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TAXONOMICAL CHARACTERIZATION OF *POSIDONIA OCEANICA* BANQUETTES AND DRIFTWOODS-RELATED FAUNA

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Chapter 1

Introduction

1.1 Boundaries of shore environments

This work represents the result of a three years long research about arthropod communities that inhabit ephemeral environments aimed to outline a faunistical characterization of *Posidonia oceanica* banquettes and driftwoods, two typical beach cast facies of the Ligurian coast.

The importance of these two ecotones in originating ecological corridors and sustain highly diverse trophic web is renowned among researchers (Boudoresque et al., 2017; Cotana et al., 2016).

The significance of woody debris along the beach is often neglected and poorly studied, as wood usually occupies relatively small patches in comparison to other common habitats, such as macrophytes or algal wracks. Sandy beaches are often devoid of biological structures and their morphology and dynamics can be defined in terms of three interacting factors: waves, tides, and sand particle size. These areas are commonly perceived by most stakeholders as ecological deserts an their value is mainly related to economical aspects, neglecting the important biological role of these environment.

According the Oloferne report (Onori et al., 2009) only 362 coastal areas covering 2200 ha can be considered as free (more than 3 km without human settlement): the 29% completely free, the 13% subjected to extensive occupation and 58% suffer from intensive occupation. The values assumes a critical importance within the regional context as consequence of the geomorphological set-up and the increasing use of shore line as recreational only area .
Beaches are high-dynamic habitats characterized by a consistent faunistic diversity (Colombini et al., 2003) and harbour indeed an extraordinary range of biological diversity, with dozens of living species which are specific to them. Sometimes this biological diversity is not very visible, due to the small size of the individuals, to the fact that they live hidden in the sand and their rarity which is closely related to littorals artificialized by inappropriate management (Boudoresque et al., 2017). Since so called marine insects have generally been ignored in many entomological reports as well as in marine invertebrate books (Cheng, 1976) the faunistic knowledge about this topic is quite rare and fragmented and more attention within beach-related environments is usually given to the study of large-scale processes disregarding the taxonomic importance of these habitats: the consulted literature on the topic indicates the existence of potentially rich faunas that - for the reason above mentioned - are often overlooked.

1.2 Answering questions

To fulfil these purposes is suitable the use of species richness estimators that allow to describe the potential richness of the investigated habitat and meaningfully infer these values. The estimation of biodiversity is an important topic of ecological research. A common form of data collected to investigate patterns of biodiversity is the number of individuals of each taxon at a series of locations. These data contain information on the number of individuals (abundance), the number of species (richness), and the relative proportion of each species within the sampled assemblage (evenness). Community data analysis and its description through indices allow the investigation of more general and functional aspects that underlie the observed species richness. Finally, the formulation of comprehensive models linking ecological aspects and taxonomical information allow the interpretation of the observed patterns.

Chapter 2

Beach ecosystems

2.1 Environmental description

2.1.1 Physical description

Sandy beaches are highly dynamic environments mainly dominated by the continuous interaction among sand, waves, and tides (McLachlan & Brown, 2006).While the evolution on the shoreline across the long period can be described as the result of the wave action, storms are phenomena of a certain intensity more related with short-term variations that are quickly mitigated as sandy beaches constitute one of the most resilient types of dynamic coastline (McLachlan & Brown, 2006).

Morphological and geometric characteristics are strictly related to wave action, grain size and the sedimentary input: a key role is also played by the equilibrium reached in relation with eustatic processes and sea level variations. A cross-shore profile articulates into three units: the backshore limited internally by dunal system, the intertidal zone or foreshore, exposed to the atmosphere and wave action and finally the intertidal area (shore face). The shore face is conventionally delimited by the closure depth, where the wave energy is not able to move sediments (near shore)(Onori et al., 2009). The dunal system - wherever present - set the inner limit of this section as in this area the influence of the wave action is null and only the wind can move the dry sand of the backshore. Along the cross-shore profile berm describes a high depositional event caused by the water infiltration into the sand. Storm berms are typical backshore features far from the ordinary berm - originated by storms characterised by waves higher run-up that cause the erosion of the ordinary berm and the deposition of bigger structures. The slope of a beach face depends on the interaction of the swash and backwash processes planing it. Even if this aspect is not merely a function of particle size (McLachlan & Brown, 2006) the decrease in size of the sediment and the increase of the mean wave height will cause the flattening process of the beach: this occurs because bigger waves result in larger swashes, which cause a greater amount of sand waterlogging and greater erosion in the backwash phase. Beach profile faces spatial and temporal variation described by the strong interaction between the beach an the wave climate. Shepard (1950) generalizing the modifications which occur on a beach according the meteorological conditions defined a summer and a winter profile. A more recent description provided by Pranzini (Pranzini, 2004) highlights a storm profile with many bars and steeper slope and a swell profile where the sediment of the bars is moved by the wave action towards the shoreline reducing the size of the bars and increasing the width of the beach. The long shore profile also assumes the shape that best fit the wave action which means in balanced situation to be orthogonal to the wave direction.

2.1.2 Interstitial environment

Sediment grains together with the pore spaces constitute the interstitial system. Sediments particles belong to a mixture coming from several processes non rarely after had been hardly reworked and included in other littoral environments by geological dynamics. The width of the spaces are controlled by several factor such as grain size, sorting shape which reflect on packing, pore size, and permeability. Because its diverse nature the interstitial system is an important habitat for organisms and for the filtration of seawater (McLachlan & Brown, 2006). Grain size is usually described according the Wentworth scale which use phi-units where $\phi = log_2\, diameter(mm)$: the use of this logarithmic scale is more diffused in sedimentology because it's easier to apply as most sediment size are mm fractions.

Under the mineralogical aspect sand grains can be grouped into three main categories, quartz fragments and Calcium carbonate is usually of biogenic origin, more abundant in beaches located at tropical latitude. Quartz comes instead from the weathering of igneous rock.

The remaining sedimentary particles derive from the modification of the silica tetrahedron and increase the mixture variability of beach sands. In terms of shape and size calcium carbonate sediments are less rounded and larger then quartz ones. Beside their origin sand grains are rarely spherical. Sphericity and roundness are both useful measure of grains shape: sphericity describe how closely the volume of a particle approximate the circumscribed sphere, roundness mostly refers to the outline of the grain. While sphericity tends not to change as results of abrasion roundness can be altered significantly during transport. Thus mineralogy, grain size and shape can influence beach composition as sediments are not evenly distributed. The sorting degree can be defined as the standard deviation of grain sizes around the geometric mean:

small values of this coefficient describe relative sediment uniformity, whereas a large value indicates poor sorting (wide range of grain sizes)(McLachlan & Brown, 2006). The use of third and fourth central moments can be used to define asymmetry and abundance of extreme particle sizes within a sediment distribution. Because of the wave action usually sandy beaches tend to be well sorted with limited skewness or kurtosis. The disposition of particles together with channels and lacunae (the interstitial system) can be used to define the porosity of a given sediment as the result of the ratio between the total volume and the total void volume. The porosity of a sediment is therefore related to the arrangement of individual grains (sediment packing). The packing of a sediment is in turn related to both the sorting and shape of sand grains, and to the nature of sediment deposition . Porosity is thus determined by the size and shape of the dominant grain size fraction and the sizes and proportions of other fractions mixed with it. Size and shape of the dominant grain size together with the size and proportions of other fraction in the sample determine the porosity which increases when the mean size of the dominant fraction decreases.

2.2 Zonation

2.2.1 A debated approach

The described habitats represent particular situations of interaction between marine and the terrestrial environments which act as important interface. These areas represent true ecotones where a clear demarcation between these domains is not always visible as in rocky shore communities. Though the bibliography on this topic is exhaustive, to date controversial positions have arisen around the zonation of sandy littorals. Moreover it's not uncommon amongst the authors the use of the same terms to describe different sectors while on the other side sometimes different terms are used to describe a unique area. This fact globally contributes to cause more confusion around this highly debated topic. A first approach (Dahl, 1952) proposed a three-zone classification based on different groups of crustaceans and tidal levels in two different seasons in cold-temperate environment. Salvat (1967) described a four-zoned beach profile according physical properties. However, some authors have suggested that through a multivariate approach is possible to better distinct biological assemblages occurring within each zone (McLachlan, 1990; Raffaelli, 1991). McLachlan and Jaramillo (1996) as well as Brazeiro and Defeo (1996) suggested that zonation varied between beach types.

In particular, the latter authors showed that zonation patterns varied with aperiodic and seasonal components while the formers have mostly focused their attention on the occurrence of distribution patterns in macrobenthic fauna at a global scale. Such lack of generality in the examined literature can result from the sampling design applied in these studies (Brazeiro & Defeo, 1996): the majority of the reviewed research has been conducted only on one sampling occasion covering as many beaches as possible each of different morphodynamic type (McLachlan, 1990; Jaramillo & Gonzalez, 1991; Raffaelli, 1991). The use of this snapshot samplings in sandy beach ecological studies - useful to understand large-scale patterns - has been widely criticized (Defeo & Rueda, 2002). The effect of seasonal and daily migrations (Scapini et al., 1992; G. Chelazzi et al., 1983), dissimilar preferences of species and different reproductive needs could be masked by such an instantaneous sampling scheme. This is particularly important when considering microtidal sandy beaches, where the large meteorological tide ranges aperiodically modify the shoreline position by wind effects. These features produces distributions different from those observed in predictable environments with tidal periodicity (de Alava & Defeo, 1991).

2.2.2 Towards a possible description

A possible characterization of the considered ecosystems follow a band division. Bands are parallel or at least sub-parallel to the shore and the width of each of these can be determined according orthogonal axis along a cross-shore profile. Even if in the study area (Chapter 3) the last band doesn't appear due to the anthropic impact on the shore line, for a complete overview a description is provided also to highlight the potential loss of biodiversity when missing. In this context the term "band" result more appropriate than plan as the second is usually adopted to describe vertical zonation rather than horizontal one like sandy beach habitats (Audisio, 2002). For each division EUNIS habitat classification (Lapresa et al., 2004) together with their CORINE (Feranec et al., 2016) correspondent are provided.

- **Intertidal** (EUNIS A2.1 to A2.4)(CORINE Land Cover 4.2.3.): this band is relatively narrow in the Mediterranean Sea ranging from few centimetres to some metres and is defined by the minimum and the maximum level reached by the astronomical tide. The tide excursion is even more reduced in the northern Mediterranean where it is mainly related to the steepness of the beach. This band is fully correspondent to the intertidal (or inter littoral) plan commonly used in marine biology. These habitats are characterised by the organic matter which is continuously floated and removed by the tide action.

- **Eulittoral** (EUNIS B1.1, A2.131, B2.1) (CORINE Land Cover 3.3.1.): traditionally this band is regarded as the lower portion of the suprallitoral and falls between the intertidal band (lower limit) and the suprallitoral one (upper limit). It is a common feature of sandy beaches lacking of vegetation with variable grain size. Usually the sea reaches this are only during exceptional tide. Across this band storms leave debris various in terms of nature and size. Two subsections are recognizable, according the sorting grade of the deposited materials: the lower eulittoral is mostly characterized by debris small in size and with a reduced gravity weight and modest mass (from few grams to some hectograms) to which belong seagrasses leaves (e.g. *Posidonia oceanica*) and fragments, small wood pieces and some bigger ones like carrions and animal residuals. The upper eulittoral features low density materials of larger dimensions like trunks, branches and stumps which are often carried by the waves or by the floods. In the past, the term eulittoral was used by some marine biologist as synonyms of middlelittoral or intertidal. The complex formed by the intertidal and eulittoral bands, washed by the waves and free of vegetation, is usually named madolitoral band (from the Latin word *madidus* which means soaked)(Audisio, 2002).
- **Supralittoral** (EUNIS B1.3, B2.1) (CORINE Land Cover 3.3.1.): the third band can be split into two different types according to the nature of the substratum. The first is characterized by sand and slope (foredune

zone - dry sandy suprallitoral) and the second is more related to plain or moderated depressions with an increasing percentage of fine fraction (silty wet beach). Both can be colonized by different plant species such as *Cakile marittima* Scop., 1772 and *Eryngium maritimum* L., 1753 for the dry type and more igrophilous and halophilous genera as *Salicornia* and *Juncus* for the silty beaches.

- **Extralittoral**(EUNIS B1.2, B1.3) (CORINE Land Cover 3.3.1.): the last band includes a wide and heterogeneous range of littoral habitats, such as embryonic dunes, stabilized dunes with many elements of the Mediterranean maquis. The dune complex of the extralittoral band together with the suprallitoral area form a dry band named siccolittoral (from the latin *siccus* which means dry).

2.3 Beach cast materials

2.3.1 Definition and classification

The area between the supralitoral and eulitoral is a narrow band named driftline - characterised by the deposit of a wide range of material cross and long shore transported. Sometimes, in coastal area involved by these dynamics, driflines may represent conspicuous facies. As matter of facts they represent a true habitat and contribute as structural element as well as trophic resources assuming relevant ecological role along the ecotone between the marine and terrestrial habitat. Such accumulations are generally named as beach cast, beach wrack or beach strand deposits: the term 'wrack' can be referred not only to plants or stranded seaweed, but it can be applied generally to any organic beach-cast material (Colombini et al., 2003). The organic material of beach cast can be composed by algae and seagrasses as well as by heterogeneous quantity of wood fragments, fruits, seeds and carrion. The stranding of all these highly erratic material depends other then some physical factors such as currents, winds and wave action the availability of organic dead matter to the beach is proximally controlled by the habitat extent, productivity, and phenology of the wrack source (Liebowitz et al., 2016). Despite the wide variety of wracks available on sedimentary shores this section takes in account seagrasses and woody debris as this research focus mainly on these kind of organic material.

- **Driftwood**: woody residuals are ubiquitous feature of beaches which assume notable consistency close to river mouths where the run-off of the hydrographic network may produce huge quantities of woody debris: increasing the distance from the river mouth marine wracks become prevalent often mixed with anthropic waste coming from the land or left in the sea. While big logs are more frequent close to rivers mouths, most of the woody residual is taken offshore and then cast ashore where it tends to concentrate in specific areas of the shoreline and where these wracks are graded.

- **Seagrasses**: the detached material from seagrasses may form large litter patches in the surf zone and huge litter banks on adjacent beaches. These vegetals are the only marine Angiospermae widely disappeared during the Eocene in the AsianPacific and the neo-tropics (Colombini et al., 2003). Two of the six species listed for the mediterranean seas are present in the Ligurian Sea (Green et al., 2003). *Posidonia oceanica* (L) Delile, 1813 forms meadows in a bathymetric range within the surface down to a maximum depth of 45 m and can settle a wide range of substrates avoiding estuaries, due to high amount of freshwater and fine sediment. *Cymodocea nodosa* (Ucria) Asch., occurs in shallow water but exceptionally can reach a depth of 30-40 m: stands in upper and lower limit are generally discontinuous. This seagrass, usually found on sandy substrate and sheltered sites, is considered a pioneer species in the succession that lead to a *Posidonia oceanica* climax as well as able to grow in areas previously colonized by *P. oceanica* (Green et al., 2003). Storms together with wave action and heavy swells remove huge amounts of seagrass materials and accumulate them along shores forming large wrack banks (McLachlan & Brown, 2006). These beached necromasses are visible along the shoreline close to *P. oceanica* meadows where generate typical depositional structures. Wherever this *P. oceanica* is absent other seagrasses such as *Cymodocea nodosa* can build even narrow and thinner deposits.
- **Inorganic material**: increasing concern arose around inorganic alloch-

thonous input associated with human activities. Man-made debris have unfortunately become an increasing component of beach-cast material. Often it is practically inseparable from natural-wrack and its presence on the beach definitely induces detrimental effect on beach environment under several aspects. Litter of various nature that are washed ashore by wave action or discarded by humans also has economic impacts such as the loss of aesthetic value in recreational areas which affect tourism-generated income (Ryan & Moloney, 1990).

2.3.2 *Posidonia oceanica* banquettes

Mediterranean drift line is typically characterised by the deposition of vegetal debris made from leaves, rhizomes and other remains of *P. oceanica* called banquettes. Banquettes are the result of a dynamic process of accretion/destruction (Mateo et al., 2003). Accretion occurs as waves break onto the shore depositing their load of *P. oceanica* leaf litter. A large amount of this necromass, representing between 10 and 55% of the primary production of the meadow, is exported (Ott & Maurer, 1977; C. F. Boudouresque et al., 2006). This corresponds to Odums concept of ”outwelling” of carbon from coastal primary producers, namely seagrass ecosystems, towards adjacent ecosystems (Ochieng & Erftemeijer, 1999). *Posidonia oceanica* sheds leaves mostly in summer and autumn (Pergent et al., 1983). Thus banquette formation is favoured in late summer and early autumn, when maximum leaf litter stocks are available in the meadow and wave action together with winds can cast ashore these materials (Simeone et al., 2013; Vacchi et al., 2017). Maximum banquette heights is usually reached in wintertime as a result of severe storms, while the beach can be free from litter during summer time (Simeone & De Falco, 2013). The banquettes set up, particularly the maximum height of their fronts, approximates the distribution of the maximum wave energy experienced by the site in a similar way as described for sand deposition dynamics (Mateo et al., 2003). Once the maximum height is attained, subsequent erosion by wave action on the base of the banquette may cause collapses of deposit portions into the water. This variable thickness can reach 3-4 m and the deposit can extent for hundreds of meters according to the morphological set up of the area and the available biomass. Thickness, volume as well as cross- and shore- length are greater on exposed beaches than on sheltered beaches (Onori et al., 2009). Because the banquettes formation is controlled by several physical factors, also the structure can change in response to wave energy wind, and beach exposition: this is deductible by the abundant forms of erosion in as well as by the abundant unstructured fronts and by the different composition of the deposit itself. The collapsed material, and\or newly generated *P. oceanica* litter, may follow two different dynamics: it can be washed away or cast onto the remaining banquette body again until maximum height is reached. On moderately exposed beaches and without anthropic disturbance, the banquette can persist year-round and the accretion over time can lead to a stratification, with layer of ancient and more compacted litter at the base, and more recent litter above. Generally, banquettes are mainly made of *P. oceanica* leaves (sometimes the accumulation looks fibrous as originated from the basal portion of the plant). The shape and the following accumulation dynamics give to the deposit a typical lamellar aspect and a compact and elastic consistence. Another important component is represented by the sand fraction, which usually increases going towards the backshore sections of the beach. A common constituent of the banquettes are aegagropilae, sea-balls made of *P. oceanica* leaf fibres, whose mainly component is lignin, which are entangled by sea motion. Broken rhizomes sometimes form part,even in small amount of the banquettes, especially on exposed littorals (Vacchi et al., 2017). Evolution and temporal persistence of banquettes as well as their structure and morphology are highly variable and lead sometimes to the formation of true bio-geomorphologic elements, yet ephemeral, but characterizing the coastal landscape and increasing the ecological diversity (Bovina, 2001). Aspects related to the recurrent deposit formation in some coastal segments as well as the stratification of the banquette may suggest the existence of ”banquettes likely formation area” (Bovina, 2001). These sites usually feature the presence of structure such as artificial or submerged reef which promotes the deposit during early building phase and protect it during the demolition processes.

2.3.3 Driftwoods

Large amounts of woody debris are annually deposited in estuaries, littoral zones and rocky shores: these accumulation - various in terms of size and origin - are generally called driftwoods. The size can range from small woody particles to branches, trunks and even logs. Beside their natural provenance, there is also a substantial subset of driftwood named drift lumber which include generic wooden artefact washed into the sea or discarded into water from shore. These deposits are by definition very different from seagrass and algal wracks, as independently from their origin, they represent almost the only vegetal contribution coming from the terrestrial domain. The volume of driftwood between locations and its rate of arrival, departure and decay is moreover variable in time and affected by many factors: the climate, the type of wood and its degree of burial determine the driftwood decay rates. In many cases erosion, wave action and chemical alteration due to the long offshore permanence may make difficult or impossible to determine the origin as well the age of a single piece of driftwood: generally wood exposed to air and sun endures longer, while that buried in sand or silt can disappear quickly, as the best conditions for the detritivorous microorganisms are damp and darkness. Differently from *P. oceanica*, driftwood decomposition rate is rather slow (Maser et al., 1988). Because of this feature, driftwoods can be expected to add unique habitat structure and resources to both intertidal and supralittoral beach communities. Winter storms are probably the main provider of sea-transported wood in estuaries and beaches. Size, mass and beach slope are the main factors that influence mobility of driftwood, which is relatively high compared to *P. oceanica* banquettes. Both natural and anthropogenic woody debris can also be transported by river in into the sea, from which it washed up onto the beaches in particular following floods. Current patterns, winds and coastal set up influence the deposition. The arrival of driftwood on the shore can probably be described more likely as a unique mass depositional event rather than as a trickle: these woody debris can constitute consistent accumulation in a medium of fine material moved about by wind, wave action and gravity where such materials will provide an impediment to such movement (Maser et al., 1988). Following the coastal anthropization processes described in chapter 3, it may be possible to hypothesize that nowadays there is more driftwood on beaches than in the past. Thus, the role of driftwood, in particular big logs and stumps, is mainly structural catching material, usually on its uphill or upstream side, or facing the prevailing winds.

2.3.4 Ecological role

Cross-habitat fluxes of resources are a common processes of a wide range of ecological systems (Polis et al., 2004). Beach environments are renowned for suffering from an almost null in situ primary production (Schooler et al., 2017; McLachlan et al., 1981). Since local macrofaunal communities are mostly composed by consumers (Ince et al., 2007) of allochtonous marine inputs - in the forms of diatoms and flagellates for the surf zone - or from the sea as stranded macrophytes, carrion and vegetal residuals of any kind are crucial for the survival of these biomes. The movement of nutrients and detritus - heavily characterized by seasonality and spatial fluctuation - from the sea to terrestrial domains can be considered one of the most extreme examples of cross-boundary subsidies as defined by Polis et al. (1997) and follow three pathways described by Catenazzi (2006):

- tidal action: waves wash marine wrack ashore, which terrestrial consumers use as source of food and shelter. Marine wrack includes marine algae, invertebrates, carcasses of marine vertebrates, detritus, and floating debris.
- biotic vectors: marine vertebrates such as seabirds, and intertidal organisms transport marine-derived energy and nutrients from sea to land, especially in places where they congregate to reproduce or nest.
- wind transport: winds can carry marine spray that is rich in nutrients from sea to land.

Within the listed processes, which summarize a source-sink dynamic in ephemeral habitats, a consistent fraction of Carbon and Nitrogen made available from primary producers - and not locally exploited - is carried to beaches where constitutes the primary food supply for the beach's supralittoral fauna, which is generally concentrated in the high eulittoral (Griffiths et al., 1983; Inglis, 1989). Thus, the features of this biomasses are likely to affect all trophic levels of sandy beaches from primary consumers, like crustaceans and insects to second and higher order of consumers though the energy transformation and transfer providing a link function to different habitats. Polis et al. (1996) estimated that the overall arthropod abundance in areas receiving input from the ocean was 2.5 to 550 times greater than mainland sites away from such input. Moreover, accumulations may also act as ”metabolic hotspots” of nutrient processing, driving a key ecosystem function of beaches (Coupland et al., 2007; Dugan et al., 2011), and so wrack accumulations have great indirect effects as well (Liebowitz et al., 2016). We can distinguish:

- *P. oceanica* banquettes and other stranded seagrasses: beach is far from being the final recipient of seagrasses litter: the necromasses continuously move under the influence of wave and wind action between the beach and the adjacent subtidal bottoms (Simeone & De Falco, 2013; Vacchi et al., 2017). However, the more consistent litter fraction is stored within the banquettes, so coastal marine habitats constitute the final destination, where they are a prominent source of nutrient and organic carbon. Litter consumption by beach detritus-feeders could be significant (C. F. Boudouresque et al., 2006), as well as the fraction carried on situ by wind, differently from what previously thought (Mateo et al., 2003; Guala et al., 2006).
- **Driftwoods**: the river discharges are the main source of driftwood. This provides a strong functional coupling between inland and marine systems through the export of terrestrial organic carbon to the ocean (Schlünz & Schneider, 2000). The overall heterogeneity of driftwood represents - through an increases of the environmental complexity - an important feature in enhancing the consistence, diversity and productivity of littoral

biota, promoting the formation of new niches, offering shelters and so regulating the predation dynamics . It is unclear, however, how woody wracks alteration process - which modifies the surface complexity of wood and the quality of trophic resources available - affects the diversity of wood-associated species and trophic interactions (Czarnecka, 2016).

2.4 Anthropogenic aspects

2.4.1 Threatened ecosystems

Coastal areas are subjected to intense stressors, especially considering that Mediterranean coastal areas host 37.2% of the human population living in the countries which board with it (UNEP, 1989).

The most challenging aspect of beach management arise from the need to balance the widespread conception as sites of intense human use and the environmental importance of these unique habitats and ecosystems. These processes are derived from the increasing pattern of shoreline urbanization and the expansion of human population (Defeo et al., 2009), resulting in widespread modifications of sandy beach ecosystems:

- **Recreation**: seashore activities mainly involve sandy beaches as prime sites for human recreation. Beach management policies related on these business sectors usually tend to improve the recreational experience often leading to harmful interventions such as beach nourishment (Speybroeck et al., 2006), grooming (Dugan et al., 2003), coastal armouring (Dugan et al., 2008), compaction, as well as light and sound pollution (Longcore & Rich, 2004), which represent without any doubt a major stressor for sandy beach ecosystems. The most obvious human impact on beach communities comes from direct crushing of indivuals (Moffett et al., 1998), despite generally macrobenthic populations respond negatively to increased human activity levels (Fanini et al., 2005). However, it results difficult to separate the effect of trampling from habitat modifications (Barros, 2001).
- **Cleaning**: for local cleaning policies, involving *Posidonia oceanica* banquettes and driftwoods, please refer to paragraph 3.2.5. Cleaning and

grooming are common practices on beaches used for tourism: these operations have significant ecological consequences, especially in regions with high levels of marine macrophyte production, reducing the habitat heterogeneity and normalizing the beach profile. The community structure of sandy beach macroinvertebrates can be closely linked to wrack deposits which provide trophic resources and habitats (Colombini et al., 2003). Wrack-associated fauna, such as talitrid amphipods, isopods and exapods, which can comprise up to 40% of the species and represent important preys for higher trophic levels, are significantly reduced in species richness, abundance, and biomass by grooming (Fanini et al., 2005). Taxa with well-developed dispersal abilities, such as flies, can be more prevalent on groomed beaches (Dugan et al., 2003).

- **Nourishment**: like many worldwide beaches, Ligurian shoreline suffers from diffused erosion (see section 3.1.1 and following). Because engineering solutions, such as seawalls and breakwaters are expensive and not efficent to prevent the loss of the intertidal beach (Hsu, Lin, & Tseng, 2007), beach nourishment has increasingly been used to combat shoreline erosion. These practices can cause ecological damage to sandy beach habitats and biota (Nelson, 1989), with implications at community, processes and ecosystem levels. Factors influencing the nature and extent of ecological impacts of nourishment are intrisc in the process itself, such as the mechanical aspect, the timing, the consistence and the quality of the new sediment. Direct effect, such as mortality for burial, or indirect ones (like prey availability) act in the short-term (C. H. Peterson & Bishop, 2005), leading to a recovery (Nelson, 1989) of species in beaches which are adapted to severe physical disturbances as storm events (Hall, 1994).
- **Pollution**: pollutants ranging from molecules to large debris interfere

with many biological aspects of faunal communities, such as physiology, survival, reproduction and behaviour in all habitats of the beach, from interstitial environments (McLachlan, 1977), to the surf zone (Noble et al., 2006). Even if plastic is extremely persistent and dominates the visible components of sandy beaches, other hazards are represented by wastewater, sewage and oil spilling. Moreover sands can be contaminated by pathogens, which are delivered to the sea either by sewage systems discharging directly into coastal waters, or by estuaries near the beaches. Oil spills are probably the most destructive source of sandy beach ecosystems, involving all trophic lelvels (Bodin, 1988). Persistence in time can be temporary as well as chronic and this feature is influenced by beach morphodynamics and exposure: increase in grain size reduces the duration of the contamination, reflecting the oil drainage time (Bernabeu et al., 2006).

- **Climate change**: even if long-lasting and large-scale stressor studies are not yet available (Defeo et al., 2009) and the magnitude of the physical changes resulting from global climate change is still uncertain (Pachauri et al., 2014), responses in community composition processes and dynamics are increasingly apparent (A. Brown & McLachlan, 2002); observation derived from other systems can be retained valid also for beach ecosystems. The rise of mean temperature and even more frequent meteorlogical anomalies can involve taxa with reduced dispersive abilities and ranges tjis may damage arthropods lacking of dispersive larval stages with particular concern to narrow-range endemic species which would be at greatest risk (O'Hara, 2002). Such species will become more and more susceptible to be replaced by species from lower latitudes. Semi-terrestrial species (e.g. insects) will suffer from changes in water and air temperatures, both directly and indirectly. Sea-level rise pushes shorelines landward, causing the inland migration of coastal deposits. Moreover, the alteration of air and sea temperatures would lead into more frequent and severe storms (Pachauri et al., 2014). This brings to an increasing beach erosion till the complete removal of the habitat in which these arthropods live.

2.4.2 Perception and management of seagrasses

The conception of *P. oceanica* banquette widely changed across time: in the past, these necromasses were considered a common feature of the Mediterranean shoreline landscape and were employed by local population for several uses, from agriculture as fertilizers (Sa'idane et al., 1979) to zootechnics(Castillo et al., 2014) and even in construction industries, where it's used (e.g. in Corsica) as thermal insulation material on roofs (Green et al., 2003). The growth of the beach-related recreational activities has imposed conditions of complete artefact situations: beach users prefer a "clean" seashore environment free from any cast-ashore weeds, seagrasses, macrophytes as well as any driftwood and the most diffused opinion contemplate this kind of natural wrack as a waste matter like cans, cigarettes smugs and plastics. The role of these wracks is far from being understood by people involved in coastal management (Kirkman & Kendrick, 1997) that have adopted temporally solutions with expensive interventions like removal and subsequent dump disposal (Borriello et al., 2010). These operations are usually carried over with mechanized rakes and trucks which remove, besides *Posidonia oceanica* leaves huge amount of sediment with high environmental coming from the transport and disposal of organic material. Beside the biological role of these formations it is generally assumed that these necromasses plays an important role in shore morphodynamics, and their removal could have a negative impact on shore stability, with particular reference to the widespread diffusion of beach erosion mechanisms (Chessa et al., 2000; De Falco et al., 2008). During the deposition phase (section 2.3.2), this seagrass modify the interaction between waves and beach profile, resulting in a reduction of sediment transport (McLachlan, 1985). Moreover, the floating fraction generate a dense suspension which by viscosity and surface tension dissipates the wave mechanical energy (C. Boudouresque & Meinesz, 1982). Furthermore, banquettes act as sediment traps and the removal without careful separation of sand from leaves would imply the loss of high amounts of sediment from the beach (De Falco et al., 2008; Defeo et al., 2009). Thus, wrack removal represents a crucial operation that must be actuated with the maximum caution. Management strategies of beach cast material lacks of laws as well as regulations: existing legislation its not easy to apply as a true classification of wrack as waste is not available yet. Only recently *P. oceanica* can be used as compostable material [1]. According to what previously reported and lacking a univocal management strategy Ministry of the Environment, land and sea (MATTM) has responded to municipalities request on the problem with the circular MATTM n. 8123/2006, which describes three possible strategies (Borriello et al., 2010):

- **On-site maintenance of banquettes**: it represents the best solution from the ecological point of view, because of the multiple roles accomplished: structural, biological and sedimentological. This strategy results applicable whenever the presence of accumulation does not clash with tourist activities and in coastal areas where the erosive phenomenon is

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[1] (D.M. 22 January 2009 of Ministero delle Politiche Agricole, Alimentari e Forestali ”Aggiornamento degli allegati al D. L.vo 29/04/06, n. 217, concernente la revisione della disciplina in materia di fertilizzanti”)

particularly accentuated. This measure should be recommended in those areas where accumulation rates are known to be relative stable, in marine protected areas or in areas A and B of National Parks.

- **Removal of stranded residuals**: when it is not possible to maintain the banquettes on site, because of the incompatibility with the destination of use of the coast, removal should be performed with the maximum care. The intervention should be limited only to the bathing season through actions aimed to beaches preservation without causing geomorphological changes to seaboard and after the removal of man-made waste present in the heap. Less consolidated banquettes seasonally present along wide portions of sandy beaches are potentially the most interested by this management strategy, since for extension and position, conflict widely with the recreational use of the shore. Biomass can be transported in the backshore of the same beach and stored (in situ storage), or moved on beaches that are vulnerable to erosion (ex situ storage) and employed in shore protection measures.
- **Dumps disposal**: is the most expensive choice (even if it is one of the most used) in terms of economic and ecological cost and have to be applied wherever true hazards such as putrefactive phenomena and mixing with human waste make non compatible the cohabitation of stranded necromasses and beach-users. Thus, banquette can be removed and disposed as municipal waste, according the existing legislation.

2.5 Biological aspects

2.5.1 Adverse habitats

Sandy beaches can be easily compared to desert environments, where several stressors push towards the boundaries of the local zoocenosys survival. The incoherent substratum - often in a thin layer - ephemeral and sometimes discontinuous in time and space, can cover up organisms and their potential trophic resources. The grain size makes the substratum of the emerged beaches unable to retain water coming from rainfall, which increases the aridity, even more in the hot season. The saltiness can be referred to the salt present in the water circulating in the substratum, wetting the sand heap and stranded material, as well as the percentage of chloride present in various forms in the troposphere and coming from the marine aerosol or crystallized on the surface. Furthermore, these environments are characterized by high diurnal temperature variations, caused by the quantity of sunlight which reaches low heat capacity grounds. The high mortality rate and the low recruitment of invertebrates, are caused by the wave and wind actions, which can be physically removed from their microhabitat, both seaward and landward. The linear disposition of these habitats along the shoreline - usually discontinuous for natural and anthropic reasons - causes adaptations challenges in reproductive patterns: species show specialized life styles, such as low active dispersion, and are characterized by small populations, often exposed to local extinctions (Audisio, 2002).

