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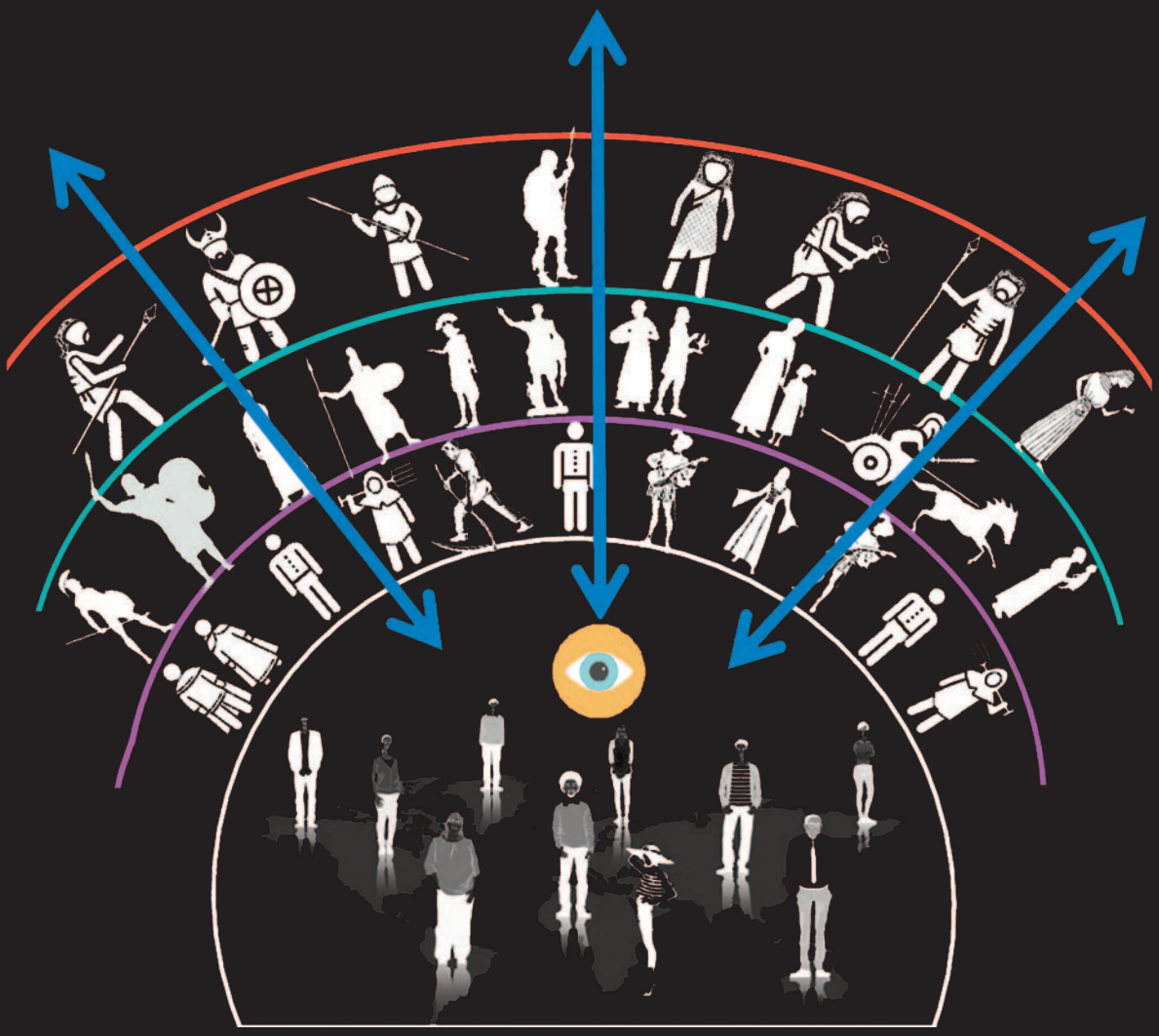

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Mirko Fecchio, Maurizio Marinato*

Change in diet or visibility problem? Observations on the marine isotopic values of early medieval populations in coastal Croatia

1. Introduction

The island of Rab is in the Kvarner archipelago of the Croatian littoral-mountain region. It has been the subject of archaeological investigations for over a decade by the Department of Cultural Heritage of the University of Padua and the Faculty of Humanities and Social Sciences of the University of Zagreb (fig. 1). The archaeological investigations have covered numerous sites both in the countryside (churches, monasteries, castles, and villas, as well as landscape analysis) (Brogiolo *et al.* 2013; Jurković *et al.* 2012; Brogiolo *et al.* 2017) and within the urban landscape of ancient Rab, a city with protohistoric origins that saw Roman and Late Antique-Byzantine phases, followed by significant Late Medieval reorganization shaping the current architectural structure (Brogiolo *et al.* 2023).

Between 2015 and 2018, archaeological campaigns were carried out in Dinka Dokule Street (fig. 1), documenting the evolution of this urban area, characterized initially by a Late Antique funerary zone, followed by a fortification from the late 6th to early 7th centuries that overlays part of the tombs (some in sarcophagi), and a series of subsequent metallurgical activities (Brogiolo *et al.* 2023).

This paper focuses on the faunal remains uncovered at the construction site for a city wall (late 6th-early 7th century AD) and in a building adjacent to the wall, dated between the 7th and 8th centuries AD; and three burials, one of which is multiple, from the initial phase. The data have been supplemented with analyses from a burial, likely dating to the early medieval period, contemporary with the

* University of Padova, Department of Cultural Heritage, *mirko.fecchio@phd.unipd.it, maurizio.marinato@unipd.it*.

