

Osteometric Analysis of South American Sea Lions (*Otaria flavescens*) Pups From Patagonia. An Assessment of Their Use as Indicators for Seasonality in Archaeological Sites

F. BORELLA,^{a*} G. L. L'HEUREUX^b AND M. F. GRANDI^c

^a CONICET-INCUIAPA, Facultad de Ciencias Sociales, Universidad del Centro de la Provincia de Buenos Aires, Olavarría, Argentina

^b CONICET-IMHICIHU. Saavedra 15, piso 5, Ciudad Autónoma de Buenos Aires, Argentina

^c Laboratorio de Mamíferos Marinos, CONICET-CENPAT, Puerto Madryn, Chubut, Argentina

ABSTRACT Zooarchaeological analyses of pinniped remains have been scarce in South America because of lack of specific studies of species determination and estimation of age and sex. Nonetheless, the presence of small and unfused bones (assigned as pup remains) of *Otaria flavescens* (*O. flavescens*) in the Patagonian archaeological record has been frequently used as an indicator of summer occupation accomplished by ecological analogues. For this reason, we carried out a postcranial skeletons osteometric study of modern pups of South American sea lions (*O. flavescens*) with known sex and aged 0–12 months, allowing a more precise age estimation of archaeological samples. Then, we revisited the evidence for seasonality in the Cabo Virgenes 6 site at Cabo Virgenes locality, one of the archaeological localities in Patagonia where the seasonality has been determined only on the basis of the presence of unfused pup bones. Our metric data study on a modern sample shows that the regression analyses generated a complementary and dependable age estimation model for unfused appendicular bones of *O. flavescens* between 0 and 12 months old that can be applied to samples recovered from archaeological sites. These osteometric studies of postcranial elements allow us to adjust the age estimation of the animal's death and re-examine seasonality of the Cabo Virgenes 6 site (Santa Cruz, Argentina). Copyright © 2013 John Wiley & Sons, Ltd.

Key words: South American sea lions; otariids pups; postcranial osteometry; seasonality indicators; hunter–gatherer; coastal archaeological sites; Patagonia; Late Holocene

Introduction

South American sea lions (*Otaria flavescens*) are one of two species of otariids commonly represented in the coastal archaeological record from South America. In the archaeological record of the coastal Patagonia, where sea lions were a frequent marine prey for Holocene hunters, there are greater quantities of non-fused *O. flavescens* remains. Thus, the most common skeletal parts in these sites are postcranial elements rather than maxillae with teeth from which would be possible to obtain dental thin sections. In spite of this,

there have been few specific studies on pinniped species determination and estimations of age or sex.

Many zooarchaeological studies from different regions have used age at death determination from animals represented in faunal assemblages to estimate the timing of coastal visits or seasonality (i.e. Parkinson, 1976; Monks, 1981; Klein & Cruz-Urbe, 1989; Woodborne *et al.*, 1995; Stora, 2002; Stora & Lougas, 2005; among others). Recent studies of epiphyseal fusion and metric data on seals offer us a better interpretation of (i) the subsistence economy and exploitation of seals in the North Atlantic (Hodgetts, 1999) and Baltic Stone Age (Stora, 2001, 2002); (ii) age composition of fur seals exploited in order to identify breeding distribution during the Late Holocene in the eastern North Pacific coast (Etnier, 2002, 2007) or in the Baltic sea (Stora & Ericson, 2004); and (iii) selective hunting and the timing

* Correspondence to: F. Borella, CONICET-INCUIAPA, Facultad de Ciencias Sociales, Universidad del Centro de la Provincia de Buenos Aires, Av. Del Valle 5737, (B7400JWI) Olavarría, Argentina.
e-mail: fborella@soc.unicen.edu.ar

of occupation in Dorset Palaeoeskimo sites from the northwest coast of Newfoundland (Hodgetts, 2005), among others.

In Patagonia, there has been no development of these kinds of studies. Nonetheless, and because these animals give birth within a short period annually, the finding of very small unfused postcranial bones in coastal assemblages – assigned as pups – has been used to determine the time of year that animals were captured and the season of occupation at these sites. Accordingly, during the past decades, an uncritical application of epiphysis fusion data has been used to suggest summer occupation in different archaeological sites from Patagonia, such as Cabo Virgenes 6 (CV6) (see L'Heureux & Franco, 2002); Punta Bustamante Site 3-Caño (Miotti, 1998) – both in the province of Santa Cruz (Argentina) – and the Ponsonby site on Riesco Island (Chile) (Lefèvre *et al.*, 2003). However, none of these authors offer compelling arguments for their basic interpretive assumption. Additionally and as previously stated by G. Monks (1981:183) 'Estimates of seasonality should be accompanied by information on the size of the sample and the number and type of seasonality indicators that these estimates are based'.

In this paper, we re-examine the assumption of seasonality at the Cabo Virgenes archaeological locality (CV6), where hunter–gatherer seasonality was sustained only by the simple presence of immature (unfused) sea lions specimens.

Because female otariids give birth within a restricted period each year (summer), the size of yearlings can be used to give a rough estimate of season of death (Hodgetts, 2005: 67) if that prey were hunted and consumed at the same time (not deferred consumption). On the other hand, there could be an alternate modality of prey consumption by storage from burials of otariids at the beach sand, such was recorded by historical observers in Cape Town South Africa. In these cases, seal meat that was buried in an appropriate subsurface environment retained the physical structure and would be able to be consumed later (Smith *et al.*, 1992: 179). Nevertheless, for the Cabo Virgenes area (and all Patagonian continental coast as well), there are no ethnographic or historic data regarding the use of such techniques to store meat and fat. Another possibility – expressed by Etnier (2002) and called 'pinniped driftwood' by Gifford and collaborators (2005) – could be the use of dry or natural dead stranding pups along the shores. But 'there is at the present no method for distinguishing scavenged dying or dead animals from those taken as primary prey' (Gifford-Gonzalez *et al.*, 2005: 27).

In this paper, we review the validity of unfused bones as the only indicators of seasonality. Here, we provide

metric data on modern and controlled samples of *O. flavescens* postcranial elements and apply these results to the faunal assemblages provided by the CV6 site as an archaeological example.

Cabo Virgenes locality and the pinnipeds zooarchaeological assemblage from Cabo Virgenes 6

Archaeological investigations at Cabo Virgenes locality suggested that inland hunter–gatherer populations exploited marine resources from 2000 BP until historic times (Borrero & Franco, 2005; Borrero *et al.*, 2008 and others). Isotopic studies of human remains from CV17 (a burial site in Cabo Virgenes) have shown that the utilisation of marine species was of minor importance compared with terrestrial mammals (Barberena, 2002; Borrero & Barberena, 2006). The lithic organisation and stable isotope data from this site suggested a sporadic and geographically marginal use of the coastal and marine resources by inland hunter–gatherers, as part of their regular ranges of action (Barberena *et al.*, 2004; Borrero, 2004; Borrero & Barberena, 2006). However, the archaeofaunal assemblages in several sites from this coastal area are dominated by seabirds (adult specimens of cormorants and penguins), pinnipeds and very few specimens of terrestrial mammals (guanacos, rodents and foxes). There also appears to have been occasional exploitation of stranded cetaceans and marine molluscs (L'Heureux & Franco, 2002; Barberena *et al.*, 2004; Borella, 2010; L'Heureux *et al.*, 2012). Additionally, no evidence of meat storage from terrestrial or marine fauna has been found in any continental Southern Patagonian archaeological sites, and as mentioned earlier, no ethnographic data are related to such practices in the area.

