Paleolithic vs. Epipaleolithic fisheries in northern Iberia

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ABSTRACT

A comparison of Paleolithic and Epipaleolithic fisheries in NW Iberia shows an overall high trophic level of catch. Freshwater fisheries (and thus their impacts) are ca. 8000 yr older than marine fisheries and have suffered virtually no changes in the region except for the increase in numbers, being focused on two families (Salmonidae, and Anguillidae to a very minor extent). Marine fisheries in the Paleolithic likely had a low impact but rapidly increased in importance, raising the average trophic level of the catch, the number of affected taxa and the proportion of marine to freshwater fisheries with time.

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Introduction

Paleolithic economy and culture were characterized by a total dependence on natural populations of their prey, and fisheries are one of the earliest uses of aquatic resources. Hunter–gatherers started very early to complete their diet harvesting fish and shellfish (e.g. Stiner and Munro, 2002; Klein et al., 2004; Richards et al., 2005); maritime skills and fishing technology were so developed in some Paleolithic cultures that pelagic fishing and the colonization of remote islands have been reported from more than 40 ka (O'Connor et al., 2011). It has been suggested that aquatic species were the main source of important nutrients such as quality proteins, fats and carbohydrates (Bicho and Haws, 2008); for many human populations, the intake of essential nutrients such as high quality animal proteins and omega-3 fatty acids still depends on extractive fisheries (e.g. Atta-Mills et al., 2004; Pauly et al., 2005).

Human exploitation, coupled with present accelerated climate change, has been identified as one of the main causes of depletion of wild fish resources (e.g. Duncan and Lockwood, 2001; Myers and Worms, 2003; Ficke et al., 2007; Garcia et al., 2012). This situation is reaching unprecedented levels, but is not new: overexploitation of wild fish by prehistoric humans has been reported in different parts of the world (e.g. Pauly, 1995; Dalzell, 1998; Jackson et al., 2001; Pauly et al., 2005; Pinnegar and Engelhard, 2008), as have evidences of early selective pressure for smaller fish size (e.g. Morales et al., 1994; Wing and Wing, 2001, Turrero et al., 2013b), consistent with harvesting large specimens and leaving only the smaller ones for reproducing. This may be extended to other aquatic resources, not only fish: intense prehistoric harvesting has left traces of selection in some shellfish species (e.g. Mannino and Thomas, 2002; Turrero et al., 2012b).

One aspect that has been less considered is the community perspective. The exploited fraction of the fish community differs largely between regions and between marine and freshwater fisheries (e.g. van der Elst et al., 2005; Worm et al., 2009; Ardura et al., 2011). In fisheries sciences it is generally assumed that fisheries have been increasingly targeted along the human history, so that catch has been progressively based on a few abundant species (e.g. Kaiser and Edward-Jones, 2006), generally from high trophic levels, which have been so intensely targeted that large predatory fish biomass is currently depleted far below sustainable levels in many cases (Myers and Worm, 2003). Average exploited trophic level is important because the depletion of predators from any given ecosystem can lead to ecological imbalance by increasing the pressure on primary producers via higher numbers of primary consumers (e.g. Frank et al., 2005). However, in some regions it has been proved that the current composition of harvested fish is similar to that previously found in prehistoric times, as demonstrated from archeological excavations where the same four fish species were still among the principal groups currently harvested (Craig et al., 2008).

In this study we will compare catch diversity between different time periods in Upper Paleolithic fisheries, estimated through direct analysis of archeological remains, and estimate their impact on marine and freshwater fish communities in each stage of the Upper Paleolithic and Epipaleolithic, using Asturias (central North Iberia) as a case study. A bibliographical survey on Paleolithic fisheries in the same region has already been published (Adán et al., 2009) and the freshwater

fisheries and their effect on Salmonids have been analysed (Turrero et al., 2012a, 2013b), but this is the first time that the ecosystem/community perspective is taken into account.

Materials and methods

Studied region

The region under study, Asturias, is a coastal province located in northwestern Spain (Fig. 1) with temperate climate, mainly sedimentary bedrock and a river network that forms deep valleys, most of them in a S–N direction. The coast is characterized by a steep bathymetry, a feature that is associated with intense marine resource exploitation in the Pleistocene (Erlandson, 2001).

