

Feeding strategies shape skeletal biomineralization in two sympatric Mediterranean sparids (Perciformes): *Sarpa salpa* vs. *Dentex gibbosus*

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Abstract: *This study investigates the skeletal Biomineralization of two sympatric typical sparid fish species, Sarpa salpa (herbivorous) and Dentex gibbosus (benthic carnivore), from the southern Mediterranean coast of Libya, to elucidate how ecological niches and feeding strategies influence skeletal adaptations. Morphometric analyses revealed significant differences between the species: S. salpa exhibited greater total length (TL), total weight (TW), and dry bone weight (DBW), with positive allometric growth ($b = 3.32$), indicating disproportionate skeletal reinforcement for hydrodynamic efficiency. In contrast, D. gibbosus displayed negative allometry ($b = 1.82$), prioritizing skeletal efficiency relative to body length, consistent with its benthic ambush predation. The DBW/TW ratio was lower in S. salpa (1.99%) compared to D. gibbosus (5.37%), reflecting higher muscle mass in the former for sustained swimming and a heavier skeleton in the latter for mechanical support during substrate interaction. X-ray fluorescence spectroscopy identified calcium (Ca) and phosphorus (P) as the primary skeletal components in both species, with S. salpa showing significantly higher P and manganese (Mn) levels, suggesting faster bone turnover or metabolic demands linked to active locomotion. D. gibbosus bones contained trace iron (Fe) and silicon (Si), likely acquired from benthic foraging. Calcium content (mostly as carbonate) increased with fish length in both species, underscoring its role in skeletal growth. Correlation analyses revealed strong Ca-P associations and negative Ca-S relationships, highlighting mineral interplay in biomineralization. The findings demonstrate that skeletal biomineralization in these species is shaped by their divergent ecological roles: S. salpa's lightweight, stiff skeleton supports midwater agility, while D. gibbosus's robust skeleton facilitates benthic stability and predation. These adaptations underscore the functional link between biomineralization, trophic ecology, locomotion, muscle mass, and protection and concealment strategies in marine vertebrates.*

Keywords: biomineralization, skeletal adaptations, morphological adaptations, sarpa salpa, dentex gibbosus.

INTRODUCTION

Biom mineralization is a fundamental biological process observed across diverse taxa, involving the deposition of minerals such as calcium carbonate (CaCO_3), silica (SiO_2), and hydroxyapatite ($\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$) to form rigid structures like bones, shells, and exoskeletons (Weiner & Lowenstam, 1989; Sigel *et al.*, 2008). This process serves critical functions, including structural support, defense, and sensory perception (Müller, 2003). In vertebrates, particularly fish, biomineralization plays a pivotal role in skeletal development, muscle attachment for locomotion, and ecological adaptation (Currey, 2002). For instance, fast-swimming fish generally exhibit stiffer yet more flexible skeletons compared to their slow-swimming counterparts, an adaptation that enhances their hydrodynamic efficiency (Goldstein, 1987; Porter *et al.*, 2007; Macesic & Summers, 2012). The degree of biomineralization and skeletal flexibility is closely tied to a fish's swimming mode, which, in turn, is largely determined by its feeding strategy and habitat (Wainwright *et al.*, 2001). Fast-swimming fish are typically pelagic carnivores. They exhibit a more muscular, streamlined body, a terminal mouth, a less dorsoventrally compressed head (if any), a narrow caudal peduncle, and a bifurcate or heterocercal caudal fin, adaptations that enhance hydrodynamic efficiency compared to slow-swimming benthic species (Webb, 1984; Wainwright *et al.*, 2002; Domenici, 2003). Herbivorous fish, which graze on seagrass and algae in midwater environments, require sustained swimming capabilities, favoring a lighter, more streamlined skeleton (Ruxton *et al.*, 2004). In contrast, benthic carnivores, which rely on ambush predation and substrate interaction, develop a more robust skeletal structure to withstand mechanical stresses (Wainwright *et al.*, 2001).

This study investigates the comparative skeletal biomineralization of *Sarpa salpa* and *Dentex gibbosus* (Perciformes: Sparidae) along the Benghazi coast, Libya, to elucidate how ecological niches and feeding strategies influence skeletal adaptations (El-Mor, 2012; Ben-Abdalla *et al.*, 2009). Through analysis of morphometric traits, mineral composition (via X-ray fluorescence spectroscopy), and biomechanical properties, we examine the functional implications of biomineralization in these look-alike, but ecologically distinct species (Golani *et al.*, 2006; Porter *et al.*, 2006; Raoult *et al.*, 2016).

Sarpa salpa and *Dentex gibbosus* are sympatric sparids inhabiting shallow Mediterranean coastal waters (Golani *et al.*, 2006). Despite apparent morphological similarities (typical sparid configuration), they exhibit divergent trophic strategies: *S. salpa* is primarily herbivorous, feeding on seagrasses and algae, while *D. gibbosus* is carnivorous, preying on benthic invertebrates (Pallaoro *et al.*, 2008; Osman & Mahmoud, 2009). These fundamental dietary differences likely drive distinct habitat preferences and morphological specializations (Wainwright *et al.*, 2002).