Taphonomic studies carried out at Cabo Virgenes suggest that differential preservation of terrestrial *versus* marine animal bones does not explain the taxonomic composition (Borrero & Barberena, 2006: 862). Therefore, we must presume that the remains of all considered *taxa* were accumulated in the sites in direct proportion to their frequency of exploitation, and factors such as preservation and recovery have not significantly affected the relative taxonomic abundances.

Cabo Virgenes 6 is one of the 20 open-air archaeological sites in the Cabo Virgenes archaeology locality (Figure 1). It is located in the province of Santa Cruz at 52°19'S, 68°22'W. Excavated under the direction of Dr Luis A. Borrero in 1999/2000, this site contains unfused pinniped bones, which were used to proposed

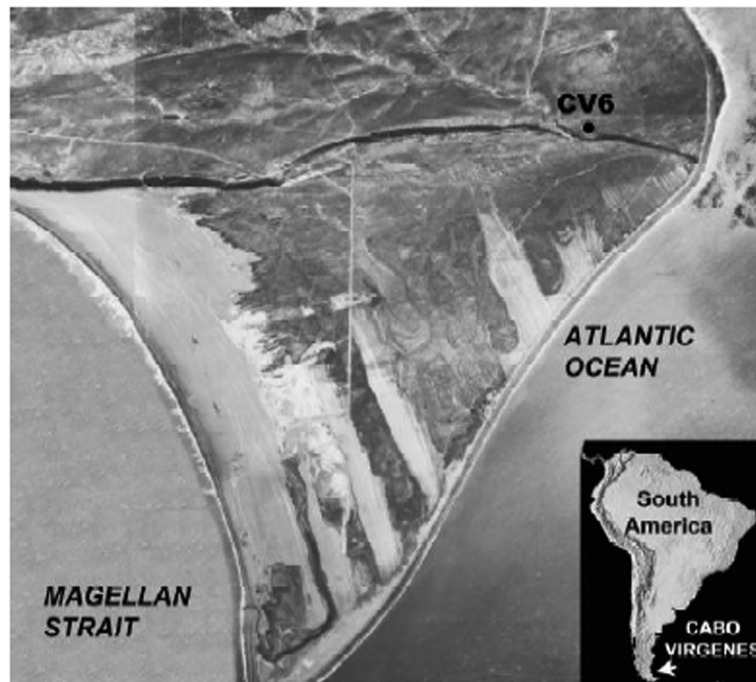


Figure 1. Localization of Cabo Virgenes-Dungeness area and Cabo Virgenes 6 archaeological site.

summer as the season of site occupation (L'Heureux & Franco, 2002). Three radiocarbon dates are currently available for CV6, two from charcoal: 1190 ± 60 (GX-25772) and 1170 ± 50 BP (Beta 144998) (L'Heureux & Franco, 2002), and one from an *O. flavescens* specimen with anthropic fracture: 1160 ± 70 (Beta 144999) (Borrero *et al.*, 2008). The last radiocarbon date on marine mammal bone could be in average of 400 years

older than the others on charcoal because of the marine reservoir effect (Stuiver & Braziunas, 1993). In spite of this, radiocarbon dates placed the main occupation of the area in the Late Holocene.

The total faunal sample recovered in 252 m² excavated from CV6 comprises of 631 bone specimens of which 49 were identified as *O. flavescens* (L'Heureux & Franco, 2002). This *taxon* is represented by some unfused bones and mainly fragments of ribs, phalanges and indeterminate vertebrae (Table 1), which corresponded to one subadult prey [NISP = 40; minimum number of individuals (MNI) = 1] and one adult prey (NISP = 2; MNI = 1).

Unfortunately, the sample of otariid remains in CV6 is small, and the relatively high percentages of natural modifications on the seal specimens (Table 2) give few complete bones. In this sense, it was only possible to measure three complete bones from this assemblage: a

Table 1. Element representation of *Otaria flavescens* from Cabo Virgenes

Elements	Minimum number of elements
Skull	1
Mandible	1
Scapula	2
Humerus	3
Radius	2
Ulna	2
Sternebrae	2
Thoracic vertebrae	1
Vertebrae indet	2
Ribs	5
Innomimates	1
Tibia	1
Astragalus	1
Calcaneus	1
Scapholunate	1
Indeterminate metapodials and phalanges	8
Total	34

Table 2. Taphonomical variables observed in *Otaria flavescens* remains from Cabo Virgenes 6

Modifications	%
Postdepositional breakage	87
Weathering	69
Root marks	69
Rodents marks	1
Carnivores marks	2
Burning	9
Cut marks	6

scapula, an ulna and the distal epiphysis of a humerus. Using measurements of three postcranial elements recovered from CV6, we discuss the previous assumption of seasonality at the Cabo Virgenes archaeological locality sustained only by the simple presence of immature specimens of sea lions.

Identifying the age classes of postcranial elements of sea lion pup archaeological remains from CV6 with more precision will allow us to understand the seasonal use of this resource and discuss the moment the individuals were caught and the season of occupation at the Cabo Virgenes locality (Borella, 2010). For that, we assume that body size of *O. flavescens* population has not changed significantly through the last 2000 years, thus making any age prediction on the basis of the modern sample of animal also valid for archaeological samples of seals (see in the following text).

Some biological and behavioural aspects of Southern sea lions with archaeological relevance

Otaria flavescens seasonally restricts breeding and birthing to the summer months. Births occurs from the second half of December to mid February, with a peak in mid-January, and mating takes place some days after birth. In the late February, adult male sea lions disperse to hauling-out grounds beyond the breeding range, accompanied by subadults and some juvenile male sea lions, whereas adult female sea lions and pups abandon the breeding area 1 or 2 months later (Ximénez, 1976; Lewis & Ximénez, 1983; Campagna, 1985; Campagna & Le Boeuf, 1988; Crespo, 1988; Crespo *et al.*, 2007).

Female sea lions have some degree of philopatry, returning to breed close to the area where they were born (Grandi *et al.*, 2008; Feijoo *et al.*, 2011). Given this behavioural pattern, it is expected that individuals are quite susceptible to terrestrial predation during the breeding season (Lyman, 1991, 1995). Then, during this season they would probably be available in dense patches restricted on the coast. This is relevant because there is no evidence that people in continental Patagonia had access to seaworthy boats. We can therefore assume that hunter-gatherer prey acquisition was on land (on shore) and does not represent long-distance transport of carcasses from other areas (see primary reference in Lanata & Winograd, 1988: 242 and Muñoz, 2011).