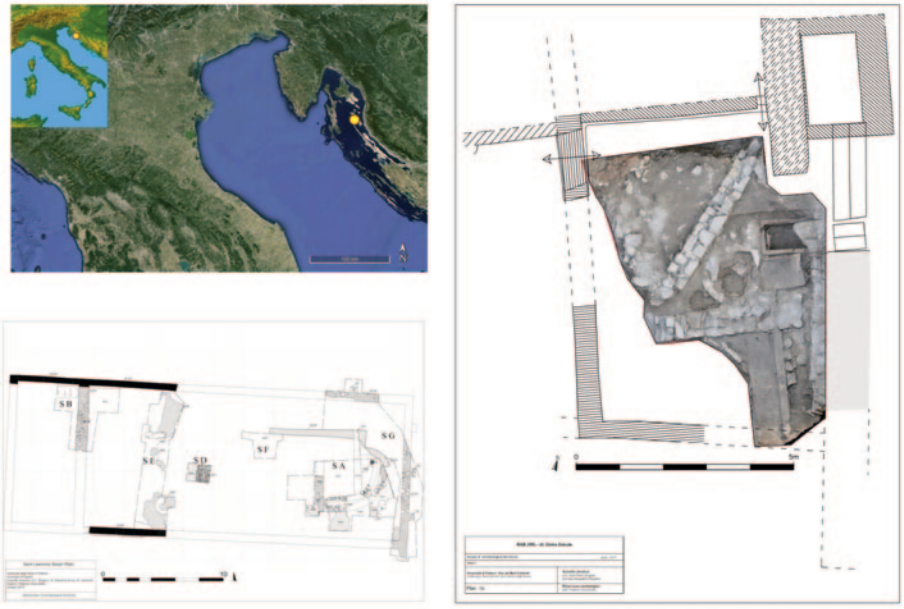

Fig. 1. Island of Rab and the excavations conducted at Dinka Dokule and St. Lawrence in Banjol.

second phase of the church of Saint Lawrence, which is three kilometres far from the Dinka Dokule site, discovered during the 2015 and 2016 excavations (Brogiolo *et al.* 2017).

This research aims to reveal, through zooarchaeological study and stable isotope analyses ($\delta^{13}C$ and $\delta^{15}N$), the aspects that characterized animal management and the diet of the early medieval population of an *emporion* of the Byzantine Empire.

2. Historical and environmental background

The history of the island of Rab dates back to the Middle Paleolithic. During the Bronze Age, several hillforts were strategically built for territorial control. Evidence of burials at Gromačica and Pečina confirms the presence of these fortified villages until the Iron Age. By the end of the Bronze Age, a tribe unified some of the hillforts, forming larger centers such as Rab and Kastelina, and building new ones. Archaeological findings indicate commercial exchanges between Liburnia, Greece, and Italy (Batovič 1987, pp. 147-169). According to Strabo, the Liburni, part of the Illyrian population, arrived on the northern Adri-

atic coasts after being expelled from Corcyra by Corinthian colonists. Pliny the Elder, in his *Naturalis Historia*, described the Liburni as savage tribes dedicated to piracy, who were defeated by Consul *Gaius Sempronius Tuditanus* in 129 BC (Wilkes 1977, p. 160). Pliny also mentioned several cities in the Gulf of Kvarner, including *Arba*, which received *jus italicum* (G. Plinio S., O.C., L. III, 140), becoming fortified military ports that controlled trade across the North of the Adriatic Sea.

With the advent of the Imperial age, the island of Rab and the entire regions of Liburnia and Dalmatia became the Province *Superior Illyricum*, renamed Dalmatia under Emperor *Titus Flavius Domitian* in 96 AD, and linked to Salona (Tomaz 2003, pp. 103-104). During the Gothic War (535-553 AD), Justinian reconquered the islands of the Kvarner, placing them under the Eastern Roman Empire. In the 7th century, while much of the Italian peninsula fell under Lombard control, Dalmatia faced Slavic invasions but retained control of the coastal areas, including Rab, which remained strongly Latin. The Dalmatian islands remained under the exarchate of Ravenna until 726 AD, then became connected to Constantinople after Ravenna fell to the Lombards in 751 AD (Tomaz 2003, pp. 240-241). In 812, the *Pax Nicephori* established imperial boundaries, placing the Dalmatian coasts and islands under Eastern dominion. Constantine VII's *De administrando imperio* (950) referred to the citizens of various Adriatic cities, including *Arba*, as Romans.

Information on the diet of Croatian populations in the Early Middle Ages is scarce, mainly due to the limited presence of written sources on the subject. Most of the available data therefore comes from biochemical analyses conducted on skeletal remains from the period, which will be examined for comparison, or from recent paleoenvironmental studies carried out on specific case studies within the archipelago.

Through the analysis of lake sediments from Vrana and Osor, the IATECA research program (Interdisciplinary Approach to the Territorial Evolution of the Kvarner Archipelago) has highlighted the evolution of ancient landscapes and socio-cultural changes on the island of Cres, located a few kilometers from Rab. Despite the chronological imprecision of sedimentary deposits over short time scales, the dating model for Vrana is more reliable than that Lake Osor's. This has allowed the reconstruction of landscape exploitation in the region from the beginning of Roman rule to the early Middle Ages.

The study on the occupation of Kvarner, focused on the southern part of Cres, highlights two significant periods. The first is characterized by the establishment of Roman power starting from the 1st century BC, followed by the territorial reorganization of northern Liburnia between the late 2nd and 4th centuries AD. During this period, the construction of urban walls and structures in cities such as Krk, Rab, and Osor, as well as the settlement of large maritime and rural estates, can

be observed. Lake sediments supplement our understanding of the region, indicating the introduction of crops such as olives in the 1st century BC, followed by walnuts and deforestation in the 2nd century AD. The 3rd century saw the introduction of cereals, vineyards, and chestnuts, reflecting an agricultural change related to regional reorganization.

In the 4th century, there was an increase in livestock around Lake Vrana, possibly linked to wool production for the Roman army. During the Byzantine period, cereal cultivation intensified, probably in response to the crisis of Mediterranean trade links from the 7th century. These transformations reflect an adaptation to socio-geopolitical and climatic dynamics, showing how the Kvarner islands were integral parts of Mediterranean exchange flows despite their apparent isolation. This study has underscored the importance of agricultural and pastoral practices in the adaptation of local communities to historical and environmental changes (Čaušević-Bully *et al.* 2021).

According to archaeobotanical studies, during the Roman and late antique periods, the diet was enriched with varieties such as spelt, barley, emmer, millet, grapes, olives, legumes, cabbage, and carrots. The cities of Narona and Vis and the areas around the city of Zara were renowned, even by the author Strabo, to produce wine and olive oil (Škegro 2006, pp.157-159; Wilkes 1992, p. 220). Although agriculture dominated, historical sources and individual archaeozoological studies in southern Dalmatia testify to the consumption of fish and animals hunted, such as deer, hares, and wild birds (Wilkes 1992, p. 222; Schwartz 1996). In Early Medieval Croatia, evidenced by the material culture of funerary contexts, a mixed agricultural model with cultivation and livestock farming of cattle, pigs, sheep, goats, and poultry emerged (Evans 1989, p. 206). The economy was also influenced by trade along the Adriatic coast to Venice, as evidenced by commercial artefacts and imported objects (Piteša 2006).

