How does shape affect predator- prey interactions in fish? Implications for marine food web structure and dynamics

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INTRODUCTION

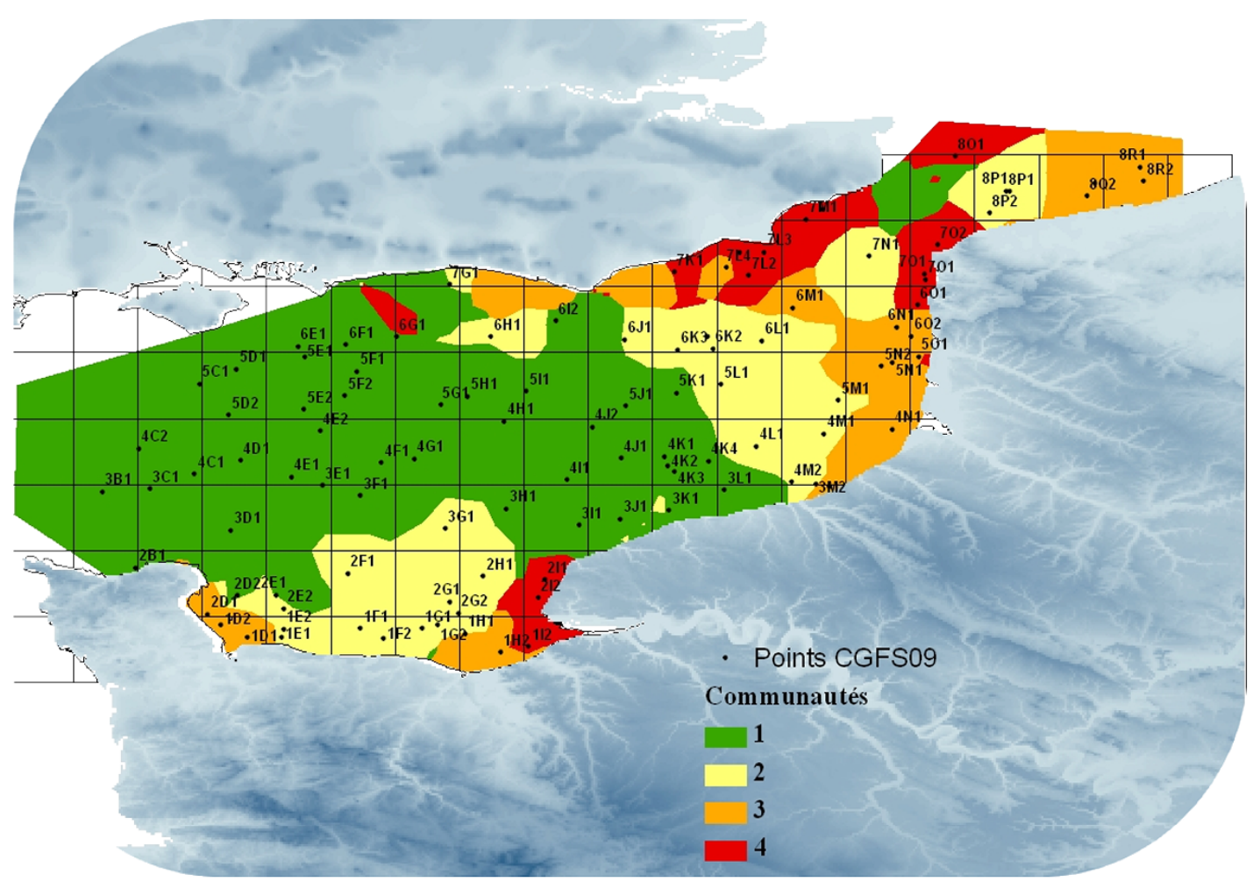
Each species pertains to a given functional niche, depending on its relationships with others species and its interactions with the abiotic environment. Understanding inter-specific interactions is critical to know and predict ecosystems' structure, functioning and dynamics, but also their response to anthropogenic impacts.Predator-prey relationship is one of the main biotic interactions as it both determines the survival of the prey and the predator and is the keystone of food webs. Unraveling the determinants of predator-prey relationships or, in other terms, the reason why a given predator catches a given prey is therefore of primary importance. Fishes are characterized by a remarkable diversity of shapes which can be associated by their feeding and predation abilities. Body morphology may affect their movements (swimming) and their predation strategy (benthic search, active hunting, ambush…). This study aims at assessing whether, besides the simple size ratio, a predator fish's morphological shape is related to its diet composition, based on four different fish species from the Eastern English Channel.