MATERIALS AND METHODS

Study Site

This study was conducted along the Benghazi coast, Libya, encompassing Juliana Port and its surrounding areas (Fig. 1). Benghazi, the country's second-largest city, serves as a major deep-sea harbor and a key industrial and commercial hub.

The coastline features numerous small seasonal estuaries, lagoons, wetlands, and tidal marshes with brackish water. Adjacent to the city lies the Benghazi Natural Reserve, which includes both marine and terrestrial habitats. The area also hosts a permanent fish landing site and market (Reynolds *et al.*, 1995).



Fig 1. The city and harbor of Benghazi.

Sample Collection

Fifteen *Dentex gibbosus* and eighteen *Sarpa salpa* specimens were collected randomly from artisanal catches at the Benghazi landing site during the fall and winter of 2019.

Morphometric Measurements

Individual fish were weighed (nearest 0.1 g) and measured for total length (nearest 0.1 cm).

Skeletal Preparation for X-Ray Fluorescence (XRF) Scanning

Collected specimens were gutted, skinned, and partially defleshed individually following established protocols (Vengadesan & Kumar, 2016; Ali, 2016; Enault *et al.*, 2016). To facilitate soft tissue removal, each specimen was immersed in boiling water for several minutes. Remaining skin, muscle, and connective tissue—including most of the perichondrium covering cartilaginous elements—were carefully excised using scalpels, tweezers, and scissors.

The cleaned skeletal structures were then submerged in a 1:1 solution of 50% ethanol and 30% H₂O₂ for 72 hours. This treatment served dual purposes: Hydrogen peroxide degraded residual organic matter, softening tissues for easier removal. Ethanol dissolved fats, initiated dehydration, and prevented cartilage disintegration.

Samples were subsequently oven-dried at 85°C for 48 hours until reaching constant weight (Fig. 2), then ground into homogeneous powder and compressed into steel rings for XRF analysis (S2 Ranger 2008, Bruker Company). All XRF procedures were conducted at the Libyan Co-operative Company (LCC) chemical laboratory in Dernah, eastern Libya.

Mineralogical analysis XRF scanning provided quantitative data on skeletal mineral oxides, a validated method for elemental and chemical composition analysis (Pessanha *et al.*, 2019).

Obtaining the Skeletal Metal Compositions

Skeletal metal compositions were calculated from the metal oxides.



Fig. 2. Skeletal preparation for X-ray fluorescence (XRF) analysis. Cleaned bone samples are shown undergoing dehydration in a drying oven at 85°C prior to grinding and compression for XRF scanning.

Statistical Analysis

Descriptive statistics for skeletal metal and non-metal compositions were calculated using Excel 2010, SPSS, and Minitab software. Inter-element correlations were assessed using Pearson's bivariate correlation analysis. Relationships between metal and non-metal concentrations and total fish length were evaluated through linear, power, and logarithmic regression models. Significant differences in mean values between species (*Dentex gibbosus* and *Sarpa salpa*) were determined using independent Student's t-tests (two-tailed, $\alpha = 0.05$).

RESULTS

Relationships Between Morphometric Parameters and Bone Weight

Sarpa salpa exhibited significantly greater values than *Dentex gibbosus* for total length (TL), total weight (TW), dry bone weight (DBW), and their relative ratios (DBW/TL% and DBW/TW%) (Table 1). Strong positive correlations were observed among these parameters, with high coefficients of determination (Tables 2-3).

All regression models (linear, power, and logarithmic) effectively described the relationship between bone weight and fish length, with R^2 values ranging from 0.714 to 0.771 (Table 4; Figs. 3-4). The power regression revealed distinct allometric growth patterns: *S. salpa* showed positive allometry ($b = 3.3247$), indicating bone weight increased faster than body length. *D. gibbosus* displayed negative allometry ($b = 1.8207$), demonstrating length increased more rapidly than bone weight.

Table 1. Comparative morphometrics of *Sarpa salpa* and *Dentex gibbosus*: total length (TL, cm), total weight (TW, g), dry bone weight (DBW, g), and percentage ratios of bone weight to length and weight.

Parameter	Species	Mean \pm SE	<i>P</i>
TL	Ss	38.935 \pm 0.92	0.000
	Dg	26.467 \pm 0.4	
TW	Ss	1050.9 \pm 69.3	0.000
	Dg	231.73 \pm 9.02	
DBW	Ss	20.94 \pm 1.66	0.000
	Dg	12.461 \pm 0.388	
DBW/TL(%)	Ss	53.78% \pm 0.141	0.117
	Dg	47.08% \pm 0.377	
DBW/WT(%)	Ss	1.99% \pm 0.003	0.000
	Dg	5.37% \pm 0.005	

Table 2. Pearson correlation matrix for *Sarpa salpa* showing relationships between bone dry weight (BDW), total weight (TW), and total length (TL).