These findings outline a continuity in the management of agricultural and food resources across historical periods, showing adaptations to available resources and the commercial dynamics of the time. The few data available in the literature on the exploitation of plant and animal resources find only some common points with what emerged from the present study.

3. Zooarchaeological evidence

The analysed archaeozoological record comprises 1403 bone fragments, of which over 72% were taxonomically identified thanks to the excellent preservation of the remains. Approximately 380 fragments, mainly ribs, and skulls of small to medium-sized herbivores, could not be identified to the species level.

Fig. 2. Percentage distribution of the Number of Remains (NR) for each animal *taxa* documented in the investigated faunal sample.

The analysis[1] has provided a comprehensive overview of animal exploitation between the 6th and 8th centuries AD, including both major domestic species (sheep and goats, pigs, and cattle) and fish resources, which were an essential food source for the island's inhabitants. The high number of butchery marks on the bones, along with the study of the age at slaughter and the sex of the individuals, has led to a deeper understanding of meat consumption by the inhabitants of ancient *Arba*.

The count of remains (NR) and the determination of the Minimum Number of Individuals (MNI) revealed that caprines (*Ovis aries* and *Capra hircus*) were the most prevalent species at the site, followed by pigs (*Sus domesticus*) and domestic chickens (*Gallus gallus*) (tab. 1). Large herbivores such as horses and cattle were much less common, with cattle represented by only 50 bone elements. Although present in minimal percentages, the faunal assemblage also includes wild mammals (*Cervus elaphus* and *Lepus europaeus*), wild birds, and tortoises, with uncertainty remaining as to whether they are *Testudo hermanni* or *Testudo graeca*, both terrestrial species. In contrast, fish resources were more frequently identified, determined to the species level and, in some sporadic cases, to the genus level (fig. 2).

4. Rearing animals on an island: the recovery of primary and secondary products

The study of slaughter age (fig. 3) and the sex determination of the main domestic species, coupled with a meticulous taphonomic analysis aimed at record-

[1] For the methodological protocol applied to the study of animal bones, reference is made to Fecchio, Tecchiati 2021, pp. 203-225, and to the zooarchaeological manuals by De Grossi Mazzorin 2008 and Gifford-Gonzalez 2018.

	Bos taurus	*Ovis aries*	*Capra hircus*	*Ovis* vel *Capra*	*Sus domesticus*	*Equus caballus*	*Gallus gallus*	*Cervus elaphus*	*Lepus europaeus*	*Galliformes*	*Testudo*	Small to medium sized herbivores	Large herbivores	ND
Calvaria	-	6	6	-	-	-	-	5	-	-	-	-	-	
Cranium	1	-	-	12	15	-	-	-	-	-	-	12	2	17
Maxilla	-	-	-	3	5	-	-	-	-	-	-	-	-	-
Dentes	7	-	-	41	24	1	-	1	-	-	-	-	-	1
Mandibula	2	6	-	23	4	-	-	-	-	-	-	-	-	-
Costae	13	-	-	19	10	-	1	-	-	-	-	66	16	61
Vertebrae	5	-	3	67	32	-	-	-	-	-	-	10	2	8
Sternum	-	-	-	-	3	-	4	-	-	-	-	-	-	-
Coracoide	-	-	-	-	-	-	3	-	-	-	-	-	-	-
Furcula	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Scapula	-	5	6	12	9	-	4	-	-	-	-	-	-	-
Humerus	1	8	6	17	16	-	8	1	-	-	1	-	-	-
Radius	4	7	4	23	5	-	2	-	-	-	-	1	-	-
Ulna	1	1	1	9	6	-	7	-	1	-	-	-	-	-
Carpalia	1	-	-	2	1	-	-	-	-	-	-	-	2	-
Metacarpus	1	7	6	3	5	-	-	-	-	-	-	-	-	-
Carpometacarpus	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Pelvis	1	3	4	10	6	1	1	-	-	-	-	1	1	2
Femur	1	3	2	20	6	-	8	-	2	1	-	1	-	3
Tibia	2	1	-	41	11	-	-	-	1	-	-	-	-	-
Tibiotarsus	-	-	-	-	-	-	9	-	-	1	-	-	-	-
Fibula	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Talus	2	3	4	1	5	-	-	-	-	-	-	-	-	-
Os sacrum	1	-	-	-	-	-	-	-	-	-	-	2	-	-
Calcaneus	1	7	1	2	11	-	-	-	-	-	-	-	-	-
Tarsalia	1	-	-	1	3	-	-	-	-	-	-	-	-	-
Tarsometatarsus	-	-	-	-	-	-	26	-	-	-	-	-	-	-
Metatarsus	1	11	3	6	10	1	-	-	-	-	-	-	-	-
Metapodia	-	-	-	17	1	-	-	-	-	-	-	-	-	-
Phalanges	5	12	11	6	20	-	4	1	-	-	-	-	-	-
Diaphyses	-	-	-	-	-	-	-	-	1	1	-	27	8	5
ND	-	-	-	-	-	-	-	-	-	-	-	-	-	134
Total	**51**	**80**	**57**	**335**	**209**	**3**	**79**	**8**	**5**	**3**	**1**	**120**	**31**	

Tab. 1. Table of terrestrial animal remains from the entire faunal assemblage.