MATERIAL & METHODS

Fish collection :

The four fish species (horse mackerel, red mullet , sea bass, and whiting) were collected during the Channel Ground Fish Survey (October 2009) on board of the N/O Gwen Drez and frozen in a freezer at − 20°C or with liquid nitrogen. Back from the survey, frozen fishes were stocked at − 20°C, waiting for the analysis.

N/O Gwen drez



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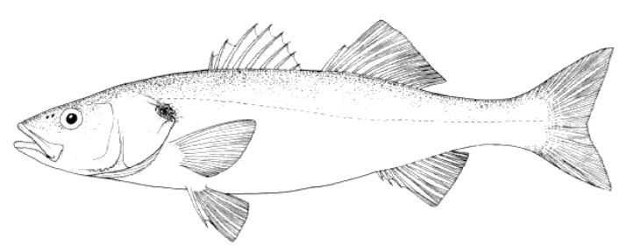
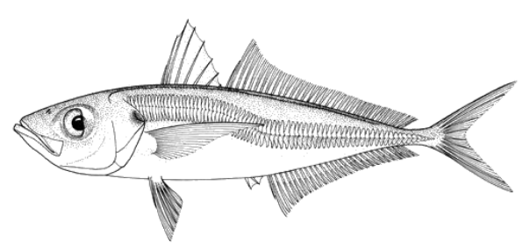
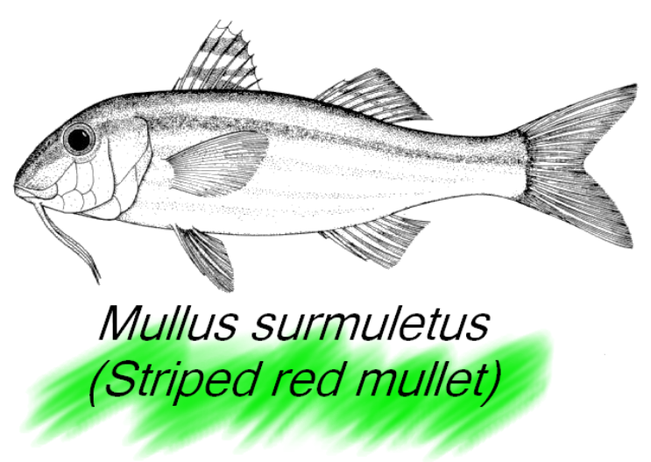




