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PETITS ANIMAUX ET SOCIÉTÉS HUMAINES. DU COMPLÉMENT ALIMENTAIRE AUX RESSOURCES UTILITAIRES
XXIV^e rencontres internationales d'archéologie et d'histoire d'Antibes
Sous la direction de J.-P. Brugal et J. Desse
Éditions APDCA, Antibes, 2004

Fishing down the food web in Iberian prehistory ? A new look at the fishes from Cueva de Nerja (Málaga, Spain)

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Résumé
La surpêche est un phénomène important et pourtant délicat à mettre en évidence dans les échantillons archéologiques. Traditionnellement, ces phénomènes ont été déduits de changements taxonomiques et des tailles des populations exploitées sur des séquences diachroniques. Dans ce travail, nous proposons de montrer qu'une nouvelle technique, le niveau trophique, peut aussi se montrer utile. À ce propos, on étudie les échantillons de poissons de l'emblématique gisement espagnol de la Cueva de Nerja, en essayant de vérifier les données qui ont été presentées pour démontrer l'existence d'une surpêche qui remonte au Paléolithique.

Abstract
Overfishing is a crucial yet elusive phenomenon to record in archaeological assemblages. Traditionally overfishing signatures in archaeozoological assemblages have been inferred on the basis of taxonomic and size changes of the exploited populations in diachronic sequences. In this paper we suggest that an additional tool, the trophic level, may prove of use in this task. To this end, the emblematic fish assemblages from the Spanish site of Cueva de Nerja are analyzed under this new perspective in an attempt to test the traditionally weak data that have been thus far invoked to postulate the incipient existence of overfishing signatures since Palaeolithic times.

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Archaeozoology offers the faunal analyst the possibility of investigating animal resource management strategies on a temporal scale that considerably widens the scope of present day actualistic analyses (Morales *et al.*, 2001). As we all know, most ecological research is carried on at a local scale, studies rarely going back in time to more than a few decades, while most research databases rarely proceed beyond the 1950s. From such restricted standpoints one wonders the extent to which present day recorded patterns and processes constitute reliable inferential tools on which to base policies or further research ; a fact all the more pressing when such policies or research efforts do not seem to be leading in the right direction.

The global collapse of commercial fisheries is a paradigmatic case in point of these previous considerations. Thus, despite intensive research and progressively more restrictive policies, this crisis has only become more acute in recent years leading some to postulate the *de facto* extinction of marine fishing in the foreseeable future (Pauly, Watson, 2003). Though many reasons exist for reaching the present state of affairs, some having nothing to do with scientific research, different authors have repeatedly stressed the inadequacies of such predictions due to the restricted temporal scope of both the databases and studies on which fishery scientists base their calculations and modelling (Pauly, Christensen, 1995 ; Watson, Pauly, 2001).

Although overfishing has not been, as of this writing, a matter of much concern for archaeologists, overharvesting of terrestrial resources has a long record that goes back at least to Martin's now classical « Overkilling Hypothesis » and Flannery's Broad Spectrum revolution (BSR) hypothesis (Martin, 1967 ; Flannery, 1969). Both cultural and environmental agents have been brought into this long-standing debate but, arguments being for the most part qualitative, strikingly little enlightenment has been accomplished, with the contestants holding firmly to their ground despite the wealth and variety of data incorporated into the discussion during these last decades (Grayson, 2001). Quantitative data are desperately needed. As Reitz (in press, b) states « …quantitative data … even unable to solve the ultimate problem of causality, will allow for the testing of data within an objective theoretical framework and will contribute to a more clearly defined approach to causality as such ». In the case of archaeological fish assemblages, a recently developed tool might well provide just that.

Methods

Conventional methods for exploring overfishing in archaeological fish remains samples include : (1) the qualitative analyses of faunal lists, (2) size and weight inferences and (3) age studies (Desse, Desse-Berset, 1993). All of these methods rely on comparative data gathered from modern analogues and all provide indirect (*i.e.*, circumstantial) evidence that needs to be framed within an adequate context. Although a detailed discussion of their pros and cons is well beyond the scope of our paper, none of them is devoid of problems in their application. The detection of overfishing events in the archaeological record, more-over, is highly vulnerable to preservational biases, implying the loss of the smallest remains and taxa, and requires large (meaning statistically significant) samples from a single sequence incorporating independent chronological stages.

