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Catch of the day: Abundance and size data of groupers (Epinephelidae) and combers (Serranidae) from Middle to Late Holocene Levantine archaeological contexts

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ABSTRACT

Groupers (Epinephelidae) are ecologically, commercially, and culturally important carnivorous fishes found throughout the world's tropical, subtropical, and temperate coastal marine waters. Due to various life history traits (e.g., late maturity, sequential hermaphroditism) and behavior (e.g., sedentary, small home ranges) groupers are susceptible to overfishing, including small-scale and recreational fishing (especially spearfishing), and their populations are declining worldwide. The eastern Mediterranean coast, home to some of the world's longest continuously occupied urban settlements, hosts important but declining grouper populations. This paper investigates how grouper and comber (fishes in the Serranidae family with similar ecology and osteomorphology, but smaller in size) abundance and catch size changed in the eastern Mediterranean from the Middle to Late Holocene, coinciding with early coastal urbanization, by estimating their relative frequency and reconstructing their size. Size reconstructions have been done from a large sample of bones (Number of Identified Specimens = 1851) recovered from Kinet Höyük in Turkey, and Tell Fadous-Kfarabida and Tell el-Burak in Lebanon, habitation sites along the Levantine coast. Our results imply that groupers in the past reached >100 cm more often than is observed today in areas open to commercial fishing. Furthermore, the apparent lack of large groupers by the Hellenistic Period at Kinet Höyük suggests fishing efforts were intense enough to have either had an appreciable effect on the size structure of local grouper populations or brought about a behavioral change to the fishes of moving to deeper waters.

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Introduction

Groupers are ecologically, commercially, and culturally important coastal, predatory fishes in the Mediterranean (Condini, García-Charton, and Garcia 2018; Guidetti and

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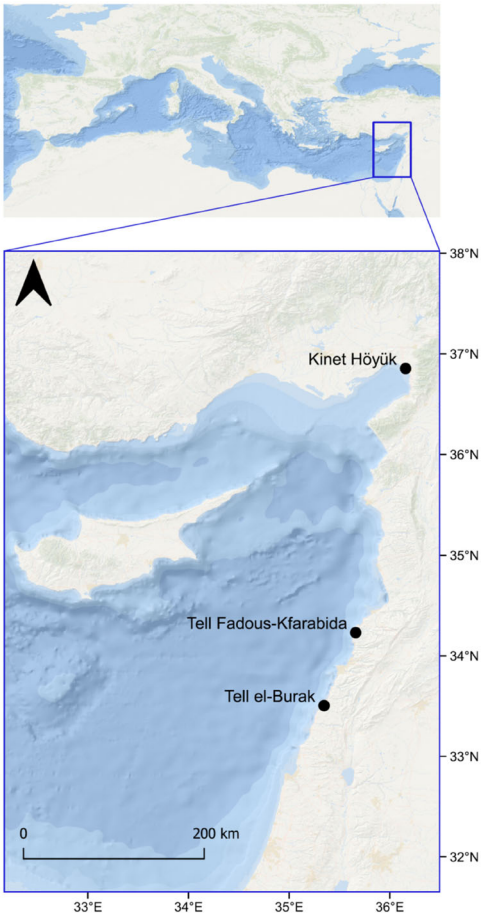


Figure 1. Archaeological site locations along the Levantine coast in the eastern Mediterranean: Kinet Höyük in present day Turkey and Tell Fadous-Kfarabida and Tell el-Burak in present day Lebanon.

Micheli 2011; Prato et al. 2013). Large predators, like groupers, are vital for healthy ecosystems and their removal can cause trophic cascades, having devastating consequences on local food webs (Baum and Worm 2009; Myers and Worm 2003). Numerous grouper species are referred to as threatened species according to IUCN Red List Assessment (Sadovy de Mitcheson et al. 2020). Reconstructing the size distribution for grouper catches in the past generates insight into past local marine ecosystem health by illustrating whether local grouper populations were well-structured and with large individuals. Large spawners may have maximized the reproductive capacity and thus endurance of past grouper populations. To gain a long-term perspective on their exploitation, this study investigates archaeological grouper and comber (osteomorphologically indistinguishable fishes to groupers) bones, which are regularly recovered from excavations in the eastern Mediterranean since the Early Holocene, with an apparent increase in abundance coinciding with coastal urbanization (Desse and Desse-Berset 1994, 1999; Mylona 2008; Van Neer 2006; Van Neer et al. 2004).

Since the eastern Mediterranean coast is home to some of the longest-settled harbor towns of the world, these grouper bones contain time series data that can serve modern

fisheries as historical baselines. Using abundance data and osteometric measurements to estimate individual size, we explore changes in grouper and comber catch sizes through the Middle and Late Holocene (ca. 3000 BC–fourteenth century AD) in the eastern Mediterranean. A minimum of 651 individual fish were studied from three archaeological sites on the Levantine coast: Kinet Höyük in Turkey, and Tell Fadous-Kfarabida (hereafter referred to as Tell Fadous) and Tell el-Burak in Lebanon (Figure 1). Significant differences in catch size based on recovery method demonstrates the importance of considering excavation records when trying to understand ancient fisheries. We contextualize abundance and catch size data with grouper and comber biology, changing coastal environments, and factors such as fishing technology and inferred commercial and cultural value.

Study species

Groupers have traditionally been treated as belonging to the subfamily Epinephelinae within the Serranidae family. However, it is currently thought that groupers should belong to the family Epinephelidae, while sea basses and combers belong to the Serranidae family (Craig, Sadovy de Mitcheson, and Heemstra 2011; Fricke, Eschmeyer, and Van der Laan 2022). Six species of grouper are native to the eastern Mediterranean: *Mycteroperca rubra*, *Hyporthodus haifensis*, and four species within the *Epinephelus* genus (*E. marginatus*, *E. costae*, *E. aeneus*, and *E. caninus*). The Serranidae family contains three species of combers found throughout the Mediterranean (*Serranus cabrilla*, *Serranus hepatus*, and *Serranus scriba*). Adult combers, which can grow up to ca. 40 cm standard length (SL), overlap in size with sexually immature groupers (Froese and Pauly 2021). Combers have similar ecology (i.e., solitary) to small groupers and exhibit minimal differences in osteomorphology (Desse and Desse-Berset 1996), presenting challenges to distinguishing their archaeological, often fragmented, bones without biomolecular tools.