2.5.2 Adaptations to maritime ecosystems

Many classes among the phylum Arthropoda have become adapted to life on the sea shore: while intertidal arachnids include Palpigradi, Scorpiones, Pseudoscorpiones, Araneae, and Acarina, the main marine insects are represented by a bunch of orders such as Thysanura, Hemiptera, Trichoptera, Coleoptera and Diptera. In returning to an aquatic medium, a typical subaerial taxon such as Hexapoda has to face several ecological, physiological and physical challenges: in favor of this process, a very important bridge function (Cheng, 1976) is solved by many ecotonal systems, like estuaries, salt marshes as well as sandy beaches and other intertidal habitats, which host the majority of these organisms. According to Usinger (1957), another highly successful group is represented by Crustacea: diversified earlier in the Cambrian period, they prevented, through competition and predation, as well as other limiting factors, the colonization of marine habitats by hexapods. The survival to these extreme habitats include a wide spectrum of adaptations, ranging from behavioural strategies like avoiding the most severe conditions, to morphological, physiological or combinations of all these features; physiological adaptations may occur in some or all instars of the life cycle. The ecological features of these habitats lead to some examples of convergent evolution, comparable to what observed both in eremic and fresh-water related fauna. One of the most common respiratory adaptations is represented by the plastron (Brocher, 1912): this term describes the gas film of constant volume held in position by hydrophobic hairs or water repellent meshworks (Thorpe, 1950). Many intertidal Diptera larvae belonging to Dolichopodiae, Tipulidae and Canacidae families show plastron-bearing spiracular gills, which allow them to feed and survive in flooded contexts (Hinton, 1966). Coleoptera related to shore habitats are remarkably similar to terrestrial species, rather than sharing some features with their freshwater correspondents. It has long been recognised that Coleoptera are capable of prolonged submersion (Doyen, 1976), but most species are only occasionally in direct contact with water (Doyen, 1976; Kensler, 1967): beetles inhabitanting mud flat and beaches rely their survival on a so defined shrinking physical gill described as a film of air retained inside burrows at the interface with the sediment or beneath large stones (Doyen, 1976; Topp & Ring, 1988). Staphylinidae beetles of the genus *Bledius* construct their own burrows, but most beach beetles utilize tunnels made by crustacea or other insects. The most common morphological modifications in many marine beetles is probably the complete or partial apterism (brachypetrism): however, some ground beetles (Coleoptera: Carabidae) show incomplete elytra but in many taxa the elytra are immovably joined along the midline, generating a subelytral cavity, which can be used as physical gill. Other hexapods like springtails (Collembola) have evolved specific cuticle areas lacking wax coverage that allow them to breath underwater, and physiological adaptations for salt and water balance (Dallai et al., 2010). Such adaptations allow some species to survive underwater for up to several days (Jacquemart & Jacques, 1980), and disperse passively on the water surface (Dallai et al., 2010). In response to the particular and sometimes severe micro- and macroclimatic conditions, many organisms have evolved particular eco-etological strategies, mainly focused to reduce the exposition to the sun radiation: e.g. the burial behaviour of many arthropods often associated to the modification of some appendages or the switch of the main daily activity patterns to night-time. On the other hand akinesis, can be observed in many terrestrial arthropods, which encounter periodic submergence in water and respond becoming dormant to reduce metabolism and prolonging their survival possibility. Less thermophilous species have shifted their reproductive cycles to autumn or even winter, with long aestivation periods. Other species make seasonally or even daily migrations between the swash line and the inner sector of the beach, to better exploit trophic resources and refuges. Finally, examples of criptyc and omocromic mimicry are not uncommon, as many species imitate the confusing pattern of the sandy littoral.

Chapter 3

Study Area

3.1 The Coast

3.1.1 A General overview

Italian coasts stretch for almost 8300 Km (*Annuario dei dati ambientali*, 2010) with a highly differentiated shoreline characterised by two main morphological type, high and rocky (59%) a low and sandy (41%). Ligurian shoreline extends for about 350 Km from the state border with France to Tuscany. The coast is characterized by relatively large beaches, nested in a rocky coast featuring pronounced headlands and cliffs. The shoreline results extremely exposed to the wave action (approximately 120° onshore wind). The Ligurian continental margin articulates in two sectors, the Western influenced by the Alpine dynamics and the Eastern more related to the Appenine processes. The Western sector is characterized by a narrower and steeper continental shelf compared to the Eastern one. The outback extension - as well as the watershed proximity and geomorphological set-up - implies that rivers flow through a short hydrographic network (ranging from 10 to about 100 Km ^{2}), thus providing a low sedimentary budget. The ratio between the territorial extension and the shoreline length is comparable to that of major Italian islands: thus, the shore line assumes a great importance both in anthropic and natural context. Ligurian beaches increased in width from the High Middle-Age to the early XIX century as a results of the diffused wood-cutting activities. In the following decades, the progressive realisation of public works to fulfil the demand of the demographic growth marked a true inversion in the previous trend (Fierro et al., 2010). Due to the regional geologic and morphological set up infrastructures like roads and railways can be carried out only close to the shoreline. Such process of coastal urbanization and the more recent use of beaches only as recreational areas put a consistent pressure on the studied environments. A more detailed description of the section is provided in next paragraphs, following the partition provided by Liguria Coast PTC (Plan for Territorial Coordination) with further zonation littoral cells and coastal waters (Fierro et al., 2010).

3.1.2 Ligurian West Coast

Two sampling sites are located along the western coast of Liguria. The Eastern limit of the first analysed section is represented by the pier of Porto Maurizio already present from the beginning of the XIX century.

The geomorphological set-up reflects the tectonical processes related to the Alpine orogenesis described by the emplacement of the main rock units together with their fracture systems following the dynamics imposed by the late neotectonics (Fierro et al., 2010). The coast articulates with rocky headlands, pocket beaches and rather short pebbly-gravelly beaches. The shoreline is SE oriented (250° approximately), which means a wide exposition to waves coming from the third quad. Sediments flow eastward partially towards S. Erasmo and S. Stefano al Mare and through Torre dei Marmi, reaching finally Imperia. Similarly to other sectors, the whole area underwent a critical erosive phase in the late XIX century, caused by the building of the railway. The sedimentary movement along the shore is furthermore influenced - other than many natural rocky headlands - by the presence of anthropic structures realized in the past decades, which have deeply modified the littoral dynamics. Most important anthropogenic artefacts are the harbours of Bordighera, Sanremo, Aregai and San Lorenzo al Mare. Capo Mele headland marks a rather abrupt turn of the coastline, which becomes NE-SW oriented and then more protected from the main waves coming from SW. The second sampling site is located not far from the Eastern boundary of the segment represented by Vado Ligure harbour, built during the 70s. This sector stretches for about 50 Km and shows geological features that differ consistently from the previous one: the geological setup both structural and morphological is affected by the alpine orogenesis but also suffers from the Apennines dynamics. Thus, the coast - NNE-SSE oriented - results more protected from the SW wind action. The continental shelf is wider and less steep than the first analysed segment. The high rocky shore between Punta Predani and Vado harbour features two artificial beaches. The overall NS direction of the coast and the wise management of the beaches by local policies make this area the only one in Western Liguria that increased in width (Fierro et al., 2010).

3.1.3 Ligurian East Coast

More sample sites are located along the middle-eastern coast of Liguria between the eastern part of Genoa and the Portofino Promontory, which protrudes offshore for more than 3 Km. This segment stretches for less than 30 Km of high rocky shore with some embayed beaches. The more recent Appennine dynamics affects the coastal set up: the rocky shore emplace onto structures orthogonal to tectonic directrixes WNW and ESE oriented (Fierro et al., 2015). Thus the coast - evenly oriented between Genoa and Recco - suddenly turns southward in the following section, which corresponds to the Western side of the Portofino Promontory. The exposition to SW wind generates two different littoral drifts Eastward between Genoa and Camogli and Northward between Punta Chiappa and Camogli, respectively. SE winds blow only towards the western part of Recco, as the other part of the area is protected from Portofino Promontory. The continental shelf is rather broad with an even morphology free from remarkable depressions and the shelf break is set at 150-200 m of depth. The first site (Nervi) falls into a section opened to all winds coming from southern quad. The described shore segment is limited in its western side by harbour of Genoa and some other structures (e.g. Fiera di Genova): the coast is mostly rocky and some small stretches of deposit coast are present in Priaruggia, Quarto, Quinto and Nervi. The coast between Nervi and Portofino features some small headlands which partially limit the littoral drift: few embayed beaches occur at the mouth of streams that provide a natural sedimentary upgrade. All the deposit coasts of these areas follow the typical evolution of the embayed beaches, with an increasing phase lasting till the beach is protected by the headlands.

3.2 Liguria Seagrasses

3.2.1 Stands and extensions

The Ligurian area is one of the best among the Italian coasts for information on the distribution and general status of seagrasses, in particular for *P. oceanica.* Almost 50 *P. oceanica* main meadows have been recorded and mapped. Their extension ranges from a few to several hectares (Green et al., 2003).
Liguria *P. oceanica* meadows and formations extend for 4.844ha and stretch for about 138 Km (43% of the whole shoreline), accounting for the 8% of the total sea bottom between the coastline and the 50 m isobath (Bianchi & Peirano, 1995): compared to other regions, the overall surface settled by this seagrass is lower, but it can be easily explained observing the morphological features of the coast and the increasing anthropic pressure along the coastal area. Observing the distribution of the municipalities interested by these seagrasses formations (Tab. 3.1) it can be easily observed that the highest percentage occurs along the Western shore, while the lowest is represented by La Spezia; Savona and Genoa present even values. Because the morphological set up (see section 3.1.1for details) as well as the beach structure without or at least with very narrow backshore, the management of *P. oceanica* banquettes represent a challenging issue. Moreover, the mild climate of the coast causes an almost continuous use of the beaches as recreational area all over the year. This results in cleaning interventions that are performed not only during summer.

Municipality	**Coastline (Km)**	***P. oceanica***	
		Km	**%**
Cipressa	2.8	2.8	100.0
San Lorenzo al Mare	3.6	1.9	53.0
Imperia	1.2	8.2	89.0
	7.6	12.9	96.3
Bergeggi	5.0	1.9	38.0
Vado Ligure	2.5	0	0.0
	7.5	1.9	19.0
Recco	2.35	0.3	12.0
	2.35	0.3	12.0

Table 3.1: Liguria seagrasses. Investigated municipality interested by P. oceanica beachcast

3.2.2 Cipressa - S. Lorenzo al Mare - Porto Maurizio

The whole area belong to the marine SCI (Site of Community Interest) Fondali Porto Maurizio S. Lorenzo al Mare - Torre dei Marmi (IT1315971) where the Western section suffers from anthropic impacts, such as the recent construction of ”Marina degli Aregai” harbour. The local *P. oceanica* meadow articulates in two different sections according some morphologic differences other than a discontinuity. The first unit, reaching 6 Km in length, is thinner in the Western section with a width ranging between 100 and 300 m width. In front of San Lorenzo al Mare it reaches its maximum width (1000 m). The upper limit is far from the shore line up to 800 m close to a wide meadow of *C. nodosa.* The Central-Western section is wider and the upper limit is set at only 5m depth. The *C. nodosa* formation occupy a wide area between Marina degli Aregai and the mouth of Rio San Lorenzo next to the *P. oceanica* meadow.

In the Eastern part of San Lorenzo, a meadow of *C. nodosa* extends for 2.5 Km at less than 10 m depth. The meadow of Porto Maurizio (2.5 Km length) reaches a considerable width (up to 2 Km, 440 ha) due to the bottom set up with the upper limit relatively close to the shore in front of Torrente Prino. The Eastern section in front of Porto Maurizio is wider in the offshore part but is more fragmented with some sand and *C. nodosa* patches. In the North-Eastern part the meadow suffers from a heavy reduction with the presence of *Caulerpa taxyfolia* (M. Vahl) C. Agardh, 1817. From the mouth of Torrente Prino to Porto Maurizio, a meadow of *C. nodosa* of 1.2 Km long occupies the area between the shore and the upper limit of the *P. oceanica*.

3.2.3 Bergeggi *P. oceanica* formations

The considered area includes some residual formations of *P oceanica* between Punta del Maiolo and Capo Vado, hardly definible as meadows (Diviacco & Coppo, 2006). The discontinuous seabeds between 4 and 16 m of depth, alternate to wide sandy area and dead matte. The total length reaches 1.8 Km with an extension of 12.5 ha for the meadow and 7.8 for the mosaic formation and 15 ha of dead matte. The first small stand is in front of Spiagga delle Sirene, between Punta del Maiolo and Punta Predani: in the past, this formation may have been probably connected with Spotorno meadow. The realization of Spiaggia delle Sirene, started in 1958, may have caused a heavy regression of *P. oceanica* formation. The heavy regression of the Bergeggi meadow is probably a consequence of the discharge of materials accomplished between 1969 an 1971 to establish the beach and coming from building Vado Ligure Power Plant.

3.2.4 Genova Quarto - Sori *P. oceanica* meadows

This wide sector of Ligurian coast (almost 11 Km), shows a bottom and coastal geomorphological set up very similar compared to the remaining Genoa shoreline, even if the influence of the metropolitan area gets less marked going Eastward: this factor allows the existence of the widest Ligurian meadow of *P. oceanica*. *P. oceanica* stands are included in B area of SCI Fondali di Boccadasse - Nervi (IT1332576) and SCI Fondali di Nervi - Sori (IT1332575): the meadow extends for about 11 Km while its mean width reaches 1000 m accounting for a surface of 830 ha, which is mainly fragmented. The upper limit is set about 5 m depth, while the lowest run between 25 and 30 m. *P. oceanica* formation of this area stretches unevenly and the upper limit withdraw to 20 m in front of river mouth and more anthropized area generating great gaps often occupied by *C. nodosa*. Between Sori and Recco, the sea bottom becomes more flat and sandy and the *P. oceanica* meadow is substituted by *C. nodosa*. The gulf of Recco recently has been involved into a deep coastal restore with the conversion of shore-parallel structures into underwater ones. Between the two areas colonized by *C. nodosa*, the only area settled by *P. oceanica* takes place.

3.2.5 Banquette management in Liguria

In 2006 data on banquette management were collected by means of a questionnaire given by ISPRA to 400 coastal municipalities (Borriello et al., 2010) to understand the magnitude of the stranding (e.g. amount of biomass)and which management strategy (e.g. removal, disposal) was applied along the coast in the period between 2001 and 2006: about the 67% of the investigated townships answered to the questionnaire independently from the presence of banquettes within their boundaries. Only 14 of 64 townships highlight issues related to banquette management: Ventimiglia, Taggia, Santo Stefano al Mare, Cipressa, San Bartolomeo al Mare (Imperia), Andora, Ceriale, Laigueglia, Noli (Savona), Recco, Rapallo, Santa Margherita Ligure, Chiavari (Genoa) and Deiva Marina (in La Spezia province). Among the remaining 50 municipalities, 29 declared not to be involved in the phenomenon: most communities fall on Imperia province, which corresponds to the area where the most consistent *P. oceanica* meadows are located . Even if different management strategies have been adopted, the most widespread was the mechanized removal of the wrack, followed by dump disposal despite the potential hazards to the beach itself. The biomass allocation in backshore (*in situ* storage) was applied only in few situations; according to the questionnaire results, only few municipalities provide to the recover of the "trapped" sediment. The removal using trucks and loaders cause the loss of huge amounts of sediment trapped in the leaves with obvious negative effects on the sediment balance of the beach (Gacia & Duarte, 2001) and huge disposal costs which can ammount to several hundred thousand euros. The Cipressa municipality both in 2005 and 2006 had chosen the *ex-situ* storage of the biomass on non-crowed beach, cutting the management costs (Borriello et al., 2010). In the Eastern Liguria two areas in the town of Recco are subject to the beaching of seagrasses, the first with a more recreational destination, the latter with a more naturalistic use: management of the seagrasses wrack on both sites lead to the removal of 189 t for 18000 euros of expenditures.

Chapter 4

Materials and Methods

4.1 Sampling sites

4.1.1 Beaches description

P. oceanica banquette have been investigate in four microtidal beaches chosen trying to summarize the wide panorama of Liguria beaches in terms of type, management and wrack features:

- **Cipressa** (code IMCI01–40, Lat. 43.8431; Lon. 7.9164) (Fig. **??**): the most western sampling site is located Eastern and not far from Marina degli Aregai harbour. The beach, managed according the policies desribed in section 3.2.5, is the product of an important intervention in early 2000s which led to the recover of 300 m of beach through a nourishment and properly protected by a groin and a offshore breakwater. The physical characteristics of the beach such as the wide exposition to winds and wave action and the presence of a consistent *P. oceanica* meadow allow the formation of the biggest investigated banquette (table XX for deposit characterization) with different cycles of accretion as well as different stratification.

- **Bergeggi** (code SVBE01–20, Lat. 44.2494; Lon. 8.4469) (Fig. **??**): this artificial beach has been created in the late 60s following the construction of the Vado Ligure power plant. The excavation provided a huge quantity of material with proper features for a large scale nourishment intervention (Fierro et al., 2010) which led to a beach extending for more than 1 Km. The *P. oceanica* wrack is rather rarefied and mainly composed by entire leaves and some rhyzomes. The merely recreational destination of the site prevents structured accumulation.
- **Nervi**(code GENE01–20, Lat. 44.3833; Lon. 9.0321) (Fig. **??**): this sampling site in the middle-Eastern part of the region is located inside the Nervi marina on the right bank of the homonymous watercourse: the beach is limited on both sides by concrete structures belonging to the Nervi marina. The area is deeply influenced by the sedimentary dynamics linking the circulation inside the marina area and the sediment provision which in the past caused several issues. Even if the beach is located in an anthropic area not far from the city centre of Genoa, representing a so called urban beach, the accumulation of *P. oceanica* can reach fair depth and length with visible structures.
- **Recco** (code GERE01–20, Lat. 44.3588; Lon. 9.1443) (Fig. **??**): this site is an embayed beach, that well represents the overall morphological set of this coast sector. The beach - named Spiaggia dei Frati - is located on the eastern limit of the Recco municipality and limited between the outer edge of the groin built in XX century and eastward by a rocky headland. Anthropic structures in outer section of the beach further reduce its width. The beach narrow and thin allow the formation of a rather consistent banquette. Being a renowned turist location, the site

is often subjected to nourishment as well as mechanized removal of the stranded seagrasses.

The fauna associated to driftwoods and other allochtonus beach wrack has been mainly studied in the western section of the Voltri municipality (code GEVO, Lat. 44.42682; Lon. 8.74189) (Fig. 4.3.a): this section is exposed to Southern winds which bring a strong wave action with particular reference to the cold season. The site is located nearby the righ bank of the mouth of Cerusa stream which is characterised by a conspicuous sedimentary provision and for its position cut apart this study area from the main beach body. Other two beaches, Torre del Mare (SVTM, Fig. 4.3.b) and Punta Predani (SVPP, Fig. 4.3.c), have been explored in the Western part of the region. Due to the coast exposition, and the sheltered configuration of Punta Predani, the woody debris were rarefied and rather ephemeral. Torre del Mare beach is intensively subjected by a artificial management that does not allow the formation of a discrete driftline.

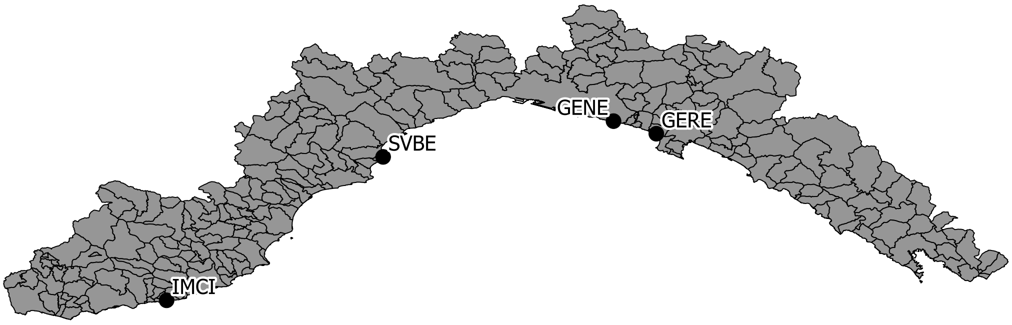

Figure 4.1: Sampling site. Liguria investigated banquettes: Imperia Cipressa (IMCI), Bergeggi Caletta (SVBE), Genova Nervi marina (GENE) and and Genova Recco "Baia dei Frati" (GERE)

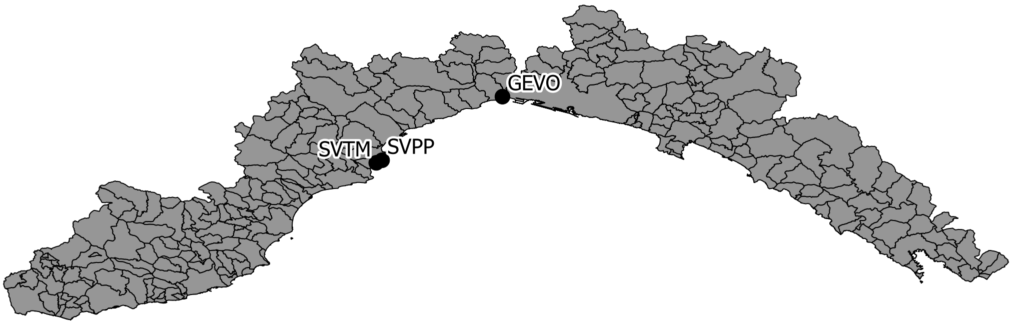

Figure 4.2: Sampling site. Liguria investigated driftwood-related communities: Bergeggi Torre del Mare (SVTM), Bergeggi Punta Predani (SVPP), Genova Voltri(GEVO)

Figure 4.3.a: GEVO Figure 4.3.b: SVTM

Figure 4.3.c: SVPP

Figure 4.3: Driftwoods. Investigated site for woody wrack associated fauna: Genova Voltri nearby Cerusa mouth (GEVO, e), Bergeggi Torre del Mare (SVTM, f) and Bergeggi Punta Predani (SVPP, g).

4.1.2 *Posidonia oceanica* banquette description

Because of its vegetal nature and the dynamics that determine its deposition the stranding of *P. oceanica* necromasses lead to a wide range of accumulation differing for depth, extension as well as the structural aspect and kind of material.

- The alteration status, determined by the energy of the wave action, the persistence in water and the residence time on the beach, has been studied along a vertical profile, to identify different layers according the macroscopic aspect of the material (Fig 4.4.a).
- As the deposit progressively accumulates on the upper section of the beach, where it lies far from wave action, is subjected to several processes like weathering, decomposition and comminution could determine variations in nutritional, microclimatic, and physical conditions. More than in any other leaf-based litter, the conditions of the organic material can change spatially, in relation to the position of wrack deposits, and temporally, as the organic material undergoes the physical dynamics of the beach environment (wind, sand covering, solar exposure, dehydration, etc.) (Olabarria et al., 2007; MacMillan & Quijón, 2012; Rodil et al., 2008). All the processes above mentioned, determine physio-chemical modifications of the deposit that can be detected examining some microenvironmental parameters such as pH and Temperature. FieldScout SoilStik pH Meter and Tescoma Presto digital thermometer were used to measure these parameters.
- Direct estimation of organic matter by loss on ignition (OM): this analysis used in soil sciences (Davies, 1974; Ben-Dor & Banin, 1989) results reliable to estimate availability of organic matter also in the purpose of this research (Ince et al., 2007). Loss on Ignition (LOI) analysis using

muffle furnace is used to determine the organic matter content (%OM) of a sample: this is a relatively simple and safe procedure compared to others used to determine OM, which sometimes require chemicals. The difference in weight before and after ignition represents the amount of the OM. In this research 3 replicas for 3 samples for both layers are used for each site.

4.1.3 Granulometric analysis

Grain size is the most fundamental physical property of sediment. Geologists and sedimentologists use grain size to study processes related to the dynamic conditions of transportation and deposition. Within this research, mainly focused on the biotic component of beach ecosystems, this analysis assumes the meaning of the characterization of sampling sites (together with other features) and the description of the interstitial environment on which many arthropods rely for their survival (e.g. Diptera larvae).

For each site three samples were hand-core collected along a cross shore transect. Grain size has been analyzed in laboratory by dry sifting progressively smaller mesh size (1/2 phi intervals) (Wentworth, 1922). The statistical parameters of grain size distribution were determined according to Folk and Ward (1957).

4.1.4 Woody beach wracks

Driftwood are by definition more heterogeneous in terms of size and origin and their deposition can lead to a wide range of accumulation. In the study area the most interesting wrack is represented by the beach segment near Cerusa mouth: this sector is often involved in the deposition of woody debris. The Cerusa creek - with a network of of $21km^2$ (Fierro et al., 2010) - and the Leira creek represent good sources of woody material with particular reference to the combined action between flood and storms. The position of this site along the shore allows the persistence of driftwood for longer time than in other areas as the removal of the material occurs only in summer. Woody components represent most of the material transported and derives from natural and anthropic source. The overall size of the material as well as the typology can give information about the energy involved in the deposition. Seldom green parts can be observed mixed with the ligneous fraction. Driftwood is best represented by small branches, canes and even logs. The decay and the alteration status is related to many aspects: due to the complexity of these processes only the physical aspect related to the fragmentation and the mechanical alteration are visible. Nevertheless, wooden artefacts react very differently from ageing and chemical processes involving saltwater and other factors then natural wood sources. Moreover according to the energy and the direction, woody debris can form a more or less continuous driftline, isolated accumulations or less visible formations of scattered material. The removal of the material - by natural backswash of following storm or by management policies - can leave some residuals along the beach creating small patches of woody litter.

4.2 Sampling techniques

4.2.1 Berlese-Tullgren funnel apparatus

This device can be described as a funnel upon which a light bulb heats the sample (soil or litter) located into a sieve. Arthropods escaping from the desiccation inducted by the heat source descend through the sieve along the funnel and finally fall into a preservative liquid.

Berlese funnel extractor can be regarded as a behavioural sampling method as it based on arthropods behavioural mechanisms (Woodcock, 2005). As for subterranean arthropods which, shun light and avoid high temperatures, the application of this protocol in this research aims to produce a temperature gradient that - drying out *P. oceanica* - leads the organisms out of the samples. The use of this sampling strategy within the study of *P. oceanica* banquettes had been experimented few times, but the present research represents the first ever extensive approach focused only on the study of seagrasses necromasses as a forest-like leaf litter. The apparatus composed by a heated-copper funnel was first designed at the turn of the century by the Italian entomologist, A. Berlese (Berlese, 1905), and later modified by the Swede, A. Tullgren (1918), who introduced the light-bulb as a heating source. During decades the apparatus has been considerably modified (Macfadyen, 1962) according the need or the specific use. A negative aspect of this extraction device is represented by the sand grains and vegetal debris that drop into the collection becker along with fauna, which makes sorting more time-consuming and labour intensive than pitfall trapping (Robertson, 2002; Edwards, 1991). This methodology can be applied to extract the active stages of any hypogean invertebrates, thus results useful for a wide range of organisms, from microarthropods such as Collembola - which cannot easily be obtained with other methods - to the larger Coleoptera.

4.2.2 Pitfall trapping

A pitfall trap is designed to sample organisms active on the ground: these devices consist of an open-mouthed collecting vessel buried in the substrate with its opening at the same level of the soil surface. The low cost and the absence of particular manifacturing process make pitfall traps one of the most obvious and wide scale adopted sampling device. This techniques represent without any doubt one of the oldest and most frequently used sampling strategies in entomological research, whose main targets are represented by epigean and wandering arthropods. From its first appearance among sampling method developed to produce qualitative data (Hertz, 1927; Barber, 1931), the potential for quantitative sampling was realized in 1941 (Fichter, 1941). Pitfall trapping has been applied to a wide range of terrestrial habitats, from desert to forest (Niemelä et al., 1986; Spence & Niemelä, 1994) to caves (Barber, 1931) and beaches (Hayes, 1970), both to study invertebrates communities (Hammond, 1990; Jarosik, 1992) - in terms of relative abundance habitat association and population estimation - to detect activity patterns (L. Chelazzi & Colombini, 1989) and distributions as well as to conduct monitoring programs (Rieske & Raffa, 1993; Simmons et al., 1998). For the last three-quarters of a century pitfall traps have proved to be one of the most versatile, useful, and widely used invertebrate sampling techniques (Leather, 2008). From a theoretical point of view some of the greatest advantages are represented by the continuous sampling which allows to remove biases - that afflict other techniques sampling one point at time - and to collect a large number of invertebrates with minimal effort. Pitfall traps are however far to be free from limitations and flaws, like the unbalanced response of each taxa to the device and the rates at which specimens are caught. Indeed the proportion of collected taxa is no longer necessarily representative of their relative abundance in the sampling habitat. According to these assumptions, the use of pitfall traps requires a comprehensive understanding of both advantages and disadvantages of this method which imply a deep knowledge of different trap designs as well as sampling strategies and ways to improve the quantitative nature of the data. The choice of this sampling strategy within this research results particularly suitable, as pitfall traps are most effective in open habitats, since they can be affected by vegetation complexity (Melbourne, 1999; Majer, 1978).

4.2.3 Experimental design

Posidonia oceanica **banquettes**

Beached seagrasses were collected mainly in autumn and winter as in these seasons - in the study area study was carried out - there's occurrence between *P. oceanica* leaf-shedding and most of storm which lead to the formation of banquettes along the Ligurian shoreline. Several physical variables have been taken in account to better describe these environments as these factors play a key role (Nguyen, 2015; Ruiz-Delgado et al., 2015; Defeo & McLachlan, 2013) in determining possible community composition and zonation (Colombini et al., 2000; Pennings et al., 2000).

- In each site 10 samples (each 2000 cc) of *P. oceanica* were randomly hand-core collected along a cross shore profile. Chronologically the first sampled location was Nervi Marina on November and December 2016, followed by Recco (February and March 2017), Cipressa (March and April 2017), Bergeggi (November and February 2018) and Cipressa (January 2018): thus, for the site of Cipressa, samples are available for potential comparisons within two sampling occasion in two different months. Fauna was extracted with a Berlese funnel apparatus (funnels were 30.5 cm in diameter, 35.6 cm height, with 30–35 mm mesh screens, fitted with 40 W tungsten-filament lamps) over becker flasks containing 70% alcohol placed at the bottom of the funnel stems over five days.
- Distance from swash line (DSL)(Fig 4.4.b): the crosshore distribution of *P. oceanica* deposits allows to take in account - besides a spatial factor - a temporal aspect directly related to its persistence on the beach. The

further the seagrass is set up away from the swash line, the longer it presumably is its residence time (Ruiz-Delgado et al., 2015).

- Level: according to what reported in section 4.1.2, two levels of *P. oceanica* status were identified and sampled (Fig 4.4.b). For each level other variables such as temperature (T) and pH have been recorded. Moreover, for each level samples of necromass have been collected for direct estimation of organic matter.
- Granulometry: for each site, samples were hand-core collected along a cross shore transect. Within the study of *P. oceanica* banquette the sediment was sampled at the depth of the two identified horizons, to better describe the vertical dimension.
- To allow comparison within-between levels, sampling occasions and sites, a ΔT has been calculated subtracting the mean monthly T obtained from world bioclim data (Hijmans et al., 2005) to try to rule out the seasonal aspect.

Woody wrack and other allocthonus input

Arthropods communities of beached ligneous materials have been collected in two following seasons from March to May in the site of Voltri: for 2018 sampling campaign unexpected logistic difficulties have prevented the Autumnal sampling sessions (Semptember, October and November). Other two locations - Torre del Mare and Punta Predani - were explored in the Western part of the region in the cold season (October). Ten pit-fall traps (opening 90 mm) loaded with a 50% solution of water and vinegar were randomly placed along cross-shore profile at increasing distance from the wrack: the opening was protected with a grid (1 cm mesh size) to prevent small vertebrates and seagulls to interact with the trap. Traps were in function for 24 consecutive

Figure 4.4.a: GENE Figure 4.4.b: GERE

Figure 4.4: P. oceanica. Experimental design: identification of levels along vertical profile according the alteration of the material (a). Cross-shore profile together with measurement of the distance from the swash line (b)

hours to minimize removal from passers-by. Similarly to what before reported for the study of *P. oceanica* communities, different environmental variables, in this case strictly related to the aboveground environment characteristics have been recorded to better relate arthropods communities in relation to habitat processes, zonation and better depict possible seasonality.

- distances of the deposit from the swashline were recorded in meters using a measuring tape .
- temperature values of the sand surface were acquired for each trap in every survey between 7:00 and 8:00 AM as this parameter can influence the activity pattern of many arthropods as well as it can better describe the surveyed context.

4.3 Arthropods identification

4.3.1 Taxonomy between difficulties and crisis

Arthropods identification especially for many important groups, has been regarded traditionally as a difficult process: behind this statement lays many taxonomic-related issues and therefore some introductory words are necessary to highlight and motivate this choice. Taxonomy is widely recongnized as a foundation science in Biology (Mallet & Willmott, 2003) and the origin of what today is called bioinformatics (Stoch, 2005). Alpha taxonomy, the discovery, description and classification of species, is crucial to answer such ecological questions as the spatial organisation of genomes, species and communities. Taxonomic information is moreover essential for addressing critical ecological and conservation issues, particularly across international borders (McNeely, 2002) and ecotones. Despite such recognized importance, in Italy it was not always considered enough by the scientific community.

4.3.2 Outlining major groups

This section provides an overview of the main taxa that can be found in sandy beaches. A more detailed description is provided in the results section. For some groups, the expertise from other institutions as well as some private researchers have been necessary: while some taxa have been identified following taxonomical criteria, others such as mites and springtails - due to their high complexity - have been analysed according a more functional approach.

Crustacea: Isopoda (Latreille, 1817)

Terrestrial isopods (commonly called woodlice) belong to the suborder Oniscidea of the order Isopoda and represent the only group of Crustacea fully adapted to live on land. With more than 3,700 species presently known, they are the reachest suborder among the Isopoda (Taiti, 2017). Nevertheless they consitute the only exclusively terrestrial group among the 11 sub-orders of Isopoda. Within trophic webs Oniscidea are mainly saprophagous or detritivores, feeding on dead vegetal material and carrion. On the other hand they represent food on the seashore for many vertebrates (birds, lizards and toads) as well as invertebrates suchs as crabs, spiders, beetles and centipedes. This suborder shows dorso-ventrally flattened, segmented body articulated into three regions. Size is rather variable from 1 to 60 mm even if most of the species do not exceed the 20 mm. Specimens determination has been kindly carried over by Pietro Gardini (DiSTAV, UniGe).

Arachnida: Acarina Leach 1817

Acarina are the largest and the most diverse group within the Arachnida arthropod class with over 55000 described species (Dhooria, 2016). Within the Acarina subclass, two superorders - Anactinotrichida and Actinotrichida - are recognized; the former with more than 15,000 species described, the latter including more than 40,000 species. For the purpose of this research, two different guilds - one mostly predaceous and one mainly saprophagous or detrititivore - have been considered:

- Mesostigmata (Anactinotrichida) formerly placed in suborder Gamasida (Krantz & Walter, 1978), order Gamasida (van der Hammen, 1989) and order Mesostigmata (Evans, 1992) are commonly known as mesostigmatan or mesostigmatid mites. Representatives of this taxon are pretty small mites (0.2–4.5 mm long) with a pair of stigmatal openings above legs III and IV and are usually associated with a distinct peritrematal groove. Chelicerae are usually chelate-dentate, but protrude as elongate stylets in some parasites. Common feature of the group are coxae freely articulating with body without prodorsal trichobothria. Mostly they are free-living predators (families Phytoseiidae and Laelapidae) or may be parasitic on vertebrates and on social insects.
- Oribatida (Actinotrichida) (Balogh & Balogh, 1992; Evans, 1992) are minute to large mites (150 to 1500mm) usually with a distinct prodorsal shield or fully sclerotized prodorsum and sometimes with extensive idiosomatic sclerotization. Palpi are commonly bisegmentate, rarely with three articles. With about 6000 species described in 100 genera (Dhooria, 2016), oribatid mites are one of the most numerically dominant arthropod groups in the organic horizons of most soils. The Italian fauna account at least 790 species (Bernini, Castagnoli, & Nanneli, 1995).

They are found throughout the soil profile, in surface litter, on grasses as well as in aquatic, semi-aquatic and coastal habitats.

Arachnida: Araneae Clerck, 1757

Spiders can be separated from all other arachnids by their petiolate, unsegmented abdomen, abdominal spinnerets, and the modification of the male palpi into sperm transfer organs. Their overall morphology hide a great taxonomic complexity (Trotta, 2004). Spiders are predator arachnids that inhabit almost all terrestrial and some aquatic habitats, and many species have developed quite extraordinary adaptations to live in extreme environments (Jocqué et al., 2006). The Italian fauna includes 1635 species (Trotta, 2010). Many spiders are adapted for life in the intertidal zone but surprisingly few have taken advantage of this habitat (V. D. R. L. Brown, 1976). Many of them live among halophilic plants and can withstand occasional submersion. Intertidal spiders consist mainly of species which live in the upper intertidal and the supralittoral zones or among halophilic plants in saltmarshes where prey are abundant. Few species live in the wrack or in the lower intertidal. Prey of intertidal spiders include insects of the intertidal zone, isopods, amphipods and other spiders. Specimens collected during this research have been determined by Dr. Alessio Trotta.

