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Billfish foraging along the northern coast of Chile during the Middle Holocene (7400–5900 cal BP)

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ABSTRACT

Early maritime adaptation is well known from eastern South America; however, evidence for navigation and large marine fish exploitation, indicative of skilled foraging techniques, remains scarce. In the Atacama Desert, north central Chile, coastal archaeological sites show that during the Middle Holocene people relied mostly on marine resources. However, evidence from one of the shell middens (Zapatero – 7400–5900 cal BP) indicates that not only were shallow waters and marine mammals exploited, but that a dedicated fishery for large pelagic fish (mainly billfish) existed; with indications suggesting that large swordfish, weighing up to 300 kg, were being caught and brought back complete to the settlement. Although the peculiar topographic and oceanographic features of the area probably allowed pelagic fish to come well inshore, this is still the oldest evidence worldwide for such a fishery. These results provide new insights into maritime adaptation and seafaring along the Chilean coast from as early as the sixth millennium BCE.

1. Introduction

Fishing is an ancient activity among modern humans dating back at least 70 000 years (Henshilwood et al., 2001). However, despite growing evidence for the use of aquatic resources by Neanderthals in Europe (Richards et al., 2001; Brown et al., 2011; Hardy and Moncel, 2011), it is only from around 17 000 years ago (during the Magdalenian period) that fishing spears and gorge hooks become increasingly common in the archaeological record (Cleyet-Merle, 1990; Gramsch et al., 2013).

Along the Pacific coast of the Americas, the oldest testimonies of fishing practice date back 12 000 years on California's Channel Islands (Rick et al., 2001; Erlandson et al., 2011), and some 11 000 years in northern Chile (Llagostera, 1979, 1992). Evidence for fishing large pelagic fish is, however, scarce worldwide, and is barely mentioned at all in the literature. Crockford (1997) does, however, report that bluefin tuna were being harvested off the coast of British Columbia as far back as 5000 years ago, and indeed the first swordfish remains recovered from archaic sites boarding the Bay of Fundy, Gulf of Maine appear to be of a similar date (Bourque, 1995, 2012). Swordfish are also present from archaeological sites in the Channel Islands, California, though these date mainly from the Late Holocene (Bernard, 2004; Erlandson et al., 2009). There is no doubt that fishing regularly for large pelagic fish would have had strong implications for the fishermen's skills and abilities, especially concerning navigation and fishing tools (Acheson, 1981). Here, we report on the discovery of an important fishery of large pelagic fish, including striped marlin, swordfish, tuna and amberjack, dating from as early as the sixth millennium BCE along the north Chilean pacific coast. This is the oldest and first clear evidence for billfish foraging in western South America.

2. Environmental setting

The Atacama coastal desert is a cool, arid region lying in central-north Chile. It measures around 1000 km from north to south, west of the Andes, and stretches roughly between Iquique (20 S) and La Serena (30 S). The Andean foothills approach the coastline and there are little or no coastal plains. This is particularly the case in this study area, an area restricted to the vicinity and north of Taltal (~24–25°S).

Rain is scarce, and at the present time no permanent river, except the Loa River 250 km north of Antofagasta, brings fresh

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water to the sea. However, small springs of water are present in the foothills, which are thought to have always provided drinking water to the coastal inhabitants (Herrera and Custodio, 2014).

Sea bottom topography along this coast is characterized by an extremely narrow continental shelf of 10–20 km (Strub et al., 1998); at 30 km the bottom depth is approximately 1000 m.

For this latitude the sea temperature is rather cold (14–16 °C) due to the Humboldt Current driving Antarctic waters to the north, and the presence of local upwelling which also bring cool nutrient-rich waters to the surface (Thiel et al., 2007). This peculiar environment enables the Atacama coast to support an abundance of marine life.

Many of the species encountered along the Atacama coast are endemics from the warm-temperate south-eastern Pacific (WTSP) province (also called the Humboldt ecosystem) which stretches from Puerto Montt (40°30′S, Chile) to the peninsula Illescas (6°S, Peru). More specifically, the Taltal region represents the southernmost part of the Humboldtian ecoregion which extends from 12°S to 25°S (Spalding et al., 2007). Here the predominant small pelagic fish are the anchovy (*Engraulis ringens*), sardine (*Sardinops sagax*), and jack mackerel (*Trachurus murphyi*). The Taltal area is also renowned for its important and ancient small-scale fishery for red cusk eel, *Genypterus chilensis* (a benthic coastal fish) and its billfish (*Xiphias gladius* and *Kajikia audax*) fishery (Philippi, 1860, 1887; Gigoux, 1943). Recreational anglers once considered Tocopilla (22°S, Chile) as the best place in the world for big swordfish, and, indeed, the area between Coquimbo and Iquique is still the subject of intense harpoon billfishery. During austral summer and autumn, many small boats can be seen fishing, staying between 10 and 20 km from the coastline to pursue swordfish. Today, fish production in Taltal is concentrated on a few species: cusk eel, palm ruff (Seriolella violacea) and jack mackerel, specifically (Sernapesca, 2015).

3. Fish ecology and behavior

Reconstruction of fish procurement in the past relies heavily on our current knowledge of the biology, ecology, and ethology of the species represented in the archaeological context. This information helps us understand where, when, and how the fish were caught.

The jack mackerel is a medium sized schooling pelagic to oceanic fish which can be found at depths of up to 100 m. During the summer it comes closer to the shore, over the narrow continental platform, forming shoals often associated with its prey: sardine (*S. sagax*) and anchovy (*E. ringens*), and the stranding of these species has been known in the past centuries from northern Chile and southern Peru (Delfín, 1901: 42; Béarez, 2012). Due to its abundance, its capture along the shoreline was probably relatively straightforward using either nets or fishhooks.