Recently, biologist Daniel Pauly and his colleagues have indirectly introduced a new tool into this arsenal, the trophic level (TL) value, which they developed as part of their ongoing effort to document secular changes in world fisheries (Pauly *et al.*, 1998). TL values are defined by the degree to which organisms feed directly on producers, the base of the food chain, which are assigned a TL value of 1. Zooplankton and phytoplanktophagous organisms, along with benthic herbivores and detritivores, are in the second level whereas carnivores occupy levels three through five. Trophic levels have now been estimated for hundreds of marine organisms of commercial interest from published mass-balanced trophic models constructed with local data that included detailed diet composition (<http://www.fishbase.org/trophic/t.html>; see figure 1 for a selection of representative mediterranean fishes). In these models fractional TLs are estimated values based on specific diet composition data and thus are a presumably robust tool in terms of comparative analyses.

By converting data reported by the United Nations Food and Agriculture Organisation (FAO) into TL data, Pauly and his colleagues have documented recurrent patterns in modern fisheries that are susceptible of being explored in archaeoichthyological assemblages. In this way, they have evidenced a pervasive, often dramatic shift in all commercial fisheries away from long-lived, high TL piscivorous demersal fishes to short-lived, planktivorous (low TL) invertebrates and small pelagic fishes that causes a gradual decrease in the mean TL of the whole fishery with time (Pauly, Christensen, 1995 ; Pauly *et al.*, 1998, 2000). This shift, which Pauly and his colleagues baptized as the « Fishing Down the Food Web » model (FIDFOW), is a response to changes in the availability (abundance) of the preferred catch. According to the model, any mean TL change in a fishery of an order of magnitude of 0,1 or larger is significant and often accompanied by rearrangements of the taxa (elements) constituting the cropped ecosystem. Under « pristine » conditions, reflected in the mean TL value of a fishery when first cropped, the model sets values of around 3 that climb to 3,4 or 3,5 during the peak of the fishing activity but eventually settle down to values of 2,9 or less as the highest TL value species become depleted and overfishing sets on the whole fishery.

From an archaeological standpoint the question now is : Are these documented patterns short-term phenomena, recording a very specific situation in world fisheries during the past half century – or perhaps since the onset of industrial fishing – but by no means general or are they instead part of a larger scale process that has been cycling for centuries or thousands of years, perhaps since the very beginning of fishing as a subsistence strategy ? The answer to this question is neither straightforward nor trivial.

Despite a wealth of potential drawbacks (see the conclusions section), by using Pauly's approach it is now theoretically possible to demonstrate that a