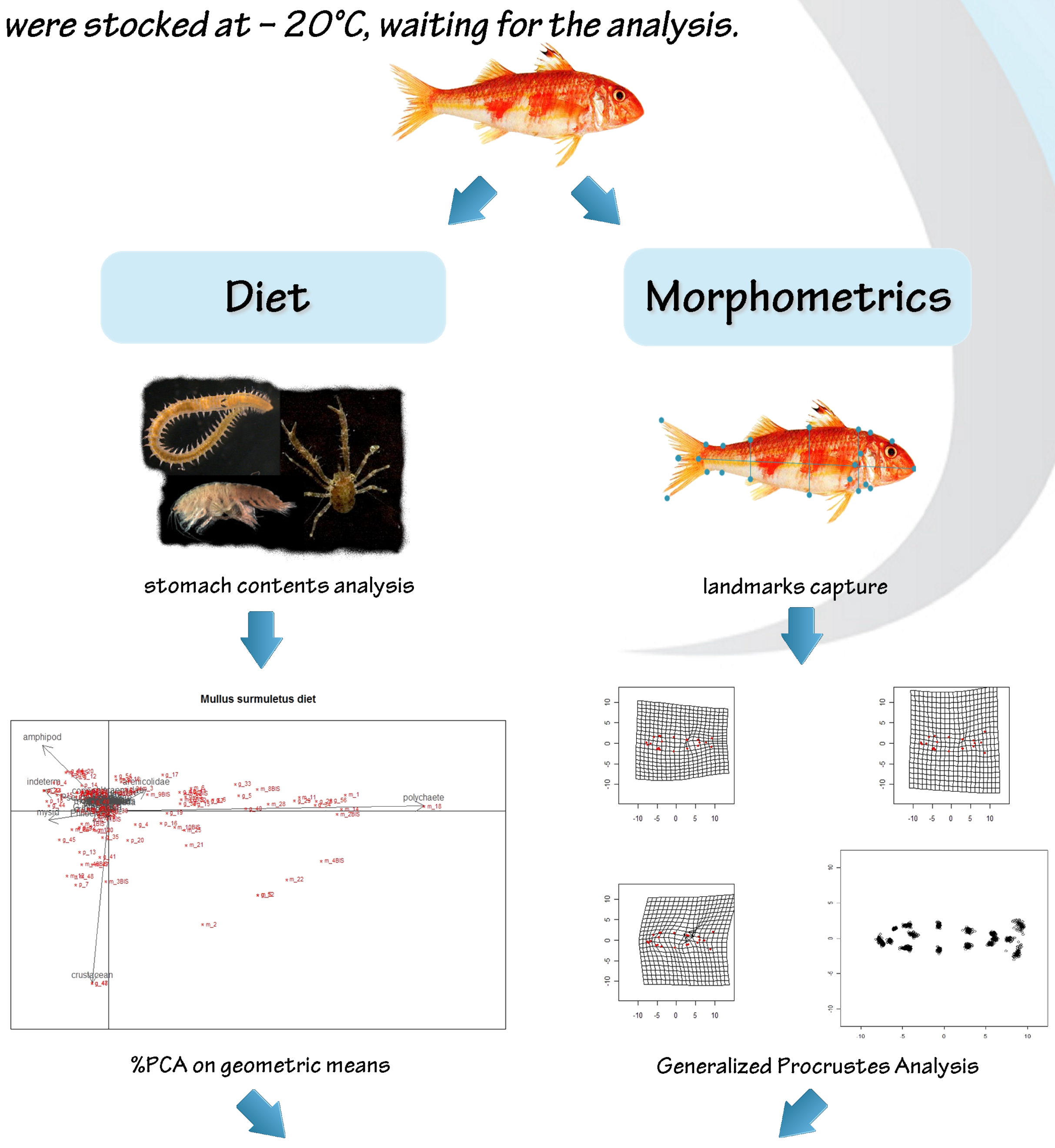


species studied

Geomorphometric analysis :

After defrosting, a numerical picture of each individual was taken and used to capture homologous landmarks (different anatomical points that would realistically describe the shape of a given fish species). Using landmark coordinates, a Generalized Procrustes Analysis (GPA, Goodall, 1991) was performed to compare individuals' shapes. GPA superimposes individual landmark configurations on the average one thanks to three steps: scaling (size standardization against centroid size), translation (centering landmark configurations), and finally rotation (to minimize the distance between homologous landmarks). The distance persisting between homologous landmarks after these operations characterizes shape differences.

A PCA was performed on the new landmark coordinates after GPA to describe shape variability between the species.



Diet

Morphometrics

stomach contents analysis

landmarks capture

%PCA on geometric means

Generalized Procrustes Analysis

Co Inertia Analysis

Diet analysis:

A Stomach Contents Analysis (SCA) was performed. Individuals were dissected, their stomach extracted and opened, and preys identified to the lowest possible taxon, counted (N) and weighed (W). The contribution of each prey species P to an individual I diet was computed as the geometric mean (%GM pi) of the number of items Npi and their weight Wpi expressed in percentage

$$\%GM_{p,i} = 100\frac{\sqrt{N_{p,i}\cdot W_{p,i}}}{\sum_{p'}\sqrt{N_{p',i}\cdot W_{p',i}}}$$

