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NON-INDIGENOUS MACROZOOBENTHIC SPECIES ON HARD SUBSTRATA OF SELECTED HARBOURS IN THE ADRIATIC SEA

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Abstract

The intense shipping traffic characterising the Adriatic Sea favours the spread of marine organisms. Yet, a study of 12 Adriatic ports (4 on the western side and 8 on the eastern side of the basin) found that non-indigenous species (NIS) accounted for only 4% of the benthic communities settled on hard substrates. The cirripeds *Amphibalanus amphitrite* and *Balanus trigonus*, found in 8 harbours, were the most common invaders followed by *Amphibalanus eburneus*, the ascidian *Styela plicata*, and the bivalve *Magallana gigas*. The highest percentage of NIS was recorded in Venice and Ploče, the harbours with the least rich native communities; the lowest percentage was retrieved in Trieste, Koper, Pula, and Rijeka, the harbours hosting the highest species diversity. In contrast, the ports of Bari and Ancona showed both high NIS percentages and highly diversified communities.

Keywords: Non-indigenous species; macrozoobenthos; hard bottom; ports; Adriatic Sea

Introduction

Human-related transport activities appear to be the main factor underpinning the different richness and identity of Non-Indigenous Species (NIS) recorded in different parts of the Mediterranean basin. Whereas most NIS recorded in the Levant may have entered through the Suez Canal, both mariculture and ships are believed to be responsible for the NIS introduced in the north-western Mediterranean and the Adriatic Sea (Zenetos et al., 2012). Species that are not demonstrably native or introduced are called cryptogenic species (Carlton, 1996). This study addressed exclusively NIS.
The Adriatic Sea is characterised by intense ship traffic. Ships transport a wide range of sessile and planktonic species in the free living and resting stage or buried in the ballast sediment as well as organisms like fish and algae, largely through hull fouling or ballast water and sediments (Carlton, 2001; Zaiko et al., 2007). Ship-related species introduction is a complex process involving survival of the organism during the journey. Successful introduction requires the species to arrive in sufficient numbers to establish a self-sustaining population outside their native habitat (Galil et al., 2008). Another substantial source of invader species is mariculture (Occhipinti-Ambrogi et al., 2011a). The growth of this sector, due to population pressure and rising demand for fish and shellfish, has led to the introduction of NIS, some of which have proved invasive and have exerted irreversible impacts on host environments (Hewitt et al., 2006). Some adapt so well that they affect species richness and the stability of native communities.
Two main hypotheses have been advanced to explain the relationship between the species diversity of a habitat and its invasibility, i.e. susceptibility to the establishment or proliferation of invaders.

According to the '*biodiversity increasing invasibility hypothesis*', which is related to the '*invasional meltdown hypothesis*' of Simberloff and Von Holle (1999), invasibility is higher in species-rich communities due to the facilitative effect of previously introduced species (Cohen and Carlton, 1998; Stohlgren et al., 2003) and to a more complete exploitation of resources. In such communities, NIS have greater chances of survival and/or a stronger ecological impact. Hard natural or man-made substrates such as artificial reefs, offshore platforms, and docks, which host highly rich communities (e.g., Thorson, 1968; Kocak et al., 1999; Thield and Ullrich, 2002; Çinar et al., 2008; Dorgham et al., 2014; Spagnolo et al., 2014; Punzo et al., 2015; Ferrero-Vincente et al., 2016), are likely be the habitats most prone to invasion and to host a large number of NIS. In contrast, according to the '*diversity resistance hypothesis*' (or '*biotic resistance hypothesis and diversity: invasibility hypothesis*'), diversified communities are highly competitive and more resistant to invasion (Elton, 1958; Stachowicz et al., 1999; Levine, 2000). As noted by Zaiko et al. (2007), the diversity of indigenous species (IS) and invasive species is likely to depend on ecosystem physical factors (natural conditions or anthropogenic stressors), which promote or inhibit invasibility.

Successful invasions crucially depend on the relationship between habitat invasibility and species invasiveness (Colautti et al., 2006). Biological traits such as life form, sociability, reproductive frequency and type, haploid/diploid dispersal, feeding method, salinity and temperature tolerance range are likely to be related to NIS invasiveness (Tyler et al., 2012; Lejeusne et al., 2014). For example, species that can survive for long periods in ballast water in the larval stage and adults of small species (e.g. crustaceans) are frequently recorded in hull fouling studies (Gollasch et al., 2000; Wonham et al., 2000; Galil et al., 2008).

NIS have been described as a potential cause of local decimation of native species (Carlton, 1993; Carlton et al., 1999; Clavero and García-Berthou, 2005; Galil, 2007), even though in some cases the evidence is only circumstantial (Williamson and Fitter, 1996; Gurevitch and Padilla, 2004). Nevertheless, they can form proliferating populations and are capable of re-structuring the food web, introducing new pathogens or parasites, and altering gene pools (Carlton, 1985; Lodge, 1993; IUCN, 2000; Mack et al., 2000; Çinar et al., 2005; Streftaris and Zenetos, 2006; Galil, 2007; Kettunen et al., 2009). In the Adriatic Sea, a well-known case is the one of the Pacific oyster *Magallana gigas*. Most introductions of this species in Europe have aimed at replacing native species or they have helped meet consumer demand after the collapse of local populations (Grizel and Héral, 1991; NIMPIS, 2002); as a result, wild *M. gigas* are now found along all the Adriatic coasts (Otero et al., 2013). *Magalana gigas* competes with native species for space and food, modifies habitats, and transfers parasites and diseases (Gutiérrez et al., 2003; Ford and Smolowitz, 2007). Similarly, the soft-bottom dwelling bivalve *Ruditapes philippinarum* has replaced its indigenous congener *R. decussatus* along the Adriatic coast (Carrieri et al., 1992; Pranovi et al., 2006; Lipej et al., 2012; Nerlović et al., 2016).

This study was performed to describe and compare the NIS settled on hard substrates in 12 harbours in the western and eastern Adriatic Sea and to establish a baseline dataset for future assessments of native species and NIS in these habitats.

Materials and Methods

Study area and sampling

The Adriatic Sea is an elongated basin with a NW-SE orientation; it is about 800 km long and 200 km wide. The northern area is shallow, rarely exceeding a depth of 46 m, whereas its depth in the central part reaches 270 m (Pomo or Jabuka Pit). The continental slope lies ca. 500 km from the northern border of the Adriatic and separates the central from the southern Adriatic, whose depth reaches 1200 m (South Adriatic Pit). The coastline of the northern and north-western area is characterised by shallow waters and sandy beaches, whereas the eastern side is deeper, rocky, and dotted with islands and islets. The distinctive hydrographic and morphological features of the northern area therefore play a role in NIS settlement and proliferation (Occhipinti-Ambrogi, 2011a).