The swordfish is a cosmopolitan species found in all warm and temperate oceans and seas. In the eastern Pacific its range extends from 50° north to 35° south. Its migration consists of movement toward temperate or cold waters for feeding in summer and back to warm waters in autumn for spawning and overwintering (Nakamura, 1985). It is generally considered an oceanic species although it is sometimes found in coastal waters, generally above the thermocline (Collette, 1995). Its preferred temperature range is from 18 to 22 °C; however, the species presents a higher tolerance to temperature variations than other billfish (Nakamura, 1985). In the Gulf of Maine, according to Bigelow and Schroeder (1953), females, much larger than the fully-grown males, are frequently encountered. The presence of swordfish was also recorded in Chile during the first naturalist work done by Molina (1782: 219). In contrast the striped marlin is restricted to the Indo-Pacific Ocean, specifically from 45° north to 30° south in the eastern Pacific (Nakamura, 1985). This oceanic species has been described by Philippi (1887) on the basis of a specimen from Iquique (20°S). Striped marlin, like other billfish, roam throughout the epipelagic zone and do not maintain a specific home range (Nakamura, 1985). Among marlins, it is probably the more tolerant to temperate waters, hence its frequency in the southeastern Pacific.

Swordfish frequently bask on the surface with their dorsal and caudal fins protruding from the water, making them susceptible to harpooners. The striped marlin is a faster swimming fish, but it also frequently comes near to the surface with only the caudal fin lobe protruding, so it is easily distinguishable from the swordfish (Philippi, 1887).

4. Archaeological context

The presence of human populations living on the Atacama coast date from the Early Holocene (Llagostera, 1992). These populations were probably associated with the Huentelauquén Cultural Complex (11 700–9500 cal BP) who settled along the coast at sites such La Chimba 13, El Obispo 1 and Los Médanos 2 (Llagostera et al., 2000; Castelleti et al., 2010; Salazar et al., 2013). This cultural complex is characterized mainly by a subsistence dependent on shellfish, shore fish (supplemented by sea lion and guanaco), and the presence of different forms of elaborate geometric sandstone artifacts (Llagostera et al., 2000; Llagostera, 2005). Their middens are composed of a variable density of shells: abalone (*Concholepas concholepas*), limpets (*Fissurella* spp.), and chitons (Polyplacophora).

During the Middle Holocene, new technological traditions emerged along the Atacama coast. Bird (1946) named it the 'Shell-Fishhook culture' due to its characteristic artifacts made of giant mussels, *Choromytilus chorus*. North of our study area this "culture" is related to the Chinchorro funerary tradition, renowned for having the oldest artificial mummification in the world (Marquet et al., 2012). In Taltal, no burials from this period are yet known, but archaeological sites show the appearance of specialized artifacts to capture and process coastal and marine resources: shell openers; fishhooks of different sizes, shapes and raw materials; fishing weights; projectile points; harpoons with bone barbs; fishing lures; and bags made of plant fibers, amongst others. No direct evidence of boat use exists during the archaic period in Chile. The oldest concrete evidence comes from a group of burial mounds at the mouth of the Loa River, dated around 215 AD, where a miniature reed raft model was discovered (Núñez-Atencio, 1986). Further indirect evidence, from the same period, comes from the remains of deep-water cusk-eels (*Genypterus* spp.) at the Punta Blanca site, just south of Tocopilla, that Llagostera (1990) associated to the use of rafts.

Communities increased in size during the Middle Holocene, as evidenced by the marked increase in the quantity and size of archaeological sites. Stratigraphic and contextual data suggests most of them were residential sites occupied in a semi-sedentary pattern. Faunal data indicates continuity in subsistence patterns from the start of the Middle Holocene. However, local diet did diversify during the Middle Holocene to include new species, focalizing on the abundant resources of high energy yields and relatively low cost procurement of the jack mackerel and sea lion, specifically.

5. Materials and methods

The fish remains were recovered during the excavation of an archaeological coastal site in northern Chile called Zapatero (Fig. 1). Situated some 50 km from the city of Taltal, just north of Paposo, the Zapatero site (24°55′42″S–70°30′58″W) was excavated during recent investigations along the coast of Taltal in 2012 (Fondecyt project 1110196).

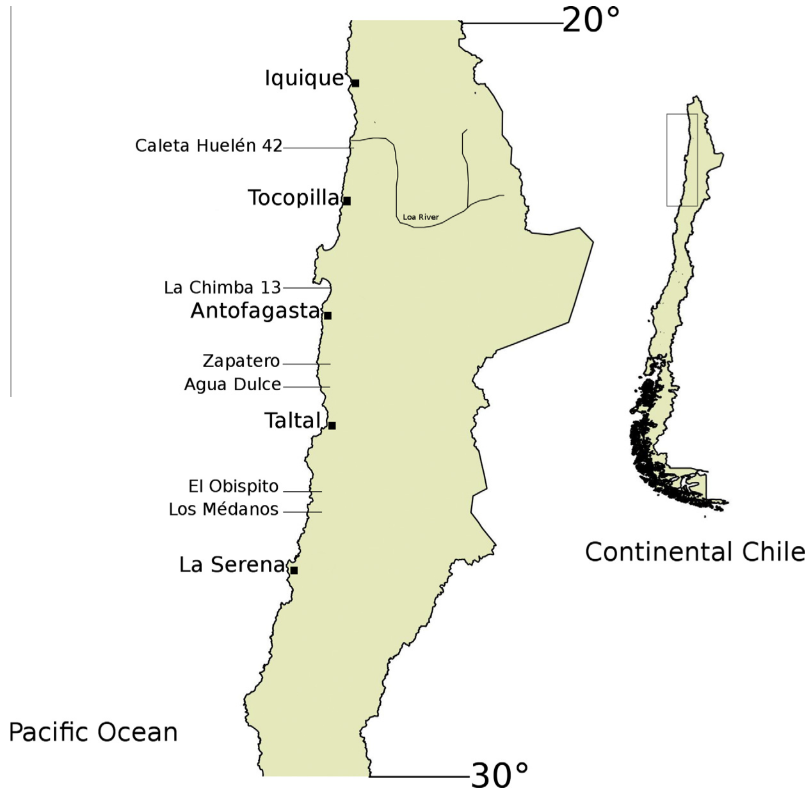

Fig. 1. Study area showing the main places cited in the text.