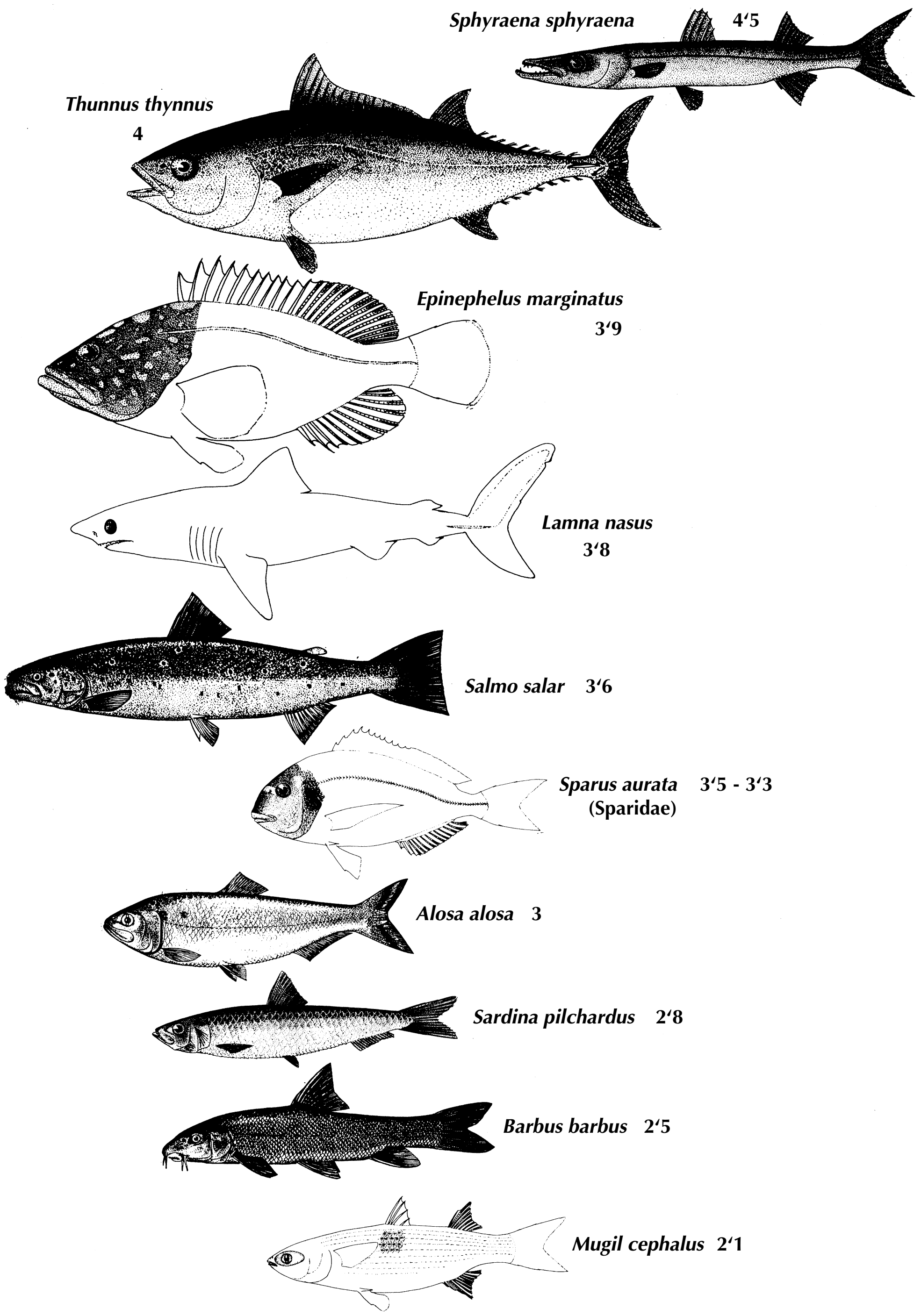

Fig. 1. *Trophic level (TL) values from selected mediterranean fishes.*

change did or did not occur in a former fishing strategy provided the appropriate data are at hand (see above) and this, as previously stated, sets the causality debate on a completely different ground, better still in case one manages to combine TL data with additional – conventional – data sets.

Pauly's approach has, in fact, now been tested on several archaeological fish assemblages with promising results (Reitz, 2003 ; in press a, b, c). Reitz's studies evidence that, as suspected for an activity that dates back to the Pleistocene, some fisheries in the Americas may have been compromised long before the 1950s when fishery statistics started to be systematically compiled and the time lapse that served as the basis for the development of the FIDFOW model was established. For such reasons, but also since the TL approach likewise provides a straightforward means for intra- and inter-site comparisons, a preliminary application to a far more ancient fish assemblage from the Iberian peninsula (*i.e.*, Cueva de Nerja) was attempted in order to hint additional explanations to those already proposed for the patterns exhibited by these faunas.

In this paper only the data for cartilaginous and bony fishes are considered. Excluding the mostly low TL invertebrates from the study will result in higher estimates of the mean TL values for each sample but, in addition to the fact that these distortions are easier to control than those deriving from a biased retrieval of fish remains, from a strictly cultural standpoint, shellfish gathering and fishing traditionally constituted different activities both in terms of seasonality and of population sectors devoted to them with little overlap in terms of species cropped.