The southern Adriatic is connected with the Ionian Sea through the Otranto Sill (780 m deep) and is a busy route for commercial and naval ships, yachts, fishing vessels, and other non-merchant craft.
The study was conducted in 12 ports identified in the framework of the BALMAS Project - Bari, Ancona, Venice, and Trieste (Italy), Koper (Slovenia), Pula, Rijeka, Šibenik, Split, and Ploče (Croatia), Bar (Montenegro), and Durrës (Albania) (Figure 1) - which have different dimensions and host different activities (Krauss et al., this issue (a); Petrocelli et al., this issue). It involved two surveys, one in spring and one in autumn 2014. Sampling sites at each port were 2-4 areas (concrete docks) selected among the busiest and covering as large a number of activities as possible. An offshore terminal about 8 km NW of Ancona was also included.
At each site, 3 vertical transects (replicates) were established 10-15 m from each other, and 3 samples measuring at least 400 cm^2 were collected near the surface, near the bottom, and in between; 400 cm^2 is considered as the minimal sampling area for Mediterranean communities (Hewitt and Martin, 2001). All organisms found in each sampling frame were carefully scraped into collecting bags. Each sample was immediately fixed with buffered formaldehyde (4-5%) and taken to the laboratory, where it was sieved through a 1 mm mesh. Organisms were collected and identified to the lowest possible taxonomic level. Photographs and videos of fouling communities were also made in some cases.
The taxonomic nomenclature followed the World Register of Marine Species (WoRMS; http://www.marinespecies.org). All species were identified; the NIS were listed as reported in recent NIS inventories of the Mediterranean Sea (Streftaris and Zenetos, 2006; Zenetos et al., 2010, 2012, 2017; Occhipinti-Ambrogi, et al., 2011a, b; Katsanevakis et al., 2014; Corriero et al., 2016; Rosso and De Martino, 2016; http://www.ciesm.org/marine/index.htm).

Data analysis

Since density data were not available for all samples, and to maximise information use, only the presence/absence of taxa was subjected to univariate and multivariate analysis.
The percentage of NIS in each port was determined to evaluate their contribution to the benthic communities.
Hierarchical cluster analysis (group average), non-metric multidimensional scaling (MDS), and an unconstrained Principal Coordinates (PCO) plot were applied to visualise possible similarities among harbours; a projection plot was drawn onto PCO axes to examine the relationship between the NIS and each harbour. Multivariate analysis was conducted with PRIMER™ ecological software package (version 6+; Clarke, 1993; Clarke and Warwick, 2001).

Results

Overview

A total of 725 taxa (IS and NIS) were collected in the 12 ports (Table 1). Most were molluscs (219), polychaetes (209), and crustaceans (147). There was a large number of sponge (39 species), ascidian (27), bryozoan (26), echinoderm (22), and cnidarian (21) taxa and only one nemertean and one phoronid worm (*Phoronis muelleri* Selys-Lonchamps, 1903) (Table 1). The molluscs *Anomia ephippium* Linnaeus, 1758, *Mytilus galloprovincialis* Lamarck, 1819 and *Ostrea edulis* Linnaeus, 1758 were the most common species, being recorded in all 12 ports, followed by the bivalves *Modiolus barbatus* (Linnaeus, 1758) and *Rocellaria dubia* (Pennant, 1777) (11 ports); by the bivalves *Chama gryphoides* Linnaeus, 1758 and *Striarca lactea* (Linnaeus, 1758) and the polychaete *Serpula verimicularis* Linnaeus, 1767 were next (10 ports). The species retrieved at 1 or 2 sites (n=548) were considered as rare.
Species richness was highest at Bari (219), Pula (203), Ancona (n=146), and Koper (138) and lowest at Ploče (n=63) (Table 1).
The characteristics of the benthic assemblages collected at the 12 harbours were analysed by MDS based on presence/absence of IS and NIS (Figure 2). The MDS findings were confirmed by cluster analysis (Figure 3a), which showed low similarity except among the ports of Split, Šibenik, and

Durrës.

Contribution of NIS to the community

A total number of 29 taxa, accounting for 4% of the total species richness, were identified as NIS (Table 3). They were mainly polychaetes (n=9), crustaceans and molluscs (n=6 each). Three bryozoans (*Bugula neritina*, *Bugulina fulva* and *B. stolonifera*), three ascidians (*Botryllus schlosseri*, *Styela canopus* and *S. plicata*), a sponge (*Paraleucilla magna*), and a cnidarian (*Oculina patagonica*) were also observed.

Despite being the taxon with the highest species number, polychaetes colonised a limited number of ports. The crustaceans *Amphibalanus amphitrite* and *Balanus trigonus* were the most successful colonisers in terms of number of ports (Figure 4), since they were found in 8 harbours, *A. amphitrite* was not found at Venice, Pula, Rijeka, and Bar whereas *B. trigonus* was not found at Pula, Rijeka, Bar, and Durrës. The next most successful invaders were the crustacean *Amphibalanus eburneus*, the ascidian *S. plicata* and the mollusc *M. gigas*: the cirriped was retrieved in 3 Croatian and 2 Italian harbours as well as in Bar, the ascidian in 2 Italian ports and in Koper, Šibenik, Split, and Durrës (Table 2). Finally, the bivalve was recorded at all 4 Italian sites as well as Koper and Pula. The bryozoan *B. neritina* was the next most common species (5 ports). Thirteen NIS were identified in 2 or 3 harbours, whereas 10 NIS were found in a single harbour.

NIS were most numerous in Bari (n=15) and Ancona (n=11), where they accounted respectively for 6.8% and 7.5% of these communities (Table 2 and Figure 5). In Bari crustaceans (n=5) and polychaetes and bryozoans (n=3 each) were the taxa most highly represented, followed by ascidians and molluscs (n=2 each) (Figure 6). The samples collected at the Ancona sites contained 4 molluscs, 3 crustaceans, 2 polychaetes, and 2 bryozoans.

Nine NIS were recorded in Venice: they were 4 crustaceans, 2 molluscs, 2 polychaetes, and an ascidian, accounting for 11.3% of all taxa (Table 2 and Figures 5 and 6). Six NIS were retrieved in Šibenik, Split, and Ploče and accounted for 5.4%, 4.7% and 9.5% of the respective communities. Five NIS were found in Koper, Pula, Bar and Durrës (3.6%, 2.5%, 5.7%, and 5.3% respectively), 4 in Trieste (3.1%), and 3 in Rijeka (2.9%).

Cluster analysis (Figure 3b) highlighted close similarities between Koper and Trieste, Ploče and Šibenik, and among Bari, Venice and Ancona.

The PCO plot explained 63.6% of total variation (Figure 7) and highlighted the uniqueness of some ports, chiefly Bar, Rijeka, and Pula, and similarities among other ports (Ancona, Bari, and Venice Trieste and Koper).

Discussion

Maritime traffic is a major vector for the introduction and spread of invasive species in the Mediterranean Sea, and the Suez Canal is probably a major source of NIS (Galil, 2006; 2012; Zenetos et al., 2012). The physical characteristics of the Adriatic Sea, and the presence of several commercial and tourist ports, marinas, and aquaculture sites make the basin a potential colonisation area for NIS.

The present study identified macrofaunal fouling communities in 12 harbours on the eastern as well as the western side of the basin. The 29 NIS described herein were identified among the 725 taxa recorded in the framework of the BALMAS Project. The rich indigenous hard-bottom communities were dominated by molluscs, polychaetes, and crustaceans. As in other Mediterranean ports, mussels and other bivalves were the most common species (e.g. Bellan-Santini, 1965; Çinar et al., 2008; Lourenço et al., 2015) and formed a secondary substrate that enhanced spatial heterogeneity and species diversity. However, NIS accounted for only 4% of species, a much lower percentage compared with other similar studies (Çinar et al., 2006, 2008; Miralles et al., 2016).

