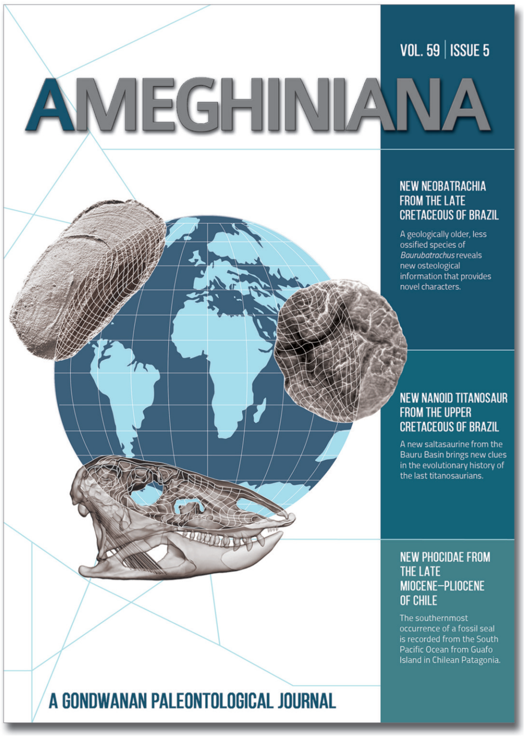
AMEGHINIANA
A GONDWANAN PALEONTOLOGICAL JOURNAL



NEW SEAL (CARNIVORA, PHOCIDAE) RECORD FROM THE LATE MIOCENE–PLIOCENE OF GUAFO ISLAND, SOUTHERN CHILE

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Submitted: 15 February 2022 - **Accepted:** 6 July 2022 - **Published:** 15 September 2022

To cite this article: Ana M. Valenzuela-Toro, Nicholas D. Pyenson (2022). New seal (Carnivora, Phocidae) record from the Late Miocene–Pliocene of Guafo Island, Southern Chile. *Ameghiniana 59*(5), 355–365.

To link to this article: http://dx.doi.org/10.5710/AMGH.06.07.2022.3498

ISSN 0002-7014

AMEGHINIANA - 2022 - Volume 59 (5): 355–365

ARTICLES

NEW SEAL (CARNIVORA, PHOCIDAE) RECORD FROM THE LATE MIOCENE–PLIOCENE OF GUAFO ISLAND, SOUTHERN CHILE

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Abstract. Several remains of fossil phocids (*i.e.*, true seals) have been consistently reported from the Late Miocene and Pliocene strata from the southwestern coast of South America. These fossils, along with those from fossil otariids (fur seals and sea lions), indicate that a widespread turnover from a phocid- to an otariid-dominated fauna in the Southern Hemisphere transpired during the Late Pliocene or Early Pleistocene. The Neogene fossil record of phocids is primarily dominated by occurrences from southern Peru and northern Chile, with a few isolated findings from central Chile. Until now, no records of fossil seals have been documented from southern Chile, constraining our understanding of the latitudinal variability of the pinniped assemblages and the mechanisms by which their faunal turnover occurred. Here we report the fossil remains of a fossil seal (Monachinae indet.) from the Late Miocene–Pliocene sediments of Guafo Island in the south of Chile. These remains constitute the southernmost occurrence of a fossil seal from the South Pacific Ocean, expanding their geographic range in the southeastern coast of South America more than 1000 km. This finding reveals that phocids inhabited temperate and subantarctic regions in Chilean Patagonia during the late Neogene, suggesting a broader environmental tolerance than previously recognized.

Key words. Marine mammals. Pinnipeds. Neogene. Southeastern Pacific Ocean. South America. Patagonia. Biogeographic patterns. Faunal turnover.

Resumen. NUEVO REGISTRO DE FOCA (CARNIVORA, PHOCIDAE) DEL MIOCENO TARDÍO–PLIOCENO DE ISLA GUAFO, SUR DE CHILE. Diversos restos de fócidos fósiles (focas) han sido consistentemente reportados en niveles del Mioceno Tardío y Plioceno de América del Sur. Estos fósiles, junto a aquellos de otáridos fósiles (lobos marinos), indican que durante el Plioceno Tardío o Pleistoceno Temprano se produjo un recambio generalizado desde una fauna dominada por fócidos a una dominada por otáridos en el Hemisferio Sur. El registro fósil de fócidos del Neógeno está dominado principalmente por ocurrencias en el sur de Perú y el norte de Chile, con algunos hallazgos aislados en el centro de Chile. Hasta ahora, no se han reportado focas fósiles en el sur de Chile, limitando nuestra comprensión de la variabilidad latitudinal de los ensambles de pinnípedos, así como de los mecanismos por los cuales ocurrió su recambio faunístico. Aquí describimos los restos fósiles de una foca fósil (Monachinae indet.) de los sedimentos del Mioceno Tardío-Plioceno de la Isla Guafo en el sur de Chile. Estos restos constituyen la ocurrencia más austral de una foca fósil en el Océano Pacífico Sur, ampliando su rango de distribución geográfica en la costa sureste de América del Sur en más de 1000 km. Este hallazgo revela que los fócidos habitaron regiones templadas y subantárticas a lo largo de la Patagonia Chilena durante el Neógeno tardío, lo que sugiere una tolerancia ambiental más amplia que la reconocida anteriormente para este grupo.