Miryapoda: Diplopoda de Blainville in Gervais, 1844

With over 12,000 described species in 145 families and 16 orders (Sierwald & Bond, 2007; Brewer et al., 2012), and an estimated global fauna of more than 80000 species, the Diplopoda (millipedes) is the third largest class of terrestrial, Arthropoda following Insecta and Arachnida (Golovatch & Kime, 2009). The group include ecologically important detritivores and valuable biogeographical indicators because of their profound diversity and ancientness, as well as reduced vagility (Hopkin, Read, et al., 1992). In contrast to the insects, diplopods have no waxy cuticle and therefore are strictly related to moist environment as the exoskeleton of these animals is highly calcified and it is permeable to water in large quantities. Diplopods have hygroreceptors (e.g., the Tomösvary organ) on their sternites and largely photonegative behavior, which together allow the animals to seek out suitably moist shelters. Thus, activity patterns of these organisms, are concentrated at dusk, during the night or early morning on the surface, when the atmospheric humidity is greater than it is during the day (Hopkin et al., 1992). Modern millipede taxonomy is largely based on male genitalia (gonopods) and spermatopositors that basically function as a pipette, being involved in the indirectdirect sperm transfer. Gonopods are usually highly complex in structure and their minor details reflec differences between species. Specimen of this research have been determined by Dr. Jörg Spelda, Curator at Zoologische Staatssammlung of München.

Hexapoda Collembola Lubbock, 1870

Springtails are a group of small hexapods once placed among Apterygota and now included into Enthognata - together with Protura and Diplura - that would probably represent a sister group of Insecta. Fewer than 8,000 species of Collembola have been described to date (Bellinger et al., 2007). The Italian fauna of arenicolous and intertidal species of Collembola includes a total of 50 species and 11 genera belonging to 4 families (Dallai et al., 2010). These values, however, must be considered preliminary because of the limited number of locations so far investigated. Collembola show a basic three tagmata body, with three segmentend thorax, and an abdomen with five segments bearing a terminal periproct: thoracic and abdominal segments may be indistinc, as happen in Symphypleona, and may give the body a more globular appearance. Head features two antennae, two optional postantennal organs, two optional composed eyes and the enthognathous mouthparts. The most curious structure, not always present, is without any doubt the posterior ventral forked abdominal appendage named *furca* which is used by springtails to jump. Collembola are one of the ecologically most diversified groups of arthropods. Deharveng et al. (2008) revised the global diversity of springtails in freshwater habitats and reported 525 water dependent collembolan species, further subdivided into the two groups of freshwater dependent (103) and anchialine or marine water dependent species (109).

Insecta: Dermaptera De Geer, 1773

Earwigs are a Polyneopteran order of apterous or winged insects with 2000 species in about 10 families widely diversified in the intertropical region, but well represented also in the Paleartic region (Gullan & Cranston, 2014): in Italy the order counts 25 specie, 21 of which autochtonous and 4 alloctonous (Vigna Taglianti, 2010). The origin of this order is dated between the late Triassic and the early Jurassic. These small to moderately sized (4–25 mm long) insects have elongated bodies and are dorsoventrally flattened. The antennae vary from short to moderate length and filiform with elongated segments. The terga of the abdominal segments overlapping, with 10 visible segments in the male and eight in the female, terminating in prominent cerci modified into forceps; these are often heavier, larger, and more curved in males than in females. In some species, females show some sort of parental care assisting the nymphs to hatch from the eggs. The forceps are used for manipulating prey, for defense and offense, and in some species for grasping the partner during copulation.

Insecta: Diptera Linnaeus, 1758

Diptera are holometabolous insects featuring a single pair of mesothoracic wings and one pair of club-shaped halteres, derived from the reduction of the metathoracic wings. These insects constitute a very important group in any ecosystem, both in term of taxonomic richness and for their dual ecological role as they are an essential fauna in the first phase of biodegradation of organic matter and are a major food source for many consumers. Two suborders are officially recognized:

- Suborder Nematocera: crane flies, gnats, and midges chiefly sketch this taxon, which includes species mostly characterized by pluriarticulate antennae and pronotum distinct from mesonotum. In Nematocera, more than in Brachycera, larvae are either eucephalic or hemicephalic, often with aquatic behaviour (e.g. Chironomidae). This grouping is considered paraphyletic as within the seven infraorders the position of some families result uncertain as phylogenetically related to Brachycera (Yeates et al., 2007).

- Suborder Brachycera: known also as true flies, this sub-order is characterized mainly by short antennae and an overall robust appearance. Larvae have wormlike body (maggots) and their cephalic region shows reduced mouthparts. Brachycera larvae commonly face three instars of development before becoming pupae inside a puparium formed from the last larval skin. Brachycera represent a clearly monophyletic taxon and the relationships between major Brachyceran lineages have become clearer in recent decades. (Yeates et al., 2007). The taxon can be subdivided into further infraorders: Stratiomyomorpha, Tabanomorpha and Xylophagomorpha that collect the majority of diptera once placed inside the Orthorrhapha. The Muscomorpha infraorder (Cyclorrhapha) consists of diptera with 3-segmented, aristate antenna and acephalic larvae with three instars. Muscomorpha are splitted into the Acalyptratae and Calyptratae based on presence of a pair of developed structures called calypters, covering the halteres.

The intertidal and supralittoral bands, as well as the most external sectors of the beach, host a fair number of these insects, whose larvae live mainly in the tidal zone or in adjacent saline biotopes (Munari, 2010). Brachycera show rather wide habitat preferences and they can be found from the tidal zone landward to the wide extralittoral without discarding the intertidal/eulittoral areas, where the larvae feed on marine wracks. Despite most of the larval instars are microdetritivorous, in many species these instars also have a diet constituted by the biofilm made of diatoms and green algae that cover wet substrates. Others show different trophic preferences, with adults that sometimes are predators. The identification of the adults been made to the family level using the key proposed by Ooesterbroek (2006), while for larval instars the same identification level has been reached through the key proposed in Smith (1989), both supported by the checklist compiled by Munari (2010). The family level identification can be retained satisfying and at the same time useful to the purpose of this research: the overall complexity of the order could easily lead to erroneous determinations and at the same time rarefy data distribution. Thus the rank reached has to be considered meaningful from the ecological point of view.

Insecta: Coleoptera Linnaeus, 1758

Coleoptera the most diverse and species-rich insect order on Earth. With more than 380,000 described extant species (Zhang, 2013), beetles constitute about the 25% of all described animal species on this planet: approx. 12,000 of them are present in Italian fauna (Audisio & Taglianti, 2010). The colonized habitats by this cosmopolitan order also include some marine environments such as hypersaline rock pools and sandy sea beaches (Audisio, 2003; Colombini et al., 2003). In Italy, there are approximately 200 beetle species that more or less permanently colonize these marine/terrestrial domains. Most are specialized taxa showing peculiar adaptations to these characteristic habitats. Several species are associated with marine vegetal wracks and animal remains (Binaghi, 1951). In comparison to rocky shores, which support relatively few supratidal Coleoptera, sand beaches are inhabited by numerous species with varying degrees of dependence on and adaptation to marine environments (Doyen, 1976).

Whenever the madolittoral is represented by a wide area, beetle communities become more stable, diversified and abundant; the consistence of their populations is rather rarefied on narrow beaches. Intertidal Coleoptera show a preference to silty-sandy habitats where they are present with several burrowing species living under the stranded necromasses of this dynamic substrates, feeding upon the allochtonous organic material carried by the wave action or hunting for other saprophagous insects; less species inhabit pebbly beaches usually under the accumulation of vegetal beach cast materials such as seagrasses (Binaghi, 1951). Adult Staphylinids are one of the most obvious taxon across the shorelines. These species are extremely mobile and often actively avoid submersion so they can be basically considered as terrestrial organisms living nearby the sea. Their larvae normally occur well above the intertidal, and are submerged only during storms, or very briefly submerged. during exceptionally high tides. In addition some xylophagous species have evolved to live only inside woods (drifwoods) that have weathered for long-time in sea water and then deposited in beaches.
The order is subdivided in two suborder:

- Adephaga includes 10 families of mostly predator insects like ground beetles (Carabidae) - which most species belong to, Cicindelinae and other families of mostly aquatic species. The most diagnostic character is the first visible abdominal sternum completely separated by the hind coxae. These beetles show simple antennae and the galeae of the maxillae are usually bisegmentate. Adults have visible notopleural sutures.
- Polyphaga is definitely the most consistent of the two suborders with 5 infraorders and 17 superfamilies accounting for almost the 90% of the described coleopteran species. Within this taxon, 14 families inhabit the shoreline. This group counts a variety of other beetles as Anthicidae,

Melyridae, Lathridiidae, Oedemeridae and Ptiliidae, which frequent the drift line, feeding on decaying wrack. These beetles are characteristic of seashores, but are not aquatic as some Adephaga.

4.4 Data analysis

4.4.1 Species Richness estimation

Measuring Biological diversity

The measurement and assessment of biological diversity (biodiversity) is one of the most challenging tasks of conservation biologists and community ecologists (Magurran, 2013; Magurran & McGill, 2011). The simplest and still the most frequently used measure of biodiversity is the species richness of an assemblage that represent an intuitive and natural index of community structure. Patterns of species richness have been measured at both small (Blake & Loiselle, 2000) and large (Rahbek & Graves, 2001) spatial scales. In richness studies, two kind of data are commonly used: incidence data, in which each species detected in a sample from an assemblage is simply noted as being present, and abundance data, in which the abundance of each species is tallied within each sample. By their nature, sampling data document only the verified presence of species in samples. The absence of a particular species in a sample may represent either a true absence (the species is not present in the assemblage) or a false absence (the species is present in the assemblage, but was not sampled). Thus, despite its coneceptual simiplicity, species richness is a problematic metric related to sampling intensity and species abundance distribution. Observed number of species in a well-defined biodiversity sample - defined species density (Gotelli & Colwell, 2001) - is far from be an unbiased estimation of true species richness. Species richness increases non-linearly with the number of individuals encountered, the number of samples collected or the area sampled, observed richness is inevitably a downward biased estimate of true richness (Colwell et al., 2012). The first issue arise with the so called sampling problem which directly rely to species richness sensitiveness to sample size. As most species can be considered rare, sampling estimates are often incomplete and species undetection represent a common issue. Moreover measuring biodiversity through species richness doesnt take in account any information connected to relative species abundance (the abundance problem). Thus counting equally all species, rare species are weighted in the same way as common ones. Incorporating the information given by abundance into a biodiversity index is fundamental for the study of several - even if not all - aspects of ecosystem function. Neverthelss rare species play sometimes a key role in ecosystem function (Terborgh et al., 2001). From a statistical perspective, species richness is very difficult to estimate accurately from a finite sample.

Softwares

Species richness estimation has been carryed out through the use of two different sofwares: EstimateS (Colwell, 2013) is a free GUI software application designed to assess and compare the diversity and composition of species assemblages based on sampling data. EstimateS computes a variety of biodiversity statistics, including rarefaction and extrapolation and estimators of species richness. The other approach involved the more recent iNEXT package (Hsieh, Ma, & Chao, 2016) within R environment (R Core Team, 2017).

Statistical framework

Within these research, estimation is based on a sample-based design according to which the sampling unit is not represented by an individual (indivudual sampling) but more than a single individual is collected simultaneously using a trap or a core set randomly and independently: this approach well reflect the sampling protocol adopted for both *P. oceanica* banquette and driftwood communities. Because it is not always possible to count individuals, estimation has been also performed on a set of sampling units in which only the incidence (presence) of each species is recorded. The use of a sample based approach via replicated incidence data (or sample-based abundance data converted to incidence) gives better estimation performance as these tecniques preserve some aspects of the spatial structure of assemblages (Colwell et al., 2004; Gotelli & Colwell, 2001) which is very common in some arhtropods as result of trophic dynamics (diptera larva) or the production of aggregating-molecules (e.g. ants or springtails). Before proceeding in any analysis data has been arranged in a species-by sampling - unit matrix W_{ij} in which there are $i = 1$ to S rows (species), $j = 1$ to R columns (sampling units). For the only purpose of this analysis the term species have to be considered as a generic taxonomic level according which any organism can be recognised and separated from the community without any doubt.

Data obtained from EstimateS (10000 permutations) aim to investigate two aspects of species richness, the first more related to alpha-diversity, the second more related to beta-diversity. To avoid any artifact due to data distribution, non parametric tests followed by pairwise comparison have been run to test differeces within site - comparing the values of different estimators - and between sites comparing the estimated values of a given index. EstimateS provide a wide range of estimators: six non parametric asymptotic richness estimators were considered (Tab. 4.1) and analyzed together with individual abundance number of singletons and doubletons. Frequency incidence data has been analyzed in iNEXT package to understand and compare patterns in richness estimation according to rarefaction and extrapolation (10000 permutations) through the use of first three order Hill numbers (Chao et al., 2014) (Tab. 4.2).

Variable	**Estimator**	**Reference**
Individual	$[t/T] * N$	(Gotelli & Colwell, 2001)
Singletons	Number of singletons	(Colwell & Coddington, 1994)
Doubletons	Species with two individuals	(Colwell & Coddington, 1994)
ACE	Abundance Coverage-based est.	(Chao, Hwang, Chen, & Kuo, 2000)
ICE	Incidence Coverage-based est.	(Chao et al., 2000)
Chao 1	Chao 1 estimator (abundance)	(Chao, 1984)
Chao 2	Chao 2 estimator (incidence)	(Chao, 1987)
Jack 1	First order Jackknife	(Burnham & Overton, 1978)
Jack 2	Second order Jackknife	(E. P. Smith & van Belle, 1984)

Table 4.1: Species estimation richness. EstimateS computated variables together with main literature references

Variable	**Estimator**	**Reference**
$q = 0$	Species richness	(Hill, 1973)
$q = 1$	Shannon diversity	(Hill, 1973)
$q = 2$	Simpson diversity	(Hill, 1973)

Table 4.2: Species estimation richness. iNEXT variables together with main literature references

Asymptotic richness estimation

These approaches are based on statistical sampling-theory methods and aim to estimate the asymptote of a species accumulation curve allowing species richness estimation (Chao & Chiu, 2016): the estimated asymptotic value is used as a species richness estimate for further comparison across assemblages. Species richness is just one example of the large number of estimators of the asymptotic number of "classes" for samples of classified objects that statistical studies have produced (Bunge & Fitzpatrick, 1993). However, several factors can affect the performance of species richness estimators (Brose et al., 2003; Brose & D. Martinez, 2004). Such factors related both to the sampling strategy such as sample size, sampling effort, and spatial coverage (i.e. the area physically covered by sampling) and to features of the sampled assemblages, as evenness of the communities, species mobility and the size of true species richness. Non-parametric estimators appear to provide the best overall performance (Hortal, Borges, & Gaspar, 2006) and are therefore the safest general option. Parametric and curve-fitting approaches rely their effectivness in the selection of a parametric function or distribution: two models with different parametric functions or distributions may fit the data equally well, but they yield widely different estimates (Chao & Chiu, 2016). Moreover, when there are multiple assemblages - as in this study - the parametric approach does not permit meaningful comparisons of assemblages with different distribution functions. Non-parametric approaches, which make no assumptions about the mathematical form of the underlying distributions of species abundance or species detection rates, avoids the above-mentioned drawbacks and is more robust in these applications. An intuitive and basic concept in non-parametric species richness estimation is that abundant species (which are certain to be detected in samples) contain almost no information about the undetected species richness. This comes particularly useful for arthropods assemblages, where a large number of rare species is the rule rather than exception. In contrast to rarefaction, richness estimators estimate the total richness of a community from a sample, and the estimates can then be compared across samples. Non-parametric estimators of species richness are minimum estimators and their computed values should be viewed as lower bounds of total species numbers, given the information in a sample or sample set.

- **Chao estimators**

  Based on the concept that rare species carry the most information about the number of missing ones, only the singletons and doubletons are used to estimate the number of missing species. Chao1 and Chao2 have been computed in their classic and bias-corrected forms along with clog-linear 95% confidence intervals (Chao, 1987).

  - Chao1 : Chao (1984) derived an estimator of the true number of species in an assemblage based on the number of rare species in the sample (i.e. singletons, or those species represented by only a single individual, and doubletons, those represented by two individuals).

$$\hat{S}_{Chao1} = \begin{cases} S_{Obs} + \frac{f_1^2}{2f_2} & iff_2 > 0 \\ S_{Obs} + f_1(f_1 - 1) & iff_2 = 0 \end{cases} \tag{4.1}$$

  - Chao2 (Chao, 1987; Colwell & Coddington, 1994) uses occurrence data from multiple samples in aggregate to estimate the species diversity of the whole assemblage. Chao2 is virtually identical to the Chao 1 estimator, with singletons being species occurring in only one sample and doubletons occurring in two samples. This estimator can also make use of the Chao 1 variance formula, with the substitution of f_1 and f_2 for Q_1 and Q_2, respectively.

$$\hat{S}_{Chao2} = \begin{cases} S_{Obs} + [(R-1)/R]Q_1^2/2Q_2 & if Q_2 > 0 \\ S_{Obs} + [(R-1)/R]Q_1(Q_1-1)/2 & if Q_2 = 0 \end{cases} \tag{4.2}$$

- **Jackknife estimators**

  Jackknife techniques were developed as a general method to reduce the bias of a biased estimator. In this context, the biased estimation is represented by the number of species observed in the sample. The basic idea behind the $j_t h$ order Jackknife method is to consider sub-data by successively deleting j individuals from the data. Both first and second order jackknife can be used within incidence data coming from R replicated samples.

  - Jackknife I: was originally developed for capture/recapture studies. The formula represents the first order version of the estimator (Burnham & Overton, 1978); the variable n represents the total number of individuals. This estimator implies that the number of undetected species is approximately the same as the number of singletons, which means that only the number of singletons is used to estimate the number of unseen species.

$$\hat{S}_{jk1} = S_{Obs} + \frac{n-1}{n} f_1 \approx S_{Obs} + f_1 \tag{4.3}$$

  - Jakknife II: according to the second-order jackknife estimator (E. P. Smith & van Belle, 1984) the estimated number of unseen species includes singletons and doubletons. The second order Jackknife has shown to be one of the most effective estimators and may be the best estimator at the moment for highly sparse collections since it is the least susceptible to sampling bias (Butler & Chazdon, 1998; Hortal et al., 2006).

$$\hat{S}_{jk2} = S_{Obs} + \frac{2n-3}{n} f_1 - \frac{(n-2)^2}{n(n-1)} f_2 \approx S_{Obs} + 2f_1 - f_2 \tag{4.4}$$

- **Coverage-Based Richness Estimators**
  Coverage-based richness estimators are modifications of the estimators discussed by Chao & Lee (1992) and then introduced into the ecological literature (Chazdon et al., 1998). ACE and ICE base their meaning in the concept of sample coverage, originally developed for cryptographic analyses during World War II by the founder of modern computer science, Alan Turing, and his colleague I. J. Good (1953; 1956). The concept of coverage of a sample is surprisingly simple and can be described as the proportion of the total number of individuals in an a assemblage that belongs to the species represented in the sample. To apply the concept of sample coverage within species richness estimation, a cut-off value k is needed to separate species frequencies into *rare* (frequency $\leq k$) and *abundant* (frequency $\geq k$) groups. The cut-off $k = 10$ is generally recommended.

- The ACE (Abundance-based Coverage Estimator) assumes that the species relative abundances of individuals in an assemblage (p_1, p_2, $p_(s-1)$, p_s) are characterised by their mean $\bar{p} = 1/S$ and coefficient of variation (CV). The squared CV - called γ^2 - is defined as:

  $$\gamma^2 = \left[S^{-1}\sum_{i=1}^{S}(p_i - \bar{p})^2\right]/\bar{p}^2 \tag{4.5}$$

  The CV parameter describes the degree of heterogeneity among species abundances: the larger the CV, the greater the degree of heterogeneity.

  $$\hat{S}_{ACE} = S_{Abun} + \frac{S_{rare}}{\hat{C}_{rare}} + \frac{f_1}{\hat{C}_{rare}}\hat{\gamma}^2_{rare} \tag{4.6}$$

  where γ^2_{rare} is the square of the estimated coefficient of variation of the species relative abundances:

  $$\gamma^2_{rare} = \left\{\frac{S_{rare}}{\hat{C}_{rare}}\frac{\sum_{i=1}^{k} i(i-1)f_i}{(\sum_{i=1}^{k} if_i)(\sum_{i=1}^{k} if_i - 1)} - 1, 0\right\} \tag{4.7}$$

- The ICE (Incidence-based Coverage Estimator) is the corresponding estimator for incidence data. In this case the number of species in the frequent group is given by $S_{freq} = \sum_{i>k} Q_i$ and for the infrequent species by $S_{infreq} = \sum_{i=1}^{k} Q_i$. Then ICE can be also expressed as:

  $$\hat{S}_{ICE} = S_{freq} + \frac{S_{infreq}}{\hat{C}_{infreq}} + \frac{Q_1}{\hat{C}_{infreq}}\hat{\gamma}^2_{infreq} \tag{4.8}$$

Rarefaction and extrapolation

The dream of every biologist involved in biotic inventories is the rigorous extrapolation of empirical sample-based rarefaction curves to estimate, with confidence intervals, how many species would be found in a larger set of samples from the same assemblage (Colwell et al., 2004). The study of sandy beach artropods communities follows the methods proposed by Collwell and Chao (2012; 2014) to face two common estimation questions:

- rarefaction is an interpolation process aimed to estimate the expected number of species in a random sample of a smaller number of individuals. This problem is addressed with classical rarefaction like Coleman rarefaction (Coleman et al., 1982) for individual-based data and with sample-based rarefaction (Bernoulli product model) for incidence frequencies. Rarefaction curves are usually created by randomly re-sampling the pool of T samples multiple times and then plotting the average number of species found in each sample.
- the second issue is an extrapolation-related problem that can be described as the estimation of the number of species expected in a larger number of individuals or across a larger sampled area. This process involves sampling-theoretic predictors for the number of species in a larger sample or larger area based on an estimated asymptotic species richness using a Bernoulli product model, based on an estimate of asymptotic species richness.

The sample size- and coverage-based integration (Chao & Jost, 2012) of rarefaction and extrapolation (Colwell et al., 2012) together represent a unified framework for estimating species richness and for making statistical inferences based on these estimates.

Sample-based R/E with Hill numbers

Hill's numbers (Hill, 1973) are a mathematically unified family of diversity indices (differing among themselves only by an exponent q that incorporate relative abundance and species richness that overcome problems of many of the diversity indices most commonly used by ecologists. Mark Hill incorporated the transformed Shannon and Gini - Simpson measures, along with species richness. Different Hill numbers ${}^{d}Q$ are defined by their "order" q according to the general formula:

$$ {}^{d}Q = \left(\sum_{i=1}^{S} p_i^q \right)^{\frac{1}{(1-q)}} \tag{4.9} $$

The parameter q is a non-negative integer that determines the sensitivity of the measure to the relative frequencies: changing the exponent yields a family of diversity indices: when q = 0, the parameter does not contribute to the sum in Eq. 4.11. Thus, only presences are counted, so that ${}^{0}Q$ represent species richness. For q=1, the equation is undefined, but its limit as q tends to 1 and this describe the exponential of the familiar Shannon index: the variable ${}^{1}D$ weighs species in proportion to their frequency. Each element W_{ij} within the species-by sampling - unit matrix is a Bernoulli random variable ($W_{ij} = 0$ or $W_{ij} = 1$), with probability π_i that $W_{ij} = 1$ and probability $1-\pi_i$ that $W_{ij} = 0$. Under these assumptions, the probability distribution for the incidence matrix is given by:

$$ P(W_{i,j} = w_{i,j} | \forall i = 1, 2, .., S, j = 1, 2, .., T) = \prod_{j=1}^{T} \prod_{i=1}^{T} \pi_i^{w_{ij}} (1-\pi_i)^{1-w_{ij}} = \prod_{i=1}^{S} \pi_i^{y_i} (1-\pi_i)^{T-y_i} \tag{4.10} $$

under the Bernoulli product model specified above, the Hill number of order q is defined as:

$$ {}^{q}\Delta = \left(\sum_{i=1}^{S} \left[\frac{\pi_i}{\sum_{j=1}^{S} \pi_i} \right]^{q} \right)^{\frac{1}{1-q}} , q \geq 0, q \neq 1 \tag{4.11} $$

When q = 2 the equation yields Simpson diversity which give more weight on the frequencies of abundant species and discounts rare species. The presented Hill numbers usually described under the abundance data framework have been recently defined for sample-based incidence data (?, ?) within the application of a Bernoulli product model (Colwell et al., 2012), which assumes that the i_{th} species has its own unique incidence probability π_i that is constant for any randomly selected sampling unit.

4.4.2 Untangling diversity

Diversity indices

Biodiversity, a multidimensional property of natural systems, is difficult to quantify partly because of the multitude of indices proposed for this purpose. Indices aim to describe general properties of communities that allow us tocompare different regions, taxa, and trophic levels (Morris et al., 2014). There have been numerous attempts to create compound indices that combine measures of richness and abundance.

- The Shannon (H') index has been a popular diversity index in the ecological literature. The Shannon index is an information-based statistic index, which means it assumes all species are represented in a sample and that they are randomly sampled. The classic formulation is provided by the following formula:

  $$H = -\sum_{i=1}^{S} p_i \, log_b \, p_i \tag{4.12}$$

  where p_i is the proportional abundance of species i and b is the base of the logarithm. In a highly diverse (and evenly distributed) system, an unknown individual could belong to any species, leading to a high uncertainty in predictions of its identity. In a less diverse system dominated by one or a few species, it is easier to predict the identity of unknown individuals and there is less uncertainty in the system (Shannon, 1948).
- The Simpson index (D) was introduced in 1949 by Edward H. Simpson to measure the degree of concentration when individuals are classified into *types*. The Simpson index is usually known as dominance index because it gives more weight to common or dominant species. The used

function follows the formulation:

$$D_2 = \frac{1}{\sum_{i=1}^{S} p^2} \tag{4.13}$$

This variation applied within this research is better known as inverse Simpson index and it's closely related to the orginal D_1, index even if the former has become even more used (Magurran, 2013). Both of these transformations aim to make the index increase as diversity intuitively increases.

- Pielou's Evennes (J') finally represents the degree to which individuals are split among species with low values, indicating that one or a few species dominate, and high values indicating that relatively equal numbers of individuals belong to each species:

$$E = \frac{H}{logS} \tag{4.14}$$

These three indices have been calculated within Vegan package (Oksanen et al., 2017) in R environment (R Core Team, 2017), and compared to asses differences in community composition and richness along vertical gradient (level) and between sites. Nevertheless, within driftwoods community Shannon and Simpson indices and Pielou's evenness have been compared to explore diversity composition across a time-related landscape instead of a space-related one.

Species Composition

Species composition has been explored trough a quite diffused algorithm. Non-metric Multidimensional Scaling (NMDS) is an uncostrained ordination technique that differs in several ways from nearly all other ordination methods. In most ordination methods, many axes are calculated, but only a few are viewed, owing to graphical limitations. In this analysis, a small number of axes are explicitly chosen prior to the analysis and the data are fitted to those dimensions. Moreover, MDS is a numerical technique that iteratively seeks a solution and stops computation when an acceptable solution has been found, or it stops after some pre-specified number of attempts. As a result, an MDS ordination is not a unique solution, and a subsequent MDS analysis on the same set of data and following the same methodology will likely lead to somewhat different ordination. Thus, Non-metric Multidimensional Scaling (NMDS) is commonly regarded as the most robust unconstrained ordination method in community ecology (Minchin, 1987). Analysis of similarities (Clarke, 1993) is a non-parametric extension of multivariate ANOVA test that becomes widely used in the field of ecology. Given a matrix of rank dissimilarities between a set of samples, each solely belong to a group, the ANOSIM tests whether we can reject the null hypothesis that the similarity between groups is greater than or equal to the similarity within the groups. Finally, Similarty percentage (Clarke, 1993) is a simple method for assessing which taxa are primarily responsible for an observed difference between groups of samples: it turns very useful to look for taxa which account from significative difference between groups. The difference is assessed throught the decomposition of Bray-Curtis dissimilarity.

Only for driftwood communities, a slighlty different algorythm using permutational analysis of variance - which seems to be less sensitive to dispersion effects

(Anderson, 2001) - have been used to test differences within month and years.

Modelling diversity

Shannon, Simpson and Evenness have been chosen as paramters to model the diversity in space (coils) and time (driftwood). To pursue this objective, three linear models have been built using as response variables three computed indices. Several Predictors have been chosen to try to describe how environmental features affect community composition. Macro Climatic variables have been extracted using WorldClim dataset (Hijmans et al., 2005) using QGis software (Team, 2018), while three field collected measurements, together to information coming from grain size sieve analysis, have been chosen to describe site micro-environmental conditions. To avoid spurious correlations, variables sharing a Spearma correlation coefficient greater than 0.75 have not included in the computing of global model (Dormann et al., 2013). Model selection and averaging have been performed trough MuMin R package (Barton, 2016). Models have been selected according to second-order Akaikes Information Criterion (Akaike, 1998; Burnham & Anderson, 2014).

Collembola lifeforms sensibility

Collembola are one of the ecologically most diversified groups of arthropods. This has enabled springtails to colonize a wide range of different microhabitats in all terrestrial and to some extent also aquatic ecosystems. Their ecological diversification is closely connected with morphological adaptations. This has enabled them to colonize a wide range of different microhabitats in all terrestrial and to some extent also aquatic ecosystems (Rusek, 2007). To investigate how enviromental set up affect their distribution, the collembola have been classificated into 4 lifeforms (Potapov et al., 2016):

- Atmobiotic life form: it corresponds to macro- and microphytobionts in Rusek (2007). These springtails are more related to macrophytes, but still can be found on the litter surface. Atmobiotic species are generally large organisms (up to 10 mm in length), brightly and often motley colored. Appendages are long and the head bears a full set of ocelli; body shape range from round to elongated.
- Epedaphic sprintails found their equivalent in epigeonts in Rusek (2007). These medium to large size collembola inhabitate the upper litter layer or the surface of fallen logs. Pigmentation is usually uniform. In this lifeform, can be observed an initial reduction of appendages.
- Hemiedaphic, or hemiedaphobionts in Rusek (2007), inhabit partly decomposed litter or rotten wood. These collembolans are of medium or small size (from 1 to 2 mm), usually with dispersed pigmentation, reduced number of ocelli and shortened appendages.
- Euedaphic life form: these collembola were classified as euedaphobionts by Rusek (2007), largely inhabiting the upper layers of the soil (humus horizon).

Within driftwood related communities, collembola lifeforms distribution have investigated through the same framework previously proposed for diversity indices using generalized linear models. Goodness of fit test have been performed trough Hosmer-Lemeshow Goodness Of Fit (GOF) Test within Resource Selection Package (Lele et al., 2019).

Chapter 5

Results

5.1 *Posidonia* oceanica banquettes

5.1.1 Enviromental variables

Enviromental variables have been analysed to provide an exhaustive description of the studied communities. According to what previously reported within the sampling framework (Sec. 4.2.3), measurement has been collected for each sample for both investigated layers. These parameters can actually describe the micro-enviromental conditions. Potential relationship between variables have been explored through Pearson correlation coefficient: collected measurements seem to be - even if weakly - negative correlated each other (Tab. 5.1).

Row	Column	r	p-val.
DSL	T	-0.079	0.434
DSL	pH	-0.267	$0.007*$
T	pH	-0.312	$0.003*$

Table 5.1: Posidonia oceanica banquettes. Enviromental variables linear correlations. Distance from swash line (DSL), temperature (T) and pH, $Pearson'sr$ correlations coefficients and related p-values (= significative p-value).*

Temperature

The analysis of temperature aim to describe the thermal condition occuring in the investigated sites during the smapling session (Tab. 5.2). The lowest temperature has been recorded in Bergeggi (November 2018), while the highest has been measured in Imperia Cipressa (16.50 C) in March 2017. Comparison within the same site for the two layers for Nervi, Cipressa (2018) and Bergeggi shows significative differences (Tab. 5.3) between sampled layers. Finally, to make the comparison between site as meaningful as possible, temperatures have been adjusted ($\mathit{\Delta T}$, Figg. 5.1.a, 5.1.b) subtracting montly mean data coming from World Bioclim (Hijmans et al., 2005): post-hoc pairwise comparison after significative non parametric ANOVA shows differences for many sites (Tab. 5.4).

Site	**Level**	**Temperature**		
		Min	**Max**	**Mean**
GERE	I	12.10	19.90	14.93
	II	13.90	20.30	16.68
GENE	I	14.10	17.50	15.42
	II	11.10	14.60	12.51
IMCI 2017	I	14.80	23.50	18.44
	II	16.50	24.90	19.74
IMCI 2018	I	12.90	13.99	14.60
	II	14.40	15.47	16.30
SVBE	I	9.20	12.30	10.39
	II	9.49	13.32	15.80

Table 5.2: Posidonia oceanica banquettes. Temperatures: minimum, maximum and mean values for each sampled layer. GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.

Site	χ^2	**Df**	**p-val.**
GENE	12.642	1	$3.77 \times 10^{-4}*$
IMCI 2018	12.137	1	$4.94 \times 10^{-4}*$
SVBE	5.851	1	$1.56 \times 10^{-2}*$

Table 5.3: Posidonia oceanica banquettes. Temperatures: comparison between sampled layers within sampling sites (= significant p-value). GENE = Genova Nervi; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.*

	GENE	**GERE**	**IMCI 2017**	**IMCI 2018**
GERE	$5,64 \times 10^{1}0-3*$	-	-	-
IMCI 2017	$1.30 \times 10^{-5}*$	0.62	-	-
IMCI 2018	0.06	0.94	0.18	0.296
SVBE	0.97	$0.03*$	$1.90 \times 10^{-4}*$	0.23

Table 5.4: Posidonia oceanica banquettes. Temperatures: post-hoc pairwise comparison between sampling sites (= significative p-value). GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.*

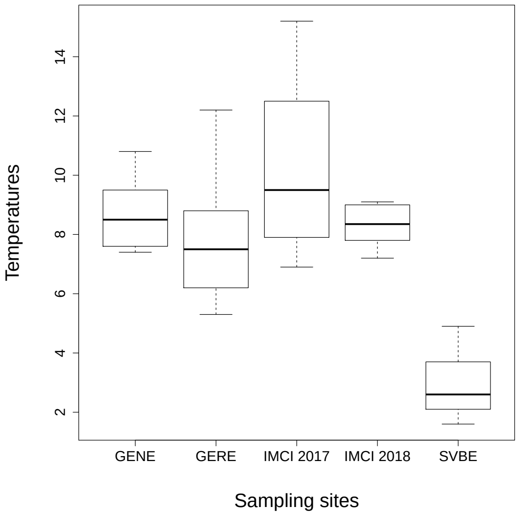

Figure 5.1.a: Level I (a)

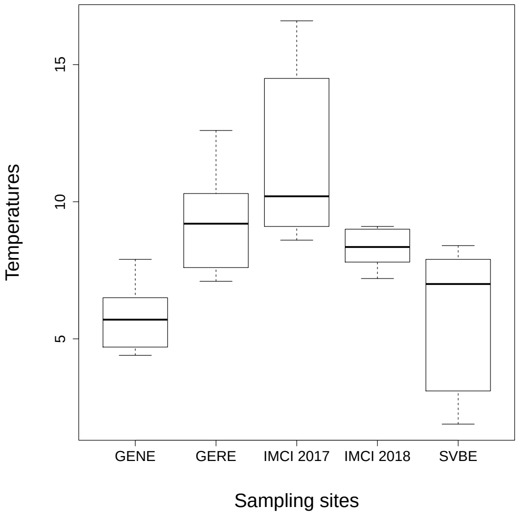

Figure 5.1.b: Level II (b)

Figure 5.1: Posidonia oceanica banquettes. Temperature: ΔT among sampling sites for upper (a) and lower (b) banquette layer. GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.

pH

Multivariate imputation by chained equations (Buuren & Groothuis-Oudshoorn, 2010) has been used to replace some missing pH values lacking due to technical problems. pH values do not show variations between levels into the same banquette but differences come from the comparison of each level between sampled banquettes. From post-hoc tests the most superficial layers show significative differences between Cipressa (2017) and Nervi (p-val. = 0.047, Fig. 5.2.a) as well as between Cipressa (2017) and Recco (p-val. = 0.039, Fig. 5.2.a). Extended differences comes from the second layers analysis (Tab. 5.6; Fig 5.2.b).