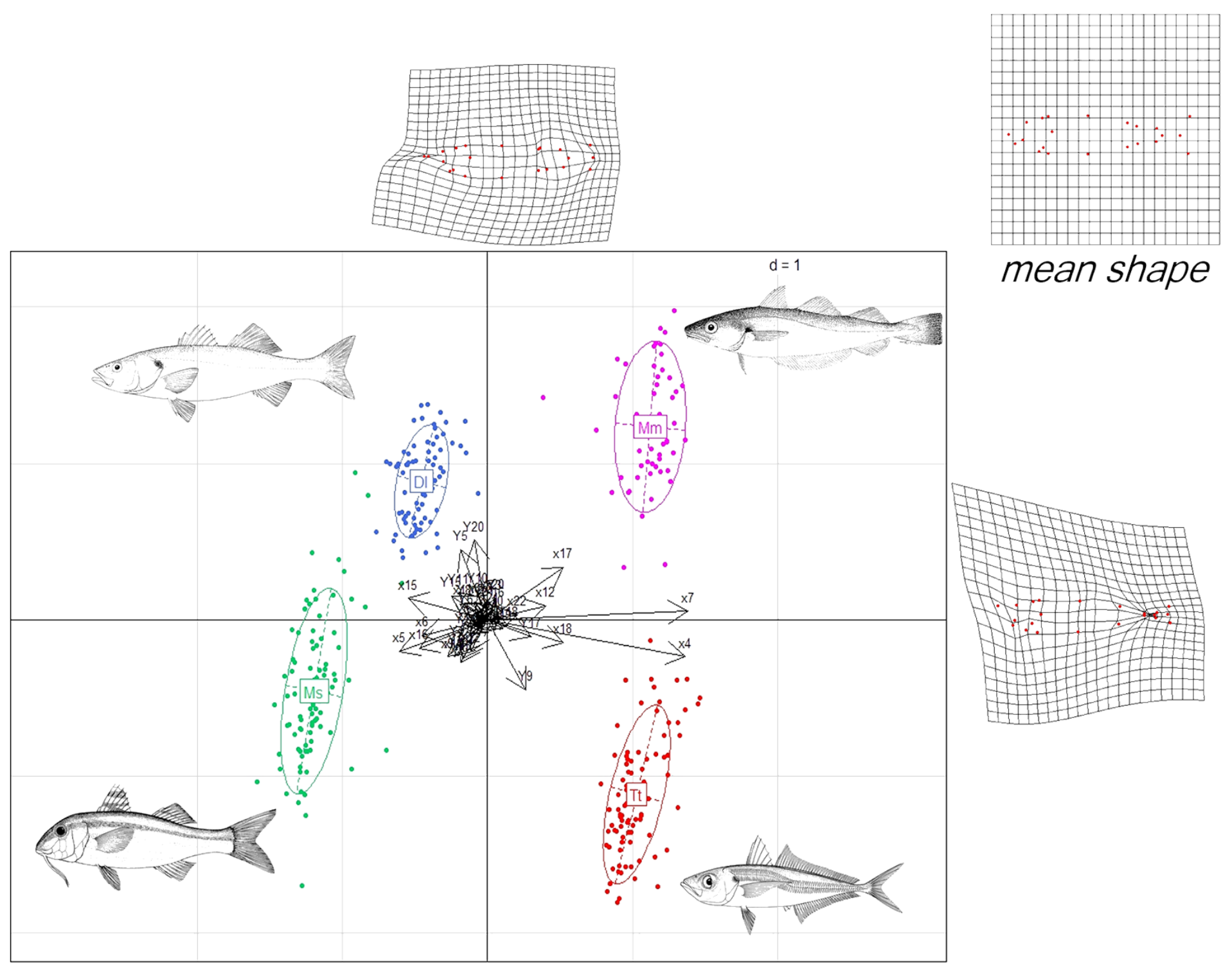
A %PCA (de Crespin de Billy et al.,2000) was performed on diet composition expressed in %GM to describe diet variability between species.

