	0.046	0.0						
M-61														
M-69	0.870	0.7	0.473	0.4	0.366	0.3	0.159	0.1	0.137	0.1	0.045	0.0	0.015	0.0
M-87	0.228	0.2	0.122	0.1										
M-90	0.545	0.4	0.415	0.3	0.234	0.2	0.144	0.1	0.060	0.0	0.019	0.0		
M-91	0.291	0.2	0.167	0.1	0.091	0.1	0.040	0.0						
M-106	0.228	0.2	0.122	0.1										
M-109	0.378	0.4	0.215	0.2	0.086	0.1	0.046	0.0						
M-111	0.545	0.4	0.415	0.3	0.234	0.2	0.144	0.1	0.060	0.0	0.019	0.0		

Remark:

5. First 8 canonical discriminant functions were used in the analyses for M-2, M-12, M-29, M-39, M-49, M-87, and M-106
6. First 7 canonical discriminant functions were used in the analysis for M-57
7. First 6 canonical discriminant functions were used in the analyses for M-5, M-40, M-43, M-50, and M-61
8. First 5 canonical discriminant functions were used in the analysis for M-5

Table S2.14 Summary of percentage of variance explained by each canonical discriminant function of eighteen toothed whale species for Early Jomon Mibiki zooarchaeological specimens examined (N = 7)

SPECIMENS	Function 1		Function 2		Function 3		Function 4		Function 5		Function 6	
	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance
No. 159	100.646	77.0	18.225	13.9	4.313	3.3	2.267	1.7	1.866	1.4	1.332	1.0
No. 161	70.344	75.8	18.798	20.2	1.811	2.0	1.000	1.1	0.431	0.5	0.257	0.3
No. 483	81.380	75.4	18.474	17.1	3.293	3.1	1.856	1.7	1.174	1.1	0.545	0.5
No. 494	70.344	75.8	18.798	20.2	1.811	2.0	1.000	1.1	0.431	0.5	0.257	0.3
No. 495	39.466	75.1	10.620	20.2	1.773	3.4	0.369	0.7	0.203	0.4	0.92	0.2
No. 748	72.975	74.4	18.396	18.7	2.765	2.8	1.855	1.9	0.934	1.0	0.493	0.5
No. 749	72.975	74.4	18.396	18.7	2.765	2.8	1.855	1.9	0.934	1.0	0.493	0.5

SPECIMENS	Function 7		Function 8		Function 9		Function 10		Function 11		Function 12		Function 13	
	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance
No. 159	0.870	0.7	0.473	0.4	0.366	0.3	0.159	0.1	0.137	0.1	0.045	0.0	0.015	0.0
No. 161	0.113	0.1	0.088	0.1										
No. 483	0.501	0.5	0.345	0.5	0.214	0.2	0.065	0.1	0.034	0.0				
No. 494	0.113	0.1	0.088	0.1										
No. 495														
No. 748	0.378	0.4	0.215	0.2	0.086	0.1	0.46	0.0						
No. 749	0.378	0.4	0.215	0.2	0.086	0.1	0.46	0.0						

Remark:

1. First 13 canonical discriminant functions were used in the analysis for No. 159
2. First 11 canonical discriminant functions were used in the analysis for No. 483
3. First 10 canonical discriminant functions were used in the analyses for No. 748 and No. 749
4. First 8 canonical discriminant functions were used in the analyses for No. 494 and No. 161
5. First 8 canonical discriminant functions were used in the analysis for No. 495

Table S2.15 Summary of percentage of variance explained by each canonical discriminant function of eighteen toothed whale species for Okhotsk Kafukai-1 zooarchaeological specimens examined (N = 9)

SPECIMENS	Function 1		Function 2		Function 3		Function 4		Function 5		Function 6	
	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance
RKA2047	47.697	78.7	10.591	17.5	1.478	2.4	0.449	0.7	0.293	0.5	0.106	0.2
RKA2804	27.222	71.8	7.125	18.8	1.990	5.2	0.933	2.5	0.515	1.4	0.148	0.4
RKA3690	79.515	77.8	17.088	16.7	2.494	2.4	1.496	1.5	0.88	0.9	0.354	0.3
RKA3982	66.766	70.5	17.117	18.1	3.780	4.0	2.263	2.4	1.798	1.9	1.313	1.4
RKA5918	81.333	75.1	18.137	16.7	3.249	3.0	1.869	1.7	1.395	1.3	0.879	0.8
RKA15283	95.608	78.9	18.133	15.0	2.968	2.5	1.875	1.5	1.060	0.9	0.824	0.7
RKA15547	68.109	83.9	10.579	13.00	1.867	2.3	0.376	0.5	0.251	0.3		
RKA17138	79.515	77.8	17.088	16.7	2.494	2.4	1.496	1.5	0.88	0.9	0.354	0.3
RKA18142	100.646	77.0	18.225	13.9	4.313	3.3	2.267	1.7	1.866	1.4	1.332	1.0

SPECIMENS	Function 7		Function 8		Function 9		Function 10		Function 11		Function 12		Function 13	
	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance	Eigenvalue	% of Variance
RKA2047														
RKA2804														
RKA3690	0.228	0.2	0.122	0.1										
RKA3982	0.650	0.7	0.384	0.4	0.353	0.4	0.144	0.2	0.086	0.1	0.017	0.0		
RKA5918	0.502	0.5	0.470	0.4	0.281	0.3	0.162	0.1	0.050	0.0	0.032	0.0		
RKA15283	0.296	0.2	0.225	0.2	0.91	0.1	0.34	0.0						
RKA15547														
RKA17138	0.228	0.2	0.122	0.1										
RKA18142	0.870	0.7	0.473	0.4	0.366	0.3	0.159	0.1	0.137	0.1	0.045	0.0	0.015	0.0

Remark:

1. First 13 canonical discriminant functions were used in the analysis for RKA18142
2. First 12 canonical discriminant functions were used in the analyses for RKA3982 and RKA5918
3. First 10 canonical discriminant functions were used in the analysis for RKA15283
4. First 8 canonical discriminant functions were used in the analyses for RKA17138 and RKA3690
5. First 6 canonical discriminant functions were used in the analyses for RKA29047 and RKA2804
6. First 5 canonical discriminant functions were used in the analysis for RKA15547

APPENDIX C

Summary of classification functions of

all zooarchaeological specimens examined

Table S3.1 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens M-3, M-20, M-28, M-69 (Early Jomon Mawaki site), No. 159 (Early Jomon Mibiki site), and RKA18142 (Okhotsk Kafukai-1 site)

(a.)

	Function	
	1	2
GWASA	-1.396	9.489
HA	3.684	2.391
GLNSA	2.474	2.347
LLPA	-2.045	-.038
LLefLtPA	9.076	-7.979
GLCAF	5.052	7.384
GWCAF	-1.819	3.220
BNA	2.069	-8.068
HNA	1.468	-1.866
GBNSA	-.446	-.231
ThLPA	-8.702	-2.705
BLPA	-7.598	.483
ThBNSA	-.790	-2.440
(Constant)	-6.585	-9.499

Unstandardized coefficients

(b.)

	Function		
	1	2	3
GWASA	-1.406	13.031	2.999
HA	3.670	2.199	-1.090
GLNSA	2.463	2.559	-.387
LLPA	-2.038	-.050	-.007
LLefLtPA	9.049	-8.032	2.451
GLCAF	5.034	5.443	-5.654
GWCAF	-1.816	3.693	-.221
BNA	2.065	-7.161	4.114
HNA	1.463	-1.457	1.289
GBNSA	-.435	-3.875	-6.123
ThLPA	-8.673	-1.575	2.782
BLPA	-7.571	.034	-.917
ThBNSA	-.791	-.489	4.095
(Constant)	-6.544	-14.427	-5.352

Unstandardized coefficients

(c.)

	Function			
	1	2	3	4
GWASA	2.083	7.060	15.333	-12.105
HA	-.195	11.907	-5.306	5.513
GLNSA	-.080	2.055	5.056	-3.981
LLPA	.417	-.226	1.930	-.787
LLefLtPA	1.314	-5.179	-5.119	19.761
GLCAF	3.109	-11.553	-18.447	-10.453
GWCAF	4.241	.425	4.737	-4.734
BNA	12.874	.913	-1.698	5.136
HNA	2.440	-2.923	-4.222	1.136
GBNSA	-4.216	7.015	-.406	2.160
ThLPA	-1.937	-.126	7.262	-.850
BLPA	-1.873	-.426	.369	1.838
ThBNSA	.531	-5.892	.376	1.925
(Constant)	-34.659	-8.345	2.827	-3.783

Unstandardized coefficients

(d.)

	Function												
	1	2	3	4	5	6	7	8	9	10	11	12	13
GWASA	-1.929	24.263	-8.395	-3.131	-9.143	-5.136	-10.474	-1.440	-21.304	.509	-25.769	1.051	-8.804
HA	5.091	1.018	-3.469	-6.829	.729	1.582	6.378	3.287	-.854	-1.239	2.039	-2.910	-4.568
GLNSA	1.648	1.458	2.349	-4.427	1.529	4.318	-.111	-3.122	4.609	2.365	-4.695	-1.957	.942
LLPA	-1.240	-.092	-.600	.374	-.762	-6.228	6.820	-2.643	2.514	3.843	-2.722	-1.106	1.104
LLefLtPA	8.260	.943	10.309	10.328	-3.959	3.295	.018	-.273	-1.058	.244	6.348	.759	2.032
GLCAF	5.603	-.205	1.489	-4.505	-7.676	-.593	-1.061	.109	1.647	4.134	.478	13.023	2.653
GWCAF	-3.096	.702	1.623	.749	-3.229	.197	-3.750	.877	16.617	-9.866	11.963	-13.553	6.519
BNA	2.954	2.119	-4.525	6.485	13.698	-.308	-.332	-3.170	-7.916	.459	3.245	-3.917	6.935
HNA	.306	2.229	.508	5.832	4.130	-2.030	-4.109	.077	8.616	-.176	1.199	4.060	-5.218
GBNSA	-1.074	-1.177	-7.530	3.276	-2.803	7.001	.742	1.902	.572	1.946	.442	.643	.952
ThLPA	-9.301	3.100	4.638	-.524	2.505	1.657	6.544	-3.950	-.791	-5.189	3.079	5.118	-1.512
BLPA	-6.573	-3.688	-1.240	-2.000	1.327	-1.212	-4.477	-.094	-8.812	5.283	5.472	-3.478	-5.511
ThBNSA	-.956	.965	3.838	-.454	3.559	-1.436	-.490	7.216	-.815	.642	-.921	.524	1.429
(Constant)	-4.826	-59.500	4.741	-5.900	7.654	2.422	10.986	5.072	18.770	-5.209	11.668	3.037	6.740

Unstandardized coefficients

Table S3.2 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens M-1, M-90, and M-111 (Early Jomon Mawaki site)

(a.)

	Function	
	1	2
GWASA	-3.424	9.704
HA	7.468	.794
GLNSA	2.550	2.271
LLeftLtPA	7.318	-7.931
GLCAF	6.780	8.127
GWCAF	-3.193	2.463
BNA	.075	-8.344
HNA	-1.563	.685
GBNSA	-.432	-.435
THLPA	-7.653	-2.554
BLPA	-7.357	.886
THNSA	-1.155	-2.693
(Constant)	-4.788	-10.654

Unstandardized coefficients

(b.)

	Function		
	1	2	3
GWASA	-3.627	13.489	.763
HA	7.449	.301	-.932
GLNSA	2.512	2.436	-.712
LLeftLtPA	7.360	-7.213	4.079
GLCAF	6.767	4.736	-7.465
GWCAF	-3.230	3.176	-.111
BNA	.104	-6.207	6.000
HNA	-1.575	1.006	.121
GBNSA	-.299	-4.837	-5.259
THLPA	-7.636	-1.295	2.587
BLPA	-7.320	.127	-1.291
THNSA	-1.197	-.069	4.326
(Constant)	-4.498	-16.160	-2.501

Unstandardized coefficients

(c.)

	Function			
	1	2	3	4
GWASA	1.996	7.186	14.694	-12.887
HA	.251	12.237	-4.647	4.827
GLNSA	-.379	2.119	4.202	-3.739
LLeftLtPA	2.508	-5.267	-1.398	17.972
GLCAF	2.432	-11.566	-18.680	-10.045
GWCAF	4.361	-.031	4.987	-4.558
BNA	13.419	.433	-1.951	5.694
HNA	2.374	-3.064	-3.879	1.292
GBNSA	-4.002	7.156	.034	1.882
THLPA	-2.568	-.210	6.608	-.164
BLPA	-1.461	-.359	.919	1.297
THNSA	.497	-5.951	.454	1.971
(Constant)	-36.183	-7.879	.071	-1.337

Unstandardized coefficients

(d.)

	Function											
	1	2	3	4	5	6	7	8	9	10	11	12
GWASA	-2.316	24.785	-8.093	-3.662	-8.497	-10.081	-1.459	-12.416	-24.074	-19.056	4.975	-10.575
HA	5.235	.957	-3.393	-6.920	.786	4.272	6.116	-.587	2.155	.864	-2.539	-4.724
GLNSA	1.856	1.359	2.414	-4.402	1.388	4.697	-5.933	3.651	-1.745	-2.540	-1.330	-.043
LLeftLtPA	7.779	.889	10.165	10.489	-4.366	2.166	.440	-1.421	2.182	5.200	-.195	2.713
GLCAF	5.649	-.341	1.511	-4.712	-7.639	-1.179	-1.210	1.956	-.895	3.066	12.676	4.411
GWCAF	-3.163	.595	1.501	.961	-3.770	-2.552	-3.462	10.514	17.273	2.508	-16.655	6.136
BNA	2.828	2.271	-4.603	6.748	13.752	.003	-.201	-7.488	-3.069	3.177	-4.998	6.367
HNA	.322	2.182	.374	5.974	3.949	-3.577	-3.734	6.831	5.267	.522	4.620	-4.311
GBNSA	-1.447	-1.086	-7.731	3.216	-3.328	6.028	.251	2.376	-1.472	1.311	.649	1.064
THLPA	-8.880	2.923	4.522	-.350	2.232	4.427	1.400	-5.891	6.495	-.094	4.173	-.222
BLPA	-7.435	-3.445	-1.264	-2.040	1.736	-3.705	.877	-5.263	-4.920	7.679	-2.550	-5.764
THNSA	-1.106	.941	3.789	-.308	3.645	-1.897	5.634	3.561	-2.673	-.525	.394	1.540
(Constant)	-4.438	-60.383	4.119	-5.238	7.193	7.591	4.887	12.238	18.453	5.369	-.149	8.428

Unstandardized coefficients

Table S3.3 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens RKA3982 (Okhotsk Kafukai-1 site)

(a.)

	Function	
	1	2
GWASA	-9.379	7.270
HA	7.957	1.557
GLNSA	-.252	1.451
LLPA	-2.162	-.646
LLeftLtPA	8.538	-7.179
GLCAF	7.139	8.897
GWCAF	-4.226	1.897
BNA	.303	-8.380
HNA	-.707	.865
GBNSA	-.663	-.634
BLPA	-6.076	.639
THNSA	-1.679	-3.092
(Constant)	1.254	-8.734

Unstandardized coefficients

(b.)

	Function		
	1	2	3
GWASA	-9.319	12.272	2.980
HA	7.926	.632	-1.759
GLNSA	-.247	2.021	.080
LLPA	-2.154	-.462	.490
LLeftLtPA	8.498	-6.736	3.522
GLCAF	7.112	4.998	-8.386
GWCAF	-4.205	2.958	.485
BNA	.298	-6.144	6.175
HNA	-.703	1.147	-.021
GBNSA	-.675	-4.993	-4.971
BLPA	-6.055	-.082	-1.133
THNSA	-1.668	-.154	4.815
(Constant)	1.218	-15.099	-4.008

Unstandardized coefficients

(c.)

	Function			
	1	2	3	4
GWASA	2.659	7.122	14.915	-13.763
HA	-1.338	11.830	-.917	5.175
LLPA	.659	-.208	1.160	-.826
GLNSA	-.199	2.055	6.382	-4.849
LLefLtPA	.367	-5.244	-.403	19.575
GLCAF	2.142	-11.635	-18.863	-8.681
GWCAF	4.248	.438	5.143	-5.383
BNA	12.433	.899	-.354	5.091
HNA	2.746	-2.908	-6.554	2.092
GBNSA	-4.334	7.002	.366	2.069
BLPA	-1.559	-.408	-.743	2.077
ThBNSA	.481	-5.894	.866	1.812
(Constant)	-32.620	-8.259	-4.254	-2.556

Unstandardized coefficients

(d.)

	Function											
	1	2	3	4	5	6	7	8	9	10	11	12
GWASA	-5.043	27.401	-1.987	-3.944	-5.995	-3.547	-7.652	-10.912	-19.148	-20.887	12.373	-9.201
HA	5.440	.310	-4.951	-6.535	-.437	.655	6.242	-1.755	.113	.827	-3.166	-4.928
GLNSA	1.390	1.359	2.341	-4.427	1.759	4.628	.739	7.066	-.054	-2.859	1.018	.311
LLPA	-.916	-.092	-.838	.410	-1.065	-7.042	5.002	6.345	-2.230	-.408	1.342	.679
LLeftLtPA	9.593	-.892	9.494	10.090	-4.291	2.940	-.911	-1.460	.088	5.424	-2.085	2.330
GLCAF	5.501	-.871	1.364	-4.765	-7.554	-1.073	-2.526	-.746	2.922	3.758	11.748	5.107
GWCAF	-3.824	1.448	3.088	.444	-2.281	.714	-2.364	7.086	16.157	3.474	-20.059	4.230
BNA	2.901	1.925	-5.658	7.117	12.878	.269	-1.195	-2.037	-8.380	2.359	-5.472	6.101
HNA	.907	2.025	.557	5.907	4.432	-1.355	-3.702	3.196	8.756	1.459	3.726	-4.270
GBNSA	-3.053	-.006	-6.656	3.322	-3.692	6.636	2.020	-.243	.652	1.502	1.211	.978
BLPA	-8.040	-2.322	.092	-2.114	2.402	-.314	-3.011	-5.157	-7.340	7.265	-1.620	-6.180
THNSA	-1.074	1.090	4.329	-.518	4.510	-.670	4.094	-4.624	2.024	-.268	1.297	1.387
(Constant)	-8.179	-60.433	-1.894	-5.084	4.831	.785	9.339	6.924	18.842	7.036	-5.348	7.778

Unstandardized coefficients

Table S3.4 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens RKA5918 (Okhotsk Kafukai-1 site)

(a.)

	Function	
	1	2
GWASA	-7.022	-1.079
HA	-9.214	-2.726
GLNSA	-3.515	-.172
LLPA	.545	-2.129
GLCAF	-7.422	6.955
GWCAF	5.508	7.448
BNA	4.137	-2.851
HNA	2.491	2.180
GBNSA	.509	.215
THLPA	8.061	-1.702
BLPA	5.481	1.981
THNSA	1.101	-2.720
(Constant)	8.117	-9.550

Unstandardized coefficients

(b.)

	Function		
	1	2	3
GWASA	-7.341	4.385	-5.395
HA	-9.120	-2.600	-1.421
GLNSA	-3.535	.287	-.494
LLPA	.581	-1.609	-1.479
GLCAF	-7.339	2.337	7.427
GWCAF	5.294	6.818	4.118
BNA	4.074	-.539	-3.418
HNA	2.423	2.064	1.145
GBNSA	.852	-5.054	4.804
THLPA	7.991	.070	-2.385
BLPA	5.499	.623	2.161
THNSA	.964	.692	-4.339
(Constant)	8.762	-14.605	-.036

Unstandardized coefficients

(c.)

	Function			
	1	2	3	4
GWASA	4.922	6.975	11.507	-9.854
HA	-.537	10.980	-4.922	12.497
LLPA	.592	-1.200	1.248	4.114
GLNSA	.293	1.220	4.084	-1.927
GLCAF	2.978	-11.133	-19.311	-12.404
GWCAF	3.725	.025	4.915	-9.590
BNA	10.722	-.629	.372	5.944
HNA	3.189	-2.045	-4.748	2.784
GBNSA	-4.350	7.370	.163	.300
ThLPA	-1.531	-.562	6.671	.605
BLPA	-1.919	-.880	.347	4.930
ThBNSA	.464	-5.873	.524	3.057
(Constant)	-34.909	-11.022	1.750	5.618

Unstandardized coefficients

(d.)

	Function											
	1	2	3	4	5	6	7	8	9	10	11	12
GWASA	-4.183	25.177	-2.556	-8.563	-7.974	-10.906	-20.077	-8.670	-22.914	.951	3.132	1.193
HA	-7.208	1.401	1.372	-2.449	3.143	6.472	1.550	4.033	-.884	-1.531	-2.406	5.041
GLNSA	-2.842	1.434	4.411	-.190	4.876	.032	-2.196	-4.312	3.851	2.946	-1.605	-1.802
LLPA	.148	-.022	-.169	.392	-6.403	6.759	-.198	-3.041	2.372	4.078	-.632	-1.246
GLCAF	-4.949	-.427	1.097	-8.469	-.975	-1.043	2.214	.896	1.134	3.738	12.624	-3.914
GWCAF	5.015	.225	-1.931	-2.337	.540	-3.573	7.872	3.579	18.177	-9.084	-14.977	-1.714
BNA	-1.696	2.685	-2.862	13.448	1.468	-.320	5.423	-1.132	-6.576	.448	-5.032	-5.206
HNA	.347	1.923	-2.662	7.268	-1.705	-4.176	-.098	-.214	7.219	-.374	4.698	4.748
GBNSA	.932	-.984	-8.845	-2.169	6.145	.809	-1.623	1.492	.578	1.954	.588	-.663
THLPA	9.910	2.822	3.842	1.750	2.045	6.547	3.467	-2.932	-.889	-5.703	4.755	1.311
BLPA	5.799	-3.457	.881	-.495	-.316	-4.500	4.625	1.885	-8.271	4.610	-3.039	7.201
THNSA	1.220	.883	4.294	3.231	-.975	-.463	-2.535	6.787	-.610	.699	.428	-1.647
(Constant)	3.500	-59.903	5.888	4.713	6.118	11.293	10.728	8.881	19.063	-5.254	1.795	-3.918

Unstandardized coefficients

Table S3.5 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens No.483 (Early Jomon Mibiki site)

(a.)

	Function	
	1	2
GWASA	-9.241	-4.368
HA	-4.937	.129
GLNSA	-4.431	.054
GLCAF	-5.080	8.608
GWCAF	4.223	7.816
BNA	1.522	-5.518
HNA	-.430	-1.956
GBNSA	1.240	.649
ThLPA	8.791	-.627
BLPA	7.131	.802
ThBNSA	1.108	-2.871
(Constant)	9.526	-4.955

Unstandardized coefficients

(b.)

	Function		
	1	2	3
GWASA	-6.880	3.697	-6.586
HA	-9.055	-2.721	-1.710
GLNSA	-3.700	.720	-.031
GLCAF	-7.349	2.260	8.168
GWCAF	5.273	6.432	4.226
BNA	4.007	-.498	-3.807
HNA	2.491	1.879	1.181
GBNSA	.968	-5.463	4.378
THLPA	7.789	.173	-2.107
BLPA	6.070	-.170	1.197
THNSA	1.054	.667	-4.593
(Constant)	8.284	-13.956	.584

Unstandardized coefficients

(c.)

	Function			
	1	2	3	4
GWASA	5.817	6.945	12.011	-10.559
HA	.491	10.444	-4.421	15.936
GLNSA	.136	1.548	3.895	-3.065
GLCAF	1.909	-11.524	-18.827	-16.244
GWCAF	3.805	-.513	5.331	-8.675
BNA	10.900	-.887	-.071	7.074
HNA	3.237	-2.488	-4.588	4.122
GBNSA	-4.055	7.424	.178	.398
THLPA	-2.171	-.274	6.414	.889
BLPA	-1.166	-1.346	.878	8.059
THNSA	.332	-5.930	.550	4.102
(Constant)	-36.509	-9.543	.663	5.095

Unstandardized coefficients

(d.)

	Function							Function			
	1	2	3	4	5	6	7	8	9	10	11
GWASA	-4.051	25.642	-2.202	-7.748	-12.765	-7.714	-19.511	-19.546	13.079	4.314	.730
HA	-7.270	1.325	1.417	-2.625	5.382	6.591	1.233	-1.142	-1.354	-2.191	4.847
GLNSA	-2.891	1.360	4.478	-.165	5.102	-5.905	-1.867	3.049	.300	-1.547	-.919
GLCAF	-4.959	-.522	1.217	-8.582	-1.215	-.518	2.270	3.068	2.040	12.503	-4.424
GWCAF	4.926	.179	-1.954	-2.570	-2.005	-.429	7.411	13.248	-14.426	-16.744	-1.538
BNA	-1.786	2.742	-3.066	13.547	1.085	.047	5.526	-4.585	5.021	-5.090	-4.726
HNA	.308	1.925	-2.771	7.295	-3.347	-2.764	-.014	5.692	-5.072	4.847	4.210
GBNSA	1.021	-.914	-8.851	-2.235	5.564	.114	-1.652	2.333	1.587	.758	-.585
THLPA	9.727	2.687	3.724	1.277	4.648	1.522	3.527	-5.670	-5.311	3.962	.262
BLPA	6.148	-3.256	.946	.164	-3.030	1.299	4.691	-3.091	7.978	-1.607	7.515
THNSA	1.246	.874	4.229	3.405	-1.713	5.520	-2.978	2.676	1.918	.376	-1.822
(Constant)	3.681	-60.732	5.183	3.911	10.443	9.093	9.998	14.505	-14.047	-.299	-4.519

Unstandardized coefficients

Table S3.6 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens M-91 (Early Jomon Mawaki site)

(a.)

	Function	
	1	2
GWASA	-4.628	7.996
HA	7.821	1.081
GLNSA	2.136	2.209
LLeftLtPA	7.771	-8.404
GLCAF	6.057	9.327
GWCAF	-3.012	1.314
BNA	1.223	-8.309
HNA	-2.467	.501
THLPA	-8.286	-3.607
BLPA	-6.975	-.443
(Constant)	-4.687	-7.171

Unstandardized coefficients

(b.)

	Function		
	1	2	3
GWASA	-5.207	10.645	3.827
HA	7.744	1.511	.675
GLNSA	2.011	2.665	.327
LLeftLtPA	7.962	-7.543	5.432
GLCAF	5.916	7.887	-7.338
GWCAF	-3.126	1.891	1.005
BNA	1.428	-7.662	4.862
HNA	-2.351	-.674	-3.233
THLPA	-8.186	-3.499	1.691
BLPA	-6.974	-.385	.345
(Constant)	-3.742	-13.308	-13.168

Unstandardized coefficients

(c.)

	Function			
	1	2	3	4
GWASA	3.343	14.052	10.670	-18.563
HA	1.214	-20.384	16.686	3.509
GLNSA	.187	2.816	2.705	-3.840
LLefLtPA	2.272	5.406	-7.380	20.194
GLCAF	2.758	-1.520	-36.285	-8.570
GWCAF	2.889	5.727	-.496	-2.688
BNA	10.803	-6.446	7.358	7.595
HNA	-.133	-4.151	2.418	5.688
ThLPA	-2.274	5.768	3.583	.084
BLPA	-2.502	.771	2.322	.711
(Constant)	-34.039	-1.417	-1.441	-2.018

Unstandardized coefficients

(d.)

	Function							Function		
	1	2	3	4	5	6	7	8	9	10
GWASA	-4.975	25.713	-9.227	1.029	-13.489	-4.011	-22.212	-23.963	.665	12.700
HA	5.846	1.602	-4.776	6.692	3.051	-5.932	2.178	2.315	-4.781	3.671
GLNSA	1.216	1.402	1.681	4.911	5.574	6.051	-.296	-3.876	-2.000	-.287
LLeftLtPA	7.424	.436	14.968	-4.787	-2.133	-1.600	.401	5.385	1.582	-2.778
GLCAF	5.042	.050	1.460	7.650	-5.644	3.053	.109	1.444	13.755	1.247
GWCAF	-3.446	.545	2.484	.212	-3.479	6.688	17.583	6.625	-13.310	-14.046
BNA	3.967	2.183	-4.894	-12.421	9.662	-2.810	-7.362	3.105	-.841	-8.165
HNA	-.140	2.120	.479	-8.158	.476	6.313	7.716	1.013	2.315	5.596
THLPA	-9.927	2.323	3.588	.442	5.828	-7.275	3.184	1.190	4.658	.496
BLPA	-7.398	-3.553	-3.801	-.602	-.476	-.976	-7.794	7.475	-2.928	4.736
(Constant)	-.551	-61.989	-.085	5.650	9.248	1.167	19.759	9.898	.897	-8.360

Unstandardized coefficients

Table S3.7 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens RKA15283 (Okhotsk Kafukai-1 site)

(a.)