Another important issue to consider is the general growth patterns of this species. South American sea lions are one of the largest and most dimorphic of the otariids (male sea lions grow to 2.8 m and weigh up to

340 kg; female sea lions to 2.2 m and up to 144 kg; Ralls & Mesnick, 2002: 1005). Newborn pups of this species are sexually dimorphic in mass and length at birth (Cappozzo *et al.*, 1991: 390). Both sexes grow at the same rate during early lactation (Cappozzo *et al.*, 1991; Drago *et al.*, 2010a, 2011) and maintain a linear body growth during the first year of life (Rosas *et al.*, 1993; Grandi, 2010; Grandi *et al.*, 2010). Later, up to sexual maturity, body growth follows a sigmoidal pattern, and male sea lions reach significantly larger sizes than female sea lions (Rosas *et al.*, 1993; Sanfelice & De Freitas, 2008; Drago *et al.*, 2009; Grandi *et al.*, 2010).

Here, we consider the timing of epiphysis fusion in the skeleton of *O. flavescens*. In an ongoing study of fusion in postcranial elements, we noted that with the exception of the atlas, there is no fusion of the epiphyses during the first 4 years of life in this species. Given the slow fusion process in postcranial bones, it is impossible to use this method to identify newborns from others pups or other immature individuals (Borella *et al.*, 2013).

Also, unlike others pinnipeds, *O. flavescens* shed their deciduous teeth during the first year of life (yearlings, *sensu* Stora, 2002:52), therefore, we cannot determine the age during the first year of life by counting growth layer groups in permanent tooth sections (Laws, 1962). This method is usually employed when permanent teeth have erupted. Fortunately, dental replacement of *O. flavescens* pups was studied by Crespo (1988: 66–68) who established four age categories for yearlings: A (0–1.5 months), B (from 1.5 to 5 months), C (from 5 to 8 months) and D (from 8 to 12 months). Crespo's dental age categories are relevant because they can be used as temporal indicators (seasonality) when yearlings are present in the archaeological record (Borella, 2010).

Because the fusion data and the counting growth layer groups in permanent tooth sections are not applicable in yearling individuals of *O. flavescens*, the bone size related to Crespo's dental categories would be the only way to discriminate age classes from immature postcranial bones in the archaeological assemblages. The correlation between the information given by tooth replacement and the postcranial skeleton size of *O. flavescens* was verified.

Material and methods

The main purpose of this study is to provide a corpus of osteometrical data from postcranial modern carcasses to be compared with archaeological bones. The results will help estimate the season of death and the timing of the coastal resource exploitation.

We carried out a morphological study of postcranial skeletons from 0- to 1-year-old modern South American sea lions pups (*O. flavescens*) of known age and sex collected from breeding colonies at Islote Lobos (Río Negro) and Punta Buenos Aires (Península Valdés, Chubut), both located on the Atlantic coast of northern Patagonia (Argentina). Deceased pups were collected opportunistically (randomly during the field trip) from a sea lion colony where they had died from natural causes or as result of adult male sea lion abduction and other traumas (Campagna *et al.*, 1988a, 1988b).

The modern sample is composed of 41 immature individuals, and the pup ages were estimated from the tooth eruption schedule (Crespo, 1988). For this paper, we analysed 11 individuals of category A (0–1.5 months), 21 from category B (1.5–5 months), one of category C (5–8 months) and eight of category D (8–12 months). Both sexes were included in this sample, 20 female and 21 male sea lions.

In each individual, 11 skeletal elements were measured following an osteometrical guide specially designed for *O. flavescens* (L'Heureux & Borella, 2011), using a digital calliper (accuracy: 0.01 mm) by a single analyst (F. Borella).

We performed an exploratory bivariate analysis and a univariate statistical analysis of the data. In order to evaluate the association and dependence relationships between postcranial sizes and age/sex, we used parametric and non-parametric statistical techniques (Spearman correlation and simple regression model analyses) with the statistics software package STATISTICA 7.0 (StatSoft Inc.). The significance value was set at 0.05 ($p < 0.05$) probability.

Three unfused appendicular bones from the modern samples, humerus, ulna and scapula, were selected. We chose these elements because they are some of the most common elements found in the archaeological assemblages from the Cabo Virgenes archaeology locality and thus are comparable to the three complete and