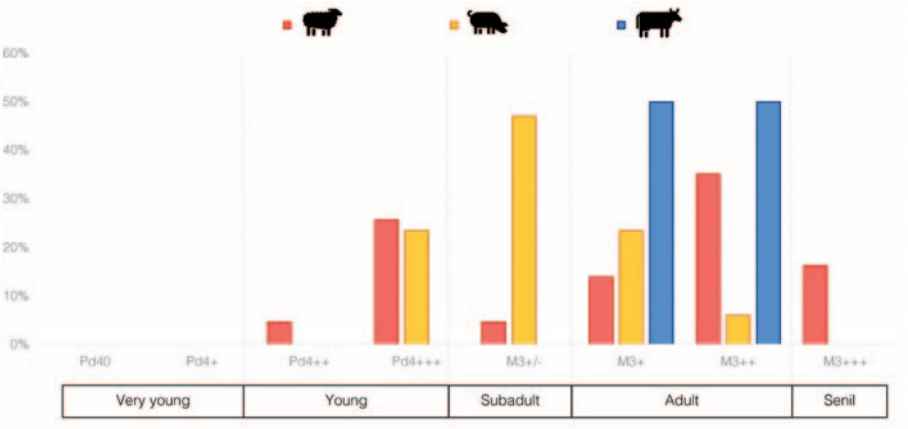

Fig. 3. Age at death for the main domestic species based on the state of eruption, replacement, and dental wear.

ing all butchery marks on the specimens, have allowed for an overall understanding of animal management. Mortality curves for pigs, obtained from the fusion state of epiphyses to the diaphysis of long bones and the degree of dental wear[2], indicate that they were slaughtered at a young or subadult age when the species reached its maximum meat yield. This, combined with numerous butchery marks along the pelvic and scapular joints, demonstrates that *Sus domesticus* constituted a fundamental protein resource in the daily diet of islanders. Pigs were typically slaughtered around 18-24 months of age; in antiquity, the development and fattening process of pigs were slower, and the peak meat yield relative to the animal maintenance costs occurred later in age compared to modern times (De Grossi Mazzorin, Minniti 2001, pp. 71-72). It can be inferred that the older specimens (5%) were predominantly female and were essential for species preservation on the site. The presence of all anatomical districts suggests that pig farming likely occurred near the site.

For domestic poultry[3], unlike the appendicular and axial regions of the skeleton, the cranial region is completely absent, as it was removed during bird slaughter and generally has a fragile structure prone to deterioration under various taphonomic processes. Small butchery traces have been identified near the wings and hind limbs of the bird, areas with less muscle mass, indicating a hypothetical division of the animal before consumption. Considering that chickens

[2] The methods of Payne 1973 and Grant 1982 were considered solely for comparison with the process currently employed by us to derive age classes based on the wear state of the occlusal surface of teeth.

[3] Cohen, Serjeantson 1986 was used to distinguish domestic avifauna from wild ones.

are easily raised in urban settings and can provide food resources both through direct slaughter and secondary product recovery, a significant number of bones in the faunal assemblage is expected.

The incidence of cattle in the faunal sample is quite low, with a minimum of two fully adult individuals. Sex determination relied on the dimensions and relative osteometric measurements of a complete metacarpal, suggesting a female specimen[4]. The few butchery remains were found along major joints and on bones with the least amount of meat, such as the astragalus, calcaneus, and metapodials, likely to select large meat portions. It can only be inferred that the few *Bos taurus* specimens were primarily exploited for traction and subsequently slaughtered for primary product recovery[5].

The use of small domestic ruminants was more intricate: the central role these species played in the island's economy is confirmed by numerous data obtained from dental erosion status and the fusion of epiphyses of long bones. The combination of both methodologies confirmed much more generalized breeding strategies. A high percentage of fully adult or senile specimens (48.7%), associated with milk and wool recovery in the case of sheep, is supplemented by a considerable number of young individuals (32%), many of whom show clear signs of butchery. The mortality curve in this case suggests a clear intention to systematically recover meat from these species.

The good frequency of anatomical parts with various diagnostic elements allowed for the distinction between sheep and goats for some fragments (Boessneck *et al.* 1964, pp. 331-358): 80 cases were attributed to *Ovis aries*, 57 to *Capra hircus*, while the remaining 335 were generic caprine remains. Taphonomic analysis of the bones of these species revealed a clear predominance of butchery cuts on goat remains relative to the number of skeletal elements. This data supports the hypothesis that, unlike *Ovis aries*, there was greater interest in meat recovery for *Capra hircus*, a fact also evidenced at other early medieval coastal sites in the Adriatic Sea (De Grossi Mazzorin, De Venuto 2009, p. 24; Powell 2004, pp. 307-313).

5. Hunting and fishing

Less than 2% of the identified remains are attributable to wild mammals and avifauna, a figure that inevitably suggests that hunting did not play an essential

[4] The data is further confirmed by the application of the Nobis index (Nobis 1954, pp. 155-194) (Bp100/GL, 51.3100/192.4 = 26.6 cm).

[5] The paleopathological study revealed evidence of animal exploitation as a workforce, indicated by a case of extensive exostosis on a third anterior phalanx and by two instances of eburnation, respectively observed in a bovine astragalus and calcaneus (Baker, Brothwell 1980).

role in the economy and diet of the island's inhabitants. This evidence could be due to intensive agriculture developed on the island, which left little room for hunting activities. Unfortunately, in the absence of studies regarding the ancient flora of the island, it is impossible to hypothesize how much territory was dedicated to agriculture and how much was left fallow.

The intensive sieving of sediment during excavation allowed the inclusion of 82 fish bone fragments in the study (tab. 2). Apparently, in the protein diet of the inhabitants of *Arba*, sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*) were present, although there are also attestations of vertebrae and cranial elements of European conger, red porgy, scorpionfish, or common smooth hound, significantly increasing the variability of resources recovered from the sea[6] (fig. 4). This data contradicts the results obtained from the isotopic signal of the examined burials. Such fish species, with demersal habits, prefer coastal habitats and only occasionally migrate to deeper waters. Therefore, fishing likely concentrated, mainly during the summer months, in the shallow waters of the bay upon which the city of *Arba* overlooked. A similar hypothesis can be advanced for the 107 remains of bivalves and gastropods related to marine malacofauna,

	Conger conger	***Dicentrarchus labrax***	***Engraulis encrasicolus***	***Mustelus mustelus***	***Pagrus pagrus***	***Scorpaenidae***	***Sparidae***	***Sparus aurata***	***Pisces***	***Caridlidae***	***Cerithidae***	***Conus mediterraneus***	***Gibbula adriatica***	***Murex trunculus***	***Patella***	***Spondylus gaederopus***	***Ostrea edulis***
Dentale	-	1	-	-	-	-	-	12	-	-	-	-	-	-	-	-	-
Dentes	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-
Premaxilla	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Maxilla	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-
Mandibula	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Iomandibula	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-
Preoperculous	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Supracleitrum	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Postcleitrum	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Vertebrae	1	5	1	3	-	-	2	8	34	-	-	-	-	-	-	-	-
Valva	-	-	-	-	-	-	-	-	-	10	-	-	-	-	17	10	2
Gasteropode	-	-	-	-	-	-	-	-	-	-	31	2	27	10	-	-	-
Total	**1**	**6**	**1**	**3**	**2**	**1**	**2**	**29**	**35**	**10**	**31**	**2**	**27**	**10**	**17**	**10**	**2**

Tab. 2. Table of marine animal remains from the entire faunal assemblage.