Some grouper species in the Mediterranean can reach maximum total lengths (TL) around 1.5 m, weigh up to 60 kg (Craig, Sadovy de Mitcheson, and Heemstra 2011), and live upwards of 60 years (Reñones et al. 2007). Life history traits such as their long time to sexual maturity, slow growth rate, sequential hermaphroditism, small home ranges, and formation of spawning aggregations make them particularly vulnerable to overexploitation (Condini, García-Charton, and Garcia 2018; Robinson et al. 2015). High frequencies of large, high-level predators suggest healthy populations, whereas if they are lacking, it can be of great detriment to the local ecosystem, impacting foraging strategies and biodiversity among other factors (Estes et al. 2011). Although habitat preferences can differ between species, groupers generally seek shelters in coastal rocky reefs. The predominant method of exploiting groupers, recreationally and by small-scale fishers, is via spearfishing, vertical jigging or line and hook, with a lower percentage caught using fixed (e.g., trammel) nets or trawling (e.g., Mavruk et al. 2018).

The dusky grouper, *E. marginatus*, is the most iconic and most studied grouper species in the Mediterranean Sea and is deemed by the IUCN Red List Assessment to be "Vulnerable" across its global distribution and "Endangered" in the Mediterranean (Pollard et al. 2018). Several modern studies have highlighted that *E. marginatus* is more abundant and on average larger in size in Marine Protected Areas (MPAs) than

Table 1. Dating of the contexts from which the fish assemblages derive. Details of the phasing by site and dates are taken from the following sources as well as personal communication with excavation directors (Beach and Luzzadder-Beach 2008; Gates 2015, 2013, 2004; Genz et al. 2016; Kamlah and Sader 2019; de Miroschedji 2013).

Time Period	Dates	Kinet Höyük Phasing	Tell Fadous Phasing	Tell el-Burak Phasing
Early Bronze Age (EBA)	3600-2000 BC	–	–	–
EBA I	3600-3000 BC	–	–	–
EBA II	3000-2850 BC	Subphases 7-14	Phase II	–
EBA III	2850-2400 BC	Subphases 1-6	Phase III-IV	–
EBA IV	2400-2000 BC	–	Hiatus + Phase V	–
Middle Bronze Age (MBA)	2000 - 1550 BC	Phase V	Hiatus + Phase VI	–
Late Bronze Age (LBA)	1550 - 1200 BC	Phase IV	–	–
Iron Age (IA)	1200-332 BC	–	–	–
Early Iron Age (EIA)	1200 - 975 BC	Phase III.III	–	–
Middle Iron Age (MIA)	975-568 BC	Phase III.II	–	E, D, C
Late Iron Age (LIA)	568-332 BC	Phase III.I	–	C, B, A
Hellenistic Period	332 - 50 BC	Phase II	–	–
Medieval Period	8th/9th ca. - 14th ca. AD	Phase I	–	–

in nearby unprotected areas (Guidetti et al. 2014; Guidetti and Micheli 2011; Sala et al. 2012). Anecdotal records from fully protected areas (La Mesa and Vacchi 1999) and historical evidence (Guidetti and Micheli 2011) suggest *E. marginatus* is naturally (i.e., in the absence of fishers) more common at very shallow depths (<3 m). Nowadays, however, they are reported to thrive within the 8–300 m depth range, with maximum population densities down to 50 m depth (Froese and Pauly 2021). Increasing evidence shows deep waters provide refuge from fishing (especially spearfishing) in unprotected areas, while shallow waters are the natural habitat of the species. Comber exploitation has been studied to a lesser extent, as combers are often regarded as being bycatch and of lesser commercial value (İlhan et al. 2010; Rachedi and Tania Dahel 2019) but their typical depth range (upper 20 m) overlaps with groupers. Changes in *E. marginatus* size structure and depth distribution, similar to other target species, can thus provide indications of the fishing pressure occurring in a given area at a given time (Guidetti and Micheli 2011).

Sites and their coastal environment

Kinet Höyük, Tell Fadous, and Tell el-Burak, located on the southern Turkish and Lebanese coasts, represent a lesser explored region of the Levant regarding ichthyoarchaeology. All three sites contain multiple phases of human occupation with material culture attesting to their function as coastal trade hubs (Table 1). These sites have been partly destroyed by conflict, construction, and industrial activities during the twentieth and twenty-first centuries strengthening the value of the bioarchaeological collections under study.

Tell el-Burak

Tell el-Burak is a small site of approximately 1.5 ha, located on a well-watered coastal plain in Lebanon with the Lebanese Mountains to the east (Sader and Kamlah 2010). An underwater survey at Tell el-Burak noted a reef in front of the site extending about 50 m where it then turns to a sandy bottom (Pedersen 2011). Tell el-Burak had three phases of occupation, first in the Middle Bronze Age (MBA, ca. 1900–1700 BC), second in the Iron Age (IA) from the last quarter of the eighth century BC to the mid-fourth century BC, and third in the late Medieval and Ottoman periods (thirteenth to seventeenth century AD) (Kamlah and Sader 2019).

During the MBA the site was dominated by a single monumental building likely established by Sidon (ca. 9 km to the north) (Sader and Kamlah 2010). In the IA, the site is thought to have been an agricultural domain of either Sidon or Sarepta (ca. 4 km to the south). The lack of a natural harbor at the site and presence of a rocky reef is thought to have made it unsuitable for large ships (Sader and Kamlah 2010), furthering the argument that it was not a maritime center, but rather an agricultural estate. Agriculture mainly focused on wine and oil production (Orendi and Deckers 2018) with ovicaprids for consumption and cattle predominantly used for traction (Çakırlar 2019; Vermeersch 2021).