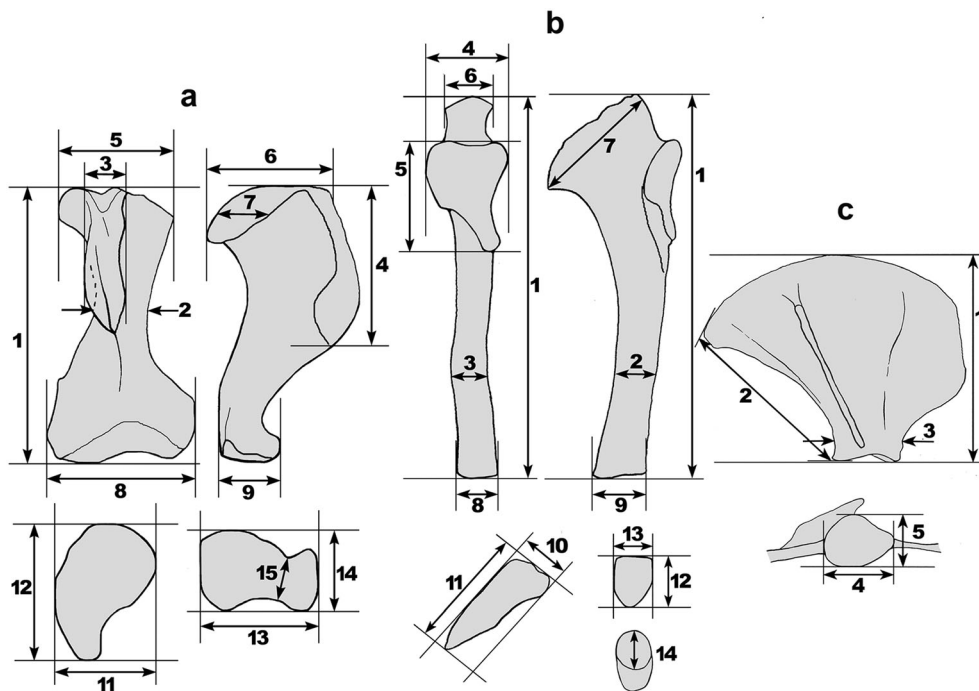


Figure 2. Measurements obtained on (a) humerus, (b) ulna and (c) scapula. Definition of measures. Humerus (a): 1 GL, (greatest) length of diaphysis; 2 SBD, (smallest) breadth of diaphysis; 3 BDT, (greatest) breadth of deltoid tuberosity; 4 LDT, (greatest) length of deltoid tuberosity; 5 BDp, (greatest) breadth of proximal diaphysis; 6 DDp, (greatest) depth of proximal diaphysis; 7 BHp, (greatest) breadth of proximal humeral head; 8 BDd, (greatest) breadth of distal diaphysis; 9 DDd, (greatest) depth of distal diaphysis; 10 SDD, (smallest) breadth of distal diaphysis. Measured in the condylar sulcus. 11 BH, (greatest) breadth of unfused head (proximal epiphysis); 12 DH, (greatest) depth of unfused head (proximal epiphysis); 13 Bd, (greatest) breadth of unfused distal epiphysis; 14 Dd, (greatest) depth of unfused distal epiphysis; 15 SDD, (smallest) depth of unfused distal epiphysis. Ulna (b): 1 GL, (greatest) length of diaphysis; 2 SDD, (smallest) depth of diaphysis; 3 SBD, (smallest) breadth of diaphysis. Measured in the same plane as SDD. 4 BDp, (greatest) breadth of proximal diaphysis; 5 LFp, (greatest) length of the facies articularis proximalis; 6 BOp, (greatest) breadth of the olecranon. Proximal diaphysis. 7 DOp, (greatest) depth of olecranon. Proximal diaphysis. 8 BDd, (greatest) breadth of unfused olecranon crest; 9 DDd, (greatest) depth of unfused olecranon crest; 10 GBO, (greatest) breadth of unfused distal epiphysis; 11 GDO, (greatest) depth of unfused distal epiphysis; 12 Ld, (greatest) length of unfused distal epiphysis; 13 Bd, (greatest) breadth of unfused distal epiphysis; 14 Dd, (greatest) depth of unfused distal epiphysis. Scapula (c): 1 GL, (greatest) length of scapula; 2 SL, (smallest) length of scapula; 3 SBN, (smallest) breadth of scapula neck; 4 BGP, (greatest) breadth of glenoid process; 5 DGP, (greatest) depth of glenoid process.

Table 3. Spearman rank order correlations

Humerus			Ulna			Scapula		
	Sex	Age		Sex	Age		Sex	Age
Sex	1.000	−0.047	Sex	1.000	−0.088	Sex	1.000	−0.009
Age	−0.047	1.000	Age	−0.088	1.000	Age	−0.009	1.000
1	0.279	0.677	1	0.101	0.755	1	0.190	0.681
2	0.327	0.673	2	0.236	0.716	2	0.148	0.690
3	0.288	0.489	3	0.187	0.593	3	0.426	0.419
4	0.279	0.749	4	0.165	0.710	4	0.338	0.656
5	0.231	0.619	5	0.425	0.414	5	0.160	0.590
6	0.257	0.529	6	0.337	0.377			
7	0.267	0.526	7	0.253	0.592			
8	0.288	0.633	8	0.223	0.593			
9	0.336	0.649	9	0.177	0.639			
10	0.159	0.658	10	—	—			
11	0.135	0.645	11	—	—			
12	−0.111	0.714	12	—	—			
13	−0.048	0.769	13	—	—			
14	0.058	0.768	14	—	—			
15	0.253	0.856						

Measurements from the humerus, ulna and scapula versus sex/age classes. All measurements are defined in Figure 2. Bold values are statistically significant ($p < 0.05$).

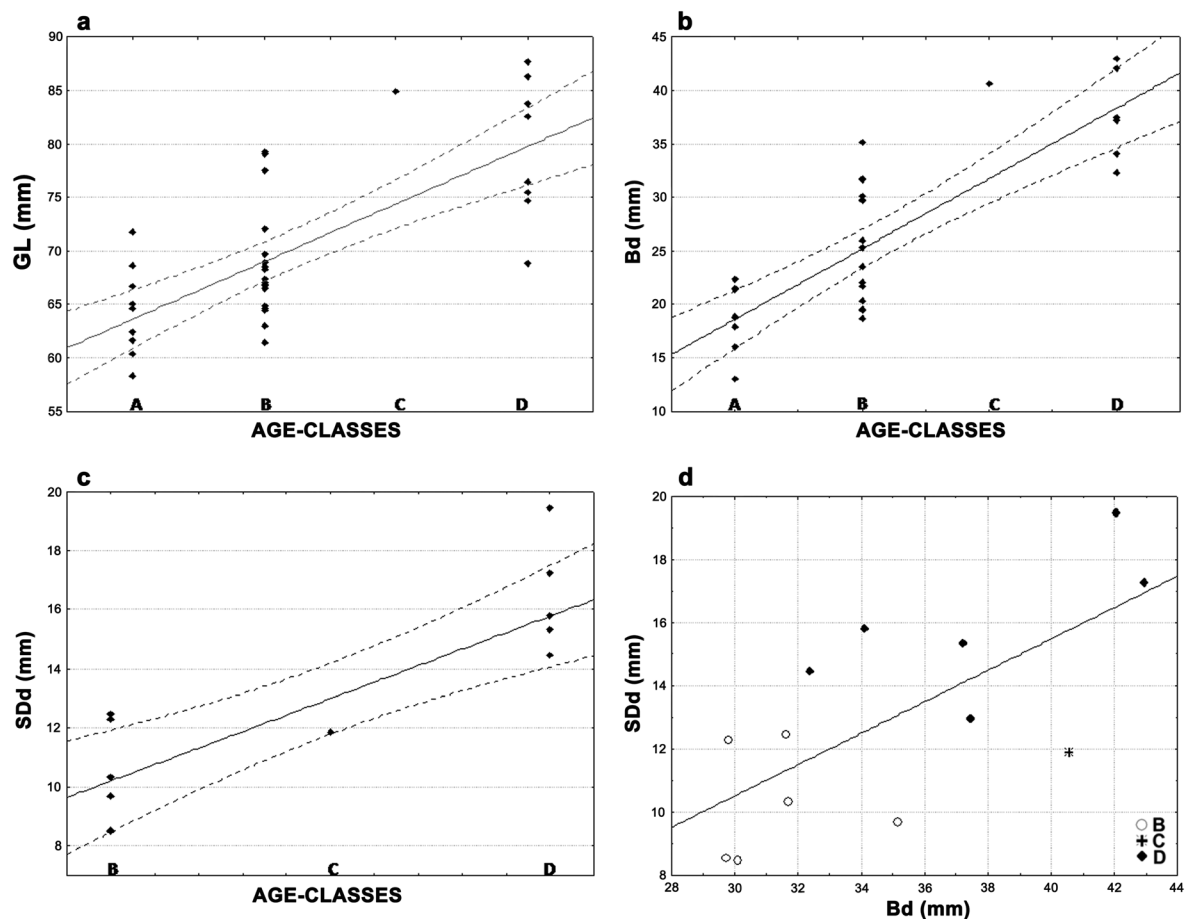


Figure 3. Regression models of Humerus. (a) Greatest length (GL) and age classes, (b) greatest breadth of unfused distal epiphysis (Bd) and age classes, (c) smallest depth of unfused distal epiphysis (SDd) and age classes and (d) bivariate plot of Bd versus SDd.

measurable postcranial bones found in CV6. Fifteen measurements were obtained on humerus, nine on the ulna diaphysis and five on the scapula. The metric variables defined for each unfused bone are shown in Figure 2.

The size patterns generated from the modern samples of sea lions were used to compare the osteometric information from the humerus, ulna and scapula of CV6, and estimate the age of death using the simple regression analyses.

Results and discussion

Modern sample

In the modern sample, the Spearman correlation analysis (Table 3) showed that the relationship between size and age was statistically significant for all metric variables obtained on three unfused long bones.