Palabras clave. Mamíferos marinos. Pinnípedos. Neógeno. Sureste del Océano Pacífico. América del Sur. Patagonia. Patrones biogeográficos. Recambio faunístico.

PINNIPEDS (SEALS, FUR SEALS, SEA LIONS, AND WALRUSES) have a globally distributed fossil record, spanning in geologic time from the late Oligocene to the Holocene (Berta *et al.*, 2018; Valenzuela-Toro & Pyenson, 2019). Based on their fossil record, pinniped communities underwent widespread ecological and taxonomic transformations late in their evolutionary history, especially during Pliocene and Pleistocene (Valenzuela-Toro *et al.*, 2013; Rule *et al.*, 2019). Nearly synchronic pinniped faunal turnovers have been described from fossil assemblages along the coastlines of western North America, western South America, South Africa, and Oceania, which have raised questions about the biotic and abiotic causes for this transition, especially relative to the global patterns of marine megafaunal extinction at the end of the Pliocene (Pimiento *et al.*, 2017).

While the Neogene pinniped fossil record from the Southern Hemisphere is almost entirely represented by phocid (true seal) occurrences, today's pinniped assemblages in the region are dominated by otariids (fur seals and sea lions) with only occasional occurrences of vagrant phocids (Cárcamo *et al.*, 2019; Costa & Valenzuela-Toro, 2021). For decades, abundant fossil remains of phocids have been collected from Miocene and Early Pliocene sediments from Australia, New Zealand, Peru, Chile, Argentina, and South Africa (de Muizon, 1981; Fordyce & Flannery, 1983; Cozzuol, 2001; Walsh & Naish, 2002; Fitzgerald, 2005; Avery & Klein, 2011; Valenzuela-Toro *et al.*, 2013, 2015; Govender, 2015; Rule *et al.*, 2019, 2020, 2021a, 2021b; Echarri *et al.*, 2021). Moreover, few and isolated phocid remains have been recovered from Pleistocene levels of Chile, New Zealand, and South Africa (King, 1983; Boessenecker & Churchill, 2016; Valenzuela-Toro *et al.*, 2016). This record contrasts with the fossil record of otariids, which is temporally and geographically more constrained, consisting of isolated remains from the Late Pliocene of Peru and South Africa, and the Pleistocene of Brazil, Chile, New Zealand, and South Africa (Valenzuela-Toro *et al.*, 2013; Boessenecker & Churchill, 2016).

Collectively, these fossil remains show that the transition from a phocid-dominated pinniped fauna to an otariid-dominated one occurred relatively synchronically across the Southern Hemisphere during the Pliocene (Valenzuela-Toro *et al.*, 2013; Rule *et al.*, 2019). The mechanism by which this faunal turnover occurred remains obscure. Nevertheless, Late Pliocene occurrences of fossil phocids from Chile and South Africa (Avery & Klein, 2011; Benites-Palomino *et al.*, 2022) and the Pleistocene of Chile (Valenzuela-Toro *et al.*, 2016) have hinted that during some part of the Pliocene and Pleistocene, phocids and otariids co-occurred in the South Pacific and Atlantic oceans, resembling the configuration of pinniped communities observed today in the North Pacific (Costa & Valenzuela-Toro, 2021).

The western coastline of South America is especially important for understanding this faunal turnover in pinnipeds. Abundant remains of fossil phocids have been reported from the Late Miocene and Early Pliocene of the Pisco Formation in southern Peru and the Bahía Inglesa Formation in northern Chile. From these units, at least four extinct species of seals have been described (*Acrophoca longirostris* de Muizon, 1981; *Piscophoca pacifica* de Muizon, 1981; *Australophoca changorum* Valenzuela-Toro *et al.*, 2015; and *Hadrokirus martini* Amson & de Muizon, 2014, described only from Peru), which suggests that phocid-dominated pinniped communities of the South Pacific had unusual ecomorpho-logical diversity (Valenzuela-Toro *et al.*, 2015) before phocids were displaced and the communities became dominated by otariids (Valenzuela-Toro *et al.*, 2013). Unfortunately, the lack of pinniped fossil records from other Miocene and Pliocene units from western South America has impeded a more refined understanding of their biogeographic pattern and environmental affinity, challenging our comprehension of the mechanisms of their faunal turnover.

Here we report the remains of a fossil phocid from the Late Miocene–Pliocene sediments from southern Chile (Fig. 1). These remains might constitute one of the youngest pre-Quaternary fossil records of a phocid seal from the Southern Hemisphere and the southernmost occurrence of a fossil seal from the South Pacific. This record expands the geographic and temporal range of the fossil record of phocids and provides new information about pinniped biogeography and their turnover in the Southern Hemisphere.

Institutional abbreviations. CAS MAM, Department of Ornithology and Mammalogy, California Academy of Sciences, San Francisco, United States. **UCSC ANTH,** Department of Anthropology, University of California Santa Cruz, California, United States. **USNM** and **USNM PAL,** Department of Vertebrate Zoology (Division of Mammals) and Department of Paleobiology, respectively, National Museum of Natural History, Smithsonian Institution, Washington, District of Columbia, United States.