Harbours are enclosed areas that are usually characterised by high pollution levels due to intense maritime traffic and to limited exposure to wind and waves. Our oceanographic investigation of 12 Adriatic harbours documented high nutrients concentrations, as expected, and unexpectedly low (and even extremely low) phosphorous concentrations, which might inhibit biological production, especially by NIS unused to such conditions (Krauss et al., this issue (b)). It should be noted that the Adriatic Sea, especially its northern basin, is characterised by freshwater inputs and by the Po River runoff (Marini et al., 2008). As regards sediments, the BALMAS Project found persistent contamination with biocides (e.g. butyltin), due to past use or recent illegal utilisation (Romanelli et al., this issue). These features may induce selection of resistant species. Indeed, the most common NIS were crustaceans such as *A. amphitrite*, *A. eburneus*, and *B. trigonus*, which tolerate pollution (Calcagno et al., 1998) as well as wide salinity and temperature ranges (Qiu and Qian, 1999). Darwin (1854) himself suggested that barnacles in the Mediterranean Sea had been carried there on ship hulls. These cryptogenic species have been among the most common in fouling communities since the 19th century. Its spread is due to a variety of vectors besides fouling and ballast transport on vessels, like the movement or detachment of buoys, commercial transport of living organisms with attached barnacles, as well as floating debris (Carlton et al., 2011).

Polychaetes were the most abundant taxonomic group of NIS. The genus *Hydroides* was the most widely represented, as *H. dianthus*, *H. elegans*, and *H. dirampha* were retrieved in all the Italian ports and *H. dirampha* was also recorded in Bar. These invasive and competitive serpulids have reached most of the Mediterranean coast attached to ships' keels (Bianchi, 1981; Galil et al., 2014). By virtue of their short larval stage and rapid achievement of sexual maturity, they have invaded several areas all over the world (Dos Santos Schwan et al., 2016), where they exert negative impacts on established ecosystems (Çinar, 2006, 2013). The three species found in this study are reported as NIS in the most recent checklist for Italian waters (Castelli et al., 2008), even though Zenetos et al. (2017) consider *H. dianthus* as native in the Mediterranean. Only two polychaetes were found in Pula and Rjeka (*Lysidice collaris* and *Pileolaria berkeleyana*). Ben-Eliahu (1972) considers the eunicid *L. collaris* as a Lessepsian migrant; however, its absence in the Levantine Sea, where the closely similar congener *L. margaritacea* has been described (Kurt-Sahin and Çinar, 2009, 2017), argues against the introduction of *L. collaris* into the Mediterranean through the Suez Canal. The first record of this species in the Mediterranean dates from 1962 in the Ciclopi Islands (western Sicily) (Tenerelli, 1962). Now *L. collaris* is distributed throughout most of the Mediterranean Sea (Iannotta et al., 2007) and is described as a NIS in the Italian seas (Castelli et al., 2008).

Pileolaria berkeleyana is a serpulid from the eastern Pacific. It was first described in the Mediterranean by Zibrowius and Bianchi (1981), in France in 1977 (Zenetos et al., 2017) and has probably been transported on ships' hulls (Zibrowius and Thorp, 1989).

The most common mollusc was *M. gigas*, which in the 1960s was introduced to Europe from the Pacific Ocean for commercial farming (Le Borgne et al., 1973). Wild populations were soon established and expanded rapidly, forming extensive and dense reef structures (Katsanevakis et al., 2014). The first record in the Adriatic Sea dates from 1964 (Matta, 1969). In the most recent checklist for Italian waters it is reported as a doubtful NIS (Schiapparelli, 2008), since it has long been present in various areas of the Mediterranean, including the whole Adriatic Sea. The Pacific oyster is a powerful vector for other epibiotic species (Occhipinti-Ambrogi, 2011a) like the bag mussel, *Arcuatula senhousia*, and the black pygmy mussel, *Xenostrobus securis*. The former species is native to the Pacific Ocean and is now common along the Mediterranean coasts of France and Italy (Adriatic Sea and north Tyrrhenian Sea; Scaperrotta et al., 2009). First recorded in the early 1990s along the northern Adriatic coasts (Lazzari and Rinaldi, 1994), *A. senhousia* was one of the NIS retrieved in Ancona, Venice, and Bar and has recently been recorded near Ploče (Despalatović et al., 2013).

Xenostrobus securis was collected only in Ancona. It comes from Australia and New Zealand and was first recorded in the Adriatic Sea in the Venetian lagoon and the Po River delta in 1992 (Sabelli and Speranza, 1993a, b; Lazzarri and Rinaldi, 1994). The species is spreading through ship traffic, and its frequent presence in lagoons and degraded environments demonstrates its considerable adaptability (www.marinealien.sinanet.isprambiente.it). The striped false limpet, *Siphonaria* *pectinata*, was retrieved only in Split, where it was first recorded in 2003 (Despalatović et al., 2008). This Atlantic gastropod was first observed in Greece in 1980 (Nikolay, 1980) and has become established in Greece, Tunisia, and Croatia. Its success is probably due to its diet, based on soft microalgae, which limits competition with other grazer species (Ocaña and Fa, 2003).

Three bryozoans were recorded. The presence of *B. neritina* on hard substrates in five ports makes it the most common species of this phylum. *Bugula neritina* is a frequent fouling organism carried by commercial and recreational craft (Floerl et al., 2004). Whereas some researchers consider it as a NIS in the Mediterranean Sea (Katsanevakis et al., 2014, Rosso and De Martino, 2016), it is described as a native species in a recent study of six Croatian marinas (Marić et al., 2016).

Ascidians are well-known invasive species in both tropical and temperate waters. Their tolerance of a wide range of physical conditions makes them highly competitive (Lindeyer and Gittenberger, 2011; Tamilselvi et al., 2011; Pineda et al., 2012a,b). Three solitary species were found in the study, *S. plicata* being the most common, as it was recorded in six harbours as well as in surrounding areas in Split, Šibenik, and Durrës. According to Pineda et al. (2012a, 2016), it does not occur outside ports or confined environments, where it withstands high pollutant concentrations and settles on docks and other artificial structures. For these reasons its diffusion probably relies on human transport vectors. *S. plicata* is believed to come from the NW Pacific and was described in warm, temperate waters of the Atlantic Ocean and of the Mediterranean already in the first decades of the 20th century (Harant 1927; Harant and Vernières 1933).

The retrieval of the scleractinian coral *O. patagonica* in Split harbour, where it was first recorded in 2011 (Cvitković et al., 2013a), is an interesting finding. The species is probably native to the southwest Atlantic and has been introduced into the Mediterranean Sea by ship traffic; it was first recorded in the Gulf of Genoa (Tyrrhenian Sea) in 1996 (Zibrowius, 1974).

Finally, the bioengineering species *P. magna* is the only sponge recorded in the study. We retrieved it in Ploče, where its first record dates from 2011 (Cvitković et al., 2013b). Besides ship traffic, the main vector for its spread is probably aquaculture (Longo et al., 2007). There are 11 known species of *Paraleucilla*; only *P. magna* has been recorded in the Mediterranean Sea (Klatau et al., 2016), being first described in 2001 in the north-western Ionian Sea (Mar Piccolo and Mar Grande of Taranto; Longo et al., 2004) due to introduction in ballast water. In 2016 it was recorded for the first time in the Sea of Marmara (eastern Mediterranean; Topaloglu et al., 2016).