	Function	
	1	2
GWASA	-5.176	6.839
HA	7.833	1.145
LLPA	-2.860	-1.855
LLeftLtPA	10.042	-6.691
GLCAF	6.005	9.317
GWCAF	-2.531	1.570
BNA	2.328	-7.296
HNA	-1.618	.954
THLPA	-8.075	-2.523
BLPA	-4.616	1.219
(Constant)	-6.495	-7.638

Unstandardized coefficients

(b.)

	Function		
	1	2	3
GWASA	-5.554	9.501	4.514
HA	7.765	1.534	.585
LLPA	-2.792	-2.099	.062
LLeftLtPA	10.093	-5.528	5.627
GLCAF	5.894	7.903	-7.335
GWCAF	-2.597	1.951	.426
BNA	2.432	-6.488	4.928
HNA	-1.554	-.075	-3.103
THLPA	-8.011	-2.458	1.154
BLPA	-4.695	1.878	1.303
(Constant)	-5.769	-14.102	-14.331

Unstandardized coefficients

(c.)

	Function			
	1	2	3	4
GWASA	2.870	7.068	6.169	-20.482
HA	1.209	-22.395	10.922	6.088
LLPA	-.373	-.311	.793	1.008
LLefLtPA	2.694	11.810	-.485	16.419
GLCAF	4.334	5.965	-36.076	.347
GWCAF	2.440	4.498	.049	-4.031
BNA	10.172	-6.729	8.462	6.304
HNA	.122	-3.596	2.475	5.904
ThLPA	-2.338	4.979	7.049	-6.322
BLPA	-2.618	1.491	3.522	-3.056
(Constant)	-34.084	-1.867	.393	-3.689

Unstandardized coefficients

(d.)

	Function									
	1	2	3	4	5	6	7	8	9	10
GWASA	-4.236	25.447	-7.158	-7.868	-11.185	-7.133	-25.786	-18.594	-6.771	12.532
HA	5.415	1.484	-5.650	-4.255	6.861	4.225	.678	-.375	5.347	3.765
LLPA	-2.039	-.197	-2.111	1.323	-3.048	9.384	-2.005	2.969	-.917	-.450
LLeftLtPA	8.969	1.098	16.087	1.886	.836	-1.059	1.506	3.081	.314	-3.000
GLCAF	5.228	.243	1.490	-9.346	-1.046	-.354	2.349	4.034	-13.408	.518
GWCAF	-3.368	.251	2.646	-1.409	-5.238	-1.197	18.685	1.472	15.724	-12.479
BNA	4.213	2.521	-4.345	14.674	4.931	-3.217	-6.657	2.035	1.932	-8.532
HNA	.081	2.290	1.105	7.461	-4.738	-2.146	8.652	1.753	-2.085	5.840
THLPA	-10.075	2.522	3.387	1.864	9.556	3.173	3.002	-2.058	-3.490	.213
BLPA	-5.700	-3.027	-2.075	-1.226	2.744	-6.840	-6.444	6.242	4.489	4.494
(Constant)	-1.843	-61.450	-2.750	.864	7.937	9.568	20.740	6.703	1.707	-7.840

Unstandardized coefficients

Table S3.8 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens M-36, M-58, M-109 (Early Jomon Mawaki site), No. 748, and No.749 (Early Jomon Mibiki site)

(a.)

	Function	
	1	2
GWASA	-6.217	-2.513
HA	-10.186	-3.027
GLCAF	-7.758	7.746
GWCAF	7.464	7.055
BNA	3.931	-3.139
HNA	2.775	2.040
GBNSA	1.028	-.160
THLPA	5.635	-1.480
BLPA	3.249	.840
THNSA	.578	-2.953
(Constant)	7.031	-8.050

Unstandardized coefficients

(b.)

	Function		
	1	2	3
GWASA	-6.371	3.952	-6.449
HA	-10.118	-2.493	-1.969
GLCAF	-7.698	2.392	8.207
GWCAF	7.348	5.965	4.455
BNA	3.887	-.438	-3.750
HNA	2.737	1.791	1.236
GBNSA	1.214	-5.643	4.304
THLPA	5.583	.390	-2.243
BLPA	3.249	.117	1.006
THNSA	.502	.873	-4.557
(Constant)	7.358	-13.861	.567

Unstandardized coefficients

(c.)

	Function			
	1	2	3	4
GWASA	5.246	5.461	11.941	-13.204
HA	1.060	11.003	-3.455	17.655
GLCAF	1.569	-10.788	-22.417	-12.051
GWCAF	3.767	-1.464	3.319	-8.899
BNA	10.738	-.842	.988	7.156
HNA	3.299	-1.897	-3.932	4.638
GBNSA	-3.992	7.320	.280	.503
ThLPA	-1.845	.323	9.424	-3.470
BLPA	-.738	-.126	4.489	4.927
ThBNSA	.261	-5.686	1.379	3.774
(Constant)	-36.306	-8.297	2.931	3.550

Unstandardized coefficients

(d.)

	Function									
	1	2	3	4	5	6	7	8	9	10
GWASA	-2.954	25.672	-1.283	-7.927	-13.595	-16.901	-22.182	13.484	3.284	-1.145
HA	-7.337	1.857	-1.515	-2.648	8.479	-.608	1.175	-1.177	-1.329	5.062
GLCAF	-4.860	-.399	-1.571	-8.651	-.695	2.426	2.421	1.826	10.335	-8.574
GWCAF	5.749	-.558	3.182	-2.509	-4.315	7.045	13.634	-14.713	-14.760	4.911
BNA	-2.128	3.104	2.307	13.611	1.541	5.253	-3.046	5.249	-7.169	-2.787
HNA	.227	1.985	2.197	7.326	-4.895	.684	4.013	-5.317	6.795	2.410
GBNSA	.885	-.880	10.176	-2.049	3.161	-1.528	1.738	1.456	1.046	-.770
THLPA	9.221	2.703	-3.470	1.258	6.582	3.147	-4.911	-5.149	2.726	-1.313
BLPA	4.254	-2.459	-2.972	.034	-.312	3.959	-1.448	8.269	.179	7.357
THNSA	1.147	.820	-5.281	3.316	1.132	-4.425	4.286	1.912	-.580	-1.955
(Constant)	-.142	-60.406	-2.305	4.003	12.774	7.625	16.850	-14.314	-1.222	-3.655

Unstandardized coefficients

Table S3.9 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens M-45 (Early Jomon Mawaki site)

(a.)

	Function	
	1	2
GWASA	-1.755	9.039
GLNSA	1.652	1.883
LLPA	-2.392	-1.176
LLeftLtPA	11.149	-7.412
GLCAF	6.127	9.089
GWCAF	-2.425	1.598
BNA	6.011	-6.834
THLPA	-9.268	-3.679
BLPA	-7.101	-.197
(Constant)	-9.233	-8.605

Unstandardized coefficients

(b.)

	Function		
	1	2	3
GWASA	-2.177	11.339	2.581
GLNSA	1.576	2.194	.077
LLPA	-2.338	-1.438	-.229
LLeftLtPA	11.223	-6.230	6.114
GLCAF	6.006	7.749	-7.267
GWCAF	-2.517	2.237	1.090
BNA	6.136	-6.357	4.001
THLPA	-9.155	-3.814	1.141
BLPA	-7.115	.110	.928
(Constant)	-8.468	-14.955	-13.621

Unstandardized coefficients

(c.)

	Function			
	1	2	3	4
GWASA	3.227	15.162	-15.120	6.103
LLPA	-.368	2.114	-1.557	-1.337
GLNSA	-.024	4.664	-3.215	2.957
LLefLtPA	2.888	-4.702	22.105	-9.751
GLCAF	5.039	-28.885	4.912	11.397
GWCAF	2.540	3.312	.026	4.693
BNA	10.161	.804	-4.747	-18.987
ThLPA	-2.220	7.092	-1.225	-.166
BLPA	-2.712	1.983	2.473	2.870
(Constant)	-34.098	1.162	-4.140	3.399

Unstandardized coefficients

(d.)

	Function								
	1	2	3	4	5	6	7	8	9
GWASA	3.375	27.563	-13.107	-6.968	-1.525	-12.781	-7.754	3.827	-29.421
GLNSA	-.691	1.477	3.339	2.901	-6.066	3.849	.986	-5.218	-3.515
LLPA	2.247	-.293	-2.473	-.707	5.540	7.437	3.641	-2.131	-2.391
LLeftLtPA	-11.298	2.150	11.667	-.561	6.137	-2.774	1.576	2.487	5.837
GLCAF	-6.366	1.169	1.253	-8.216	-6.074	7.754	.481	10.453	-.607
GWCAF	3.694	-.676	3.959	-5.567	-2.138	-.457	-2.456	-17.472	20.028
BNA	-5.115	2.894	-8.094	15.947	4.715	-3.614	2.627	-.196	5.027
THLPA	10.729	1.608	5.473	4.932	2.542	2.868	-4.600	6.254	2.485
BLPA	6.261	-3.716	-2.015	.622	-1.181	-9.824	8.246	4.213	-.486
(Constant)	.457	-62.448	5.769	1.980	-2.346	15.009	-1.380	-3.587	17.205

Unstandardized coefficients

Table S3.10 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens M-8 (Early Jomon Mawaki site)

(a.)

	Function	
	1	2
GWASA	-6.367	5.248
HA	7.975	2.514
LLPA	-2.897	-2.603
LLeftLtPA	10.484	-5.999
GWCAF	1.289	9.087
BNA	5.344	-2.530
HNA	-2.046	.118
THLPA	-8.208	-4.167
BLPA	-3.776	2.592
(Constant)	-6.038	-8.936

Unstandardized coefficients

(b.)

	Function		
	1	2	3
GWASA	-6.867	8.306	5.227
HA	7.884	2.584	-.880
LLPA	-2.805	-2.605	1.066
LLeftLtPA	10.555	-4.415	6.225
GWCAF	1.101	7.678	-7.098
BNA	5.416	-2.280	1.616
HNA	-1.948	-.936	-2.576
THLPA	-8.124	-3.565	3.170
BLPA	-3.910	2.960	-.162
(Constant)	-5.048	-15.693	-12.571

Unstandardized coefficients

(c.)

	Function			
	1	2	3	4
GWASA	4.297	8.438	-20.587	-14.591
HA	2.961	-20.279	6.192	-1.616
LLPA	-.360	-.223	1.032	1.515
LLefLtPA	2.601	11.677	16.363	-3.929
GWCAF	2.672	4.618	-4.095	-5.598
BNA	10.550	-5.610	6.517	11.851
HNA	.302	-3.238	5.962	2.910
ThLPA	-2.108	5.795	-6.159	9.334
BLPA	-2.075	2.122	-3.051	-2.517
(Constant)	-34.621	-2.219	-3.527	14.391

Unstandardized coefficients

(d.)

	Function								
	1	2	3	4	5	6	7	8	9
GWASA	4.859	25.404	-7.699	-6.274	-12.357	-7.531	-23.790	-21.695	12.364
HA	-5.960	1.526	-5.699	-7.166	5.576	4.042	1.479	1.355	3.958
LLPA	2.006	-.200	-2.058	2.146	-2.780	9.426	-2.503	2.343	-.489
LLeftLtPA	-8.291	1.092	16.139	1.196	1.049	-1.006	1.134	3.154	-2.999
GWCAF	.780	.364	3.040	-6.205	-6.833	-1.632	20.470	7.901	-11.926
BNA	-7.216	2.691	-2.931	10.081	6.105	-3.037	-6.682	1.818	-8.440
HNA	-.155	2.298	1.496	9.321	-3.190	-1.896	7.868	1.557	5.747
THLPA	10.019	2.494	3.424	1.406	9.990	3.389	2.662	-2.859	.090
BLPA	4.760	-3.000	-2.006	-2.933	2.212	-6.949	-6.496	6.774	4.643
(Constant)	1.861	-61.464	-2.800	1.520	8.448	9.827	19.712	8.524	-7.820

Unstandardized coefficients

Table S3.11 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens M-21 (Early Jomon Mawaki site)

(a.)

	Function	
	1	2
GWASA	-5.777	-2.794
HA	-10.532	-3.072
GLCAF	-8.244	7.995
GWCAF	7.801	7.003
BNA	4.289	-3.203
HNA	3.163	2.113
THLPA	5.895	-1.435
BLPA	3.267	.693
THNSA	.606	-3.044
(Constant)	6.851	-7.691

Unstandardized coefficients

(b.)

	Function		
	1	2	3
GWASA	-5.623	-.827	5.976
HA	-10.472	-1.962	3.716
GLCAF	-8.119	7.579	-3.084
GWCAF	7.822	5.876	-4.723
BNA	4.214	-3.266	.618
HNA	3.101	1.131	-3.155
THLPA	5.879	-1.280	.780
BLPA	3.219	.127	-1.691
THNSA	.714	-1.440	5.070
(Constant)	6.373	-10.648	-6.099

Unstandardized coefficients

(c.)

	Function			
	1	2	3	4
GWASA	6.938	5.593	12.367	-12.095
HA	2.708	-19.279	3.180	18.090
GLCAF	1.258	14.783	-31.071	-14.737
GWCAF	2.486	.988	3.900	-8.638
BNA	8.318	-4.972	2.781	7.661
HNA	1.251	-5.391	-2.162	4.892
ThLPA	-1.553	2.728	9.203	-3.018
BLPA	-1.031	.607	4.903	5.468
ThBNSA	-1.495	4.755	-.764	3.817
(Constant)	-35.709	4.397	.775	2.932

Unstandardized coefficients

(d.)

	Function							Function	
	1	2	3	4	5	6	7	8	9
GWASA	-2.396	25.632	-7.199	-12.550	-13.897	-22.774	17.423	3.450	-.447
HA	-7.456	2.038	-3.492	7.834	1.335	-.501	-2.404	-2.974	4.761
GLCAF	-5.019	-.285	-9.018	-.523	.623	4.078	2.730	11.758	-5.458
GWCAF	5.740	-.598	-1.038	-6.786	5.151	11.982	-18.074	-14.158	.557
BNA	-1.973	3.153	13.889	1.965	5.093	-.265	5.923	-6.373	-4.649
HNA	.347	1.951	7.973	-3.914	-1.340	4.073	-5.085	6.591	3.966
THLPA	9.540	2.213	.387	6.234	5.828	-4.344	-3.358	3.924	-.739
BLPA	4.424	-2.652	-.593	.444	2.546	1.469	8.657	-2.246	7.238
THNSA	1.515	.597	1.485	4.407	-6.217	3.026	.692	-.512	-2.015
(Constant)	-1.022	-60.651	2.336	12.908	6.353	14.953	-17.357	-.141	-3.658

Unstandardized coefficients

Table S3.12 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens M-2, M-12, M-29, M-39, M-49, M-87, M-106 (Early Jomon Mawaki site), RKA17138, and RKA3690 (Okhotsk Kafukai-1 site)

(a.)

	Function	
	1	2
GWASA	-2.769	8.015
LLPA	-2.888	-1.842
LLeftLtPA	12.206	-6.104
GLCAF	6.209	9.532
GWCAF	-2.757	1.192
BNA	6.809	-5.926
THLPA	-8.352	-2.871
BLPA	-6.046	.905
(Constant)	-9.074	-8.815

Unstandardized coefficients

(b.)

	Function		
	1	2	3
GWASA	-3.258	10.086	2.551
LLPA	-2.791	-2.203	-.259
LLeftLtPA	12.251	-4.674	6.162
GLCAF	6.052	8.219	-7.240
GWCAF	-2.859	1.752	1.075
BNA	6.930	-5.266	4.032
THLPA	-8.266	-2.858	1.171
BLPA	-6.132	1.384	.975
(Constant)	-8.099	-15.111	-13.648

Unstandardized coefficients

(c.)

	Function			
	1	2	3	4
GWASA	3.257	5.819	-15.192	10.371
LLPA	-.358	.237	-.807	-2.602
LLefLtPA	2.852	8.321	14.755	-10.589
GLCAF	5.019	-25.680	17.671	3.339
GWCAF	2.544	2.519	.163	5.295
BNA	10.157	.961	-9.804	-17.102
ThLPA	-2.224	7.560	-5.771	4.447
BLPA	-2.722	4.289	-.208	5.850
(Constant)	-34.093	-1.123	-2.909	4.179

Unstandardized coefficients

(d.)

	Function							
	1	2	3	4	5	6	7	8
GWASA	3.499	27.761	-11.996	-7.238	-.867	-16.361	-10.562	-27.155
LLPA	2.282	-.346	-1.907	1.272	-9.679	2.422	3.211	-.732
LLeftLtPA	-11.500	2.641	13.577	2.367	.910	.310	2.378	3.517
GLCAF	-6.366	1.207	1.087	-9.881	1.891	11.391	2.754	-6.009
GWCAF	3.839	-1.034	3.605	-5.959	-.894	-2.475	-3.576	26.254
BNA	-5.298	3.382	-8.000	16.484	3.070	-1.702	2.848	4.309
THLPA	10.623	1.746	5.801	5.770	2.216	7.106	-2.943	-1.299
BLPA	5.920	-3.086	-1.201	.328	6.622	-6.821	8.273	-2.735
(Constant)	.082	-62.593	3.762	.780	-2.294	15.804	.564	16.663

Unstandardized coefficients

Table S3.13 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens No.494 and No.161 (Early Jomon Mibiki site)

(a.)

	Function	
	1	2
GWASA	-4.903	-4.883
HA	-10.813	-3.343
GLCAF	-7.672	9.312
GWCAF	7.458	6.245
BNA	3.719	-3.018
HNA	3.495	2.284
THLPA	6.045	-2.612
BLPA	3.298	-.825
(Constant)	6.267	-4.448

Unstandardized coefficients

(b.)

	Function		
	1	2	3
GWASA	-4.722	.378	13.695
HA	-10.767	-1.581	5.242
GLCAF	-7.581	7.208	-8.403
GWCAF	7.512	5.195	-4.801
BNA	3.653	-3.005	1.227
HNA	3.443	.509	-4.867
THLPA	6.015	-1.959	2.505
BLPA	3.305	-.235	1.655
(Constant)	5.801	-11.669	-14.398

Unstandardized coefficients

(c.)

	Function			
	1	2	3	4
GWASA	6.510	12.052	8.508	-23.073
HA	1.818	-23.436	10.343	1.641
GLCAF	2.149	9.188	-36.404	4.650
GWCAF	1.847	5.411	-.250	-4.972
BNA	7.978	-6.829	7.113	7.509
HNA	.979	-6.252	2.542	8.775
THLPA	-1.331	7.174	6.996	-.140
BLPA	-1.463	3.144	4.328	7.996
(Constant)	-33.814	3.078	-.633	7.367

Unstandardized coefficients

(d.)

	Function							
	1	2	3	4	5	6	7	8
GWASA	3.499	27.761	-11.996	-7.238	-.867	-16.361	-10.562	-27.155
LLPA	2.282	-.346	-1.907	1.272	-9.679	2.422	3.211	-.732
LLeftLtPA	-11.500	2.641	13.577	2.367	.910	.310	2.378	3.517
GLCAF	-6.366	1.207	1.087	-9.881	1.891	11.391	2.754	-6.009
GWCAF	3.839	-1.034	3.605	-5.959	-.894	-2.475	-3.576	26.254
BNA	-5.298	3.382	-8.000	16.484	3.070	-1.702	2.848	4.309
THLPA	10.623	1.746	5.801	5.770	2.216	7.106	-2.943	-1.299
BLPA	5.920	-3.086	-1.201	.328	6.622	-6.821	8.273	-2.735
(Constant)	.082	-62.593	3.762	.780	-2.294	15.804	.564	16.663

Unstandardized coefficients

Table S3.14 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens M-54 (Early Jomon Mawaki site)

(a.)

	Function	
	1	2
GWASA	-2.839	3.147
LLPA	2.598	-2.039
LLeftLtPA	-9.852	-5.336
GLCAF	-10.428	5.407
GWCAF	4.656	3.533
THLPA	8.015	-2.696
BLPA	6.594	2.122
(Constant)	9.713	-8.086

Unstandardized coefficients

(b.)

	Function		
	1	2	3
GWASA	-2.638	5.852	5.711
LLPA	2.542	-2.345	.007
LLeftLtPA	-9.837	-3.785	6.007
GLCAF	-10.369	4.343	-4.832
GWCAF	4.717	3.773	-.737
THLPA	7.955	-2.622	1.246
BLPA	6.631	2.446	.027
(Constant)	9.211	-14.673	-13.739

Unstandardized coefficients

(c.)

	Function			
	1	2	3	4
GWASA	12.683	6.432	-24.712	-19.568
LLPA	-.550	.195	-.258	-3.091
LLefLtPA	2.669	8.454	16.583	-7.447
GLCAF	6.784	-25.276	16.455	7.208
GWCAF	.408	2.399	.824	12.125
ThLPA	-1.646	7.547	-7.086	1.687
BLPA	-2.683	4.311	-1.111	7.511
(Constant)	-35.981	-1.458	-.542	14.461

Unstandardized coefficients

(d.)

	Function						
	1	2	3	4	5	6	7
GWASA	3.088	28.444	-15.157	-.913	-9.384	-23.455	19.934
LLPA	2.299	-.461	-1.605	-9.779	1.465	3.483	1.713
LLeftLtPA	-11.575	3.227	13.511	1.090	-.880	3.633	-2.136
GLCAF	-8.739	3.072	-3.426	3.316	9.954	4.957	4.427
GWCAF	3.319	-.760	1.768	1.245	-7.261	7.764	-25.275
THLPA	10.737	1.346	7.503	1.039	8.324	-1.927	-.247
BLPA	6.307	-3.619	-.393	6.676	-7.162	3.519	7.102
(Constant)	-3.184	-61.767	4.338	-1.883	11.741	11.780	-15.949

Unstandardized coefficients

Table S3.15 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens M-5, M-40, M-43, M-50, and M-61 (Early Jomon Mawaki site)

(a.)	Function 1	Function 2
GWASA	-13.067	-8.873
GLCAF	-10.041	7.542
GWCAF	10.339	8.906
BNA	-.256	-4.072
THLPA	6.858	-1.464
BLPA	5.224	.661
(Constant)	11.762	-1.684

Unstandardized coefficients

(b.)	Function 1	Function 2	Function 3
GWASA	-12.836	-1.566	21.665
GLCAF	-9.908	6.171	-6.758
GWCAF	10.410	6.367	-10.075
BNA	-.340	-3.638	2.866
THLPA	6.816	-1.358	.954
BLPA	5.221	.423	-.838
(Constant)	11.158	-10.399	-20.415

Unstandardized coefficients

(c.)	Function 1	Function 2	Function 3	Function 4
GWASA	7.860	11.474	-12.601	-12.522
GLCAF	3.514	-28.590	13.749	4.270
GWCAF	1.972	2.439	4.847	-9.531
BNA	7.719	2.560	-13.461	14.667
ThLPA	-1.130	9.445	1.224	-1.089
BLPA	-1.538	5.611	4.475	7.226
(Constant)	-34.011	1.533	8.843	.187

Unstandardized coefficients

(d.)	Function 1	Function 2	Function 3	Function 4	Function 5	Function 6
GWASA	-2.775	31.468	-3.276	-21.627	-7.785	16.838
GLCAF	-6.089	2.142	-9.715	9.160	-8.392	3.896
GWCAF	7.481	-3.348	-6.217	2.097	14.241	-21.263
BNA	-4.045	4.120	16.666	2.924	5.136	-1.158
THLPA	11.662	-.247	4.374	2.641	-7.803	-1.120
BLPA	4.596	-3.321	1.439	1.464	6.582	9.018
(Constant)	-10.485	-62.510	-.964	14.304	-.127	-15.671

Unstandardized coefficients

Table S3.16 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens RKA2047 (Okhotsk Kafukai-1 site)

(a.)	Function	
	1	2
GLCAF	-10.132	7.200
GWCAF	2.749	3.769
BNA	-.411	-5.086
HNA	-2.621	-.699
THLPA	6.084	-1.719
BLPA	5.866	1.531
(Constant)	1.950	-8.933

Unstandardized coefficients

(b.)	Function		
	1	2	3
GLCAF	-9.911	6.062	-8.850
GWCAF	3.157	5.559	4.220
BNA	-.516	-3.597	8.566
HNA	-2.639	-.452	1.272
THLPA	6.050	-1.387	2.416
BLPA	5.857	.550	-4.386
(Constant)	1.185	-11.608	-4.119

Unstandardized coefficients

(c.)	Function			
	1	2	3	4
GLCAF	5.027	-24.038	-17.978	1.645
GWCAF	4.263	7.142	-4.039	-15.247
BNA	9.350	3.819	15.116	3.761
HNA	2.007	-.733	12.387	7.528
ThLPA	-1.222	9.628	-.090	-1.109
BLPA	-1.821	5.454	-2.345	9.010
(Constant)	-29.711	8.192	-2.491	-6.689

Unstandardized coefficients

(d.)	1	2	3	4	5	6
GLCAF	-5.723	.367	-11.200	9.594	-1.388	7.323
GWCAF	6.156	10.049	-7.879	-15.343	-3.720	-10.320
BNA	-4.193	6.776	12.796	3.800	6.192	-8.172
HNA	-2.129	6.776	4.297	-5.147	-2.507	8.503
THLPA	11.547	1.249	3.783	6.786	-5.008	1.382
BLPA	4.944	-4.267	1.582	-.490	10.823	2.278
(Constant)	-11.592	-32.506	-1.854	1.523	-6.515	-.235

Unstandardized coefficients

Table S3.17 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens RKA2804 (Okhotsk Kafukai-1 site)

(a.)	Function 1	Function 2
HA	-11.906	-4.103
GLNSA	-.276	.157
GLCAF	-2.117	11.286
BNA	4.041	-3.413
HNA	5.424	3.069
THNSA	4.192	-2.526
(Constant)	4.797	-8.771

Unstandardized coefficients

(b.)	Function 1	Function 2	Function 3
HA	-11.839	-2.489	5.083
GLNSA	-.251	.629	1.144
GLCAF	-2.044	10.159	-5.746
BNA	4.001	-3.236	1.334
HNA	5.390	1.987	-3.495
THNSA	4.228	-.939	4.642
(Constant)	4.597	-10.737	-2.658

Unstandardized coefficients

(c.)	Function 1	Function 2	Function 3	Function 4
HA	4.266	-17.200	11.123	9.658
GLNSA	-.452	.297	6.021	-2.753
GLCAF	2.651	20.598	-19.858	-21.309
BNA	9.887	-4.720	4.891	4.492
HNA	2.923	-4.508	-1.956	3.930
ThBNSA	-1.403	4.858	.318	5.454
(Constant)	-30.695	4.616	-.506	5.175

Unstandardized coefficients

(d.)	Function 1	Function 2	Function 3	Function 4	Function 5	Function 6
HA	10.159	-.234	4.157	.888	-6.431	1.518
GLNSA	.212	1.763	4.856	6.714	3.962	.487
GLCAF	-.210	.832	7.278	-11.220	5.951	.541
BNA	3.647	5.854	-11.522	6.255	.374	-10.373
HNA	-1.309	4.933	-7.733	-1.145	3.217	8.815
THNSA	-4.130	4.854	.398	-.286	-5.746	-.677
(Constant)	-15.693	-25.544	2.141	-.743	-4.403	.359

Unstandardized coefficients

Table S3.18 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens No.495 (Early Jomon Mibiki site)

(a.)	Function 1	2
HA	-11.346	-2.975
GLCAF	-8.044	11.337
GWCAF	9.619	-.168
BNA	3.675	-3.639
HNA	3.728	1.294
BLPA	4.483	-1.884
(Constant)	.163	-7.484

Unstandardized coefficients

(b.)	Function 1	2	3
HA	-11.269	-.677	6.961
GLCAF	-7.932	8.032	-13.257
GWCAF	9.814	3.164	8.375
BNA	3.592	-3.318	2.428
HNA	3.679	.026	-3.697
BLPA	4.486	-.932	3.215
(Constant)	-.258	-10.892	-5.123

Unstandardized coefficients

(c.)	Function 1	2	3	4
HA	1.110	23.383	3.664	-.841
GLCAF	2.680	-31.330	-24.057	6.594
GWCAF	4.151	-5.677	12.397	-18.813
BNA	9.224	9.138	4.606	2.495
HNA	1.851	6.196	-3.267	8.397
BLPA	-1.542	.356	9.348	7.195
(Constant)	-28.735	-4.004	1.474	-6.378

Unstandardized coefficients

(d.)	Function 1	2	3	4	5	6
HA	9.688	1.350	-5.036	2.611	-6.540	3.311
GLCAF	4.401	-2.096	-9.066	-1.324	13.972	.565
GWCAF	-8.932	15.247	-3.675	-9.666	-9.767	-6.106
BNA	3.654	3.533	13.729	8.618	-1.232	-7.718
HNA	-.423	4.940	7.943	-6.251	4.013	6.964
BLPA	-6.243	-1.139	-.111	9.978	-1.105	5.221
(Constant)	-5.833	-33.739	-3.457	-5.113	.224	-1.701

Unstandardized coefficients

Table S3.19 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens No.495 (Early Jomon Mibiki site)

(a.)	Function 1	2
LLeftLtPA	-9.351	-5.344
GLCAF	-10.557	6.388
GWCAF	5.036	3.422
THLPA	7.113	-2.595
BLPA	7.850	1.190
(Constant)	6.565	-5.517

Unstandardized coefficients

(b.)	Function 1	2	3
LLeftLtPA	-9.336	-3.394	6.895
GLCAF	-10.439	5.601	-4.350
GWCAF	5.394	4.949	2.807
THLPA	7.091	-2.149	2.111
BLPA	7.876	.836	-1.293
(Constant)	5.776	-9.934	-9.526

Unstandardized coefficients

(c.)	Function 1	2	3	4
LLefLtPA	3.264	9.543	-16.838	-8.564
GLCAF	11.018	-22.087	-6.992	5.765
GWCAF	5.853	4.477	10.079	-6.186
ThLPA	-1.685	7.355	7.505	-.110
BLPA	-3.463	3.965	2.294	11.597
(Constant)	-27.452	1.628	15.314	.215

Unstandardized coefficients

(d.)	Function 1	2	3	4	5
LLeftLtPA	-10.006	8.775	9.841	-1.387	1.827
GLCAF	-8.771	3.266	-5.354	10.604	4.799
GWCAF	4.928	10.656	-7.547	-15.806	-10.090
THLPA	10.559	4.065	5.741	7.773	-2.343
BLPA	7.790	-4.846	.157	-3.006	10.078
(Constant)	-.096	-35.356	-2.905	3.714	-6.119

Unstandardized coefficients

Table S3.20 Summary of classification functions out of three superfamilies (a), four families (b), five subfamilies (c), and eighteen species (d) of zooarchaeological toothed whale specimens M-23 (Early Jomon Mawaki site)

(a.)