Fig. 2. Coastal environment at Zapatero shell midden and location of the Unit 1 excavation.

The Zapatero site is a shell midden of at least 6000 m^2. Though originally it occupied an even larger area, it has been severely affected by diverse processes or erosion, including torrential rain and probable marine transgressions during the Late Holocene. Dense hearths are intersected with thick middens containing abundant seashells, fish bones, marine and terrestrial mammals, lithic debris, and bone, stone, and shell artifacts, attesting to the cultural origins of the deposit. After a semi-sedentary residential occupation of the site (Salazar et al., in press), at around 5500 cal BP stone habitation structures appear in different areas of the site, also associated with dense refuse and artifacts.

The excavation took place at the top of Zapatero shell midden (Fig. 2), at an altitude of 18 m.a.s.l. The Unit 1, a 2×2 m unit was excavated stratigraphically, using 10 cm levels within strata. A 220 cm deep sequence was encountered, divided into 13 layers and 23 levels. Four radiocarbon dates were obtained from charcoal samples (Table 1) placing the identified cultural sequence during the Middle Holocene between 7400 and 5900 cal BP.

All sediments were dry-sieved in the field over 3 mm mesh, and faunal remains were directly sorted into shells, fish, and tetrapod classes. All recovered faunal remains were then transported to the anthropology laboratory of the Universidad de Chile, Santiago. Some of the fish remains were exported to the Muséum national d'histoire naturelle (MNHN) in Paris for fine grain taxonomic identification.

All bones and otoliths susceptible to be identified were used. Identification was performed to the lowest taxon identifiable, most often to species level. All fish bones and otoliths were quantified using NISP (number of identified specimens), MNI (minimum number of individuals), and weight measures (to the nearest 0.01 g). MNI were estimated based on symmetry and size for

Table 1
Radiocarbon dates from Zapatero Unit 1 excavation (calibration curve: SHCal 04).

Context	^{14}C yr BP	Cal yr BP (2σ)	Sample	Lab. no.
Zapatero, Unit 1, Layer 4, Level 5	5230 ± 25	5901–5996	Charcoal	UGAMS-18076
Zapatero, Unit 1, Layer 7, Level 12	5810 ± 30	6477–6661	Charcoal	Beta-333511
Zapatero, Unit 1, Layer 10, Level 20	6490 ± 40	7276–7430	Charcoal	Beta-333512
Zapatero, Unit 1, Layer 12, Level 22	6180 ± 25	6943–7159	Charcoal	UGAMS-18075

paired specimens, and calculated by square meter and level. Estimations of size and total fresh weight were done by comparison with specimens from the project and MNHN fish bone reference collections. Billfish bone identification greatly beneficiated from the consultation of the publications of Conrad (1937), Gregory and Conrad (1937), Nakamura (1983), and Davie (1990).

Complete skeletons of large pelagic fish are rare in osteological collections: for *X. gladius*, we used a 7.7 kg and 1.325 m fork length (FL) specimen from Ecuador; for *K. audax*, a 43 kg and 2.210 m FL specimen from Ecuador. In order to improve our capacity of size estimation for swordfish, two partial skeletons (few vertebrae) of this species were collected at fish markets: one in Taltal (dressed weight ca. 85 kg) and one in Antofagasta (DWT ca. 285 kg). These dressed weights (DWT: gilled, gutted, part of head off, fins off) were converted into round weights (RWT: total live weight) using the relationship given by Miyake (1990): RWT = 1.33 DWT. The RWT obtained are 113 and 379 kg respectively. This latter specimen would correspond to a 3 m LJFL swordfish (i.e. measured from the lower jaw tip to the fork of the tail).

Chondrichthyes, or cartilaginous fish, are difficult to identify on the basis of their vertebrae morphology, the same with determining the vertebral rank and size along the rachis. Therefore, in most cases, specific level identification, size estimation, and MNI calculations were not performed for this taxonomic group.

Since the excavation of Unit 1 produced an excessive amount of fish remains, the results presented here are based on approximately half their total amount (i.e. the material from square meters A2 and B1). Study of shells and tetrapods is still underway but it is worth noting the dominance of rocky habitat gastropods like *C. concholepas* and *Fissurella* spp. (Olguín-Olate, 2013) and the presence of sea turtles, dolphins or porpoises, sea lions, and some camelids (PB, pers. obs.).

Following Hewes (1948) we here define "fishing" as that category of human activity devoted to the capture or gathering of aquatic animals. This definition lumps together fish, sea turtles, and sea mammals as objects of fishing.

Terminology concerning coastal domain exploitation is still unsatisfactory despite an attempt at clarification by Pickard and Bonsall (2004). Water depth is a key parameter that needs to be considered, and we propose the use of the following definitions: inshore fishing is practiced in the coastal or littoral zone, down to 30 m depth; offshore fishing is practiced in deeper water but within sight of land (<5 km); finally, open sea fishing is practiced out of sight of land.