Site	**Level**	**pH**		
		Min	**Max**	**Mean**
GERE	I	7.42	7.83	8.11
	II	7.40	7.97	8.17
GENE	I	7.40	8.35	7.85
	II	7.97	8.52	8.14
IMCI 2017	I	7.12	7.41	8.10
	II	6.97	7.30	7.80
IMCI 2018	I	7.35	7.70	8.00
	II	7.56	7.72	7.82
SVBE	I	6.25	7.56	8.80
	II	7.65	8.25	8.60

Table 5.5: Posidonia oceanica banquettes. pH: minimum, maximum and mean values for each sampled layer. GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.

	GENE	**GERE**	**IMCI 2017**	**IMCI 2018**
GERE	0.85	-	-	
IMCI 2017	$1.30 \times 10^{-4}*$	$7.58 \times 10^{-3}*$	-	-
IMCI 2018	$0.03*$	0.33	0.59	0.296
SVBE	0.95	$0.41*$	$3.80 \times 10^{-6}*$	$2.73 \times 10^{-3}*$

Table 5.6: Posidonia oceanica banquettes. pH: post-hoc pairwise comparison between sampling sites (= significative p-value).GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.*

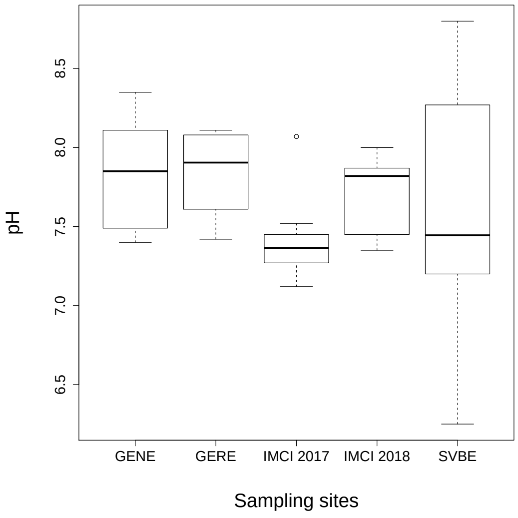

Figure 5.2.a: Level I (a)

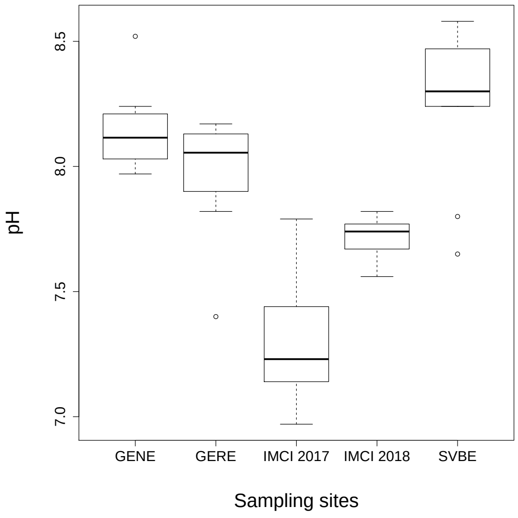

Figure 5.2.b: Level II (b)

Figure 5.2: Posidonia oceanica banquettes. pH: measured values for upper (a) and lower (b) banquette layer. GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.

Organic Matter

Organic matter (expressed as percentage) varies greatly both among and within the same site (Fig. 5.3): even without any inference, it can be observed as the site of Nervi is the poorest in term of this resource, while the site of Recco is the richest. These differences can be also interpreted according the status of the banquette (physical alteration) and the grain size of the investigated area. While Recco banquette is actually quite altered and the necromass higly fragmented, in Nervi and Imperia banquettes leaves and other part of *P. oceanica* are still visibile. However, statistical comparisons show generalized differences (5.10 a and b) that support what observed.

Site	**Level**	**Organic (%)**
GERE	I	38.89
	II	12.38
GENE	I	69.18
	II	68.80
IMCI 2017	I	59.01
	II	50.17

Table 5.7: Posidonia oceanica banquettes. Loss On Ignition: percentage of organic matter from sampled banquette. GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017.

	IMCI	**GENE**
GENE	0.08	-
GERE	0.06	$3.80 \times 10^{-5}*$

a) Upper layer (Level I)

	IMCI	**GENE**
GENE	$0.04*$	-
GERE	0.06	$6.0 \times 10^{-6}*$

b) Lower layer (Level II)

Table 5.10: Posidonia oceanica banquettes. Organic matter: post-hoc pairwise comparison (= significative p-value) for upper (a) and lower (b) banquette layer. GERE = Genova Recco; GENE = Genova Nervi; IMCI = Imperia Cipressa 2017.*

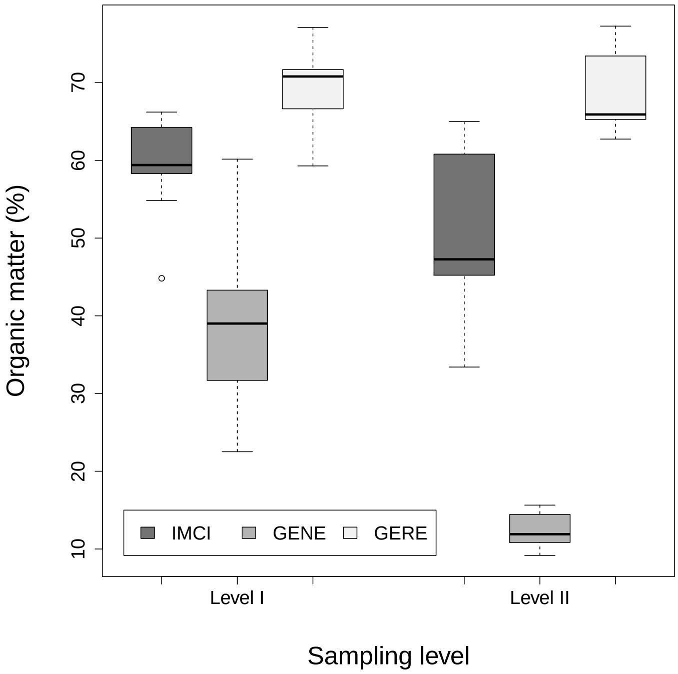

Figure 5.3: Posidonia oceanica banquettes. Organic matter percentage. GERE = Genova Recco; GENE = Genova Nervi; IMCI = Imperia Cipressa 2017.

Granulometry

Grain size analysis is usually adopted by geologists and sedimentologists to understand depositional dynamics. In the current research, this techniques besides providing useful information to describe sampling sites, gives further information about the environmental setup of the studied habitats that together with other variables can influence the distribution and the adundance of the arthropods. Several parameters have been used mainly to charaterize the beaches (Tab. 5.11 and 5.12) following the classification proposed by Folk (1970)(Tab.). Because of the huge fraction of coarser sediments in the sampling sites, a classification according Jennings and Shulmeister (2002) has been attempted: Recco can be classified as a pure gravel beach, while Cipressa and Nervi can be considered as a composite gravel beach, and finally Nervi can be likely considered as a mixed sand and gravel beach with a considerable sandy fraction. Sorting spread between well sorted (Nervi) to poorly sorted (Cipressa).

Site	**Level**	**D50(Φ)**	**Mz(Φ)**	**Mean(Φ)**
GERE	I	-3.14	-2.46	-3.00
GENE	I	1.44	1.40	1.40
	II	1.40	1.24	1.28
IMCI	I	-1.42	0.49	-1.63
	II	-2.91	-2.,17	-2.62
SVBE	I	-1.73	-2.00	-1.94
	II	-1.85	-2.00	-1.97

Table 5.11: Posidonia oceanica banquettes. Grain size analysis: calculated size-related parameters expressed in phi units (Φ) for sampled site and levels. GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; SVBE = Savona Bergeggi.

Site	**Level**	**Deviation**	**Skewness**	**Kurtosis**
GERE	I	1.48	0.41	1.38
GENE	I	0.44	-0.08	1.11
	II	0.66	-0.20	1.24
IMCI	I	1.09	0.08	1.58
	II	1.48	0.33	1.15
SVBE	I	1.18	-0.04	1.47
	II	0.93	-0.02	1.17

Table 5.12: Posidonia oceanica banquettes. Grain size analysis: calculated distribution-related parameters for sampled sites and levels. GERE = Genova Recco; GENE = Genova Nervi; IMCI = Imperia Cipressa 2017; SVBE = Savona Bergeggi.

Site	Level	Gravel	Sand	Silt	Type
GERE	I	83.05	16.82	0.13	Gravelly - Sandy gravelly
GENE	I	0.76	99.19	0.05	Sandy
	II	4.26	95.51	0.22	Sandy
IMCI	I	63.69	35.88	0.44	From Sandy to Gravelly
	II	81.81	17.15	1.05	From Sandy gravelly to Gravelly
SVBE	I	87.30	14.99	0.07	Mainly Gravelly
	II	87.12	12.87	0.01	Gravelly

Table 5.13: Posidonia oceanica banquettes. Grain size analysis: sedimentary and beach classification according Folk (1970) and Jennings & Shulmeister (2002). GERE = Genova Recco; GENE = Genova Nervi; IMCI = Imperia Cipressa 2017; SVBE = Savona Bergeggi.

5.1.2 Community composition

A general overview is provided to describe features of species richness and to better explain and understand further analysis. Within 100 samples, 37 different taxa have been identified according different taxonomic levels considered reliable for the purposes of this study. Observed taxa range from four (Cipressa 2018) to a maximum of 22 for the same sampling site in the previous year. Total individual abundances range from 208 (Bergeggi) to a maximum of 1013 (Cipressa 2017). Species accumulation curve calculated with speaccum function inside R package vegan (Oksanen et al., 2017) show how the number of observed species S_{Obs} increases with sample size: species-poor communities like Recco (Fig. 5.9.a) and Cipressa (2018)(Fig. 5.5.b) show a rather quick growth leading to an early asymptote. On the other hand, Cipressa (2017)(Fig. 5.5.a) and Nervi (Fig. 5.4.b) show more even curve without reaching a true asymptote. Accumulation curve of Bergeggi (5.6.a) after a first asymptote start to growth again. The way according which these curved growth can be undestood looking at observed values coming from summary table (Tab. 5.16).

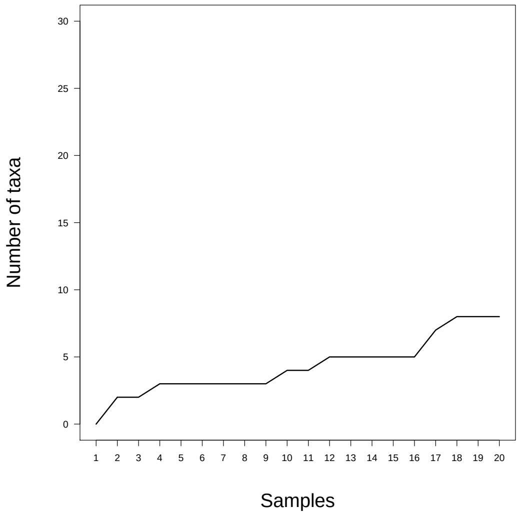

Figure 5.4.a: GERE

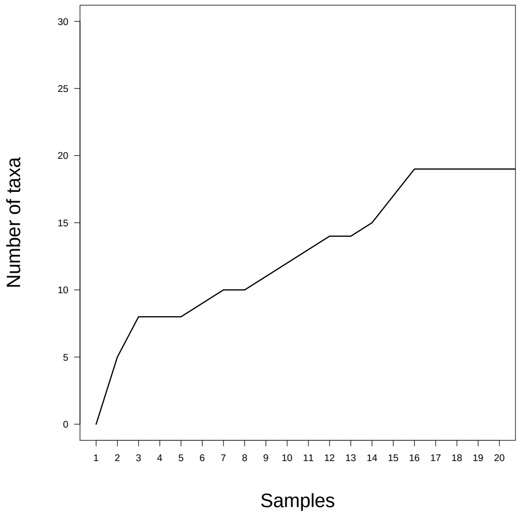

Figure 5.4.b: GENE

Figure 5.4: Posidonia oceanica banquettes. Species accumulation curves computed for Recco (GERE) and Genova Nervi (GENE) banquettes.

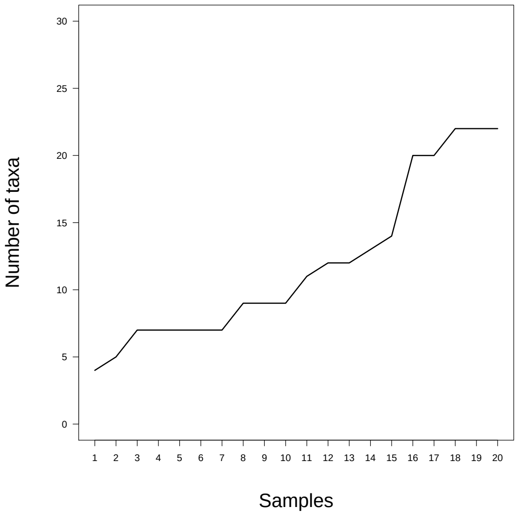

Figure 5.5.a: IMCI 2017

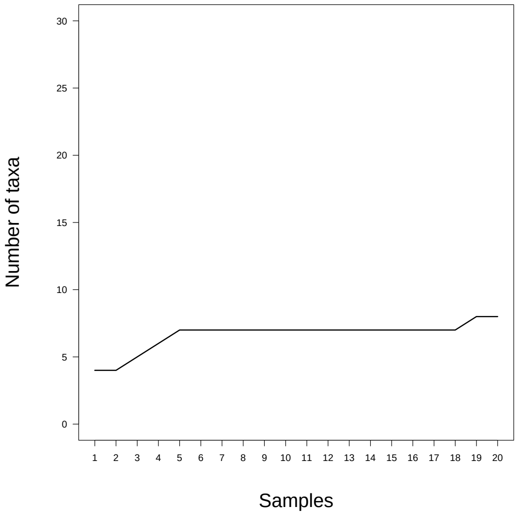

Figure 5.5.b: IMCI 2018

Figure 5.5: Posidonia oceanica banquettes. Species accumulation curves computed for Imperia Cipressa banquette in two consecutive years (IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018).

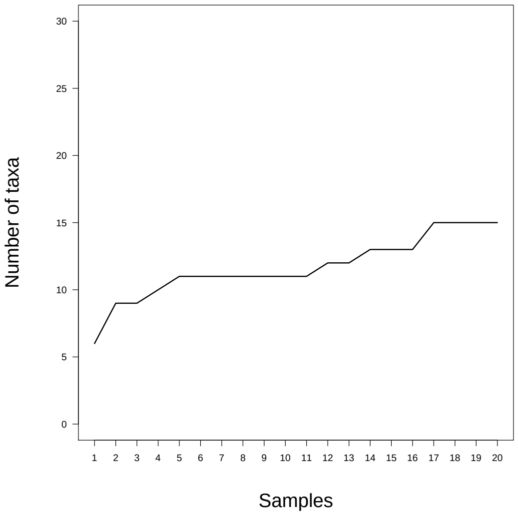

Figure 5.6.a: SVBE

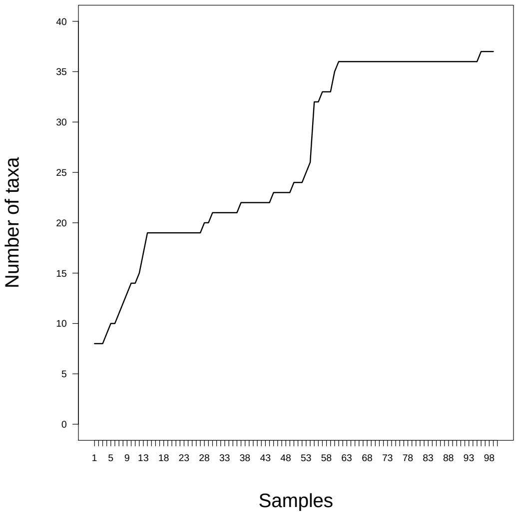

Figure 5.6.b: Total

Figure 5.6: Posidonia oceanica banquettes. Species accumulation curves computed for Bergeggi banquette (SVBE) and fol all observed samples.

5.1.3 Patterns of abundance and rarity

The number of individuals, which greatly differs among sampling sites (One-Way Anova: p-value $= 9.7 \times 10^{-11}$, $F = 17.4$ with 4 and 95 Df, Tab.5.14(b)) does not account to the same variations between site in terms of species richness (Kruskal-Wallis: $\chi^2 = 55.833$, $Df = 4$, p-val. $= 2.174 \times 10^{-11}$, Tab. 5.14). Communities closer in terms of individual abundance can include great difference within observed species: Recco and Nervi are relatively close in terms of individuals (respectively 402 and 323 Tab. 5.15) but the latter sampling site hosts almost twice the species richness (Tab. 5.14). Moreover some communities (Cipressa 2017) can be charachterized by both high values of species and individual abundance. A potential factor that can be used to assess patterns in observed taxonomical richness is represented by the so called *rare species.* The comparison of the abundance of singletons and doubletons (Fig. 5.7.a) - after their conversion into percentages (Tab. 5.16 and Fig.5.7.b) - results much effective to explain what observed: most species-rich sites are usually characterized by high values of *rare species* with particular contribution of doubletons.

	GERE	GENE	IMCI 2017	SVBE
GENE	$3.6 \times 10^{-8}*$	-	-	-
IMCI 2017	$2.3 \times 10^{-5}*$	0.66	-	-
SVBE	0.64	$4.8 \times 10^{-5}*$	0.005	-
IMCI 2018	$2.9 \times 10^{-7}*$	0.79	0.79	$2.2 \times 10^{-4}*$

Table 5.14: Posidonia oceanica banquettes. Post-Hoc pairwise comparison for observed species (S_{Obs}) between sampling sites (= significative p-value). GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.*

	GERE	GENE	IMCI 2017	SVBE
GENE	0.94	-	-	-
IMCI 2017	$2.64 \times 10^{-7}*$	$7.73 \times 10^{-9}*$	-	-
SVBE	0.94	0.55	$6.73 \times 10^{-6}*$	-
IMCI 2018	0.74	0.99	$1.43 \times 10^{-9}*$	0.29

Table 5.15: Posidonia oceanica banquettes. Post-Hoc pairwise comparison for the number of individuals (Ind., b) between sampling sites (= significative p-value). GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.*

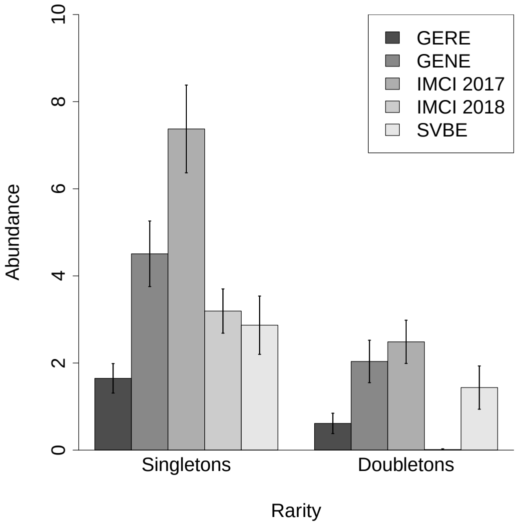

Figure 5.7.a: Mean values

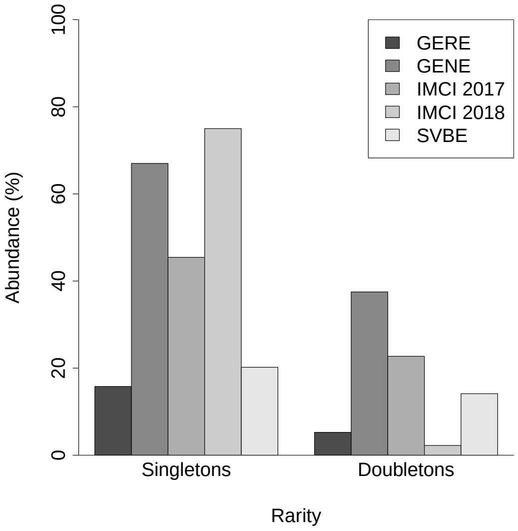

Figure 5.7.b: Percentage

Figure 5.7: Posidonia oceanica banquettes. Mean values (a) and percentage (b) of rare species (singletons and doubletons) for each investigated site. GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.

5.1.4 Asymptoctic richness estimation

Data obtained from Estimates have been used for comparison within and between sampling sites. For each site, six non parametric asymptotic richness estimator, - two abundance based (Chao 1 and ACE) - and four incidence based (Chao 2, Jackk 1, Jackk 2 and ICE)- were considered and analyzed (Fig. 5.9.a). Moreover an overall estimation of the banquettes fauna is provided to better describe sampling effort. For every sampling site, species richness is generally underestimated (Tab. 5.16): to make comparisons as meaningful as possible estimated species richness have been tested within same class estimators (e.g Chao 1 and ACE) to avoid any error yielded by the formulation of the estimator.

Both Jackkinfe estimators (Figg. 5.9.a and 5.9.b) show a true asymptotical shape only for the site of Bergeggi. Nervi and Cipressa (2017) reach the same trend only within the second order estimator, which includes also doubletons in its formulation. Thus, Jackk 1 and Jackk 2 assess a satisfying sampling effort to describe taxonomic richness within these three sites. Recco and Cipressa (2018) show a rather linear trend, indicating that these communities can potentially account for a major species richness increasing the sampling effort. Both Chao1 and Chao 2 (Figg. 5.10.a and 5.10.b) indicate an adequate sampling effort to characterize Bergeggi, Nervi and Cipressa (2017), while a less clear trend is depicted by Recco and Cipressa (2018). Because of the number of doubletons (Tab. 5.15), Bergeggi reaches quite soon the asymptote within Chao 2 (Fig. 5.10.b) performance, while other sites show a more conservative trend. Finally, the two coverage-based estimators (Figg. 5.11.a and (5.11.b) perform very closely in the estimation process (5.16). The weird behaviour of the ICE for some sites can be related to the discrimination between common and uncommon species within the estimation process.

	GERE	**GENE**	**IMCI 2017**	**SVBE**	**IMCI 2018**	**IMCI**	**Total**
Individuals	402	323	1013	280	477	1490	2495
Singletons	3	5.36	10	3.03	6	11.01	10.5
Singletons (%)	20.60	23.73	33.52	19.12	39.91	42.35	28.38
Doubletons	1	3	5	2.12	0.18	6	10
Doubletons (%)	7.66	10.71	11.30	9.57	0.16	23.07	27.02
Samples	20	20	20	20	20	40	100
S_{obs}	8	19	22	15	8	26	37
Chao 1	12.49	26.53	36.16	18.68	22.97	42.97	42.99
Chao 2	17.50	26.75	44.09	18.84	22.25	49.54	52.90
ACE	11.69	23.20	43.14	16.58	22.97	49.67	47.89
ICE	19.95	25.88	43.58	22.05	24.00	46.83	51.1
Jack 1	12.75	24.70	32.45	18.02	13.70	35.70	44.83
Jack 2	17.25	26.78	38.09	19.08	19.10	41.55	49.52

Table 5.16: Posidonia oceanica banquettes. Individuals, singletons, doubletons, reference sample, observed species (S_{obs}) and estimated species richness according six asymptotic estimators. GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi; Total = overall estimated species richness.

	GERE			**GENE**			**IMCI 2017**			**SVBE**			**IMCI 2018**		
	Obs.	Est.	%	Obs.	Est.	%	Obs.	Est.	%	Obs.	Est.	%	Obs.	Est.	%
Chao 1	8	12.49	64.05	19	26.53	71.62	22	36.16	60.84	15	18.68	80.30	8	22.97	34.82
Chao 2	8	17.50	45.71	19	26.75	71.02	22	44.09	49.90	15	18.84	79.62	8	22.25	35.95
ACE	8	11.69	68,43	19	23.20	81.90	22	43.14	51,00	15	16.58	90.47	8	22.97	34.82
ICE	8	19.95	40.10	19	25.88	73.41	22	43.58	50,48	15	22.05	68.03	8	24.00	33.33
Jack 1	8	12.75	62,75	19	24.70	76.92	22	32.45	67,80	15	18.02	83.24	8	13.70	58.39
Jack 2	8	17.25	46,38	19	26.78	70.95	22	38.09	57.76	15	19.08	78.62	8	19.10	41.88

Table 5.17: Posidonia oceanica banquettes. Number of the recorded species (Obs), estimated (Est.), and percentage (%) of the estimated richnessvalues for Recco (GERE), Nervi (GENE), Imperia Cipressa 2017 and 2018 (IMCI 2017 and IMCI 2018) and Bergeggi (SVBE).

	Total		
	Obs.	Est.	%
Chao 1	37	42.99	86.06
Chao 2	37	52.90	69.94
ACE	37	47.89	81.90
ICE	37	51.10	77.26
Jack 1	37	44.83	82.53
Jack 2	37	49.52	74.72

Table 5.18: Posidonia oceanica banquettes. Number of the species recorded (Obs), estimated (Est.), and percentage (%) of the estimated value for fhe whole investigated area (Total)

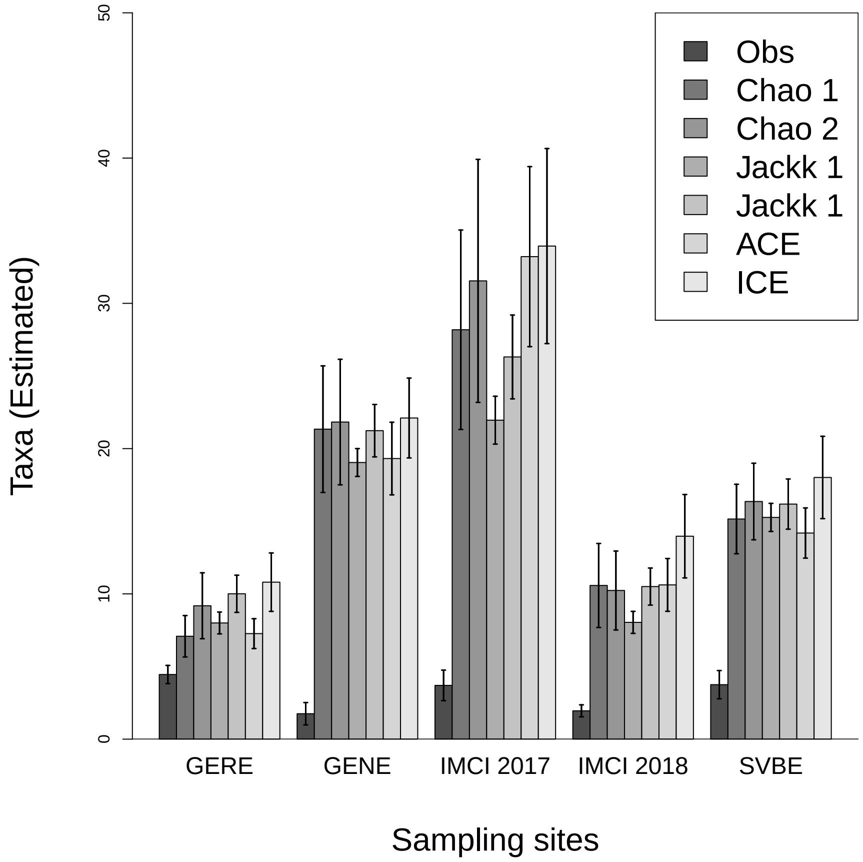

Figure 5.8: Posidonia oceanica banquettes. Asymptotic richness estimation: mean values and standard deviations for observed (S_{Obs}) and estimated taxonomic richness for each sampling site. GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.

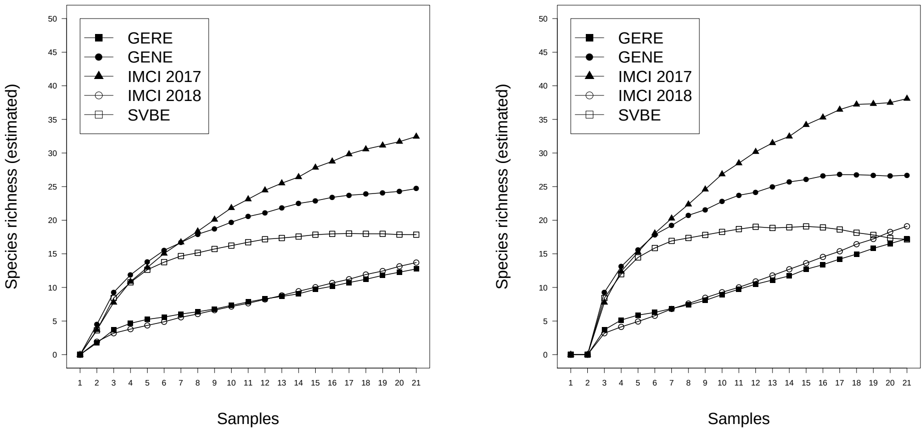

Figure 5.9.a: Jackk 1

Figure 5.9.b: Jackk 2

Figure 5.9: Posidonia oceanica banquettes. Asymptotic richness estimation: first (a) and second order Jackknife (b) for each sampled sites. GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.

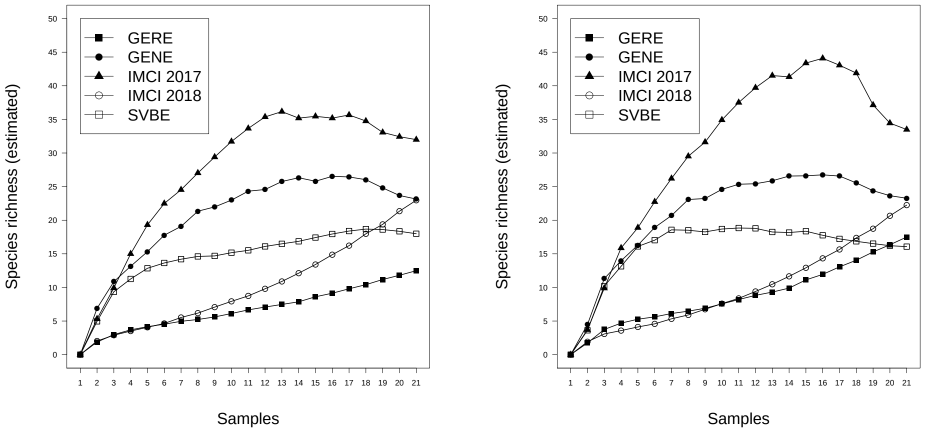

Figure 5.10.a: Chao 1 Figure 5.10.b: Chao 2

Figure 5.10: Posidonia oceanica banquettes. Asymptotic richness estimation: Chao estimators for abundance (a) and incidence data (b). GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.

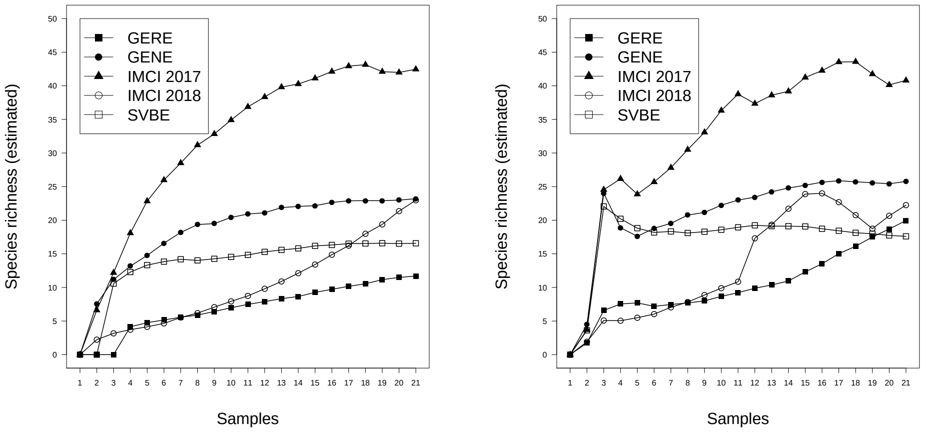

Figure 5.11.a: ACE

Figure 5.11.b: ICE

Figure 5.11: Posidonia oceanica banquettes. Asymptotic richness estimation: abundance (a) and incidence (b) based coverage estimators. GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.

Asymptotic estimation within site

To test differences within each site according to the framework provided in section 5.1.4 two non-paramteric tests have been used, Wilcoxon Mann-Whitney for abundance-based estimators and Kruskal-Wallis tests (Bonferroni continuity correction) for incidence-based estimator. Whenever the non-parametric ANOVA gave overall significative values ($\alpha = 0.05$), pairwise comparison according to Nemenyi test (Pohlert, 2014) was performed. ACE and Chao 1 don't differ in terms of estimated species richness for the banquette community of Recco (Chao 1 - ACE: W = 184, p-val. = 0.675). The omnibus test for incidence-based estimators for surveys carryed out in Recco and Nervi shows no significative values ($\chi^2 = 4.275$, df = 3, p-val. = 0.2333; Nervi $\chi^2 = 7.3834$, df = 3, p-val. = 0.0606). Different informations come from the estimation performed in Nervi and Cipressa (2017 survey) by abundance based estimators (Nervi: W = 278.5, p-value = 0.03485; Cipressa W = 123 p-value = 0.0385): the coverage-based show different - respectively lower (5.12.a) and higher (5.12.b)- values. In estimated species this is probably related to different community compostion in term of *weight* that some species have. Nemenyi test for Cipressa (2017 season) shows differences within estimations (Tab. 5.21(a), Fig. 5.13): while Chao 2 accounts for singletons and doubletons, leading to a greater species richness estimation, first order Jackknife in its original formulation relies its estimation only on singletons. ICE is more related to the coverage concept that include all the sampled community (not just singletons) and thus gives a slightly high estimation in terms of species richness. Asymptotic estimation in Aregai di Cipressa (2018 sampling session) shows no differences in estimated values between Chao 1 and ACE (W = 197.5, p-val. = 0.9568), as well as between incidence based estimators ($\chi^2 = 6.2896$, df = 3, p-val. = 0.0983) and this is probably due to the poor observed diversity. Within

Bergeggi banquette investigation, Kruskal-Wallis post hoc shows some significative differences (Tab. 5.21 (b)) among estimated values since the community, rather poor in terms of abundance, features several singletons.

	Chao 2	**Jack 1**	**Jack 2**
Jacck 1	0.0086$*$	-	-
Jacck 2	0.31	0.48	-
ICE	0.93	0.0009$*$	0.0868

a) IMCI 2017.

	Chao 2	**Jack 1**	**Jack 2**
Jacck 1	0.399	-	-
Jacck 2	0.955	0.159	-
ICE	0.024$*$	$6.5 \times 10^{-5}*$	0.095

b) SVBE.