The highest correlations between size and age category for humeri were observed in all variables measured on the distal epiphysis [variables breadth of unfused distal epiphysis (Bd), depth of unfused distal epiphysis

(Dd) and smallest depth of unfused distal epiphysis (SDd); 13–15 in Figure 2(a)], followed by variables greatest length (GL) and length of deltoid tuberosity measured in the unfused diaphysis (LDT) (variables 1 and 4; Figure 2(a)). The highest correlations for ulnas were observed in the GL, smallest depth of diaphysis (DD) and breadth of proximal diaphysis (BDp) variables (variables 1, 2 and 4 in Figure 2(b)) and the GL and DD variables for the tibiae (variables 1 and 3 in Figure 2(c)).

In summary, results show that all appendicular bone sizes are significantly correlated with age. So, we can assume that these dimensions are potentially good for predicting age of *O. flavescens* postcranial elements.

It is important to note that association relationships between diaphysis size and sex are very low. Only one variable of the humerus diaphysis, two of the ulna and one of the scapula neck reach a low but statistically significant probability of sexual dimorphism ($p < 0.05$; Table 3). This observation is very interesting because biologists have measured sexual dimorphism in newborn pups from body mass and standard length. On that basis, they suggest that 'Southern sea lions females

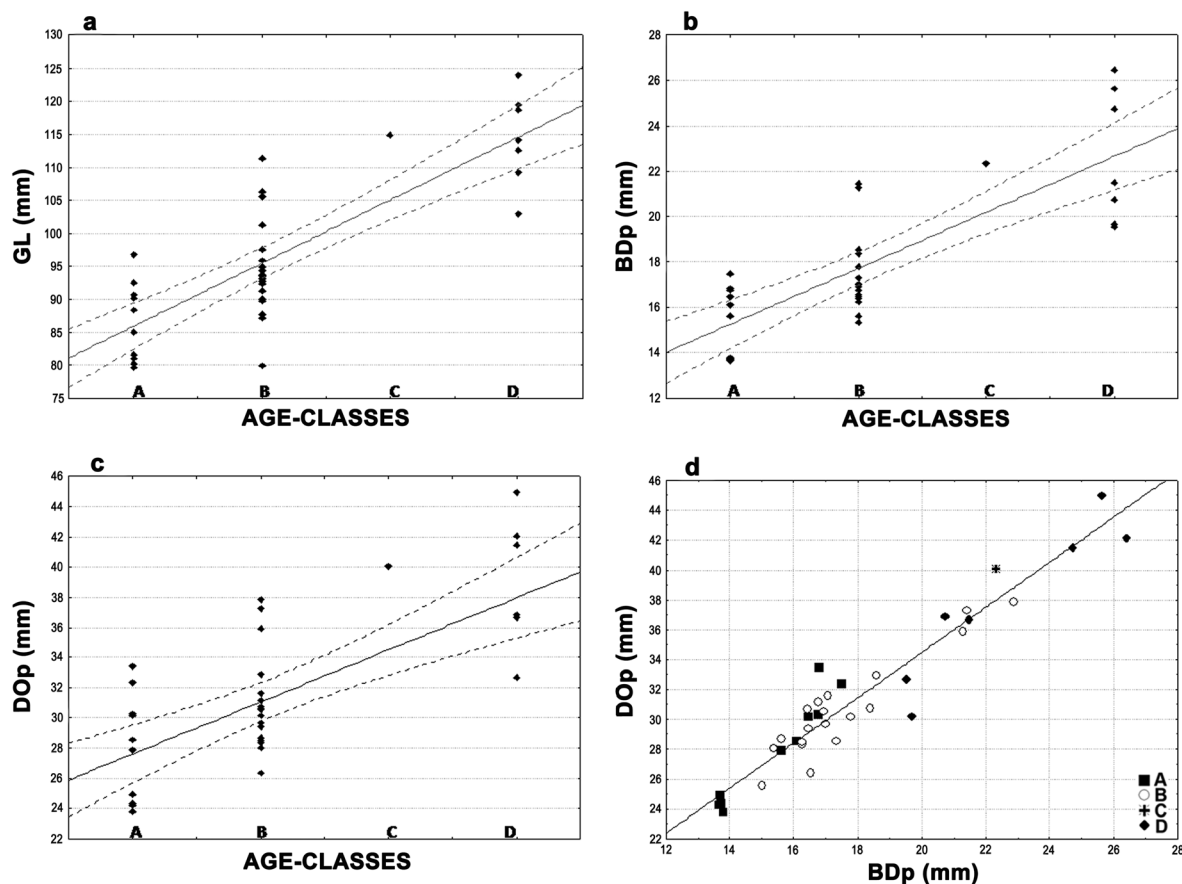


Figure 4. Regression models of Ulna. (a) Greatest length (GL) and age classes, (b) greatest breadth of proximal diaphysis (BDp) and age classes, (c) greatest depth of olecranon – proximal diaphysis – (Dop) and age classes and (d) bivariate plot of BDp versus Dop.