[6] For the determination of marine fish species, reference was made to the anatomical atlas by Cannon (1987) and the website of the University of Nottingham, available at the following link: http://fishbone.nottingham.ac.uk/. For acquiring osteometric measurements, Morales, Rosenlund 1979 was consulted.

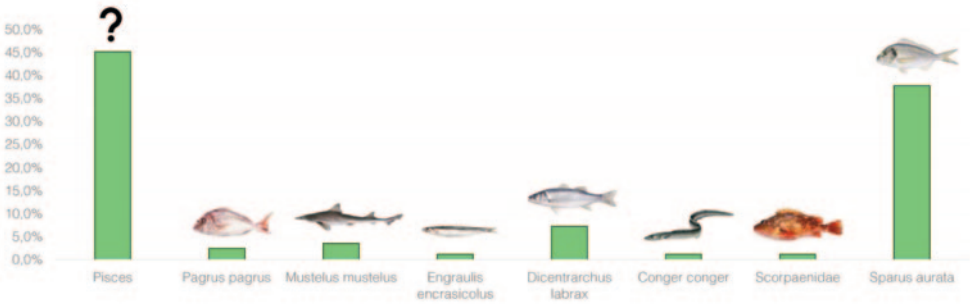

Fig. 4. Percentages, based on the Number of Remains, of the fish species identified.

most of which were collected in the intertidal zone, on sand, or the rocky shores. Murices (*Murex trunculus*), limpets, or the more common *Cerithidae* show no signs of breakage, indicating selection for food purposes. In the case of bivalves, only a few nicks on the edge attributable to the pressure exerted at the time of opening the molluscs were observed. Much more prized was the consumption of the spiny oyster (*Spondylus gaederopus*), present in almost 10% of the entire investigated malacofauna.

6. Anthropological and stable carbon and nitrogen isotope analyses

In the case of the Rab Island context, four burials were considered for stable carbon and nitrogen isotope analysis: three from the urban context of Dinka Dokule and one from the rural site of the Church of Saint Lawrence. A total of six individuals were studied anthropologically (Casolin 2020/2021). From the urban context, a sarcophagus containing three subjects was identified: two mature adult males (individuals A and B) and one adolescent (individual C) approximately 18-20 years old. The second tomb from this context is a stone coffin burial of a subadult subject approximately six months to one year old. The last tomb from the urban context was a pit burial of an elderly adult woman. Finally, in the Saint Lawrence context, a single pit burial of a mature adult female was identified. The small number of burials does not allow for conclusions or hypotheses about the island's population, but it provides an informative basis for future work starting from other sites. Regarding the health status of the studied individuals, none exhibited pathological signs indicative of malignant neoplasms or infectious diseases. Only common skeletal alterations were found, such as periosteal reactions, osteoarthritis, nonspecific stress indicators, nonspecific infections, and dental pathologies. Specifically, only the infant dis-

played *cribra orbitalia* (Walker *et al.* 2009) as a nonspecific stress indicator, with a mild occurrence in the roof of the right orbit. Hypoplasia (Ortner 2003; Hillson 2005) was identified in three cases from the city: the senile adult female, the mature adult male (individual A), and the adolescent, with an onset age ranging between 3.5 and 5 years.

Osteoarthritis (Ortner 2003; Waldron 2009), attributable to age and physical activity, was documented in the analyzed sample, with the vertebral column being the most affected skeletal region. Specifically, several cases involving the vertebral bodies were observed among the studied adults. Schmorl's nodes and a herniated disc were present in the two mature adult males (A and B) from the city. Additionally, there was fusion of two thoracic vertebral arches in the mature adult female from San Lorenzo, and slight eburnation on the superior and inferior facets of the lumbar vertebrae in the senile adult female buried in the city. Other skeletal regions, though less affected, also exhibited arthritic alterations, such as the shoulder girdle, particularly the clavicles, ribs, and hands. Dental pathologies (Hillson 2005) were extensively documented in all adult subjects and the adolescent. Several cases of widespread periodontopathy and dental wear on both dental arches were found. Adults and adolescents from the city exhibited small amounts of tartar. Only two individuals (the senile female and adolescent from the town) presented early stages of caries (respectively: on the right third maxillary molar and the right first maxillary molar). The mature adult female from San Lorenzo was the only one showing antemortem loss of all mandibular molars.

Except for the senile female, all adults exhibited periostitis of the lower limbs (primarily *tibiae* and *fibulae*) as a nonspecific infection. This alteration involves ossification of the periosteum following trauma or nonspecific infectious processes (Ortner 2003). A unique case identified in the analyzed sample was a metabolic endocranial pathology of uncertain etiology found in a senile female from the city. This case involved internal frontal hyperostosis, characterized by a subcircular apposition of new bone, approximately 4.4x3.5 mm, on the endocranial surface near the frontal crest.

For the isotopic study[7], two bone fragments (usually from femurs and ribs) and the dentin of the first permanent molar were sampled from the six individuals, for eleven samples. Sampling from these two tissues allows for the reconstruction of dietary changes during life stages, as collagen from femurs provides information

[7] The standard collagen extraction protocol (Richards, Hedges 1999; Privat *et al.* 2002) was performed on bone and teeth samples. Analyses were conducted using an Elementar Analyzer EA – Flash 2000 connected via ConFlo to a Thermo Fisher Delta V Advantage mass spectrometer, located in the Department of Geosciences (Unipd). CH6 and CH7, N-1 and N-2, UREA, and ALANINE were used as international standards during the analysis phase. All twenty-three analyzed samples met the C:N ratio within the range of 2.9 and 3.6.