Table 5.21: Posidonia oceanica banquettes. Estimated richness: pairwise comparison within sampling sites of Cipressa 2017 (IMCI 2017, a) and Bergeggi (SVBE, b) (= significative p-value).*

Asymptotic estimation between sites

Between-sites comparison allow to infer the overall estimated richness better than a single or a class of estimators. Even if for all estimators Kruskal-Wallis test shows significative differences (Tab. 5.22) in evaluating species richness between sites, the contribution to the overall difference coming from site is not even: pairwise comparison after Nemeny shows for all estimators closer values of species richness for Nervi and Cipressa (2017) communities (Tab. 5.28) as well for Recco and Bergeggi (Tab. 5.28) and finally between Cipressa 2018

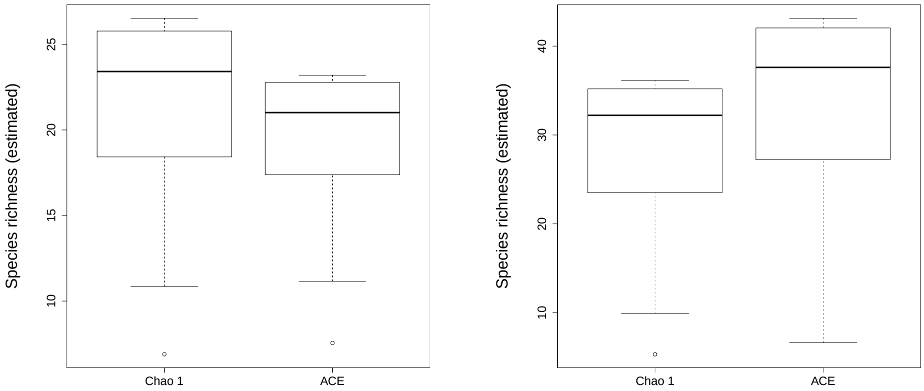

Figure 5.12.a: Nervi

Figure 5.12.b: Cipressa 2017

Figure 5.12: Posidonia oceanica banquettes. Asymptotic richness estimation. Abundance-based estimators (Chao 1 and ACE) for the sites of Nervi and Cipressa (2017).

and Nervi (Tab. 5.28). In comparing estimated species richness within the same site of Cipressa in two following years all estimators highlight significant differences with the exception of first and second order Jackknife (Jackk 1: p-val. = 0.26, Jackk 2: p-val. = 0.08): this last observation can be answered according to the formulation of the two estimators and the relatively high percentage of singletons in the second site (individual abundance Cipressa 2017 = 1013; Cipressa 2018 = 477).

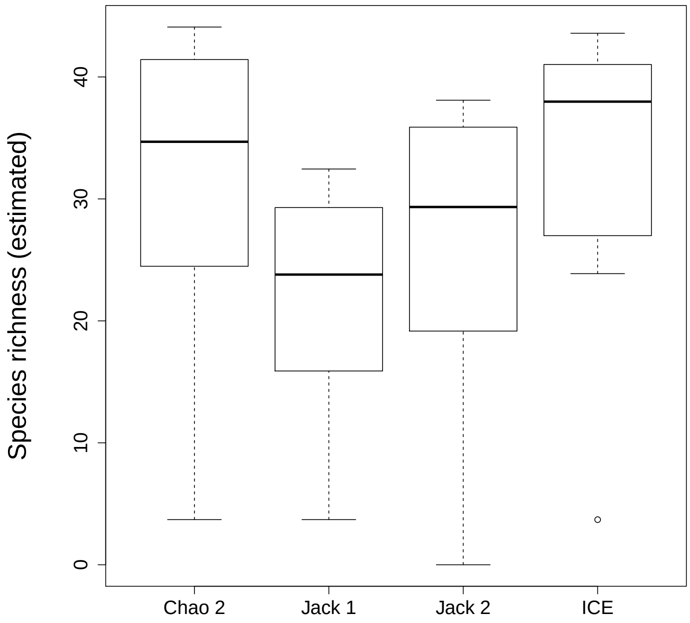

Figure 5.13: Posidonia oceanica banquettes. Asymptotic richness estimation. Incidence-based estimation for the site of Imperia Cipressa (2017 survey).

Estimator	χ^2	Df	$p - val.$
Chao 1	59.27	4	$4.12 \times 10^{-12}*$
Chao 2	55.10	4	$3.10 \times 10^{-11}*$
Jacck 1	54.74	4	$3.68 \times 10^{-11}*$
Jacck 2	47.41	4	$1.26 \times 10^{-9}*$
ACE	61.52	4	$1.39 \times 10^{-12}*$
ICE	58.61	4	$5.69 \times 10^{-12}*$

Table 5.22: Posidonia oceanica banquettes. Asymptotic richness estimation: differences of estimated richness between sites(= significative p-value).*

	GERE	**GENE**	**IMCI 2017**	**SVBE**
GENE	$1.34 \times 10^{-6}*$	$-$	$-$	$-$
IMCI 2017	$3.48 \times 10^{-10}*$	6.59×10^{-1}	$-$	$-$
SVBE	6.59×10^{-1}	$8.38 \times 10^{-4}*$	$1,34 \times 10^{-6}*$	$-$
IMCI 2018	$1.11 \times 10^{-2}*$	2.43×10^{-1}	$6.05 \times 10^{-3}*$	3.32×10^{-1}

Table 5.23: Posidonia oceanica banquettes. Asymptotic richness estimation: Chao 1 estimation post-hoc pairwise comparison between sites (= significative p-value). GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.*

	GERE	**GENE**	**IMCI 2017**	**SVBE**
GENE	$2.33 \times 10^{-5}*$	–	–	–
IMCI 2017	$1.72 \times 10^{-8}*$	6.90×10^{-1}	–	–
SVBE	9.93×10^{-1}	$1.70 \times 10^{-4}*$	$2,17 \times 10^{-7}*$	–
IMCI 2018	$4.60 \times 10^{-2}*$	2.85×10^{-1}	$9.67 \times 10^{-3}*$	1.35×10^{-1}

Table 5.24: Posidonia oceanica banquettes. Asymptotic richness estimation: Chao 2 estimation post-hoc pairwise comparison between sites (= significative p-value). GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.*

	GERE	**GENE**	**IMCI 2017**	**SVBE**
GENE	$9.51 \times 10^{-6}*$	–	–	–
IMCI 2017	$4.94 \times 10^{-7}*$	9.82×10^{-1}	–	–
SVBE	1.00	$1.11 \times 10^{-5}*$	$5,85 \times 10^{-7}*$	–
IMCI 2018	$5.14 \times 10^{-3}*$	5.94×10^{-1}	2.63×10^{-1}	5.71×10^{-3}

Table 5.25: Posidonia oceanica banquettes. Asymptotic richness estimation: First order Jackknife estimation post-Hoc pairwise comparison sites (= significative p-value). GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.*

	GERE	**GENE**	**IMCI 2017**	**SVBE**
GENE	$4.44 \times 10^{-5}*$	–	–	–
IMCI 2017	$7.34 \times 10^{-7}*$	9.32×10^{-1}	–	–
SVBE	9.98×10^{-1}	$1.92 \times 10^{-4}*$	$4,09 \times 10^{-6}*$	–
IMCI 2018	$3.71 \times 10^{-2}*$	4.02×10^{-1}	8.04×10^{-2}	8.72×10^{-2}

Table 5.26: Posidonia oceanica banquettes. Asymptotic richness estimation: Second order Jackknife estimation post-hoc pairwise comparison between sites (= significative p-value). GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.*

	GERE	**GENE**	**IMCI 2017**	**SVBE**
GENE	$4.72 \times 10^{-6}*$	–	–	–
IMCI 2017	$4.30 \times 10^{-11}*$	3.22×10^{-1}	–	–
SVBE	6.33×10^{-1}	$2.50 \times 10^{-3}*$	$3.11 \times 10^{-7}*$	–
IMCI 2018	$1.95 \times 10^{-2}*$	2.72×10^{-1}	$1.00 \times 10^{-3}*$	4.61×10^{-1}

Table 5.27: Posidonia oceanica banquettes. Asymptotic richness estimation: ACE estimation post-hoc pairwise comparison between sites (= significative p-value). GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.*

	GERE	**GENE**	**IMCI 2017**	**SVBE**
GENE	$4.21 \times 10^{-5}*$	–	–	–
IMCI 2017	$8.89 \times 10^{-11}*$	1.70×10^{-1}	–	–
SVBE	6.15×10^{-1}	$1.29 \times 10^{-2}*$	$6.50 \times 10^{-7}*$	–
IMCI 2018	1.79×10^{-1}	1.17×10^{-1}	$3.75 \times 10^{-5}*$	9.36×10^{-1}

Table 5.28: Posidonia oceanica banquettes. Asymptotic richness estimation: ICE estimation post-hoc pairwise comparison between sites (= significative p-value). GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.*

5.1.5 Untangling diversity

Diversity indices

Three of the most used indices within community studies provide a good overview of the arthropods communities (Fig. 5.14): the lowest value of the Shannon index has been calculated for the upper layer of Imperia Recco while the highest belong to the upper layer of Nervi (Tab. 5.29). Similarly, the samples of the upper layer of Recco account for the lowest Simpson index while the highest values are reached by the upper Layer of Nervi (Tab. 5.29). Finally the minimum evenness has been observed by the upper layer of Recco (Tab. 5.31). More interesting is the comparison of the three indices between sites and levels. Scheirer-Ray-Hare test shows that values of all three indices (Tab. 5.32 a–c) do not vary significantly within the same site, but only between sites.

Species Composition

Despite the goodness of the representation (Fig. 5.15.b), condisering just two dimensions, NMDS obtained from community data (Jaccard distance) does not highlight clear differences neither between sites (5.15.a) nor between levels. The relative proximity of most of the points (Samples) indicates rather similar assemblages which explain the overlapping hulls. Only few samples coming from different sites are relatively far from each other. Nevertheless One-Way Anosim ran with the same metric of non metric-MDS give a significative p-val. but weak R^2 values (p-val. = 0.001 $R^2 = 0.20$) seems to confirm what previously observed in the previous ordination. After the removal of most ubiquitarious taxa such as Acarina Mesositgmata, Oribatida and Collembola, the Simper analysis enligths potential taxa which account for significant differences between sites: the cumulative contribution (CC) of each taxon to global

Site	**Level**	**Shannon (H')**			
		Min	**Max**	**Mean**	**sd**
GERE	I	0.98	0.64	0.33	0.23
	II	0.35	1.06	0.78	0.28
GENE	I	0.43	1.86	1.11	0.48
	II	0.36	1.63	1.15	0.33
IMCI 2017	I	0.32	1.44	0.77	0.34
	II	0.22	0.92	0.58	0.27
IMCI 2018	I	0.28	0.87	0.63	0.18
	II	0.41	0.64	0.53	0.08
SVBE	I	0.41	1.55	1.01	0.31
	II	0.56	1.56	1.04	0.36

Table 5.29: Posidonia oceanica banquettes. Shannon index (H'): Calculated minimum, maximum, mean and sd for each sampled layer. GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.

diversity has been reported together with its p-values (from Tab.1 to Tab.9).

Modelling diversity

For each diversity index, two groups of global models have been formulated. Since Spearmans rank correlation coefficient for wind speed and rain indicated rather strong negative correlation (Spearmann Rho = -0.93, $p < 0.0001$), these two variables have not been included in the same global model build process. The indices (H', D and J') have been modelled as response of 4 habitat-related variables (pH, T, DSL and Mz) and 4 environmental variables (Diurnal range, Wind speed, monthly maximum temperature and Rain). From these global

Site	**Level**	**Simpson (^2D)**			
		Min	**Max**	**Mean**	**sd**
GERE	I	1.041	1.800	1.306	0.34
	II	1.246	2.782	2.023	0.53
GENE	I	1.207	5.233	2.943	1.42
	II	1.254	4.500	2.812	0.94
IMCI 2017	I	1.170	3.368	1.894	0.68
	II	1.125	2.189	1.499	0.34
IMCI 2018	I	1.135	2.174	1.758	0.36
	II	1.324	1.800	1.559	0.17
SVBE	I	1.324	3.206	2.257	0.64
	II	1.600	4.500	2.694	1.09

Table 5.30: Posidonia oceanica banquettes. Simpson index (D). Calculated minimum, maximum, mean and sd for each sampled layer. GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.

models, 127 nested candidates models have been built. Since models with a $\Delta AICc > 2$ show substantial differences (Burnham & Anderson, 2014), only few models for each index fall into the $\Delta AICc < 2$ range (Tab. 5.43 and 5.45 for Shannon (H') and Tab. 5.44 and 5.46 for Simpson). Following model averaging consists in making inference based on the whole set of candidate models, instead of basing conclusions on a single model, allowing to make more robust inference based on the information contained in the entire model set. Since low R^2 values can be effectively uninformative, Shannon wind-related model, wind-related Simpson model and both models involving Pielou evenness (J') have been discarded (Shannon Wind: 0.40, Simpson- Rain related

Site	**Level**	**Pielou (J')**			
		Min	**Max**	**Mean**	**sd**
GERE	I	0.1414	0.9183	0.4529	0.36
	II	0.5033	1.0000	0.7799	0.19
GENE	I	0.2645	1.0000	0.9179	0.22
	II	0.5127	0.9602	0.7859	0.17
IMCI 2017	I	0.2749	0.8292	0.5949	0.20
	II	0.2408	0.6647	0.4684	0.13
IMCI 2018	I	0.2522	0.9940	0.6989	0.24
	II	0.5917	0.9183	0.7706	0.11
SVBE	I	0.4338	0.9464	0.7042	0.15
	II	0.6784	0.9697	0.8422	0.09

Table 5.31: Posidonia oceanica banquettes. Pielou's evenness (J'). Calculated minimum, maximum, mean and sd for each sampled layer. GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.

= 0.39, Evenness Wind: 0.20, Evenness Rain: 0.26). Shannon model (Tab. 5.47) shows that within micro-environmental variables, both pH and grains size have a significant influence on the estimated parameters, while rainfall is the only climatic variable with significant coefficient. Dominance index models related to rainfall ($R^2 = 0.40$) show overall significant values for all variables with particular attetion to Rainfall and pH (Tab. 5.48).

Factor	**Shannon (H')**		**Simpson (D)**		**Pielou (J)**	
	χ^2	**p-val.**	χ^2	**p-val.**	χ^2	**p-val.**
Site	27.00	$1.98 \times 10^{-5}*$	23.67	$9.30 \times 10^{-5}*$	17.20	$1.73 \times 10^{-3}*$
Level	0.02	0.89	0.02	0.90	1.08	0.30
Site*Level	4.43	0.35	3.34	0.50	7.98	0.09

Table 5.32: Posidonia oceanica banquettes.Scheirer-Ray-Hare test. Differences in calculated indices for Site (five levels) and Level (two level) and their interaction. (= significative p-value).*

Taxa	**CC**	**p-val.**
Anthomyiidae larvae	0.172	0.63
Plagiolepis sp.	0.309	$1.99 \times 10^{-3}*$
Sphaeroceridae adults	0.378	0.33
Sciaridae adults	0.447	0.18
Coleoptera larvae	0.513	0.10
Psychodidae adults	0.570	0.06
Staphylinidae	0.623	0.99
Zygentomata	0.676	0.07
Hemiptera	0.726	0.08

Table 5.33: Posidonia oceanica banquettes. Simper: cumulative contributions (CC) and p-values of most influential species between Nervi and Recco banquettes communities (= significative p-value).*

Taxa	**CC**	**p-val.**
Anthomyiidae larvae	0.139	0.92
Coleoptera larvae	0.255	0.49
Plagiolepis sp.	0.349	$2.99 \times 10^{-3}*$
Sphaeroceridae adults	0.413	0.24
Staphylinidae	0.471	0.97
Psychodidae adults	0.520	$4.09 \times 10^{-2}*$
Sciaridae adults	0.568	0.32
Ephydridae larvae	0.616	0.22
Talitridae	0.656	0.59
Ptiliidae	0.692	0.50
Hemiptera	0.724	0.25

Table 5.34: Posidonia oceanica banquettes. Simper: cumulative contributions (CC) and p-values of most influential species between Nervi and Cipressa (2017 sampling) banquettes communities (= significative p-value).*

Taxa	**CC**	**p-val.**
Staphylinidae	0.147	$2.99 \times 10^{-3} *$
Anthomyiidae larvae	0.279	0.97
Coleoptera larvae	0.388	0.67
*Plagiolepis*sp.	0.476	$1.99 \times 10^{-3} *$
Talitridae	0.524	0.39
Sphaeroceridae adults	0.570	0.62
Sciaridae adults	0.615	0.35
Chaerea maritimus	0.660	$5.99 \times 10^{-3} *$
Psychodidae adults	0.698	0.22
Stenophiloscia glarearum	0.732	$1.69 \times 10^{-2} *$

Table 5.35: Posidonia oceanica banquettes. Simper: cumulative contributions (CC) and p-values of most influential species between Nervi and Bergeggi banquettes communities (= significative p-value).*

Taxa	**CC**	**p-val.**
Anthomyiidae larvae	0.193	0.07
*Plagiolepis*sp.	0.313	$7 \times 10^{-3} *$
Sciaridae adults	0.419	$1.89 \times 10^{-2} *$
Sphaeroceridae adults	0.525	0.06
Coleoptera larvae	0.630	0.65
Heleomyzidae adults	0.709	0.06

Table 5.36: Posidonia oceanica banquettes. Simper: cumulative contributions (CC) and p-values of most influential species between Nervi and Cipressa (2018 sampling) banquettes communities (= significative p-value).*

Taxa	**CC**	**p-val.**
Anthomyiidae larvae	0.222	$9.992 \times 10^{-3}*$
Coleoptera larvae	0.381	$0.03*$
Psocoptera	0.450	$0.01*$
Ephydridae larvae	0.515	0.10
Ptilidae	0.568	0.25
Dermestidae	0.620	0.02
Talitridae	0.667	0.48
Staphylinidae	0.713	0.98

Table 5.37: Posidonia oceanica banquettes. Simper: cumulative contributions (CC) and p-values of most influential species between Recco and Cipressa (2017 sampling) banquettes communities (= significative p-value).*

Taxa	**CC**	**p-val.**
Staphylinidae	0.211	$9.992 \times 10^{-3}*$
Anthomyiidae larvae	0.420	$7.992 \times 10^{-3}*$
Coleoptera larvae	0.555	0.08
Talitridae	0.615	0.22
Chaerea maritimus	0.669	$6.99 \times 10^{-3}*$
Ptiliidae	0.715	0.30

Table 5.38: Posidonia oceanica banquettes. Simper: cumulative contributions (CC) and p-values of most influential species between Recco and Bergeggi banquettes communities (= significative p-value).*

Taxa	**CC**	**p-val.**
Anthomyiidae larvae	0.367	$9.99 \times 10^{-4}*$
Sciaridae adults	0.477	0.02
Sphaeroceridae adults	0.586	0.07
Heleomyzidae adults	0.695	$7.992 \times 10^{-3}*$
Coleoptera larvae	0.804	0.60

Table 5.39: Posidonia oceanica banquettes. Simper: cumulative contributions (CC) and p-values of most influential species between Recco and Cipressa (2018 sampling) banquettes communities (= significative p-value).*

Taxa	**CC**	**p-val.**
Staphylinidae	0.167	$7.992 \times 10^{-3}*$
Coleoptera larvae	0.299	$0.03*$
Anthomyiidae larvae	0.425	$0.99*$
Ephydridae larvae	0.495	$1.29 \times 10^{-2}*$
Talitridae	0.566	0.10
Ptilidae	0.631	0.07
Chaerea maritimus	0.680	$3.996 \times 10^{-3}*$
Stenophiloscia glarearum	0.718	$1.99 \times 10^{-2}*$

Table 5.40: Posidonia oceanica banquettes. Simper: cumulative contributions (CC) and p-values of most influential species between Cipressa (2017 sampling) and Bergeggi banquettes communities (= significative p-value).*

Taxa	**CC**	**p-val.**
Coleoptera larvae	0.165	0.02∗
Anthomyiidae larvae	0.327	0.031
Sphaeroceridae adults	0.425	0.09
Sciaridae adults	0.500	0.12
Heleomyzidae adults	0.575	0.08
Ephydridae larvae	0.636	0.15
Ptilidae	0.687	0.28
Talitridae	0.731	0.45

Table 5.41: Posidonia oceanica banquettes. Simper: cumulative contributions (CC) and p-values of most influential species between Cipressa banquettes communities accross two consecutive years (2017 and 2018) (= significative p-value).*

Taxa	**CC**	**p-val.**
Staphylinidae larvae	0.210	1.99×10^{-3}∗
Coleoptera larvae	0.358	0.06
Anthomyiidae larvae	0.480	0.80
Sciaridae adults	0.547	0.14
Sphaeroceridae adults	0.614	0.27
Heleomyzidae adults	0.680	0.09
Talitridae	0.741	0.25

Table 5.42: Posidonia oceanica banquettes. Simper: cumulative contributions (CC) and p-values of most influential species between Bergeggi and Cipressa (2018 sampling) banquettes communities (= significative p-value).*

Int.	**N. Par.**	**df**	**logLik**	**AICc**	$\Delta AICc$	**Weight**
−13.070	6	8	−17.585	53.2	0.00	0.394
−11.000	5	7	−19.283	54.1	0.92	0.248
−11.820	5	7	−19.516	54.6	1.39	0.197
−9.972	4	6	−20.915	55.0	1.78	0.162

Table 5.43: Posidonia oceanica banquettes. Shannon index (H'): list of best models laying within two points of AICc. Int. = intercept value, N. Par = number of parameters included in the model, df = degrees of freedom, logLik = log-likelihood value, AICc = Second-order Akaike Information Criterion, Weight = Akaike weights.

Int.	**N. par.**	**df**	**logLik**	**AICc**	$\Delta AICc$	**Weight**
−25.80	5	7	−88.945	193.4	0.00	0.696
−27.18	6	8	−88.536	195.1	1.66	0.304

Table 5.44: Posidonia oceanica banquettes. Simpson index (D): List of best models laying within two points of AICc. Int. = intercept value, N. Par = number of parameters included in the model, df = degrees of freedom, logLik = log-likelihood value, AICc = Second-order Akaike Information Criterion, Weight = Akaike weights.

Int.	**Drn**	**DSL**	**pH**	**Rain**	**T. max**	**Mz**	**df**	**logLik**	**AICc**	$\Delta AICc$	**Weight**
−13.070	2.995	0.1107	2.365	1.1380	−0.8037	0.10150	8	−17.585	53.2	0.00	0.394
−11.000	1.382	0.1036	2.545	0.8416		0.08323	7	−19.283	54.1	0.92	0.248
−11.820	2.956		2.167	0.9736	−0.7442	0.08449	7	−19.516	54.6	1.39	0.197
−9.972	1.459		2.347	0.7077		0.06851	6	−20.915	55.0	1.78	0.162

Table 5.45: Posidonia oceanica banquettes. Shannon index (H') model selection table: Int. = intercept value, Drn = monthly diurnal range, DSL = distance from the swash line, Rain = monthly rainfall, T. max = monthly maximum temperature, Mz = mean grain size, df = degrees of freedom, logLik = log-likelihood, AICc = Second-order Akaike Information Criterion, Weight = Akaike weights.

Int.	**Drn**	**DSL**	**pH**	**Rain**	**T. max**	**Mz**	**df**	**logLik**	**AICc**	$\Delta AICc$	**Weight**
−25.80	6.886		5.918	2.020	−2.575	0.2032	7	−88.945	193.4	0.00	0.696
−27.18	6.928	0.1225	6.137	2.202	−2.640	0.2220	8	−88.536	195.1	1.66	0.304

Table 5.46: Posidonia oceanica banquettes. Simpson index (D) model selection table: Int. = intercept value, Drn = monthly diurnal range, DSL = distance from the swash line, Rain = monthly rainfall, T. max = monthly maximum temperature, Mz = mean grain size, df = degrees of freedom, logLik = log-likelihood, AICc = Second-order Akaike Information Criterion, Weight = Akaike weights.

Parameter	**Estimate**	**Std. Error**	**Adj. SE**	**z val.**	$Pr(>\|z\|)$
Int.	-11.81	2.90	2.94	4.02	$5.82 \times 10^{-5}*$
Drn	2.34	1.25	1.26	1.85	0.06
DSL	0.07	0.07	0.07	0.98	0.33
pH	2.37	0.67	0.68	3.50	$4.6 \times 10^{-4}*$
Rain	0.96	0.30	0.30	3.24	$4.6 \times 10^{-3}*$
T. max	-0.46	0.52	0.52	0.88	0.38
Mz	0.09	0.03	0.03	2.85	$4.35 \times 10^{-3}*$

Table 5.47: Posidonia oceanica banquettes. Shannon index (H'): full averaged model. Int. = intercept value, Drn = monthly diurnal range, DSL = distance from the swash line, Rain = monthly rainfall, T. max = monthly maximum temperature, Mz = mean grain size

Parameter	**Estimate**	**Std. Error**	**Adj. SE**	**z-val.**	$Pr(>\|z\|)$
Int.	-26.22	6.58	6.69	3.91	$8.94 \times 10^{-5}*$
Drn	6.90	2.74	2.80	2.47	$0.01*$
pH	5.98	1.57	1.60	3.75	$1.78 \times 10^{-4}*$
Rain	2.10	0.63	0.65	3.21	$1.32 \times 10^{-3}*$
T. max	-2.60	1.10	1.11	2.33	0.02
Mz	0.21	0.07	0.07	3.00	$2.74 \times 10^{-3}*$
DSL	0.03	0.09	0.10	0.38	0.7

Table 5.48: Posidonia oceanica banquettes. Simpson index (D): Full averaged model. Int. = intercept value, Drn = monthly diurnal range, DSL = distance from the swash line, Rain = monthly rainfall, T. max = monthly maximum temperature, Mz = mean grain size

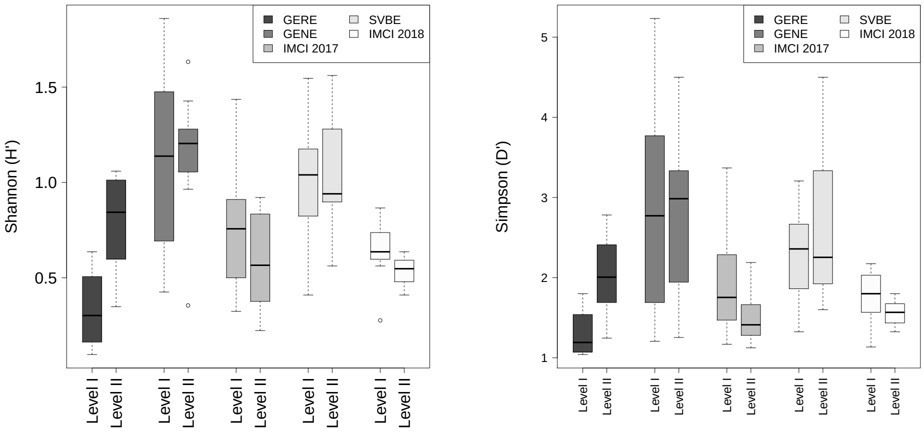

Figure 5.14.a: Shannon

Figure 5.14.b: Simpson

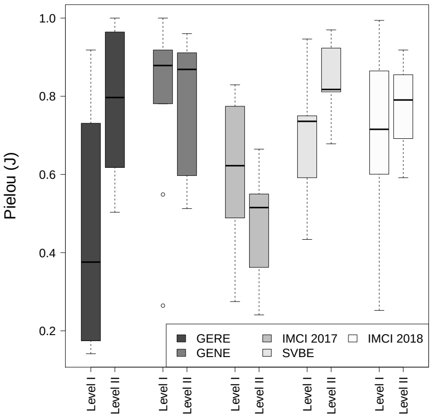

Figure 5.14.c: Pielou

Figure 5.14: Posidonia oceanica banquettes. Calculated Shannon's diversity (H'), Simpsons' dominance (D) and Pielou's evenness (J') for all sampled sites and layers

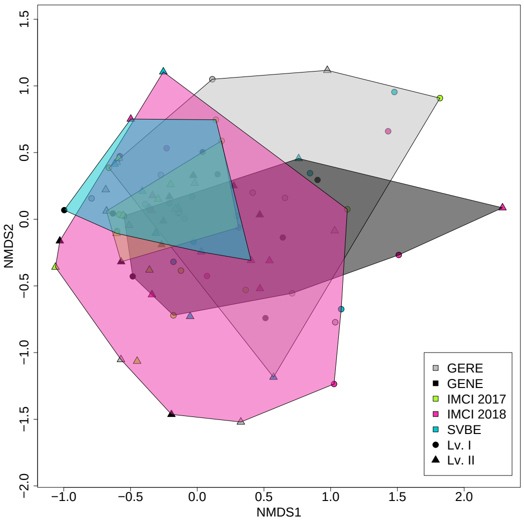

Figure 5.15.a: NMDS

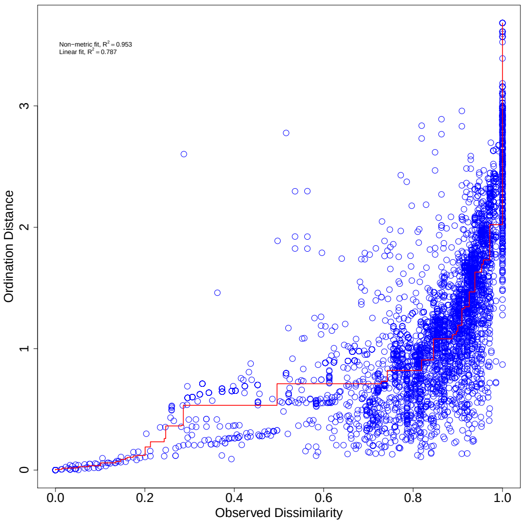

Figure 5.15.b: Stressplot

Figure 5.15: Posidonia oceanica banquettes. Non metric multidimensional scaling (NMDS, a) and stressplot (b) of investigated sites according communities composition (Jaccard dsitance). GERE = Genova Recco; GENE = Genova Nervi; IMCI 2017 = Imperia Cipressa 2017; IMCI 2018 = Imperia Cipressa 2018; SVBE = Savona Bergeggi.

5.1.6 Taxonomical characterization

ARACHNIDA: ARANEAE Clerck, 1757

DICTYNIDAE O.P.-Cambridge, 1871 The Dictynidae is a relatively rich Family of small size (1.3–8.0 mm) spiders encompassing 563 species in 48 genera. In Europe, the family is present with 78 species in 18 genera (Platnick, 2007). Among the Bergeggi *P. oceanica* samples some specimens of a smallground dwelling spider have been collected: the identification revealed to be *Chaerea maritimus* Simon (1884): the species represents a new record for the Italian fauna even if already collected along other shores of the Mediterranean Basin (Boudoresque et al., 2017). *Chaerea* is a monotypic genus created by Simon in 1884 and redefined by the same in 1892, to accommodate *C. maritimus.*

INSECTA: DIPTERA Linnaeus, 1758

Within *P. oceanica* banquettes 12 different families - three Nematocera and nine Brachycera ones - have been collected (Fig. 5.16.a and **??**). Larval instars are represented by members of Anthomyiidae, Dolichopodidae, Muscidae, Chironomidae, Coelopidae and Ephrydidae (Tab. 5.49, Fig. 5.18.a), while adults belong to Psychodidae, Heleomyzidae, Sespidae, Ephydridae, Sciaride, Sphaeroceridae and Chironomidae (Tab. 5.50, Fig. **??**) . Within the description of this group, the main challenge as pointed out by Karl and Munari (1930; 2010) is to discriminate within species that are strictly related for their life cycle to the beach environment from those that are maringally related to it. Moreover, there is an interesting observation which arise from data and it is that within *P. oceanica* banquettes most larval instars belong to the Brachycera suborder, while Nematocera are mostly represented by adults probably due to the life cycle of these animals. True flies have mostly terrestrial larvae, while Nematocera have usually a immature instar more related to water, such as Tipulidae.

- Sciaridae Billberg, 1820 are rather small Nematocera (up to 1 mm long), usually dark-coloured or yellowish, with a slender body, long legs and unmarked wings with sometimes a characteristic shaded or reduced venation. Sciaridae occur on all continental areas (except Antarctica) and on many oceanic islands with around 2,500 species and 92 genera (Zhang, 2013). The larvae are largely terrestrial but restricted mainly to wet habitats even if in some species develop in semi-aquatic habitats. Sciarid larvae generally feed on decaying plant material, animal excrements, or fungi, while the adults can be found mainly near the larval habitat.
- Psychodidae Newman, 1834 is a family of Nematocera including 2600 species, mostly distributed in the tropics (B. Peterson et al., 1981). These small Diptera are thickly haired with a characteristic short and erratic flight and rheniform eyes. Wings are usually broad, held roof-like over the abdomen at rest, marked by equally developed longitudinal veins with a conspicuous reduction or absence of the cross venulation. Psychodid larvae, mainly saprophagous, can be collected in moist environments rich in decomposing material and rather stable micro-environmental conditions. Adults are mainly nocturnal and in daytime they are found resting in shaded places. Most species are found in wooded areas near streams or marshes. Their relationship with the shoreline environments is related to their vulgar name of "sand flies" related to the larvae emergence.
- Chironomidae Newman, 1836 is a big Family consisting of about 120 genera and over 5000 species. Larvae of these Nematocera can be used as indicators of water pollution. The adults are known as harlequin flies

and often hover in swarms over streams and ponds, mostly living for only a few hours or a few days. Most of Chironomidae are terrestrial with aquatic or terrestrial larvae, but about 12 genera with 50 species are marine and restricted to intertidal zones (Hashimoto, 1976). Unlike their freshwater relatives, larvae of marine chironomids lack anal gills and prothoracic respiratory horns are absent in the pupae. In addition, the antennae, palpi and eye facets are highly reduced in the adults of most genera.

- DOLICHOPODIDAE, Latreille, 1809 or long-legged flies, are one of the largest families of Diptera, with more than 6,000 species worldwide. Dolichopodids occur in all terrestrial habitats, but generally prefer humid areas where they may be the most abundant family of Diptera (Pollet, Brooks, & Cumming, 2004). Truly aquatic species are not decribed but many are semi-aquatic; only a restricted number of species is able to carry over their life-cycles at the shores of saline inland bodies or in intertidal zone along seashores. The larvae usually prey on small invertebrates in soil and rotting organic matter. Larva is usually whitish, cylindrical, slightly tapered anteriorly. Head segment are rather short, unsclerotized externally, with four lobes. Internal sclerotized part - including mandibular-maxillary sclerites - are brown to black in color. The posterior surface of the terminal segment crossed with a vertical and a horizontal furrow delimiting four or more fleshing lobes giving a truncated and clubby appearance, is one of the most common features of these Diptera. Within this study only immature instars have been collected.
- SEPSIDAE Walker, 1833. The Sepsidae is a well-founded monophyletic family of acalyptrate flies; the European fauna comprises nine genera with 44 species (Pont & Meier, 2002). Despite the small amount of spe-

cies, Sepsidae are among the most common acalyptrate flies in Europe. The adults - slender, ant-like flies with relatively few bristles or hairs (Oosterbroek, 2006) - are generally observed near the larval habitats, usually in somewhat open habitats: the only common feature is that they have to contain decaying organic material. Adult sepsids are indeed dependent on the availability of two kinds of food: the females of at least most species are incapable of producing eggs without first feeding on decaying organic material for several days. The second kind of food required is carbohydrates, usually obtained from flowers as well as from rotting fruits, trees and sap.

- HELEOMYZIDAE Westwood 1840 include small to large species of acalyptrate, largely variable in color between dark yellow, to ochre and grey in colour: 145 species are known to occur in Europe and adjacent areas according to Fauna Europaea (Pape et al., 2015). Most remarkable feautres of these flies are wings with costa spinose and interrupted near junction with subcosta and dorsal preapical seta present on tibiae (Oosterbroek, 2006). It is difficult to make any general statements about the biology of Heleomyzidae, because they show a remarkable variety of habits (Giudice & Woźnica, 2013): members of this family have various trophic habits, mostly related to decaying materials of both animal and vegetal origin, even if several species are phytophagous.
- COELOPIDAE Hendel, 1910 is a family of acalyptrate Diptera. Larva is typical of saprophagous Muscomorpha, elongate, tapering anteriorly and subtruncate posteriorly. Body surface appears rather smooth, except for several rows of small spines, ventrally near segmental margins. The cephalopharyngeal skeleton carries mandibles evolved in form of simple hooks. Adults are robust flies from black to grayish in color with a

slightly to strongly flattened thoracic dorsum. One of the most distinguishable features is represented by the face profile, strongly concave and uniformly sclerotized as in many flies previously classified as Cyclorrhapha. Thorax elements such as postpronotum and scutum are usually densely covered with many fine or setose hairs. Members of this family have hind tibiae with long dorsal preapical bristles, while fore tibia is without apical bristles. Coelopidae generally inhabit coastal habitats, but only a few species are specialized to live and breed (larva in particular) exclusively on the beach, where the larvae develop in vegetal necromasses washed up by the sea. Larvae and adults can be found throughout the year in the same habitats.