6. Results

Across the entire sequence excavated at Zapatero, fish remains clearly predominate. All came from cultural layers representing in situ hearths and/or primary and secondary refuse areas within the site. The two square meters studied provided numerous fish bones, both cranial and vertebral. Otoliths (fish inner ear biominerals) were present but rare. From a total of 21 730, 17 560 (81%) could be identified to at least family level, but most often to genus or species level. The identified fish remains comprised a total weight of 19.1 kg: 78% of the overall weight (Table 2). This notably high identification ratio was partly due to the abundance of one species: the jack mackerel (which possesses several readily identifiable hyperostotic bones) and to the typical bones of billfish (Fig. 3). On the other hand, it is worth noting that many large fragments of vertebral spines, pterygiophores, fin rays and unidentified parts, which belonged to either swordfish or marlin, were classified as unidentified as it was difficult to attribute them specifically. This explains why the weight of unidentified teleosts is especially high (Table 2).

Almost all the identified taxa were bony fish belonging to 19 families, and 26 genera and species, as most genera are monospecific in the area (Table 2; Table 3). For cartilaginous fish, only three families were recognized with certainty at Zapatero: Triakidae, Carcharhinidae and Lamnidae (*Isurus oxyrinchus*).

The jack mackerel *T. murphyi*, a teleost species, represents 86.5% of the fish remains identified, and 86.9% of the corresponding bone weight (Table 2). Other notable species (>1% NISP or bone weight) were: snoek (6.9% NISP), cusk eels (1.9% NISP), bonito (1.7% NISP), striped marlin (3.9% bone weight), and swordfish (1.9% bone weight); all of which, except the bentho-demersal cusk eels, can be classed as medium to large size pelagic fish. By grouping all the families into two large ecological categories, pelagic fish and bentho-demersal fish, it appeared that pelagics made up 97% of the total NISP.

The combined medium sized species (jack mackerel, snoek, bonito, skipjack, palm ruff) made up 95.2% (NISP) and 91.5% of the bone weight. The large species (swordfish, marlin, tuna, amberjack, pelagic sharks) represented 1.8% of NISP and 6.8% of the bone weight. Small pelagic fish were almost entirely absent from the assemblage, except for a few specimens of menhaden (0.04% NISP). Typical Humboldt ecosystem coastal rockfish (e.g. serranids, labrids, sebastids, cheilodactylids) were also poorly represented accounting for just 3% of the overall NISP; with almost 2% of that figure being the cusk-eel, an abundant demersal fish in the area.

Fish remains were present in all excavated layers of Zapatero, with layer 6 providing the richest sequence for almost all the important species (Table 2). Jack mackerel was well represented with 5690 remains in this layer (37% of the total NISP for the species), while striped marlin was represented by 47 remains (48% of total marlin NISP). Among other important species only snoek (*Thyrsites atun*) was more frequent in layer 4, the second most important layer for jack mackerel and striped marlin.

The overwhelming proportion of jack mackerel, however, needs to be mitigated. Its hyperostotic bones (e.g. supraoccipital crest, opercula, caudal vertebrae) definitely favor the preservation and identification of its remains (Meléndez et al., 1992; Béarez, 1997). The medium size specimens of jack mackerel were roughly estimated to around 42 cm SL (standard length) and 1 kg. If we calculate the biomass of the jack mackerel by multiplying the average weight by the MNI we obtain 2140 kg of fresh fish. The individual size of the billfish was much more difficult to evaluate since several very large specimens of swordfish, that were present in the assemblage, were much bigger than our reference collection specimen. Both billfish were represented mainly by their vertebral remains, along with some broken pieces of flattened rostrum, in the case of the swordfish, and several predentary bones (5), in the case of the marlin. However, based on the reference collection and the extra vertebrae obtained at fish markets from the study area, ranges and mean weight could be roughly estimated. The weight of the striped marlin ranged between 15 and 100 kg, with a large majority of them weighing over 50 kg, a conservative mean was around 65 kg. The largest swordfish precaudal vertebra was compared with the same rank precaudal vertebra of the ≈380 kg specimen and their sizes were strikingly similar (Fig. 4). In order not to exaggerate the maximum size of the archaeological specimens, we considered that the weight of the swordfish ranged between 50 and 300 kg. All specimens probably weighed over 50 kg, with a conservative mean of 150 kg. Therefore, if we calculate the biomass for the two billfish, we obtain 2015 kg (65×31) for the striped marlin, and 1650 kg (150×11) for the swordfish. This would mean that billfish contributed far more than jack mackerel to the diet, at least during the period in which their remains are more abundant in the Zapatero shell midden (i.e. around 6000–6500 cal BP).

Along with billfish, other large pelagic fish were also recognized: shark, tuna, and amberjack. Shark and ray vertebrae are difficult to

Table 2
Fish remains identified from different layers at Zapatero: NISP, MNI, weight in grams, and respective percentages.