Prehistoric remains

Like other researchers (e.g. Gobalet et al., 2004, Davis and Pyenson, 2007), we have relied on museum archives for obtaining the archeological materials analysed in this study. The remains from several archeological sites in Asturias (Fig. 1) were located and identified in the Museo Arqueológico de Asturias (Regional Archaeological Museum). They were obtained from different excavations conducted in the region by different archeological teams at different moments in time; this means that recovery methods were not standardized, but since all of the available materials (from selected pieces to excavation debris) were analysed, we feel confident that differential visibility would not be an issue. Excavation dates and recovery methods, which can be used as a proxy for excavation bias, are given in Table 1.

Fish remains were identified thanks to comparative collections hosted at the University of Oviedo and the Museo Nacional de Ciencias Naturales (National Museum for the Natural Sciences), and are given as minimum number of individuals (MNI). The studied remains were clearly labelled and are deposited at the Museum again, where they will be available for further studies. Dates and excavation details were found in excavation reports and published literature and can be seen in Supplementary Table 1. The remains cover a 15,000 yr span, between 21 ka and 6 ka, and are classified following the archeological chronological scale in technocomplexes or cultures: Solutrean (~20 to ~16 ka), Magdalenian (~16 to ~12 ka), Azilian (~12 to ~9 ka) and Asturian (~9 to ~6 ka; these last two technocomplexes are usually considered generically as Epipaleolithic).

Trophic levels for species were taken from Sanchez and Olaso (2004) and FishBase (Froese and Pauly, 2013); average trophic levels for families and orders were taken from Sea Around Us (2013).

Statistical analyses

The statistical significance of differences between prehistoric catch distributions per taxonomic group was tested with chi-square tests with Yates' correction when necessary.

Results

Prehistoric fisheries

The careful exam of more than a thousand boxes of excavation debris and other archived materials yielded 109 fish remains from nine different sites (Supplementary Table 1) that were identified to the lowest possible taxonomic level (Table 1). These remains measured from 32 to 1.5 mm in their greatest dimension. The dataset was not distributed equally among sites, since La Riera (Fig. 1, point 9) and Cueva Oscura (Fig. 1, point 2)
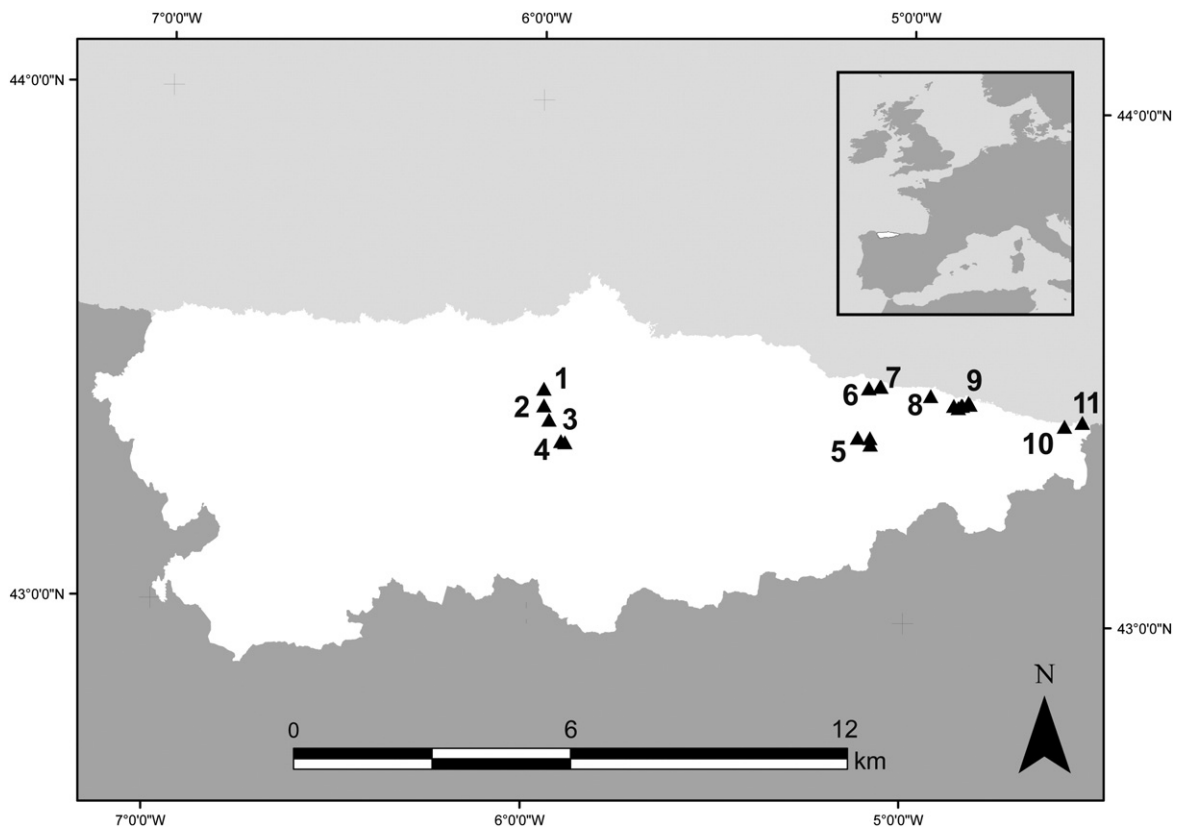