	Function	
	1	2
GWASA	-13.203	-7.780
GWCAF	4.664	14.482
BNA	-5.008	.339
THLPA	7.589	-3.747
BLPA	4.237	.850
(Constant)	11.932	-4.317

Unstandardized coefficients

(b.)

	Function		
	1	2	3
GWASA	-12.758	.560	22.974
GWCAF	4.969	9.718	-17.711
BNA	-5.055	-.050	-1.156
THLPA	7.493	-3.011	3.561
BLPA	4.262	.474	-1.200
(Constant)	10.730	-13.189	-18.787

Unstandardized coefficients

(c.)

	Function			
	1	2	3	4
GWASA	10.064	-9.389	-7.296	-7.480
GWCAF	2.349	2.622	-8.913	-7.260
BNA	8.123	-7.358	12.625	13.054
ThLPA	-.699	7.881	6.082	-2.907
BLPA	-1.072	5.435	-3.426	8.637
(Constant)	-34.590	11.279	5.184	-3.065

Unstandardized coefficients

(d.)

	Function				
	1	2	3	4	5
GWASA	-.983	31.517	-7.728	-21.169	17.622
GWCAF	4.240	-2.520	-11.897	13.637	-17.679
BNA	-7.366	5.821	12.626	5.180	.229
THLPA	11.780	-.909	7.429	-4.133	-3.118
BLPA	3.619	-3.228	.663	5.189	9.998
(Constant)	-12.807	-62.270	4.027	10.503	-17.323

Unstandardized coefficients

APPENDIX D

Combined-groups plot of canonical function analysis

of all zooarchaeological specimens examined

Figure S4.1 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-3).

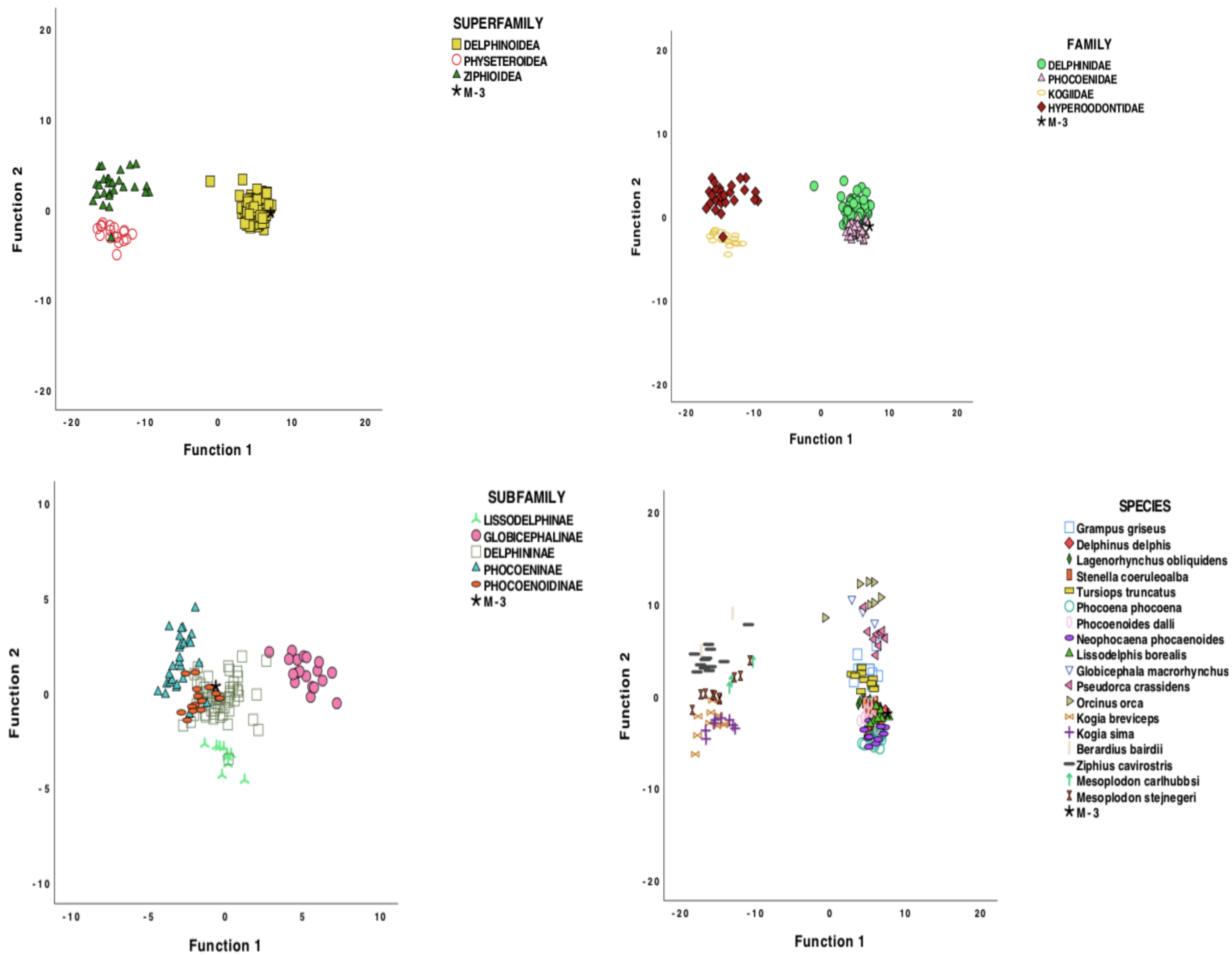


Figure S4.2 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon zooarchaeological specimen (M-20).

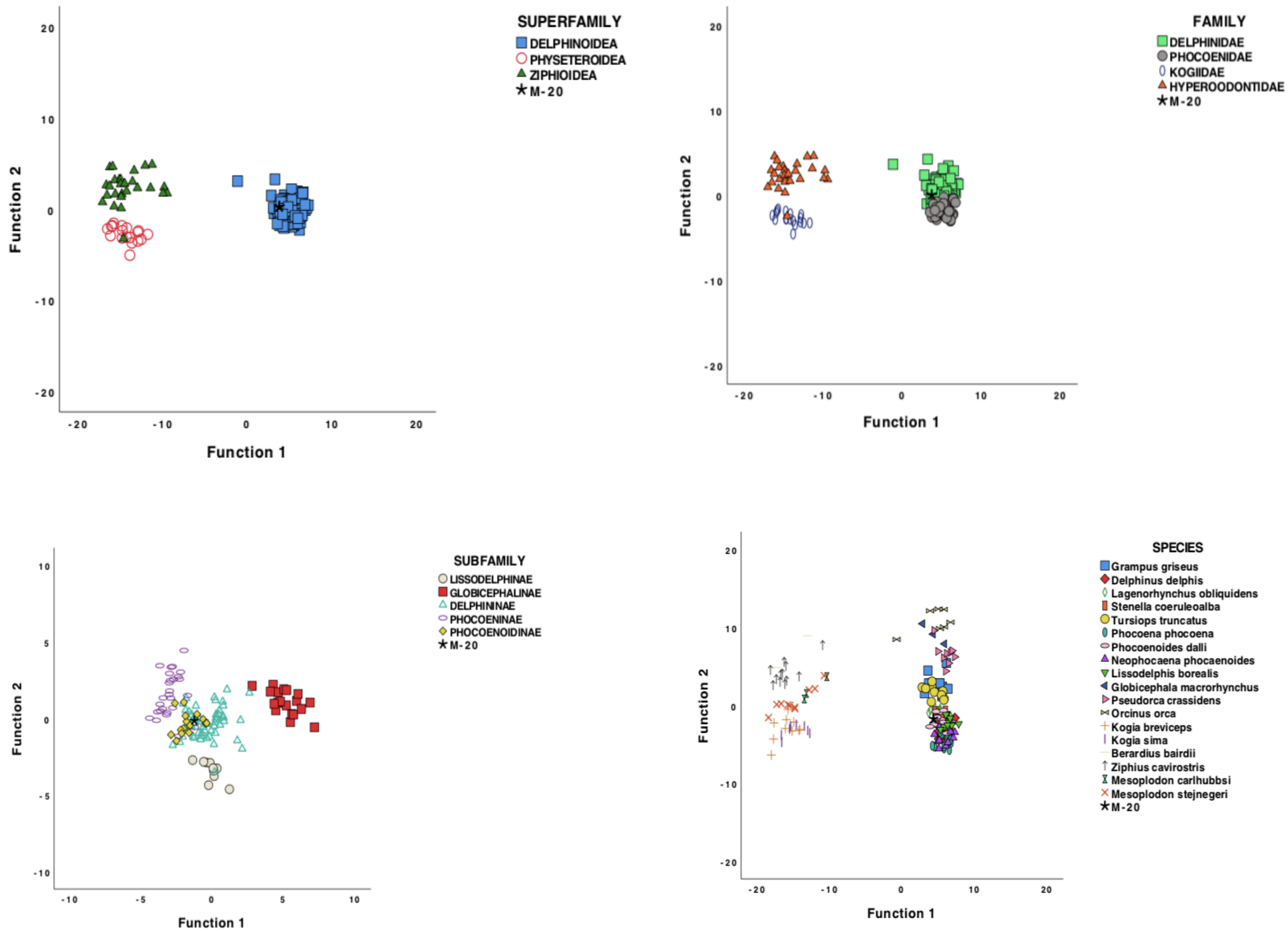


Figure S4.3 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon zooarchaeological specimen (M-28).

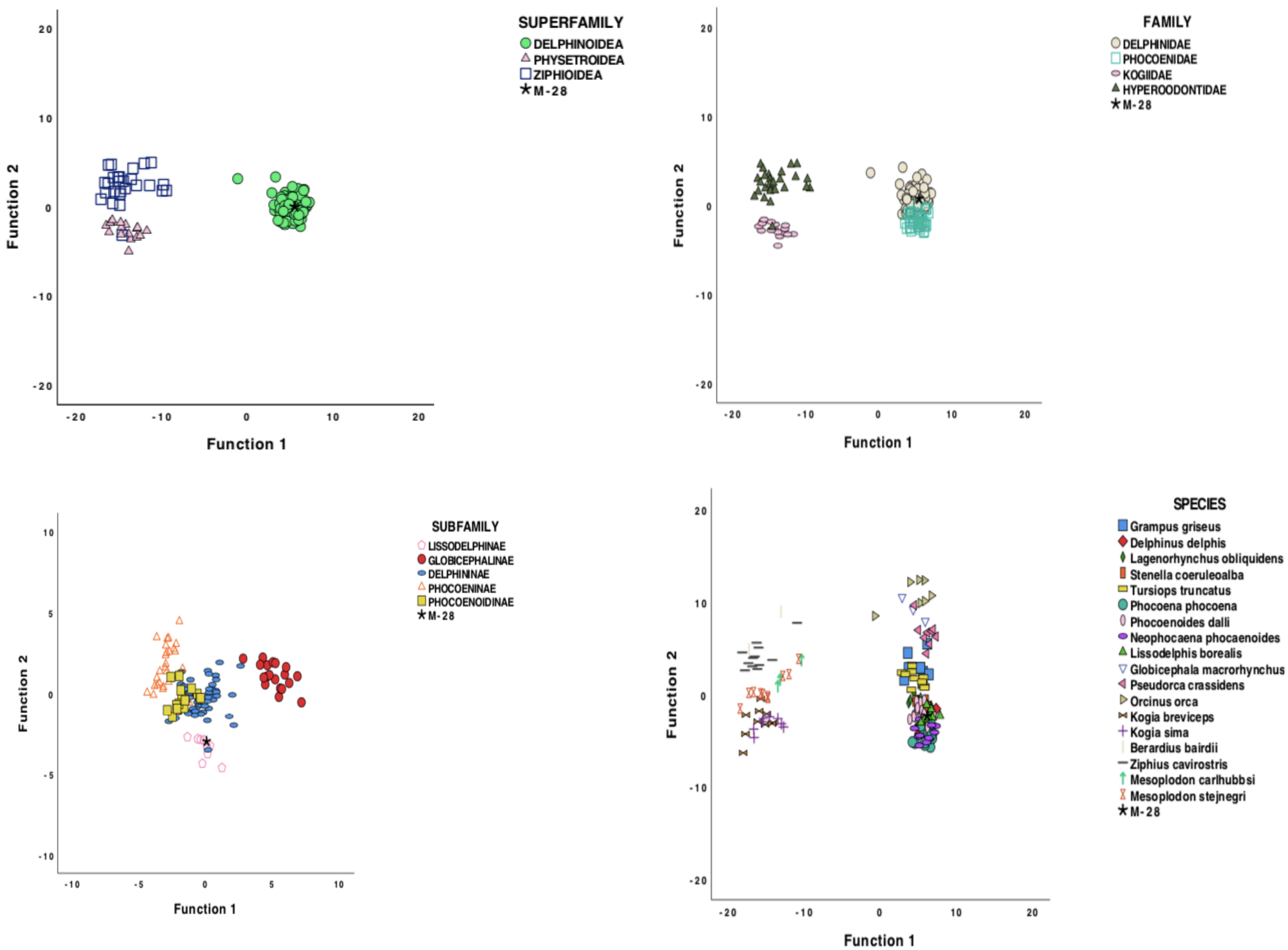


Figure S4.4 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-69).

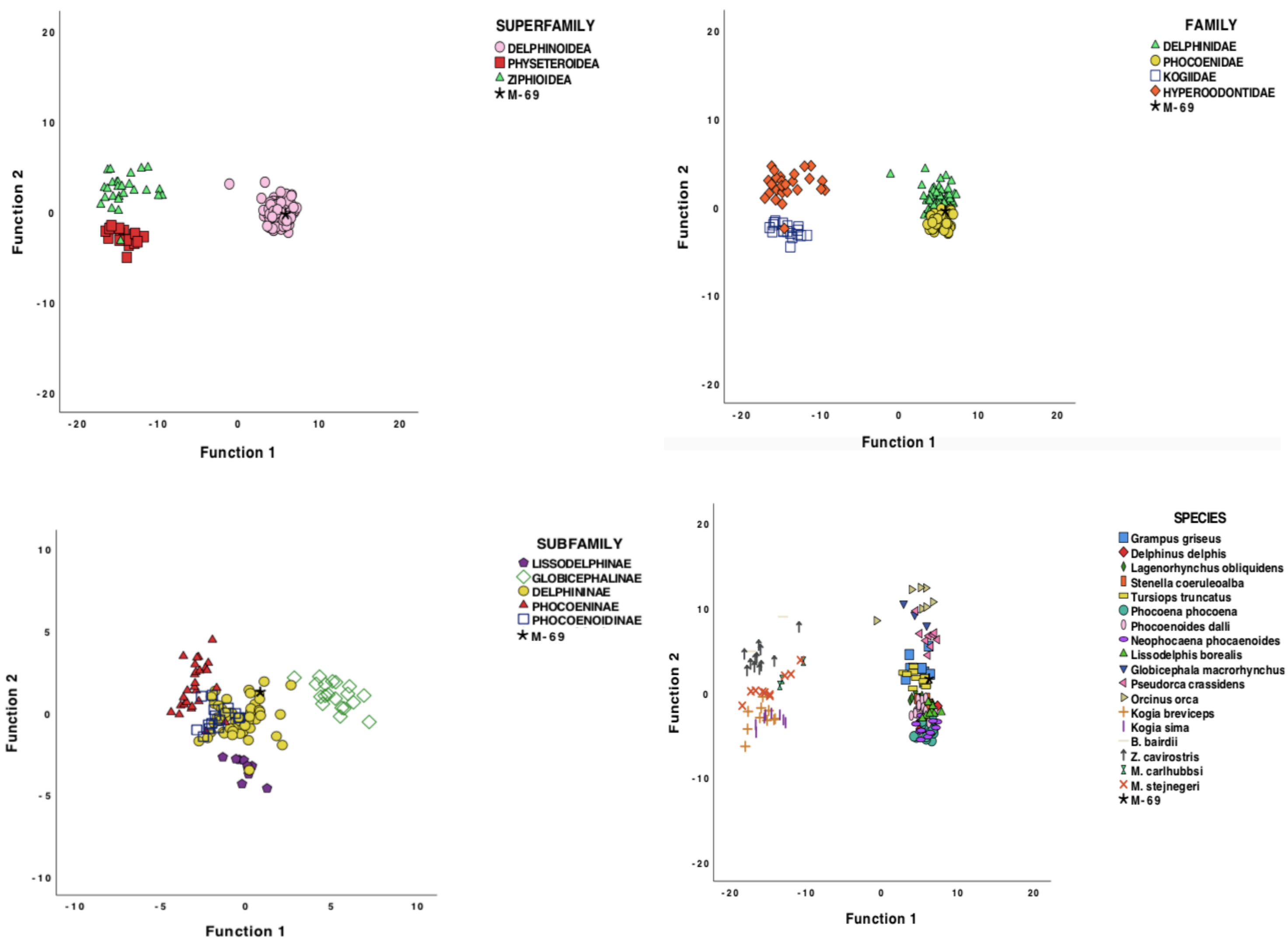


Figure S4.5 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mibiki zooarchaeological specimen (No.159).

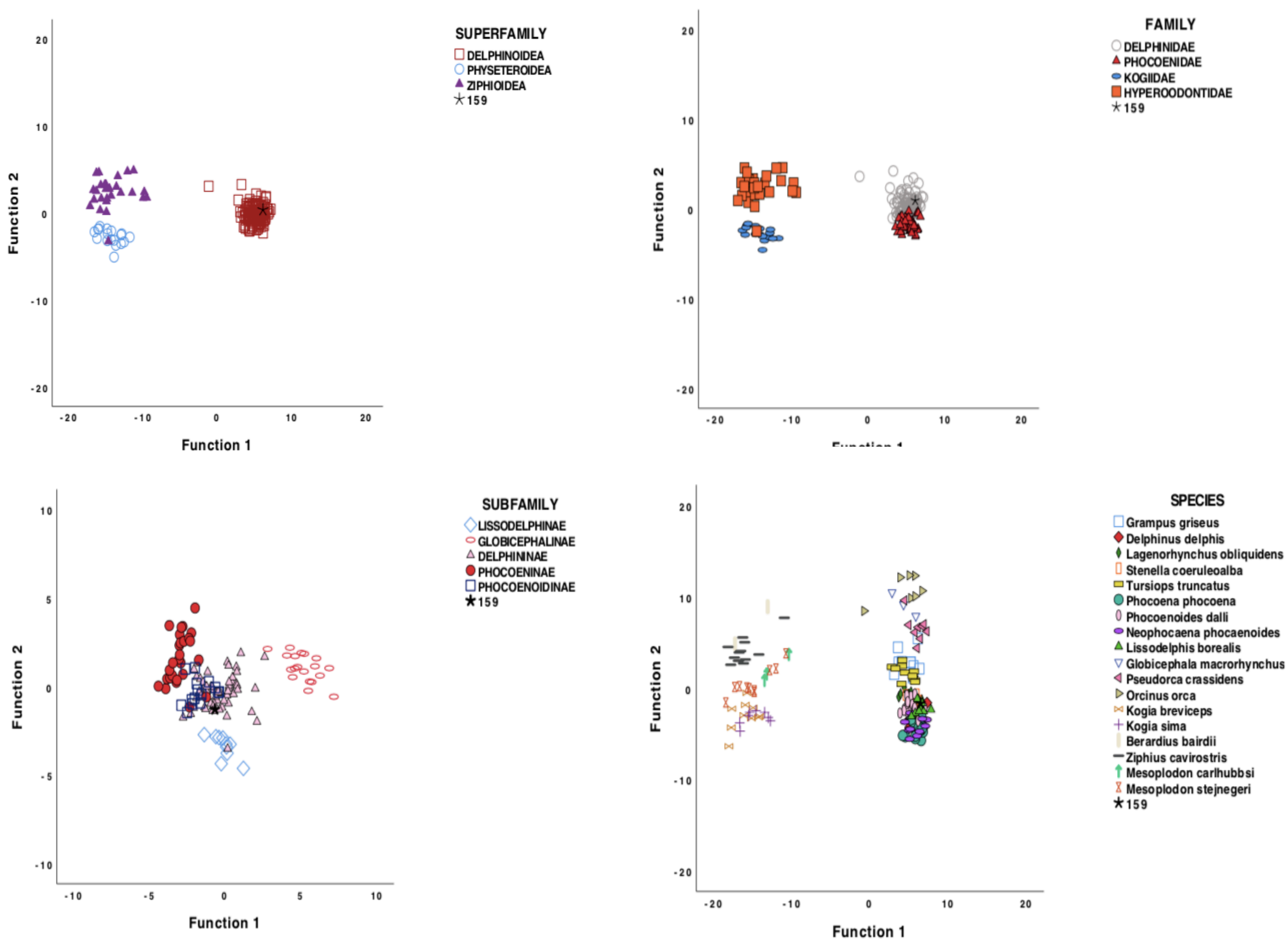


Figure S4.6 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Okhotsk Kafukai-1 zooarchaeological specimen (RKA18142).

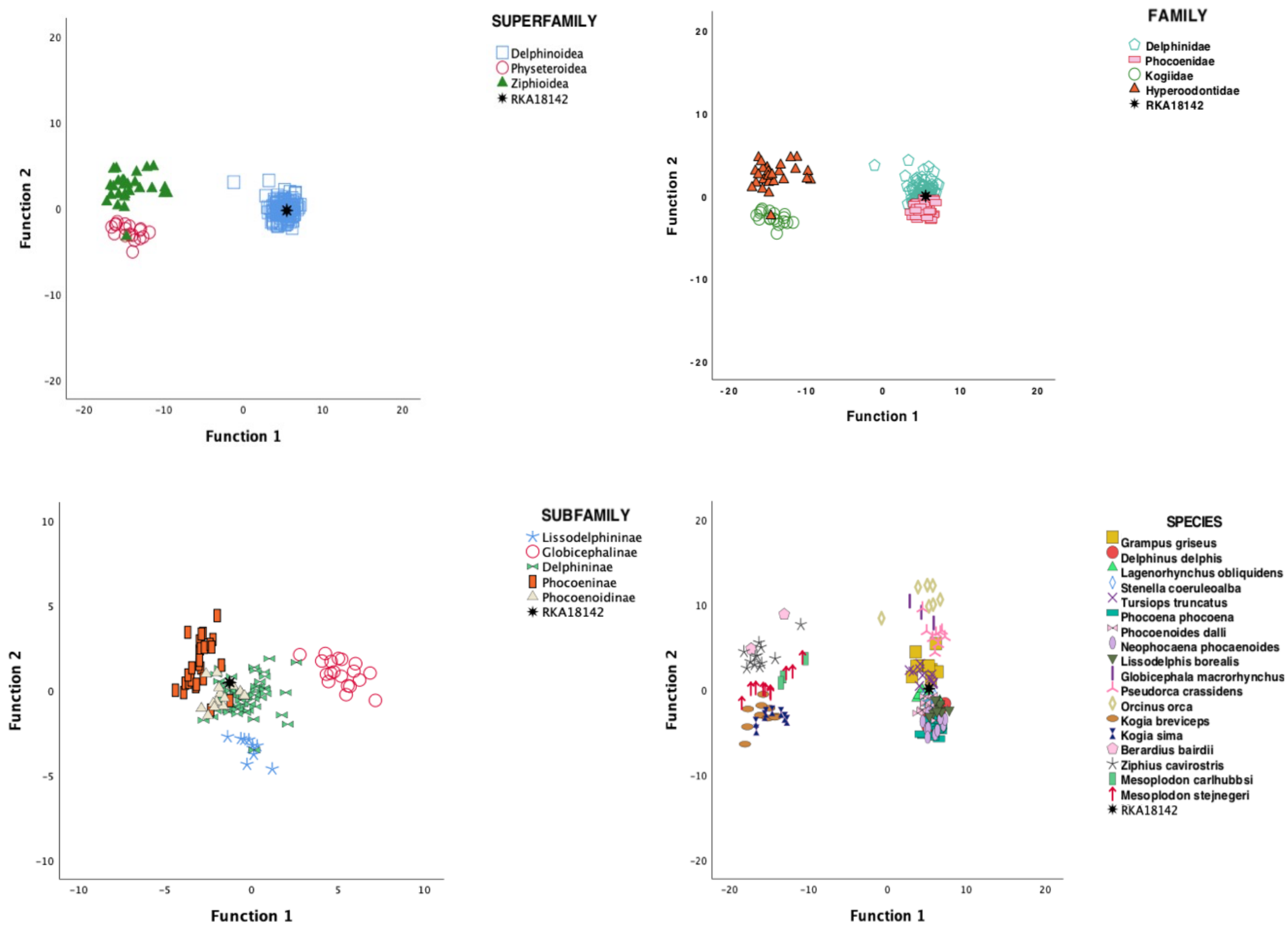


Figure S4.7 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-1).