Taxon	Layer/NISP															MNI		Weight	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	Total	%	Total	%	Total	%
Trachurus murphyi (jack mackerel)	4	159	1408	3179	1371	5690	671	336	343	1417	454	161	3	15,196	86.54	2140	86.22	16596.09	86.90
Thyrsites atun (snoek)		20	121	595	59	33	9	2	10	213	103	54	1	1220	6.95	84	3.38	728.30	3.81
Genypterus spp. (cusk-eel)		6	40	29	12	140	16	9	6	58	23	1		340	1.94	40	1.61	229.02	1.20
Sarda chiliensis (bonito)			8	16	8	216	7	34	1	4		1		295	1.68	26	1.05	138.90	0.73
Chondrichthyes (shark)		6	52	18	7	34	8	13	7	6	11	3		165	0.94			113.98	0.60
Kajikia audax (striped marlin)			4	20	3	47	17	6	1					98	0.56	31	1.25	741.33	3.88
Semicossyphus darwini (sheephead)		4	1	4	2	23	2	3		4	7			50	0.28	18	0.73	69.17	0.36
Cilus gilberti (corvina drum)	1	2	3	7	5	21	2	2	1		2	1		47	0.27	36	1.45	18.40	0.10
Sebastes oculatus (rockfish)			4	8	4	16	3			2				37	0.21	23	0.93	8.16	0.04
Seriola lalandi (amberjack)			1	1	1	11	6			4				24	0.14	21	0.85	70.42	0.37
Xiphias gladius (swordfish)				2		8	11		2					23	0.13	11	0.44	356.52	1.87
Sciaena deliciosa (lorna drum)		1	2	6		2	1			1	1	1		15	0.09	13	0.52	2.15	0.01
Paralichthys adspersus (flounder)				4	1	1				1				7	0.04	6	0.24	4.20	0.02
Ethmidium maculatum (menhaden)						1					6			7	0.04	2	0.08	2.00	0.01
Paralabrax humeralis (rock seabass)				2		3				1				6	0.03	6	0.24	2.30	0.01
Katsuwonus pelamis (skipjack tuna)				3		3								6	0.03	5	0.20	1.12	0.01
Isacia conceptionis (cabinza grunt)				2		1	1				1			5	0.03	4	0.16	0.74	0.00
Pinguipes chilensis (sandperch)				1		1				1				3	0.02	3	0.12	1.50	0.01
Thunnus sp. (tuna)				1			1							2	0.01	2	0.08	9.65	0.05
Seriolella violacea (palm ruff)				1		1								2	0.01	2	0.08	1.50	0.01
Aplodactylus punctatus (marblefish)				1			1							2	0.01	2	0.08	0.70	0.00
Cheilodactylus variegatus (morwong)						1				1				2	0.01	2	0.08	0.50	0.00
Hemilutjanus macrophthalmos (seabass)				2										2	0.01	1	0.04	1.30	0.01
Bovichtus chilensis (thornfish)							2							2	0.01	1	0.04	0.20	0.00
Girella laevifrons (sea chub)						2								2	0.01	1	0.04	0.20	0.00
Graus nigra (sea chub)												1		1	0.01	1	0.04	0.40	0.00
Cheilotrema fasciatum (croaker)				1										1	0.01	1	0.04	0.10	0.00
Total NISP	5	198	1644	3903	1473	6255	758	405	371	1713	608	223	4	17,560		2482		19098.85	
Unidentified teleosts	1	133	569	412	152	1691	489	36	162	210	256	59		4170				5360.91	
Grand total	6	331	2213	4315	1625	7946	1247	441	533	1923	864	282	4	21,730				24459.76	
Identification ratio														80.81%				78.08%	

Fig. 3. Typical remains of swordfish (A–C) and striped marlin (D–G). (A) Fragment of rostrum; (B and C) dorsal and anterior view of a caudal vertebra (59.6 mm diameter); (D) predentary; (E) precaudal vertebra; (F) penultimate caudal vertebra; (G) hypural plate. Scale bar = 1 cm.

identify to species level and to attribute an accurate size, so they were all grouped in the higher taxon Chondrichthyes. Most of them were houndsharks (Triakidae) but, apart from these coastal benthic species, there were at least two specimens of shortfin mako (Lamnidae: *I. oxyrinchus*) present. Tuna, likely yellowfin (*Thunnus albacares*), or bigeye (*T. obesus*), were represented by two caudal vertebrae: one from a ca. 25 kg specimen and the other from a ca. 40 kg specimen. The most predominant fish, however, was the yellowtail amberjack (*Seriola lalandi*) with 21 individuals ranging from 8 to 20 kg.

No cut-marks were observed in the fish assemblage, though many fish bones were partially burnt. Interestingly, one marlin vertebra showed a clear perforation (Fig. 5) which predates the excavation process, and which might correspond to damage caused during its capture (e.g. spearing).

7. Discussion

7.1. Billfish archaeology

Although the swordfish is now established worldwide, its presence has been seldom recorded in prehistoric archaeological sites. In European contexts swordfish are extremely rare; with only one citation in Mesolithic Denmark (Enghoff et al., 2007) and one in the Neolithic French Mediterranean (Poplin, 1975). In Asia, prehistoric billfish are also rare and are known only from Taiwan (Li, 2002), the Marianas Islands (Leach et al., 1988), and Japan (Kaneko et al., 1958 cited in Ueyanagi, 1974). This latter evidence dates back 3–4000 years ago, during the Jomon period, and contains the vertebrae and rostrum of both striped marlin and swordfish. The strongest evidence for billfish remains, therefore, are those reported from several North American archaeological sites, particularly in the Gulf of Maine and along the California coast.

Swordfish are common from archaic period sites along the Gulf of Maine coast (e.g. the Turner Farm site), with evidence from the Small Stemmed Point tradition around 5000 BP, and during the Moorehead phase until 3800 BP (Spiess and Lewis, 2001; Sanger, 2009; Bourque, 2012). These studies indicate that swordfish was a significant part of the diet, and that they were entering the Gulf of Maine and coming inshore. In California, both species have already been identified from several middens, (e.g. Ventura 63 site; Van Slyke, 1998), although only from more recent contexts. On the Channel Islands, swordfish occurs generally at a lower density, during the last 1500 years (Davenport et al., 1993; Erlandson

Table 3
Distribution into families of the identified fish remains (NISP and bone weight) of site Zapatero.