Archaeozoological fish frequencies, as represented by the NISP (number of identified remains) were assigned a TL value using data summarized by Pauly and his colleagues (<http://www.fishbase.org/trophic/t.html>). Occasionally, it was necessary to use higher taxonomic levels because either the identification of the archaeozoological samples or Pauly's data were insufficiently precise. In those cases where an archaeological taxon is not included by Pauly, the TL for the closest taxonomic category – never above genus level – was taken provided modern data on diets evidenced a close correspondence between the two (in our case one minor taxon, *Labrus sp.*, fell into this category).

Following Reitz (2003) the formula : $TL_i = \sum (TL_{ij})(NISP_{ij}) / \sum NISP_i$ is used to solve for the mean trophic level for the time period i. The trophic level (TL_{ij}) of each taxon (j) for the time period (i) is multiplied by the NISP for that taxon (j) for that period (i). TL_{ij} is then divided by the summed NISP for that time period. This formula estimates the mean TL for each chronostratigraphical assemblage[1].

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[1] The NISP, rather than any alternative estimator, was chosen because, in addition to simplicity and repeatability of computing, this parameter represents an absolute calibration, rather than an estimation, and does not deflate the samples as most other estimators do. In archaeozoological collections, finally, those problems of interdependence that the NISP may provoke appear to be minimal provided we deal, as seems to be the case here, with conventional food refuse accumulations (Grayson, 1984 ; Gautier, 1984).

Fig. 2. *Location of the Cueva de Nerja site.*

Since changes in species frequencies are the agents responsible for most TL value shifts, the fish assemblages from Cueva de Nerja have been further divided into three analytical categories, namely : (a) low TL taxa (TL = 2 to 3,2) comprising partially herbivorous groups such as the Mugilidae, (b) medium TL taxa (TL = 3,3 to 3,5) that include omnivores which eat both fishes and invertebrates such as the Sparidae and Sciaenidae and (c) high TL taxa (TL > 3,6) that include the strictly piscivorous groups such as the Serranidae, Scombridae and Carangidae.

Materials and results : the site and fishes from Cueva de Nerja

Operated as a tourist attraction since the mid 1960s, Cueva de Nerja is a spectacular karst complex one kilometre away from the coast and 158 m above sea level (fig. 2). Since the Gravetian period and up until the late Chalcolithic (*i.e.*, 24 000 BC to 2300 BC) a deep sedimentation sequence occurred at the entrance of the cave, an area later divided into three zones (Vestíbulo, Torca and Mina).

Throughout that sequence, human activities took place and were mostly responsible for the accumulation of an impressive paleobiological record that includes some 30 000 botanical and close to 250 000 animal remains from isotopic stages 1 and 2 (Jordà *et al.*, 2003)

The fish remains that constitute the basis of our analysis were studied by Roselló *et al.* (1995) to whom we address readers for specifics. These samples were screened in the Salas de la Mina and Torca (mesh sizes : 5 mm to 2 mm) during excavations conducted by M. Pellicer from 1980 to 1982 and belonged to four chronological horizons : (1) Late Magdalenian [uncalibrated ^{14}C dates for the Mina (GAK 8965 : 14570 ± 540 BC) and for the Torca (GAK 8976 : 11380 ± 276 BC and GAK 8966 : 11830 ± 340 BC)], (2) Epipalaeolithic (GAK 8964 : 8630 ± 350 BC), (3) Neolithic (GAK 8960 : 3840 ± 140 BC and GAK 8969 : 2860 ± 220 BC) and (4) Chalcolithic (2300 BC, no ^{14}C dates available) with transitional levels of debatable reliability lying in-between them.