about the last 10-20 years of life and ribs about the last 5-10 years, while teeth provide information from childhood (Hakenbeck 2013). To avoid variations in isotopic composition, bone collagen was extracted from non-affected bone areas (Olsen *et al.* 2014). To calibrate and analyse the human diet, contemporaneous fauna samples were collected from the burials. The sampling sought to include the highest representativeness of different taxa, including herbivores, omnivores, birds, and fish. Carnivores were the only absent group. In total, eighteen samples were taken, with only one failing during collagen extraction. The data obtained shows that individuals from both urban and rural contexts had a similar diet. Carbon values are plotted on the x-axis, while nitrogen is on the y-axis (fig. 5). The value of carbon in collagen, between -19.43‰ and -17.40‰, is relatively narrow, indicating a diet based on the consumption of C_3 plants. Carbon values in dentin, although there are only three samples from the urban collective tomb, have an even narrower range but are entirely similar to those of bone collagen (-19.01‰ to -19.65‰). Therefore, individuals' diets did not change significantly over their lifetimes. Nitrogen values in collagen have ranged from 9.07‰ to 12.03‰, indicating that individuals had a diet primarily based on terrestrial C3 resources with a good protein intake. Dentin data is in line with collagen, ranging from 9.48‰ to 10.10‰. Comparing isotopic results with anthropological and paleopathological data, no difference in diet based on sex of adults was observed. The highest nitrogen value corresponds to the infant, mainly due to information recorded in their bones during breastfeeding (Richards *et al.* 2002). The second male from the urban collective tomb has the highest nitrogen values among adults, while the adolescent buried in the same sarcophagus has the lowest values among all analysed subjects, suggesting limited access to protein resources.

Regarding fauna, all samples have a C_3-based diet except for the two sea bream samples, which show much higher carbon values, indicating a C_4-based diet (average carbon: -10.20‰, average nitrogen: 6.72‰). Herbivores have the lowest nitrogen values[8], while birds have the highest carbon and nitrogen values. Sheep and goats[9] have higher nitrogen values compared to other herbivores, and pigs[10] have similar values to them. Birds have a much more varied diet[11]. Variations within individual species may be due to different dating or dietary stresses experienced by different specimens during life.

8 On average, cattle show carbon values of -19.91‰ and nitrogen values of 4.70‰. Horses exhibit carbon values of -20.46‰ and nitrogen values of 3.95‰. Deer, on the other hand, displays carbon values of -21.24‰ and nitrogen values of 4.63‰. Finally, hares demonstrate values of -20.27‰ for carbon and 4.36‰ for nitrogen.

9 Sheep and goats exhibit an average carbon value of -20.81‰ and a nitrogen value of 5.50‰.

10 Pigs exhibit an average carbon value of -20.55‰ and a nitrogen value of 6.22‰.

11 Roosters and *Galliformes* exhibit an average carbon value of -19.32‰ and a nitrogen value of 7.05‰.

Fig. 5. The graph compares the values of stable carbon and nitrogen isotopes in bone collagen, tooth dentin of the analyzed individuals, and collagen from the selected fauna.

7. Tracing dietary changes in coastal Croatian sites between the Roman and Early Medieval periods

The results obtained from archaeozoological and isotopic analyses of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) on human and animal bone samples from two sites located in the island of Rab have been compared with data from fourteen different Croatian sites, ascertained through a meticulous survey of existing literature (tab. 3). All these sites are either adjacent to or near the Adriatic Sea, thereby ensuring geographical consistency in the comparisons (fig. 6). These sites cover a considerable chronological range, from the Roman period to the end of the Early Middle Ages. This temporal breadth has not only allowed us to contextualize the results obtained for the interred individuals and fauna of Rab within a specific ge-

	Site	Chronology	Bibliography
1	Rab	6th-8th century AD	-
2	Hvar - Radoševic	5th-early 7th century AD	Zagorc *et al.* 2024
3	Velim - Velištak	7th-mid 9th century AD	Lightfoot *et al.* 2012
4	Podvršje	5th-early 7th century AD	
5	Glavice Gluvine	8th-early 10th century AD	
6	Radašinovci - Vinogradine	9th-early 10th century AD	
7	Šibenik – Sveti Lovre	9th-early 11th century AD	
8	Zadar-Relje	3rd-4th century AD	
9	Vis-Bandirica	2nd century BC-2nd century AD	
10	Dubravice	8th-9th century AD	Gunjaca 1987; Novak *et al.* 2016
11	Stranče - Gorica	8th-mid 9th century AD	Novak *et al.* 2016
12	Konjsko polie – Livade	9th century AD	Petrinec 2005; Novak *et al.* 2016
13	Omišalj - Mirine	5th-7th century AD	Čaušević-Bully *et al.* 2023
14	Martinšcica	5th-7th century AD	Čaušević-Bully *et al.* 2023
15	Vaćani	8th-10th century AD	Novak *et al.* 2016

Tab. 3. Sites considered for comparing stable isotope analyses with chronology and reference bibliography.

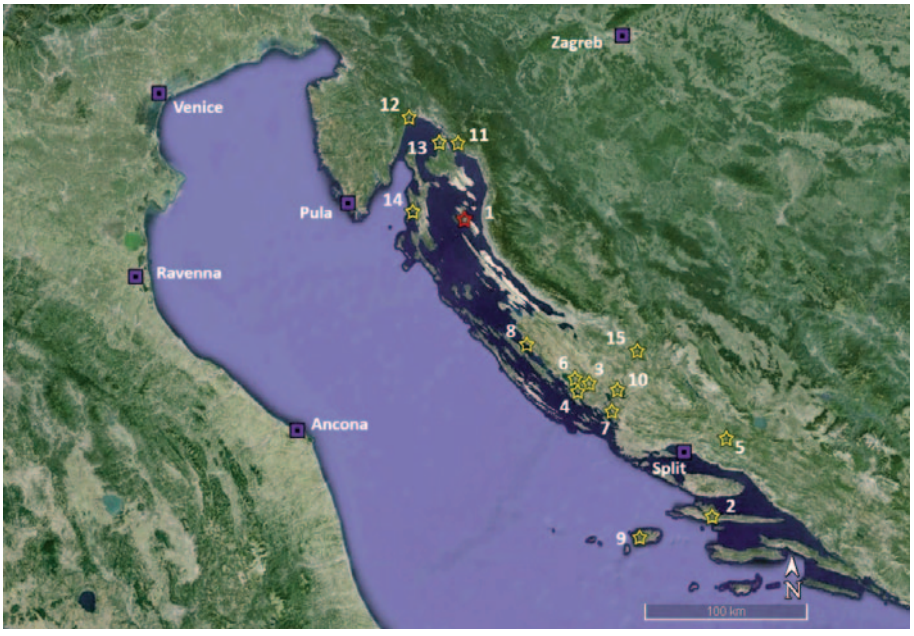

Fig. 6. Distribution of the sites considered for comparing stable isotope analyses.

ographic framework but also to observe potential dietary evolutions from the 2nd century BC to the 11th century AD.