Taxa	NISP	% Total ID	Bone weight (g)	% Total ID
Carangidae	15,220	86.67	16666.51	87.26
Gempylidae	1220	6.95	728.3	3.81
Ophidiidae	340	1.94	229.02	1.20
Scombridae	303	1.73	149.67	0.78
Chondrichthyes (shark)	165	0.94	113.98	0.60
Istiophoridae	98	0.56	741.33	3.88
Sciaenidae	63	0.36	20.65	0.11
Labridae	50	0.28	69.17	0.36
Sebastidae	37	0.21	8.16	0.04
Xiphiidae	23	0.13	356.52	1.87
Serranidae	8	0.05	3.6	0.02
Paralichthyidae	7	0.04	4.2	0.02
Clupeidae	7	0.04	2	0.01
Haemulidae	5	0.03	0.74	0.00
Pinguipedidae	3	0.02	1.5	0.01
Kyphosidae	3	0.02	0.6	0.00
Centrolophidae	2	0.01	1.5	0.01
Aplodactylidae	2	0.01	0.7	0.00
Cheilodactylidae	2	0.01	0.5	0.00
Bovichtidae	2	0.01	0.2	0.00
Total ID	17,560		19098.85	
Teleostei UID	4170		5360.91	
Grand total	21,730		24459.76	

Fig. 4. Comparison between modern (dorsoventral posterior diameter = 54.4 mm) and archaeological (dorsoventral posterior diameter = 54.7 mm) swordfish vertebrae of the same rank. Scale bar = 1 cm.

et al., 2009), though it became increasingly important to the Chumash people (Bernard, 2004).

The first mentions of swordfish remains from the coastal archaeological middens of Chile are by Bird (1943) and, less substantially, Oliver-Schneider (1943) and Zlatar-Montan (1987). The former mentions this species without any detail from Punta Pichalo (19°36′S): a preceramic site with obvious maritime orientations (Bird, 1943: 273). Oliver-Schneider (1943: 101) reports frequent findings of the rostral remains of this species in the Indian cemeteries of the Gulf of Arauco (∼37°S), of unknown chronological period but evidently more recent. Zlatar-Montan (1987) observed a single piece of swordfish rostrum among the fish assemblage of the Caleta Huelén 42 site, located on the mouth of the Loa River, and dated it to the Late Archaic period (4500 cal BP). More recently, low numbers of swordfish remains have been recovered from two Middle Holocene sites, Punta Negra-1 (Contreras et al., 2011) and Agua Dulce (Olguín et al., 2014). The Agua Dulce site (25°15′46″S–70°26′31″W) is located some 40 km south of Zapatero, and was radiocarbon dated between 6800 and 6200 cal BP. As far as we know, however, no mention of archaeological remains of striped marlin exists in the Chilean record.

Billfish were present in Zapatero layers 9 to 3, dated between 7400 and 5900 cal BP, but predominantly in layer 6. No evidence exists of swordfish beaching themselves, or dying at sea and then drifting ashore (Sanger, 2009: 8), hence the abundance of billfish at Zapatero, both in terms of MNI and biomass, excludes the occasional capture of some stranded individuals. Considering that the processing of billfish, due to their extremely large body size, might produce wide spatial dispersion of skeletal remains, calculations of MNI by layer for the two square meters studied would give lower values for both swordfish and marlin (5 and 9, respectively). However, these values are still high if we consider that billfish remains were also present in the other two square meters of the excavation. The only explanation is that they had a dedicated and systematic fishery, with the fishermen of Zapatero having to navigate offshore in order to reach them. The big question is: how far did they need to go? Several elements might indicate that it was not necessary to stray far from the coastline, and that the fishermen probably sighted the fish from, or near, the shore. Firstly, swordfish usually migrate from open waters toward the continental shelf in summer when the coastal waters warm up, as do the many small pelagic fish (i.e. sardines, jack mackerels) or squids on which they prey. Secondly, billfish generally bask on the surface, their protruding dorsal and caudal fins making them visible from a distance of at least several hundred meters, to a practiced eye. In addition, they can also jump clear of the water, making them even more obvious. Thirdly, the presence of ancient billfishing off the Atacama coast could be intrinsically linked with the oceanological characteristics of the area. The continental shelf in front of the Atacama coast is particularly narrow and the seabed steeply sloped, an important feature in understanding why large pelagic fish venture close to shore. A famous example is the harpoon swordfishery in the Strait of Messina, which has a minimum width of 3 km and a sill depth of only 120 m. This coastal fishery has been in use since at least historical times, and is well described by Polybius (ca. 203–120 BC). He noted the use of a harpoon with a barbed and detachable head, and the presence of a look-out man on the hill who indicated the presence and position of the fish to the fishermen in the boat. Other citations, which refer to the eastern Pacific coast, also point out the coastal behavior of billfish. Around the Channel Islands, California, Grey (1919: 45) commented that "There are kelp-beds along the shore, and the combination of deep water, kelp, and small fish is what holds the swordfish there in August and September". In Chile, Farrington (1953: 8), a big-game fisherman, quoted "When fishing out of Iquique you always have the mountains back of the port in view, and it is a simple matter to find the way to and from the harbor".