Figure 1. Map of the studied region, in the Principality of Asturias with the archeological sites considered for this study marked as triangles. 1: La Paloma; 2: Cueva Oscura de Ania; 3: Sofoxó; 4: La Lluera, Las Caldas; 5: Los Azules, La Güelga, El Buxu; 6: El Cierro, Les Pedroses; 7: La Lloseta, Tito Bustillo; 8: El Penicial; 9: Coberizas, Arnero, Bricia, Cuetu la Mina, La Riera, Fonfría, Balmori; 10: Mazaculos; 11: El Pindal.

Table 1

Summary of the archaeological dataset distributed in Upper Palaeolithic periods. Recovery methods: s/wb, sieving of sediment or retrieval of whole blocks of material; hp, hand-picking of prominent remains.

Archeological site (excavation date, recovery method/s)	Undetermined Upper Paleolithic	Solutrean	Magdalenian	Azilian	Asturian	N (proportion over the total MNI)
Balmori (1969, s/wb)			*Salmo* spp: 1		*Salmo* spp: 1	2 (1.8%)
Bricia (1953, hp)					Perciformes: 2	2 (1.8%)
Buxu (1987–1988, s/wb)	*Salmo* spp: 6					6 (5.5%)
Coberizas (1969, s/wb)			*Salmo* spp.: 1		Sparidae: 1 Perciformes: 2 *Salmo* spp.: 1	5 (4.6%)
Cueva Oscura (1975–1978, s/wb)	*Salmo* spp.: 2		*Salmo* spp.: 10	*Salmo* spp.: 6		18 (16.5%)
Mazaculos (1977, s/wb)	*Dentex dentex* 1 Sparidae: 1 Perciformes: 2					4 (3.7%)
Penicial (1969, s/wb)					Perciformes: 3 Pleuronectiformes: 3 *Salmo* spp.: 2 *Conger conger*: 1	9 (8.3%)
El Pindal (1953, hp)	Sparidae: 1					1 (0.9%)
La Riera (1976–1977, s/wb)		*Salmo* spp: 20	*Salmo* spp: 2	*Anguilla* spp.: 1 *Conger conger*: 4 Gobidae: 17 Other Perciformes: 1 *Salmo* spp: 1	Sparidae: 2 Gobidae: 7 Perciformes: 5 Pleuronectiformes: 1 *Plectorhinchus mediterraneus* 1	63 (56.9%)
Proportion over the total MNI	11.9%	18.3%	12.8%	27.5%	29.4%	

contributed more than 70% of the remains. The spatial location of those sites was also different. Two of them, Buxu (Fig. 1, point 5) and Cueva Oscura, are located in upstream river valleys, at 12 and 19 km respectively from the current coastline. Accordingly, remains found there corresponded solely to *Salmo* specimens, most likely caught in freshwater. The other sites are closer to the coast, and only one of them (Balmori: Fig. 1, point 9) did not contain marine taxa (Table 1).

The taxonomic status of the identified specimens in the dataset can be seen in Table 2. Four orders (Anguilliformes, Perciformes, Pleuronectiformes and Salmoniformes) were identified. Their contribution to the total number of specimens was different (Fig. 2), with a majority of Salmoniformes (49%) followed by Perciformes (42%), which include Gobidae, Haemulidae (with *Plectorhinchus mediterraneus*) and Sparidae (with *Dentex dentex*), some Pleuronectiformes, one vertebra clearly identified as an eel (*Anguilla*, Anguilliformes) and five vertebrae from conger (*Conger conger*, Anguilliformes). These results are comparable to those of a bibliographical survey considering the period 35–6 ka (Adán et al., 2009). Both datasets contain a majority of Salmoniformes and less abundant marine catches (Fig. 2); the main difference was a larger proportion of marine fish in our dataset. The difference between the two datasets is statistically significant (chi-square = 43.91, 4 degrees of freedom, P = 3×10^{-4}). The river catch was almost identical except for the *Anguilla* from the Azilian period (Table 1) in our dataset; the marine catch in our dataset contained more Perciformes than that in Adán et al. (2009).