Tell Fadous

Tell Fadous is a Bronze Age site in central Lebanon, similar in size to Tell el-Burak, covering an area of about 1.5 ha (Genz 2010). Unlike Tell el-Burak, Tell Fadous is located on a cliff overlooking the coast lined with rocky outcrops anglers use to fish from today. An underwater survey of the small natural bays near Tell Fadous indicated that the rocky shoreline there experiences high wave activity which has likely eroded the shoreline over time (Pedersen 2007). Tell Fadous was occupied from the late Chalcolithic/Early Bronze Age (EBA, ca. 3400 BC) to the MBA (ca. 1500 BC) (Höflmayer et al. 2014). Most of the archaeological finds, including the fish bones for this study, come from the fortified EBA occupation (ca. 2700–2300 BC). Tell Fadous was likely an administrative site connected with the nearby Bronze Age center of Byblos (Genz et al. 2016). Botanical and faunal remains indicate a heavy reliance on agriculture and animal husbandry, as well as regular fishing and shellfish gathering (Deckers et al. 2021; Genz et al. 2016).

Kinet Höyük

Kinet Höyük, identified with Classical Issos, is a mound occupying about 3.3 ha in the most northeastern corner of the Mediterranean Sea in Iskenderun Bay (Gates 2015). Kinet Höyük was positioned on a promontory with a bay located to the north and an estuary on the south (fed by the River Deli Çay), with both of these being filled with alluvial sediments by the Hellenistic Period (Beach and Luzzadder-Beach 2008).

Kinet Höyük was occupied and fortified in the EBA (ca. 2800–2400 BC), followed by a "collapse" toward the end of this period (2300–2000 BC) (Eslick 2021). The EBA assemblage from Kinet Höyük is contemporary with the Tell Fadous assemblage. In the MBA (2000–1550 BC), Kinet Höyük was reoccupied, with ceramic finds connecting the

site to Cyprus (Kozal 2006). The Mediterranean connections expanded in the LBA (1550–1150 BC) with finds of Hittite style pottery (coinciding with a strong Hittite influence of the Kinet Höyük port [Gates 2013]), Aegean style transport jars, Canaanite jars with seal impressions, and Cypriot copper (Yildirim and Gates 2007). Throughout the Iron Age (1150–330 BC), Kinet Höyük was a place of cross-cultural exchange between the Mediterranean and Near East (Hodos, Knappett, and Kilikoglou 2005). After being abandoned in the Hellenistic Period (330–50 BC), Kinet Höyük was again reoccupied during the Crusader era (late twelfth to early fourteenth centuries AD) with finds indicating trade connections spanning Italy to Syria (Redford et al. 2001). The inhabitants of Kinet Höyük predominantly relied on cereal agriculture and animal husbandry, with their diets also incorporating aquatic resources and occasionally wild mammals (Cakirlar 2003; Çizer 2006).

Materials and methods

Recovery

From Tell el-Burak all fish remains in this study were recovered via hand collection during excavations (although additional fish remains come from the heavy residue of floatation, none were identified as grouper or comber). At Kinet Höyük and Tell Fadous specimens came from hand collection and wet sieving through 2 mm mesh size. Floating for light archaeobotanical remains have yielded fish remains from 1 mm, 0.5 mm, and 0.2 mm mesh sizes as well, but none could be attributed to groupers or combers. Grouper and comber bones at the three sites chiefly come from trash middens and/or secondary mixed contexts. The Number of Identified Specimens (NISP) by site for grouper and comber bones is 1488 at Kinet Höyük, 287 at Tell Fadous, and 76 at Tell el-Burak. Additional details of the excavations can be found in the Supplementary Materials. Out of the 467 grouper and comber articulars, dentaries, quadrates, and premaxillae identified (bones used for osteometric size reconstruction) from the three sites, 54% provided at least one osteometric measurement to allow size reconstruction, suggesting relatively well-preserved bones. Only six specimens, all from Kinet Höyük, displayed signs of burning.

Size reconstruction

Size reconstruction from grouper and comber bones has been done to determine the size distribution of these fishes in the past; a strikingly low proportion of large fish may cautiously suggest heavy exploitation of local grouper and comber populations. Determining catch sizes in the past contributes to gaining an understanding of past grouper and comber fisheries in the eastern Mediterranean. Morphologically distinct elements (e.g., premaxillae, dentaries) were identified using the modern reference materials at Tübingen University, University of Groningen, and the Royal Belgian Institute of Natural Sciences. Except for a few instances (i.e., placement of a foramen on the dentary and shape of denticles on the preopercular in only two species of grouper [Desse and Desse-Berset 1996]), no clear anatomical differences were noted that can distinguish grouper and comber bones morphologically. Any fish estimated to be less than 40 cm

TL can be assumed to either be a comber (Serranidae) or sexually immature grouper (Epinephelidae), based on the reported maximum comber size and the size of grouper sexual maturity (Froese and Pauly 2021).

It is common for size reconstruction of archaeological fish to be done by taking measurements of cranial elements (e.g., Casteel 1976). Measurements for this study were taken as described in Morales-Muñiz and Rosenlund (1979) using the depictions shown for Gadus and *Epinephelus* sp. specific measurements as presented in Desse and Desse-Berset (1996). Previously published (Desse and Desse-Berset 1996) and newly developed regression equations (Supplementary material, Figures S1–S4) were used for size reconstructions. Where multiple measurements could be taken from the same bone, the average of the estimated sizes has been used. Estimated fish sizes are reported here as total length (TL). Where metrics were not possible, 400 bones were compared with 22 modern specimens ranging in size from 12 to 82 cm SL in the reference collection at the Royal Belgian Institute of Natural Sciences in Brussels.