- SPHAEROCERIDAE Macquart, 1835 is a Family of Acaplyptrate flies easily recognizable by the short thick first tarsomere of the hindleg (B. Peterson et al., 1987), dark in color, and sometimes with brown legs and head. The World Sphaeroceridae are represented by 1,339 valid species in 111 genera (Roháček et al., 2001). Although they are sometimes called small dung flies, dung is only one of many habitats occupied by these Diptera. The larvae live in a wide range of rotting organic materials and presumably feed on micro-organisms and leaf litter but some species can be associated to organic matter washed up on the shore as well as rotting vegetable matter. In this family, wing reduction is not uncommon, with some apterous species (Oosterbroek, 2006). Thus, adults are rather mediocre fliers. They can be found on decaying matter of plant and animal origin.
- EPHYDRIDAE Zetterstedt, 1837 is one of the largest taxa within the acalyptrate Diptera, with some 1,700 species and 115 genera recorded in the world fauna (Zatwarnicki, 1992; Foote, 1995). This family shows

broad ecological tolerances and is commonly encountered in physiologically stressful marine environments, such as rocky shores, sandy beaches, estuarian and tidal marshes, and mangrove swamps, hence the common names "shore flies" and "brine flies". Larvae can range from dorsoventrally flattened to cylindrical, body shape with up to eight pairs of abdominal prolegs. One of the most interesting structures are the respiratory tubes bearing terminal spiracles and sometimes accessory filaments which represent a typical adaptation to improve breathing processes in stressful environments. Mandibles are not joined together behind mouth opening. The adults are small or minute in size (1–16 mm), dull and dark in color, with prominent face and gaping mouth. These Diptera are generally semi-aquatic, living on or near the larval habitat where they walk about on the surface of the mud or water or climb on low, emergent vegetation. Feeding processes are quite similar between larva and imago. Immature exploit the abundant microflora of diatoms and other algae, decomposing plant material, and detritus; adults are known to feed on such microscopic resources with their broad mouthparts efficiently evolved to gather microorganisms from flat, open surfaces.

- ANTHOMYIIDAE Robineau-Desvoidy 1830 family has been collected with several immature specimens within samplig sites. Larvae are typical Muscidiform (maggots) slender, smooth, ornated by a fine cuticular granulations and sparse patches of fine spicules. The anal end is subtruncate. These acephalic larvas posses a generalized cephalopharyngeal skeleton of saprophagous form, bearing simple, usually short and weakly curved mandibles. Anterior spiracles carry few to many papillae while posterior one are situated slightly dorsal to the center of spiracular disc: each spiracle have three circular, short or long oval, or linear spiracular openings (in the last larval instar) that radiate outward from a slight marginal ecdysial scar. The family is world wide distributed but it is best represented in the Temperate Zones of the Holarctic region. The larvae are mostly phytophagous or saprophagous. Some are scavengers or coprophagists, living in droppings of animals and birds. Others are found on the seashore feeding on wracks such as *Fucellia* sp.

- MUSCIDAE Latreille 1802 is a wide Calpyptrate Diptera family accounting for around 575 species enclosed in 45 genera within the European region (Oosterbroek, 2006). Larvae have usually a subcylindrical shape, tapered anteriorly, with cuticular thickenings. Posterior spiracles of the last larval stage are represented by three openings - more or less sinuate - located on a truncate anal segment and arranged in an arc around a clearly visible ecdysial scar; anterior spiracles are palmate. Mandibles are usually fused or appressed, dental sclerites at base of mandible separate or fused. Larvae of this family occur in many habitats such as decaying vegetation of many kinds, from fruit to logs. Larval food is known for rather few species; most of them are apparently coprophagous or saprophagous, or either facultative or obligate predators of insects larvae or other invertebrates (B. Peterson et al., 1987).

Site	**Date**	**Family**	**Abundance**
GENE	2016 XI 18	Chironomidae Newman, 1836	1
GENE	2016 XI 18	Anthomyiidae Robineau-Desvoidy 1830	77
GENE	2016 XII 02	Chironomidae Newman, 1836	2
GENE	2016 XII 02	Anthomyiidae Robineau-Desvoidy 1830	2
IMCI	2017 III 15	Anthomyiidae Robineau-Desvoidy 1830	8
GERE	2017 III 16	Anthomyiidae Robineau-Desvoidy 1830	33
IMCI	2017 IV 13	Anthomyiidae Robineau-Desvoidy 1830	3
IMCI	2017 IV 13	Ephydridae Zetterstedt, 1837	4
IMCI	2017 IV 13	Dolichopodidae Latreille, 1809	2
IMCI	2017 IV 13	Muscidae Latreille 1802	1
SVBE	2017 XI 29	Ephydridae Zetterstedt, 1837	2
SVBE	2018 II 21	Anthomyiidae Robineau-Desvoidy 1830	9
SVBE	2018 II 21	Ephydridae Zetterstedt, 1837	2
SVBE	2018 II 21	Coleopidae Hendel, 1910	1

Table 5.49: Posidonia oceanica banquettes. Diptera families (larval stage) collected among all investigated banquettes. GERE = Genova Recco; GENE = Genova Nervi; IMCI = Imperia Cipressa; SVBE = Savona Bergeggi.

Site	**Date**	**Family**	**Abundance**
GENE	2016 XI 18	*Sciaride Billberg, 1820*	6
GENE	2016 XI 18	*Sphaeroceridae Macquart, 1835*	2
GENE	2016 XI 18	*Psychodidae Newman, 1834*	2
GENE	2016 XI 18	*Heleomyzidae Westwood 1840*	1
GENE	2016 XII 02	*Sphaeroceridae Macquart, 1835*	3
GENE	2016 XII 02	*Psychodidae Newman, 1834*	3
GENE	2016 XII 02	*Sespidae Walker, 1833*	1
IMCI	2017 III 15	*Sphaeroceridae Macquart, 1835*	1
IMCI	2017 III 15	*Chironomidae Newman, 1836*	1
IMCI	2017 IV 13	*Canacidae Jones, 1906*	2
IMCI	2017 IV 13	*Ephydridae Zetterstedt, 1837*	1
IMCI	2018 I 31	*Sciaride Billberg, 1820*	1
IMCI	2018 I 31	*Heleomyzidae Westwood 1840*	1

Table 5.50: Posidonia oceanica banquettes. Diptera families (adult stage) collected among all investigated banquettes. GENE = Genova Nervi; IMCI = Imperia Cipressa.

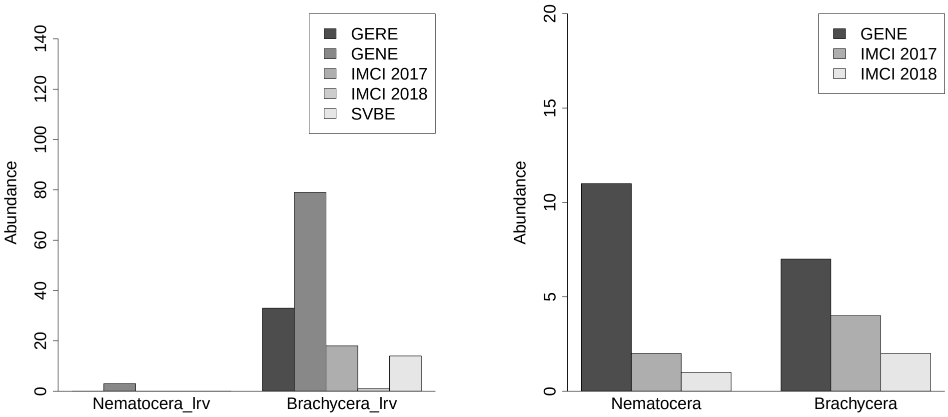

Figure 5.16.a: Larvae

Figure 5.16.b: Adults

Figure 5.16: Posidonia oceanica banquettes. Diptera Suborders collected among all investigated banquettes: larval stages (a) and adults (b)

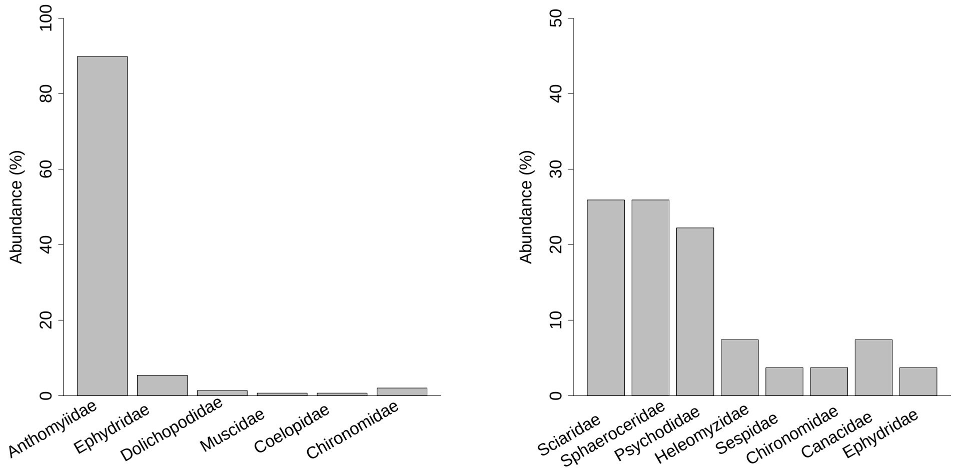

Figure 5.17.a: Larvae

Figure 5.17.b: Adults

Figure 5.17: Posidonia oceanica banquettes. Diptera families collected among all investigated banquettes: larval stages (a) and adults (b)

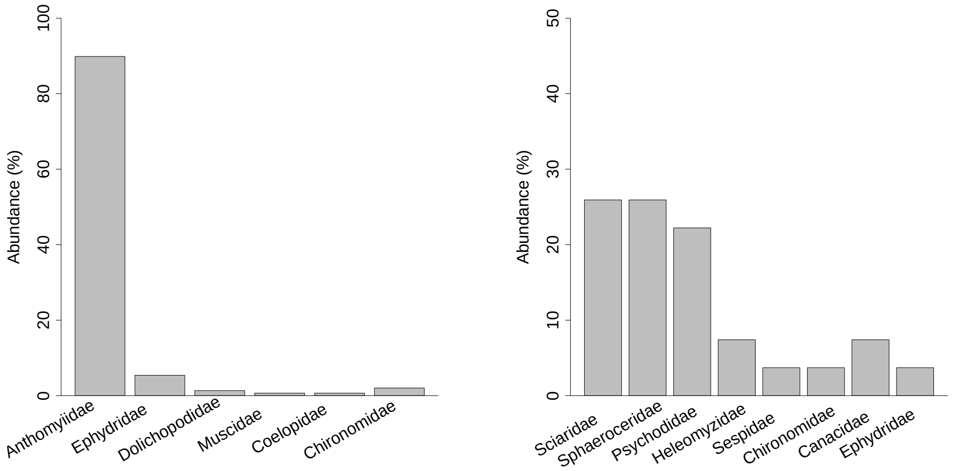

Figure 5.18.a: Larvae

Figure 5.18.b: Adults

Figure 5.18: Posidonia oceanica banquettes. Diptera families collected among all investigated banquettes: larval stages (a) and adults (b)

INSECTA: COLEOPTERA Linnaeus, 1758

This section provides a description of the observed coleoptera collected in the characterization of the Posidonia Oceanica banquette along the Liguria coast. Within this study 6 families have been observed (Tab. 5.51, Fig. 5.19.a and Fig. 5.19.b): most of families species observed can be considered saprophagous with particular adaptation to mycetophagy and sometimes (e.g. Staphylinidae)larvae and adults feed upon the same resources.

- HISTERIDAE Gyllenhal, 1808. This is a Coleoptera family found throughout the world with somewhat fewer than 4,300 species, 165 of which are currently known in Italy (Penati, 2009). Histerids are fairly markedly thermophilous and mainly predators of insect larvae, such as cyclorraphan Diptera and xylophagous Coleoptera: because of the composition of their diet, these predators are mainly found in environments where there is decomposing organic matter where prey live. Adults are round or oval in dorsal view and stout with often truncate elytra, exposing the last 2 abdominal terga. All species have geniculate antennae with a compact, usually 3-segmented club. Colouring is rather variable, from black to rufescent, metallic, often displaying red marks (Arnett Jr & Thomas, 2000). The most typical genera for the studied environments are represented by Halacritus and Hypocaccus (Baeckmanniolus)(Audisio & Taglianti, 2010) in Italy represented by *Halacritus. punctum* (Aube, 1842) and *Hypocaccus dimidiatus dimidiatus* (Illiger,1807). In this study a specimen of Halacritus punctum, was found in the long-surveyed site of Imperia. This species is one of the smallest Italian Histeridae and shows a strict associations to a wide range of wrack from *Zostera* sp. to driftwoods (Vienna, 1980). Its diet is unknown but according to its habitat preferences and the very small size, it probably hunts for microscopic invertebrates (Audisio & Taglianti, 2010).

- PTILIIDAE (Erichson, 1845): this is a Coleoptera family found throughout the world with somewhat fewer than 4,300 speices Ptiliidae is a highly diverse, yet poorly known family of minute beetles that include some of the smallest know coleoptera (about 0.6–0.8 mm in length). Approximately 70 genera and over 550 species within three subfamilies have been described worldwide (Arnett Jr & Thomas, 2000). The overall appearnce of these beetles is rather elongate and oval and usually dark-coloured. Their common names (featherwing beetles) comes from slender whorls of setae on each antennomere and fringes of setae along the margin of the hindwings, which often protrude from beneath the elytra when at rest. Some Ptiliidae exhibit vestigial or complete absence of hindwings. According to Johnson only around 70 species are known from Italy (Löbl & Smetana, 2004). Adults and larvae are not uncommon inhabitants of rotting organic material in a wide range of habitats: few species, common in the Mediterranean basin, occur typically under stranded *P. oceanica* and other seaweeds on the beach. Five adults specimen of *Actinopterix fucicola* (Allibert, 1844) were collected in the site of Bergeggi. Two specimen belonging to the genus *Ptiolum* were collected in the site of Cipressa (2017).
- STAPHYLINIDAE Latreille, 1802: is the largest or second-largest family of beetles, with over 46,200 known species placed in more than 3,200 genera after the inclusion of several subfamilies (in particular, Pselaphinae, Scaphysominae and Scydmaeninae) traditionally considered separate families (Arnett Jr & Thomas, 2000). Despite the endless morphological diversity of this family, most staphylnids may be recognized by the very short elytra which leave most of the abdomen exposed. Staphyl-

inidae are quite ubiquitarious beetles, with a particular preference for plant debris and decaying material. Within the coastal ecotone only few species can be considered as marine: about 442 species in 102 genera and seven subfamilies are known to be confined to seashore habitats (Jeon & Ahn, 2007), accounting for 0.93% of the total number of species Staphylinidae (Arnett Jr & Thomas, 2000), and very close to the approximately 1% of rove beetles that Moore and Legner (1976) said were known to be confined to seashore habitats. Two species of genus *Myrmecopora (Xenusa)*, *M. uvida* (Erichson, 1840) - a species widespread in the western Palaearctic (Frank & Ahn, 2011) - and *M. sulcata* (Kiesenwetter) 1850 have been collected both in Bergeggi banquette. *Omalium* species, with particular reference to the subspecies *O. riparium impar* Mulsant & Rey 1862, represent another of the few species that occupy seashores often associated with drifted seaweed.

- DERMESTIDAE Gyllenhal 1808: can be considered in some way similar to Histeridae (Brusca, 1973). The oval or obovate, compact body shape, clubbed antennae and the structure of the hind coxae excavated for the reception of the femora distinguish most adults of this Family. A dense covering of setae or scales and the presence of a median ocellus make easier the recognition of many of the members of this Family. Just 95 among the 700 global species belong to the Italian fauna (Arnett et al., 2002; Nardi & Háva, 2013). Most dermestids are scavengers, feeding on dried carrion or plant materials - larval stages in particular - whose presence in the Recco banquettes more probably related to.
- CRYPTOPHAGIDAE Kirby 1837, or silken fungus beetles are elongate-oval beetles (1–6 mm. in length) beloging to a relatively large family including around 800 described species worldwide, with slightly fewer than 150

species known in Italy (Audisio & Taglianti, 2010; Leschen, 1996). Their common name suggest that members of this family appear to feed on fungi, although most live as microphagous in a wide variety of habitats and occur in decaying enviroments that promote fungal growth (Leschen, 1996). Only a restricted number of species species have also adapted to life in piles of stranded plant debris (chiefly *Zostera*). Nevertheless, the genus *Atomaria* often occurs along with beach-drift material, as in the case of the two specimens collected in Recco.

- LATRIDIIDAE Erichson 1842. The body appears elongate and brown to piceous in colour. Tarsi with three tarsomeres, small size (1–3mm), and elongate-oval body characterize this family. Latridiidae is a rather small Family including around 800 described species worldwide (Arnett et al., 2002), with only 100 species known to occur in Italy. Adults and larvae of this family seem to be related on fungi, although most live as microphagous in a wide variety of habitats (e.g. rotting wood, vegetal remains and debris) (Audisio & Taglianti, 2010): few species have also adapted to life in piles of stranded plant debris on beaches. Among the coleoptera collected in Nervi *P. oceanica* banquette, the first specimen of *Cartodere (Aridius) bifasciata* (Reitter, 1877) has been identified for Liguria: this Australian species was first described in the late XIX Century from specimens, found on tobacco imported in Germany (Reitter, 1877).

Site	**Date**	**Family**	**Species**	**Abundance**
GERE	2017 III 16	Dermestidae	*Anthrenus sp.*	1
GERE	2017 III 16	Cryptophagidae	*Atomaria sp.*	2
GENE	2016 XII 02	Staphylinidae	*Anotylus hamatus* (Fairmaire & Laboulbne, 1856)	1
GENE	2016 XII 02	Latridiidae	*Cartodere (Aridius) bifasciata* (Reitter, 1877)	1
GENE	2016 XII 02	Staphylinidae	*Sepedophilus sp.*	1
IMCI	2017 III 15	Dermestidae	*Anthrenus sp.*	1
IMCI	2017 IV 13	Histeridae	*Halacritus punctum* (Aub, 1843)	1
IMCI	2017 IV 13	Staphylinidae	*Myrmecopora (Xenusa) sulcata* (Kiesenwetter, 1850)	1
IMCI	2017 IV 13	Ptiliidae	*Ptiolum sp.*	3
IMCI	2017 IV 13	Staphylinidae	*Remus filum* Kiesenwetter, 1849	1
SVBE	2017 XI 29	Ptiliidae	*Actinopteryx fucicola* (Allibert, 1844)	5
SVBE	2017 XI 29	Staphylinidae	*Myrmecopora (Xenusa) uvida* (Erichson, 1840)	7
SVBE	2018 II 21	Staphylinidae	*Myrmecopora (Xenusa) uvida* (Erichson, 1840)	1
SVBE	2017 XI 29	Staphylinidae	*Omalium riparium impar* Mulsant & Rey, 1862	1
SVBE	2017 XI 29	Staphylinidae		2
SVBE	2017 II 21	Staphylinidae		3

Table 5.51: Posidonia oceanica banquettes. Coleoptera collected among all investigated banquettes. GERE = Genova Recco; GENE = Genova Nervi; IMCI = Imperia Cipressa; SVBE = Savona Bergeggi.

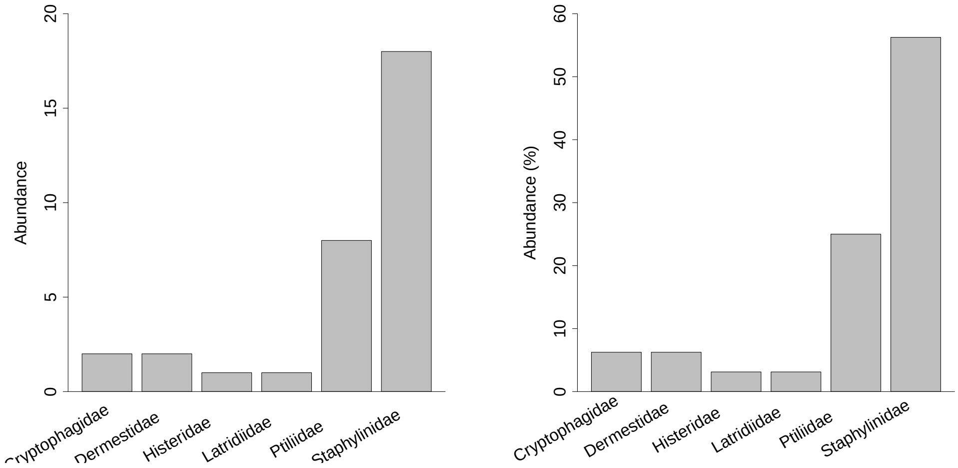

Figure 5.19.a: Absolute Figure 5.19.b: Relative

Figure 5.19: Posidonia oceanica banquettes. Coleoptera families absolute (a) and relative percentage abundance (b).

5.2 Driftwoods

5.2.1 Environmental variables

Differently from what described from *P. oceanica*-associated fauna as driftwood-related communities are mainly related to upper sand layers and field collected variables within driftwoods include just T, distance from the shoreline (DSL) and distance from the wrack: those considered meaningful to explain the distribution of the organisms along a cross shore section. More relevance within this framework - to the purpose to explore variation in time - has been given to climatic variable obtained through wordclim data (Hijmans et al., 2005).

Granulometry

Since the investigated segment of shore face several storms in the cold season potential variation in the grain size distribution has been investigated trough sieving for both years. From tables 5.52 and 5.53, it is evident that between the two years there are some slight differences: the 2018 sediment is richer in its gravel fraction even if 2017 results coarser. Distribution curves look very close (Fig. 5.20.a and 5.20.a), and a univariate Wilcoxon test confirm no variation in grain distribution between the two consecutive years (W = 123.5, p-val. = 0.223).

Site	**Year**	**D50(Φ)**	**Mz(Φ)**	**Mean(Φ)**
Voltri	2017	0.27	0.26	0.26
	2018	−0.10	−0.20	−0.17

Table 5.52: Driftwoods. Grain size analysis:alculated size-related parameters expressed in phi units (Φ) for the site of Voltri across two consecutive years.

Site	Year	Deviation	Skewness	Kurtosis
Voltri	2017	0.72	−0.02	1.22
	2018	1.19	−0.16	1.37

Table 5.53: Driftwoods. Grain size analysis: calculated distribution-related parameters for the site of Voltri across two consecutive years.

Site	Level	Gravel	Sand	Silt	Type
Voltri	2017	5.58	94.03	0.36	Sandy Gravel
	2018	21.49	78.47	0.04	Sandy to Sandy-Gravel

Table 5.54: Driftwoods. Grain size analysis: sedimentary classification according Folk (1970)

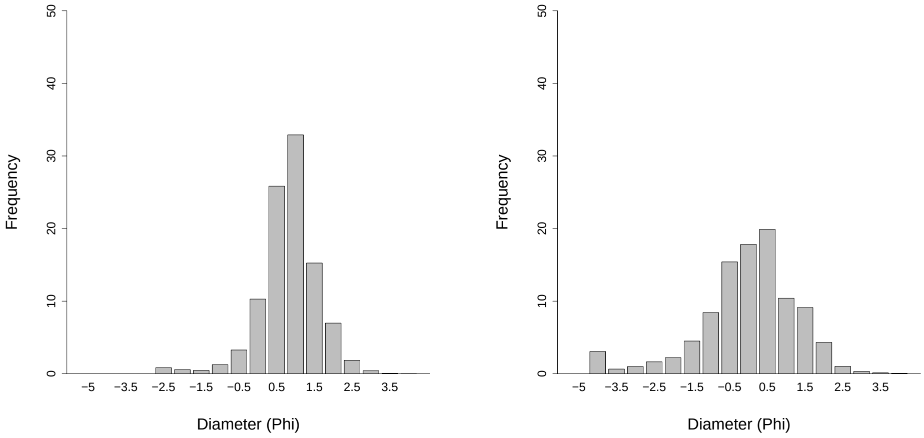

Figure 5.20.a: 2017

Figure 5.20.b: 2018

Figure 5.20: Driftwoods. Grain size analysis: granulometric curve of Voltri sampling site for two consecutive years (2017 and 2018

5.2.2 Community composition

Species richness and community composition have been analysed in a slightly different way from those of banqettes communities: as sampling effort greatly differs among sampling site (Tab. 5.55) any difference estimated-based on samples between communities will result meaningless. Taxonomic richness as well as other values are reported just for descriptive purposes. According to what already observed for *P. oceanica* banquettes communities, also driftwoods-related fauna result highly described by the rare species (Tab.5.55) which amount up to the 30% for all the sampled beaches (Tab. 5.56). Nevertheless, meaningful comparisons through asymptotic richness can be addressed for the site of Voltri along three pit-fall trapping sessions occurred in the same months (March, April and May) for two consecutive years (2017 and 2018).

Site	T	S_{Obs}	**Ind.**	**Singletons**	**Doubletons**
GEVO 2017	60	45	738	24.00	5.00
GEVO 2018	30	30	1083	12.00	5.17
SVTM	8	7	30	5.00	0.14
SVPP	10	12	67	5.32	3.00

Table 5.55: Driftwoods. Samples (T), Observed species (S_{Obs}), individuals (Ind.), singletons and doubletons for driftwoods-related communities. GEVO 2017 = Genova Voltri 2017; GEVO 2018 = Genova Voltri 2018; SVTM = Savona Torre del Mare; SVPP = Savona Punta Predani.

Site	S_{Obs}	**Singletons %**	**Doubletons %**
GEVO 2017	45	34.57	7.70
GEVO 2018	30	30.84	10.71
SVTM	7	41.29	0.59
SVPP	12	36.81	13.63

Table 5.56: Driftwoods. Singletons and doubletons percentage according observed species (S_{Obs}) for driftwoods-related communities. GEVO 2017 = Genova Voltri 2017; GEVO 2018 = Genova Voltri 2018; SVTM = Savona Torre del Mare; SVPP = Savona Punta Predani.

5.2.3 Asymptoctic richness estimation

Abundance and incidence based asymptotic estimators all account for satisfying sampling effort for the site of Voltri, both for 2017 (60 samples) and 2018 (30 samples). Bergeggi (Caletta site) and Punta Predani show different patterns in species richness estimation: while the former site does not reach the asymptote for all estimators the site of Punta Predani shows a rather early asymptote despite the low number of collected samples.

For 2017 sampling season carried out in Voltri, estimated richness (Fig. 5.21) significatively differs both within incidence- and abundance-based estimator (Tab. 5.2.3; Incidence based $\chi^2 = 44.801$, df = 3, p-value = 1.02×10^{-9}; abundance based: W = 2279, p-value = 0.012). The same output has been obtained from 2018 sampling season in the same site (Tab. 5.2.3; incidence based; $\chi^2 = 19.163$, df = 3, p-value = 2.53×10^{-4}; abundance based:W = 293.5, p-value = 0.021). Estimated richness converge within the survey of Bergeggi where all estimators lead more or less to the same values (Tab. 5.2.3); incidence based:$\chi^2 = 5.328$, df = 3, p-value = 0.149; abundance based: W = 23, p-value = 0.382).

Finally for the site of Punta Predani while abundance based perform the same estimation, incidence based differs significatively (Tab. 5.2.3; $\chi^2 = 14.13$, df = 3, p-value = 0.003), especially the coverage estimator ICE and the two Jackknife estimators (Tab. 5.58): the higher values of the ICE estimator can be easily understood according to coverage concept in the formulation of the estimator.

Site	**Chao 1**	**Chao 2**	**Jackk 1**	**Jackk 2**	**ACE**	**ICE**
GEVO 2017	104.63	90.47	68.60	85.15	93.81	95.20
GEVO 2018	44.39	50.42	42.57	51.10	46.74	48.68
SVTM	16.67	20.13	12.25	16.75	28.56	42.83
SVPP	20.54	19.04	16.50	17.88	23.73	22.61

Table 5.57: Driftwoods. Estimated species richness according six asymptotic estimators. GEVO 2017 = Genova Voltri 2017; GEVO 2018 = Genova Voltri 2018; SVTM = Savona Torre del Mare; SVPP = Savona Punta Predani.

	Chao 2	**Jacck 1**	**Jacck 2**
Jacck 1	0.532	-	-
Jacck 2	0.970	0.805	-
ICE	0.108	0.001	0.034

Table 5.58: Driftwoods. Nemenyi pairwise comparison after significative Kruskal-Wallis test among incidence-based estimator performances.

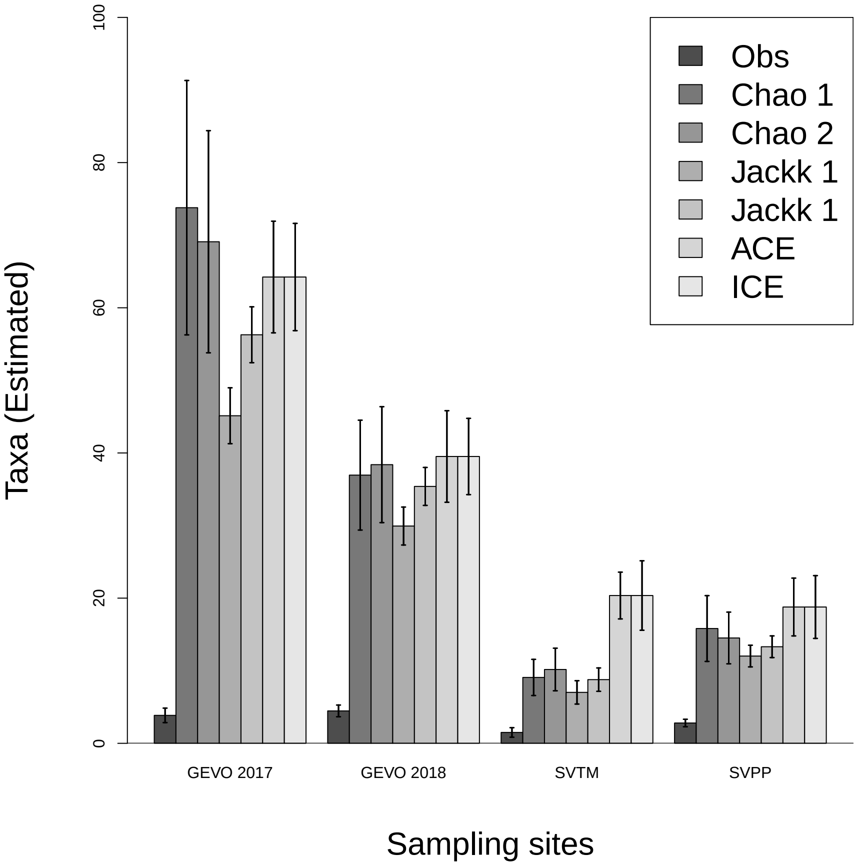

Figure 5.21: Driftwoods-related communities asymptotic richness estimation. Mean values and standard deviations for observed (S_{Obs}) and estimated taxonomic richness for each sampling site. GEVO 2017 = Genova Voltri 2017; GEVO 2018 = Genova Voltri 2018; SVTM = Savona Torre del Mare; SVPP = Savona Punta Predani.

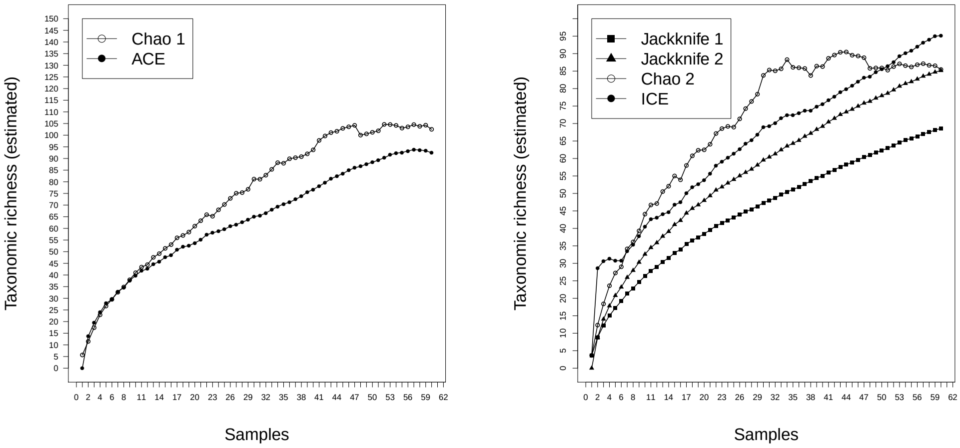

Figure 5.22.a: Abundance-based Figure 5.22.b: Incidence-based

Figure 5.22: Driftwoods. Asymptotic richness estimation for Voltri 2017 sampling season according abundance-based (a) and incidence-based (b) estimators.

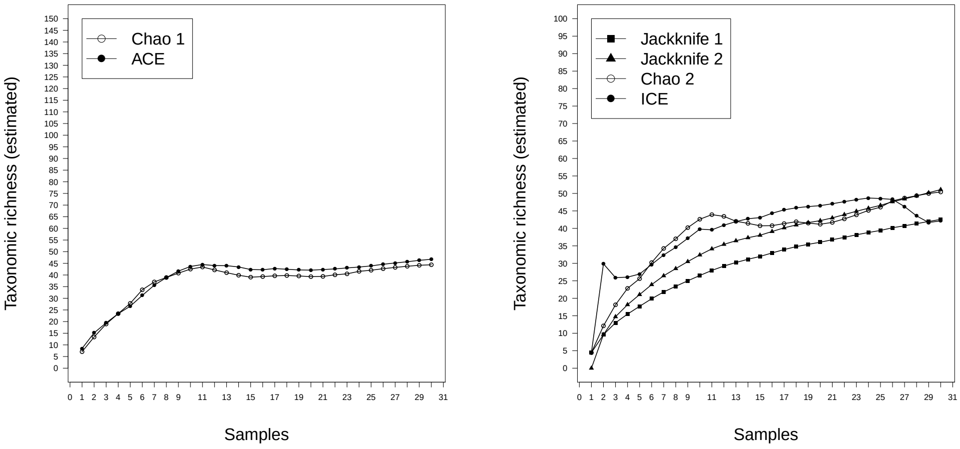

Figure 5.23.a: Abundance-based Figure 5.23.b: Incidence-based

Figure 5.23: Driftwoods. Asymptotic richness estimation for Voltri 2018 sampling season according abundance-based (a) and incidence-based (b) estimators.

5.2.4 Comparison through rarefaction and extrapolation

The great difference in sample size (or reference sample) derived from the heterogeneous sampling effort among sampling sites would probably lead to inaccurate estimations based on the analytical approach used for banquettes. Thus the approach followed in this sections recalls the frameworks discussed in Paragraphs 4.4.1 and 4.4.1): one of the great advantages of the use of the iNEXT package is the possibility to compare estimated richness values (q= 0,1,2) through the concept of sample coverage.