MATERIAL AND METHODS

Referred Specimen. USNM PAL 706597 consists of a left tibia and fibula, an ectocuneiform, and an incomplete phalanx. The specimen was collected by William Zinsmeister during a field expedition in 1970, aboard the National Science Foundation's Research Vessel *Hero* during its transit from the United States to Antarctica.

Specimens Observed. *Acrophoca longirostris* (USNM PAL 443495), *Allodesmus kelloggi* Mitchell, 1966 (*Allodesmus kernensis* Kellogg, 1922 according to Boessenecker & Churchill, 2018; USNM PAL 23249), *Arctocephalus townsendi* Merriam, 1897 (CAS MAM 3000, 30876), Monachinae indet. (USNM PAL 205850), *Callorhinus ursinus* Linnaeus, 1758 (CAS MAM 2334), *Erignathus barbatus* Erxleben, 1777 (USNM 307617), *Eumetopias jubatus* Schreber, 1776 (CAS MAM 16245, 22199, UCSC ANTH 11821/1, 11821/2), *Halichoerus grypus* Fabricius, 1791 (USNM 244346, CAS MAM 22571), *Leptonychotes weddellii* Lesson, 1826 (USNM 550359), Phocidae indet. (USNM PAL 175578), *Lobodon carcinophagus*

Hombron & Jacquinot, 1842 (USNM 269722), *Mirounga angustirostris* Gill, 1866 (CAS MAM 962, 1137), Odobenidae indet. (USNM 335573, 335514), *Ommatophoca rossii* Gray, 1844 (USNM 339989), *Phoca vitulina* Linnaeus, 1758 (CAS MAM 21377, 20852, UCSC ANTH 110911/2), *Piscophoca* sp. (USNM PAL 443891, 443891, 443898, 443899), *Zalophus californianus* Lesson, 1828 (CAS MAM 15262, 15979, 15978, 23000, 21038, 16607, 16608, UCSC ANTH 11811/7, 110811/05), *Zalophus wollebaeki* Sivertsen, 1953 (CAS MAM 24364, 24363). All these specimens corresponded to physically mature individuals as indicated by the suture closure of their bony elements.

Morphometric analysis. We recorded six measurements of the tibia and fibula of USNM PAL 706597 using a digital caliper with an accuracy of 0.1 mm (Tab. 1). We also recorded the greatest length and the transverse diameter of shaft at the narrowest point of the tibia of extant and extinct pinniped taxa were measured (Tab. S1).

Collection permits. No permits were associated with the collection of this specimen because none existed at the time. Instead, the fossil collection during this expedition was authorized *de facto* by the presence of Chilean authorities (*i.e.*, Chilean Navy). USNM PAL 706597 was donated by W. Zinsmeister to the National Museum of Natural History, Smithsonian Institution.

SYSTEMATIC PALEONTOLOGY

MAMMALIA Linnaeus, 1758 *sensu* Rowe, 2020
CARNIVORA Bowdich, 1821 *sensu* Hassanin *et al.*, 2021
PINNIPEDIA Illiger, 1811 *sensu* Wolsan & Sato, 2020
PHOCIDAE Gray, 1821 *sensu* Berta & Wyss, 1994
MONACHINAE Gray, 1869

MONACHINAE INDET.
Figure 2

Locality. USNM PAL 706597 was collected on Guafo Island, located about 125 km southwest of Chiloé Island, in Los Lagos Region, southern Chile (Fig. 1).

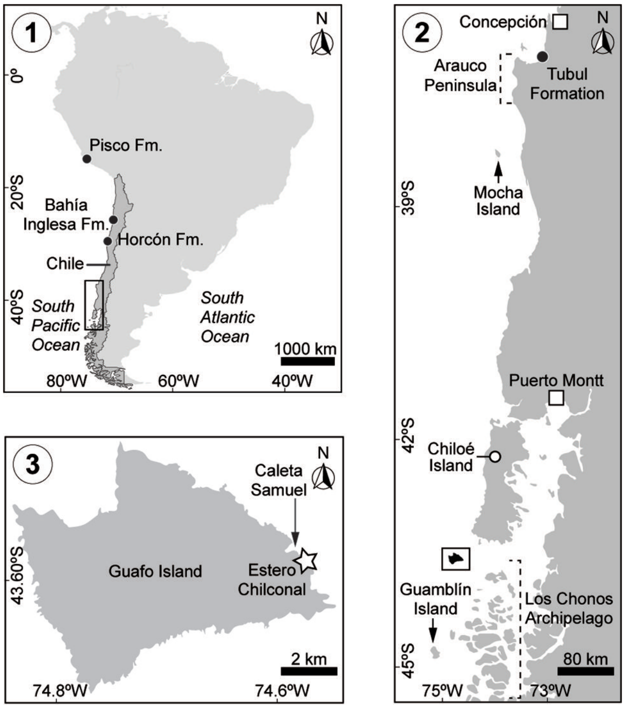

Figure 1. Geographic origin of Monachinae gen. et. sp. indet. (USNM PAL 706597). 1, map of South America showing the area in which USNM PAL 706597 was found (indicated by rectangle) and the location of fossiliferous localities in the southeastern South America where Neogene remains of fossil pinnipeds have been reported in the continent (indicated by black dots); 2, detail of the Arauco Peninsula, Chiloé Island, the Los Chonos Archipelago, and the Guafo Island (indicated by rectangle) in Los Lagos Region, southern Chile; 3, detail of Guafo Island; star indicates the area in which USNM PAL 706597 was collected according to original fieldnotes.