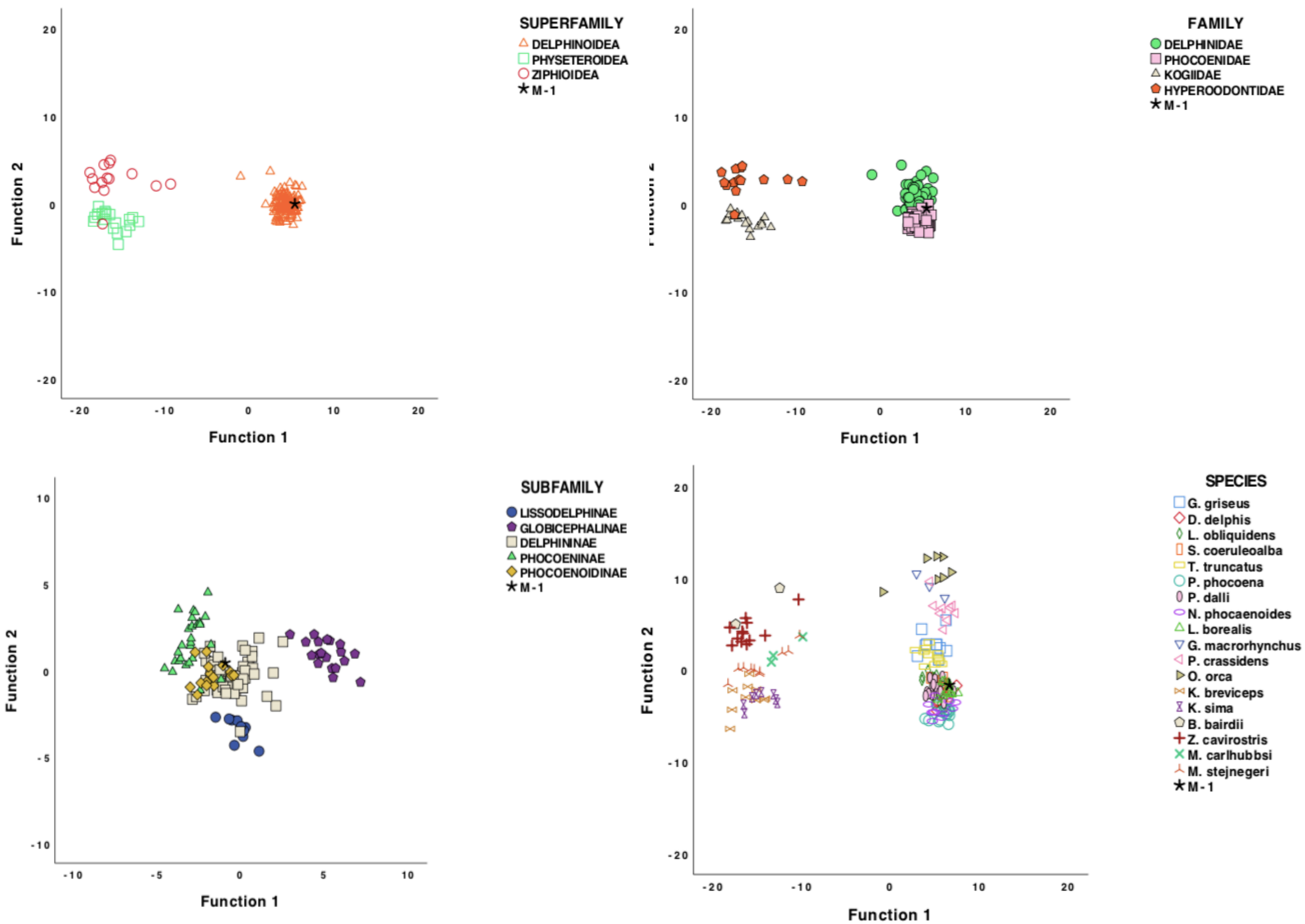


Figure S4.8 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-90).

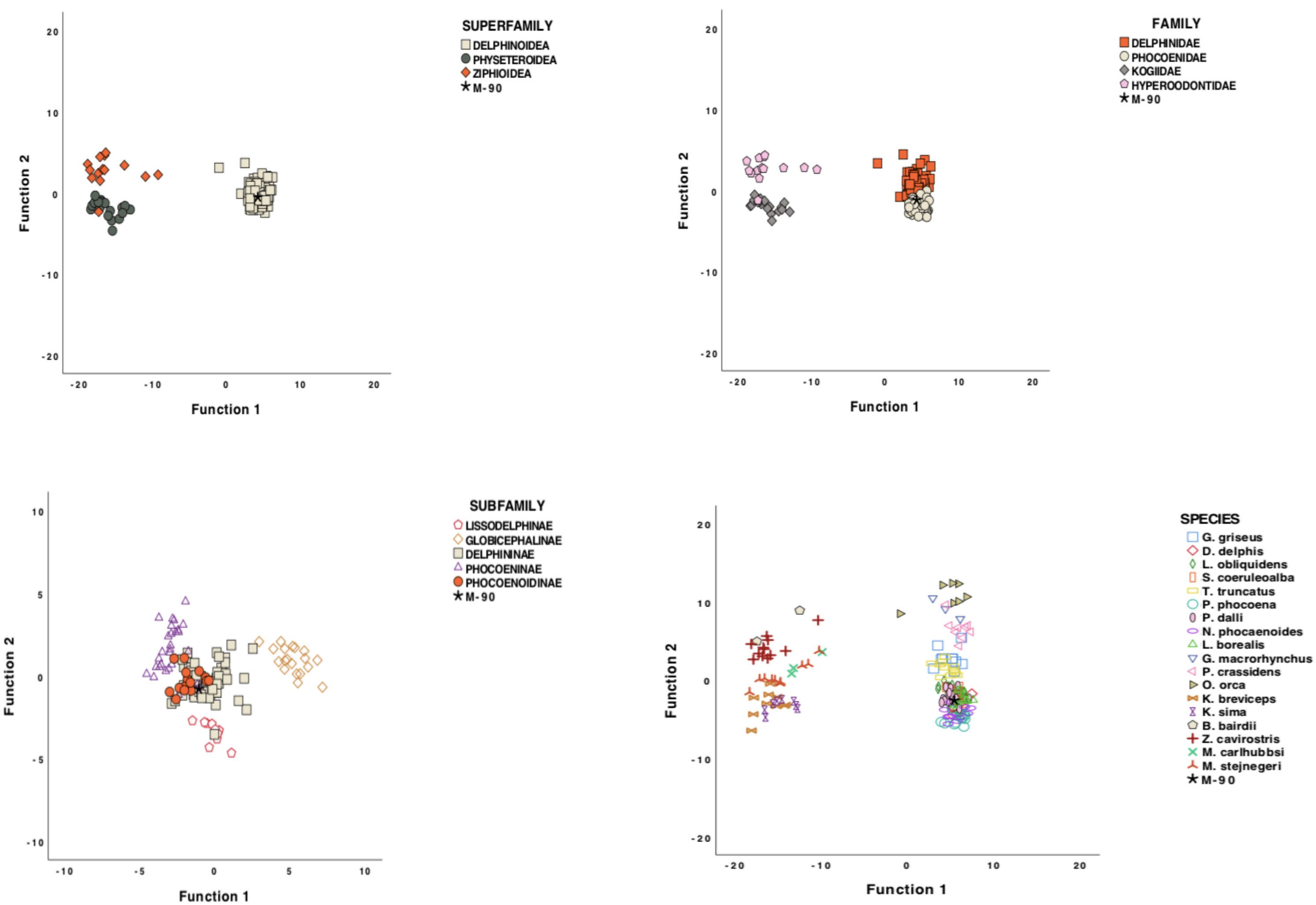


Figure S4.9 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-111).

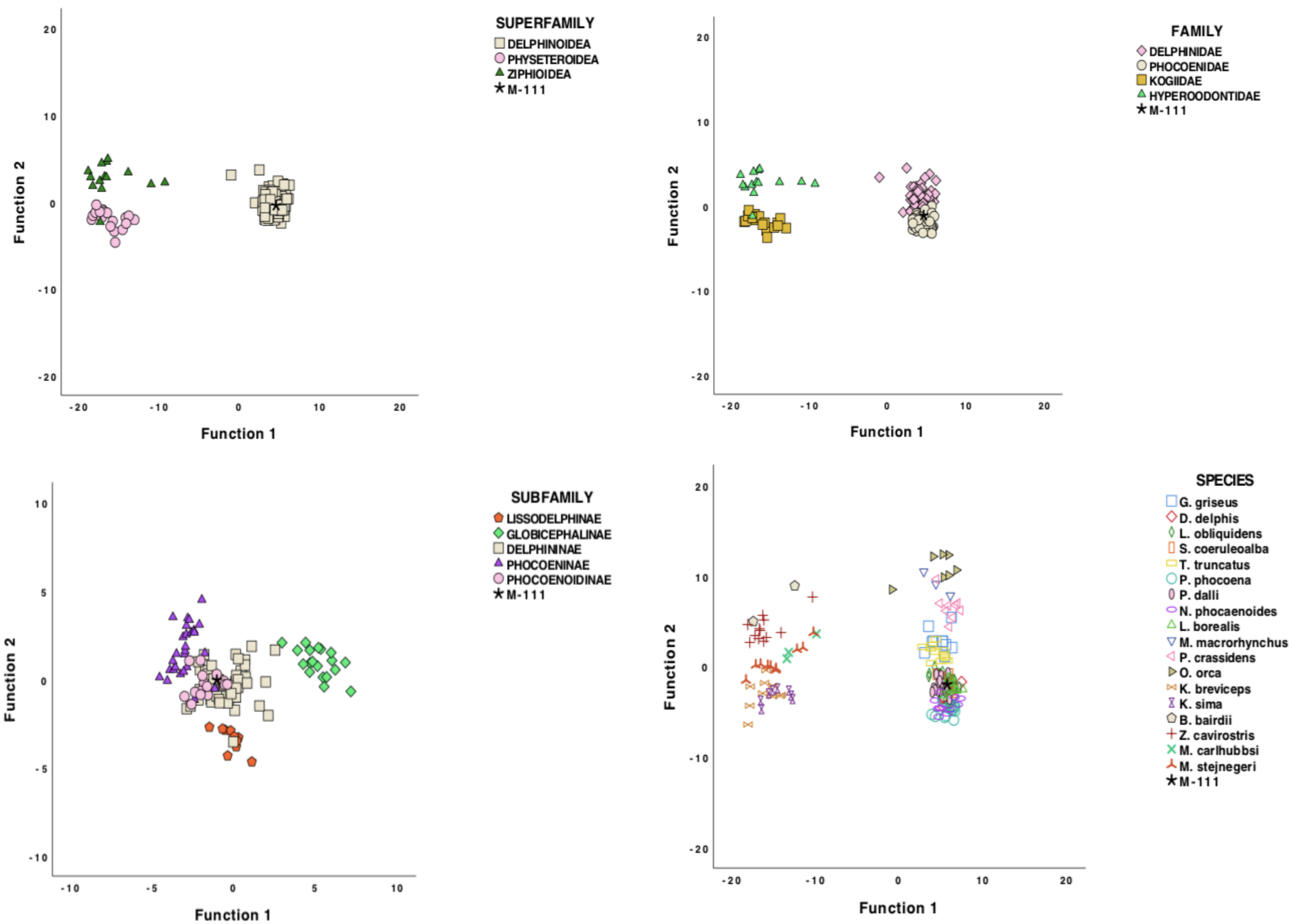


Figure S4.10 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Okhotsk Kafuki-1 zooarchaeological specimen (RKA3982).

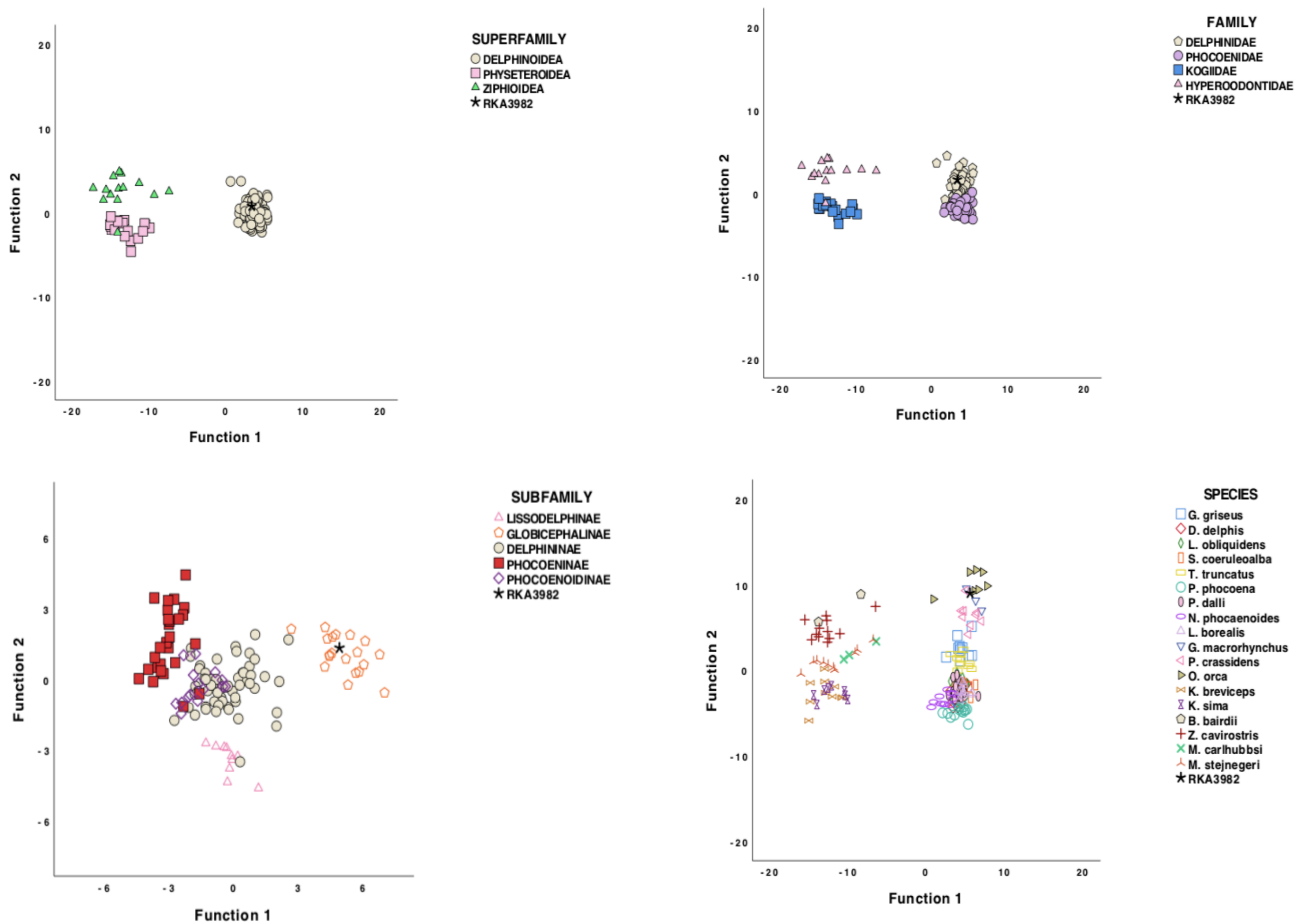


Figure S4.11 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Okhotsk Kafukai-1 zooarchaeological specimen (RKA5918).

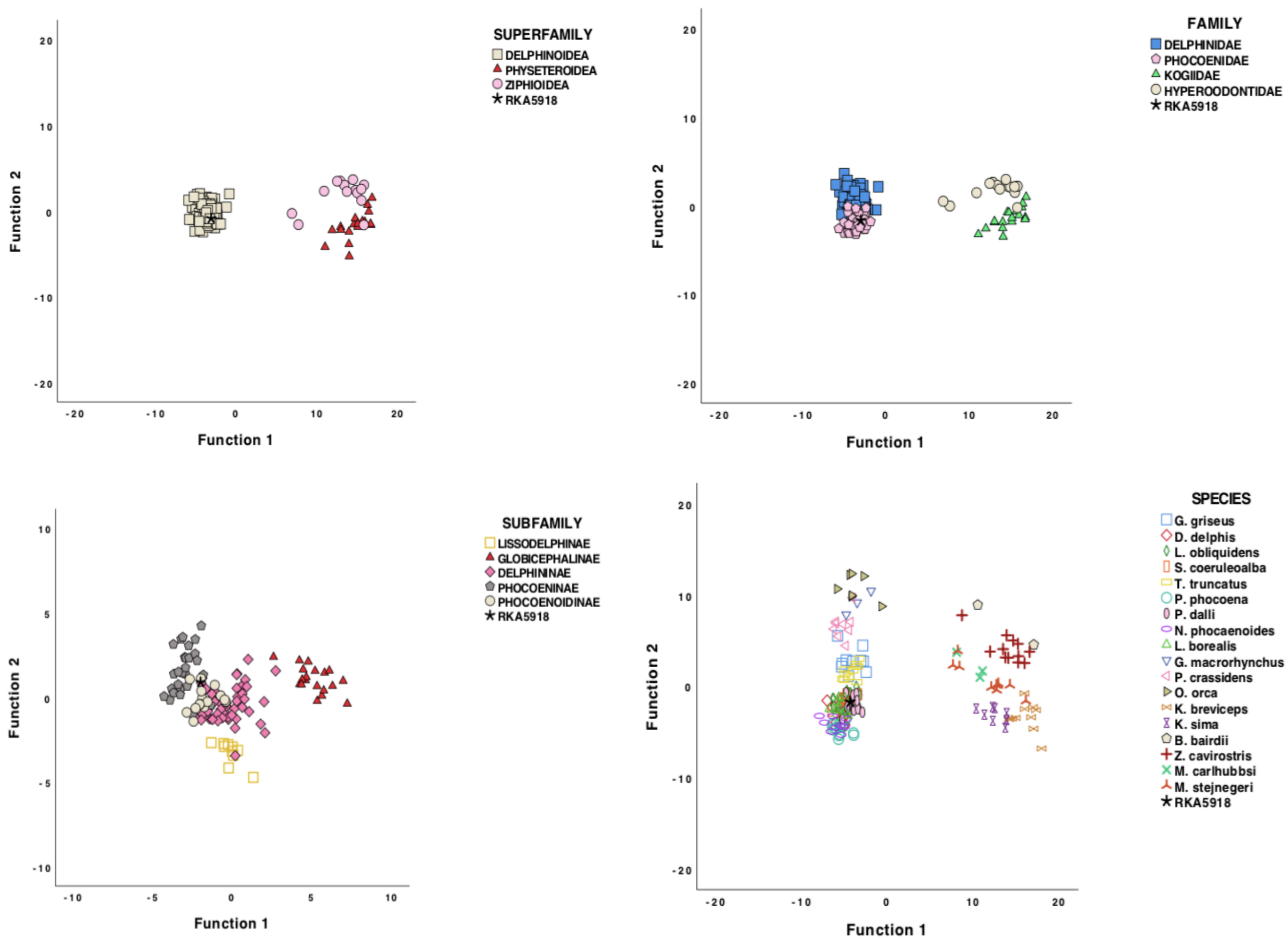


Figure S4.12 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mibiki zooarchaeological specimen (No.483).

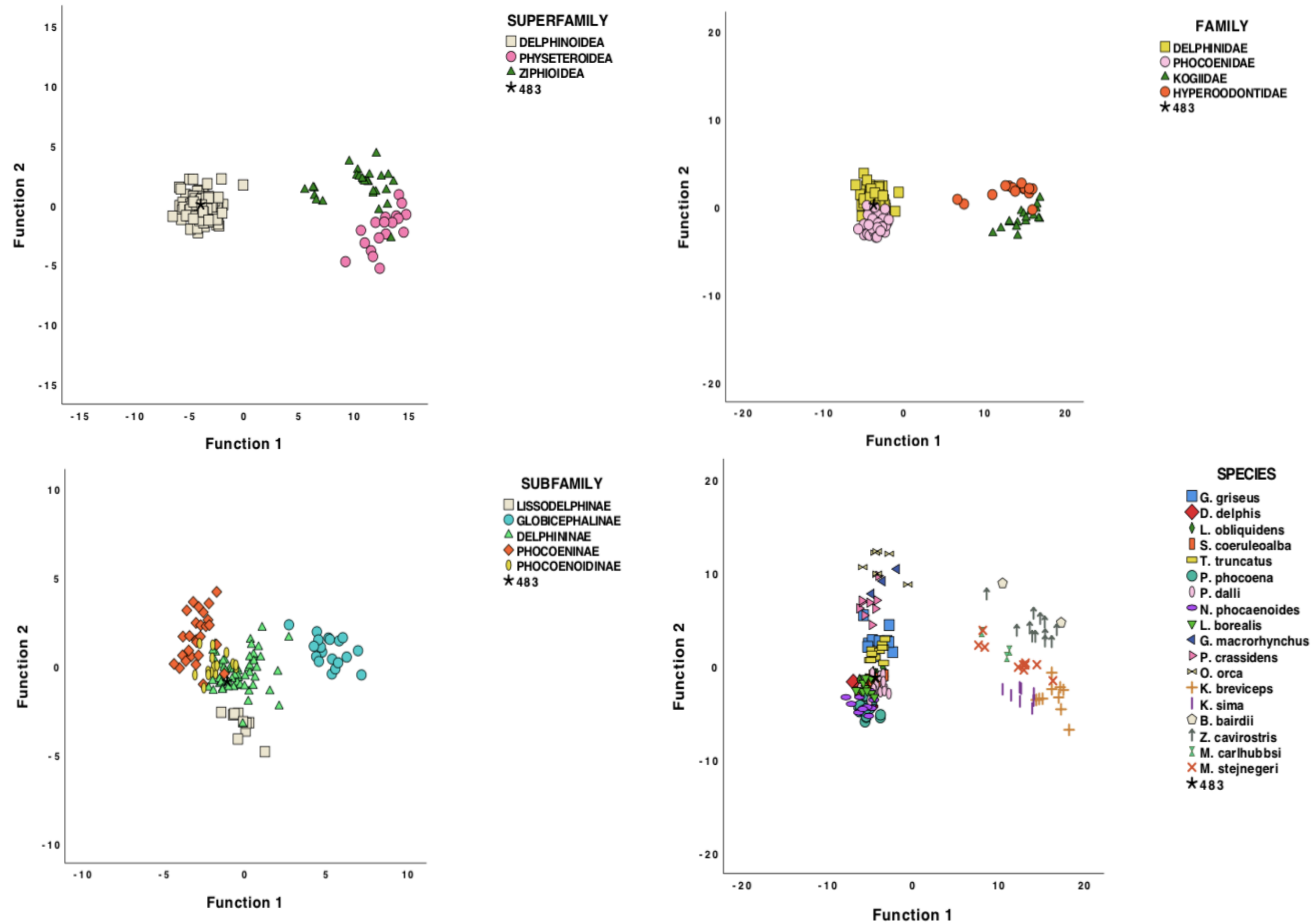


Figure S4.13 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-91).

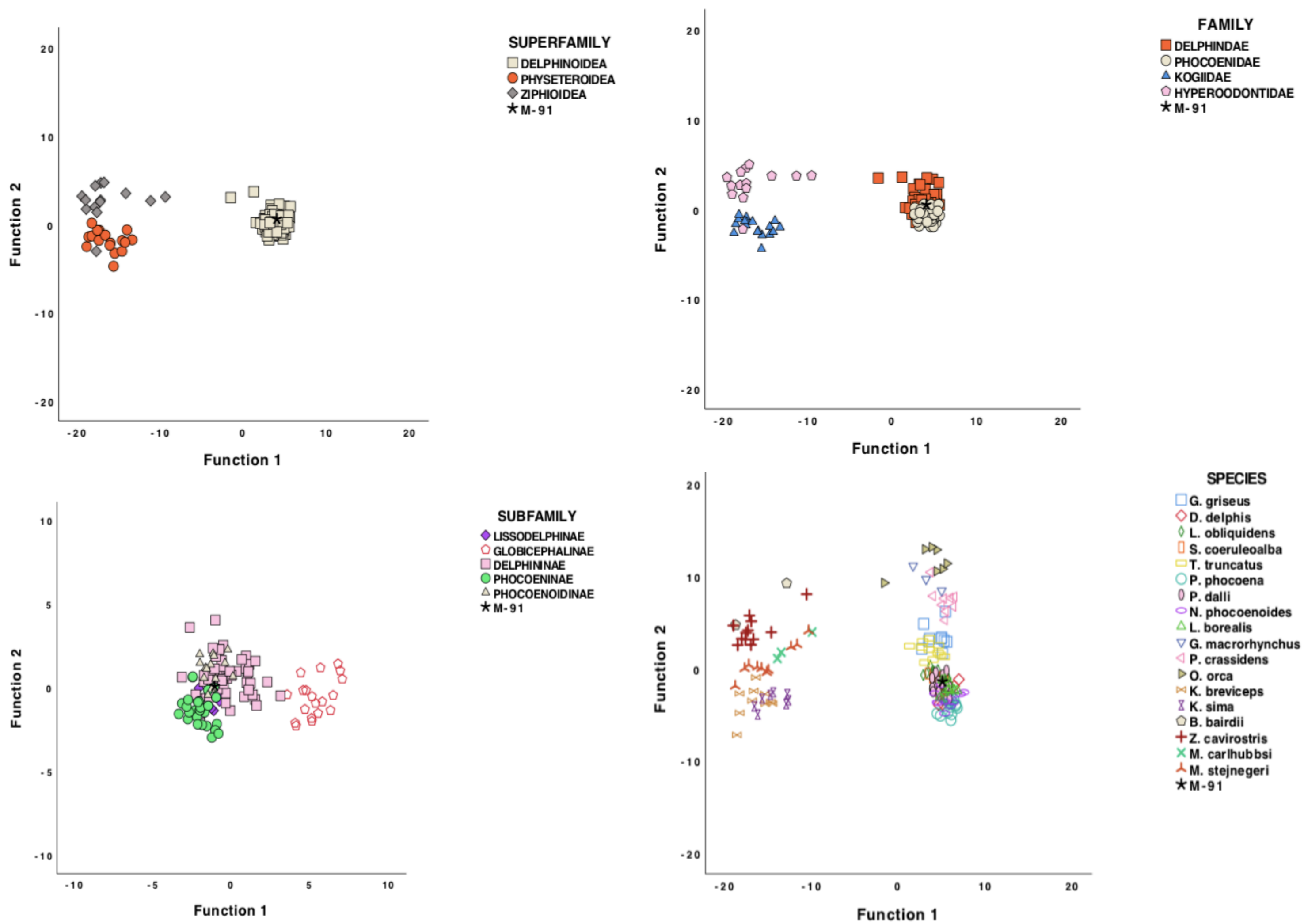


Figure S4.14 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Okhotsk Kafukai-1 zooarchaeological specimen (RKA15283).

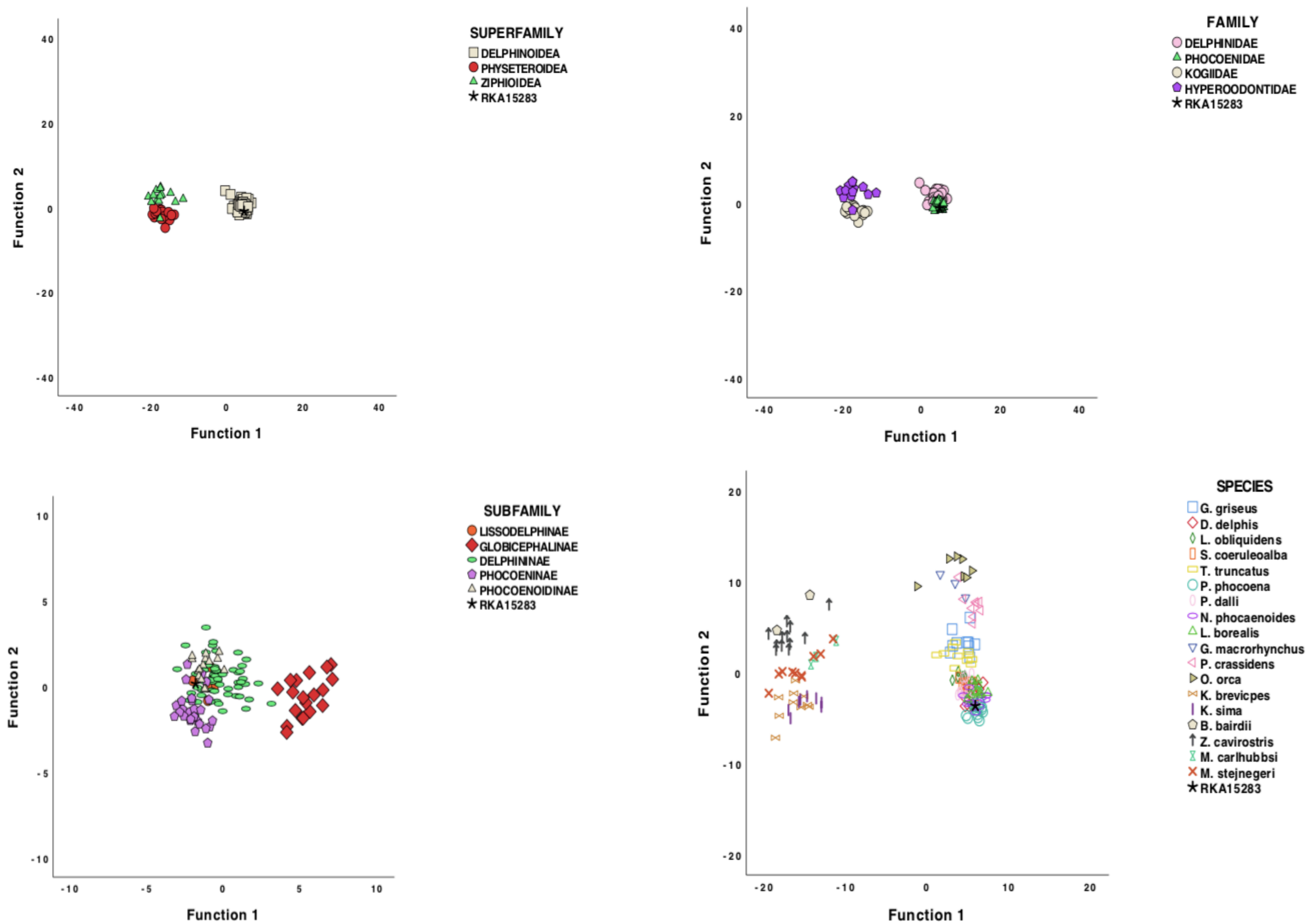


Figure S4.15 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-36).