Rarefaction In the first case, the comparison between sampling sites involves only rarefaction, as an excessive extrapolation beyond the double of reference sample size will give inappropriate estimates (?, ?): the coverage-based rarefaction curves for each sample have been constructed for all the calculated Hill's numbers. Then, we identified the curve with the lowest final sample coverage 5.27.a. Because of the small sample size, a numerical approach has been preferred and minimun calculated coverage are reported in Table 5.59. Interpolated values for all samples except for Bergeggi (observed) show that Punta Predani is the most species-poor site (lowest qd), while Voltri (2017 sampling survey) accounts for the highest species richness. In terms of abundance, as well as in term of dominance, the lowest values have been achieved by Bergeggi which describes a rather poor community respect to the values reached by Voltri (both in 2017 and 2018). If the comparison would have been carried out according minimum sampling size (t = 8, Tab. 5.60) Punta Predani would have surpassed Bergeggi in terms of species richness. It is also interesting to observe that, with this sample size even if Punta Prodani, Voltri (2017, and in particular 2018) have closer coverage values (0.790, 0.768

and 0.720).

Site	T	Method	Order	SC	qD	qD LCL	qD UCL
GEVO 2017	3	Int.	0	0.558	8.472	7.546	9.398
	3	Int.	1	0.558	7.471	7.008	8.474
	3	Int.	2	0.558	6.998	6.376	7.621
GEVO 2018	2	Int.	0	0.553	7.007	6.151	7.863
	2	Int.	1	0.553	6.625	5.755	7.495
	2	Int.	2	0.553	6.241	5.438	7.045
SVTM	8	Obs.	0	.527	7.000	3.341	10.659
	8	Obs.	1	.527	4.899	2.208	7.590
	8	Obs.	2	.527	3.429	1.145	5.712
SVPP	3	Int.	0	0.552	6.175	4.436	7.914
	3	Int.	1	0.552	5.637	4.279	6.995
	3	Int.	2	0.552	5.088	3.752	6.425

Table 5.59: Driftwoods. Rarefaction to minimum sample coverage (SC). Values of the estimated diversity (qD) of order q (0= species richness, 1= Shannon exponential, 2= inverse Simpson) together with lower and upper confidence limits (qD LCL and qD UCL) for observed and interpolated (Int.) values of a sample of size T. GEVO 2017 = Genova Voltri 2017; GEVO 2018 = Genova Voltri 2018; SVTM = Savona Torre del Mare; SVPP = Savona Punta Predani.

Extrapolation between sites A first extrapolation is possible doubling the minimum sample size (t = 16, Tab. 5.61). The values of coverage greatly vary among sites from Bergeggi (0.697) to Punta Predani(0.943): this means that species richness (as well as other diversity indices) of the latter site is close to its maximum value (asymptote). On the other hand, Voltri shows for

Site	T	Method	Order	SC	qD	qD LCL	qD UCL
GEVO 2017	8	Int.	0	0.720	15.395	13.621	17.169
	8	Int.	1	0.720	11.954	10.458	13.450
	8	Int.	2	0.720	9.401	8.214	10.588
GEVO 2018	8	Int.	0	0.768	15.738	13.313	18.164
	8	Int.	1	0.768	11.620	9.814	13.426
	8	Int.	2	0.768	8.891	7.659	10.123
SVTM	8	Obs.	0	.527	7.000	3.341	10.659
	8	Obs.	1	.527	4.899	2.208	7.590
	8	Obs.	2	.527	3.429	1.145	5.712
SVPP	8	Int.	0	0.790	10.911	8.380	13.442
	8	Int.	1	0.790	8.644	6.194	11.095
	8	Int.	2	0.790	6.834	4.818	8.850

Table 5.60: Driftwoods. Rarefaction to minimum sample size (T= 8). Values of the estimated diversity (qD) of order q (0= species richness, 1= Shannon exponential, 2= inverse Simpson) together with lower and upper confidence limits (qD LCL and qD UCL) for observed and interpolated (Int.) values of coverage SC. GEVO 2017 = Genova Voltri 2017; GEVO 2018 = Genova Voltri 2018; SVTM = Savona Torre del Mare; SVPP = Savona Punta Predani.

both years comparable values of species richness even if with different coverage values (2017 = 0.802, 2018 = 0.850).

Rarefaction and Extrapolation within sites A second extrapolation have been carried out within the site of Voltri in two consecutive years, taking advantage to the unexpected event that have led to an unbalanced survey through two seasons. This time, the rarefaction curve is computed down to

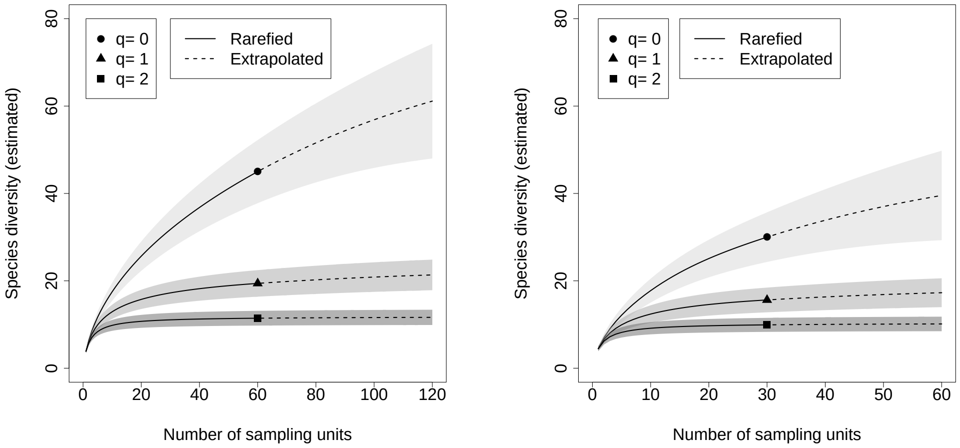

Figure 5.24.a: GEVO 2017

Figure 5.24.b: GEVO 2018

Figure 5.24: Driftwoods. Rarefaction/extrapolation curves for the site of Voltri across two consecutive years. Species richness (q= 0), exponential Shannon (q= 1) and inverse Simpson index (q = 2) computed for 2017(a) and 2018(b) surveys. Solid line = rarefaction, dashed line = extrapolation. Filled symbols have been placed in correspondence of the respective sample size

the minimum sampling coverage (Fig. **??**) of 0.905 that corresponds to 59 and 30 samples for 2017 and 2018 surveys, respectively (Tab. 5.62). The first sample (chronologically speaking) shows overall higher values compared to the consecutive year. After pushing the extrapolation to the same number of samples (T=60), the estimated values show superior taxonomic richness in 2017 sampling season (Tab. 5.63). Kolmogorov-Smirnov test evidenced meaningful differences between estimated values within rarefaction according to minimum sample coverage ($D = 0.559$, $p - val. = 3.26 \times 10^{-06}$, Fig. 5.28.a) but the null hypothesis cannot be rejected if values from extrapolation to maximum sample size are used ($D = 0.233$, $p - val. = 0.076$, Fig. 5.28.b).

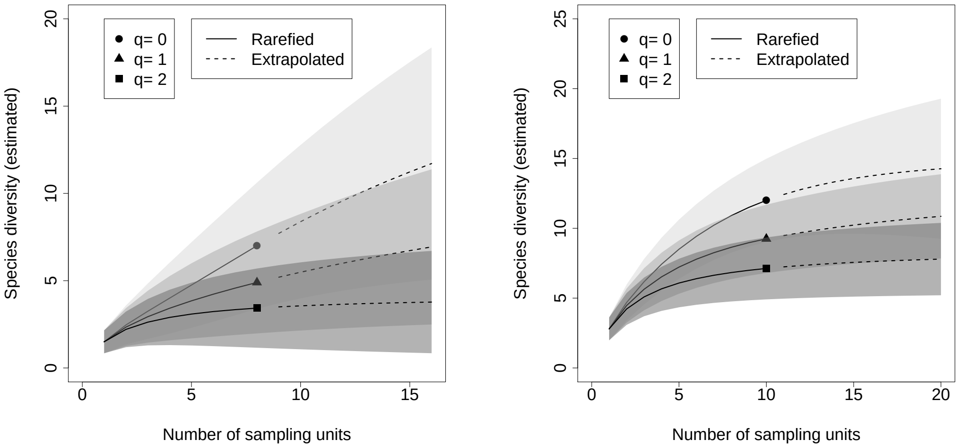

Figure 5.25.a: SVTM

Figure 5.25.b: SVPP

Figure 5.25: Driftwoods. Rarefaction/extrapolation curves for the sites of Bergeggi Torre del Mare (SVTM) and Bergeggi Punta Predani (SVPP). Species richness (q= 0), exponential Shannon (q= 1) and inverse Simpson index (q = 2). Solid line = rarefaction, dashed line = extrapolation. Filled symbols have been placed in correspondence of the respective sample size

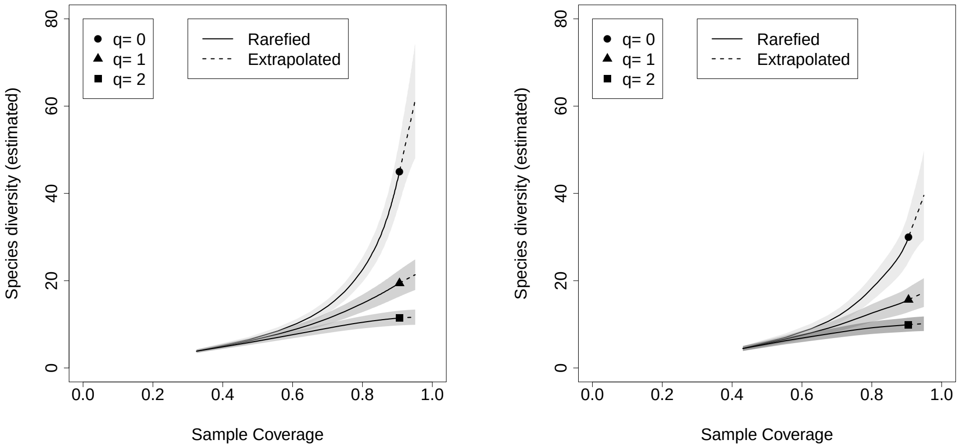

Figure 5.26.a: GEVO 2017 Figure 5.26.b: GEVO 2018

Figure 5.26: Driftwoods. Coverage based rarefaction/extrapolation curves for the site of Voltri across two consecutive years. Species richness (q= 0), exponential Shannon (q= 1) and inverse Simpson index (q = 2) computed for 2017(a) and 2018(b) surveys. Solid line = rarefaction, dashed line = extrapolation. Filled symbols have been placed in correspondence of the respective maximum observed coverage.

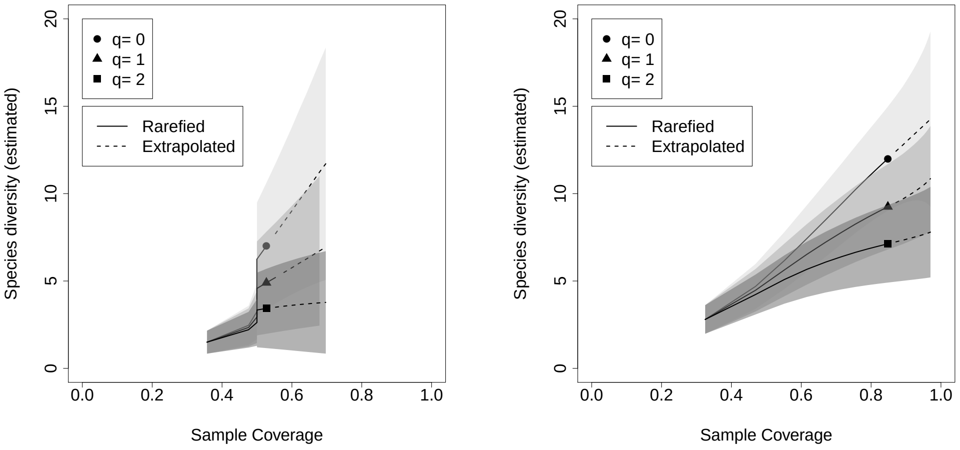

Figure 5.27.a: SVTM

Figure 5.27.b: SVPP

Figure 5.27: Driftwoods. Coverage based rarefaction/extrapolation curves sites of Bergeggi Torre del Mare (SVTM) and Bergeggi Punta Predani (SVPP). Species richness (q= 0), exponential Shannon (q= 1) and inverse Simpson index (q = 2). Solid line = rarefaction, dashed line = extrapolation. Filled symbols have been placed in correspondence of the respective maximum observed coverage.

Site	**T**	**Method**	**Order**	**SC**	**qD**	**qD LCL**	**qD UCL**
GEVO 2017	16	Int.	0	0.802	22.729	19.823	5.635
	16	Int.	1	0.802	14.873	12.837	16.909
	16	Int.	2	0.802	10.480	9.156	11.804
GEVO 2018	16	Int.	0	0.850	22.592	18.549	26.634
	16	Int.	1	0.850	13.924	11.436	16.413
	16	Int.	2	0.850	9.568	8.056	11.080
SVTM	16	Ext.	0	0.697	11.710	5.127	18.294
	16	Ext.	1	0.697	6.935	2.903	10.966
	16	Ext.	2	0.697	3.775	0.626	6.925
SVPP	16	Ext.	0	0.943	13.759	9.789	17.728
	16	Ext.	1	0.943	10.380	7.627	13.132
	16	Ext.	2	0.943	7.618	5.201	10.034

Table 5.61: Driftwoods. Extrapolation to maximum recommended sample size (T = 16). Values of the estimated diversity (qD) of order q (0= species richness, 1= Shannon exponential, 2= inverse Simpson) together with lower and upper confidence limits (qD LCL and qD UCL) for interpolated (Int.) and extrapolated (Ext.) values of coverage SC. GEVO 2017 = Genova Voltri 2017; GEVO 2018 = Genova Voltri 2018; SVTM = Savona Torre del Mare; SVPP = Savona Punta Predani.

Site	T	Method	Order	SC	qD	qD LCL	qD UCL
GEVO 2017	59	Int.	0	0.905	44.633	38.071	51.195
	59	Int.	1	0.905	19.366	16.239	22.493
	59	Int.	2	0.905	11.437	9.748	13.126
GEVO 2018	30	Obs.	0	0.905	30.000	24.158	35.842
	30	Obs.	1	0.905	15.626	12.801	18.451
	30	Obs.	2	0.905	9.920	8.297	11.544

Table 5.62: Driftwoods. Rarefaction to minimum sample coverage (SC) for Voltri site in two consecutive years (2017 and 2018). Values of the estimated diversity (qD) of order q (0= species richness, 1= Shannon exponential, 2= inverse Simpson) together with lower and upper confidence limits (qD LCL and qD UCL) for observed and interpolated (Int.) values of a sample of size T.

Site	T	Method	Order	SC	qD	qD LCL	qD UCL
GEVO 2017	60	Obs.	0	0.906	45.000	37.512	52.488
	60	Obs.	1	0.906	19.412	16.554	22.271
	60	Obs.	2	0.906	11.443	9.829	13.058
GEVO 2018	60	Ext.	0	0.949	39.544	28.357	50.731
	60	Ext.	1	0.949	17.279	14.296	20.263
	60	Ext.	2	0.949	10.134	8.455	11.813

Table 5.63: Driftwoods. Extrapolation to maximum recommended sample size (T= 60)for Voltri site in two consecutive years (2017 and 2018). Values of the estimated diversity (qD) of order q (0= species richness, 1= Shannon exponential, 2= inverse Simpson) together with lower and upper confidence limits (qD LCL and qD UCL) for interpolated (Int.) and extrapolated (Ext.) values of coverage SC.

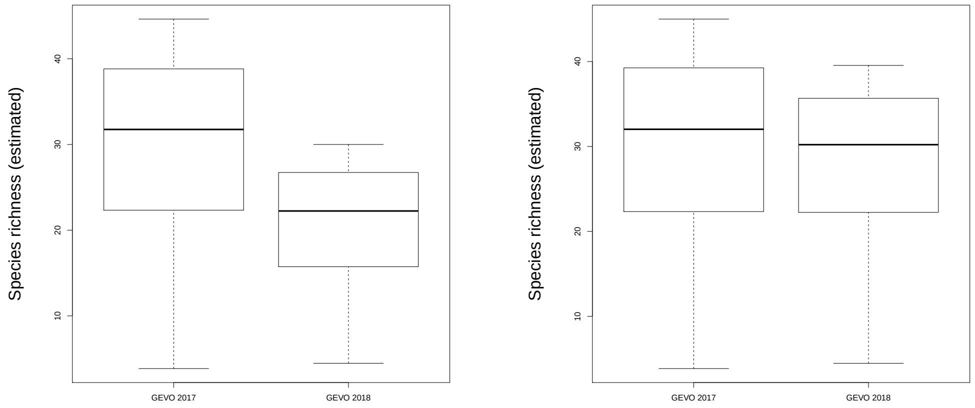

Figure 5.28.a: Rarefaction

Figure 5.28.b: Extrapolation

Figure 5.28: Driftwoods. Rarefaction to minimum sample coverage (a) and extrapolation to maximum sample size (b) for the site of Voltri in two consecutive years (2017 and 2018).

5.2.5 Untangling diversity

Diversity indices

Within driftwood associated arthropods the comparison of calculated indices gives some interesting results. Considering just 2017 sampling season comparison between months does not account for statistically significant values (Tab. 5.64) for Shannon (χ^2 = 6.111, df = 5, p-value = 0.296, Fig. 5.29.a), Simpson (χ^2 = 2.662, df = 5, p-value = 0.752, Fig. 5.29.b) and Pielou (χ^2 = 5.173, df = 5, p-value = 0.395, Fig.5.29.c) indices. Different information comes from comparing the three indices between consecutive years (2017 and 2018): for March and May together, Shannon, Simpson and Pielou univariate non-parametric comparison do not show significant differences (Tab. 5.64, Figg. 5.30.a, 5.30.b and 5.30.c), while for the month of March only the two years show some difference.

Species Composition

Non-metric MDS (Jaccard distance) converge to an optimal solution already with two axes. Communities of March, April and May compared for two consecutive years greatly overlap without evident differences from a graphical point of view (Figg. 5.31.a, 5.31.b). Permanova (Jaccard distance) run to test if Year (two level, 2017,2018) and Month (3 levels, March, April and May) show a significative change in terms of community for year, for month as well as for the interaction of the two factors (Tab. 5.65). As previously happened for *P. oceanica* banquettes communities the overall R^2 is rather low (0.33) that means the current analysis is not powerful enough. Simper analysis do not enlight significant contribution to overall diversity for all levels of tested factors even after the removal of obiquitarious taxa, such as springtails and

Indices	**Period**	**W**	**p-val.**
Shannon (H')	Mar 17-18	39	0.740
	Apr 17-18	45	0.004
	May 17-18	58	0.552
Simpson (D)	Mar 17-18	71	0.364
	Apr 17-18	72	0.003
	May 17-18	61	0.412
Pielou (J')	Mar 17-18	49	0.193
	Apr 17-18	79	$9.14 \times 10^{-5}*$
	May 17-18	61	0.412

Table 5.64: Driftwoods. Wilcoxon's Test between months of two following years (Period) of the three calculated indices (Shannon, Simpson and Pielou), for the site of Voltri.

mites.

Factor	**Df**	**Sums Of Sqs**	**Mean Sqs**	**F**	R^2	$Pr(>F)$
Year	1	1.16	1.16	4.42	0.06	0.001*
Month	2	2.93	1.46	5.59	0.14	0.001*
Year*Month	2	2.55	1.27	4.86	0.12	0.001*
Residuals	54	14.14	0.26		0.68	
Total	59	20.77			1.00	

Table 5.65: Driftwoods. Permanova table (Jaccard distance) run on Voltri 2017 and 2018 data.

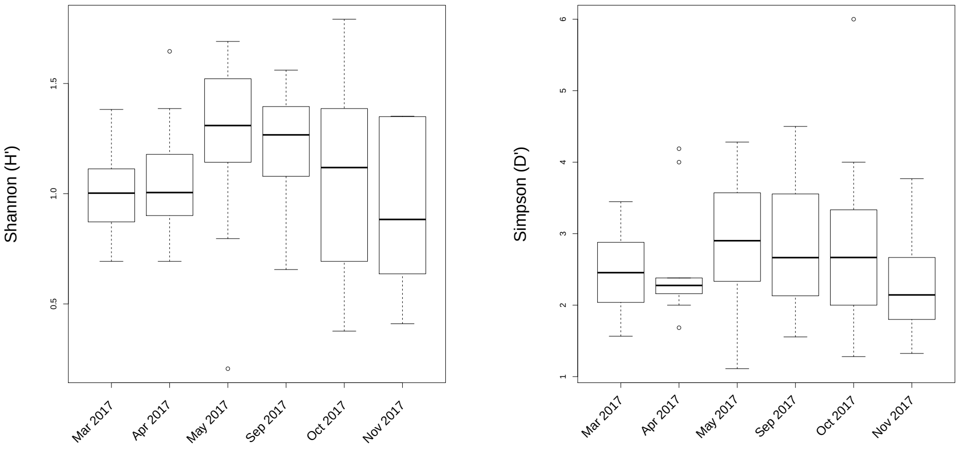

Figure 5.29.a: Shannon

Figure 5.29.b: Simpson

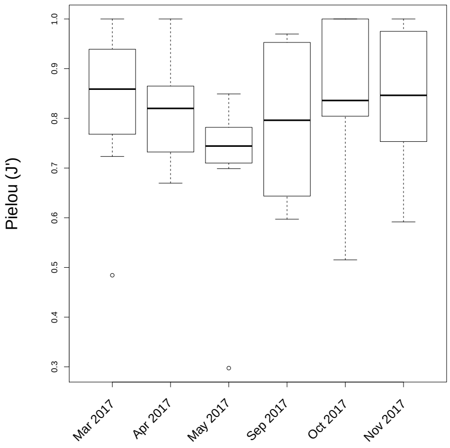

Figure 5.29.c: Pielou

Figure 5.29: Driftwoods. Calculated entropy (Shannon, a), dominance (Simpson, b) and evenness (Pielou, c) along 2017 sampling season for the site of VOltri

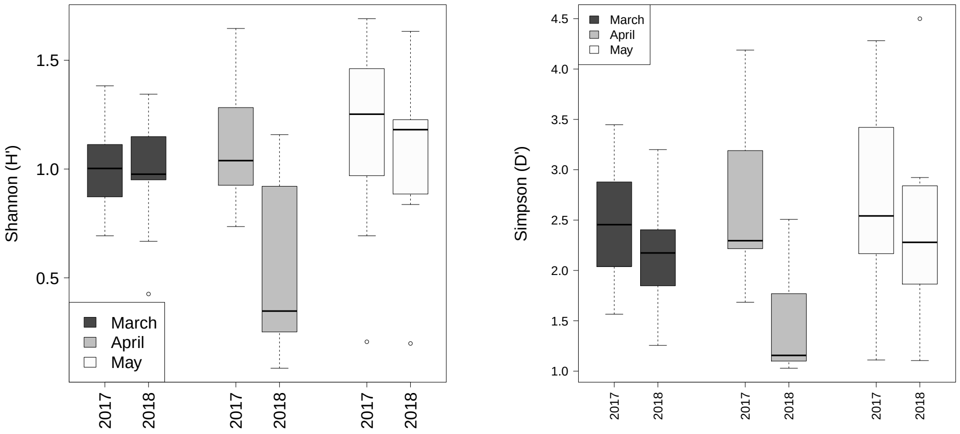

Figure 5.30.a: Shannon

Figure 5.30.b: Simpson

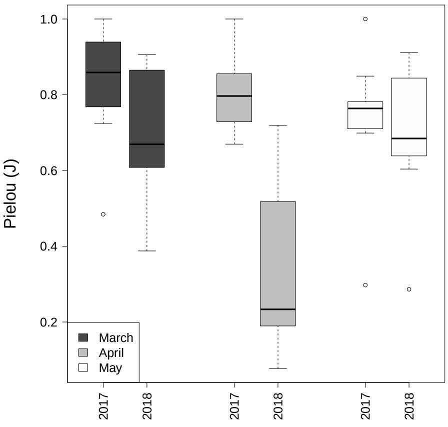

Figure 5.30.c: Pielou

Figure 5.30: Driftwoods. Entropy (Shannon, a), dominance (Simpson, b) and evenness (Pielou, c) compared for same month in 2017 and 2018 sampling seasons.

Int.	**N. par.**	**df**	**logLik**	**AICc**	$\Delta AICc$	**Weight**
0.2473	4	6	27.365	-41.6	0.00	0.570
2.5520	3	5	25.239	-39.7	1.91	0.219
0.3212	5	7	27.575	-39.6	1.99	0.211

Table 5.66: Driftwoods. Pielou evenness (J'): list of best models laying within two points of AICc. Int. = intercept value, N. par = number of parameters included in the model, df = degrees of freedom, logLik = log-likelihood value, AICc = Second-order Akaike Information Criterion, Weight = Akaike weights.

Modelling diversity

Spearman's rank correlation coefficient for diurnal range and rainfall indicated strong negative correlation (Spearman Rho = -0.881, p-val. $< 2.20\times^{-16}$). Two group of global model were built around this correlation. The indices (H, D and J) have been modelled as response of four habitat-related variables (mean grain size, Mz - temperature, T - distance from swashline, DSL and ditance from the wrack, Dw) and three environmental variables (diurnal range, wind speed, rain). From these global models 64 nested candidates models have been fitted. Even if usually for $\Delta AICc > 2$, models show substantial differences (Burnham & Anderson, 2014). In this case the $\Delta AICc$ range has been raised up to four points to allow more models to be candidates. Due to the low R^2 of the fitted regressions, involving Shannon entropy and Simpson dominance have to be discarded. Pielou's J' models (Tab. 5.67 and 5.67) both account for T, Wind and Mz as driving factors in estimated Evenness (Tabb. 5.70 and 5.71). These models will be discussed even if their R^2 account respectively for 0.42 (diurnal range related) and 0.41 (rain related).

Int.	N. par.	df	logLik	AICc	$\Delta AICc$	Weight
2.552	3	5	25.239	−39.7	0.00	0.276
4.018	5	7	27.398	−39.2	0.43	0.223
3.564	4	6	26.167	−39.2	0.48	0.217
2.685	4	6	25.941	−38.7	0.94	0.173
2.593	4	6	25.513	−37.9	1.79	0.113

Table 5.67: Driftwoods. Pielou evenness (J'): list of best models laying within two points of AICc. Int. = intercept value, N. par = number of parameters included in the model, df = degrees of freedom, logLik = log-likelihood value, AICc = Second-order Akaike Information Criterion, Weight = Akaike weights.

Collembola lifeforms sensibility

Generalized linear models have been fitted to model the abundance of each lifeform described in section 4.4.2 as response of a set of enviromental variables. Euedaphic, Hemiedaphic, Atmobiotic and Epedaphic abundances have been modelled as response of four habitat-related variables (Mz, T, DSL and Dw) and three environmental variables (diurnal range, wind speed and rain). Global models for which Hosmer-Lemeshow Goodness Of Fit (GOF) test gave significant p-val. were discarded (both Euedaphic models: $\chi^2 = 116.13$, df = 8, p-val. $< 2.20 \times -16$ and $\chi^2 = 3960$, df = 8, p-val. $< 2.20 \times -16$; Hemiedaphic model: $\chi^2 = 627.45$, df = 8, p-val. $< 2.20 \times -16$; Atmobiotic model = $chi^2 = 18.078$, df = 8, p-val. = 0.02065). From these global models, 64 nested candidate models have been fitted. Since models with a $\Delta AICc > 2$ show substantial differences (Burnham & Anderson, 2014) only a restricted amount of candidates for each lifeforms fall into the $\Delta AICc < 2$ range. Thus, selected models have been then subjected to model averaging to give as meaningful as

Int.	**Drn**	**DW**	**T**	**Wind**	**Mz**	**df**	**logLik**	**AICc**	*ΔAICc*	**Weight**
0.2473	1.471		−0.6334	−0.8462	0.8124	6	27.365	−41.6	0.00	0.570
2.5520			−0.3801	−0.8134	0.6160	5	25.239	−39.7	1.91	0.219
0.3212	1.447	−0.0081	−0.6325	−0.8684	0.8031	7	27.575	−39.6	1.99	0.211

Table 5.68: Driftwoods. Pielou's evenness (J'). Model selection table. Int. = intercept value, Drn = monthly diurnal range, DW = distance from the wrack, T = measured ground temperature, Wind = monthly wind speed, Mz = mean grain size, df = degrees of freedom, logLik = log-likelihood, AICc = Second-order Akaike Information Criterion, Weight = Akaike weights.

Int.	**DSL**	**DW**	**Rain**	**T**	**Wind**	**Mz**	**df**	**logLik**	**AICc**	*ΔAICc*	**Weight**
2.552				−0.3801	−0.8134	0.6160	5	25.239	−39.7	0.00	0.276
4.018	0.09301		−0.2124	−0.5246	−1.1650	0.8903	7	27.398	−39.2	0.43	0.223
3.564		−0.1670	−0.4630	−0.8471	0.7044	6	26.167	−39.2	0.48	0.217	
2.685	0.06936		−0.4093	−1.0430	0.7367	6	25.941	−38.7	0.94	0.173	
2.593		−0.00947		−0.3840	−0.8401	0.6089	6	25.513	−37.9	1.79	0.113

Table 5.69: Driftwoods. Pielou's evennes model selection table: Int. = intercept value, DSL = distance from swash line, DW = distrance from the wrack, Rain = monthly rainfall, T = measured ground temperature, Wind = monthly wind speed, Mz = mean grain size, df = degrees of freedom, logLik = log-likelihood, AICc = Second-order Akaike Information Criterion, Weight = Akaike weights.

Parameter	**Estimate**	**Std. Error**	**Adj. SE**	**z-val.**	$Pr(>\|z\|)$
Intercept	0.77	1.465	1.48	0.52	0.60
Drn	1.14	0.88	0.89	1.28	0.20
T	-0.58	0.18	0.18	3.23	$1.26 \times 10^{-3}*$
Wind	-0.84	0.30	0.31	2.74	$6.22 \times 10^{-3}*$
Mz	0.77	0.16	0.16	4.87	$1.10 \times 10^{-6}*$
DW	-1.71×10^{-3}	6.81×10^{-3}	6.90×10^{-3}	0.25	0.80

Table 5.70: Driftwoods. Pielou evenness (J'): full averaged model. Int. = intercept value, Drn = monthly diurnal range, DW = distance from the wrack, T = measured ground temperature, Wind = monthly wind speed, Mz = mean grain size

Parameter	**Estimate**	**Std. Error**	**Adj. SE**	**z-val.**	$Pr(>\|z\|)$
Int.	3.12	0.94	0.95	3.28	$1.03 \times 10^{-3}*$
T	-0.44	0.12	0.12	3.67	$2.42 \times 10^{-4}*$
Wind	-0.94	0.36	0.37	2.57	$1.03 \times 10^{-2}*$
Mz	0.72	0.17	0.17	4.19	$2.84 \times 10^{-5}*$
DSL	0.03	0.06	0.06	0.58	0.56
Rain	-0.08	0.13	0.13	0.65	0.52
DW	$-1.96 \times 10^{-3}*$	$5.34 \times 10^{-3}*$	$5.40 \times 10^{-3}*$	0.20	0.84

Table 5.71: Driftwoods. Pielou evenness (J'): full averaged model. Int. = intercept value, DSL = distance from swash line, DW = distrance from the wrack, Rain = monthly rainfall, T = measured ground temperature, Wind = monthly wind speed, Mz = mean grain size

Int.	N. par.	df	logLik	AICc	$\Delta AICc$	Weight
−0.48	3	4	−152.88	314.2	0.00	0.34
3.99	4	5	−152.18	315.1	0.83	0.23
−3.55	2	3	−154.69	315.7	1.44	0.17
−0.16	4	5	−152.71	316.1	1.90	0.13
−0.38	2	3	−154.96	316.2	1.96	0.13

Table 5.72: Driftwoods. Epedaphic lifeforms models: list of best models laying within two points of AICc. Int. = intercept value, N. par = number of parameters included in the model, df = degrees of freedom, logLik = log-likelihood value, AICc = Second-order Akaike Information Criterion, Weight = Akaike weights.

possible explanation of the observed distribution. Epedaphic models based on five parameters (Tab. 5.72 and 5.80) shows meaningful weight of the Temperature in relation to Hemiedaphic lifeform. The second model, fitted to the same abundance data (Tab. 5.73) with the introduction of the diurnal range factor (and Rain Removal), shows a more extended significance mainly described by a micro-environmental variable (grain size) and a climatic variable (diurnal range, Tab. 5.81). Hemiedaphic springtails show higher sensibility for all fitted parameters (Tab. 5.74 and 5.82) with the exception of DSL. Finally, the model fitted for Atmobiotic lifeform (Tab. 5.75) shows significative values for DW, Mz and Wind (Tab. 5.83).

Int.	**N. par.**	**df**	**logLik**	**AICc**	$\Delta AICc$	**Weight**
−0.48	3	4	−151.27	311.0	0.00	0.51
3.99	4	5	−150.79	312.3	1.29	0.27
−3.55	4	5	−150.95	312.6	1.60	0.23

Table 5.73: Driftwoods. Epedaphic lifeforms models: list of best models laying within two points of AICc. Int. = intercept value, N. par = number of parameters included in the model, df = degrees of freedom, logLik = log-likelihood value, AICc = Second-order Akaike Information Criterion, Weight = Akaike weights.

Int.	**N. par.**	**df**	**logLik**	**AICc**	$\Delta AICc$	**Weight**
12.91	6	7	−460.08	935.5	0.00	0.54
15.51	5	6	−461.43	935.9	0.35	0.46

Table 5.74: Driftwoods. Hemiedaphic lifeforms models: list of best models laying within two points of AICc. Int. = intercept value, N. par = number of parameters included in the model, df = degrees of freedom, logLik = log-likelihood value, AICc = Second-order Akaike Information Criterion, Weight = Akaike weights.

Int.	**N. par.**	**df**	**logLik**	**AICc**	*ΔAICc*	**Weight**
2.66	4	5	−66.37	143.5	0.00	0.35
2.58	5	6	−65.88	144.8	1.32	0.18
6.31	3	4	−68.26	145.0	1.54	0.16
−3.58	5	6	−65.99	145.0	1.56	0.16
5.45	4	5	−67.21	145.1	1.69	0.15

Table 5.75: Driftwoods. Atmobiotic lifeforms models: list of best models laying within two points of AICc. Int. = intercept value, N. par = number of parameters included in the model, df = degrees of freedom, logLik = log-likelihood value, AICc = Second-order Akaike Information Criterion, Weight = Akaike weights.

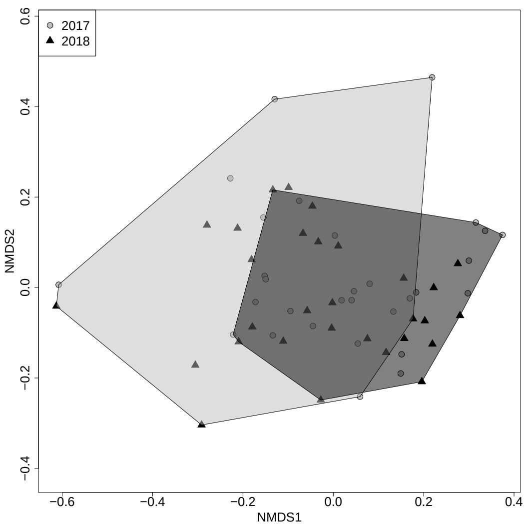

Figure 5.31.a: Non-metric MDS

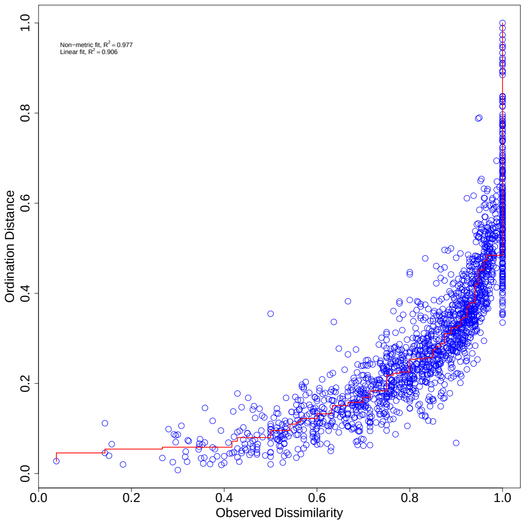

Figure 5.31.b: Stressplot

Figure 5.31: Driftwoods. Non metric multidimensional scaling (NMDS, a) and stressplot (b) of Voltri site across two consecutive years (2017 and 2018) according communities composition (Jaccard dsitance).