When comparing the fisheries from the different periods within our dataset (with 97 MNI after the removal of specimens of uncertain date), it is clear that more varied fish were caught in later periods (Fig. 3), whereas Solutrean and Magdalenian catch were exclusively composed

of Salmonids. The ratio of marine fisheries to total catch increased spectacularly along the Epipaleolithic (Fig. 3, Table 3). The distribution of total catch in marine and freshwater families was highly significantly different between the Paleolithic and the Epipaleolithic periods (chi-square = 57.17, 1 d.f., P = 2×10^{-6}).

Fisheries diversity and trophic level

Changes in total catch diversity occurred along the studied period, from one order fished in the Solutrean and Magdalenian to four orders fished in the Epipaleolithic (Tables 1 and 3). However, trophic level (TL) was slightly lower in Epipaleolithic than in Paleolithic average catch due to the prevalence of highly predatory Salmonids (TL = 3.8) in early fisheries.

When freshwater and marine fisheries are analysed separately (Table 3), there are differences between different prehistoric periods only for marine fisheries. In the considered region, the targeted freshwater taxa were the same across the Paleolithic and Epipaleolithic, and in similar proportions: a majority of *Salmo* and a small proportion of *Anguilla* in the Epipaleolithic. Consequently, the trophic level exploited in freshwater in this region did not vary substantially (although *Anguilla* has a TL of 3.5). On the other hand, regional marine fisheries seemed to start, at least to a significant extent, in the Azilian. The trophic level of the marine catch was similar in the Asturian and the Azilian periods (Table 3), due to different combinations of Sparidae (average TL = 3.31), Pleuronectiformes (TL = 3.49), Gobiidae (TL = 3.11), *Conger* (TL = 4.3) and *Plectorhinchus* (TL = 3.5). The distributions of Azilian and Asturian catch in fish orders (Salmoniformes,

Table 2

Taxonomic status and most likely fisheries environment of the archeological remains found in the studied dataset.

| Species	Genus	Family	Order	Fisheries environment
	Salmo	Salmonidae	Salmoniformes	Freshwater
	Anguilla	Anguillidae	Anguilliformes	Freshwater
C. conger	*Conger*	Congridae	Anguilliformes	Marine
P. mediterraneus	*Plectorhinchus*	Haemulidae	Perciformes	Marine
D. dentex	*Dentex*	Sparidae	Perciformes	Marine
		Sparidae	Perciformes	Marine
		Gobiidae	Perciformes	Marine
			Perciformes	Marine
			Pleuronectiformes	Marine
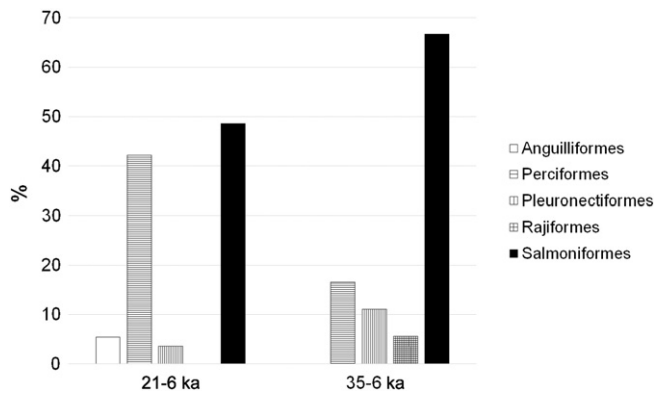
Figure 2. Proportions of different taxonomic orders in prehistoric fisheries (MNI: Minimum Number of Individuals). Data for the period 35–6 ka from Adán et al. (2009); data for the period 21–6 ka from this study.

Perciformes, Pleuronectiformes and Anguilliformes) were statistically different (chi-square = 7.93, 3 d.f., P = 0.04).

Discussion

As a whole, the changes in the use of faunal resources found in this study emphasize the increasing importance of marine resources in the Upper Paleolithic (e.g. Richards et al., 2005). These results are consistent with those found for most Iberian regions (e.g. Aura et al., 1998; Straus, 2005; Bicho and Haws, 2008; Cortés-Sánchez et al., 2008).