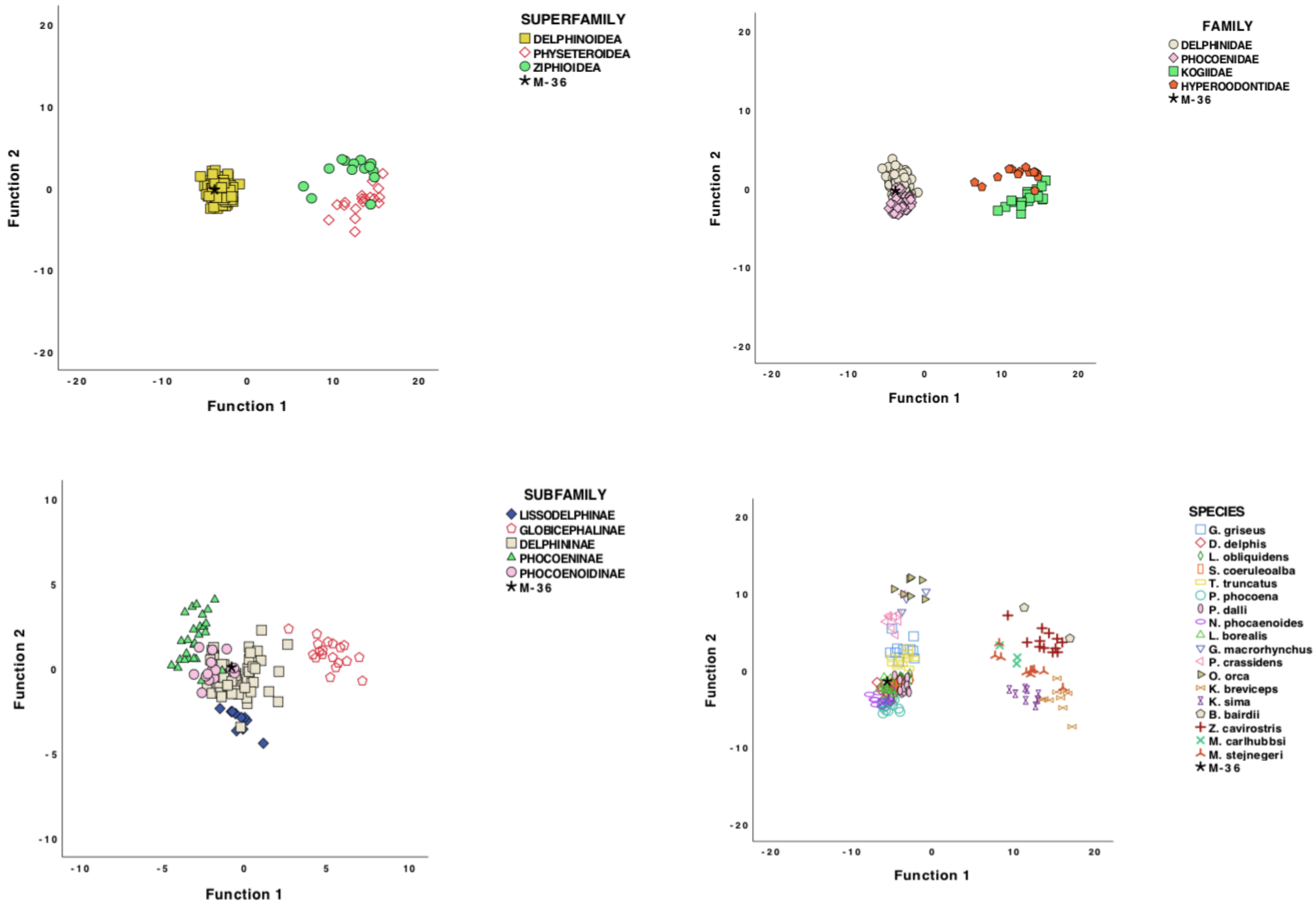


Figure S4.16 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-58).

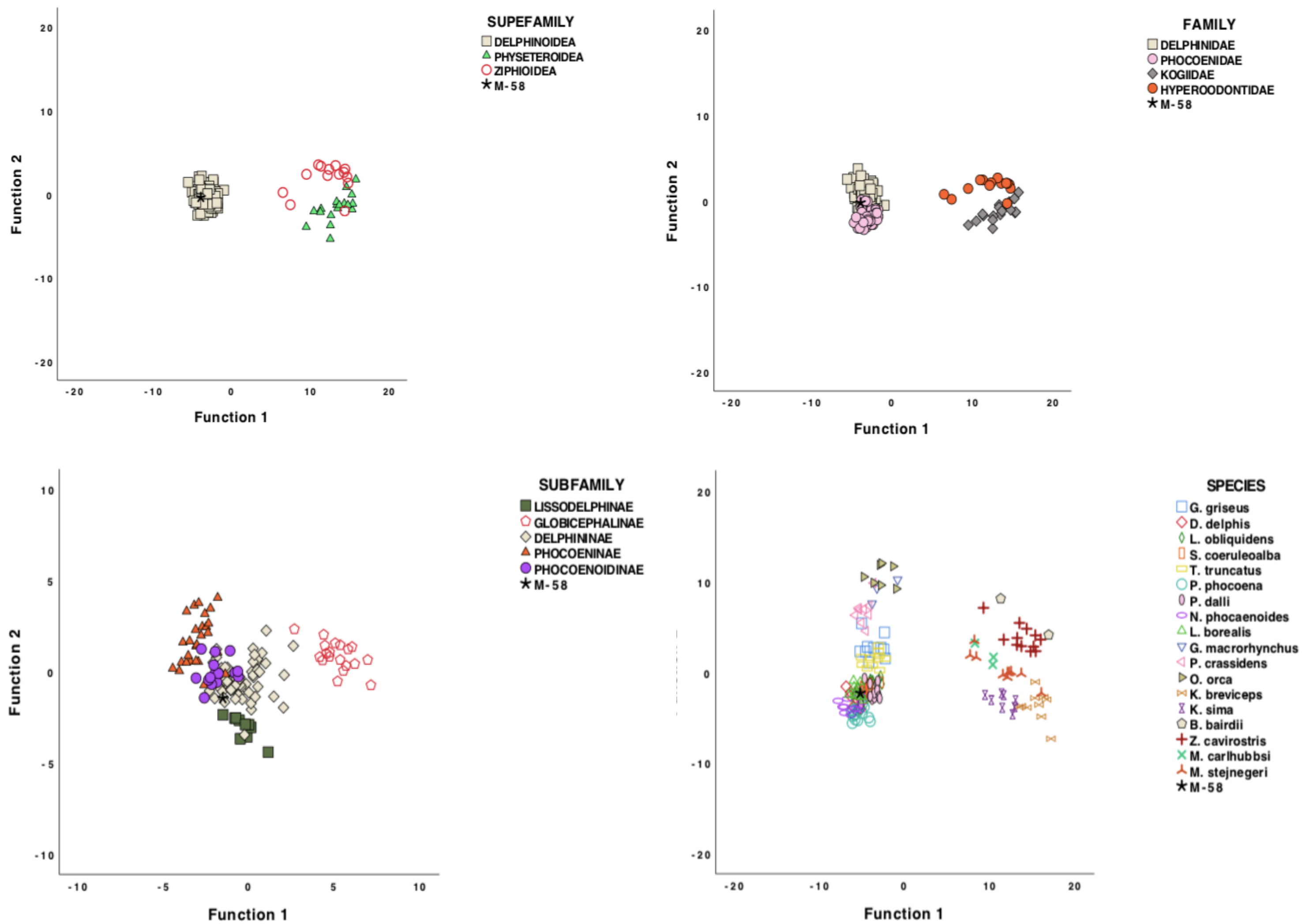


Figure S4.17 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-109).

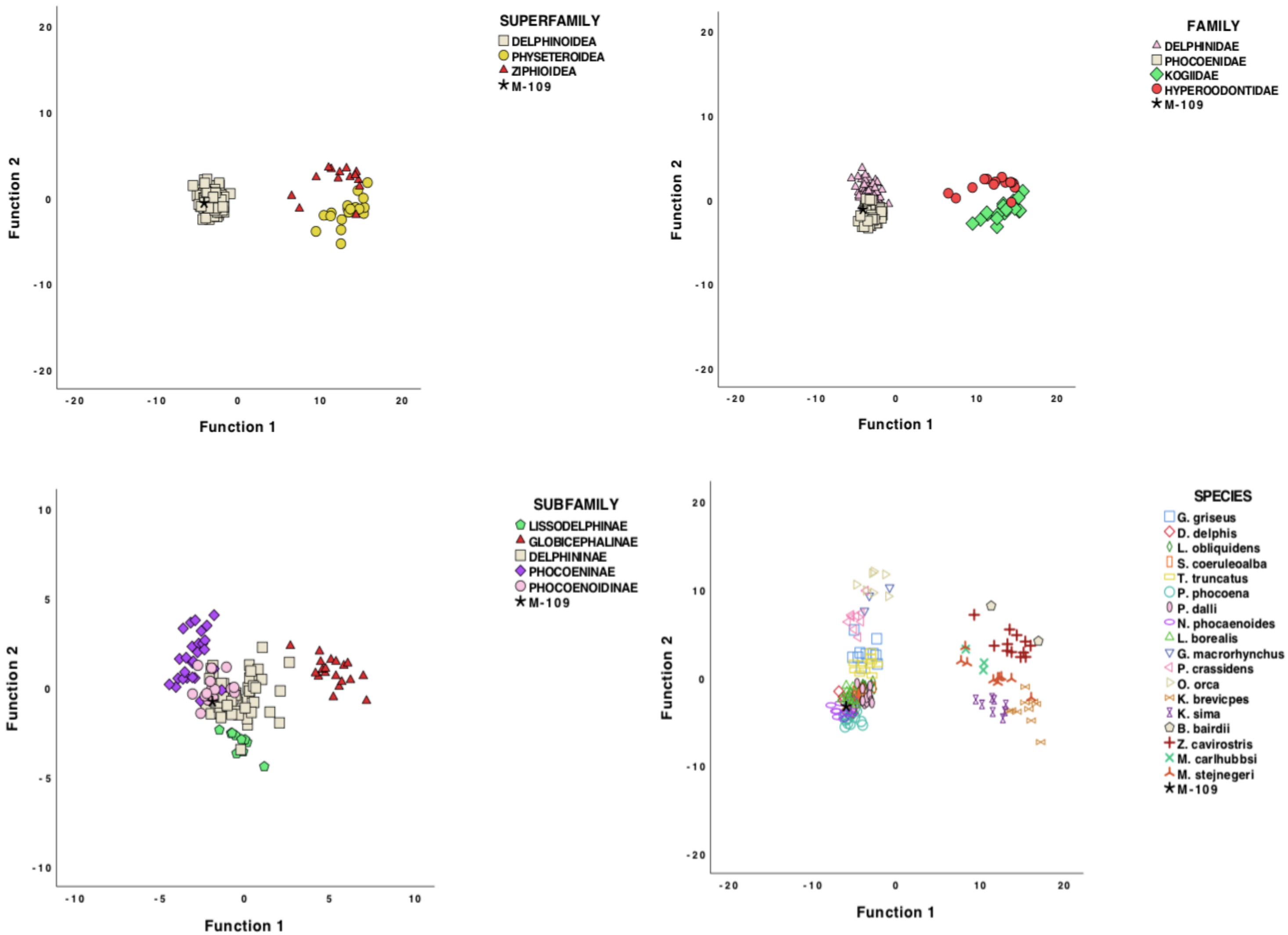


Figure S4.18 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mibiki zooarchaeological specimen (No.748).

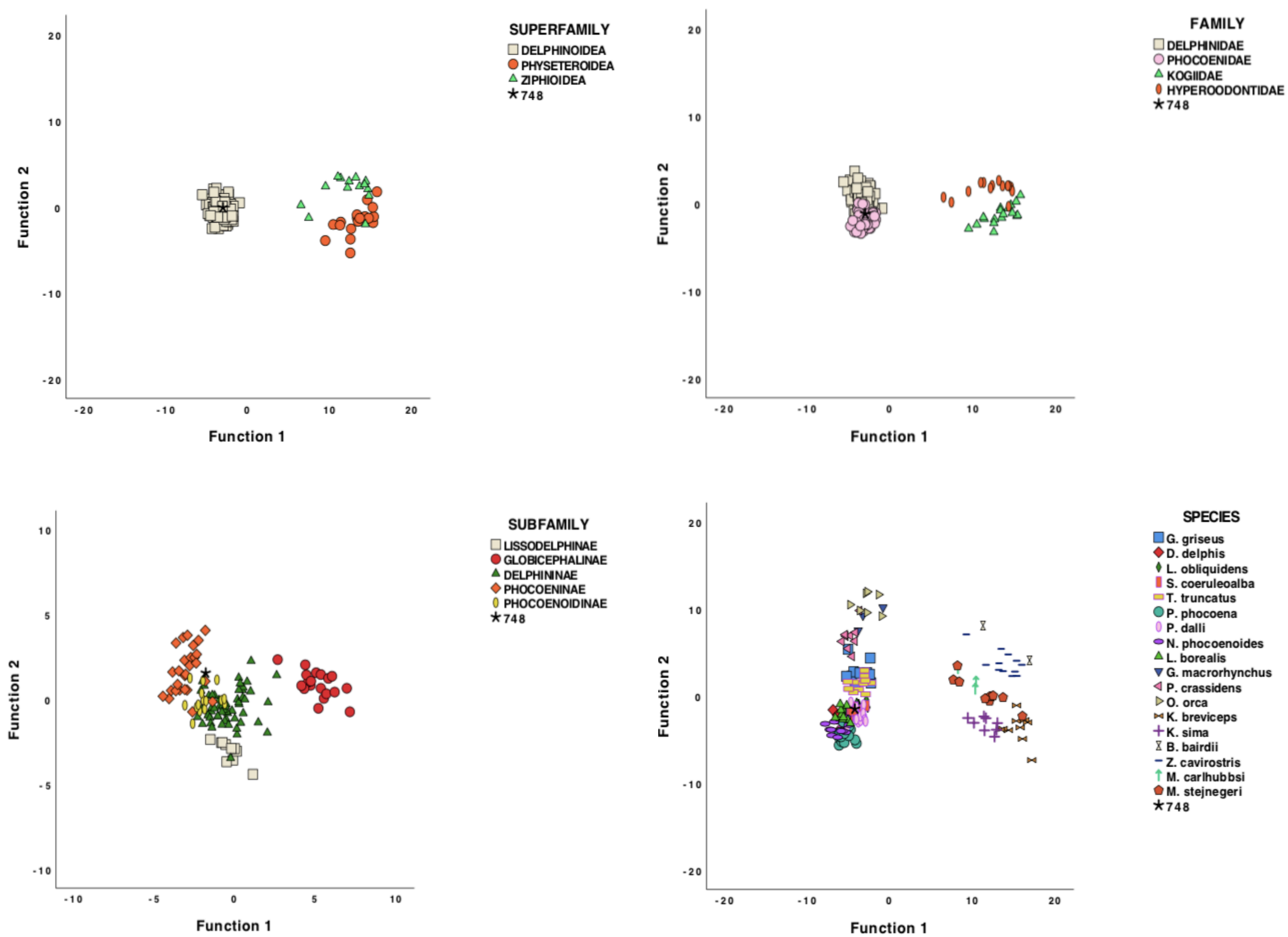


Figure S4.19 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mibiki zooarchaeological specimen (No.749).

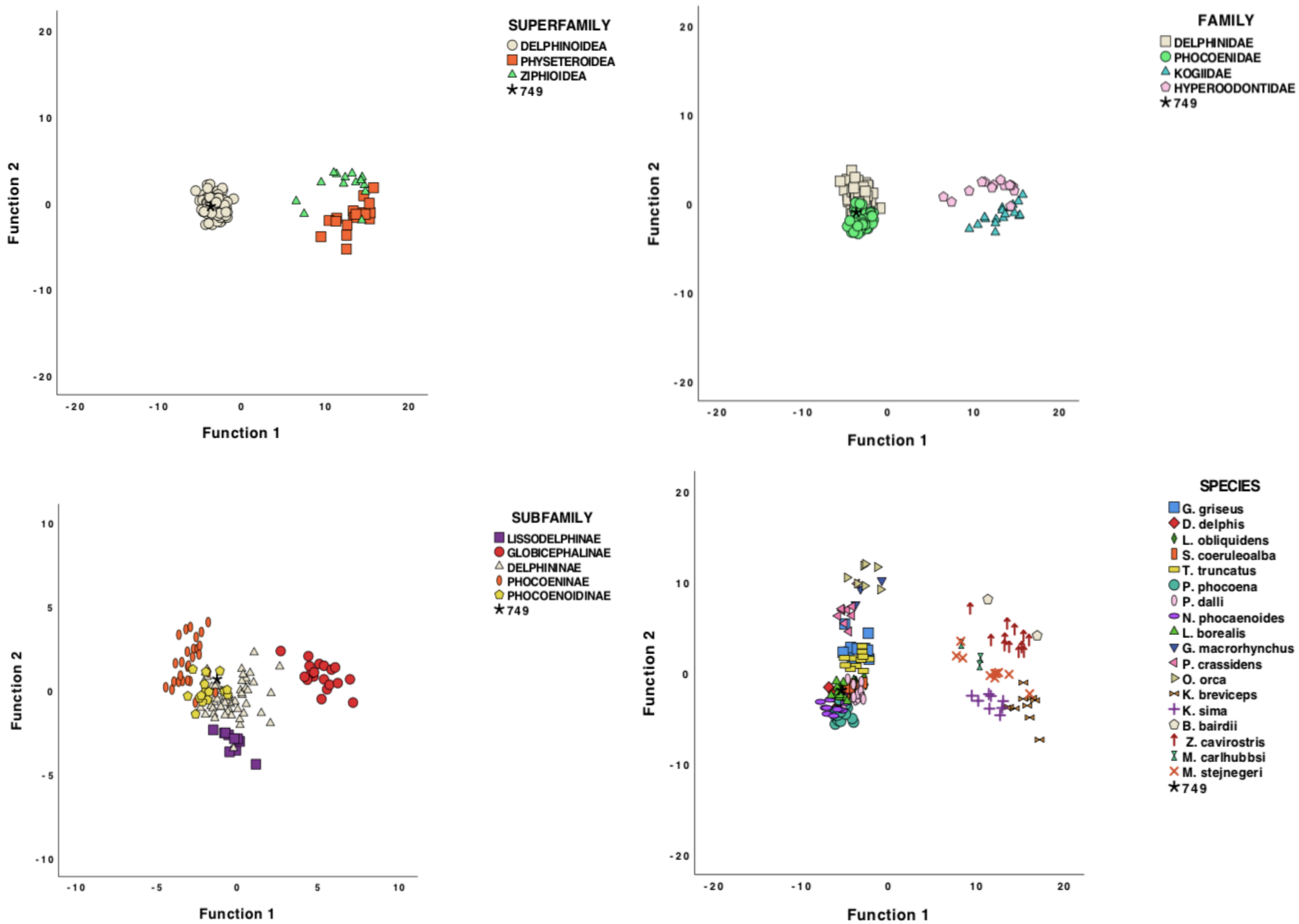


Figure S4.20 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-45).

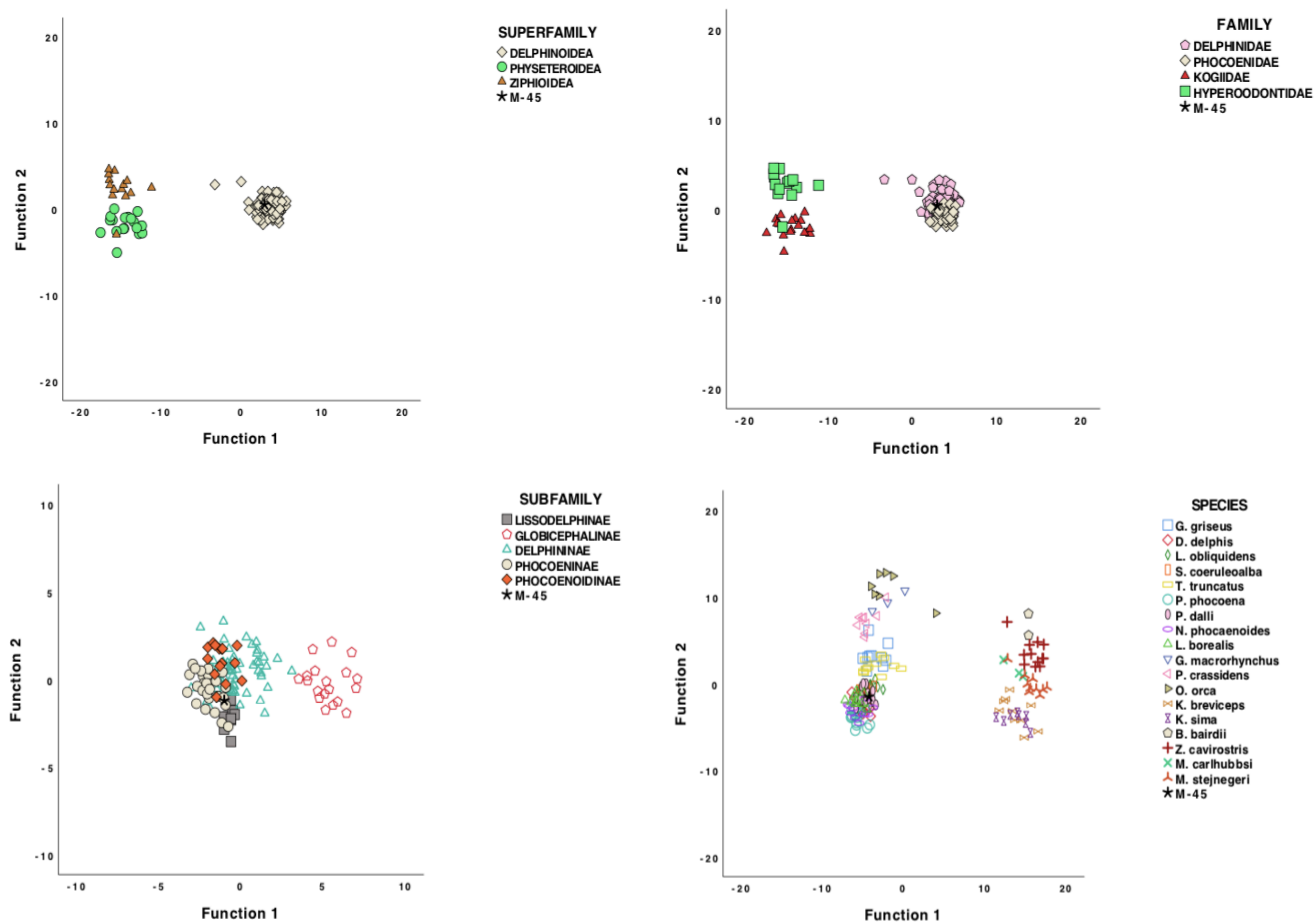


Figure S4.21 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-4).

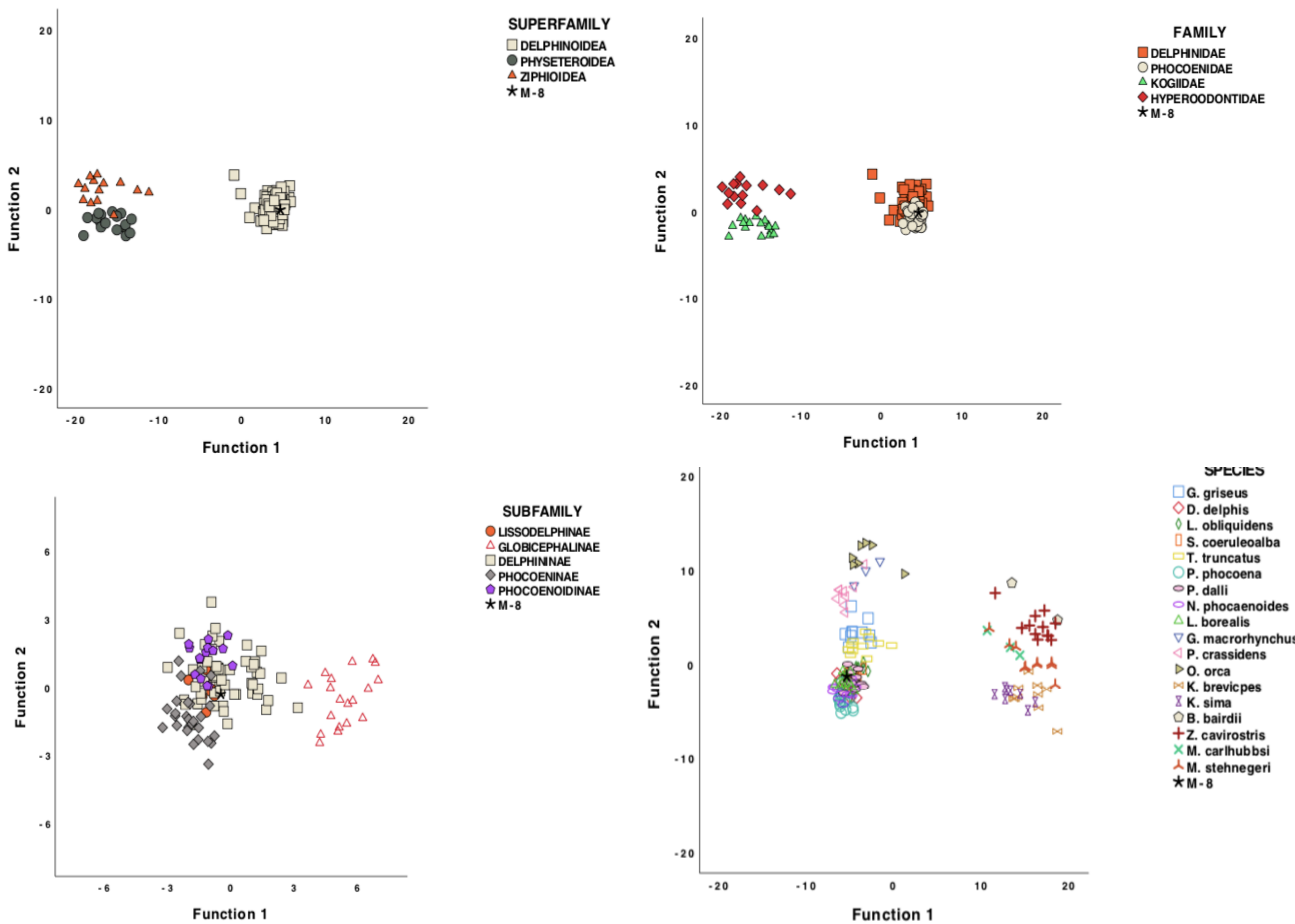


Figure S4.22 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-21).