At Zapatero, we believe that both billfish species could be caught fairly close to shore, especially considering that by 7000 cal BP these big fish were probably found much closer to shore than they are today. Moreover, to navigate in the open sea, out of sight of land, necessitates specific knowledge of orientation and great tenacity. The Chile Coastal Current which flows northward, parallel to the coastline, is often strong, reaching its peak in autumn (Thiel et al., 2007). This makes it extremely difficult for a boat to remain close to its starting point. In addition, the capture of large and heavy fish, in these conditions, would necessitate

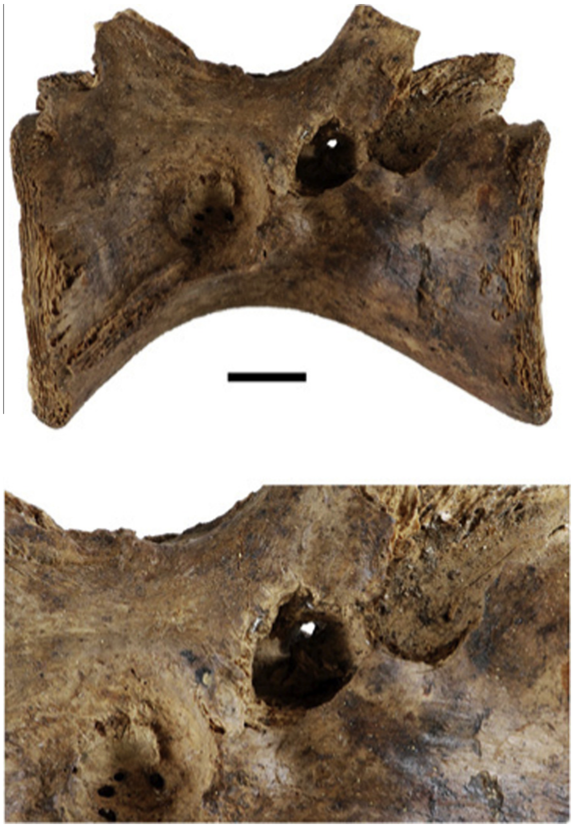

Fig. 5. Perforated striped marlin precaudal vertebra. Scale bar = 1 cm.

Fig. 6. Lithic projectile point recovered at Zapatero, with a sketch of how it could have been used to fit a detachable head of a harpoon designed for marine mammals and large fish capture (modified from Llagostera (1989)). Scale bar = 1 cm.

considerable energy to bring them back to land. Problematically, billfish do not form schools, and individuals are usually dispersed at wide intervals (Nakamura, 1985); seeking for them in the open sea would result in a significant increase of time and energy consumed.

7.2. Fishing technology

Obviously, the presence of billfish among the diet of archaic fishermen has numerous implications regarding their fishing skills and technology. These fish can become quite substantial: the International Game Fish Association (IGFA) record for swordfish (from Iquique, May 7th 1953) is 536 kg, and for striped marlin is 224 kg. Another record from the area, which lasted for 13 years, is 390 kg for a 4.2 m swordfish caught off Tocopilla on April 28th 1940. The striped marlins found in northern Chile are also among the biggest, weighing up to 219 kg (Farrington, 1953). To catch such large fish with a hook and line appears to be unlikely, since most recognized hooks in Zapatero were small in size and made from shell. They would probably not have had enough resistance for the traction exerted by large billfish. Moreover, the presence at Zapatero of sharks, like the mako, which would rapidly cut through any fiber line, suggests that a hook and line was not appropriate for fishing large pelagics. Today, swordfish is harpooned offshore or in open sea, from small platforms at the prow of artisanal boats during the summer season (December to April), when the fish is found close to the surface and can be easily harpooned. Spearing or harpooning with barbed points is among the earliest methods used for hunting or fishing, dating back at least 90 000 years (Yellen, 1998). Because several kinds of spearheads are known from the archaic archaeological sites in the area (Llagostera, 1989), including Zapatero (Fig. 6), harpooning seems to be the most likely fishing practice employed for billfishing. Harpooning would also have been an appropriate technique for the mako shark, amberjack, dolphin, and sea lion, although the latter may have just been clubbed along the shore.

The finding at Zapatero of a perforated vertebra from a striped marlin (Fig. 5) might confirm this hypothesis. Even if the evidence is not completely convincing, since the perforation hole is quite wide compared to its depth, the use of a dully pointed bone spear remains plausible.

Evidently, billfish cannot be taken from shore, and necessitate a boat of some sort to be used in their capture. Regarding the kind of craft that may have been employed, one of the main problems raised is the determination of the raw material used for their construction, as no directly relevant data is available. Wood is completely absent from the area, and was probably already the case in the Middle Holocene, however, ethnohistorical observations from the 16th century may give some indication. For example, the Spanish chronicler Cieza de León (1553: 251) wrote that in the Tarapacá Region "los indios hacen balsas para sus pesquerías de grandes haces de avena o de cueros de lobos marinos".[1] With the exception of the Loa river, water courses are virtually absent today along the coastal cordillera of the Atacama Desert, but some sedge could have grow in certain places making reed boat construction possible (cf. e.g. Peruvian caballitos or Chumash Tule balsa). This simple boat, with a low technological input, seems more affordable to early coastal residents; however, paleoenvironmental studies do not indicate that the climate would have been any more humid during the Middle Holocene along the semiarid coast of Chile (Maldonado and Villagrán, 2006). Alternatively, skin boats could have been used as sea lions abound, but supporting evidence is lacking. Skin boats would leave few archaeological traces, and although sea lion bone remains are common among archaeofaunal assemblages, no remains referable to boat construction have been

[1] «Indians make rafts for their fishing of large oats (*reed?*) bundles or sea-lion skins.»