Formation and Age. Fieldnotes indicate that USNM PAL 706597 (Zinsmeister field number 656) derived from a wave-cut marine platform comprising Plio–Pleistocene sediments near Estero Chilconal on the east side of Guafo Island, and it was "dragged off a beach bench at low tide." The geology of Guafo Island has been characterized as entirely composed of gray siltstones and yellowish sandstones and siltstones with an abundant fossil invertebrate fauna (*e.g.*, bivalves, gastropods, brachiopods, echinoderms, and crustaceans) largely exposed in the eastern, near Caleta Samuel, and southeastern sides of the island, near Estero Chilconal (Frassinetti, 1997, 2000; Griffin & Nielsen, 2008). Field notes indicate that the original rock unit in which USNM PAL 706597 was found was broadly coquina-like with abundant remains of gastropods belonging to the genus *Turritella* Lamarck, 1799 (*i.e.*, *Incatella chilensis* Sowerby, 1846), which are evident in the consolidated coquina of the rock matrix in which the specimen is embedded (Fig. 2.1).

Previously, the age of the fossil fauna from Guafo Island was assigned to the Late Pliocene based on the presence of bivalve and gastropod species shared with the Late Pliocene

Horcón Formation of central Chile, the Tubul Formation near Concepción, and unnamed Pliocene strata at Mocha Island. The latter two deposits are located at ~850 km north of Guafo Island, near the Arauco Peninsula (Fig. 1) (Tavera Jerez & Veyl, 1957; Biró-Bagóczky, 1979). Bivalve and gastropod species are also shared with strata on Guamblín Island, located ~140 km south Guafo Island, adjacent to the Los Chonos Archipelago (Frassinetti, 1997, 2000). However, the presence of *Turritella chilensis* Sowerby, 1846 (= *I. chilensis* according to DeVries, 2007) and bivalves, such as indeterminate *Panopea* Ménard de la Groye, 1807, and *Chorus doliaris* Philippi, 1887 at Guafo Island (Nielsen & Valdovinos, 2008) broadens our age assignment and suggests a Late Miocene to Early Pliocene age for USNM PAL 706597, based on the presence of these taxa in coeval deposits from southern Peru and northern Chile (de Muizon & DeVries, 1985; DeVries, 1997). Nevertheless, more recent studies have emphasized that this faunal mixture encompassing species from the Miocene, Pliocene, and even the Early Pleistocene (*i.e.*, from localities of the Tubul Formation and at Guamblín Island) might result from the downslope transport of Late Miocene strata and their re-deposition into younger sediments (Nielsen & Valdovinos, 2008). Indeed, similar processes have been established for other Mio–Pliocene marine deposits in the south of Chile, including the Navidad, Ranquil, and Lacuí formations (Finger *et al.*, 2007; Schwarzhans & Nielsen, 2021; but see Gutiérrez *et al.*, 2013, and Finger *et al.*, 2013). Yet, in the absence of more precise dating, we argue for a broad Late Miocene–Pliocene age for USNM PAL 706597.

DESCRIPTION

Tibia and fibula

USNM PAL 706597 includes a left tibia and fibula embedded in consolidated matrix (Fig. 2.1–2.2), which exposes their posteromedial surface, and a reduced section of the proximal articular surface and part of the distal end. The tibia and fibula are longitudinally elongated. The maximum length of the tibia is 216 mm (Tab. 1); however, it is missing its distalmost section, and the distal condyle could not be observed. The proximal portion of the tibia and fibula are incompletely preserved and partially covered by epoxy glue. Nevertheless, the lateral and the medial-most portion of the medial epicondyles are present, and their position suggests that both epicondyles are aligned forming a straight and horizontal tibial plateau. The lateral epicondyle is rounded in shape and is slightly excavated. The medial-most portion of the medial epicondyle is preserved, and it is semilunar in shape.

The medial and lateral epicondyles are separated by a deep, round, and relatively narrow depression. The medial and distal sections of the tibial and fibular shaft are nearly complete. The narrowest transverse section of the tibia measures 32 mm (representing ~12% of the maximum length of the tibia) giving a relatively robust overall aspect to the tibia. The post-tibial fossa is delimited by the lateral and medial margins of the tibia and fibula, respectively. This fossa is deep and anteroposteriorly elongated, extending over more than half of the diaphysis of the tibia, corresponding to the insertion area of the *tibialis caudalis*. Moreover, the separation between the lateral and medial margins of the tibia and fibula, respectively, is broad and sickle-shaped,

TABLE 1. Measurements USNM PAL 706597 in cm.