Analysis of the benthic population records (IS + NIS) highlighted distinctive characteristics of the 12 harbours, whereas analysis of the NIS data alone highlighted several similarities among some of the ports. In fact, the fouling community found in Koper was very similar to the one seen in Trieste, the community identified in Šibenik was similar to the one in Ploče and Split, and the Ancona community shared several similarities with those in Venezia and Bari. The similar composition of the fouling communities of NIS in Koper and Trieste can be explained with their proximity (only 10 km). As regards Šibenik and Ploče, although the two sites are far removed, their location in river estuaries makes them ecologically similar. Such conditions can favour, for example, the colonisation of *P. magna*, which has a preference for these environments (Longo et al., 2007). Bari, Ancona, and Venice are also several hundred kilometres apart and are different in terms of size and amount of maritime traffic hosted. Moreover, whereas the surroundings of Bari and Venice are characterised by soft shores, Ancona is close to the Conero Promontory. This is one of the few rocky coastal areas in the western Adriatic, and is likely to affect both the benthic and finfish communities living in the vicinity of Ancona harbour. The eastern Adriatic ports are also surrounded by rocky shores. For the NIS living on hard substrates this may involve a different degree of connectivity and the possibility of spreading autonomously (i.e. without being carried) along the coast from a port to another. Surprisingly, the ports that are farthest from one another – Bari and Venice seemed to share more NIS species than ports that are closer together and are connected through rocky stretches of coast. Ploče and Venice were characterised by low level diversity of the native communities and by a high proportion of NIS. Since Venice hosts ship traffic from and to Asia as well as Central and Eastern Europe (www.port.venice.it), it would be expected to host a large number of NIS. In Ploče, more than 90% of ships sail to harbours in the Mediterranean Sea (www.lukaploce.hr; www.dzs.hr; Croatian Bureau of Statistics).

The similar percentage of NIS recorded in Ploče and Venice is probably due to weak competition from the species-poor native communities, as noted by Stachowicz et al. (1999) and Miralles et al. (2016). In contrast, the substrates sampled in Trieste and Koper were characterised by a low proportion of NIS and highly diverse benthic communities. It is conceivable that the limited niches available for the invaders (Stachowicz et al., 1999) resulted in strong competition and resistance, in line with the '*diversity resistance hypothesis'*. Moreover, the fact that the two ports are almost exclusively connected with Mediterranean harbours (David and Gollasch, 2015; www.porto.trieste.it) reduces the scope for the introduction of NIS from very distant places. NIS percentages in Bari and Ancona (both linked with Egypt) were high despite their rich communities, a finding that seems to agree with the '*biodiversity increasing invasibility hypothesis*'. Although these data seem contradictory, we agree with Zaiko et al. (2007) that biotic and abiotic factors are crucial in defining the invasibility of Adriatic harbours by NIS.

Finally, the accuracy of our NIS list can probably be improved, both because we could not find experts for all the taxonomic groups to be analysed in some countries and because of some taxonomic inconsistencies; on the other hand, some groups (e.g., sponges, amphipods) are particularly difficult to identify (Occhipinti-Ambrogi et al., 2011), and all checklists require continuous updating. These limitations notwithstanding, we feel that our study provides a starting point for a greater understanding of NIS dynamics in the Adriatic ports.

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CAPTIONS OF TABLES AND ILLUSTRATIONS

Table 1 - Number of taxa identified (IS + NIS) grouped by phylum or subphylum, total, and in each harbour.

Table 2 - NIS distribution and species richness in the 12 harbours investigated.

Figure 1 - Map of the 12 harbours.

Figure 2 - Non-metric multidimensional scaling plot based on NIS and IS presence/absence in the 12 harbours.

Figure 3 - Hierarchical clustering dendrograms including a) the overall communities (NIS + IS) and b) NIS alone.

Figure 4 - Number of harbours where each NIS was recorded.

Figure 5 - NIS percentage in terms of number of species in the overall communities.

Figure 6 - Number of NIS subdivided into phyla found at the different harbours. CRUS = Crustacea; CNI = Cnidaria; MOLL = Mollusca; ASCI = Ascidiacea; POLY = Polychaeta; BRYO = Bryozoa; PORI = Porifera.

Figure 7 - PCO ordination with projection of individual NIS onto the ordination axes.

Table 1

Table 1

Phylum/Subphylum	Total	Italy				Slovenia	Croatia					Montenegro	Albania
		Bari	Ancona	Venice	Trieste	Koper	Pula	Rijeka	Šibenik	Split	Ploče	Bar	Durrës
Porifera	39	14	1	1	5	11			9	8	5	4	6
Cnidaria	21	4	3	1	3	4			5	3	1	5	2
Platyelminthes	3	1	1	2	1								
Nemertea	1		1	1	1								
Mollusca	219	45	42	19	45	27	84	57	51	64	31	23	49
Polychaeta	209	58	32	18	29	43	119	45	14	15	6	22	7
Sipuncula	7	4	1		3				2	3		1	2
Pycnogonida	3	1	1		2								
Crustacea	147	62	51	28	34	31			15	16	8	14	11
Phoronida	1					1							
Bryozoa	26	10	8	1		5			5	4	3	11	7
Echinodermata	22	9	2	3	4	5			7	7	5	4	4
Ascidiacea	27	11	3	6	2	11			5	8	4	4	7
Total	725	219	146	80	129	138	203	102	113	128	63	88	95

Table 2

Table 2

		Italy				Slovenia	Croatia					Montenegro	Albania
		Bari	Ancona	Venice	Trieste	Koper	Pula	Rijeka	Šibenik	Split	Ploče	Bar	Durrës
Porifera	*Paraleucilla magna* Klautau, Monteiro & Borojevic, 2004								X		X		
Cnidaria	*Oculina patagonica* de Angelis, 1908									X			
Mollusca	*Anadara transversa* (Say, 1822)		X				X						
	Arca tetragona Poli, 1795	X											
	Arcuatula senhousia (Benson, 1842)		X	X								X	
	Magallana gigas (Thunberg, 1793)	X	X	X	X	X	X						
	*Siphonaria pectinata (*Linnaeus, 1758)									X			
Polychaeta	*Ficopomatus enigmaticus (*Fauvel, 1923)								X		X		
	Hydroides dianthus (Verrill, 1873)	X	X	X									
	Hydroides dirampha Mörch, 1863	X										X	
	Hydroides elegans (Haswell, 1883)	X	X	X									
	Lysidice collaris Grube, 1870						X	X					
	Neanthes agulhana (Day, 1963)							X					
	Palola valida (Gravier, 1900)											X	
	Pileolaria berkeleyana (Rioja, 1942)						X	X					
	Spirorbis marioni Caullery & Mesnil, 1897						X						
Crustacea	*Amphibalanus amphitrite* (Darwin, 1854)	X	X		X	X			X	X	X		X
	Amphibalanus eburneus (Gould, 1841)	X		X					X	X	X	X	
	Amphibalanus improvisus (Darwin, 1854)	X	X	X									
	Balanus trigonus Darwin, 1854	X	X	X	X	X			X	X	X		
	Monocorophium sextonae (Crawford, 1937)				X	X							
	Paracerceis sculpta (Holmes, 1904)	X		X									
	Xenostrobus securis (Lamarck, 1819)		X										
Bryozoa	*Bugula neritina* (Linnaeus, 1758)	X	X								X	X	X
	Bugulina fulva (Ryland, 1960)	X	X										X
	Bugulina stolonifera (Ryland, 1960)	X											
Ascidians	*Botryllus schlosseri* (Pallas, 1766)												X
	Styela canopus (Savigny, 1816)	X											
	Styela plicata (Lesueur, 1823)	X		X		X			X	X			X
Total		15	11	9	4	5	5	3	6	6	6	5	5