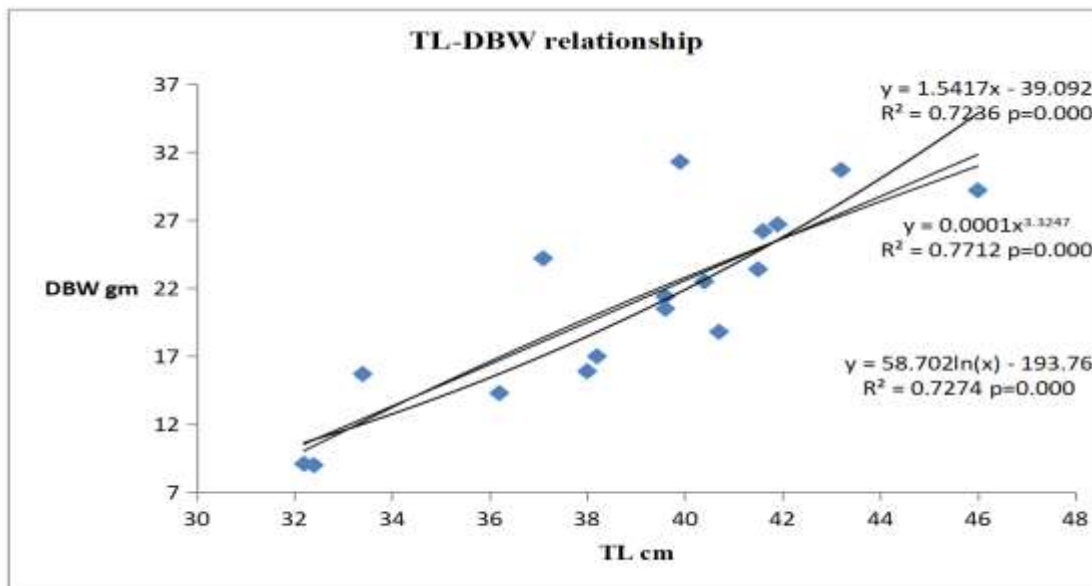
	TL	TW
TW	.920**	
DBW	.851**	.896**

Table 3. Pearson correlation matrix for *Dentex gibbosus* showing relationships between bone dry weight (BDW), total weight (TW), and total length (TL).

	TL	TW
TW	.920**	
BDW	.851**	.896**

Table 4. Regression models comparing dry bone weight (DBW) and total length (TL) relationships in *Sarpa salpa* and *Dentex gibbosus* (L = linear, P = power, Log = logarithmic).

Species	Regression	a	b	R ²	P
<i>S. salpa</i>	L	-39.092	1.5417	0.7236	0.000
	P	0.0001	3.3247	0.7712	0.000
	Log	- 193.8	58.702	0.7274	0.000
<i>D. gibbosus</i>	L	- 9.272	0.8212	0.7138	0.000
	P	0.0319	1.8207	0.7159	0.000
	Log	- 59.77	22.06	0.7255	0.000

**Fig. 3. Relationship between total dry bone weight (DBW) and total length (TL) in *Sarpa salpa* showing linear (L), power (P), and logarithmic (Log) regression models.**