Greatest length tibia	21.6
Greatest diameter of the shaft at the distal end of the tibia	3.9
Greatest diameter of the shaft at the proximal end of the tibia	4
Transverse diameter of the shaft at the narrowest point of the tibia	3.2
Greatest diameter of proximal epiphysis (medial and lateral epicondyle) of the tibia	4.2
Greatest length fibula	17.6[1]
[1]Incomplete measurement	

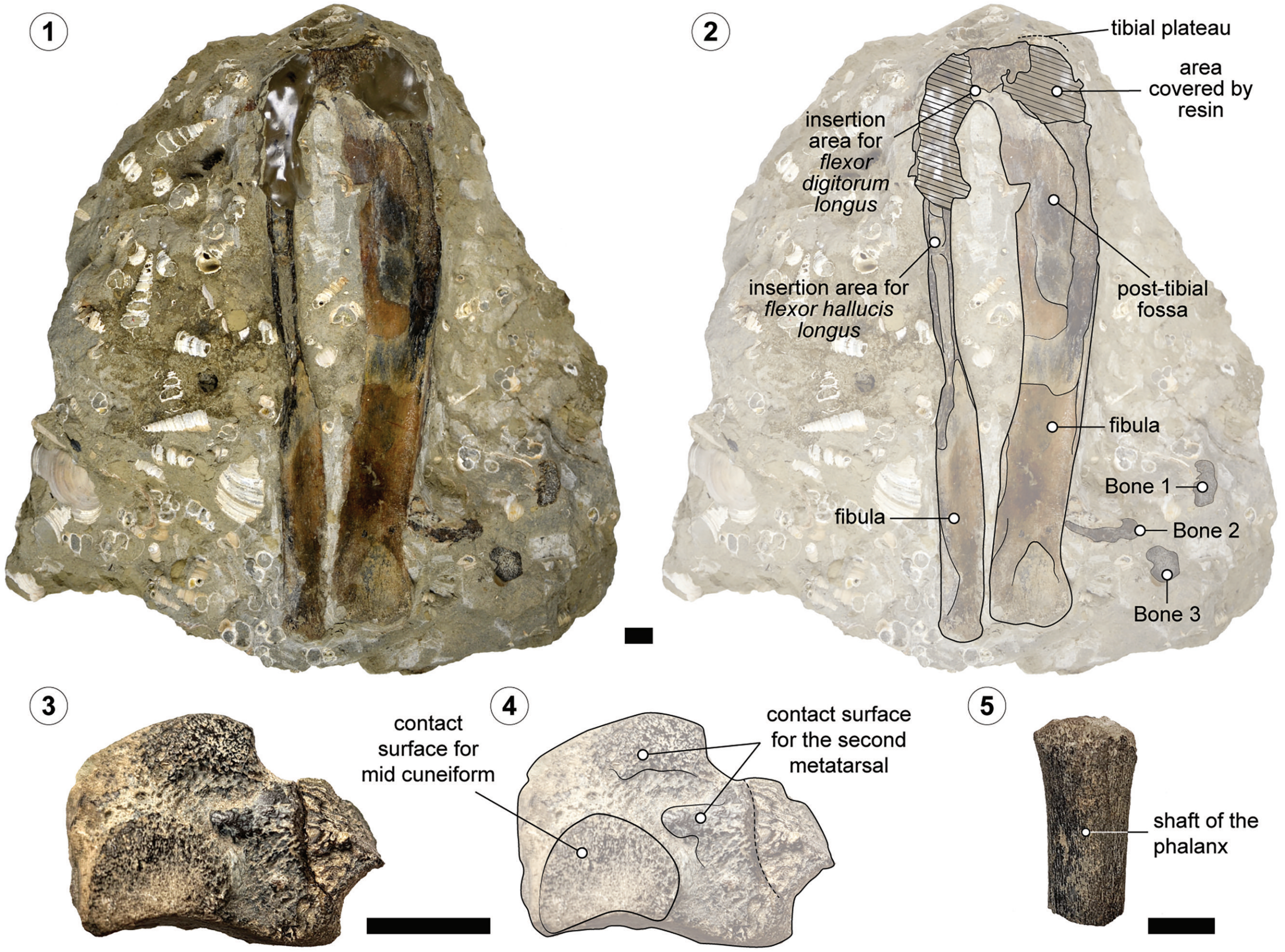

Figure 2. 1–2, lateral view of left tibia-fibula of Monachinae indet. (USNM PAL 706597); **3–4,** left ectocuneiform in medial view; **5,** phalanx in dorsal view. Scale bars equal 1 cm for 1 and 2, and 2 cm for 3, 4, and 5.

reaching ~24 mm at its broadest point. The medial margin of the distal section of the tibia is prominent suggesting an enlarged area for the attachment area of the *gracilis*, *semimembranosus*, and *semitendinosus*. The insertion area of the *popliteus* is not preserved; however, its base indicates that this area was well developed. While not completely preserved, the distal-most section of the tibia has a slight bulge in its fibular side. The area of insertion of the *flexor digitorum longus* in the distal portion of the tibia is partially preserved and suggests that the attachment area for this muscle was longitudinally oriented.

The diaphysis of the fibula is nearly straight. Its proximal fourth is missing; however, its second and third quarter display two semi-parallel and prominent ridges along its longitudinal axis, which correspond with the insertion area for the *flexor hallucis longus*. The distal half of the fibular shelf is lateromedially expanded and is slightly concave. Unfortunately, as occurred with the tibia, the fibula lacks its distalmost section including its distal condyle and their morphology could not be observed.