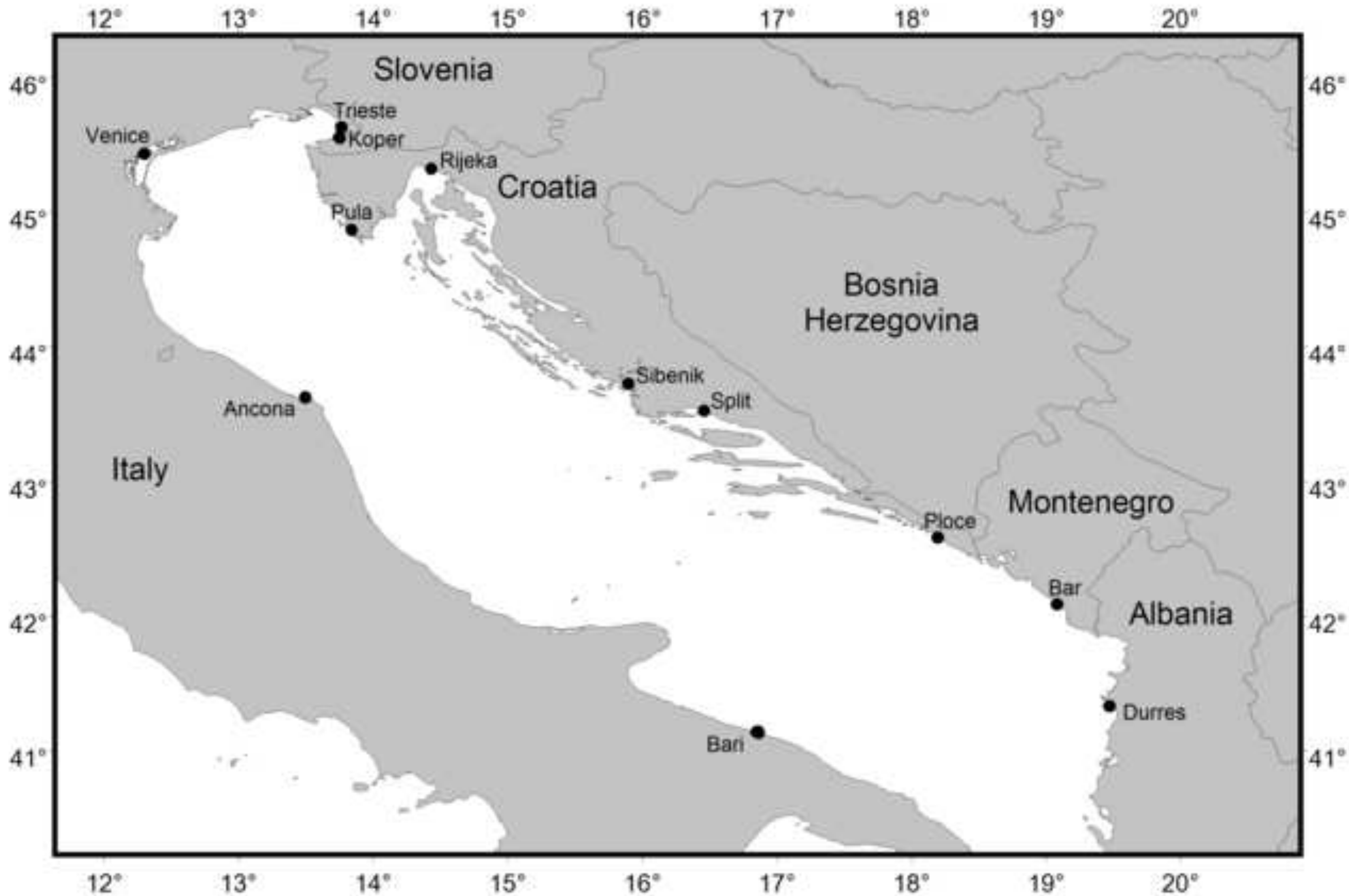

12°
13°
14°
15°
16°
17°
18°
19°
20°
46°
45°
44°
43°
42°
41°
Slovenia
Trieste
Koper
Venice
Rijeka
Croatia
Pula
Bosnia
Herzegovina
Sibenik
Split
Ancona
Italy
Montenegro
Ploce
Bar
Albania
Durres
Bari

Figure 2

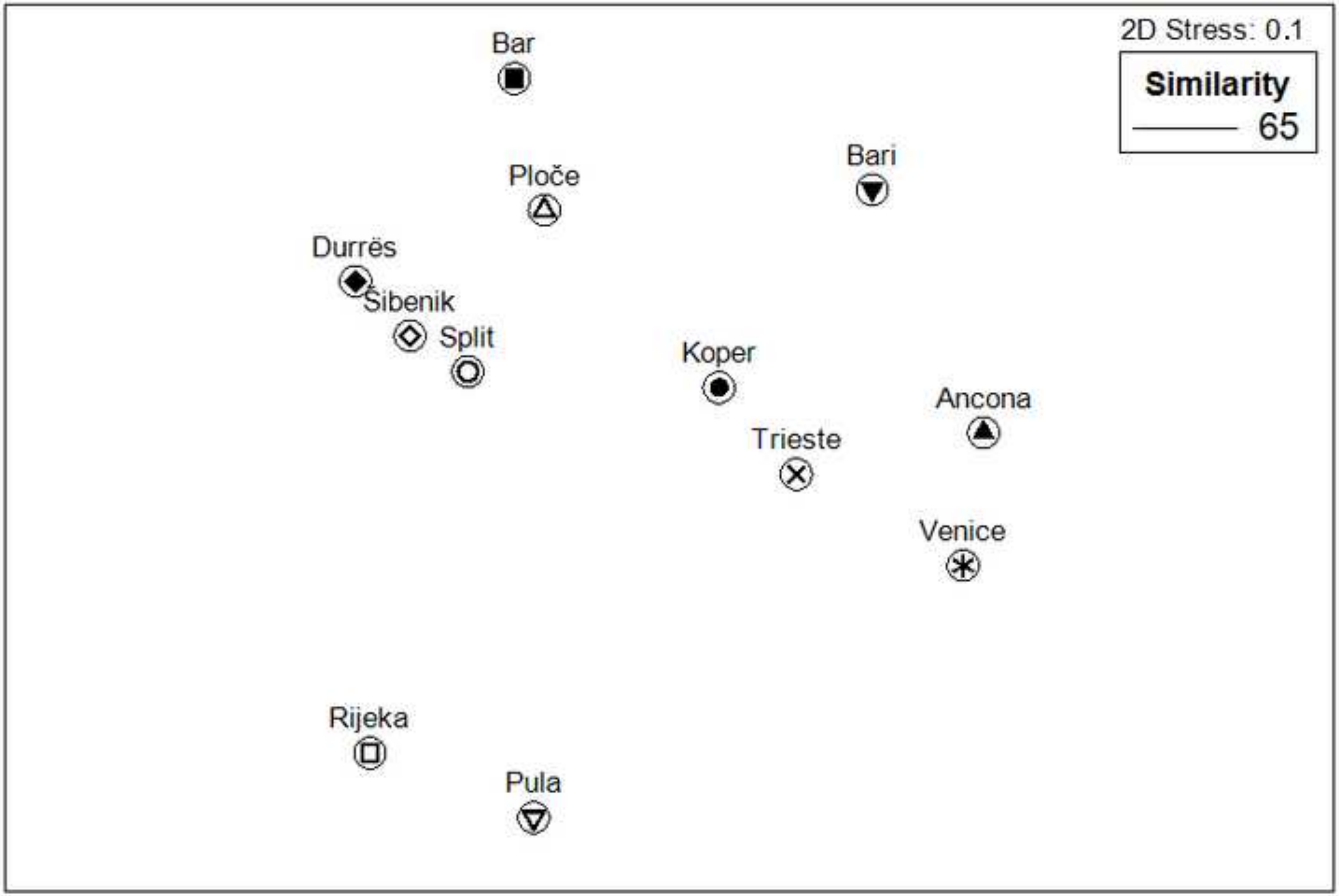

2D Stress: 0.1
Similarity
65
Bar
Bari
Pločе
Durrës
Šibenik
Split
Koper
Ancona
Trieste
Venice
Rijeka
Pula