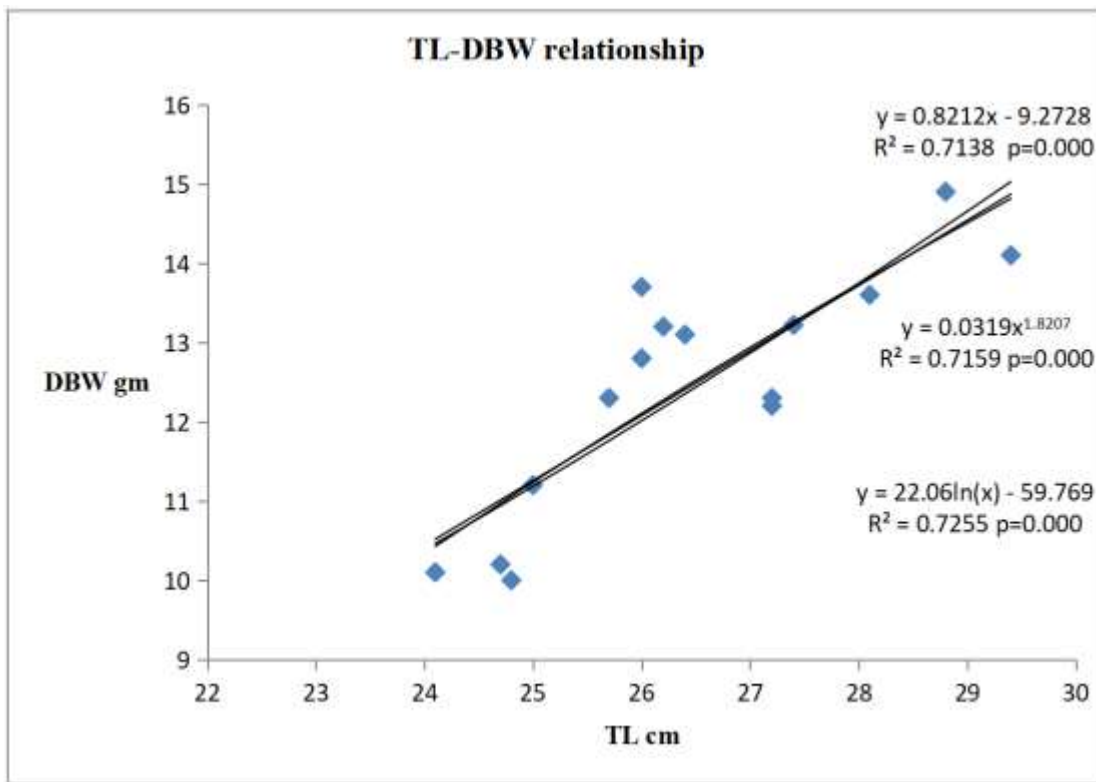


Fig. 4. Relationship between total dry bone weight (DBW) and total length (TL) in *Dentex gibbosus* showing linear (L), power (P), and logarithmic (Log) regression models.

Metal and Non-Metal Composition of Fish Bones

The percent composition of metal and non-metal in the bones of both fish species, listed in descending order of concentration, was as follows: Ca > P > S > Na > Mg > Cl > Si > Mn > Fe (Table 5; Fig. 5). Calcium (Ca) was by far the most abundant element, followed by phosphorus (P), sulfur (S), sodium (Na), magnesium (Mg), and chlorine (Cl), with silicon (Si), manganese (Mn), and iron (Fe) present in trace amounts. Potassium (K) and titanium (Ti) were undetectable in the bone samples.

Notably, silicon (Si) and iron (Fe) were found only in minimal quantities in *Sarpa salpa*. Statistical analysis revealed no significant differences in the concentrations of homologous metal/non-metal pairs between the two species—except for phosphorus (P) and manganese (Mn), which were significantly higher in *Sarpa salpa* than in *Dentex gibbosus* (Table 16).

Table 5. Percentage composition of metal and non-metal (mean \pm standard error) in the bones of *Sarpa salpa* and *Dentex gibbosus*. *: present in trace amounts. Means with different superscripts are significantly different (highlighted green).

Metal characters	Species	Mean \pm SE
Ca	Ss	24.449 \pm 0.0971 ^a
	Dg	24.632 \pm 0.104 ^a
P	Ss	2.1398 \pm 0.0401 ^a
	Dg	2.0419 \pm 0.0205 ^b
S	Ss	0.32967 \pm 0.00494 ^a
	Dg	0.31963 \pm 0.00914 ^a
Na	Ss	0.2410 \pm 0.0126 ^a
	Dg	0.2107 \pm 0.0129 ^a
Mg	Ss	0.1996 \pm 0.0178 ^a
	Dg	0.1902 \pm 0.0248 ^a
Cl	Ss	0.053294 \pm 0.000206 ^a
	Dg	0.053500 \pm 0.000429 ^a
Si	Ss	0.000000 \pm 0.000000*
	Dg	0.0127 \pm 0.0127*
Mn	Ss	0.006241 \pm 0.000046 ^a
	Dg	0.005587 \pm 0.000088 ^b
Fe	Ss	0.000000 \pm 0.000000*
	Dg	0.00215 \pm 0.00215*
Al	Ss	0.00862 \pm 0.00568 ^a
	Dg	0.000567 \pm 0.0000567 ^a
K	Ss	0.000000 \pm 0.000000*
	Dg	0.000000 \pm 0.000000*
Ti	Ss	0.000000 \pm 0.000000*
	Dg	0.000000 \pm 0.000000*