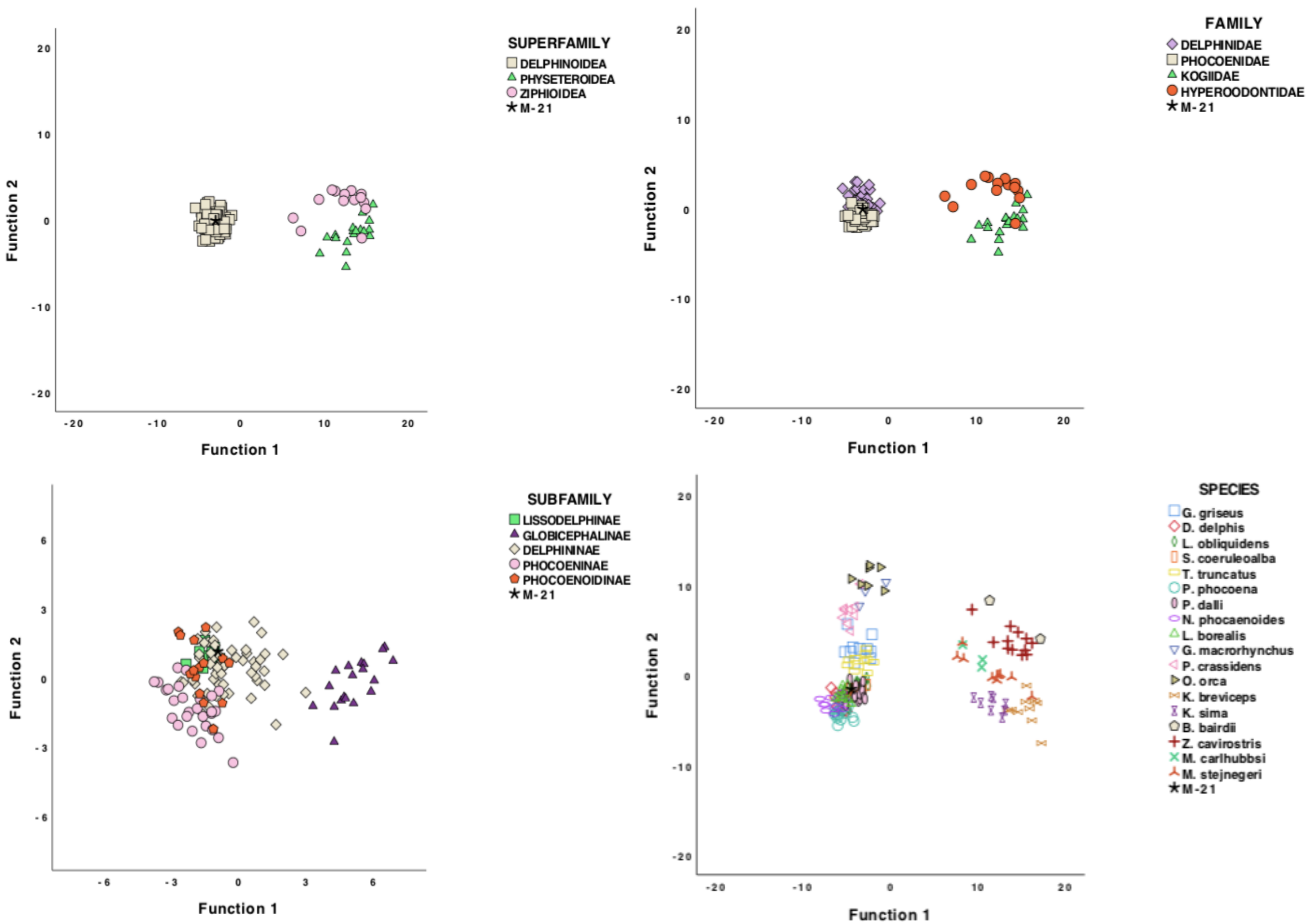


Figure S4.23 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-2).

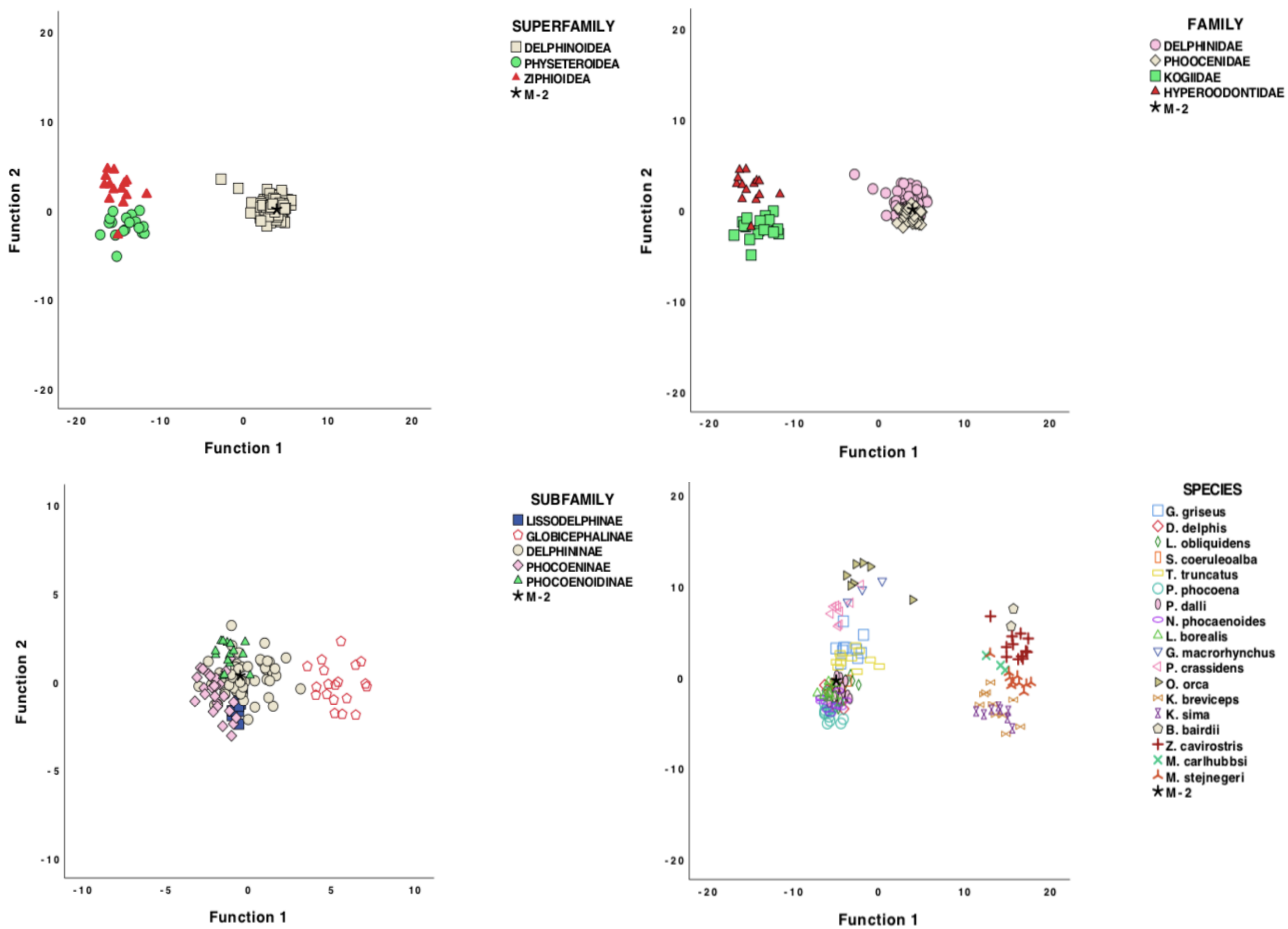


Figure S4.24 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-12).

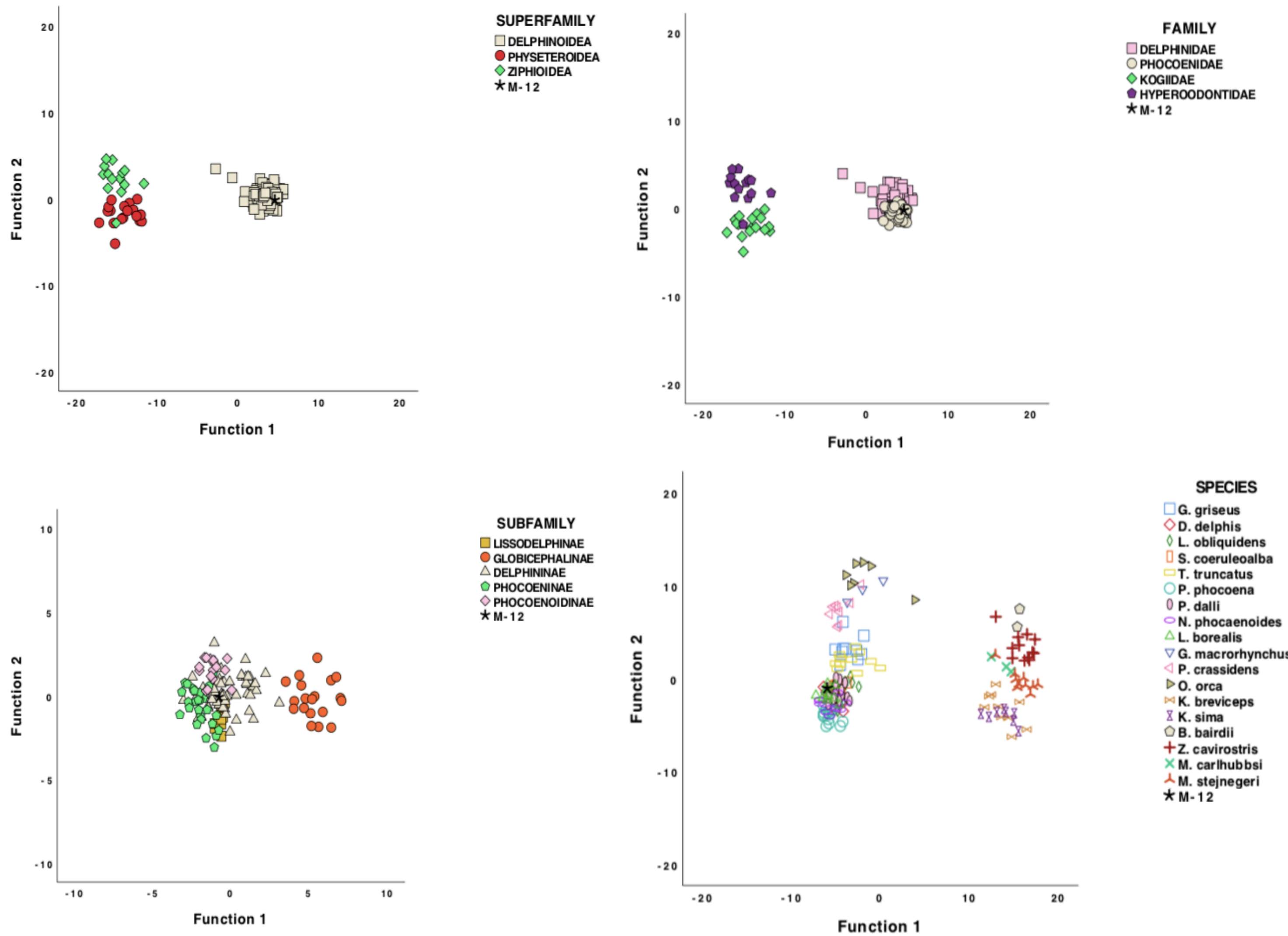


Figure S4.25 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-29).

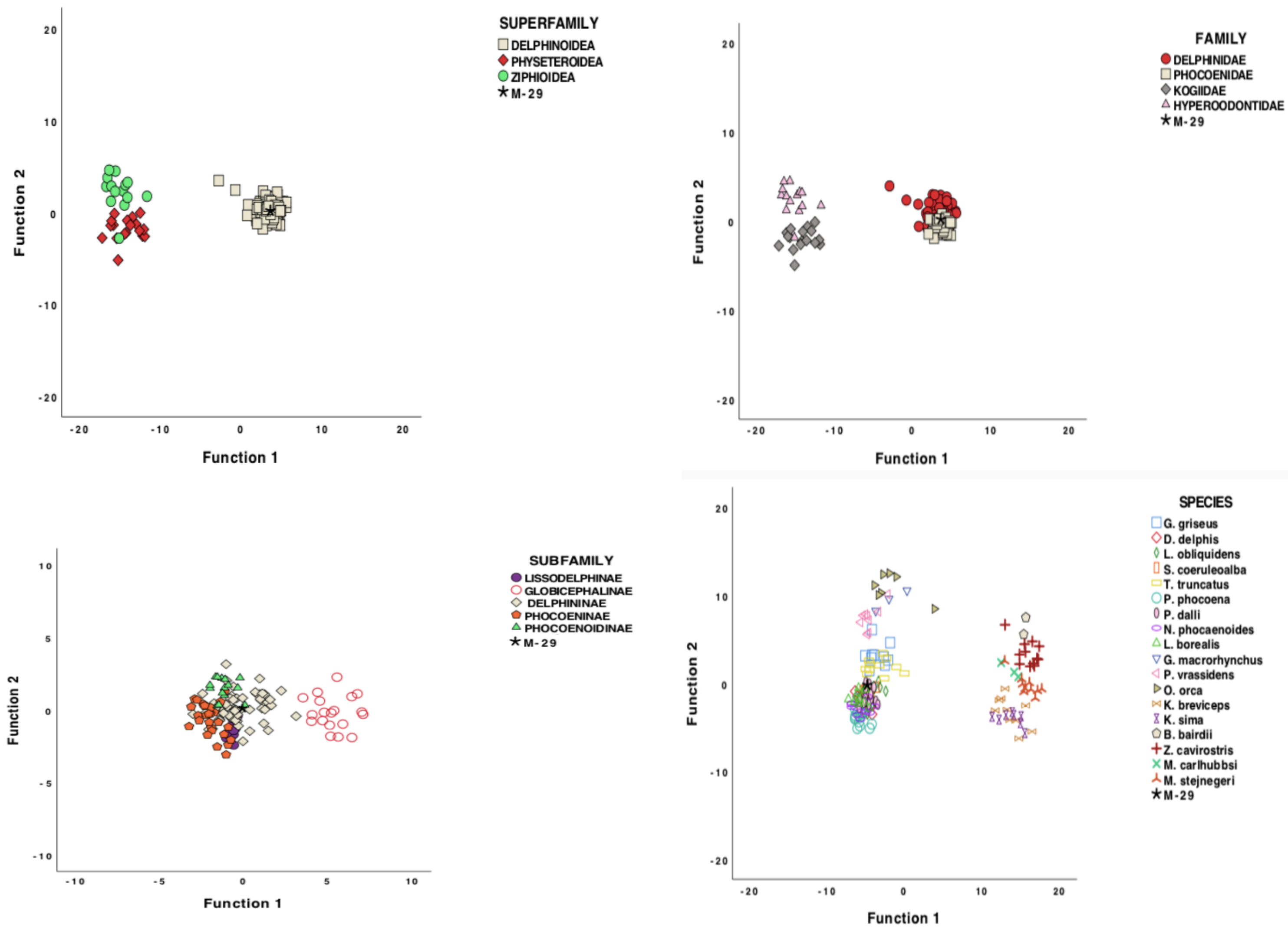


Figure S4.26 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-49).

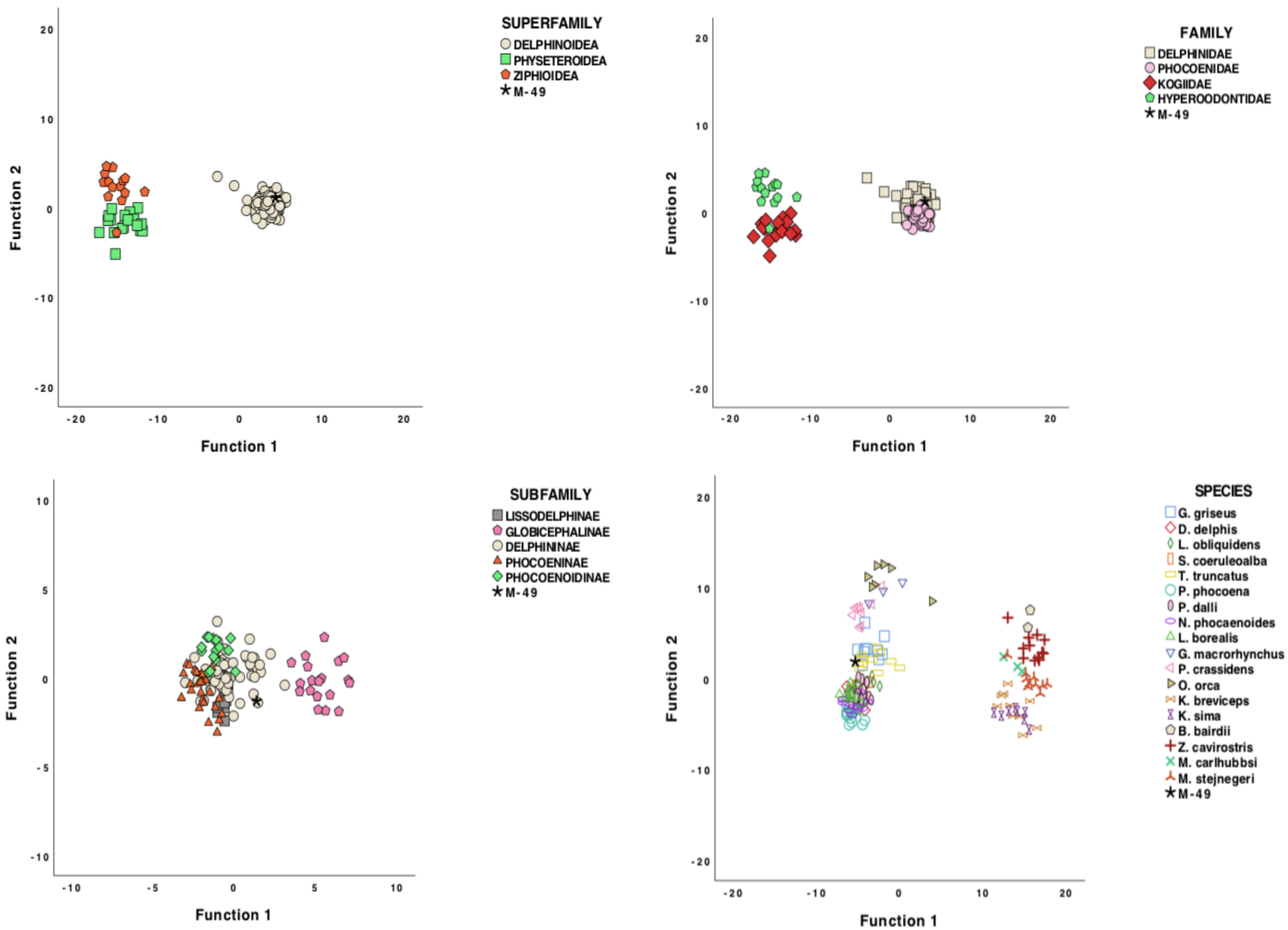


Figure S4.27 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-87).

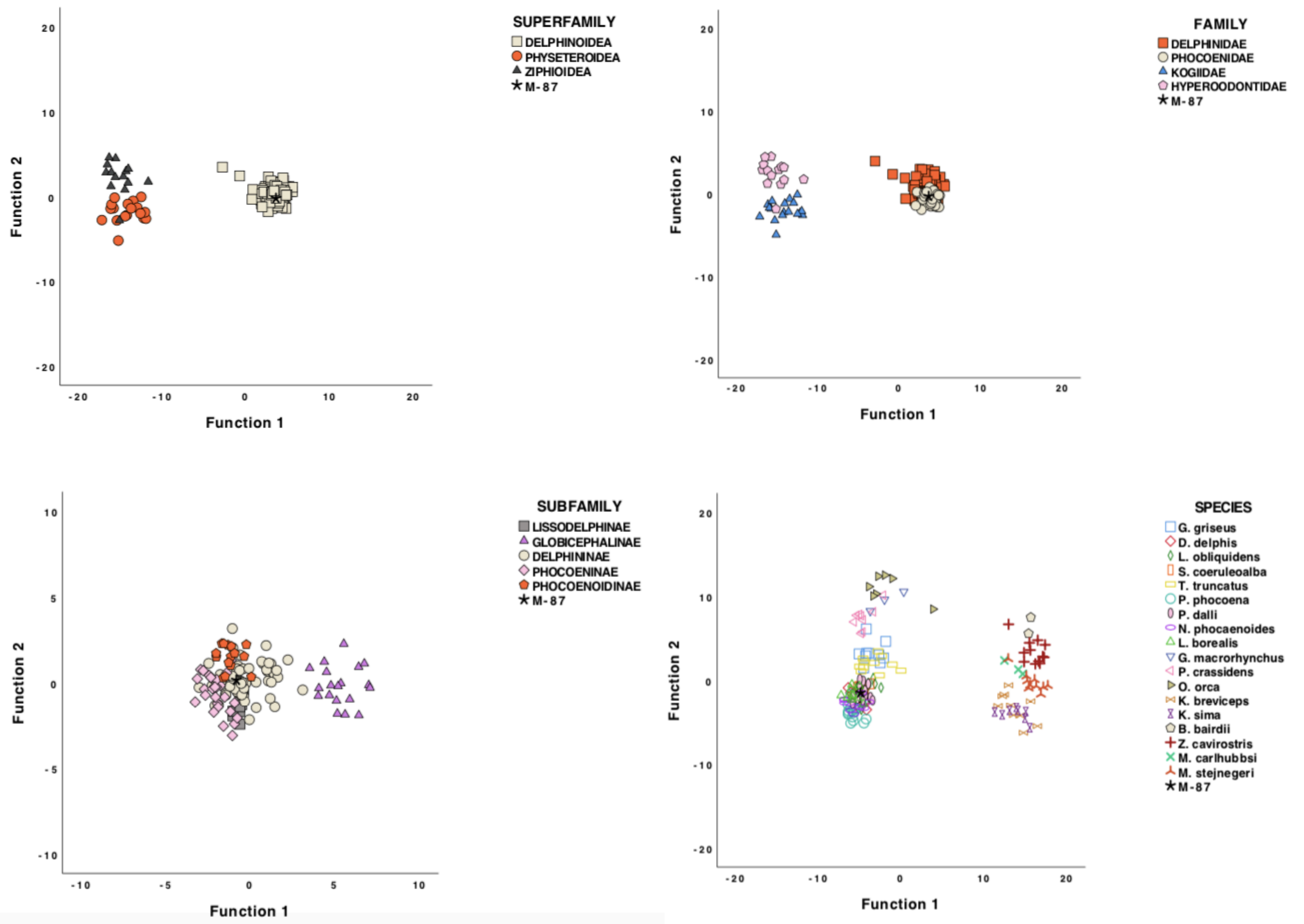


Figure S4.28 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-106).

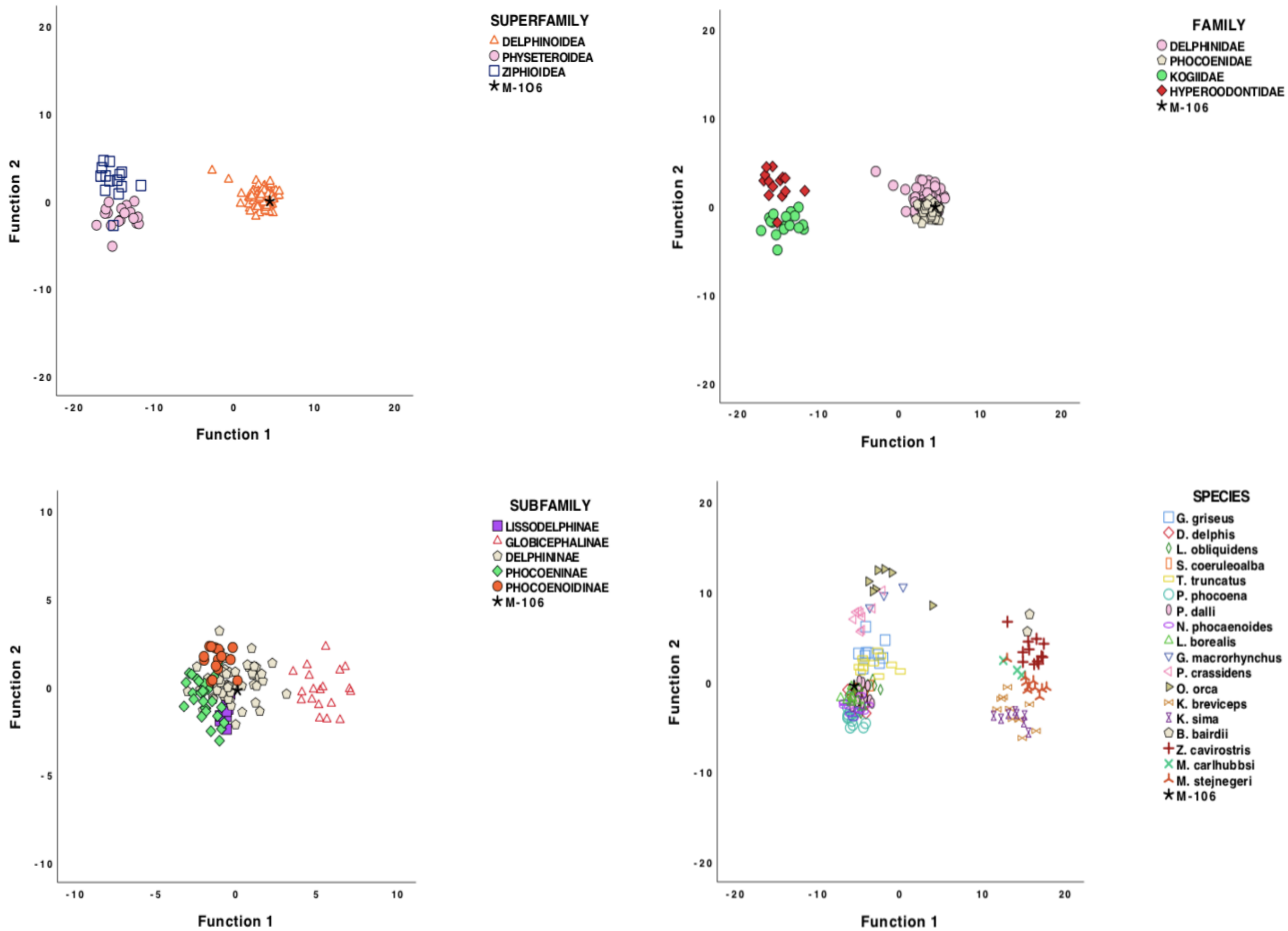


Figure S4.29 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Okhotsk Kafukai-1 zooarchaeological specimen (RKA17138).