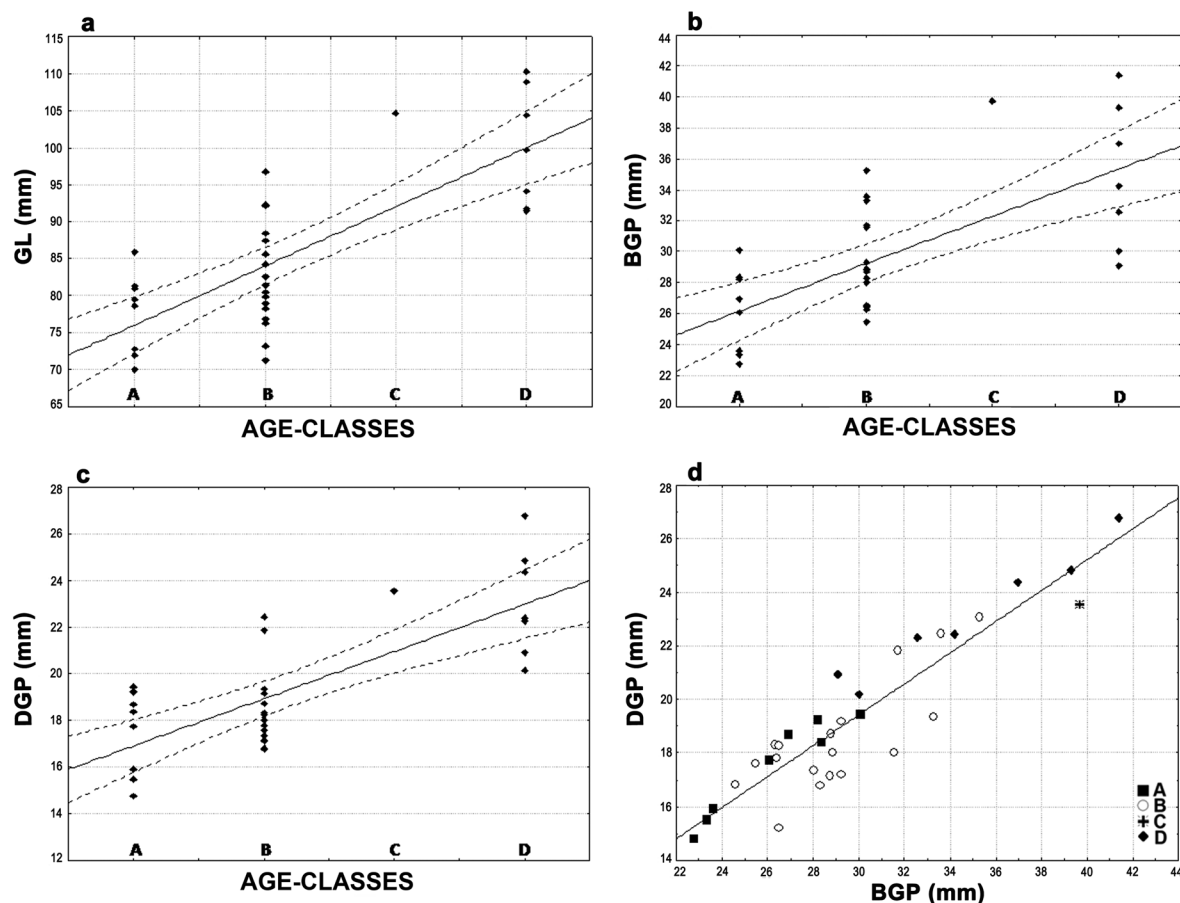


Figure 5. Regression models of Scapula. (a) Greatest length (GL) and age classes, (b) greatest breadth of glenoid process (BGP) and age classes, (c) greatest depth of glenoid process (DGP) and age classes and (d) bivariate plot of BGP versus DGP.

invest more in sons than in daughters during gestation', and 'because size dimorphism present at birth persists, sons may continue to be more costly than daughters to their mothers during lactation' (Cappozzo *et al.*, 1991: 391). At osteological levels, sexual dimorphism is not expressed in the same way in different skeletal regions. In forelimbs, it does not seem relevant within the first year of life. Therefore, all these bones would be useful to generate models to estimate age-at-death.

We develop predictive models for estimation of age-at-death for *O. flavescens* pups using a simple regression analysis with different continuous dependent variables (selected for having a high size-age class correlation, and because some of these variables are measured in archaeological bones) and one interval-independent variable (age categories). The ultimate aim of developing models to estimate age-at-death from postcranial elements of otariids is to produce reliable information to discuss seasonal exploitation of the Patagonian coast by hunter-gatherers during the Late Holocene.

For the humerus, the GL of the unfused diaphysis, greatest Bd and SDd of unfused distal epiphysis are shown in Figure 3(a–c). For the ulna, a model of age estimation for the GL, greatest BDp of proximal diaphysis and the greatest depth of olecranon (DOp) was performed (Figure 4(a–c)). On the scapula, the GL, the greatest breadth of glenoid process (BGP) and the greatest depth of glenoid process (DGP) were used (Figure 5(a–c)). We also explored the bivariate metrical behaviour of selected variables (Figures 3(d), 4(d) and 5(d)).

The regression model of the GL on age classes showed a good fit to the humerus ($r = 0.724$; $R^2 = 0.524$; *adjusted* $R^2 = 0.511$; $F_{(1,36)} = 39.689$; $p = 0.000$; $SE = 5.516$). The best fit to the humerus were found on the distal epiphysis, both the Bd on age classes ($r = 0.809$; $R^2 = 0.655$; *adjusted* $R^2 = 0.664$; $F_{(1,30)} = 56.928$; $p = 0.000$; $SE = 4.943$) as the variable SDd on age classes ($r = 0.830$; $R^2 = 0.688$; *adjusted* $R^2 = 0.660$; $F_{(1,11)} = 24.287$; $p = 0.000$; $SE = 1.963$) (Figure 3(a–c)).

The regression model of the GL on age classes shows the best fit to the ulna ($r = 0.821$; $R^2 = 0.673$; *adjusted* $R^2 = 0.664$; $F_{(1,35)} = 72.164$; $p = 0.000$; $SE = 6.975$). For the proximal epiphysis, we observed a good fit for BDp on age classes ($r = 0.769$; $R^2 = 0.592$; *adjusted* $R^2 = 0.580$; $F_{(1,35)} = 50.748$; $p = 0.000$; $SE = 2.141$) and DOp on age classes ($r = 0.683$; $R^2 = 0.467$; *adjusted* $R^2 = 0.452$; $F_{(1,35)} = 30.583$; $p = 0.000$; $SE = 3.857$) (Figure 4(a–c)).

The regression model of the GL on age classes shows the best fit to the scapula ($r = 0.767$; $R^2 = 0.587$; *adjusted* $R^2 = 0.574$; $F_{(1,32)} = 45.405$; $p = 0.000$; $SE = 7.089$). The glenoid process diameters exhibit a high relationship with the age classes: BGP on age classes ($r = 0.678$; $R^2 = 0.459$; *adjusted* $R^2 = 0.442$; $F_{(1,32)} = 27.135$; $p = 0.000$; $SE = 3.494$) and DGP on age classes ($r = 0.714$; $R^2 = 0.509$; *adjusted* $R^2 = 0.494$; $F_{(1,32)} = 33.169$; $p = 0.000$; $SE = 2.090$) (Figure 5(a–c)).

Scatterplots of metric variables (millimetre) versus age categories show high dependence among these variables and allow prediction of age-at-death of *O. flavescens* unfused postcranial elements. These bone sizes (variables) would be good predictors of age of pups of *O. flavescens* despite the fact that the variability of sea lion pups size inside each age class is broad (Figures 3(a–c), 4(a–c) and 5(a–c)).

Looking at the bivariate scatterplots generated for the proximal epiphysis of the ulna and the glenoid process of the scapula, sizes overlap between age categories (Figures 4(d) and 5(d)). This is not observed by plotting the diameters of the humerus distal epiphysis, because the 'A' age class is not represented (Figure 3(d)).

Regression analyses on the unfused appendicular bones of *O. flavescens* pups generated an age estimation model independent of body size variations between sexes. The limitation of this procedure is that there is an over-lap between the age groups, and we do not know the size variability in age group C (represented by only one individual). The strengths are that the variables for all unfused bones analysed presented strong dependence relationships between sizes and age categories, and these were highly statistically significant ($p < 0.000$).

Archaeological sample

In South American sea lions, many postcranial measurements are good estimators of age (Table 3), but it is not always possible to take them on all archaeological bones because of postdepositional damage and moderate/high fragmentation (as in CV6; see Table 2). In Baltic sites, for example, with other species of seals, archaeologists have taken three different measurements