Minimum Number of Individuals (MNI) has been used as opposed to Number of Identified Specimens (NISP) to estimate the relative abundance of different sized groupers and combers at each site. MNI was determined per context, meaning that if multiple elements were estimated to be from a fish of the same size, those elements would collectively be counted as one fish instead of as multiple fish. Statistical analyses were performed only for size estimates determined by metrics (as opposed to by comparison) and were done using the Past software (version 4.07) (Hammer, Harper, and Ryan 2001). Following Shapiro Wilk tests for normality, one-way analysis of variance (ANOVA) or Welch's tests were used to test differences of size estimations among different periods at $\alpha = 0.05$ significance level.

Estimating grouper and comber abundance through time

Few ichthyoarchaeological studies (Capriles et al. 2014; Rebolledo, Béarez, and Zurro 2021; Van Neer et al. 2013) take into account the volume of soil excavated, sieved, and/or floated. This is important because of the demonstrated impact the mere act of sieving can have on the size and diversity of fishes recovered in archaeological contexts (Clason and Prummel 1977; Zohar and Belmaker 2005).

Due to excavation records being readily available for Kinet Höyük, but not the other two sites, the total volumes of soil excavated and sieved were determined. This was done to investigate if and how the interpretation of past grouper fisheries would change if all of the soil on site were sieved. Abundance by time period was calculated as MNI per volume of soil. To calculate the volume of soil from which hand collected material was obtained, we looked at locus sheets to determine the area and depth (cubic meters) of each locus excavated. For calculating the volume of soil from which sieved bones were obtained, we looked at botanical sampling records to find the volume (liters) of soil floated and subsequently sieved per locus (Gates et al. 2020). It is not standard for all of the soil excavated at a site to be sieved to recover small artifacts and bioarchaeological remains, meaning the total volume of soil excavated at a site far exceeds the volume of soil sieved.

To compare volumes by recovery method, cubic meters were converted to liters. These calculations showed approximately 1% of the total volume of soil excavated was sampled

Table 2. Size ranges for grouper and combers as estimated via osteometrics from hand collected and sieved material.

Archaeological site	Minimum TL (cm)	Maximum TL (cm)	Average TL (cm)	Standard error	Sample size
Kinet Höyük	19.5	156.3	73.7	2.23	156
Tell Fadous	20.3	155.4	61.0	2.28	88
Tell el-Burak	25.1	52.1	38.0	3.2	8

for flotation (and subsequent sieving of the resultant heavy residue) at Kinet Höyük. The densities of groupers and combers were determined by calculating the MNI per cubic meter of soil sampled (sieved material) and MNI per cubic meter of soil excavated (hand collected material). For demonstrative purposes, we present hypothetical MNIs by size categories to show what the size distribution of groupers and combers may have been if all the soil excavated at Kinet Höyük were sieved. To generate this artificial estimation, MNI data by size category for the sieved material was multiplied by 99 as the volume of soil excavated was approximately 99 times greater than the volume of soil sampled for flotation and then sieving. As a word of caution, this approach is not without its limitations—soil sampling at Kinet Höyük often targeted particular contexts such as near hearths or floors as opposed to being totally random throughout a site.

Results

Size estimates (specifically by metrics, Table 2) could be determined for 502 groupers and combers from Kinet Höyük, 127 from Tell Fadous, and 22 from Tell-el Burak. Size reconstructions are reported as TLs and the original measurements with estimated SLs are provided online at http://doi.org/10.6084/m9.figshare.18976331. The fish estimated to be less than 40 cm TL represent combers and small groupers, 40–80 cm TL medium-sized groupers, and anything over 80 cm TL a large grouper.

Tell el-Burak

Groupers and combers come from the MBA (MNI = 11), Iron Age (MNI = 6), and the final five specimens from mixed contexts. The grouper and comber remains (MNI = 22) recovered from Tell el-Burak came from fish ranging in size from 20 to 70 cm, with 45% of the assemblage being combers or small groupers and 55% being medium-sized groupers (Figure 2A). While sample size is small, there are no large groupers; the largest recorded grouper is in the 61–70 cm TL size category.

Tell Fadous

The groupers and combers (MNI = 127) from Tell Fadous range in size from 11 to 155 cm (TL) with 23% of the assemblage being combers and smaller groupers (<40 cm TL), 61% medium-sized groupers (40–80 cm TL), and 16% large groupers (>80 cm TL) (Figure 2B). Approximately 70% of the groupers and combers come from the EBIII Period (MNI = 89). Statistical comparisons by time period are between the EBIII, EBIV, and MBA periods as there was only one grouper or comber from the EBII. One-way ANOVA of the groupers and combers from the sieved material indicates no

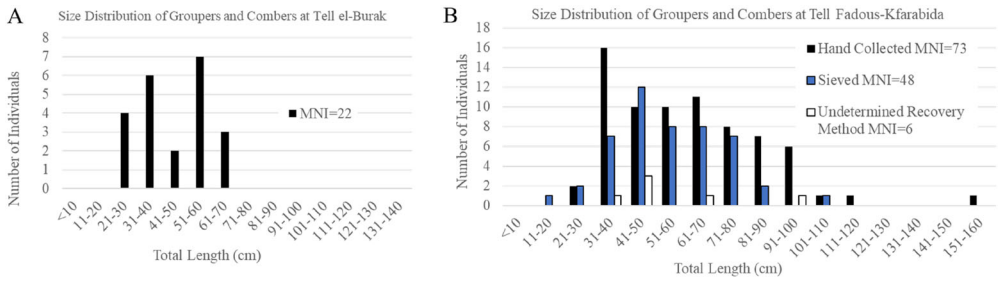


Figure 2. (A) Size distribution of groupers and combers recovered from Tell el-Burak (hand collection) and (B) Tell Fadous-Kfarabida (hand collection and sieving).

significant difference among time periods [$F(2, 34) = 0.46$, $p = 0.63$] and a Welch's test of the hand collected material also indicates no significant difference among time periods ($F = 3.30$, $df = 2.85$, $p = 0.18$).