Ectocuneiform

An isolated element collected with the tibia and fibula corresponds to a complete left ectocuneiform (Fig. 2.3–2.4). The facet for the navicular on its proximal surface is anteroposteriorly elongated and concave. The plantar tuberosity is preserved and rectangular. The surface of contact for the cuboid consists of four facets, distributed in the edges of the bone, except for a conspicuous circular facet in the center point. Deep and irregular furrows separate these facets. The facet for the mesocuneiform in its medial surface is semicircular, convex, and occupies about half of the anteroposterior length of the ectocuneiform. The facet for the metatarsal II is partially worn; however, its base suggests that it has an oval shape. The anterior facet for the metatarsal III is ellipsoidal and convex. The dorsal surface displays some rugosities consistent with the insertions of the *flexor hallucis brevis* and the *tibialis caudalis*.

Phalanx

Another isolated element corresponds to the distal half of a phalanx, missing its epiphyseal region (Fig. 2.5). The diaphysis is oval in cross-section. Given its fragmentary nature, the side of this element could not be determined.

DISCUSSION

Taxonomic identification

We identify USNM PAL 706597 as a pinniped based on the longitudinal elongation of its tibia and fibula (Berta & Wyss, 1994). Nevertheless, USNM PAL 706597 is distinguished from odobenids by an overall smaller size despite indications of physical maturity, including the greatest length and diameter of the tibial shaft (Fig. 3 and Supplementary Fig. 1). Indeed, USNM PAL 706597 shares the size configuration of extinct monachine seals (*i.e.*, *Acrophoca* and *Piscophoca*) when the greatest length of the tibia and the transverse diameter of the shelf at the narrowest point are considered (Fig. 3). Odobenids (walruses) have a remarkably larger length and diameter of the tibial shaft than USNM PAL 706597, phocids, and otariids. Extant otariid species display high variability in the greatest length of the tibia; yet, they have a relatively narrower transverse diameter of the tibial shaft than USNM PAL 706597 and phocids except for small-sized harbor seals. Large body-sized otariids such as male Steller sea lions (*Eumetopias jubatus*) and California sea lions (*Zalophus californianus*) have a relatively wider transverse diameter of the tibial shaft (overlapping with the size range of some phocids). However, their greatest length is larger than those by USNM PAL 706597 and most extinct monachinae seals (*e.g.*, *Acrophoca*).

The semilunar separation between the lateral and medial margins of the tibia and fibula is consistent with the configuration displayed by phocid seals. It contrasts with the narrower and rectangular aspect of the post-tibial fossa by otariids (Howell, 1929). Further, the relatively robust overall aspect of the tibia mirrors the condition shown by extant and extinct monachine seals, distinguishing from phocine seals which tend to have a thinner and curved appearance.

The apparent alignment of the lateral and the medial epicondyle forming a straight and horizontal plateau resembles some extinct monachine seals such as *A. longirostris* and *P. pacifica*; this condition differs from otariids such as California sea lions (*Z. californianus*), in which the tibial plateau is canted and not perpendicular to the long axis of the tibia. The semilunar shape of the medial epicondyle of the tibia resembles the condition displayed by *Acrophoca*, in which the medial epicondyle has a noticeable notch, and