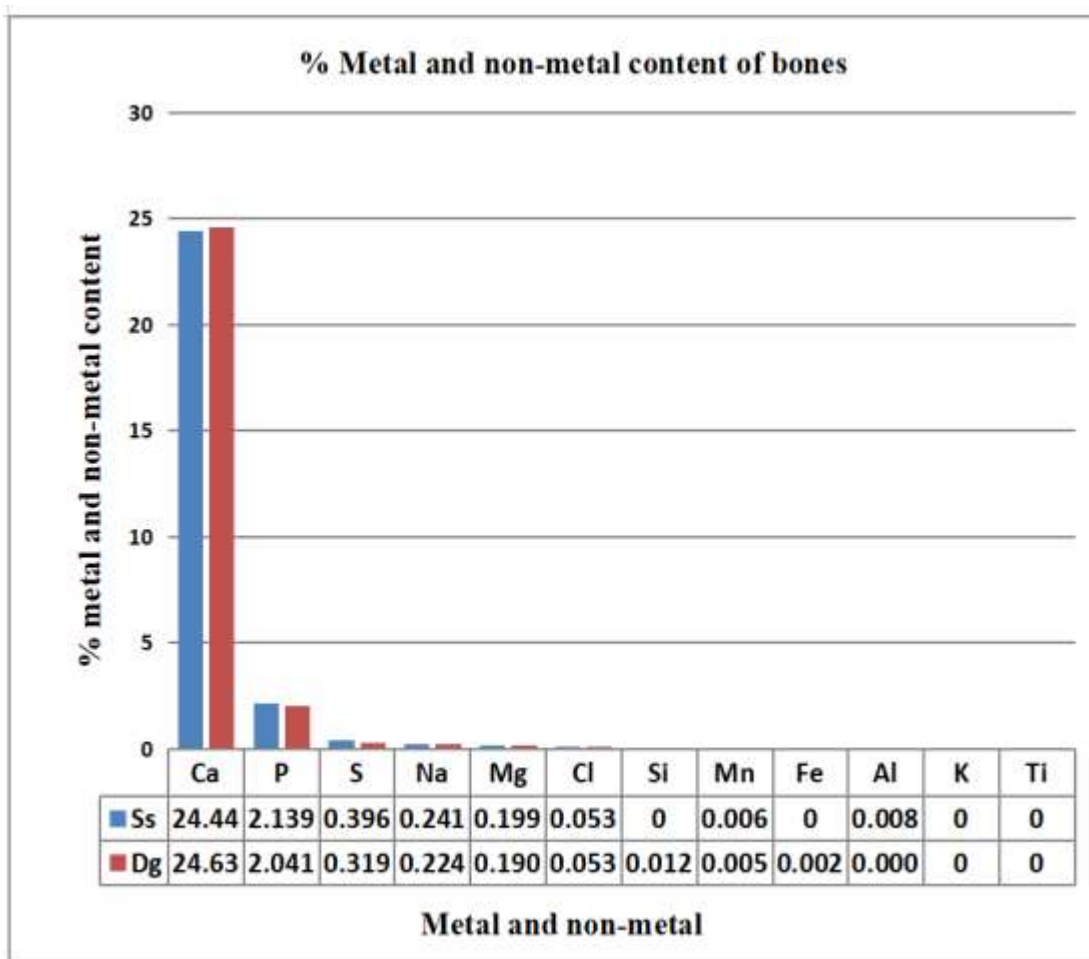


Fig. 5. Percentage composition of metal and non-metal in the bones of *Sarpa salpa* and *Dentex gibbosus*, ranked in descending order of concentration.

Correlations Between Metal/Non-Metal and Their Relationships with Fish Length

Binary Correlations

The binary correlations among percentage concentrations of metal and non-metal in *Sarpa salpa* and *Dentex gibbosus* are presented in Tables 6 and 7.

a) *Sarpa salpa*

Most metal and non-metal correlations were weak and non-significant (Table 6). However, we identified several significant relationships:

Calcium (Ca) exhibited:

Moderate positive correlations with sodium (Na; $r = X$, $p < 0.05$) and titanium (Ti; $r = 0.492$, $p < 0.05$).

A strong positive correlation with phosphorus (P; $r = 0.604$, $p < 0.05$).

A strong negative correlation with sulfur (S; $r = -0.796$, $p < 0.01$).

Sulfur (S) showed a strong negative correlation with phosphorus (P; $r = -0.684$, $p < 0.01$).

Table 6. Pearson correlation matrix of metal and non-metal concentrations (%) in *Sarpa salpa* bone tissue. Statistically significant positive (green) and negative (blue) correlations are highlighted.

	Al	Ca	Mg	Na	Cl	S	Mn	P
Ca	.230							
Mg	-.093	.434						
Na	.109	.484*	.137					
Cl	.084	-.061	.194	-.044				
S	-.166	-.796**	-.308	-.429	.252			
Mn	-.096	-.107	-.188	-.166	-.089	-.002		
P	.151	.604*	.164	.416	.208	-.684**	-.249	
Ti	.277	.492*	.100	.192	-.14	-.16	-.06	-.08

b) *Dentex gibbosus*

Al, Si, Fe, Ti and K were almost absent in bones (Table 7), therefore, their binary correlations with each other and with the other metals and non-metals were invalid.