Fig. 7. Pictograph representing swordfish harpooning. Rock art from El Médano ravine, Taltal, Chile.

recovered at the Zapatero site or at other sites of the same period. Skin boats are depicted by the first European travelers (e.g. Frézier, 1716; Orbigny, 1839–43), but these models are likely to be much more elaborate than the ones, potentially, in use during the Archaic period. Simple or double floats for better stability, sewn from sea lion skins and then inflated, could have served as rudimentary boats able to carry two fishermen: one paddling and directing the boat, the other one ready to harpoon the prey. The use of similar but smaller floats, which the fisherman could have released once the fish was harpooned, might have protected the fishermen on their boat from attack by the billfish (Gudger, 1940). Swordfish, particularly, are considered extremely dangerous and are capable of attacking boats.[2] They tend to dive deep when harpooned, while marlins first make several leaps into the air and then swim wildly in broad circles near the surface (Nakamura, 1949; Sanger, 2009). These mighty fish can fight for two hours or more before getting tired (Ellis, 2013). For these reasons, we agree with Spiess and Lewis (2001: 133), and Sanger (2009) that the harpoon and float technology seems the most logical model for archaic swordfishing.

Regarding the way the fish arrived at the site, the presence at Zapatero of head bones (predentaries) and rostrum fragments[3] as well as vertebrae and hypural plates (Fig. 3), indicates that the billfish were brought complete to the site. The amount of meat that a billfish yields is important, reaching several tens of kilograms per specimen. This has implications about meat preservation and/or the size of the community living at Zapatero, if it is assumed that most fresh fish was eaten locally. Even if large fish preserves better than small fish, fresh fish kept in the shade has to be consumed within a few days of being caught in temperate climate, and more rapidly in a tropical climate (Huss, 1988). However, in addition to being consumed in fresh form, preservation techniques such as drying and/or salting could have been used to preserve the flesh of the fish.

7.3. Anthropology of billfishing

Considering the apparent boundless wealth of the sea at that time, and the abundance of inshore fish, one may wonder why the fishermen of Zapatero went to sea to seek and fight with such dangerous fish: was it necessity or choice? Regardless of energy input, a special relationship is often established between certain animals and humans (Ingold, 1986), and it seems that human consciousness has often selected the most powerful species in order to make them respected allies. Large pelagics might have been considered as trophies, or at least prestigious prey. Indeed, the social and symbolic value of swordfish is documented as having been important to both Maine's Red Paint People and Chumash cultures (Davenport et al., 1993; Noah, 2003; Bernard, 2004; Bourque, 2012). The presence, a few kilometers from the site of Zapatero, of the Quebrada El Médano rock paintings, provides further insight into this issue. This gorge contains more than a thousand petroglyphs depicting marine and terrestrial animals, including scenes of group fishing from boats and guanaco hunting with arrows (Contreras et al., 2008; Berenguer, 2009). Among marine life, sea lions, whales, sea turtles, sharks, and billfish are represented (Fig. 7). The age of the paintings is still under controversy, but it is generally considered that they were made before the first half of the second millennium A.D. (Berenguer, 2009). Although there is no evidence to link the paintings directly to the Zapatero people, if we agree that they are linked with the subsistence strategies of the local inhabitants as an expression of their identity, and considering that foodways are highly conservative, it appears plausible that a strong link existed between these paintings and large pelagic fishing in the Atacama Region since the Middle Holocene.

8. Conclusion

The people who lived at Zapatero during the 6th and 5th millennium BCE were skilled fishermen able to catch large pelagic fishes of impressive size. They clearly focused their fishing activities on pelagic species, especially medium sized jack mackerel and large sized billfish, while coastal rockfish were mostly neglected. Offshore pelagic fishing represents a high investment of time and energy in fishing technology, and there is no doubt that the systematic capture of billfish must have been, if not risky, extremely dangerous for the fishermen. Interestingly, at Zapatero, striped marlin were targeted more frequently than swordfish, which is surprising since striped marlins swim faster and are less easily approached when surfaced than swordfish. However, even though they seem to be less common today, Rivas and Smith (1955: 19) mention that during their angling operations off northern Chile, 361 striped marlins *vs*. 93 swordfish were sighted. Therefore, despite a likely higher frequency of striped marlin along the Atacama coast at the time, prey selection was probably due rather to the swordfish being just too large and dangerous for fishermen operating on small boats. Even if we believe that billfishing was a kind of "big game hunting", fishermen appear to have preferred to target the striped marlin, a more manageable yet still prestigious prey.

Throughout the arid coast of the Atacama, evidence of billfishing is scarce, however swordfish remains have been recovered from the Late Intermediate Period (ca. 1000–1400 AD) at sites close to Tocopilla (F. Fuentes-Mucherl, unpublished data), and discovery of swordfish-bearing sites will hopefully increase with future investigations. The presence of billfish remains in the Atacama coastal sites seems to be specific to this part of the Chilean littoral: no swordfish or marlin remains have yet been found in the extreme north of Chile or along the Peruvian coast (Reitz, 2001; Béarez, 2012). This may be linked to cultural factors, but more likely to oceanographic features that influence pelagic fish habitat (e.g. continental shelf extension, water temperature, oxygen, prey distribution). As most of these species come inshore during summer, fishing activity was more intense during this period of the year and it is likely that the occupation of the site was seasonal.

Finally, we can conclude that the Zapatero fishermen who engaged large billfish with a hand-thrust spear were most definitely skilled mariners. In contrast, their navigational capabilities may have been more rudimentary if fishing was practiced within sight of land, and in the areas adjacent to the site they occupied.

[2] «But sometimes it happens that the man rowing is wounded, right through the boat, by the immense size of the animal's sword; for it charges like a boar, and hunting the one is very like hunting the other." Polybius

[3] In the Gulf of Maine, swordfish rostra were extensively used for artifacts (Bourque, 2012), which seems not to have been the case at Zapatero.

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