Kinet Höyük

The groupers and combers (MNI = 502) from Kinet Höyük range in size from 11 to 156 cm TL. Combers and small groupers (MNI = 129) compose 26% of the assemblage, with a MNI of 73 from hand collected material and a MNI of 56 from sieved material. Medium-sized groupers (MNI = 314) account for 63% of the assemblage, with a MNI of 299 from hand collected material and a MNI of 15 from sieved material. Regarding the large groupers, a MNI of 1 comes from sieved material and a MNI of 58 from hand collected material, jointly constituting 12% of the assemblage (Figures 3 and 4, Supplementary material, Tables S1 and S2). All large groupers (MNI = 59) were recovered from secondary and tertiary contexts, mostly mixed middens.

Assessing osteometric size estimations from the hand collected material, a Welch's test indicates no significant difference between time periods (albeit it should be noted this p-value is close to the significance threshold) ($F = 2.75$, $df = 13.19$, $p = 0.053$). An independent t-test comparing the hand collected material from the Hellenistic and Medieval periods indicates a significant difference between these two time periods ($p < 0.01$), with larger individuals in the Hellenistic Period.

For the sieved material, a Welch's test indicates no statistically significant difference in size estimates between all the time periods ($F = 2.98$, $df = 6.89$, $p = 0.09$). There is only one comber or grouper from the Early Iron Age (EIA) sieved material for which size could be estimated and therefore it is excluded from statistical analyses.

Catch size estimates of the EBA and MBA at Kinet Höyük are similar with 60% of the grouper and comber specimens coming from groupers of 40–110 cm TL. Within the Bronze Age at Kinet Höyük, particularly large (>100 cm TL) groupers are only recovered from the MBA and LBA occupations. The EIA, MIA, and LIA at Kinet Höyük are when the greatest proportion of the grouper and comber assemblages are groupers over 100 cm TL (9.5%, 6.8%, and 7.2%, respectively).

Medium- and large-sized groupers dominate the hand collected comber and grouper assemblage from the Hellenistic Period (~85% being groupers of 60–110 cm TL) compared to the Medieval Period with 50% of the grouper and comber assemblage being

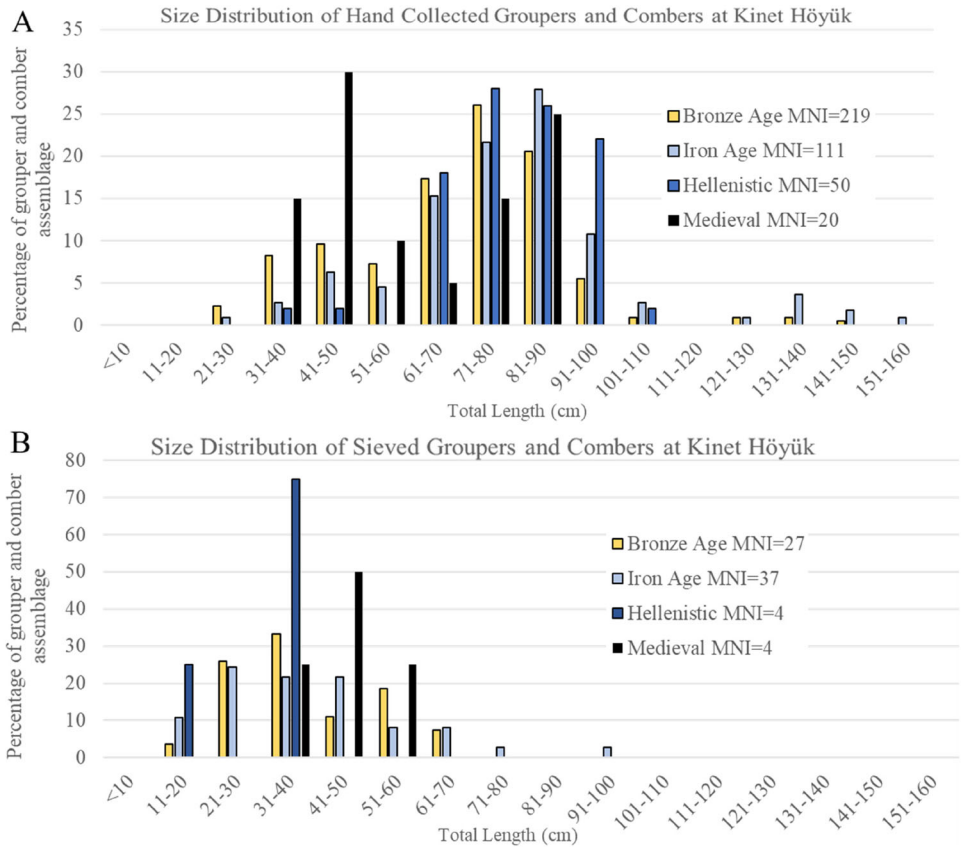


Figure 3. (A) Size distribution of groupers and combers from Kinet Höyük from hand collected and (B) sieved recovery methods.

fish of 31–50 cm TL. Of particular note, by the Hellenistic and Medieval periods, there are exceptionally few groupers over 100 cm (one from an MNI of 78). In most of the earlier periods (excepting the EBA) the percentage of groupers over 100 cm is higher, they are 7% of the assemblage for the MBA, 3% for the LBA, 10% for the EIA, 7% for the MIA, and 7% for the LIA.