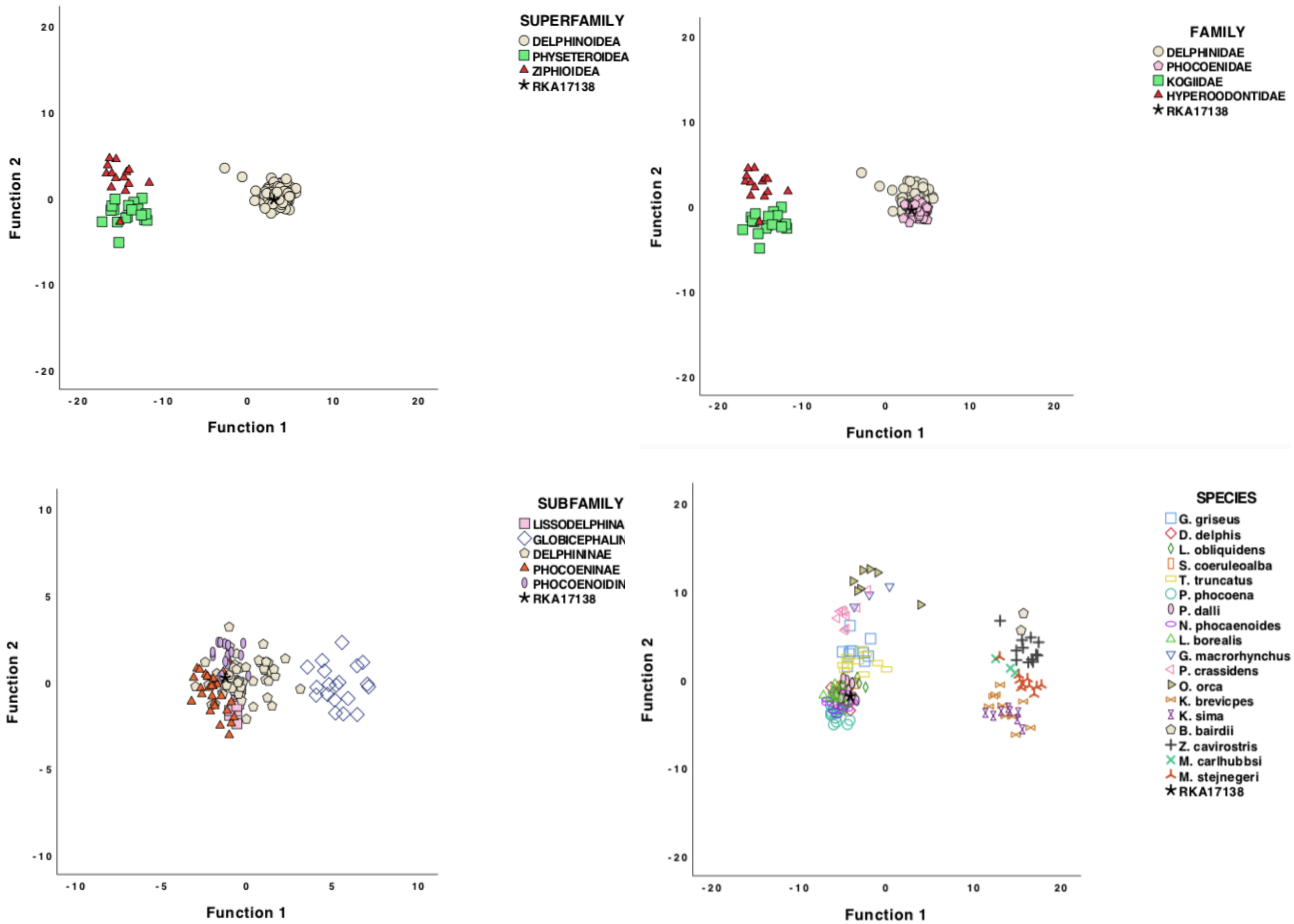


Figure S4.30 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Okhotsk zooarchaeological specimen (RKA3690).

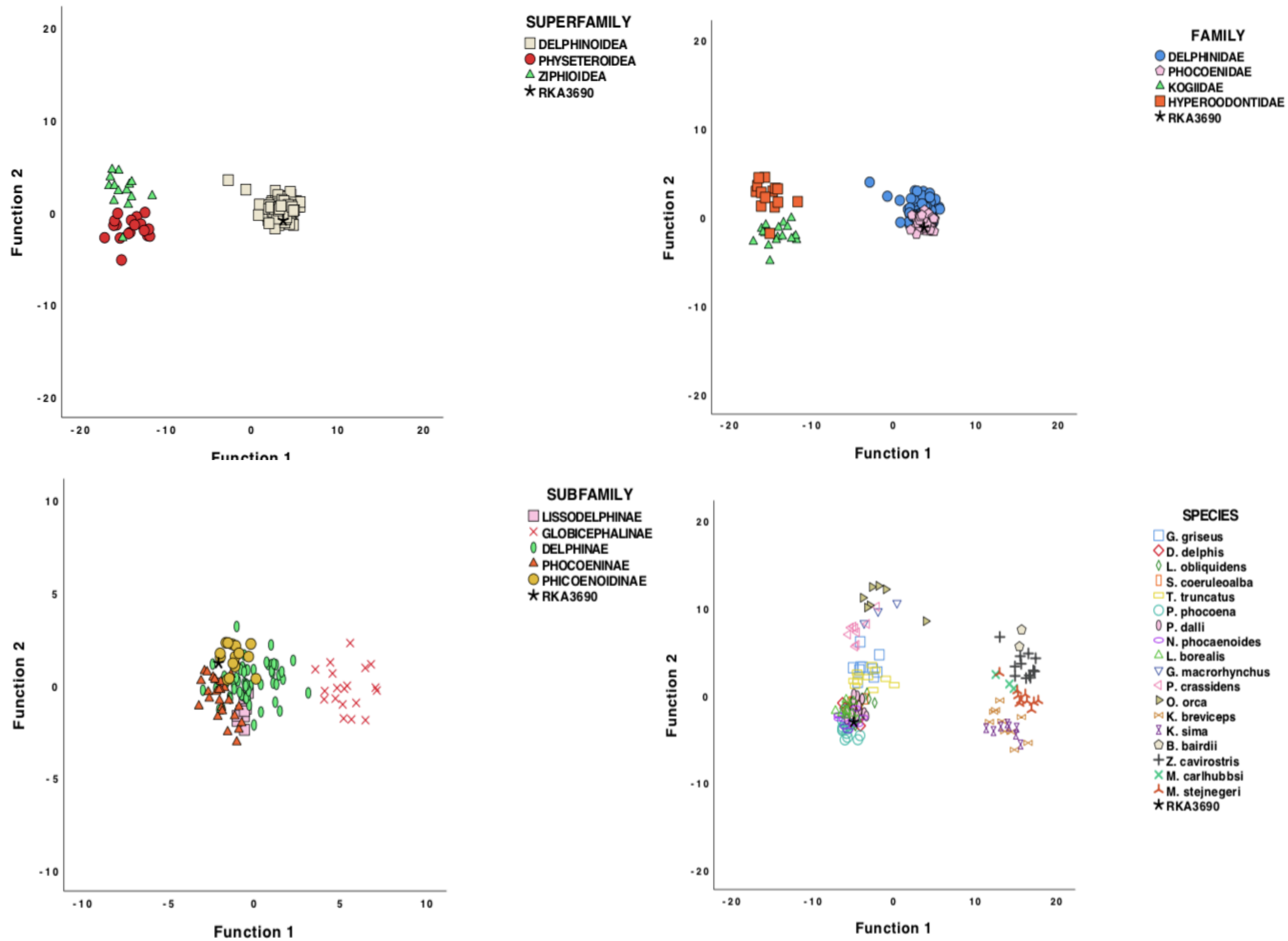


Figure S4.31 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mibiki zooarchaeological specimen (M-39).

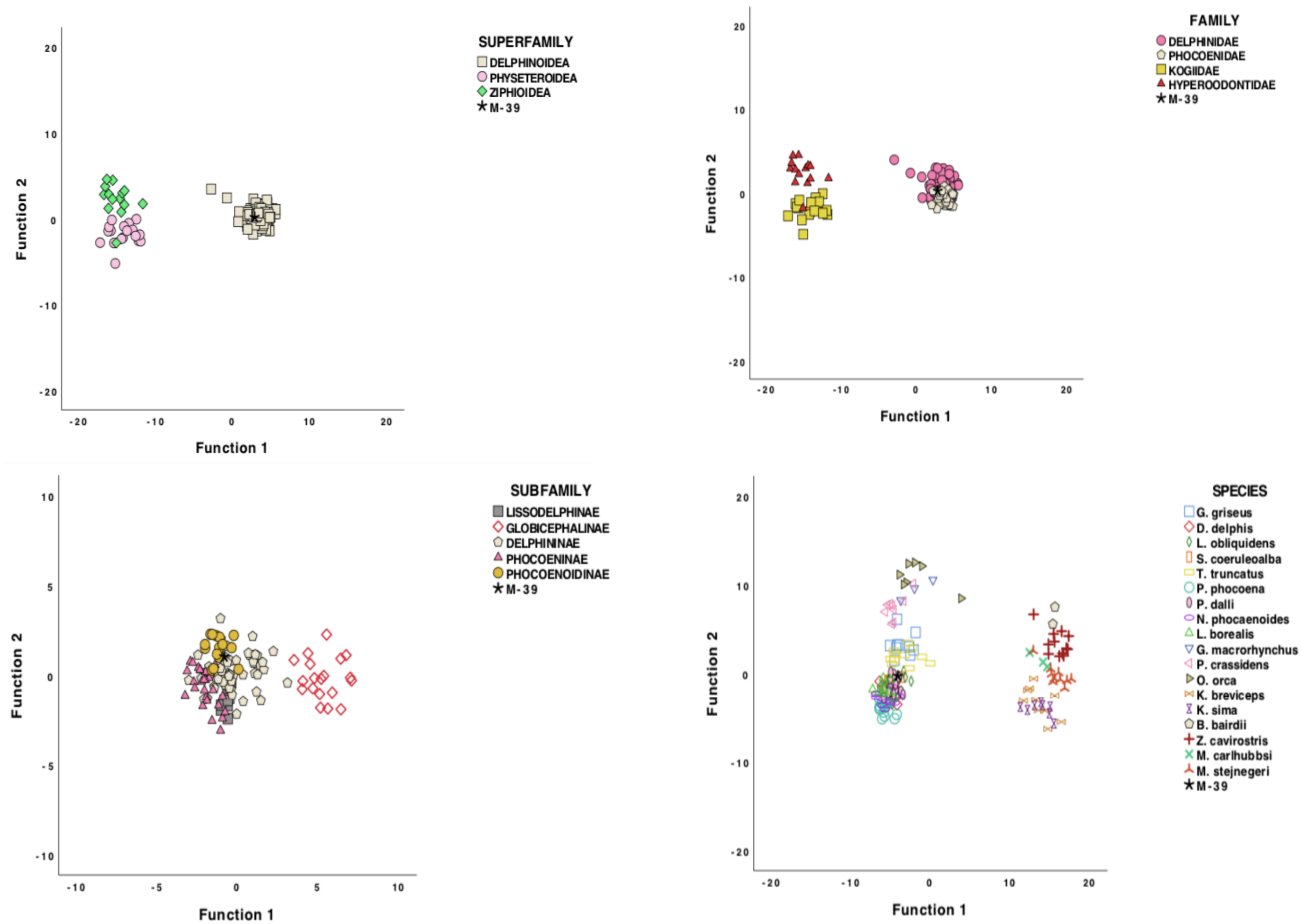


Figure S4.32 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mibiki zooarchaeological specimen (No.494).

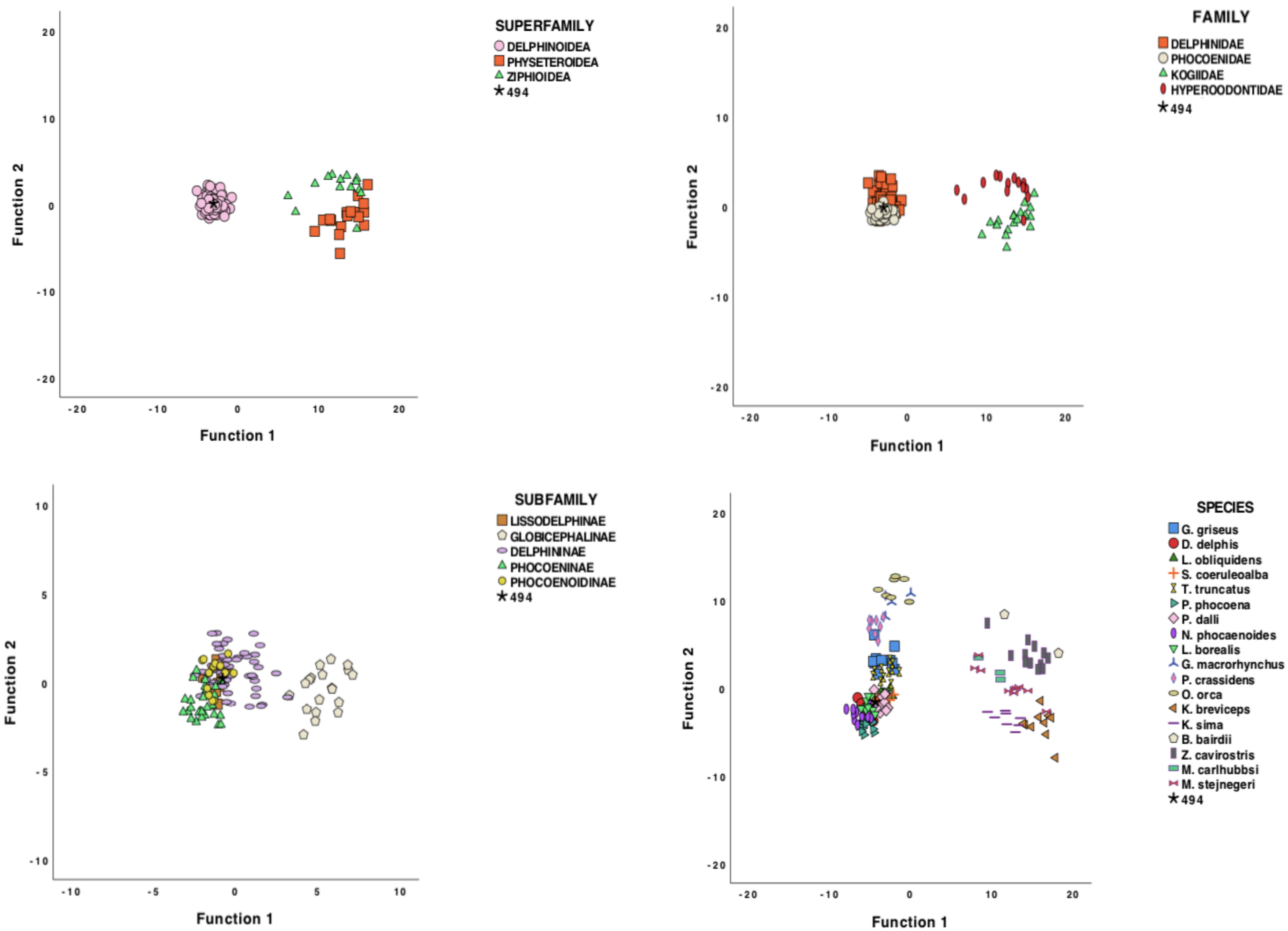


Figure S4.33 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mibiki zooarchaeological specimen (No.161).

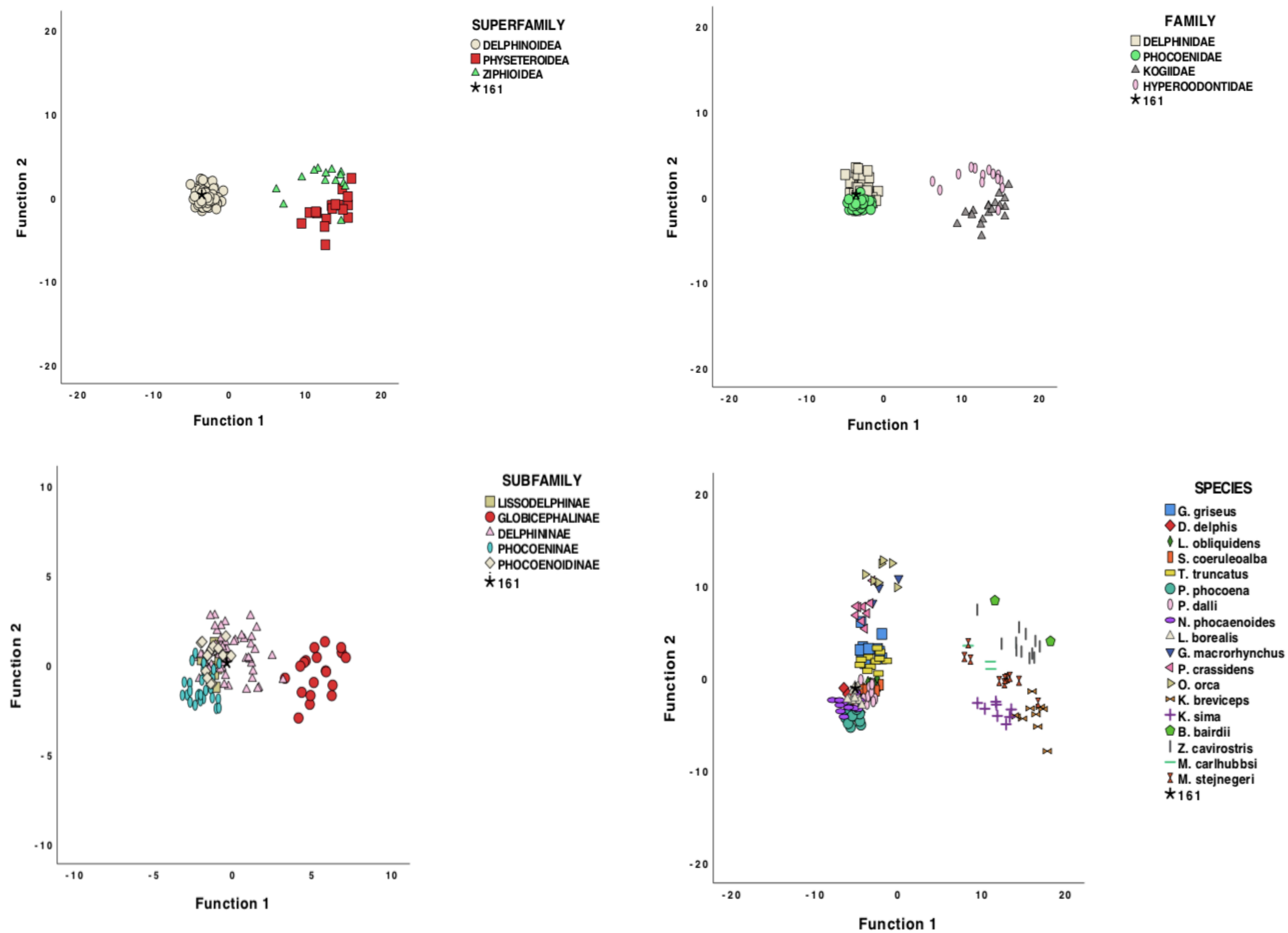


Figure S4.34 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-54).

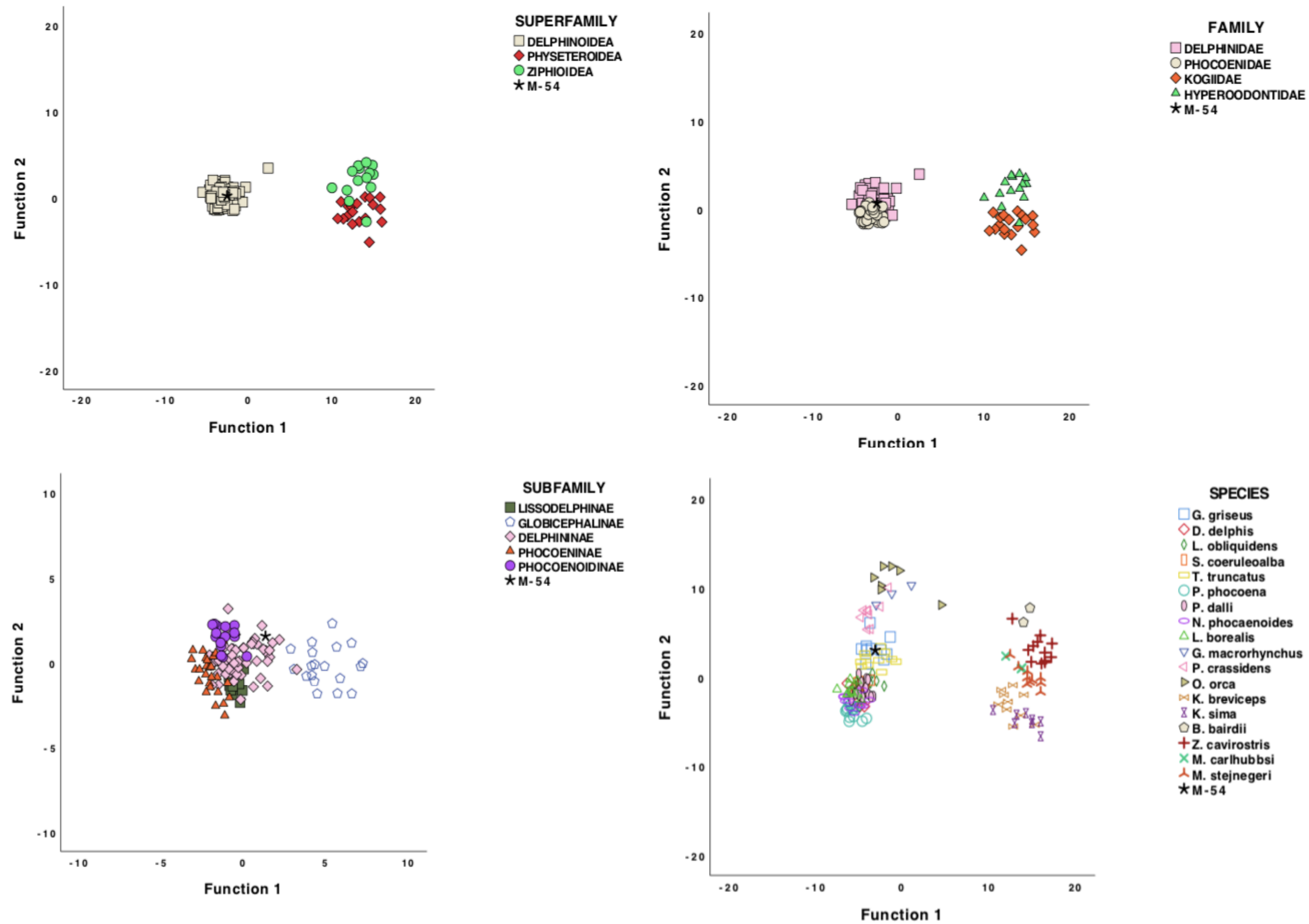


Figure S4.35 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-5).

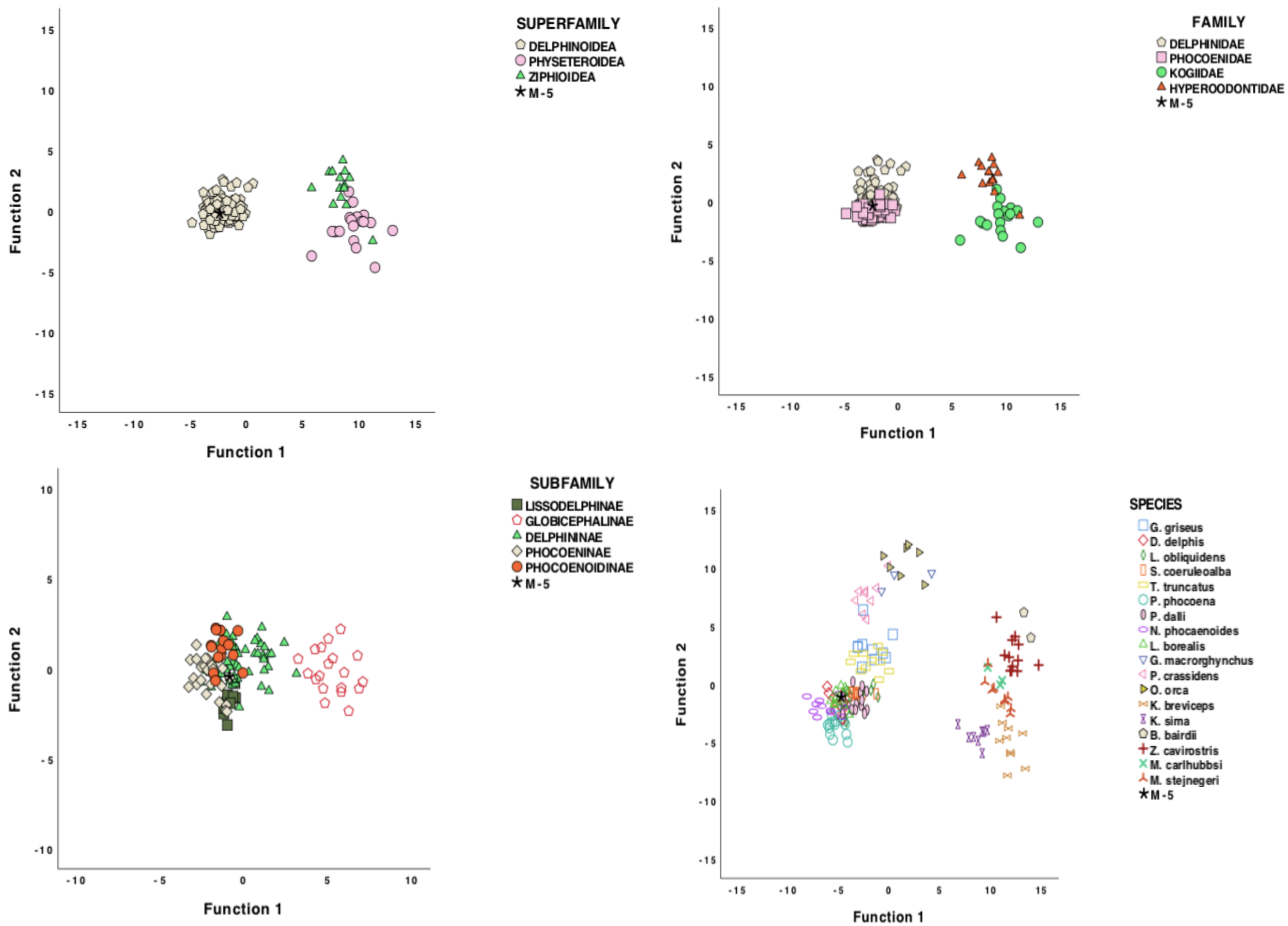


Figure S4.36 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon zooarchaeological specimen (M-40).

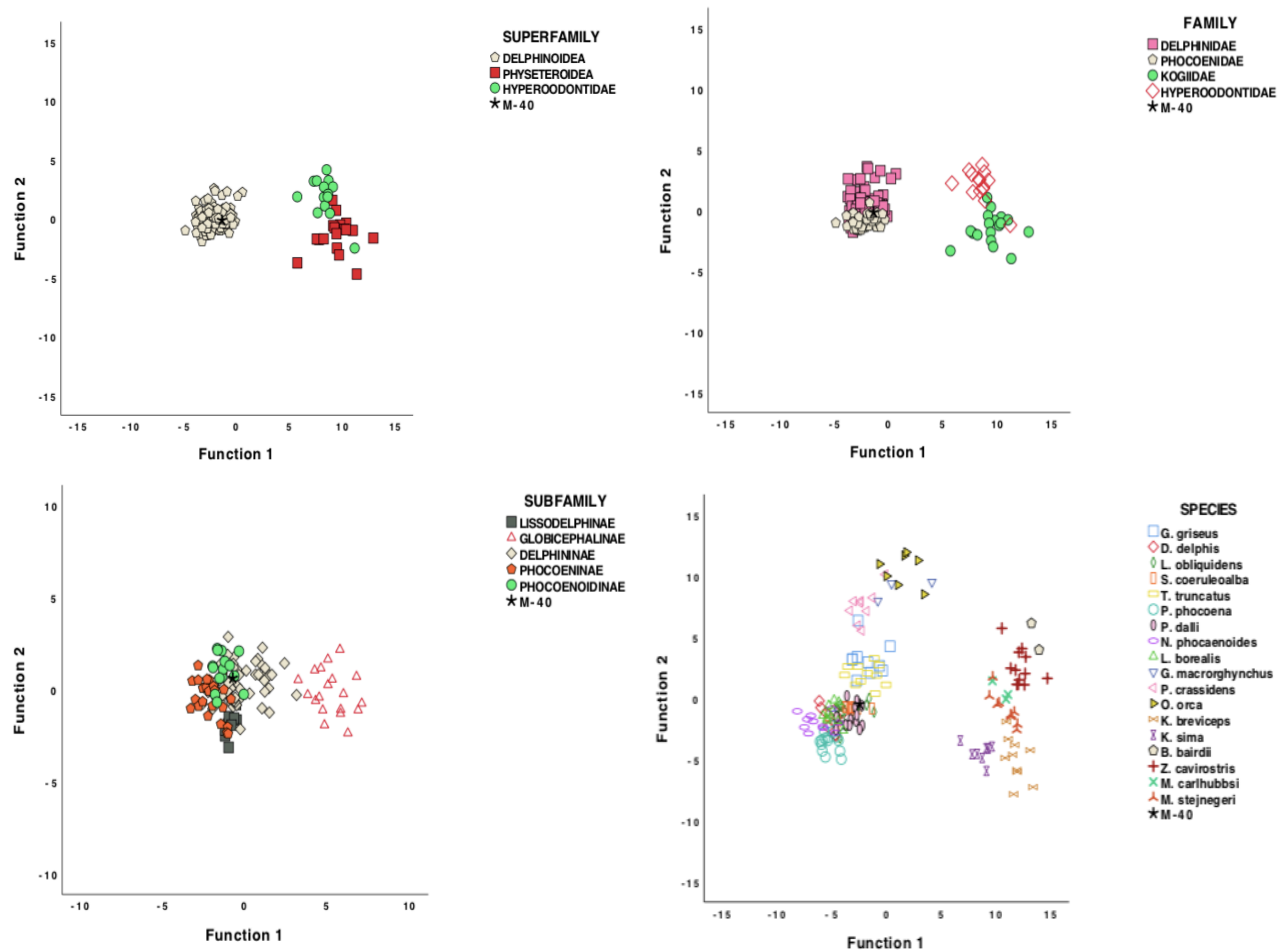


Figure S4.37 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon zooarchaeological specimen (M-43).