Figure 3

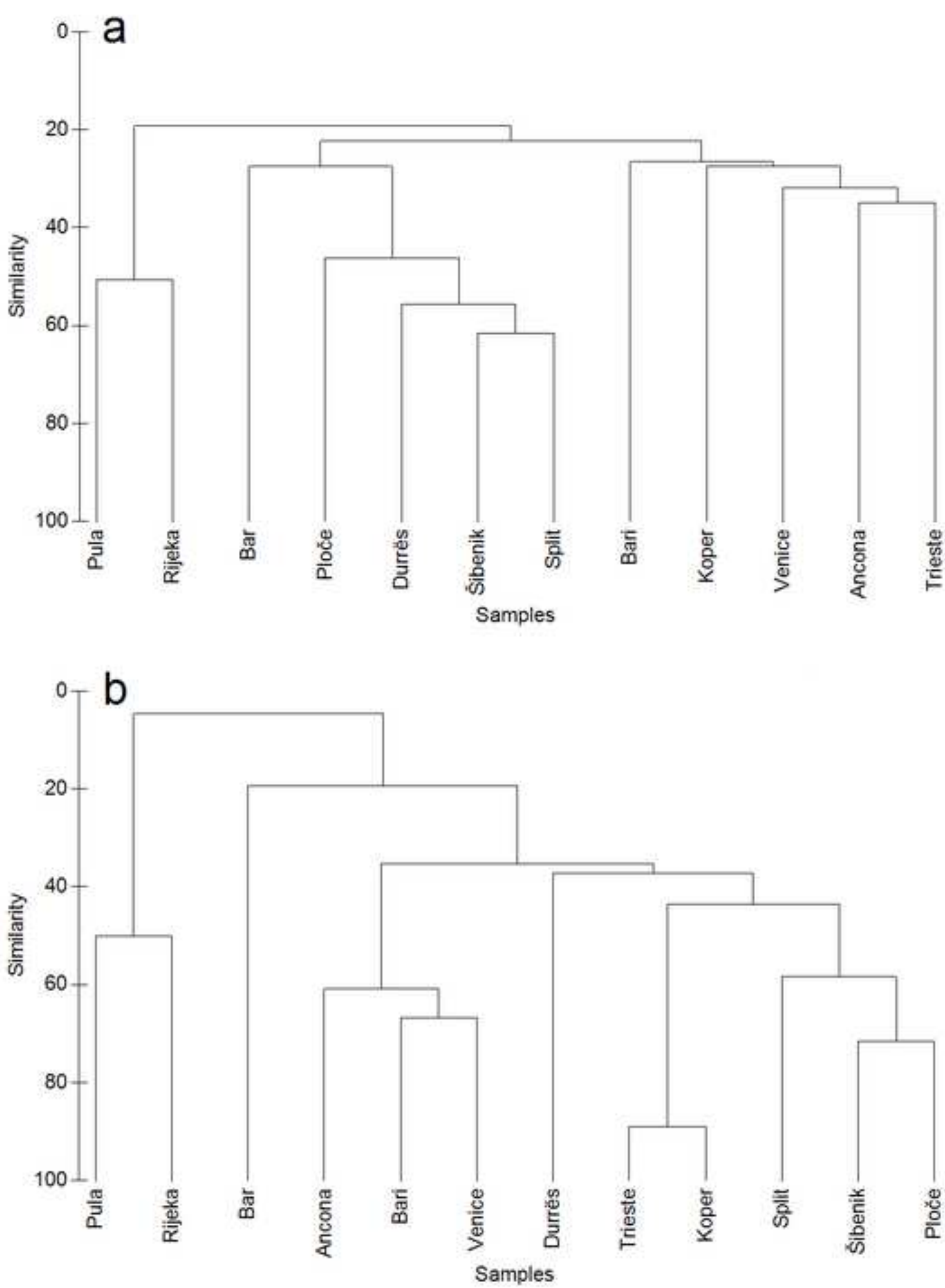