Grouper and comber abundance and density at Kinet Höyük

Figure 5 shows a comparison of the raw data and the inflated, hypothetical MNIs by size category at Kinet Höyük if all soil had been sieved. This extrapolation suggests that if all excavated soil had been sieved, the abundance of combers and smaller groupers in the assemblage would have been markedly greater than medium and large groupers. These graphs should be considered cautiously, as archaeobotanical reports detailing the volume of soil floated could not be located for every locus and locus dimensions (x, y, z) were sometimes estimated from the excavation records. Most importantly, we cannot assume each locus yielded the same amount of grouper bones per volume (cubic meter) of soil. The density of grouper and comber remains from hand collected material is

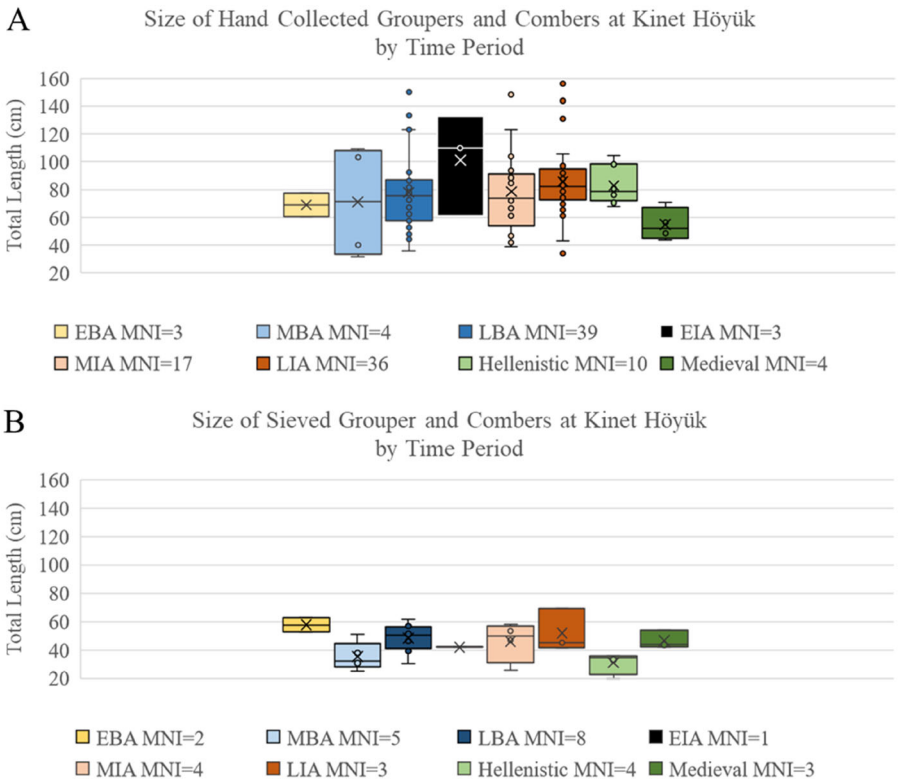


Figure 4. (A) Estimated size of groupers and combers from hand collected and (B) sieved material by time period at Kinet Höyük as estimated by osteometrics.

lowest in the MIA (0.004 Epinephelidae and Serranidae MNI/m^3) and highest in the LIA (4.20 Epinephelidae and Serranidae MNI/m^3) (Table 3).

Discussion

Generally, the size ranges of groupers in the assemblages we studied are comparable with zooarchaeological evidence for grouper fishing at other Middle to Late Holocene sites in the eastern Mediterranean. Predating our study material, from Neolithic Cyprus, groupers with sizes ranging from ca. 25 to 100 cm TL were reported (Desse and Desse-Berset 1994, 2011). Contemporary with our study sites, EBA Ashqelon reported an estimated size range of 44–70 cm SL from 18 bones (Lernau 2004), LBA Tell Abu Hawam with an MNI of seven groupers had a size range of 25–100 cm TL (Zohar and Artzy 2019), and Bronze Age Sidon recovered groupers ranging in size from 20 to 90 cm SL (Van Neer 2006). Interestingly, the medieval site of Tel Taninim in the southern Levant, similar to the medieval occupation at Kinet Höyük, only has groupers (or combers) (MNI = 2) of smaller sizes present (estimated sizes of 36 cm and 29 cm, TL or SL not specified) (Gertwagen 2016). Collectively, these sites represent a small sample size from which there are no apparent trends of changes in catch size over time. The minimal recovery of combers and small groupers can likely be attributed to hand-collection recovery methods during excavations.