Preciously little in the way of a clear pattern was evidenced by the fishes from the two assemblages from sala de la Torca and sala de la Mina. Of the three most common species from the 20 taxa recorded, pandora (*Pagellus erythrinus*) was present throughout the sequence though truly frequent (close to 40 % of the total NISP) only in the late Magdalenian, and dwindled to a mere 5 % during the Chalcolithic. An inverse trend was observed in the porgy (*Pagrus pagrus*), which from 3 % in Late Magdalenian went up to 50 % during Chalcolithic times, lending ground to the thought that some sort of faunal replacement was caused by progressively more rocky shores and bottoms as the Flandrian transgression proceeded (Roselló *et al.*, 1995). The third of the main species, the grouper (*Epinephelus marginatus*), did not appear in the Palaeolithic levels and exhibited a normal distribution with lows during the Epipalaeolithic and Chalcolithic and a peak in the middle of the Holocene (*i.e.*, the Neolithic).

More revealing than these fluctuating frequencies were the data gathered on sizes, for here it was clear that with independence of the species considered, the three main taxa evidenced a similar trend of increasing *mean* size towards the Neolithic, decreasing thereafter. This size increment during the Neolithic was peculiar in that it occurred while the range of sizes decreased, hinting at the targeting of the largest specimens (Roselló *et al.*, 1995, p. 179, 190, 196). For this reason, the subsequent decrease of mean size yet increase in the range of sizes during the Chalcolithic was taken by the authors as an indication of the existence of an overfishing trend at Cueva de Nerja ; a striking conclusion in the light of the episodic and diachronic nature of its chronological stages (*ibid.* ; Morales *et al.*, 2001).

Armed with this background, a look at figure 3 is revealing in several aspects. The first remarkable fact is the comparatively high mean TL value (3,44) given the predictions of the FIDFOW model. From an actualistic standpoint one could well argue that the pristine stage had been already surpassed and that the fishery, if one may call it so, had been already under way for some time. Equally revealing is the fact that middle, not low level, TL taxa constitute the bulk of the assemblage, and also that high TL taxa are ten times more common than low TL taxa. Since low TL taxa are most abundant close to shore or in estuaries whereas high TL taxa at Nerja include a large contribution of the highly pelagic and migratory scombrid and carangid fishes (mostly *Trachurus trachurus*) the idea of an incipient, technologically backward fishery seems questionable.

A third pattern appears to be the rather dramatic increase in mean TL values once the Holocene sets in, its subtler version being the very gradual rising of these values until Neolithic times, followed by a slight inversion of the tendency thereafter. Still, the most striking feature of the analysis is the evolution of the high TL fishes' frequencies throughout the Holocene. These values treble with the onset of the Epipalaeolithic, peak to 60 % of the « catch » during the Neolithic, and diminish again afterwards with the decreasing trend values mirroring those from the incremental pre-Neolithic phase. Should these trends couple with the aforementioned targeting on larger sizes, the impression of an intensification of the fishing effort would greatly benefit. A final feature, not really a trend, is the nil contribution of low TL fishes throughout the sequence which renders the story of the fishes from Cueva de Nerja as a complementation tale between the medium TL and the high TL fishes.

Discussion

Traditionally, fishes constitute the most ambiguous set of data from Cueva de Nerja's faunal assemblages as can be deduced from the rather weak, often conflicting statements found in the various papers dealing with this group (Aura *et al.*, 2001, 2002, 2003 ; Morales *et al.*, 1998a, b). The only coincidences in these works relate to the sheer diversity of taxa indicative of a far from technologically backward « fishery » capable of targeting both demersal and pelagic species including migratory taxa such as the mackerels (*Scombrus sp.*), since Magdalenian times, which is when the fishery was established according to Aura and his colleagues. Beyond this nothing but differences exist. In this way, trying to make sense of the diachronic frequency changes they record at the level of family, Aura *et al.* (2001, 2002) and Jordà *et al.* (2003) argue from an essentially environmental standpoint and link the changes to the approaching coastline which the last transgression provoked. While not denying such a possibility, Morales *et al.* (1998a) are far from satisfied with some of the patterns recorded on their fish assemblages (see above), as their main concern is the reliability of the fish sample as a faithful recorder of both cultural or environmental changes (« The key point would be to demonstrate that this sudden appearance of marine taxa did, in fact, occur at this moment [*i.e.*, the Magdalenian period] and is not simply a side effect of a biased record » *ibid.* : p. 42). The matter is essentially philosophical. Due to the meticulous retrieval methods and the quantity and quality of the paleobiological evidence, Aura and his colleagues take the fish data at face value but Morales *et al.* (1998a) think that something is still hiding from sight. What seems a bit awkward for authors who argue that (lit.) « …changes on faunal assemblages are probably