Calcium (Ca) demonstrated:

A strong positive correlation with phosphorus (P; $r = X$, $p < 0.01$)

A moderate positive correlation with titanium (Ti; $r = X$, $p < 0.05$)

A moderate negative correlation with manganese (Mn; $r = X$, $p < 0.05$)

Phosphorus (P) displayed:

A highly significant positive correlation with calcium (Ca; $r = X$, $p < 0.001$)

Highly significant negative correlations with silicon (Si), aluminum (Al), and iron (Fe) (all $p < 0.001$)

Table 7. Pearson correlation matrix of metal and non-metal concentrations (%) in *Dentex gibbosus* bone tissue. Statistically significant positive (green) and negative (blue) correlations are highlighted; yellow-highlighted cells indicate invalid correlations (trace concentration).

	Si	Al	Fe	Ca	Mg	Na	Cl	S	Mn	P
Al	1.000**									
Fe	1.000**	1.000**								
Ca	-.507	-.507	-.507							
Mg	-.408	-.408	-.408	.162						
Na	-.024	-.024	-.024	.050	.176					
Cl	-.090	-.090	-.090	.044	.267	.011				
S	.515	.515	.515	-.291	-.09	-.12	.010			
Mn	.531	.531	.531	-.566*	.055	.180	-.17	-.07		
P	-.792**	-.792**	-.79**	.670**	.529	.069	.169	-.35	-.43	
Ti	-.310	-.310	-.310	.539*	.169	-.03	-.09	-.50	-.05	.435

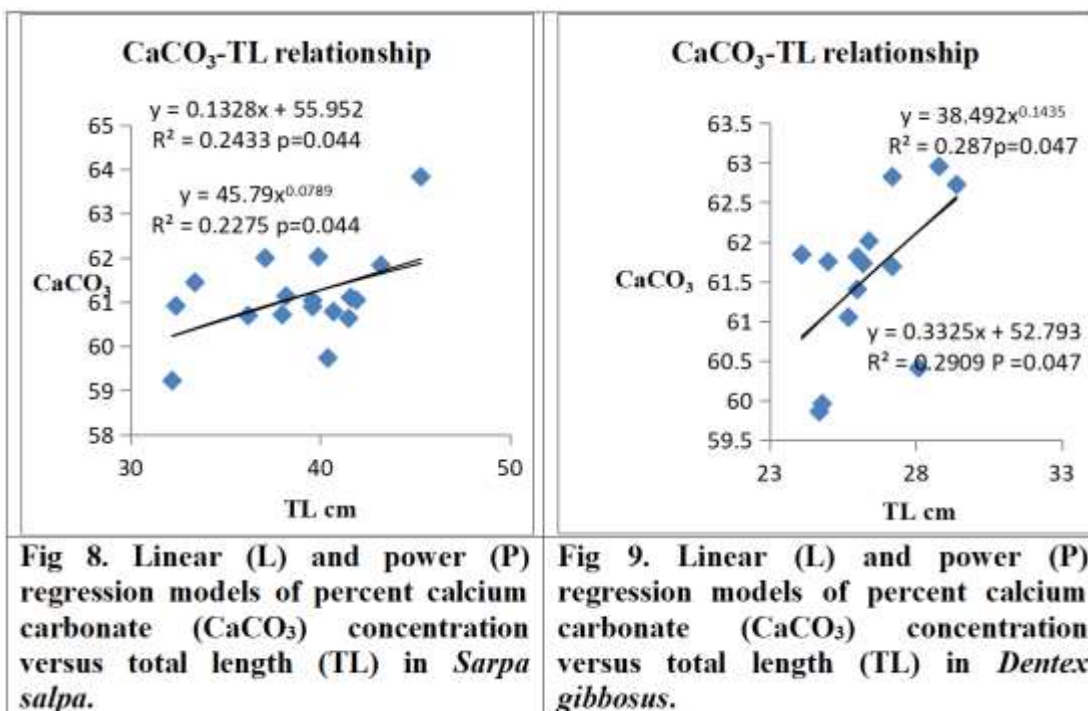
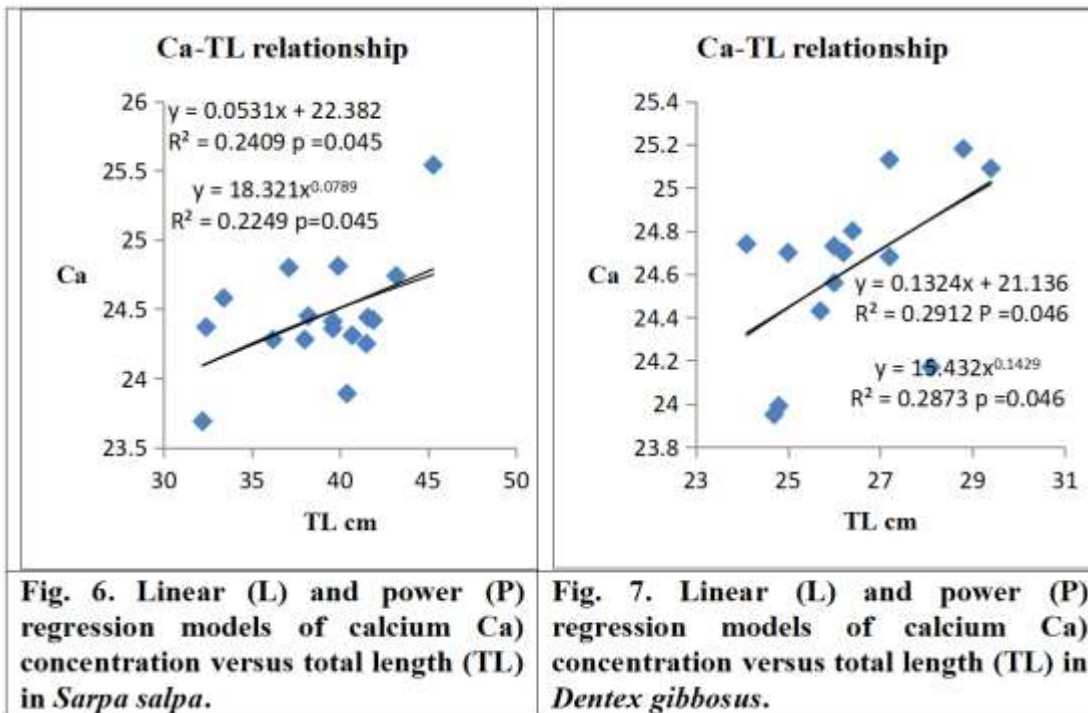
Regression Analysis of Metal and Non-metal with Fish Length