RESULTS

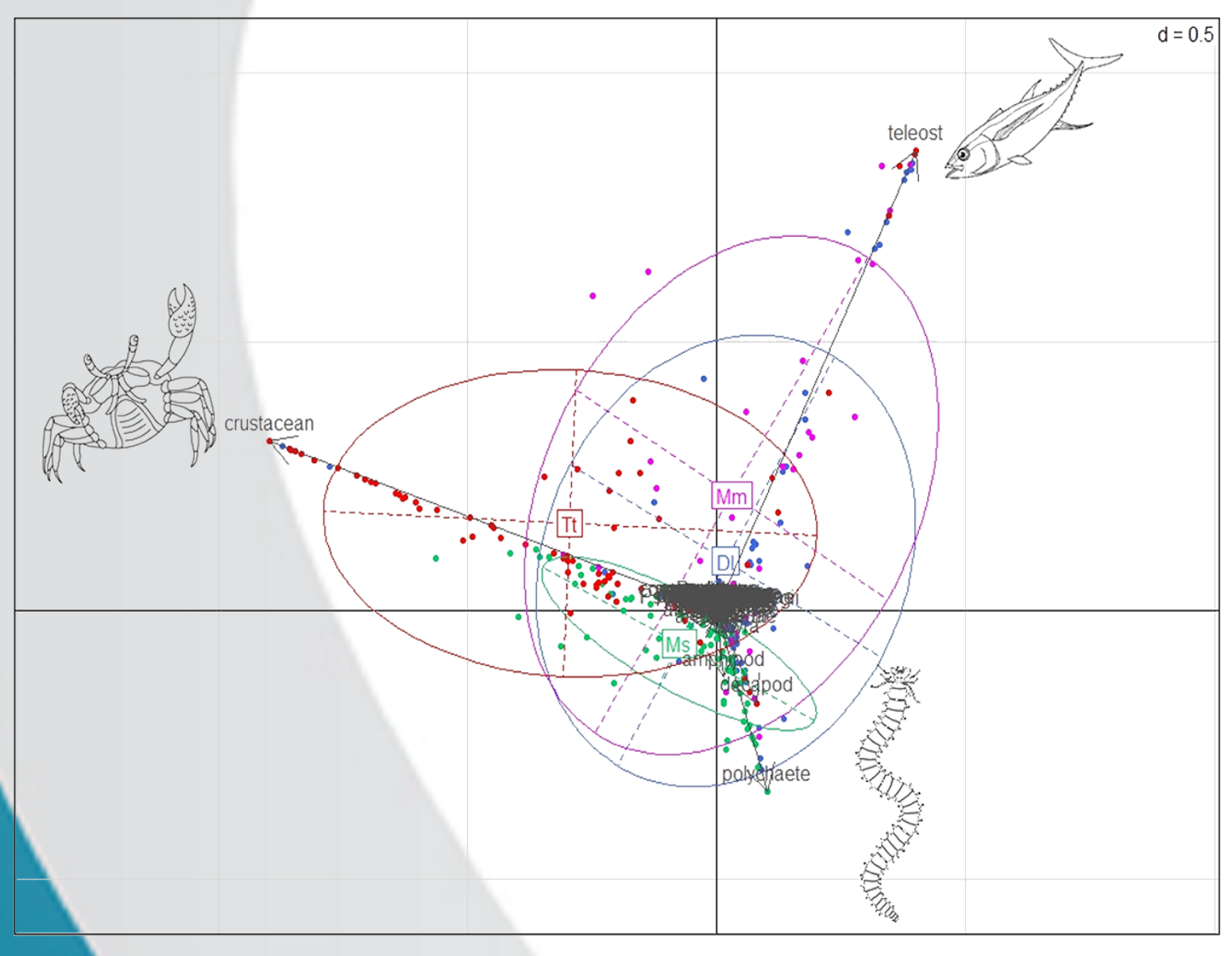
GPA:

The first axis (PC1) is mainly related with the caudal area. The caudal peduncle becomes thinner and the caudal fin area decreases with positive values along PC1, a shape that is characteristic of a carangiform swimming (fast, propulsive power on tail). Negative value along PC1 are related to a thicker caudal peduncle that can be linked to sub-carangiform swimming with a large caudal fin as a response to the need for rapid acceleration and maneuvering. Fishes with positive values on the second axis (PC2) have a more triangular head, and a thicker rear third of the body.

The four species are well separated by their morphology. Whiting and horse mackerel show a thinner caudal area, when sea bass and red mullet are less slender. A slender body, with short and strong caudal peduncle holding a tail with hydrodynamic shape is a proxy of fast swimming.