In all the contexts examined, stable isotopic analyses were conducted on human and animal remains to calibrate the local trophic level. Among the fourteen sites considered, two present burial phases are attributable to the Roman occupation (Zadar-Relja - 3rd-4th century AD; Vis-Bandirica - 2nd century BC-2nd century AD), while another four are assignable to the Late Antique phase between the 5th and early 7th centuries AD (Hvar-Radošević; Podvršje; Omišalj-Mirine; Martinščica). More numerous are the Early Medieval sites (Velim-Velištak; Glavice Gluvine; Radašinovci-Vinogradine; Šibenik-Sveti Lovre; Dubravice; Stranče-Gorica; Konjsko polje-Livade), which have allowed us to obtain a local isotopic signal from the 7th to the 11th centuries AD.

The isotopic averages of 65 human bone samples from the Roman period, 68 from the Late Antique period, and 293 from the Early Medieval period, as well as 90 contemporaneous faunal samples, have provided the opportunity to verify possible variations in human and animal diets over the centuries[12]. These variations possibly reflect socioeconomic, environmental, and cultural changes that have characterized the area over time.

The comparison of carbon and nitrogen values across the various analyzed populations reveals a notable similarity, with some local peculiarities and variations related to the different historical periods considered (fig. 7).

During the Roman period, analyses conducted by Lightfoot (2009) and Lightfoot et al. (2012) on the two examined contexts show differences. However, a diet predominantly based on C_3 terrestrial resources with a variable contribution of marine proteins emerges. For instance, at Vis-Bandirica, the diet was primarily composed of C_3 plants with a variable intake of marine proteins, while at Zadar-Relja, a C_3-based diet was observed, but with the consumption of C_4 plants and/or low trophic level marine foods.

In the Late Antiquity period, a similar situation to the Roman period is observed, with a diet predominantly based on the C_3 ecosystem and limited use of marine resources. Specifically, Podvršje presents a range of values similar to Vis-Bandirica (Lightfoot 2009; Lightfoot *et al.* 2012). Samples from Mirine and Martinšćica indicate a diet based on C_3 plants with a pronounced intake of C_4-type vegetables. Individuals from Martinšćica seem to have consumed a higher quantity of C_4 food, which could indicate the consumption of algae and other marine foods (Cauševič-Bully *et al.* 2023). On the island of Hvar, the analyzed individuals reveal a diet similar to that of the two insular sites of Cres and Krk, with a C_3-based diet and minimal consumption of marine foods (Čaušević-Bully *et al.* 2023; Novak *et al.* 2016).

[12] In the count, human and animal bone samples from the site of Rab are also included.

- Rab S. Lorenzo Collagen
- Rab Dinka Dokule Collagen
- Rab Dinka Dokule Dentine
- *Sus domesticus*
- *Ovis aries*
- *Capra hircus*
- *Bos taurus*
- *Equus caballus*
- *Cervus elaphus*
- *Lepus europaeus*
- *Gallus Gallus*
- *Galliformes*
- *Sparus aurata*
- Zadar - Relje
- Vis - Bandarica
- Podvrške
- Mirine-fulfinum
- Martinšćica
- Hvar Radošević
- Velim - Velištak
- Glavice Gluvine
- Radašinovci - Vinogradine
- Šibenik - Sveti Lovre
- Vaćani-Laluše
- Dubravice
- Stranče-Gorica
- Konjsko polje
- Caprid Roman (Lightfoot *et al.* 2012)
- Cattle Roman (Lightfoot *et al.* 2012)
- Pig Roman (Lightfoot *et al.* 2012)
- Dog Roman (Lightfoot *et al.* 2012)
- Horse Roman (Lightfoot *et al.* 2012)
- *Capra/ovis* (Novak *et al.* 2016)
- Caprid E.M. (Lightfoot *et al.* 2012)
- Cattle E.M. (Lightfoot *et al.* 2012)
- Pig E.M. (Lightfoot *et al.* 2012)
- Dog E.M. (Lightfoot *et al.* 2012)
- Equid E.M. (Lightfoot *et al.* 2012)

Comparison sites

- Roman period
- Late Antique period
- Early medieval period

Fig. 7. The graph shows the comparison of carbon and nitrogen isotopic data of the analyzed subjects from the Island of Rab with Roman, Late Antique, and Early Medieval contexts from the islands, coast, and inland of Croatia.

During the Early Medieval period, the eight contexts considered show values indicating a relatively uniform diet among the inhabitants of the eastern Adriatic coast, based on C_3 terrestrial resources, with a variable intake of C_4, mainly due to millet consumption, and a very low contribution of marine resources (Novak *et al.* 2016). At Velim-Vel̆ištak, subjects presented a diet that included a variable intake of C_4 or low trophic level marine proteins and a good consumption of animal proteins. At Glavice Gluvine, most of the population consumed a higher quantity of C_4 plants, such as millet, while $\delta^{15}N$ values were less varied, suggesting less diversified use of animal resources. At Radašinovci-Vinogradine, millet consumption varied within the population, with a high intake of animal proteins and a certain variety in the quantity consumed. At Šibenik-Sveti Lovre, compared to the previous three contexts, a greater consumption of C_3 resources and small amounts of freshwater resources, visible from high trophic levels, is observed, given the proximity to the mouth of the Krka River (Lightfoot 2009; Lightfoot *et al.* 2012).

Regarding the remaining four sites – Dubravice, Stranče-Gorica, Konjsko polje-Livade, Omišalj-Mirine, and Vaćani-Laluše – it was possible to detect a diet mainly based on C_3 terrestrial resources, with some intake of C_4 foods or possibly marine origin (Novak *et al.* 2016). These results are entirely similar to those of the other Early Medieval contexts analyzed by Lightfoot *et al.* 2012.

Another notable finding from this comparison is the absence of distinctions based on sex and age at death among adults. However, for subadult subjects, a certain variety is observed: although they fall within adult ranges, in some cases, they show greater variability, especially in $\delta^{13}C$ values, covering a broader range, indicating higher consumption of C_4 or marine resources (Novak *et al.* 2016; Čaušević-Bully *et al.* 2023; Zagorc *et al.* 2024). The variability in $\delta^{15}N$ values in subadults is primarily linked to the weaning phase.