All regression analyses between metal and non-metal concentrations in bone and fish length were non-significant except for calcium (Table 8 and Figs 6-7). This demonstrates that while calcium content increases with fish growth (as measured by length), all other measured elements maintain constant proportions in bone tissue throughout development.

The calcium carbonate (CaCO_3) content in bones gradually increases during growth - particularly with length - in both fish species (Figs. 8 and 9).

Table 8. Linear (L) and power (P) regression analyses of metal and non-metal concentrations versus total length in *Sarpa salpa* and *Dentex gibbosus*. Only calcium (highlighted green) showed statistically significant positive relationships (b positive, $p < 0.05$).

Metal & non-metal	Regression	<i>S. salpa</i>				<i>D. gibbosus</i>			
		a	b	R ²	P	a	b	R ²	P
Ca	L	22.38	0.053	0.241	0.05	21.14	0.132	0.291	0.05
	P	18.32	0.079	0.225	0.05	15.43	0.143	0.287	0.04
P	L	2.304	-0.004	0.009	0.72	1.482	0.021	0.191	0.12
	P	2.819	-0.076	0.009	0.72	0.799	0.286	0.191	0.12
S	L	0.359	-0.001	0.019	0.60	0.596	-0.010	0.227	0.48
	P	0.448	-0.084	0.017	0.60	5.425	-0.867	0.240	0.09
Na	L	0.132	0.003	0.039	0.45	0.22	-5E-16x	-2E-14	
	P	0.068	0.338	0.019	0.45	0.22	-2E-13	4E-13	
Mg	L	0.126	0.002	0.009	0.72	0.065	0.010	0.027	0.57
	P	0.079	0.231	0.002	0.72	3E-05	2.596	0.089	0.57
Cl	L	0.057	0.000	0.029	0.51	0.054	-0.000	0.005	0.81
	P	0.073	-0.1	0.024	0.51	0.061	-0.054	0.004	0.81
Si	L					0.262	-0.009	0.096	0.22
	P								
Mn	L	0.01				0.01	5E-17x	7E-13	
	P	0.01	-3E-13	3E-13		0.01	7E-13	-4E-13	
Fe	L					0.044	-0.002	0.096	0.28
	P								
Al	L	0.019	-0.00	0.002	0.88	0.015	0.001	0.096	0.28
	P								
K	L								
	P								
Ti	L								
	P								



Discussion

The ecological divergence between *Sarpa salpa* and *Dentex gibbosus* is rooted primarily in their feeding strategies. *S. salpa* is an herbivorous species that grazes on seagrass and algae slightly above the seabed, minimizing direct contact with the substrate. In contrast, *D. gibbosus* is a benthic carnivore

that preys on crustaceans, mollusks, and small fish, often requiring it to dig into sediments to capture prey. These trophic roles strongly influence their habitat use and physical adaptations. Herbivory in *S. salpa* promotes continuous midwater locomotion and exposure to predators, demanding efficient swimming and predator evasion. Meanwhile, the ambush-based carnivory of *D. gibbosus* favors concealment, short bursts of movement, and substrate engagement.

These behavioral and ecological distinctions are mirrored in the fish's morphology and swimming capacities. *S. salpa* has a fusiform body, terminal mouth, narrow caudal peduncle, and bifurcated tail—traits promoting sustained, agile swimming. Its countershaded coloration (silvery ventrally, darker dorsally) provides camouflage from both aerial and aquatic predators, a widespread adaptation among pelagic and semi-pelagic fish (Ruxton *et al.*, 2004). Conversely, *D. gibbosus* displays a deeper body, lunate caudal fin, and broader caudal peduncle, supporting a lifestyle based on sudden propulsion rather than continuous movement. Its pale rose coloration blends with sandy substrates, aiding camouflage during benthic foraging.