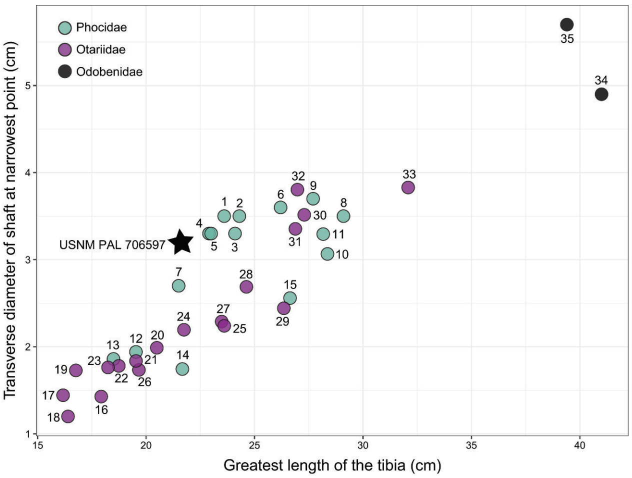

Figure 3. Plot of the greatest length of the tibia versus the transverse diameter of the tibial shaft at the narrowest point (in cm) of phocids (green), otariids (purple) and odobenids (black). Black star indicates USNM PAL 706597. Inset numbers: **1,** *Acrophoca longirostris* (USNM PAL 443495); **2,** *Piscophoca* sp. (USNM PAL 443891, left side); **3,** *Piscophoca* sp. (USNM PAL 443891, right size); **4,** *Piscophoca* sp. (USNM PAL 443898); **5,** *Piscophoca* sp. (USNM PAL 443899); **6,** Monachinae indet. (USNM PAL 205850); **7,** Phocidae indet. (USNM PAL 175578); **8,** *Erignathus barbatus* (USNM 307617); **9,** *Halichoerus grypus* (USNM 244346); **10,** female *Mirounga angustirostris* (CAS 1137); **11,** female *Mirounga angustirostris* (CAS 962); **12,** female *Phoca vitulina* (CAS 20852); **13,** female *Phoca vitulina* (CAS 21377); **14,** *Phoca vitulina* (UCSC ANTH 110911/2); **15,** female *Halichoerus grypus* (CAS 22571); **16,** female *Arctocephalus townsendi* (CAS 3000); **17,** female *Arctocephalus townsendi* (CAS 30876); **18,** female *Callorhinus ursinus* (CAS 2334); **19,** female *Zalophus californianus* (CAS 15262); **20,** female *Zalophus californianus* (CAS 15978); **21,** female *Zalophus californianus* (CAS 23000); **22,** female *Zalophus californianus* (CAS 21038); **23,** female *Zalophus californianus* (CAS 16608); **24,** male *Zalophus wollebaeki* (CAS 24363); **25,** male *Zalophus wollebaeki* (CAS 24364); **26,** male *Zalophus californianus* (CAS 15979); **27,** male *Zalophus californianus* (CAS 16607); **28,** *Zalophus californianus* (UCSC ANTH 11811/7); **29,** *Zalophus californianus* (UCSC ANTH 110811/05); **30,** female *Eumetopias jubatus* (CAS 22199); **31,** male *Eumetopias jubatus* (UCSC ANTH 11821/1); **32,** male *Eumetopias jubatus* (UCSC ANTH 11821/2); **33,** male *Eumetopias jubatus* (CAS 16245); **34,** Odobenidae indet. (USNM 335573); **35,** Odobenidae indet. (USNM 335514). Data in Supplementary Table 1.

subcircular outline in its lateral margin. Nevertheless, the semilunar shape of USNM PAL 706597 distinguishes from some extant Monachinae such as crabeater seals (*Lobodon carcinophagus*), Weddell seals (*Leptonychotes weddellii*), Ross seals (*Ommatophoca rossii*), Northern elephant seals (*Mirounga angustirostris*), and some otariids such as Steller sea lions (*E. jubatus*), Galapagos sea lions *(Zalophus wollebaeki*), and *Z. californianus*, in which the lateral margin of the medial epicondyle has a less conspicuous notch, conferring a subcircular aspect to this structure. Broadly, the deep, round, and relatively narrow depression between the medial and lateral epicondyles resembles the morphology of *Acrophoca* and living monachines such as *O. rossi*, *L. carcinophagus*, and *M. angustirostris*. While the insertion area for the *popliteus* is not preserved, its base suggests that it is well developed as in *Acrophoca* and *Piscophoca*, contrasting from extant monachine seals in which this area is less prominent (de Muizon, 1981). In addition, the distal-most section of the tibia has a slight bulge in its fibular side and the distal half of the fibular shelf is slightly concave resembling the condition displayed by *A. longirostris*.

Consequently, we identify USNM PAL 706597 as a pinniped based on the longitudinal elongation of its tibia and fibula. The broad and oval shape of the post-tibial fossa and the straight nature of the tibial plateau indicates that this specimen belongs to a Phocidae. Furthermore, the relatively robust aspect of the tibia in combination with its size proportions suggests that this specimen corresponds to a monachinae seal. Specifically, its preserved morphology is indistinguishable from *A. longirostris*; however, because of the absence of additional diagnostic features in the distal section of the tibia and fibula, we identify this specimen as Monachinae indet.

Phocid paleobiogeography along the western South American coastline

The pinniped fossil record from western South America is largely represented by findings from the Late Miocene and Early Pliocene of Pisco and Bahía Inglesa formations in southern Peru and northern Chile, respectively (Fig. 1.1; *e.g.*, de Muizon, 1981; Walsh & Naish, 2002; Valenzuela-Toro *et al.*, 2013, 2015; Amson & de Muizon, 2014; Pyenson *et al.*, 2014; Oyanadel-Urbina *et al.*, 2021). Specifically, the Bahía Inglesa Formation has yielded several remains of marine vertebrates, including phocids, cetaceans, aquatic sloths, sea birds, and fishes (Walsh & Naish, 2002; Walsh & Suárez, 2006; Pyenson *et al.*, 2014). Its depositional environment has been interpreted as a highly productive littoral to a sublittoral environment (Walsh & Hume, 2001; Walsh & Suarez, 2006) with temperate and warmer conditions than today (Oyanadel-Urbina *et al.*, 2021). In addition to the abundant remains from the Bahía Inglesa Formation, a few isolated pinniped records from the Late Pliocene Horcón Formation have been reported from central Chile (Benites-Palomino *et al.*, 2022). The faunal assemblage from the Horcón Formation suggests that this unit was deposited in an inner shelf environment and had warmer conditions than today (Chávez Hoffmeister *et al.*, 2014) mirroring the globally warm conditions during the Pliocene (see Ravelo *et al.*, 2006; Dekens *et al.*, 2007; Westerhold *et al.*, 2020).