Trophic level	2 - 3’2	3’3 - 3’5	> 3’6	Mean TL
Magdalenian	1’5	85’5	13	3’4405
Epipaleolithic	-	62’5	37’5	3’4875
Transition	-	0	0	3’6384
Neolithic	2	3	0	3’6849
Transition	-	48’6	51’4	3’6914
Chalcolithic	-	4	6	3’6224
Nerja total	1	69’5	29’5	3’5382

Fig. 3. *Trophic levels (TL) of the fish assemblages from the joined chronostratigraphical stages from the Sala de la Torca and Sala de la Mina (NISP data taken from Roselló* et al.*, 1995)*

Trophic level	2 - 3’2	3’3 - 3’5	> 3’6	Mean TL
Magdalenian	20	60	20	3’4032
Epipaleolithic	7	14	79	3’6467

Fig. 4. *Trophic level data from Sala del Vestibulo (NISP data taken from Aura* et al.*, 2001).*

Trophic Level	2 - 3’2	3’3 - 3’5	> 3’6	Mean TL
Magdalenian	42’5	57	0’2	2’9609
Epipaleolithic	38	62	0’3	2’9021

Fig. 5. *Trophic level data from Sala de la Mina (NISP data taken from Aura* et al.*, 2001).*

linked more to subsistence strategies than to the Tardiglacial deglaciation » (Aura *et al.*, 2001, p. 9) is to see that only in the case of fishes would environmental factors be the decisive factor shaping the paleocenoses.

In order to frame our previous results within a comparative setup, we estimated those same mean TL values for the samples given by Aura and his colleagues in their papers. These samples come from two different areas of the cave (Sala de la Mina, another fraction of which had been previously studied by the authors (see above) and the Sala del Vestíbulo, documenting the richest paleobiological sequence from Cueva de Nerja). As it so happens, such calculations presented us with some problems since Aura and his colleagues do not report NISPs nor do they present taxonomic data below family level. NISPs could be, nevertheless, retro-calculated from percentage values since in one of their papers the total NISPs somehow slipped in (Aura *et al.*, 2002). TL estimations posed no problem as all of the families reported appear in <http://www.fishbase.org/trophic/t.html>.

Data appear in figures 4 and 5. Each sample has to be presented in isolation since, contrary to the case with our assemblages, the samples are not homogeneous. Although at the level of mean TL value, Sala del Vestíbulo essentially duplicates our previously recorded pattern (compare fig. 3 and 4), the composition percentage of the three TL groups is quite different between both samples thus conveying the impression of very heterogeneous faunas throughout.

One may argue that the high frequencies recorded for the low TL fishes on Aura’s samples evidence a more careful retrieval technique. To some extent this is true, for Jordá’s team used mesh sizes smaller than those used by Pellicer, and some of the low TL taxa (clupeids in particular) are significantly smaller on the average than the remaining families thus far described at Cueva de Nerja. Yet this can not be the sole explanation of these different faunal spectra, since among other things :

(1) Almost all of the low TL remains belong to a family (Mugilidae, grey mullets) of comparable size to the systematically most abundant fishes at Nerja (*i.e.*, Sparidae, sea breams). If Pellicer's team managed to retrieve many sparids, why did they miss the mullets ? Obviously, there might be an ontogenetic side to this feature (if all these mullets represent juveniles, for example), but considering the lack of measurements one is left wondering.