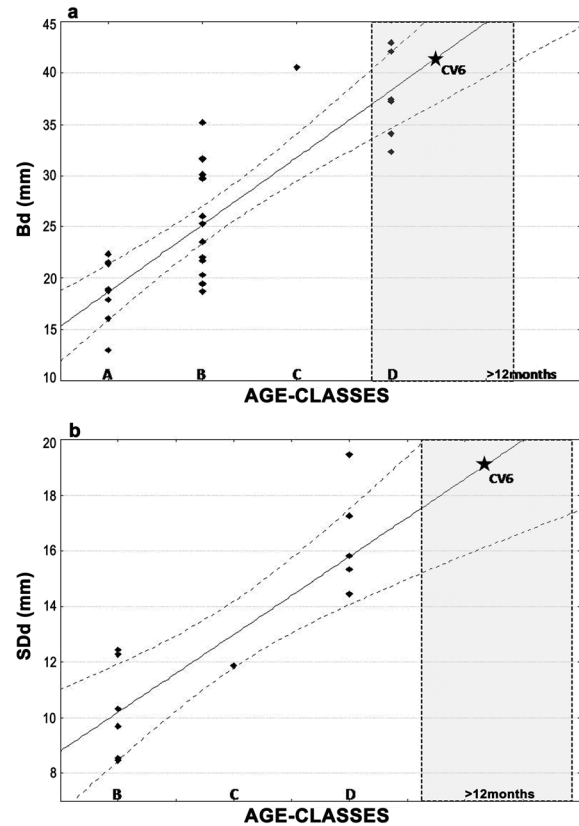


Figure 6. Age estimation of CV6 humerus using Bd and SDd variables. The shaded region represents the estimation standard error.

of femurs [the smallest length of corpus, the smallest breadth of the diaphysis and the greatest depth of the diaphysis (*sensu* Stora, 2002:51)], and three of the humerus [cross-section of diaphysis (*sensu* Stora & Ericson, 2004:125), the smallest diagonal breadth of the diaphysis and the smallest height of the diaphysis (*sensu* Stora & Lougas, 2005:100)] depending on each sample.

Thus, the element chosen depends on the kind of items recovered, the fragmentation state and the weathering stage of elements in each archaeological assemblage.

Moreover, zooarchaeological marine mammals' remains from many Atlantic Patagonian littoral sites are numerically small compared with other parts of the world (New Zealand, Northeastern Pacific of North America or Tierra del Fuego Island). For that reason, and because complete and unweathered small individual bones are scarce in the CV6 assemblage (Table 2), only one proximal ulna, one epiphysis distal of humerus and one scapula assigned as pup remains were selected from the CV6 faunal assemblage. The three bones were recovered from the same excavation unit (N° 4) and level. This spatial proximity, their fusion stage and laterality suggest that they likely correspond to the same individual.

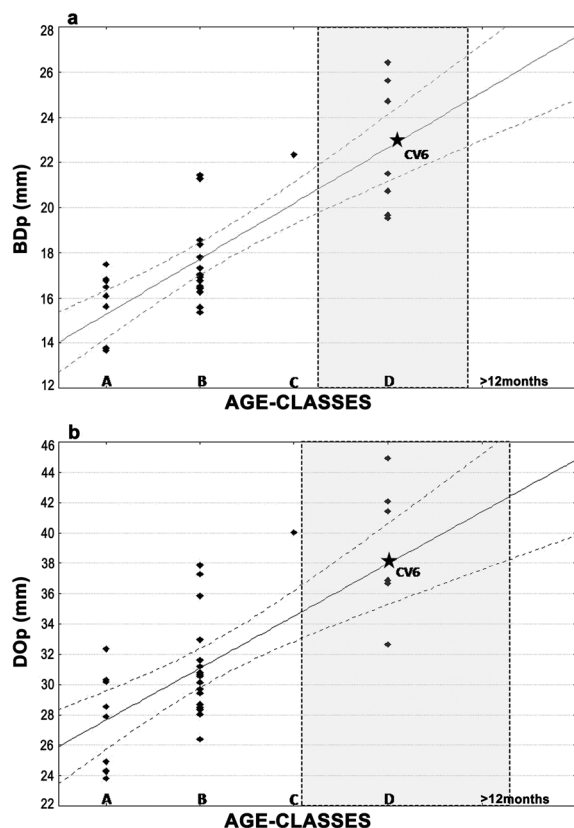


Figure 7. Age estimation of CV6 ulna using BDp and DOp variables. The shaded region in represents the estimation standard error.

We used the age-estimation models generated by regression analyses on the modern unfused appendicular bones of *O. flavescens* pups. The standard errors generated by those analyses are broad and prevent an unequivocal age estimation from archaeological specimens. Nevertheless, we consider this method that allows for adjustment of pup age estimates, which cannot be defined by the stages of fusion or cut thin sections of teeth.

Using the size pattern obtained for distal humeri to check the age of archaeological humerus from CV6, we observed that the variables greatest Bd (Figure 6(a)), such as the SDd (Figure 6(b)), on average, the individual could be over 12 months old at the time of death. If we consider the error of the estimate, the age range would be between 8 months and older than 1 year (Figure 6(b)). Taking into account, the best fit of the regression model for the humerus, we found that on the distal epiphysis, both the Bd and the SDd provided reliable age estimates for archaeological specimens.

The greatest breadth of the ulna proximal diaphysis (BDp) presents a good and significant association/

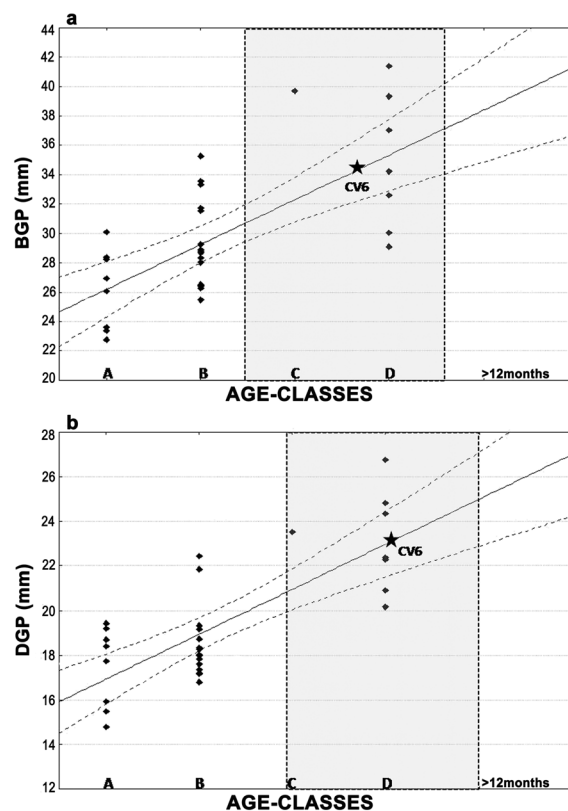


Figure 8. Age estimation of CV6 scapula using BGP and DGP variables. The shaded region represents the estimation standard error.

dependence relationship between this dimension and the age category. The age estimation shows that the size of BDp for the CV6 ulna corresponds to a modern individual between 5/8 and 12 months, being, on average, an individual of age class 'D' (Figure 7(a)). The age estimation derived from the proximal ulna variable shows an age indicator for this archaeological specimen, which would represent an age class 'D' individual, but when considering the broad standard error, the estimated age would include between 5 and older than 12 months (Dop in Figure 7(b)).

The age estimation of archaeological maximum BGP from the scapula suggests a range of error of age that goes beyond age classes C and D (Figure 8(a)) for this individual, and another metric variable (DGP) located, on average, the archaeological individual with 'D' modern sea lions of 8–12 months old and with an error range that include the size variation of classes C and D (Figure 8(b)).