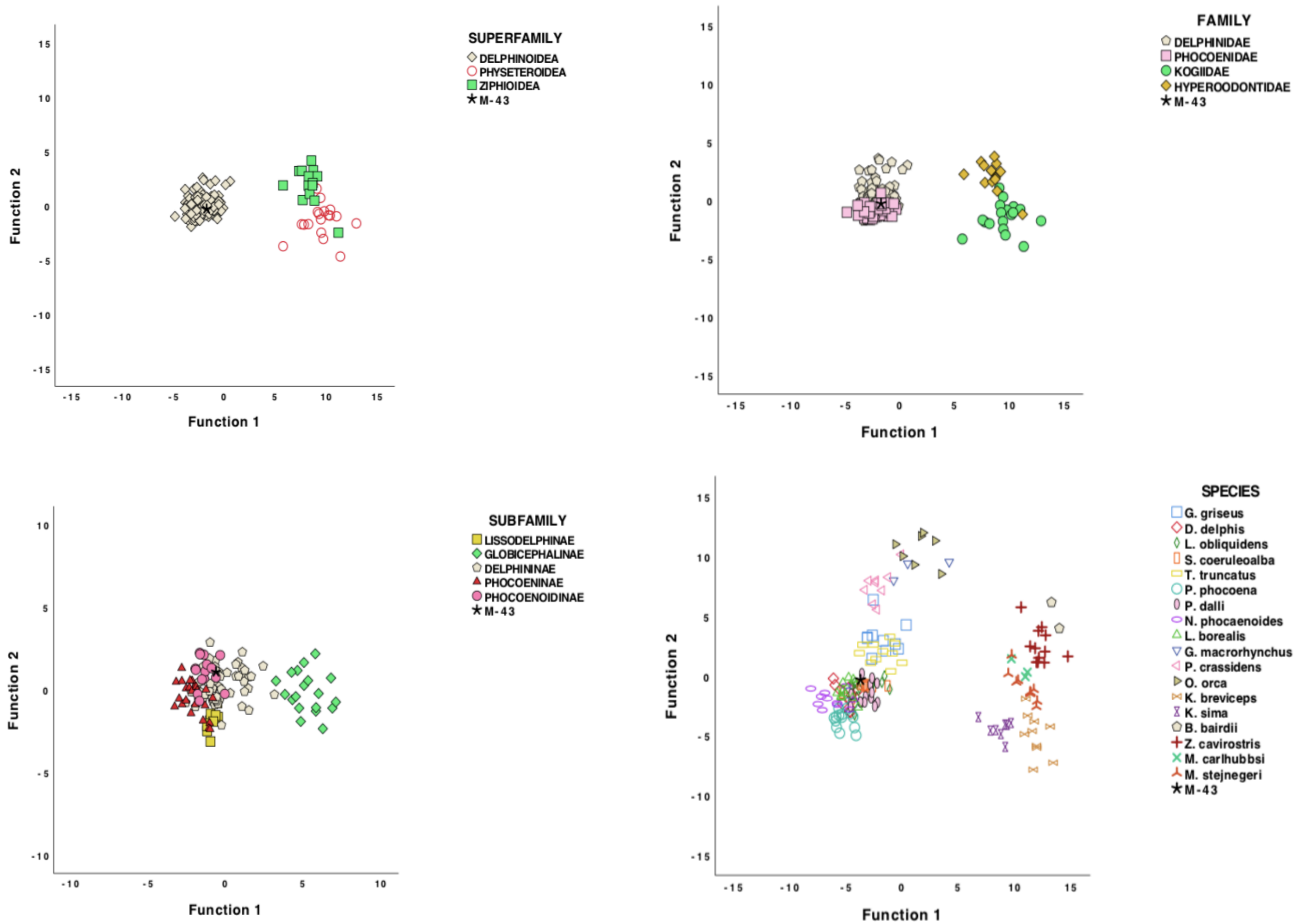


Figure S4.38 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mawaki zooarchaeological specimen (M-50).

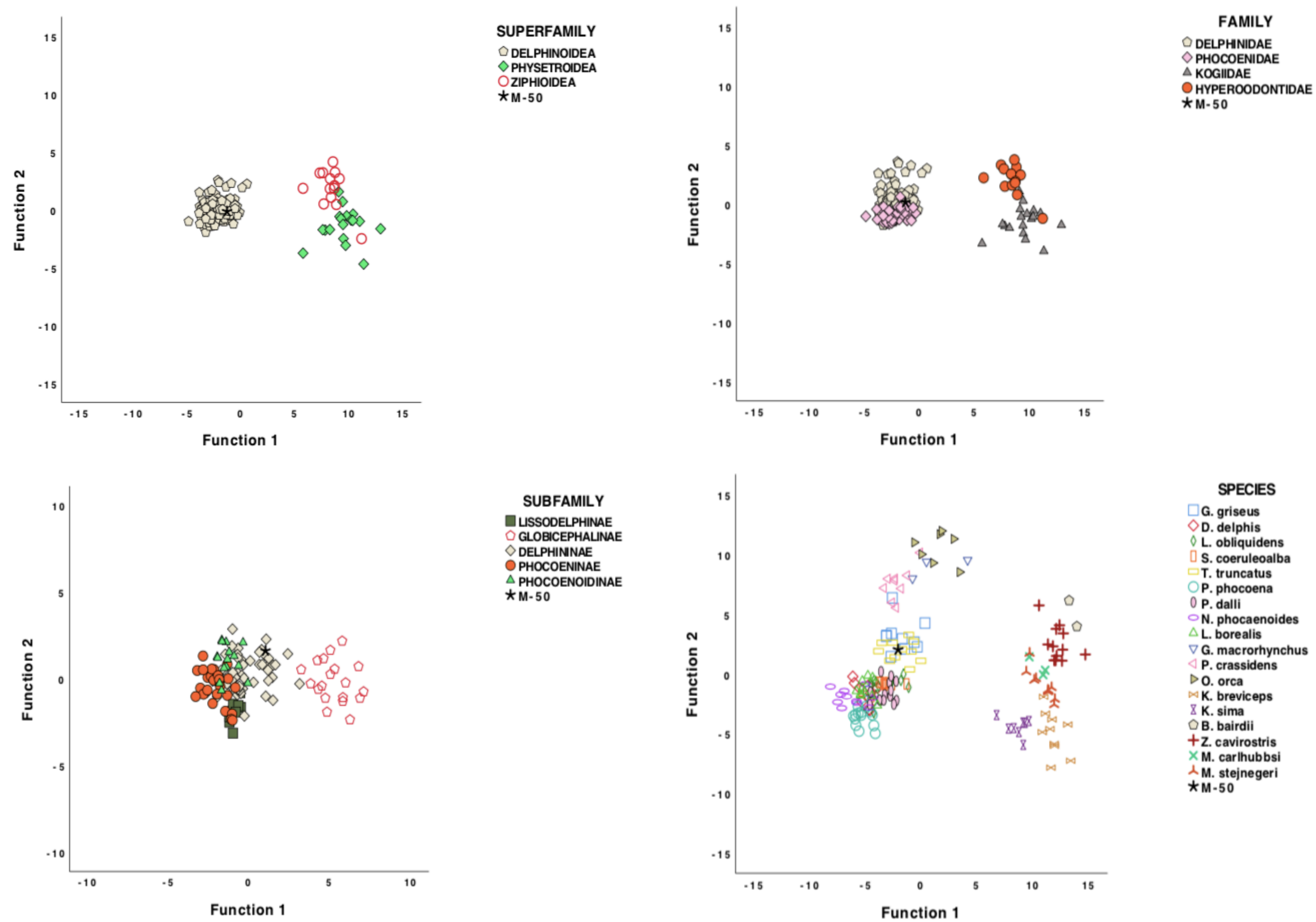


Figure S4.39 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon zooarchaeological specimen (M-61).

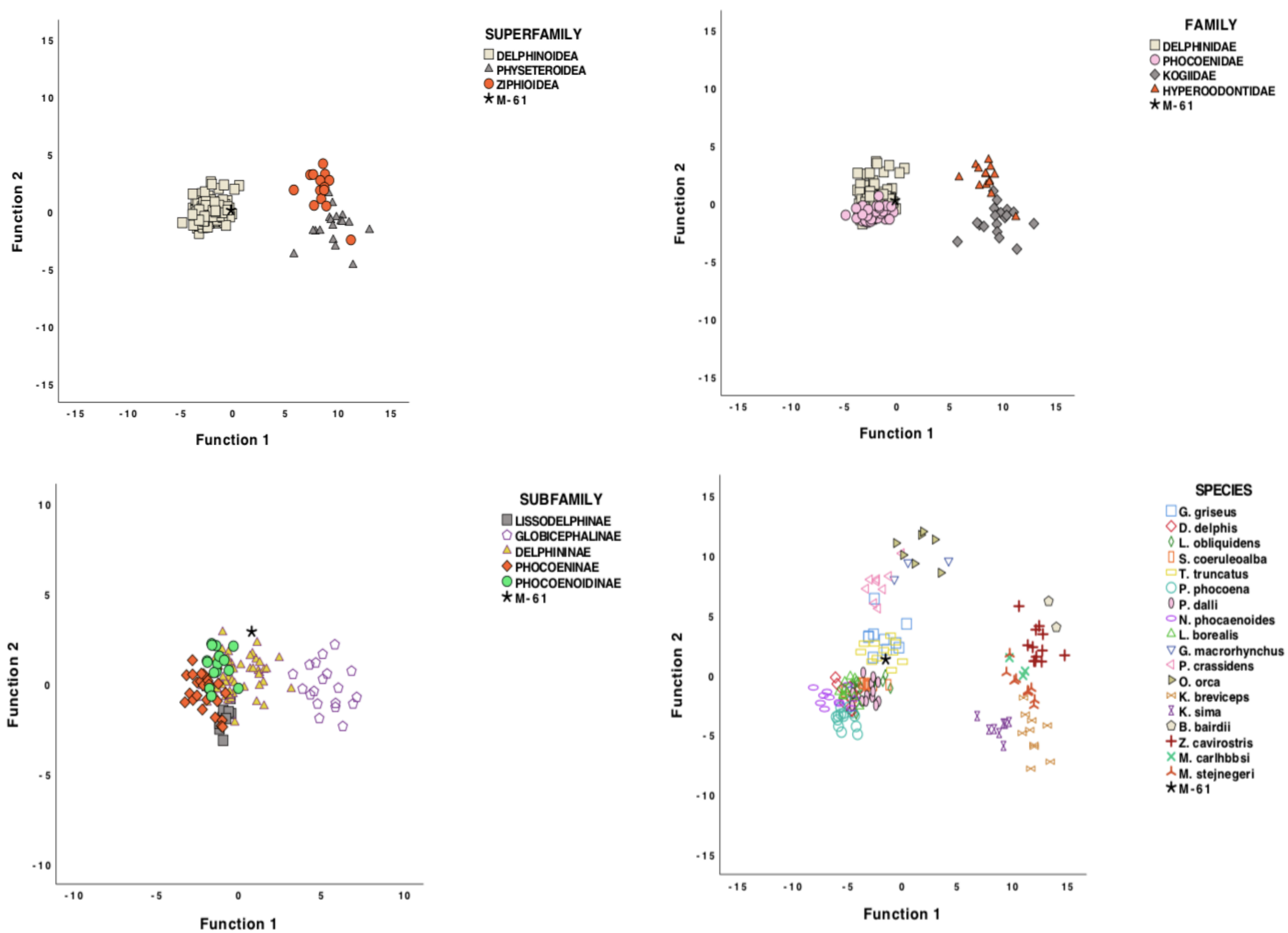


Figure S4.40 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Okhotsk Kafukai-1 zooarchaeological specimen (RKA2047).

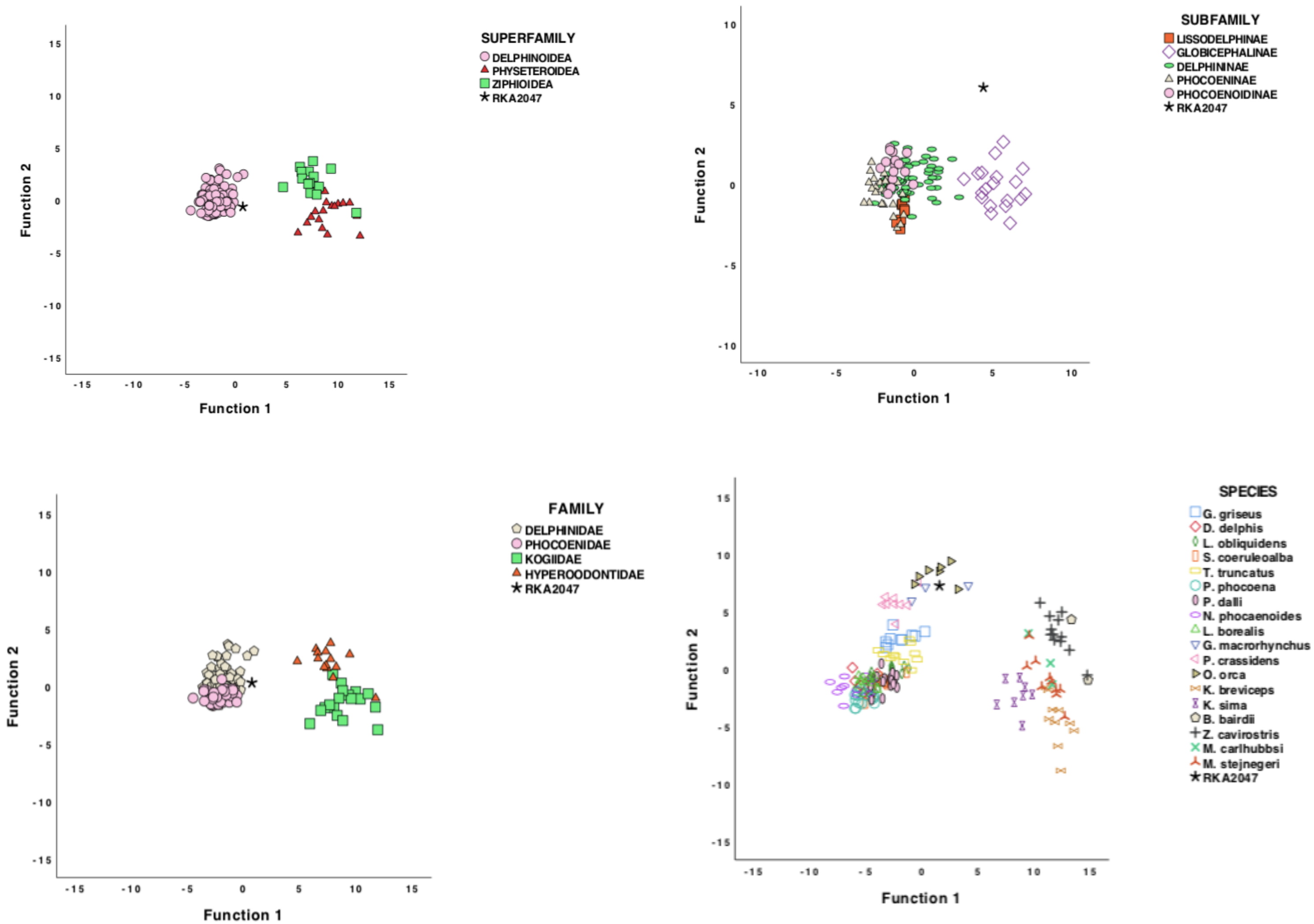


Figure S4.41 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Okhotsk Kafukai-1 zooarchaeological specimen (RKA2804).

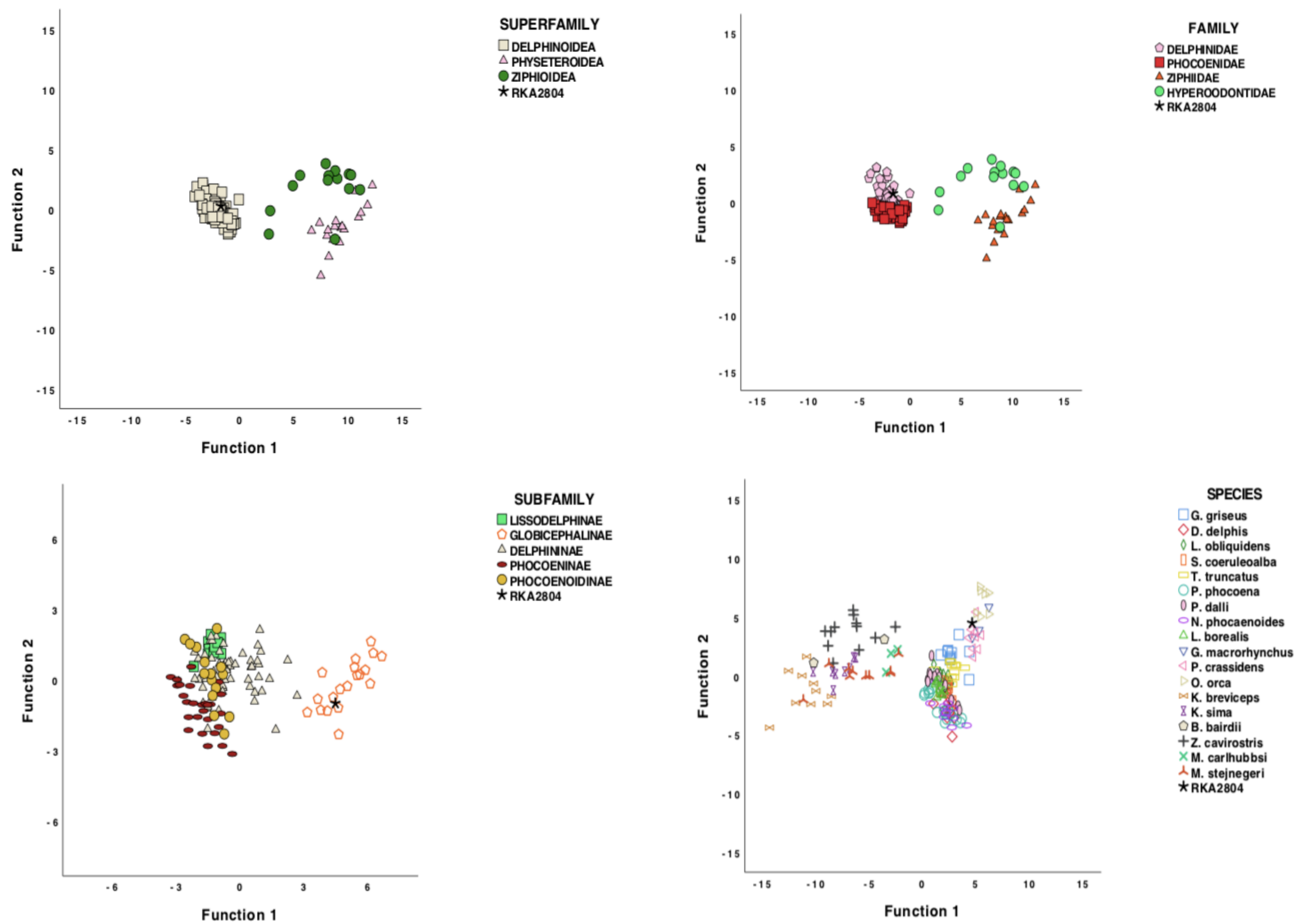


Figure S4.42 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Early Jomon Mibiki zooarchaeological specimen (No.495).

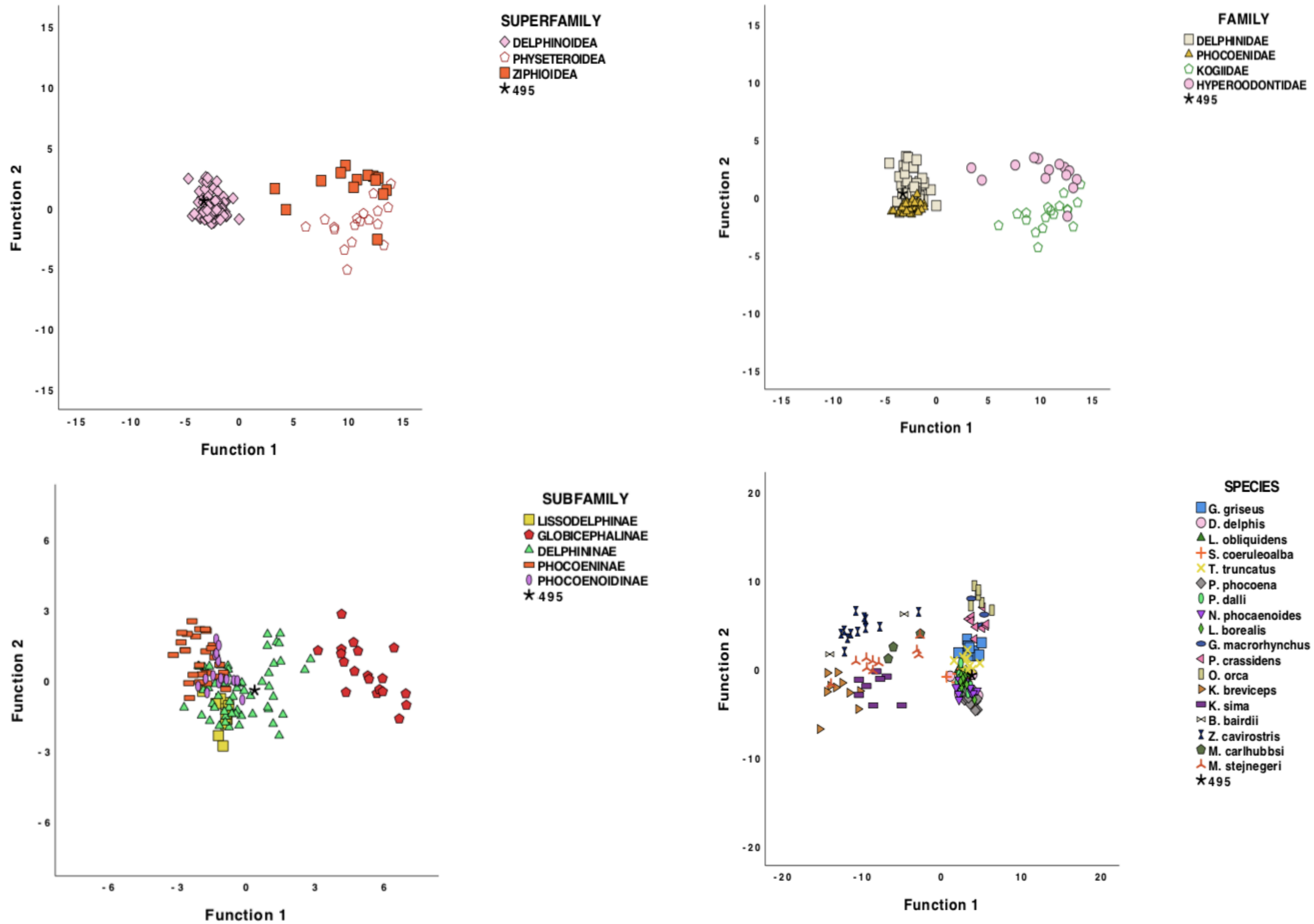


Figure S4.43 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Okhotsk Kafukai-1 zooarchaeological specimen (RKA15547).

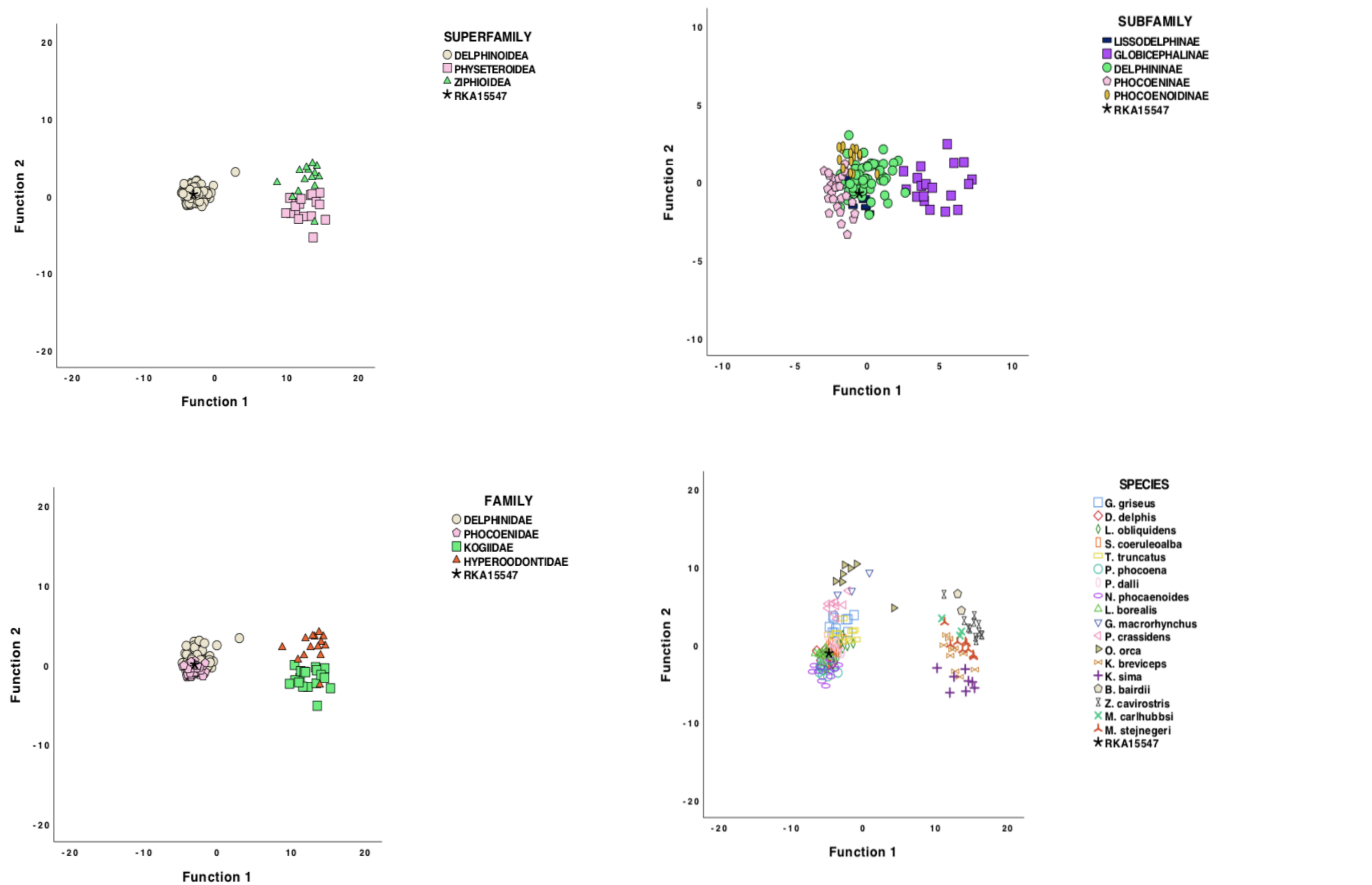


Figure S4.44 Combined-groups plot of the first two canonical discriminant functions of the atlas and axis vertebra for the superfamily, family, subfamily and species level classification of Okhotsk Kafukai-1 zooarchaeological specimen (M-23).