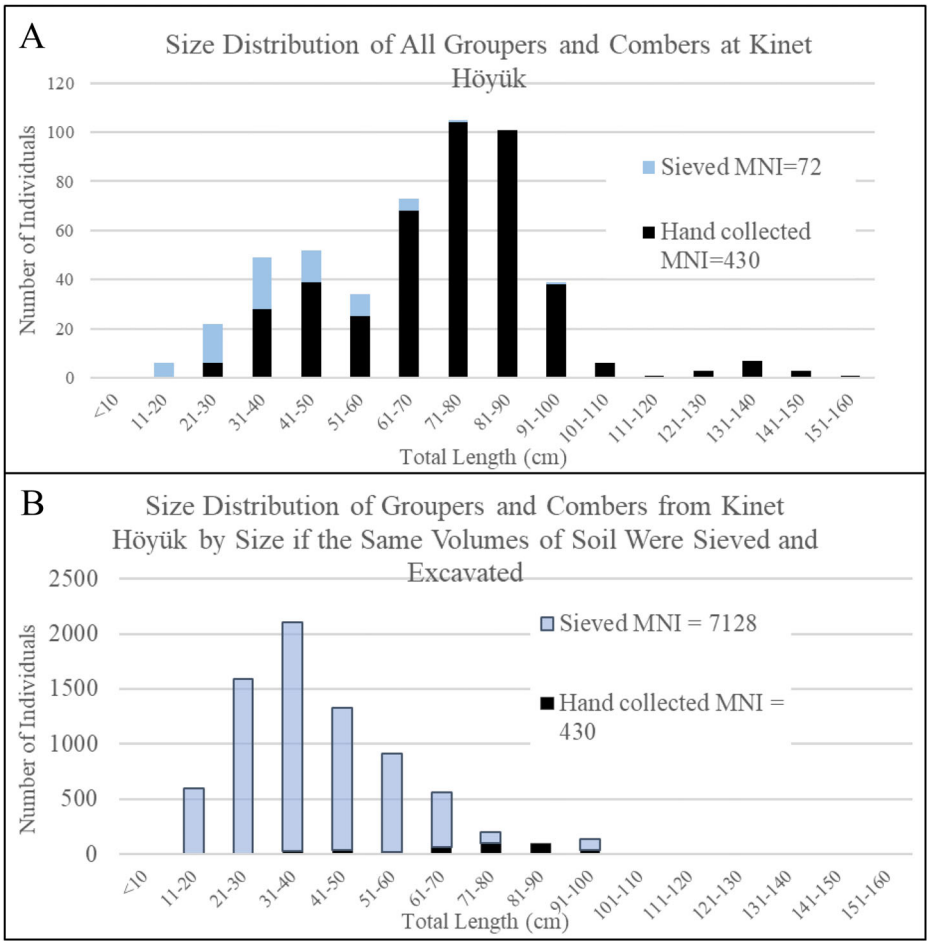


Figure 5. (A) Size distribution of all combers and groupers from Kinet Höyük as estimated by osteometrics and comparison with a reference collection. (B) Hypothetical size distribution of groupers and combers at Kinet Höyük if all soil excavated at the site was also sieved.

Table 3. Soil volumes by recovery method with MNI of groupers and combers and their density by time period at Kinet Höyük.

	Hand collected				Sieved			
Time period	Volume (m^3)	MNI EPI + SER	Average density (EPI + SER/ m^3)	Standard deviation	Volume (liters)	MNI EPI + SER	Average density (EPI + SER/ Liter)	Standard deviation
EBA	159	32	2.32	7.42	1373	14	0.016	0.033
MBA	30	37	2.52	3.26	1323	16	0.016	0.025
LBA	616	166	1.91	6.24	2526	41	0.028	0.036
EIA	42	16	0.83	1.59	909	18	0.019	0.029
MIA	227	1	0	0.04	1523	25	0.014	0.028
LIA	514	267	4.2	12.37	3391	30	0.017	0.025
HELL	83	25	0.99	1.49	868	13	0.009	0.021
MED	157	1	0.4	2.54	1349	12	0.008	0.014

Our results from Kinet Höyük and Tell Fadous show that catching impressively large groupers (>100 cm TL) was not uncommon in the past. At Kinet Höyük, by the LIA, there is an apparent increase in the consumption of large groupers (Çakırlar, Ikram, and Gates 2016) and the highest density (abundance) of groupers and combers is observed, directly preceding the Hellenistic and Medieval periods when large groupers become virtually absent from the ichthyofaunal assemblages. The reduced abundance of groupers and combers in the Hellenistic and Medieval periods (Table 3) based on lower densities additionally coincides with when large groupers over 100 cm TL become virtually absent from the assemblages. The only statistically significant difference in catch sizes at Kinet Höyük is between the Hellenistic and medieval occupations. There are very few large groupers by the Hellenistic Period at Kinet Höyük and they are completely absent by the Medieval Period (Figures 3 and 4). When the discrepancies in volumes of soil are accounted for (Figure 5), however, the entire narrative of grouper and comber exploitation at Kinet Höyük dramatically changes to present a picture of groupers over 100 cm TL being exceptionally rare and an exploitation emphasis on combers and/or small groupers. Due to the inaccessibility of field data for other sites, abundance of groupers and combers over time at Tell el-Burak and Tell Fadous could not be determined.

Understanding fishing activities and past local ecosystems cannot be done in a vacuum of solely looking at MNIs and catch size data. Additional factors need to be considered to more holistically assess these findings such as past coastal morphology, fishing technology, and sociocultural circumstances.

Knowledge of changes to past coastlines is critical for contextualizing changes in fishing catches (e.g., Morales-Muñiz and Roselló-Izquierdo 2016). Today, the Levantine coast is relatively straight with few natural harbors and/or deep anchorages but this was not the case until the Late Holocene. The alluviation of the River Deli Çay at Kinet Höyük during the Hellenistic Period in turn may have meant that over time the coastline was sandier with increasingly less rocky seabed, consequently decreasing the suitable habitat available to most groupers (but not combers). The precise nature of seabeds in the Bronze and Iron Age beside Tell el-Burak and Tell Fadous remains to be studied.

Due to the range of sizes and variety of fishing technology recovered from the region, the exact method for fishing groupers and combers remains speculative (Morales-Muñíz 2010; Morales-Muñiz and Roselló-Izquierdo 2016). An absence of large fish may be attributed to heavy exploitation of groupers along this part of the Levantine coast since the Bronze Age, which could be a result of either fishing pressures or the adoption of fishing strategies better suited to grouper fisheries (i.e., targeting spawning aggregations). Alternatively, it may be that such a high abundance of smaller predatory fish is natural and the product of high population turnover rates.

Hooks, spears, and/or tridents have been discussed and depicted as the most suitable means for fishing groupers in prehistory (Guidetti and Micheli 2011; Morales-Muñíz 2010), which is consistent with modern methods of grouper exploitation in the eastern Mediterranean (Mavruk et al. 2018). Small pebbles (ca. 2–3 cm diameter, weighing 8 g [Hermann Genz, personal communication]) from the EBA with a manmade groove were recovered from Tell Fadous which may have been used as line weights or for nets to catch combers or groupers. Sinkers for nets and hooks from Bronze Age Tell el-Burak have been recovered from excavations (Schmitt 2019). From Kinet Höyük, lead sinkers, spear

points (which may have been used for fishing or other purposes), and in particular an impressive hook (ca. 7 cm) from the Iron Age have been recovered (Marie-Henriette Gates, personal communication). Considering the range of technologies recovered and feasible for catching groupers and combers, it is difficult to discern precise fishing methods and/or if fishing technology played a significant role in catch sizes.