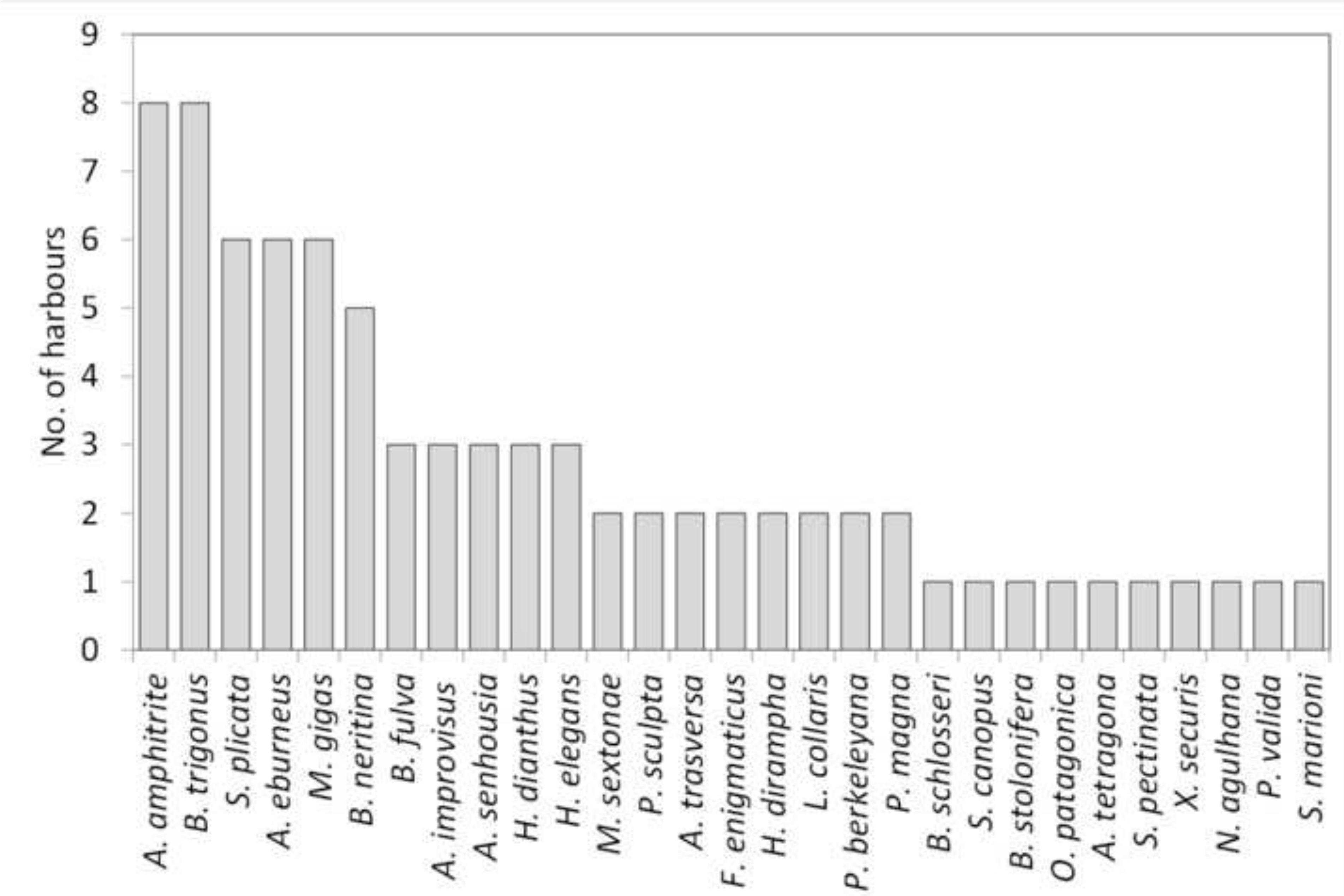
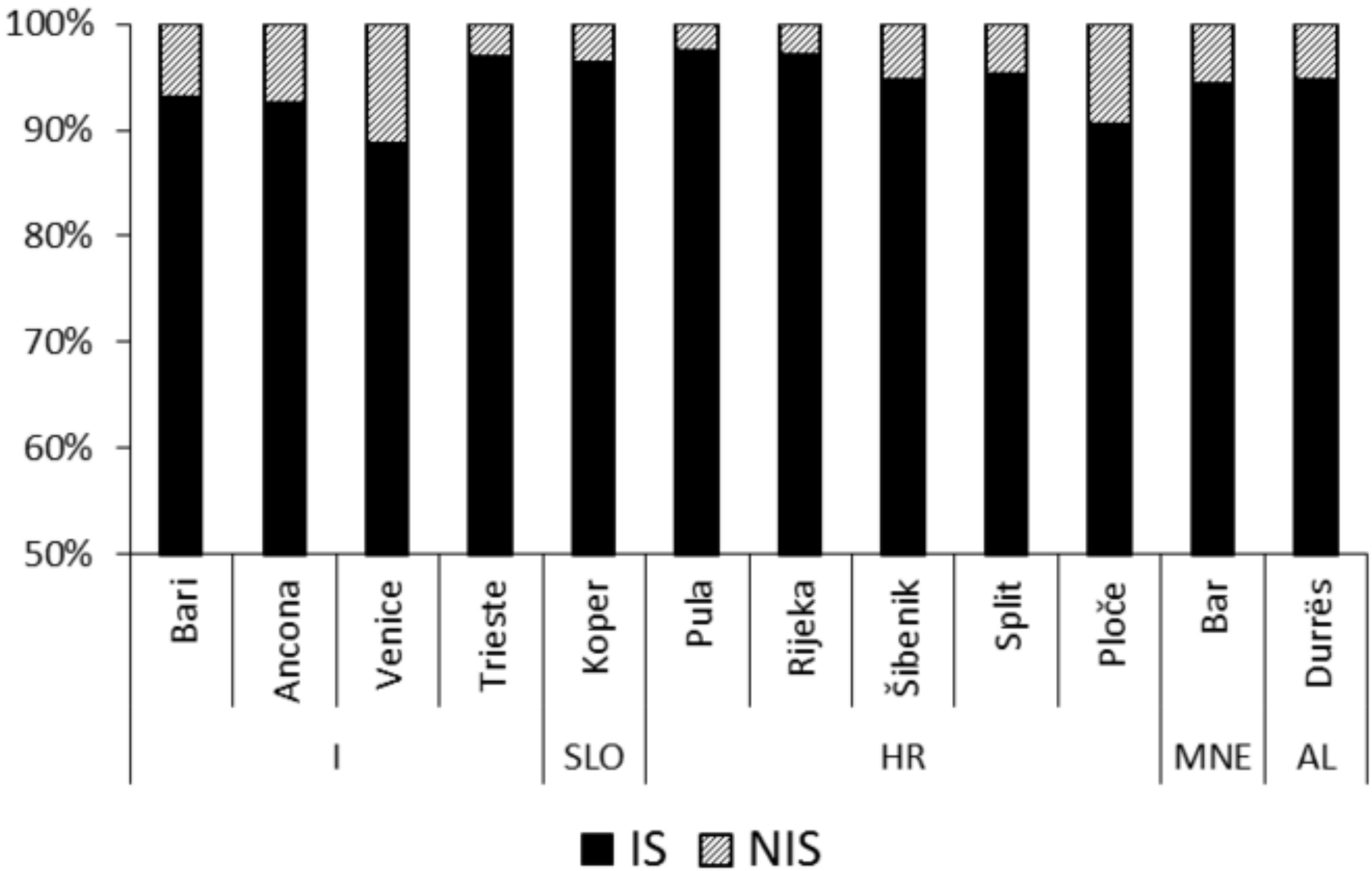