While no direct paleoenvironment reconstructions for the Guafo Island exist, the fossil remains of the bivalve *Panopea* with their valves articulated and in life position (Frassinetti, 1997) suggest the prevalence of shallow marine settings for this unit. Paleoecological studies using foraminifera from the Pleistocene Tubul Formation and unnamed strata from Guamblín Island (Plio–Pleistocene) have revealed that these units had a nearshore open water depositional environment, with the predominance of cold-temperate surface waters and depths lower than 100 m (Biró-Bagóczky, 1979; Frassinetti & Covacevich, 1995; Frassinetti, 2000; Nielsen *et al.*, 2005). Although the species composition between these two units relative to those described in Guafo Islands differs, the substrate preferences of these groups is similar across units (Nielsen, 2015). These observations hint that comparable depositional conditions might have occurred at these three geological units, suggesting the prevalence of relatively stable cold environmental settings during the Mio–Pliocene, which likely extended until today. Therefore, the finding of USNM PAL 706597 from Guafo Island reveals that during the Neogene, seals inhabited temperate and subantarctic regions along the coast of the eastern South Pacific, suggesting a broad environmental tolerance resembling the habitat flexibility displayed by some pinniped species from the eastern North Pacific (Costa & Valenzuela-Toro, 2021).

Chilean Patagonia is currently recognized for having high marine productivity resulting from the convergence of the

Humboldt and the Cape Horn currents that transport subantarctic surface water into the western coast of South America and the southern Chilean fjords, respectively (Silva & Neshyba, 1979; Thiel *et al.*, 2007; Montecino & Lange, 2009; Strub *et al.*, 2019). Today, Guafo Island fosters essential breeding, foraging, and transit sites for several marine vertebrates, including seabirds such as sooty shearwaters (*Puffinus griseus* Gmelin, 1789), and Magellanic penguins (*Spheniscus magellanicus* Forster, 1781), among several others, and marine mammals such as South American fur seals (*Arctocephalus australis* Zimmermann, 1783) and South American sea lions (*Otaria flavescens* Shaw, 1800) (Reyes-Arriagada *et al.*, 2006, 2009; Pavés & Schlatter, 2008; Pavés *et al.*, 2016; Seguel *et al.*, 2017; Seguel & Pavés, 2018). Although increased sightings of Southern elephant seals (*Mirounga leonina* Linnaeus, 1758) have been documented in this island over the last decades (*e.g.*, Cárcamo *et al.*, 2019), no reproductive colonies have been reported in this area (Seguel & Pavés, 2018). Together, these observations imply that water temperature shifts alone might not have been the driving cause of the phocid depletion in the southeastern Pacific and suggest that other factors, such as widespread sea-level oscillations driving habitat loss during the Pliocene (Pimiento *et al.*, 2017), might have played a major contributing role in the occurrence of the pinniped turnover.

CONCLUSIONS

A new record of phocid postcranial remains (USNM PAL 706597) from Guafo Island extends the geographic range of the phocid fossil record in Chile by 1000 km and represents one of the most southerly occurrence records. The specimen diagnostically belongs to Phocidae and shows strong morphological similarity with Monachinae - a group extant today in the region, especially in the Southern Ocean. Its age likely corresponds to Late Miocene to Pliocene, based on associated invertebrates. The fossil mollusks found with the specimen, especially bivalves and gastropods, are taxonomically similar to those assemblages found nearby at other Miocene and Pliocene deposits on Patagonian outcrops near the Arauco Peninsula and the Los Chonos Archipelago, including those at Mocha Island (S. Nielsen, unpublished data), and more broadly with fossil invertebrates from sedimentary basins in central and northern Chile. This record of an extinct monachine seal from Guafo Island is consistent with a late Neogene turnover in pinniped fossil assemblages from a phocid-dominated to an otariid-dominated one. More geographic and temporal sampling will refine the scope of this turnover and possibly assist with finding mechanisms that have driven similar faunal turnovers in co-occurring marine taxa, such as seabirds and cetaceans.

ACKNOWLEDGMENTS

We thank W. Zinsmeister for collecting and donating the phocid specimen that formed the basis for this study. M. Flannery at the Ornithology and Mammalogy Department of the California Academy of Sciences, and R. Baldwin of the UCSC Anthropology Department provided access to the pinniped osteological collection. A. Guzmán assisted in data collection, and R. Otero with access to literature. We acknowledge N. D. Smith, G. P. Dietl, D. Chaney, C. A. Pierce, J. Nakano, and J. Stroman for aiding in the pursuit of the stakeholders associated with the donation of this specimen to USNM. J. Nakano, A. Millhouse, K. Klim assisted with accession and access of this specimen at USNM. Funding was provided by the University of California Santa Cruz Division of Physical and Biological Sciences, the Graduate Student Association, and the Ecology and Evolutionary Biology Department; the Peter Buck Predoctoral Fellowship of the National Museum of Natural History, Smithsonian Institution; the Society for Marine Mammalogy; and ANID PCHA/Becas Chile, Doctoral Fellowship, Grant No. 2016-72170286. We appreciate the detailed comments from the editor Sven Nielsen, as well as those from the production editors J. Echevarría and J. Bodnar, and reviewers R.W. Boessenecker and J. Rule, whose feedback improved this manuscript.

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doi: 10.5710/AMGH.06.07.2022.3498

Submitted: 15 February 2022

Accepted: 6 July 2022

Published: 15 September 2022