PCA after Generalized Procrustes Analysis



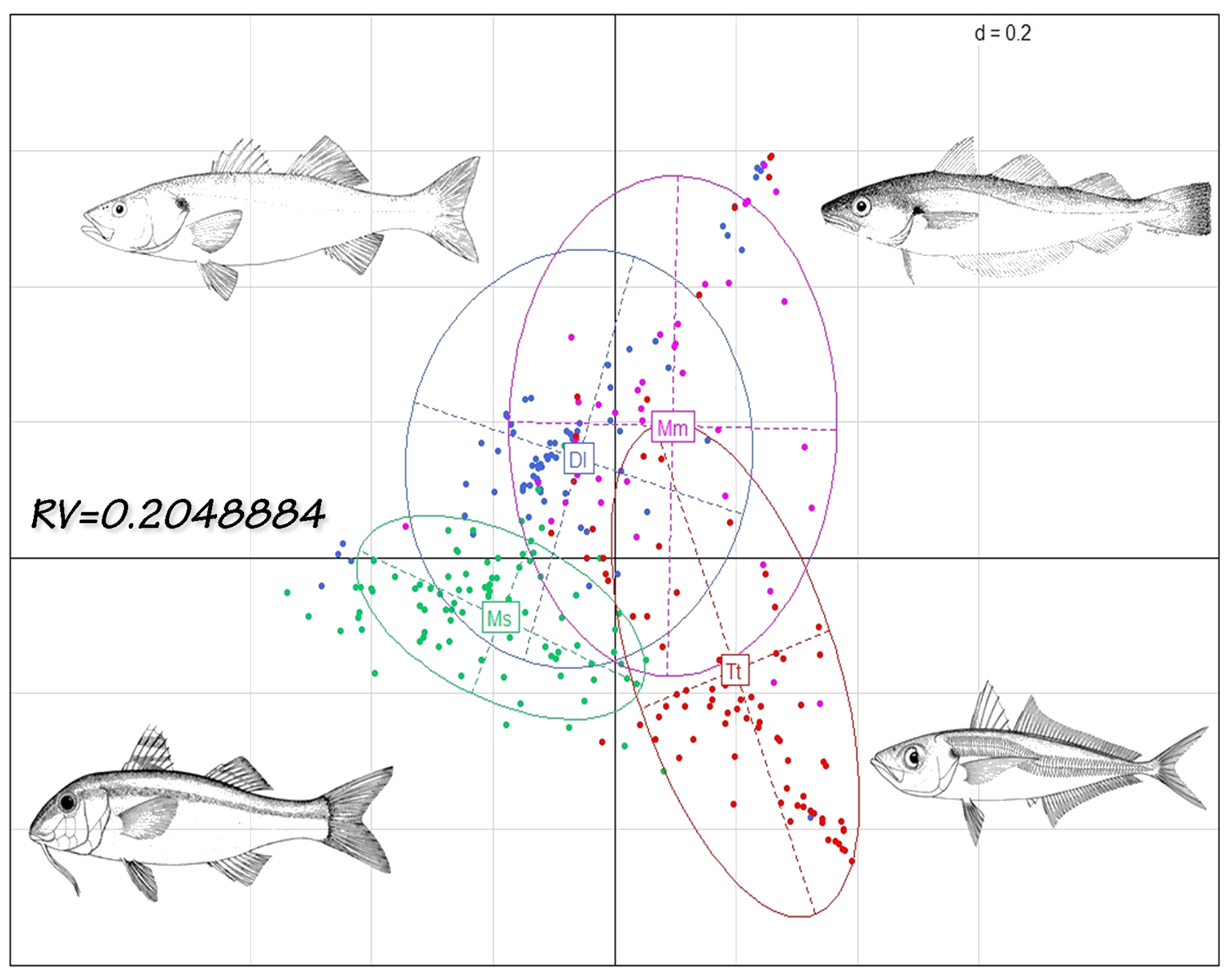
%PCA after Stomach Content Analysis

%PCA:

Three main prey categories emerge from diet data: crustaceans, teleosts, and polychaetes. Whiting and sea bass have similar diet, and both are mainly piscivorous, compared to the other two species. Red mullet eats polychaete essentially, while horse mackerel prefers crustacean. The %PCA result highlights that the trophic niche of these species overlaps largely. It is particularly true between sea bass and whiting, which share most of their preys. Red mullet's trophic niche is totally include in sea bass's and whiting's one. Horse mackerel has a more divergent trophic niche .

COA:

There is a relatively good association between morphology and diet in this 4 fish species expressed as ~20% co-inertia (RV). Despite the initially observed differences in their morphology, these four species exhibit important trophic niche overlap which seems to be partly related to morphology. A trophic niche overlap is a sign of interspecific competition, which is an important biotic relationship that requires to be understood. Notably, it seems that trophic niche overlap between sea bass and whiting is largely related to the similarity of the shape of their head which is longer and more triangular than that of red mullet and horse mackerel. In contrast, trophic niche divergence between red mullet and horse mackerel is associated with dissimilarity in the shape of the caudal area. Whiting and horse mackerel are probably active hunters whereas seabass and red mullet, which show cruise swimming and maneuvering, can combine short chase and benthic searching.



Co Inertia Analysis

CONCLUSION

Fish species exhibit a wide variety of morphology and diet which are both related to functional diversity. In this study, we considered four species with different diets and investigated if their shape can be used as a functional determinant of their trophic guilds.

We found that diet and morphology are partly related in our four fish species, particularly the morphology of the caudal area, related to swimming and hunting, and the shape of the head, related to prey handling and ingestion, playing a major role in trophic niche overlap or differentiation. Trophic competition, as expressed by trophic niche overlap, is thus partly related to morphological similarity and conversely trophic diversity is related to morphological diversity. Both aspects are thus important for functional diversity and its conservation in the context of the mitigation of anthropogenic impacts.

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