Sociocultural and political factors may have also played a role in the distribution of catch sizes at each site. Cylinder seals in administrative buildings and a small-scale beam made of bone represent high-status finds at Tell Fadous in the EBA (Genz 2013, 2011). Of the large groupers recovered from Tell Fadous (MNI = 19), four were from Building 1 which has been deemed an "elite residence" and eight large groupers were from Building 4, which was noted to be very large and likely served an administrative or public purpose (Genz et al. 2016). The contexts in which most of the large groupers were recovered at Tell Fadous suggest the largest fish may have been reserved for more elite members of society.

When the size distribution and density of recovered grouper and comber bones of Bronze Age Kinet Höyük are compared with occupations of the same time periods at Tell el-Burak and Tell Fadous, larger groupers were being caught more consistently at Kinet Höyük. The low density of grouper and comber remains from hand collected material in the MIA (Table 3) coincides with a focus at Kinet Höyük on domesticates such as pigs and sheep (comparable to other MIA Levantine sites) (Lehmann 2016). In the LIA is the highest density which is contemporary with a time period of feasting upon groupers in the Levant (Çakırlar, Ikram, and Gates 2016) and cultural influence from the heavily marine resource exploiting inhabitants of the Aegean (Mylona 2008).

The lack of large groupers and smaller sample size at Tell el-Burak could be attributed to the inhabitants being more focused on agricultural endeavors than exploiting marine resources in the MBA and Iron Age (Orsingher et al. 2020; Sader and Kamlah 2010). Paleodietary studies at Sidon further indicate that MBA inhabitants of this region were minimally consuming marine resources (Stantis et al. 2022). More holistic insight regarding the intensity of marine exploitation at our study sites requires, and is pending, full ichthyoarchaeological analyses.

There are relatively high percentages of groupers >100 cm TL in all Iron Age periods at Kinet Höyük. Levantine Iron Age coincides with the rise of city states and high levels of trade throughout the Mediterranean, particularly at Kinet Höyük where in the eighth and ninth centuries BC fine tablewares and vessels from Greece, Cyprus, and Phoenicia have been recovered (Hodos, Knappett, and Kilikoglou 2005). Furthermore, much of the Iron Age pottery at Kinet Höyük is surmised to have been locally made in imitation of Greek and Cypriot styles (Hodos, Knappett, and Kilikoglou 2005), testament to the local influence of Grecian and Cypriot cultures. Contemporaneous with evidence for grouper butchery at Kinet Höyük are Classical Greek comedies which attest to the luxury status of large, solitary fish—in particular their heads (Wilkins 2000). A high abundance of butchered grouper cranial bones and scarcity of the axial skeleton at late fifth century BC Kinet Höyük demonstrates the formalized processing of grouper heads for local consumption (Çakırlar, Ikram, and Gates 2016). This butchery evidence and the abundance of large groupers (40% of the LIA Epinephelidae and Serranidae assemblage)

may represent the development of a local cultural preference for serving and consuming large groupers that was influenced by connections with Greece.

Combining catch size data and abundance of combers and groupers at Kinet Höyük paints a picture of intensive fishing for combers and smaller groupers. Thus, large groupers may not have been selectively fished, enabling local grouper populations to be characterized by a high proportion of large spawners.

Despite no great advancements in grouper fishing technology (Morales-Muñíz 2010), centuries of intensive grouper fishing may have caused some "fishing down the food web" (Pauly et al. 1998) at Kinet Höyük. Modern data from MPAs and aforementioned observed changes in depth distribution based on fishing efforts helps us to interpret this notable decrease in large groupers after the LIA at Kinet Höyük. The potential outcomes include the possibility that intensive, persistent fishing efforts were detrimental to the size structure of local grouper populations over time or caused a behavioral change of becoming less targetable by moving deeper to seek refuge from fishing pressures.

Today, large groupers exceeding 100 cm TL are rarely reported in modern Mediterranean ecosystems, and when they are, they are observed in well-enforced, fully protected, and long-established MPAs (Hackradt et al. 2014). Given fishing size-selectivity, especially of spearfishing, larger grouper individuals (mostly males and highly fecund females, both effective predators in their ecosystems) tend to be predominantly removed from local populations (Sbragaglia et al. 2021). Fishing thus truncates the size and age structure of such populations, impacting their sex ratio, spawning-stock biomass, and recruitment levels, in turn increasing the extinction risk of these species, at least locally where fishing is intense. Moreover, groupers of targetable size tend to move deeper to escape spearfishers (Guidetti and Micheli 2011). Fishing regulations, particularly within well-enforced MPAs, have proven effective to promote the recovery of local grouper populations due to the resulting increased presence of large-sized individuals (Di Franco et al. 2009; Sala and Giakoumi 2018).

Conclusion

Osteometric size reconstructions from grouper and comber bones recovered at the Mid–Late Holocene coastal settlements of Kinet Höyük, Tell Fadous, and Tell el-Burak suggest frequent exploitation from a population in which large (>80 cm TL) groupers are not uncommon, indicating healthy, well-structured local populations with large spawners allowing for population persistence. Of note, the recovery of impressively large (ca. 100–150 cm TL) groupers from Kinet Höyük and Tell Fadous coincides with the rise of coastal urbanism in the Levant and establishes an important ecological baseline for the eastern Mediterranean today. The diachronic sample from Kinet Höyük, however, indicates that very large groupers may have become rare by the Hellenistic Period and virtually absent by the Medieval Period, hinting at possible overexploitation. The case study of soil volumes by recovery method at Kinet Höyük serves as a cautionary tale when making conclusions from traditionally reported zooarchaeological data such as NISP and MNI. Sieved samples yielded a lot of Serranidae and/or smaller (<40 cm TL) Epinephelidae suggesting that at Kinet Höyük combers and smaller groupers were more frequently captured than larger groupers. If fishing efforts were predominantly affecting smaller fish, thus

avoiding the consequences of selectively fishing large individuals, past grouper populations may have been comparable to those found in well-enforced MPAs today.

Supplementary Files

Additional details of excavations; Additional details of obtaining soil volumes excavated; Tables S1, S2, S3; Figures S1, S2, S3, S4.

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The authors report there are no competing interests to declare.

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