(2) If the retrieval technique was the sole responsible agent dictating the frequencies of different sized groups, why are both of Aura's samples so different ?

From our standpoint, the most parsimonious explanation accounting for these differences is the fact that each sequence in each area, no matter how close to each other, is recording independent events. In other words, as suspected, the faunal evidence is far more complex and patchy than some authors seem willing to admit.

Within such a framework one should concentrate on the major features of the putative patterns, namely :

(1) Already during Magdalenian times both our samples and those from Sala del Vestíbulo exhibit rather high mean TL values as well as an increase in TL during the Epipalaeolithic, more pronounced in our samples (fig. 3) than those from the Vestíbulo area (fig. 4).

(2) In both our samples and those from Vestíbulo this increase in TL mean value is brought about by a dramatic and complementary shift that raises the frequencies of the high TL taxa while diminishing those from both the low and medium TL groups. Again, differences relate to specific values yet the trends are similar in both cases.

(3) The sequence from Aura's Sala de la Mina area, on the other hand, is not only set at significantly lower mean TL values, it also remains essentially constant in the transition from the Pleistocene to the Holocene. This is due to the combined large amount of mugilids along with the almost absence of high TL taxa it features in both stages, and the impression conveyed is that this fishing seems to have been carried out either through completely different methods (Shoal interception ?) or else in an altogether different kind of environment (Estuary ? Lagoon ?).

Unfortunately, one can not proceed further in terms of temporal comparisons with the data provided by Aura and his colleagues as their analyses do not cover the latter stages of the Holocene which we have incorporated here (fig. 3). Thus, since the causal link among all of the samples is still far from clear and the isolated nature of the accumulation episodes a far more likely event in the light of the present evidence, the most one can say to conclude is that the evidence provided by the TL analyses, with exceptions, not only reinforces the idea of a well developed marine « fishery » from its presumed moment of origin (*i.e.*, The Magdalenian ?) at Cueva de Nerja, but likewise documents signatures of a process of intensification through time that complements those inferred through the classical methods of archaeoichthyological research.

Conclusions

One would be mistaken to think that TL analysis holds the key for spotting, let alone understanding, overfishing events in the archaeological record. Foremost among the TL tool drawbacks is the fact that TL values have been estimated for modern-day adults yet we know that there are many sources of variability that should be kept in mind. Ontogenetically, for example, we know that fish diets undergo dramatic shifts with postlarvae starting life as planktivores – both phyto and zooplankton at times – and adults climbing up the ladder of carnivory thus progressively increasing their TL values (Helfman, Collette, Facey, 1997). Under such circumstances, TL values, as they currently stand, constitute point estimates over a wide range of values that, coupled with size increments, one would do well to record for future studies.

Likewise, both spatial and temporal differences in diet have been recorded for the same species often from the same size. The former as well as the latter are theoretically easy to cope with when they do not imply large time intervals (*e.g.*, seasons). But what about diet shifts in the deep past ? For many of the commercial fishes feeding habits have changed dramatically as a result of the fishing fleets targeting their traditional prey items (Jackson *et al.*, 2001 ; Pauly, Watson, 2003). Such diet shifts, more often than not, involve the species preying progressively lower on the food chain. Fig sponges (*Suberites ficus*), for example, have become a regular preyed item by no less than five per cent of the bluefin tunas (*Thunnus thynnus*) feeding on the New England continental shelf (Chase, 2002). In view of this, how can one think that modern analogues constitute adequate inferential tools for archaeozoologists ?

No matter how restricted the TL is in its application, what the faunal analyst needs at this point, as stated at the beginning, is to diversify its « tool-kit » and to this end TL analysis is a welcomed addition that one would do well to explore in detail. Only after a systematic application to faunal samples will one be able to determine its pros and cons, thus the specifics of its appropriate use. It is hoped that this contribution will serve as a motivating start for others to follow.

Acknowledgements

Our deepest gratitude to Jean Desse and Nathalie Desse-Berset whose invitation to attend the Antibes meeting and interest in our research precipitated the presentation of this paper.

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