In comparison with archaeological data and possible indicators of social status, most contexts do not show diet variations attributable to the burial location, tomb type, or presence of grave goods. The only exception involves two adult males from Vaćani, who present high $\delta^{15}N$ values indicative of greater animal resource consumption and were buried in sarcophagi with rich grave goods (Novak *et al.* 2016).

The Early Medieval individuals from Rab exhibit data similar to other contemporary sites but with a diet entirely and predominantly based on C_3 terrestrial resources and good consumption of animal proteins.

Regarding the fauna, a comparison was made with that analyzed in the study by Lightfoot *et al.* (2012), both for the Roman and Early Medieval periods and with the only sample from the Early Medieval context of Vaćani (Novak *et al.* 2016). Different taxa generally fall within the range of a diet primarily based on C_3 plants, except for the Early Medieval pigs and dogs studied by Lightfoot et al.

(2012), which show greater variability and partial consumption of C_4 resources. The observed differences, mostly at the trophic level, can be correlated with chronological differences between the analyzed samples. As for fish, at the current state of research, comparisons are not possible, as the only samples analyzed are those present in this study.

8. Conclusion

The analysis of faunal remains has provided a detailed overview of animal exploitation practices from the 6th to the 8th century AD on the island of Rab. This study examined the use of major domestic species (goats, pigs, and cattle) and aquatic resources in the local diet. Pigs, constituting approximately 15% of the faunal sample, were slaughtered and butchered on-site, with a particular focus on major joints for meat distribution. Swine husbandry primarily targeted meat production, with slaughtering typically occurring between 18 and 24 months of age. Poultry, crucial to Rab's urban economy, provided quick access to protein resources through meat and eggs. Sheep and goats, predominant in the sample, played a central role in the local economy, both for secondary product recovery and meat consumption. Analysis of fish and bivalve remains highlighted their contribution to the island's protein intake, featuring prized species like *Ostrea edulis* and *Spondylus gaederopus* among marine finds. Unlike fishing, hunting played a minor role in the island's economy and diet, possibly due to intensive agriculture and deforestation for goat husbandry. With limited studies on plant species and cultivated fruits, the relationship between cultivated and uncultivated areas on the island remains uncertain.

The analysis of carbon and nitrogen values across various populations reveals significant similarities, with local peculiarities and historical period variations. During the Roman period, diets were mainly based on C_3 terrestrial resources with variable marine protein intake, as seen in Vis-Bandirica and Zadar-Relja. In Late Antiquity, diets remained predominantly C_3-based with limited marine resources, as observed in Podvršje, Mirine, and Martinšćica. In the Early Medieval period, diets were relatively uniform along the eastern Adriatic coast, primarily based on C_3 terrestrial resources with variable C_4 intake, mainly from millet, and minimal marine resources. Notable sites include Velim-Veliš̌tak, Glavice Gluvine, Radašinovci-Vinogradine, and Šibenik-Sveti Lovre. The remaining sites (Dubravice, Stranče-Gorica, Konjsko polje-Livade, Omišalj-Mirine, and Vaćani-Laluše) also showed similar dietary patterns. No significant diet differences based on sex or adult age were found, but subadults showed greater variability in $\delta^{13}C$ values, indicating higher C_4 or, possibly, marine resource intake. Archaeological data mostly did not indicate social status-based dietary differences, ex-

cept for two adult males from Vaćani. Faunal comparisons showed diets primarily based on C_3 plants, with some variability in pigs and dogs. The most prominent finding from the comparison of both diachronic and contemporaneous contexts is that, despite originating from islands, coastal areas, and inland zones not far from the coast, the consumption of marine proteins is very low. In many contexts, the positive carbon values have been more closely associated with millet consumption. In the absence of strontium isotope analysis, we cannot be certain whether the individuals buried at Rab and Banjol are local residents, a consideration that could isotopically explain the absence of marine resources in their diet. This hypothesis, in our view, is contradicted by the results of isotopic analyses obtained for the comparison sites. To achieve greater discrimination between consumers of terrestrial and marine resources in the study area, future analyses utilizing stable oxygen ($\delta^{18}O$) and sulphur ($\delta^{34}S$) isotopes would be desirable. These, along with the already obtained carbon and nitrogen isotopic signals, would highlight the actual exploitation and consumption of marine resources (Craig *et al.* 2006).

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Abstract

The zooarchaeological analysis conducted at the archaeological site of Dinka Dokule in the city of Rab (Croatia) outlined an overall picture of animal exploitation during the early medieval phase of occupation of this building (6th-8th century AD). This includes both the main domestic species and the fish resources. The reconstruction of the complex animal butchery process, combined with stable isotope analyses ($\delta^{13}C$ and $\delta^{15}N$) on both fauna and human remains from contemporary burials, has enhanced the understanding of the consumption of plant and, above all, animal products. Comparison with other Croatian sites reveals similar dietary patterns with some changes from the Roman to the Early Medieval period. Despite the presence of various species of marine fish among the meal remains stable isotope analyses have not indicated significant consumption of marine resources.
Keywords: Late Antiquity - Early Middle Ages, zooarchaeology, stable isotopes, Island of Rab.

L'analisi zooarcheologica condotta nel sito archeologico di Dinka Dokule, nella città di Rab (Croazia), ha delineato un quadro complessivo dello sfruttamento animale durante la fase di occupazione altomedievale di questo edificio (VI-VIII secolo d.C.). Questo comprende sia le principali specie domestiche sia le risorse ittiche. La ricostruzione del complesso processo di macellazione degli animali, combinata con le analisi degli isotopi stabili ($\delta^{13}C$ e $\delta^{15}N$) sia sulla fauna che sui resti umani provenienti da sepolture contemporanee, ha migliorato la comprensione del consumo di prodotti vegetali e, soprattutto, animali. Il confronto con altri siti croati rivela modelli alimentari simili, con alcuni cambiamenti dal periodo romano a quello altomedievale. Nonostante la presenza di varie specie di pesci marini tra i resti dei pasti, le analisi degli isotopi stabili non hanno indicato un consumo significativo di risorse marine.
***Parole chiave**: Tarda Antichità - Alto Medioevo, zooarcheologia, isotopi stabili, isola di Rab.*

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