The continuous improvement of fishing gear is apparent in the European archeological record (e.g. Cleyet-Merle, 1990), and this might have allowed the capture of increasingly smaller fish in a same taxon, at least in freshwater (for an example in salmonids see Turrero et al., 2013b). These improvements might also explain the increase in the diversity of prehistoric marine fisheries in the Asturian period, since better fishing gear would allow the catch of more diverse marine fish. Another possible explanation for this increase would be early offshore fisheries in the region, although the remains identified to species level correspond to species that live in habitats close to the coast (*Plectorhinchus mediterraneus*, *Conger conger*, *Dentex dentex*) and at this moment we have no evidence of offshore catch. Yet another possibility is resource depletion: the recourse to marine fisheries and, thus, the increase in fisheries diversity, could have been motivated by a scarcity of preferred targets. Thus, it may be the depletion of preferred resources which drove technological innovation forwards in order to acquire a broader range of fisheries.
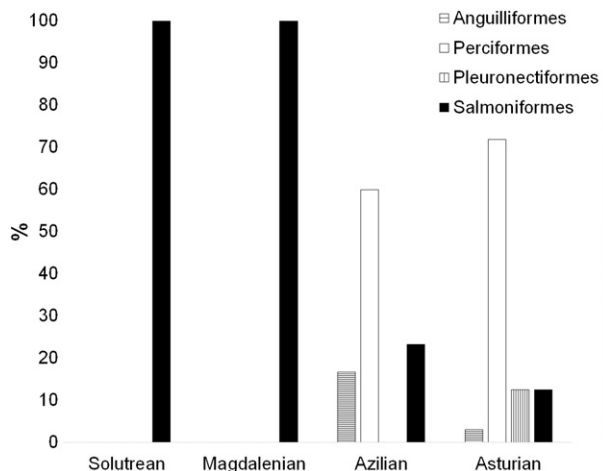

Figure 3. Proportions of taxonomic orders in different Paleolithic periods (in MNI, minimum number of individuals).

Table 3
Taxonomic diversity of freshwater and marine fisheries in the studied periods. FR: family richness (i.e. number of taxonomic families); TL: trophic level (weighted average).

	Freshwater		Marine		% marine
	FR	TL	FR	TL	
Solutrean	1	3.8	0	–	0
Magdalenian	1	3.8	0	–	0
Azilian	2	3.76	2	3.33	73.3%
Asturian	1	3.8	5	3.27	87.5%

This study provides a clue for future conceptual advances in the current discussion about how old is the impact of fisheries: it may have been different in freshwater and marine ecosystems, likely higher in the former. Although it is undeniable that prehistoric impacts were very high in some areas (e.g. Pauly et al., 2005), Bicho and Haws (2008) argued that the global impact of prehistoric human populations on wild marine resources would have likely been minimal, considering the small size of human populations at that time and the enormous resilience of large populations of marine species.

Misrepresentations in the Paleolithic data are possible, since they are based on museum collections, which may be biased in a number of ways (preservation and/or visibility of the remains, excavation methods, sieve mesh size, etc.), and our sample sizes are relatively small. For instance, we believe that the small sample size from Balmori (only two specimens recovered) is what singles it out as the only coastal site without marine taxa. We have been as thorough as possible in our analysis of the remains, but the archives might have been biased to begin with, especially the older the excavations are. However, the size range of the remains (Results section) and the fact that only three of the remains come from sites where recovery was performed through hand-picking of remains (Table 1) argue against a strong bias in our dataset.

The results presented here, together with data from a larger study on the location of Paleolithic settlements in the region (Turrero et al., 2013a), reinforce the view of Paleolithic humans as opportunistic predators. In times when settlements were located near rivers, fisheries were dominated by freshwater taxa; when human settlements were preferentially located near the coast, marine fisheries gained importance regardless of the distance to nearby rivers. Mean distance from a site to the nearest river increased from 301 m in the Upper Paleolithic (**n** = 98, the whole population) to 597 m in the Epipaleolithic (**n** = 136, the whole population), while average distance to the (current) coastline decreased, from almost 11 km in the Upper Paleolithic (**n** = 56, random subsample) to 5.1 km in the Epipaleolithic (**n** = 54, random subsample). This suggests that, whatever the reason for the change of settlement background, Paleolithic humans mainly exploited readily available resources.

Acknowledgments

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.yqres.2014.04.007.

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