a
b
Similarity
0
20
40
60
80
100
Pula
Rijeka
Bar
Ploče
Durrës
Šibenik
Split
Bari
Koper
Venice
Ancona
Trieste
Samples

Figure 4



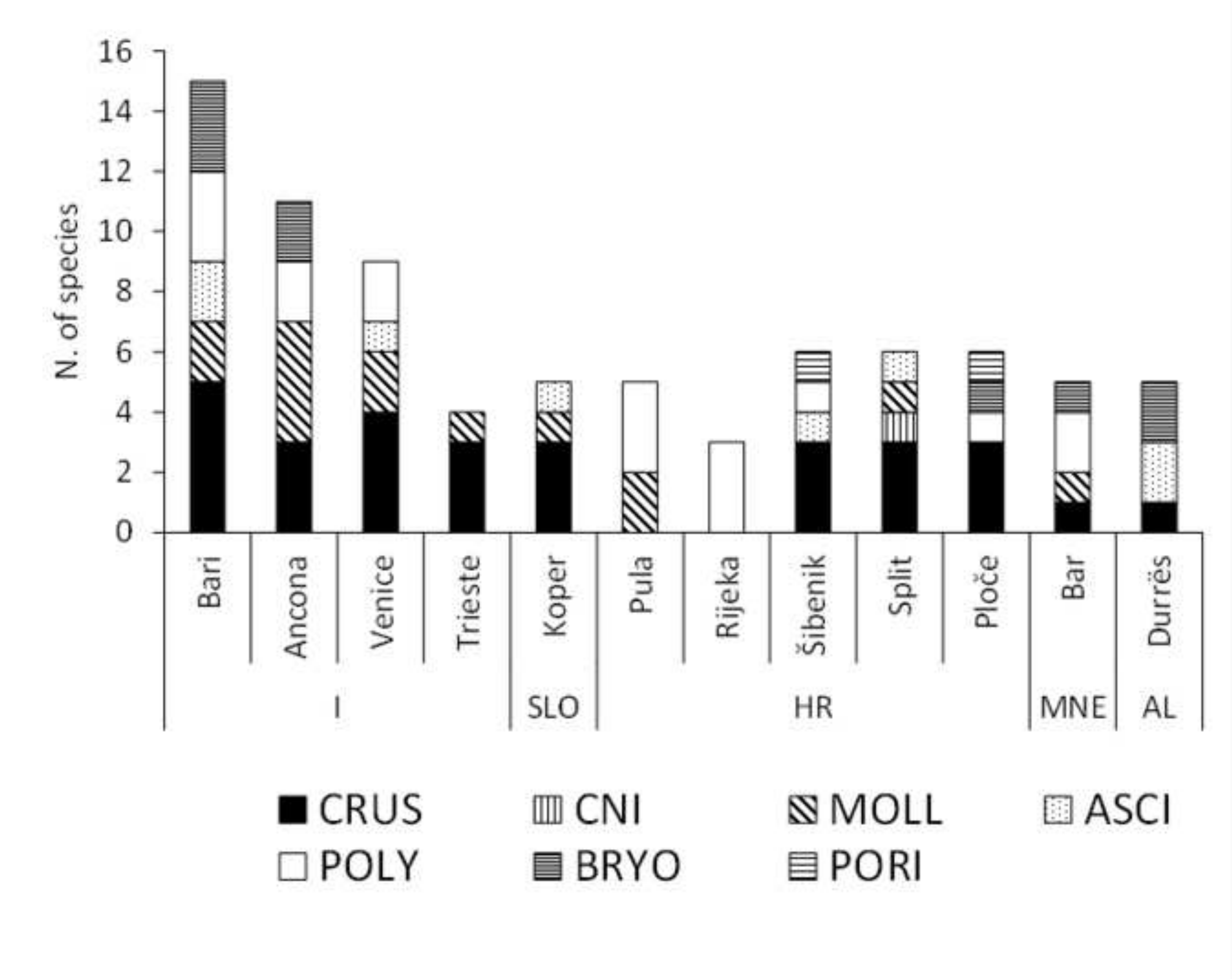
No. of harbours
0
1
2
3
4
5
6
7
8
9
A. amphitrite
B. trigonus
S. plicata
A. eburneus
M. gigas
B. neritina
B. fulva
A. improvisus
A. senhousia
H. dianthus
H. elegans
M. sextonae
P. sculpta
A. trasversa
F. enigmaticus
H. diramphа
L. collaris
P. berkeleyana
P. magna
B. schlosseri
S. canopus
B. stolonifera
O. patagonica
A. tetragona
S. pectinata
X. securis
N. agulhana
P. valida
S. marioni

Figure 5



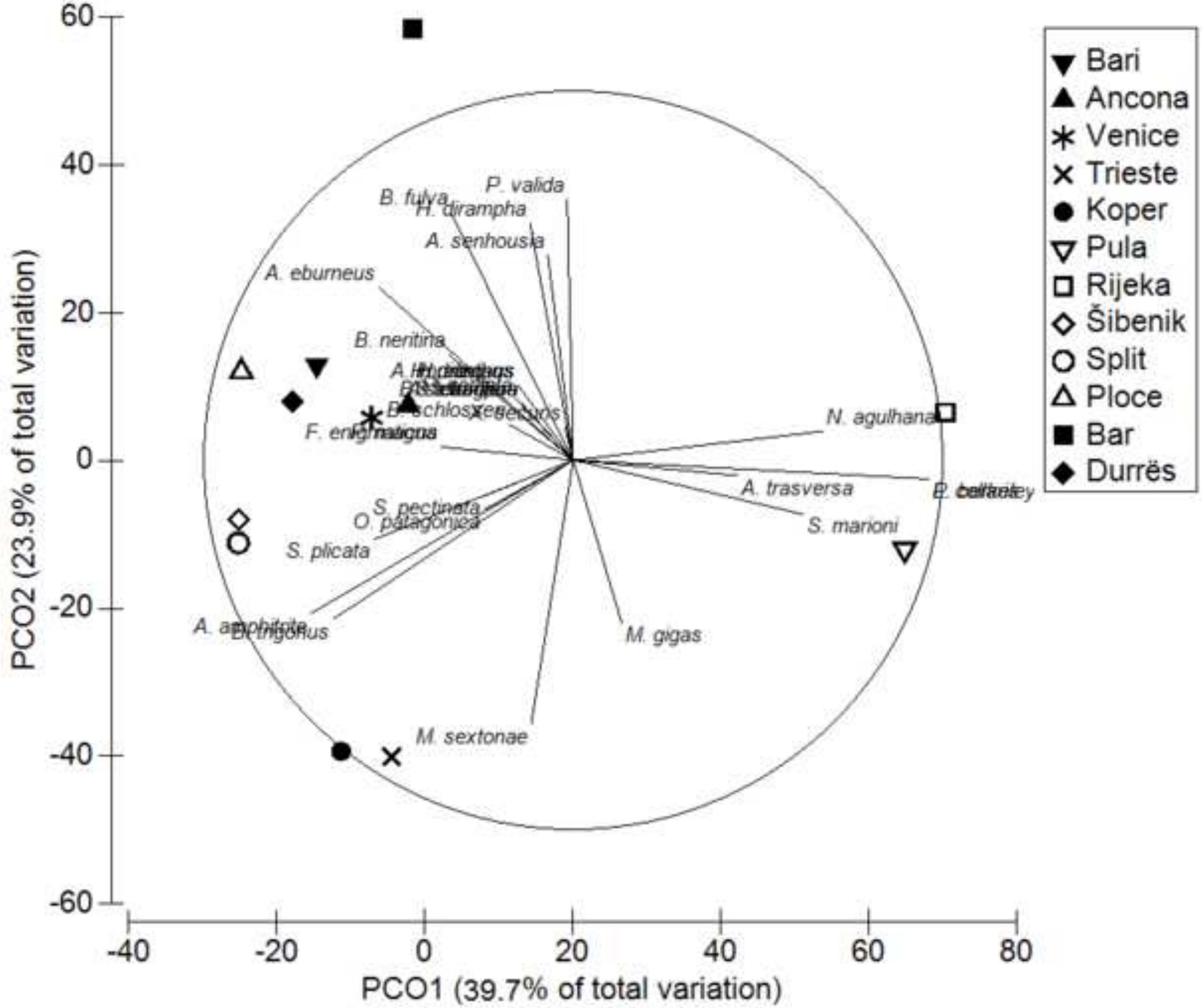
100%
90%
80%
70%
60%
50%
Bari
Ancona
Venice
Trieste
Koper
Pula
Rijeka
Šibenik
Split
Ploče
Bar
Durrës
I
SLO
HR
MNE
AL
IS
NIS

Figure 6



16
14
12
10
8
6
4
2
0
N. of species
Bari
Ancona
Venice
Trieste
Koper
Pula
Rijeka
Šibenik
Split
Ploče
Bar
Durrës
I
SLO
HR
MNE
AL
CRUS
CNI
MOLL
ASCI
POLY
BRYO
PORI

Figure 7


PCO2 (23.9% of total variation)
PCO1 (39.7% of total variation)
60
40
20
0
-20
-40
-60
-40
-20
0
20
40
60
80
Bari
Ancona
Venice
Trieste
Koper
Pula
Rijeka
Šibenik
Split
Ploce
Bar
Durrës
P. valida
B. fulva
H. dirampha
A. senhousia
A. eburneus
B. neritina
N. agulhana
A. trasversa
S. marioni
S. pectinata
O. patagonica
S. plicata
M. gigas
M. sextonae