These traits have implications for skeletal design. *S. salpa* shows positive allometric bone growth ($b = 3.32$), where bone weight increases disproportionately with size, suggesting structural reinforcement suited to hydrodynamic demands. In contrast, *D. gibbosus* exhibits negative allometry ($b = 1.82$), indicating skeletal growth prioritizes efficiency relative to body length—a common feature in ambush predators (Wainwright *et al.*, 2001). Muscle-Bone Allocation and Performance Data from dry bone weight-to-total weight (DBW/TW) ratios reinforce these interpretations. *S. salpa* has a low DBW/TW ratio (1.99%), signifying greater muscle mass relative to skeleton—an adaptation for active swimming. *D. gibbosus* displays a higher ratio (5.37%), implying more skeletal mass per unit of body weight—consistent with the need for mechanical support during substrate interaction and forceful, short movements.

Species	DBW/TW(%)	Interpretation
S. salpa	1.99	More muscle mass (related to body weight) relative to bone — adapted for active swimming.
D. gibbosus	5.37	Heavier skeleton relative to muscle mass — suited for mechanical support and substrate contact.

Interestingly, the dry bone weight-to-length (DBW/TL) ratios were similar across species, suggesting comparable skeletal investment per unit length. However, *S. salpa* distributes this over a longer, more streamlined body, while *D. gibbosus* compresses it into a compact form adapted to confined motion near or within sediment.

Bone Composition and Biomineralization Patterns XRF analyses confirm that bones of both species are composed primarily of calcium (Ca) and phosphorus (P), characteristic of vertebrate biomineralization, typically in the form of hydroxyapatite ($\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$), which provides rigidity and resistance to compression (Weiner & Wagner, 1998). Calcium content increased with fish length in both species, affirming its role in skeletal growth.

However, mineral profiles differ in functionally meaningful ways. *S. salpa* had significantly higher phosphorus and manganese levels. Elevated P may indicate faster bone turnover or higher metabolic demand—plausible given the species' sustained swimming and muscle use (Currey, 2002). Manganese may support collagen synthesis and bone matrix development (Leach & Harris, 1997). In contrast, *D. gibbosus* bones contained more iron and silicon, potentially acquired through prolonged contact with sediment and ingested prey. Silicon, while trace in fish bone, may influence collagen cross-linking (Jugdaohsingh, 2007), and iron could reflect environmental exposure rather than functional necessity.

Functional Implications of Biomineralization

Biomineralization supports more than structural integrity; it underpins crucial biological roles such as protection, locomotion, and sensory function (Müller, 2003), in addition to body form and skeletal muscles mass. In *S. salpa*, a light yet stiff skeleton, in addition to the streamline body form, facilitate efficient swimming and energy conservation. In *D. gibbosus*, biomineralization enhances bone robustness to withstand mechanical stress from digging and powerful lunges. Both species exhibit adaptations consistent with their ecological strategies: *S. salpa*: Hydrodynamic efficiency, midwater mobility, and predator evasion. *D. gibbosus*: Skeletal resilience, substrate interaction, and stealth predation.

CONCLUSION

Biomineralization in *Sarpa salpa* and *Dentex gibbosus* reflects an intricate relationship between ecological niche, feeding strategy, morphology, and locomotor function. Evolution has sculpted two distinct skeletal frameworks: one optimized for mobility and efficiency in the water column, the other for robustness and mechanical leverage near the seabed.

Feature	<i>Sarpa salpa</i>	<i>Dentex gibbosus</i>
Habitat	Midwater herbivore	Benthic carnivore
Swimming style	Fast, sustained	Slow, ambush bursts
Body form	Fusiform, forked tail	Deep body, lunate tail
Camouflage	Countershading	Coloration-matching sediment
DBW/TW (%)	1.99	5.37
Allometry	Positive (b = 3.32)	Negative (b = 1.82)
Mineral traits	High Ca, P & Mn	High Ca, Fe & Si
Functional focus	Agility, speed	Stability, digging power

These distinctions illustrate that biomineralization is not a passive process but is actively shaped by environmental demands and functional needs. It is thus a vital component of evolutionary adaptation in marine vertebrates.

Recommendations

In the present study, the interpretation of the positive and negative correlations observed between some of the metal and non-metal pairs constituting the skeletal bones of both fish can not be inferred from the present data. It is recommended that more data points, and more sensitive scanning method than the (XRF) Scanner used here, should be used in future studies. Biomineralization studies are better coupled with mode of feeding, protection and concealment, habitat, body form and morphology, muscle mass, and swimming.

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