According to the laterality of the measured elements, spatial proximity of their recovery and the low variation of the estimated ages for the studied bones, we assume that it is a single individual processed at CV6. Furthermore, the CV6 assemblage is small, has a high

fragmentation, and the minimum number of elements of *O. flavescens* is very low, thus, it is more conservative to assume an MNI of 1 for the *O. flavescens* pups at the site.

Taking this into account, we can conclude that the small bones of *O. flavescens* recovered at CV6 and assigned as a pup were from one individual (MNI = 1), which would have been more than 5 months old and could have well be over a year at the time of dead or capture, considering the error in the estimation of age. On average, across the three bones, there is an individual of age class D (between 8 and 12 months). Therefore, it is not a newborn, and this result has consequences on previous inferences performed about summer exploitation at CV6.

It is always difficult to evaluate prehistoric exploitation with a small sample, but the archaeological evidence from Cabo Virgenes gives the impression that it was opportunistic and complemented with other coastal resources. Because archaeofaunal evidence from sites in Cabo Virgenes shows the predominance of avian and seals, the isotopic analyses show a systematic consumption of both marine and terrestrial resources (Borrero & Barberena, 2006: 861). Moreover, and according with this information, we can sustain that there were ephemeral occupations in this area, with a very low intensity of predation over pinnipeds, at least during prehistoric times.

Conclusions

The application of the age estimation models on three archaeological specimens (humerus, ulna and scapula) showed how the age of sea lions processed in CV6 is, on average, about 8–12 months of age (for ulna and scapula) or slightly more than 12 months in the case of humerus. This masks the timing of death estimation and the validity of hunting season. The mere presence of yearling pups as an indicator of seasonality could be misleading because they are not suitable to determine the season of death. Only by identifying newborns aged 1 month, we can determine the site seasonality (Borella, 2010). Therefore, measurements of bones from age category 'A' within yearling pups would be the unique postcranial indicator useful for suggesting a summer capture and the presence of reproductive sea lions colonies near archaeological sites.

The dependable age estimation model generated for unfused appendicular bones of *O. flavescens* between 0 and 12 months can be applied to samples recovered in any archaeological site of the Patagonian coast. Because of the inability of doing dental thin-section cuts in sea lion pups (younger than 1 year), the osteometric

studies on their postcranial elements provide a new and complementary way to evaluate the age of the animals at death and allow estimation of seasonality at the same time. As Stora (2002) has demonstrated, size comparisons of seal bones are a particularly useful tool for seasonality estimations. We consider that the measures obtained from long bones of age category 'A' are the only unequivocal postcranial markers useful to sustain an interpretation of summer exploitation of this species and the presence of breeding colonies next to archaeological sites. However, as suggested by Monks (1981), in order to use these data to infer seasonality of capture, it may be better to use a larger sample along with other indicators to develop testable hypotheses.

Because our growth curves were derived from modern comparative specimens, it is possible to consider that this sample might differ in body size from the archaeological specimens because of environmental fluctuations. However, no significant changes in climatic conditions in the last 2000 years in the area were recorded (Moy *et al.*, 2009). Paleoclimatic data from Southern South America indicate an overall decrease in temperature and an increase in Westerlies during the last 2000 years, which, culminates in the last few hundred years during the time of the European Little Ice Age (Moy *et al.*, 2009: 385). The pollen records, particularly between 1270 and 700 years BP, are dominated by *taxa* that, in the present day, are associated with low moisture levels. These pollen spectra are similar to the recent comparative sample of the swamp (Mancini, 2007). Recent studies of sea surface temperature suggest that in central-northern Patagonia and Beagle Channel, the temporal profiles of oxygen stable isotope ratios revealed similar patterns, characterised by high temperatures throughout most of the Late Holocene with a cold phase during the Little Ice Age and a recent warming (Saporiti *et al.*, 2013).

The results reached are based on the assumption that modern populations of sea lions are more similar in body size, over the course of their growth and development, than those encountered in the archaeological record from Patagonia. Climatic change and overhunting by humans are factors that could lead to changes in body size (Stora & Ericson, 2004). In this study, the first factor can be dismissed because there have been no significant changes in climatic conditions during the past 2000 years (Mancini, 2007; Moy *et al.*, 2009 and Saporiti *et al.*, 2013).

The second factor does not involve overexploitation by hunter–gatherers, but in Patagonia (Argentina), South American sea lions were heavily exploited from the 1920s to the 1960s, and their populations reduced to less than 10% of pre-exploitation numbers (Crespo

& Pedraza, 1991; Reyes *et al.*, 1999; Schiavini *et al.*, 2004; Drago *et al.*, 2009; Grandi *et al.*, 2010). After three decades of stagnation, population began to recover in the early 1990s after the crises of industrial fishing of hake (*Merluccius hubbsi*), a resource principal in the diet of *O. flavescens* (Crespo & Pedraza, 1991; Reyes *et al.*, 1999; Schiavini *et al.*, 2004). Although there is evidence that there was a reduction in skull size in South American sea lions due to density-dependent growth during the period of population recovery (Drago *et al.*, 2010b), we do not know if the present population abundance is different from the ancient one. Moreover, the present abundance is still below the estimated historical numbers at the beginning of the 20th century when they were over-hunted (Crespo & Pedraza, 1991; Grandi *et al.*, 2012).

Considering that current density represents only 44% of the sea lion pre-exploitation abundance (Grandi, 2010), we can assume that actual body sizes are similar to sea lions living in highly dense conditions, such as populations before exploitation or even ancient populations (without strong human influence). Furthermore, it is important to mention that the specimens of our modern reference sample that were used here were collected between 2008 and 2011, when the density of population was already recovered, and after the crises of hake fishery mentioned by Drago and collaborators (2010b). Therefore, if the current pattern of sea lions behaviour is the same as it was in the past, identifying newborn pup remains in the archaeological record has the potential to address seasonality determination. In addition, and given the remarkably synchronous sea lions birthing behaviour, identifying the presence of newborn pups is the only way to document the exploitation of sea lion colonies (Lyman, 1991, 1995).

As mentioned, summer exploitation inferred only from an archaeological pup record is untrustworthy. The finding of unfused sea lions pup bones in the archaeological record can involve different age categories, ranging from pups about only a couple of months old up to individuals older than 1 year old (male and female). Therefore, the presence of pups in the archaeological record does not mean that their capture occurred necessarily during the summer.

Analyses based only on the presence of unfused bones of immature sea lions as a summer occupation indicator are dubious because the presence of yearling pup bones does not assure the season of death if we do not have an accurate determination of their age (Borella, 2010). The epiphyseal fusion in *O. flavescens* occurs over a long period and therefore does not provide an accurate estimate of seasonality. Although some bone measurements

obtained are suitable for determining age, other seasonality methods (Monks, 1981) should not be excluded to obtain more precise interpretations.

According to the preliminary results obtained here, the sea lion from CV6 may be, on average, a 'D' individual (8–12 months old) and, taking into account the wider ranges of estimation method, may have from 5 to older than 12 months. Therefore, it is not a newborn and cannot be used to determine summer exploitation at Cabo Virgenes locality (cf. L'Heureux & Franco, 2002). On the basis of these results, we propose that there is a need to review other cases in Patagonia, where archaeological seasonality was estimated solely from the presence of small pup bone remains (sea lions pups of age class 'A').

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