Int.	**T**	**DW**	**Mz**	**Rain**	**Wind**	**df**	**logLik**	**AICc**	$\Delta AICc$	**Weight**
−0.4807	0.19		1.14		−2.451	4	−152.884	314.2	0.00	0.344
3.9970	0.14		1.55	−0.75	−2.818	5	−152.178	315.1	0.83	0.227
−3.5500	0.22		1.25			3	−154.698	315.7	1.44	0.168
−0.1584	0.18	−0.03	1.11		−2.707	5	−152.713	316.1	1.90	0.133
−0.3805	0.20				−2.747	3	−154.960	316.2	1.96	0.129

Table 5.76: Driftwoods. Epedaphic lifeforms model selection table: Int. = intercept value, T = measured ground temperature, DW = distance from the wrack, Mz = mean grain size, Rain = monthly rainfall, Wind = monthly wind speed, df = degrees of freedom, logLik = log-likelihood, AICc = Second-order Akaike Information Criterion, Weight = Akaike weights.

Int.	**T**	**D. range**	**DSL**	**Mz**	**Wind**	**logLik**	**AICc**	$\Delta AICc$	**Weight**	
−23.83		13.41		2.65	−3.69	4	−151.270	311.0	0.00	0.507
−24.81		13.74	−0.22	2.33	−2.85	5	−150.795	312.3	1.29	0.266
−17.74	0.06	9.73		2.17	−3.20	5	−150.949	312.6	1.60	0.228

Table 5.77: Driftwoods. Epedaphic lifeforms model selection table: Int. = intercept value, T = measured ground temperature, D. range = monthly mean diurnal range, DSL = distance from the swash line, Mz = mean grain size, Wind = monthly wind speed, df = degrees of freedom, logLik = log-likelihood, AICc = Second-order Akaike Information Criterion, Weight = Akaike weights.

Int.	**T**	**DW**	**Mz**	**Rain**	**Wind**	**df**	**logLik**	**AICc**	$\Delta AICc$	**Weight**
−0.48	0.19		1.14		−2.45	4	−152.884	314.2	0.00	0.344
3.99	0.14		1.55	−0.75	−2.82	5	−152.178	315.1	0.83	0.227
−3.55	0.22		1.25			3	−154.698	315.7	1.44	0.168
−0.15	0.18	−0.03	1.11		−2.71	5	−152.713	316.1	1.90	0.133
−0.38	0.20				−2.75	3	−154.960	316.2	1.96	0.129

Table 5.78: Driftwoods. Hemiedaphic lifeforms model selection table: Int. = intercept value, T = measured ground temperature, DW = distance from the wrack, Mz = mean grain size, Rain = monthly rainfall, Wind = monthly wind speed, df = degrees of freedom, logLik = log-likelihood, AICc = Second-order Akaike Information Criterion, Weight = Akaike weights.

Int.	**T**	**DSL**	**DW**	**Mz**	**Rain**	**df**	**logLik**	**AICc**	$\Delta AICc$	**Weight**	
2.65	0.08		0.19	−7.83		−4.63	5	−66.368	143.5	0.00	0.349
2.58	0.07	0.72	0.23	−6.51		−6.21	6	−65.879	144.8	1.32	0.180
6.31			0.21	−7.60		−6.84	4	−68.260	145.0	1.54	0.161
−3.58	0.11		0.18	−8.87	1.69	−6.32	6	−65.999	145.0	1.56	0.160
5.45		1.01	0.27	−5.78		−8.66	5	−67.216	145.1	1.69	0.149

Table 5.79: Driftwoods. Atmobiotic lifeforms model selection table: Int. = intercept value, T = measured ground temperature, DSL = distance from the swash line, DW = distance from the wrack, Mz = mean grain size, Rain = monthly rainfall, df = degrees of freedom, logLik = log-likelihood, AICc = Second-order Akaike Information Criterion, Weight = Akaike weights.

Parameter	**Estimate**	**Std. Error**	**Adj. SE**	**z-val.**	$Pr(>\|z\|)$
Int.	0.07	3.43	3.46	0.02	0.98
T	0.18	0.05	0.05	3.78	$1.58 \times 10^{-4}*$
Mz	1.10	0.73	0.74	1.50	0.13
Wind	-2.20	1.57	1.59	1.39	0.17
Rain	-0.17	0.44	0.44	0.38	0.70
DW	-4.36×10^{-3}	0.02	0.02	0.19	0.85

Table 5.80: Driftwoods. Epedaphic models: full averaged model. Int. = intercept value, T = measured ground temperature, D. range = monthly mean diurnal range, DSL = distance from the swash line, Mz = mean grain size, Wind = monthly wind speed.

Parameter	**Estimate**	**Std. Error**	**Adj. SE**	**z-val.**	$Pr(>\|z\|)$
Int.	-22.70	7.76	7.85	2.89	$3.84 \times 10^{-3}*$
Drn	12.66	3.91	3.96	3.20	$1.39 \times 10^{-3}*$
Mz	2.45	0.70	0.69	3.52	$4.36 \times 10^{-4}*$
Wind	-3.36	1.37	1.39	2.41	$0.01*$
DSL	-0.06	0.15	0.14	0.39	0.70
T	-0.01	0.04	0.04	0.31	0.76

Table 5.81: Driftwoods. Epedaphic models. Full averaged model. Int. = intercept value, T = measured ground temperature, Drn = monthly mean diurnal range, DSL = distance from the swash line, Mz = mean grain size, Wind = monthly wind speed

Parameter	**Estimate**	**Std. Error**	**Adj. SE**	**z-val.**	$Pr(>\|z\|)$
Intercept	14.10	4.27	4.33	3.26	$1.12 \times 10^{-3}*$
T	0.42	0.02	0.03	16.76	$2.00 \times 10^{-16}*$
Drn	-14.98	2.19	2.22	6.75	$2.00 \times 10^{-16}*$
DSL	-0.21	0.26	0.30	0.81	0.42
DW	-0.20	0.03	0.03	7.30	$2.00 \times 10^{-16}*$
Mz	-7.21	0.49	0.50	14.54	$2.00 \times 10^{-16}*$
Wind	11.63	0.97	0.98	11.89	$2.00 \times 10^{-16}*$

Table 5.82: Driftwoods. Hemiedaphic models. Full averaged model: Int. = intercept value, T = measured ground temperature, DW = distance from the wrack, Mz = mean grain size, Rain = monthly rainfall, Wind = monthly wind speed

Parameter	**Estimate**	**Std. Error**	**Adj. SE**	**z-val.**	$Pr(>\|z\|)$
Int.	2.65	4.80	4.84	0.55	0.58
T	0.06	0.06	0.06	1.05	0.29
Drn	0.21	0.10	0.10	2.03	$0.04*$
DSL	-7.41	1.70	1.71	4.33	$1.45 \times 10^{-5}*$
DW	-6.14	2.67	2.70	2.27	$0.02*$
Mz	0.28	0.59	0.60	0.47	0.63
Wind	0.27	0.98	0.99	0.27	0.78

Table 5.83: Drifwoods. Atmobiotic models. Full averaged model: Int. = intercept value, T = measured ground temperature, DSL = distance from the swash line, DW = distance from the wrack, Mz = mean grain size, Rain = monthly rainfall

5.2.6 Taxonomical characterization

MYRIAPODA: DIPLOPODA De Blainville in Gervais, 1844

Myriapods fauna have been sampled only within driftwoods and includes two orders, three families accounting for 14 specimens all collected in Voltri site.

- POLYXENIDAE Lucas, 1840 is a Family of millipedes belonging to the order Polyxenida with approximately 47 species described in 19 genera (Zhang, 2013) easily recognizable for their blistly aspects. The family is placed in a separate sub-class of the Diplopoda, the Penicillata as the sclerites are not impregnated with calcium salts and do not form arched dorsal shields or coalesce into rigid units as in the Chilognatha. The specimen collected within the driftwood study belong to the species *Polyxenus lagurus* (Linnaeus, 1758) reknown for his wide distribution covering most of the Euro-Mediterranean region and great part of the North America (Golovatch & Kime, 2009). One of the most interesting strategy of this species is the opportunistic parthenogenesis howed by many populations (Enghoff, 1994), but also by its myrmecophily (Stoev & Lapeva-Gjonova, 2005). The literature on millipedes tends to associate *P. lagurus* mostly with trees while other studies report wider habitat preferences as maritime therophyte zone on rocky seacliffs (Alexander, 2006).
- JULIDAE Leach, 1814 contains more than 600 described species and is the dominant family of millipedes in the western part of the Palaearctic region. The generic diversity is by far highest in Europe with 60 genera and 519 species (Enghoff, Petersen, & Seberg, 2011).
  - *Cilindroiulus* genus consists in over 100 species distribuited from Central Asia to Macaronesia with high taxonomic values in South-

ern Europe, with particular reference to Italy and the island of Madeira which hosts an endemic species swarm (Kime & Enghoff, 2017; Enghoff, 1983). Several species have spread northwards into the rest of Europe while some pioneering and anthropochorous taxa are becoming globally widespread. The presence of a relatively high number of setae on the anal valves on collected samples, allows to exclude several species, such as *C. Parisiorum* (Brölemann & Verhoeff, 1896) and *C. arborum* (Verhoeff, 1928).

Plausible options are represented by species *C. limitaneus* (Brölemann, 1905) - widely distributed at the French Riviera - *C. parisiorum* (Brl̈emann & Verhoeff, 1896) and *C. truncorum* (Silvestri, 1896), the last one probably originating form northern Africa, but now widely distributed in anthropogenic habitats.

- *Ommatoiulus* is a large genus with 47 European species, mostly from the Iberian peninsula, where many new species are currently being found (Kime & Enghoff, 2017). These Diplopoda show high variability in gonopods, resulting that some of the species may turn out to be synonyms of others. Specimens collected are all females which increase the difficulty of the identification process. According to previous records the species can be putatively three: *Ommatoiulus sabulosus* (Linnaeus, 1758), *Ommatoiulus parallelus* (C. L. Koch, 1847) and *Ommatoiulus albolineatus* (Lucas, 1845). The commonly found specimens of *O. sabulosus* show two light ribbons, which are distinctly separate and contrasting. In the sampled material the ribbon is only interrupted by a small dark line and the light ribbons are not much contrasting. The eurytopic distribution and the association with warm habitats and sandy areas give some credits to the *sabulosus* option. For *O. albolineatus* (Lucas, 1845) records come only from the French Riviera and western Liguria while *O. parallelus* - often found on dry, gravelly slopes - is widely distributed among Italy.

  - *Brachyulus* includes only eight species unevenly distributed across the Mediterranean region where the presence results mainly from anthropochorus processes. The single male collected can potentially belong to two species: *Brachyulus Lusitanus* (Verhoeff, 1898) - mostly associated to meadows but also recorderd from sandy area of the Adriatic coast or *Brachyulus stuxbergi* (Fanzago, 1875) which seems to tolerate relatively arid conditions as well maquis and gardens (Kime & Enghoff, 2017). Both genera are already known for Italy with *Brachyulus lusitanus* covering a larger areal.

- Nemasomatidae Bollman, 1893 comprises small, *juliformian* millipedes with slender bodies (Enghoff, 1985) represented in Europe by four species (Kime & Enghoff, 2017). Its members are dis-junctly distributed throughout the Holarctic Region, mostly in its temperate areas, where they occur in forests, on seashores, or in caves. *Thalassisobates littoralis* (Silvestri, 1903) is reported from the western Mediterranean and Atlantic areas but the ecounter with this Julida become even more rarefied along Adriatic, Sardinia and Sicily coasts. This species is basically considered European, with a secondary, likely anthropochorous colonisation of North America (Golovatch & Kime, 2009). The species is strictly associated with intertidal environments, where it is found in *Zostera* and other seagrasses deposits, although it prefers rocky, pebbly beaches or those with alternating sand and calcareous pebbles.

INSECTA: DERMAPTERA DE GEER, 1773

Two cosmopolitan or subcosmopolitan species occur along the Mediterranean coastlines: *Anisolabis maritima* (Bonelli in Gen, 1832) and *Labidura riparia* (Pallas, 1773). However, only the first, *A. maritima* can be considered truly cosmopolitan and its a genuine halobiontic element, exclusive of the intertidal zone of the rocky or gravel coasts. Within the study only *L. riparia* has been collected for both sexes for a total of 24 specimens in the site Voltri. The species is a truly paleartic element even if in the past *L. riparia* was defined cosmpolitan as result from an wrong taxonomical interpretation according which many taxonomists have included in its variability some taxa that have to be considered different species (Vigna Taglianti, 2010). The species typically, although not exclusively, lives on stranded residues (Audisio, 2002). This typical alophilous and termophilous element can be observed along seashore, on sandy beaches but also nearby salt marsh as well as along creek bed and dunal sytems. *L. riparia* represent an indicator of coastal and fluvial riparian communities (Vigna Taglianti, 2011), which are quickly rarefying and disappearing.

INSECTA: COLEOPTERA Linnaeus, 1758

This section provides a description of the observed Coleoptera collected in the characterization of driftwoods and other woody debris. Within this research 10 families were observed (Tab. 5.87, Fig 5.32.a and 5.32.b). Some specimens collected surveying driftwood are more related to the wood itself and hardly can be considered as marine. The Cerambycid *Parmena unifasciata* (Rossi, 1790) is s quite widespread longhorn beetle and its presence in the site of Voltri is probably related to the woody wracks. Moreover, the Cryptophagid family account for a specimen of *Cryptophagus*, quite typical of these habitats as reported in previous studies (Colombini et al., 2005). Family are listed according to the Italian checklist order.

- CARABIDAE Latreille, 1810. Carabids (ground beetles) is a fairly large cosmopolitan family of 35,000 species of active invertebrates predators. Although body shapes and coloring is various, most species show a shiny black or metallic colour. These beetles are distinguishable for filiform antennae, constricted thorax, five-segmented hind tarsi. Larvae are similar to those of rove beetles, with paired urogomphi. Elytra are often fused rendering the beetles unable to fly. Within the 1,350 Italian species (Vigna Taglianti, 2005), 80 can be associated to marine environments but only a few can be regarded as "marine specialists": these ground beetles are mostly associated with marine debris stranded on sandy and pebbly beaches. *Lionychus quadrillum* (Carabidae Dromini) (Duftschmid, 1812) is a typical species of xeric habitats, as halophylous species can also be found along dried river beds. *Parophonus maculicornis* (Duftschmid, 1812) extends its distribution also to sandy areas colonized by psammophylous vegetation. *Tachyura parvula* (Dejean, 1831) represents a more obiquitarious species.
- STAPHYLINIDAE Latreille, 1802. As this family has previously been described, only an addition to the actual faunistic record is made: for other species related to vegetal debris (e.g. *Myrmecopora*), please refer to section 5.1.6. Adult *Cafius xantholoma* (Gravenhrst 1806) are highly resistant to wetting and may able to take flight directly from the water surface (Backlund, 1944).
- ELATERIDAE Leach 1815. This Coleoptera family of about 10,000 species worldwide, and around 250 Italian species (Platia, 1994). Adults posses a combination of an elongate, narrow body shape, opposed to a large and freely articulating prothorax. Legs are usually long and slender and the

head bears serrate antennae. This group shows a very different ecology between larvae, which are mostly predaceous, and adults that are related to debris- and root eaters. Their common name, *click-beetles*, comes from their ability to hop by suddenly clicking their thorax muscles. *Zorochros boubersi* Leseigneur, 1970 - not particularly related to beach environment - is the only species present in the beach of Voltri.

- NITIDULIDAE Latreille 1802, or sap beetles are a small beetle family composed by 2,800 species and 172 genera (Audisio, 1993). For Italy just 200 species are recorded, 174 of which are autochtonous, while 19 are introduced and acclimatized with certainty. Adults have elongate and depressed body with a size ranging from 1.5 to 12 mm, often with bright black or brown yellowish marks; the whole body is usually covered by a short and sparse vestiture. Nitidulidae show a broad spectrum of feeding habits: most members are primarily saprophagous and mycetophagous. Three different species not strictly related to driftwoods have been collected along Voltri site: *Carpophilus sp.*, two specimen of *Epuraea ocularis* Fairmaire, 1849, and *Stelitoda geminanta* (Say, 1825), native of Central America, North America, Oceania and South America.
- OEDEMERIDAE Latreille 1810 is a family of the superfamily Tenebrionoidea, including around 1,500 species worldwide (Campbell, 1991), which nearly 80 live in Europe, and 44 in Italy (Magistretti, 1967; Audisio & Taglianti, 2010)). Oedemeridae are soft-bodied beetles with elongated body, pronotum broadened anteriorly lacking of margin on lateral borders. Despite some species are endophytic phytophagous at the larval instar, and antophagous as adults, most Oedemerids are xylophagous. *Nacerdes melanura (Linnaeus, 1758)*, is mostly associated with coastal habitats where it regularly develops inside stranded trunks and shows a

remarkable resistance to salt water.

- ANTHICIDAE Latreille 1802 (ant-like flower beetles) is a cosmopolitan family of Coleoptera Polyphaga, represented by about 100 genera and 3,500 species worldwide (Audisio & Taglianti, 2010). An abruptly constricted head forming a neck with the pronotum wider in the anterior region and narrow in the basal ends together with a pronotal base narrower than elytral base, explain their common name of ant-beetles. All species of these saprophagous and sometimes opportunistic arthropods predators are terrestrial and live in a wide range of different habitats, including sandy ground near freshwater or marine areas. In Italy many species are related to marine debris. Other species of these psammophilous beetles are mainly related to the outer sector of the beach or other coastal habitats such as river mouths. Among Anthicidae, the genus *Anthicus* results scattered within the Mediterranean region. Specimens of *Anthicus genei* La Fert-Snectre, 1849 - a rather rare species typical of small sandy beaches of rocky coast (Audisio, 2002) was collected in 2017 Voltri surveys. Other Anthicids found in the same site belong to the species *Endomia unifasciata* (Bonelli, 1812) a typical inhabitant of arid or at least temporarily dried sandy habitats (Kejval, 1998). More euryecious and/or termophilous species are represents by *Hirticomus hispidus* (Rossi, 1792), *H. quadriguttatus* (Rossi, 1792) and *Microhoria fasciata* (Chevrolat, 1834) found in the same site.
- TENEBRIONIDAE Latreille 1802 (darkling beetles) is a large and diverse Coleoptera family represented by approx. 20,000 species worldwide (around 3,000 species in Euro-Mediterranean areas, nearly 320 in Italy) (Audisio & Taglianti, 2010). Most species are xerophilous, saprophagous and frequently associated with xeric soils, chiefly in sandy substrates, under

stones, debris, or coastal vegetation, where they constitute an important component of the Mediterranean coastal ecosystems (Fattorini, 2002). Many of these beetles live in coastal habitats, but only a few of them are regularly associated with stranded marine debris: genus *Phaleria* Latreille, 1802 is represented by eight species (Audisio & Taglianti, 2010; Löbl & Smetana, 2008) scattered in the Mediterranean basin. Along the monthly surveys in Voltri many specimens of *Phaleria bimaculata* (Linnaeus, 1758) were collected. Other three tenebrionids were classified as *Opatrum sculpturatum* Fairmaire, 1860.

- CULRCULIONIDAE Latreille 1802 encloses almost 60,000 (Arnett Jr & Thomas, 2000) species worldwide of which 2000 belong to the Italian fauna (Audisio & Taglianti, 2010). Weevils can be easily distinguished by other families for their elongate rostrum bearing the mouthpart at the apex. Antennas are geniculate with compact club. Italian weevils are phytophagous with rather few exceptions: a number of species are xylophagous, and only among them it is possible to find some intertidal elements associated with marine habitats, in particular with driftwood of any sort. *Brachytemnus porcatus* (Germar, 1824) found in the study area as well as *Amaurorhinus bewickianus* (Wollaston, 1860) more related to wet woods, where females lays eggs, and *Echinodera hypocrita* (Boheman, 1837).

Site	**Date**	**Family**	**Species**	**Abundance**
GEVO	2017 III 31	Anthicidae	*Anthicus genei* (La Fert-Senctre, 1849)	1
GEVO	2017 III 31	Anthicidae	*Hirticomus quadriguttatus* (Rossi,1792)	1
GEVO	2017 III 31	Carabidae	*Lionychus quadrillum*(Duftschmid, 1812)	2
GEVO	2017 III 31	Carabidae	*Parophonus maculicornis* (Duftschmid, 1812)	1
GEVO	2017 IV 11	Curculionidae	*Brachytemnus porcatus* (Germar 1824)	1
GEVO	2017 IV 11	Nitidulidae	*Carpophilus sp.*	1
GEVO	2017 IV 11	Anthicidae	*Endomia unifasciata* (Bonelli, 1812)	1
GEVO	2017 IV 11	Tenebrionidae	*Opatrum sculpturatum* sculpturatum Fairmaire, 1860	1
GEVO	2017 IV 11	Cerambycidae	*Parmena unifasciata* (Rossi, 1810)	1
GEVO	2017 IV 11	Carabidae	*Tachyura parvula* (Dejean, 1831)	1
GEVO	2017 IV 11	Tenebrionidae	*Phaleria bimaculata bimaculata* (Linnaeus, 1758)	2

Table 5.84: Driftwoods. Coleoptera collected among all investigated sites. GEVO = Genova Voltri; SVTM = Savona Torre del Mare; SVPP = Savona Punta Predani.

Site	**Date**	**Family**	**Species**	**Abundance**
GEVO	2017 V 11	Anthicidae	*Anthicus genei* (La Fert-Senctre, 1849, 1849)	2
GEVO	2017 V 11	Carabidae	*Apristus europaeus* Mateu, 1980	1
GEVO	2017 V 11	Anthicidae	*Endomia unifasciata* (Bonelli, 1812)	1
GEVO	2017 V 11	Anthicidae	*Hirticollis quadriguttatus* (Rossi, 1792)	1
GEVO	2017 V 11	Carabidae	*Lionychus quadrillum*(Duftschmid, 1812)	1
GEVO	2017 V 11	Anthicidae	*Microhoria fasciata fasciata*(Chevr., 1838)	1
GEVO	2017 V 11	Oedemeridae	*Narcedes melanura* (Linnaeus, 1758)	1
GEVO	2017 V 11	Nitidulidae	*Stelidota geminata* (Say, 1825)	1
GEVO	2017 V 11	Elateridae	*Zorochros boubersi* (Leseigneur, 1970)	1
GEVO	2017 V 11	Staphylinidae		1
GEVO	2017 V 11	Tenebrionidae	*Phaleria bimaculata bimaculata* (Linnaeus, 1758)	4
GEVO	2017 IX 28	Carabidae	*Apristus europaeus* Mateu, 1980	1

Table 5.85: Driftwoods. Coleoptera collected among all investigated sites. GEVO = Genova Voltri; SVTM = Savona Torre del Mare; SVPP = Savona Punta Predani.

Site	**Date**	**Family**	**Species**	**Abundance**
GEVO	2017 IX 28	Anthicidae	*Anthicus genei* (La Fert-Senctre, 1849)	1
GEVO	2017 IX 28	Tenebrionidae	*Phaleria bimaculata bimaculata* (Linnaeus, 1758)	58
GEVO	2017 X 19	Nitidulidae	*Epuraea ocularis* (Fairmire, 1849)	2
GEVO	2017 X 19	Staphylinidae	*Omalium riparium impar* Mulsant & Rey, 1862	1
GEVO	2017 X 19	Tenebrionidae	*Phaleria bimaculata bimaculata* (Linnaeus, 1758)	1
GEVO	2017 X 19	Staphylinidae		1
GEVO	2017 IX 28	Tenebrionidae	*Phaleria bimaculata bimaculata* (Linnaeus, 1758)	71
GEVO	2017 XI 15	Staphylinidae	*Cafius xantholoma* (Gravenhorst, 1806)	1
GEVO	2017 XI 15	Staphylinidae	*Omalium riparium impar* Mulsant & Rey, 1862	1
GEVO	2017 XI 15	Elateridae	*Zorochros boubersi* (Leseigneur, 1970)	1
GEVO	2017 XI 15	Tenebrionidae	*Phaleria bimaculata bimaculata* (Linnaeus, 1758)	3
SVTM	2017 XI 29	Anthicidae	*Myrmecopora (Xenusa) uvida* (Erichson, 1840)	1

Table 5.86: Driftwoods. Coleoptera collected among all investigated sites. GEVO = Genova Voltri; SVTM = Savona Torre del Mare; SVPP = Savona Punta Predani.(Follow)

Site	**Date**	**Family**	**Species**	**Abundance**
SVTM	2017 XI 29	Staphylinidae	*Proteinus ovalis* Stephens, 1834	3
SVPP	2017 XI 29	Staphylinidae	*Omalium riparium impar* Mulsant & Rey, 1862	3
GEVO	2018 III 22	Cryptophagidae	*Cryptophagus sp.*	1
GEVO	2018 III 22	Curculionidae	*Echinodera hypocrita* Boheman, 1837	1
GEVO	2018 III 22	Tenebrionidae	*Opatrum sculpturatum sculpturatum* Fairmaire, 1860	2
GEVO	2018 III 22	Tenebrionidae	*Phaleria bimaculata bimaculata* (Linnaeus, 1758)	7
GEVO	2018 IV 26	Tenebrionidae	*Phaleria bimaculata bimaculata* (Linnaeus, 1758)	16
GEVO	2018 V 17	Curculionidae	*Amaurorhinus bewickianus* (Wollaston, 1860)	1
GEVO	2018 V 17	Anthicidae	*Endomia unifasciata* (Bonelli, 1812)	1
GEVO	2018 V 17	Anthicidae	*Hirticomus quadriguttatus* (Rossi,1792)	6
GEVO	2018 V 17	Anthicidae	*Hirticollis ispidus* (Rossi, 1792)	1
GEVO	2018 V 17	Tenebrionidae	*Phaleria bimaculata bimaculata* (Linnaeus, 1758	18

Table 5.87: Driftwoods. Coleoptera collected among all investigated sites. GEVO = Genova Voltri; SVTM = Savona Torre del Mare; SVPP = Savona Punta Predani.

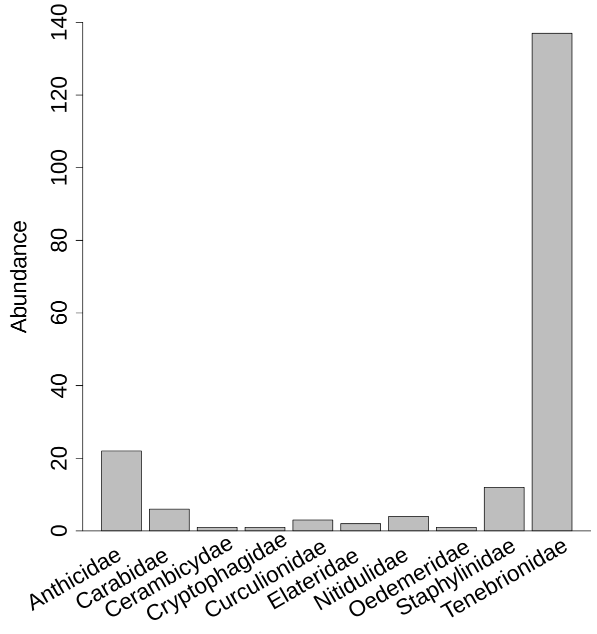

Figure 5.32.a: Absolute

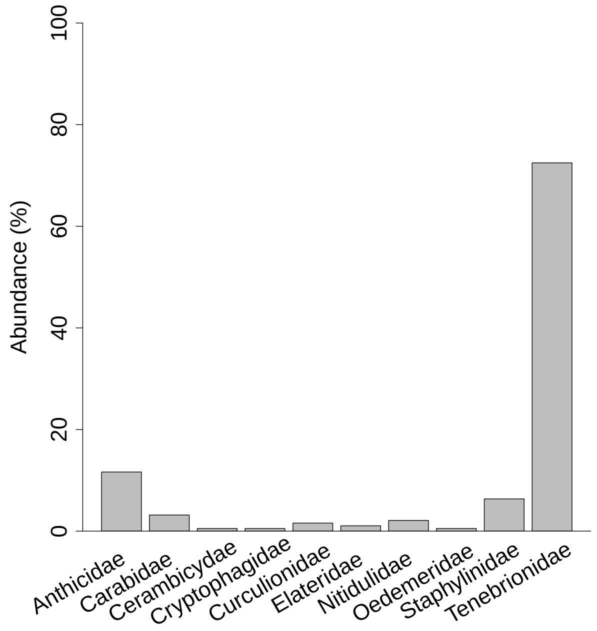

Figure 5.32.b: Relative

Figure 5.32: Driftwoods. Coleoptera families (adults) absolute (a) and relative percentage abundance (b).

INSECTA: DIPTERA Linnaeus, 1758

Diptera assemblages within driftwoods research were studied following the same experimental design provided for other taxa. Before proceeding in the description of the observed taxa a remark should be done: the collected Diptera, belonging to 19 Families (mostly adults) (Tab. 5.88, Fig. 5.33.a and 5.33.b) are not strictly related to the woody debris but can be considered - due to the high mobility of the considered order - rather euriecious and only marginally dependent from the beach environment. Diptera family previously described are not reported. Along the drifwoods study a larva of Calliphoridae was recorded but has to be considered as a casual encounter, due to the sampling strategy used.

- LIMONIDAE Speiser, 1909 is a family of Nematocera (Oosterbroek, 2006). This family includes 560 species and 70 genera morphologically distinguishable for the short and incospicuos rostrum, moniliform antenna and wing at rest carried along the body. As their related family Tipulidae, Limonidae inhabit a wide range of habitats and micro-habitats chatacterized by high moist gradient: from soils rich in humus as well as leaf litter, swamps and marshes. Limonidae also successed in colonizing the intertidal and brackish water environments.
- ANTHOMYZIDAE Czerny, 1903 is a small Family (around 100 species) of slender-bodied acalyptrate flies, with long narrow wings and relatively short legs. The majority of Palaearctic species of Anthomyzidae are only active in the daytime. Adults are usually associated with meadow and grassland with a discrete moist gradient (Roháček, 2006). Some species of the genus *Cercagnota* are preferentially associated with coastal swamps and saltmarshes, or anymway related to halophilous vegetation (Rohácek, 1999).

- Drosophilidae Rondani, 1856 constituts a cosmopolitan family of acalyptrate Brachycera represented in the Paleartic region by 17 genera and about 120 species (Bächli, 2015). Dropsophilidae are minute to medium sized (1.5-7 mm) flies, with variable body colour, from yellow to brownish to black, showing often a striped pattern on thorax and abdomen and with eyes often clear red. Recognizeble characters are tibiae always remarkably with dorsal preapical bristle, incomplete subcostal vein, and usually plumose arista with both dorsal and ventral rays. Adults are attracted by generic rotting organic material, though some species are usually found along seashore (Escher et al., 2004). Some specimens belonging to the genus *Drosophila* were collected from Punta Predani trapping session.
- Scatopsidae Newman, 1834 is represented by 350 species in 32 genera (Wagner et al., 2008) of small midges described among all zoogeographic regions. Scatopsidae are minute to small, rather stoutly built, generally blackish midges with holoptic eyes, with a typical eye-bridge above antennae (Oosterbroek, 2006) and with reduced wing venulation. Adults are found in a wide range of habitats, with slightly preference for marshy and open areas: water related species have been recorded only from the Palaearctic region with particular reference to immature saprophagous instars inhabitating decomposing material. Only one specimen was collected within Voltri surveys.
- Chloropidae Rondani, 1856 is a family of acalyptratrated flies distributed worldwide and globally comprises 200 genera and about 3,000 species in 4 subfamilies (Nartshuk, 2014). European species account for 65 genera and about 395 species (Oosterbroek, 2006). Adults are encountered chiefly in open habitats such as meadows and marshlands:

several species are related to flowers. These flies show great color range, from black to gray to yellow, the mesonotum often has a striped pattern. The presence of this family in the sampling site of Voltri may be related to the presence of *Crithmum maritimum* L..

- SYRPHIDAELatreille, 1802 is a family of cyclorrhaphan flies which accounts 90 genera and about 830 species in Europe (Oosterbroek, 2006). The general body shape range from slender to stout flies, often with white or yellow marks on the head, but more often on the abdomen. The most remarkable features of this Family is the batesian mimicry. Adults are often abundant and occur at low and high altitudes where they are found in a wide range of habitats, from deserts to rain forests: some species are coastal in distribution such as the common European syrphid, *Eristalinus aeneus* (Hartley, 1961).
- HELCOMYZIDAE Hendel, 1924 is a small group of acalyptrate Brachycera represented in Europe by only two species, while the group is widely diffused and diversified in New Zealand and South America. Once the family was included together with Dryomyzida in the superfamily Sciomyzoidea (Steyskal, 1957). Usually these flies show grey pruinose color pattern, sometimes with cryptic mimicry pattern and are densely covered with fine setae. Species of this small family occur along the coast where the adults are often found on the beach, making a short flight when disturbed. The larvae live in seaweed washed up on the shore and which has dried to a greater extent than the seaweed in which Coelopidae live (Oosterbroek, 2006).
- HYBOTIDAE Falln, 1816) is a small group of Brachycera enclosing 440 species once considered a subfamily of Empididae (Chvála, 1983). Adults are medium sized flies, usually dark but variable in colour, with a general

slender and thin body with rather round head which bears big usally-holopctic eyes. Adults prey on small insects and other arthropods, catching their prey in flight or while walking or running about on the ground, as well as or tree trunks and leaves. These flies can also be spotted among the the decomposing wrack as well as running on the wet sand (Yerbury, 1919).

- SCATOPHAGIDAE Robineau-Desvoidy, 1830 is a Brachycera Family mainly spread across the Palearctic and Nearctic regions with only few species from the Southern Hemisphere. The group counts worldwide 500 species placed in 66 genera, of which 160 in Europe (Oosterbroek, 2006)) of bristled usually dark-coloured flies, with slender body with an elongated, cylindrical abdomen. Wings are usually clear - not rarely, clouded crossveins or other wing pigmentations can be observed. Adults hunt for insects or other small invertebrates and many species are coprophagous. Some specimens were found inside pit-fall traps placed in Voltri.
- DOLICHOPODIDAE *sensu latu*includes the subfamilies Parathalassiinae and Microphorinae. The latter of these was formerly placed in th Empididae, and Microphoridae was once considered a separate family (Sinclair & Cumming, 2006). The adults of Microphorinae are predators mainly on flying Diptera, but some species forage by walking about on tree trunks or prey on aquatic insects, including those that have just pupated near to the shoreline.
- TEPHRITIDAE Newman, 1834 is a Brachycera Family represented in Europe by 70 genera and 270 species (Oosterbroek, 2006). Tephritidae are usually colourful flies and wings show characteristic markings and vein Sc abruptly bent forward toward the costa making a nearly right angle. Adult Tephritidae are good fliers often found on the host plant

or while feeding on nectar, pollen, plant juices, rotting plant material or honeydew. A specimen collected in Punta Predani belonged to species *Ceratitis capitata* the Mediterranean fruit fly, not related to the shoreline environment, but widely known from most warm temperate and tropical countries.

Site	**Date**	**Family**	**Abundance**
GEVO	2017 III 31	Sciaridae Billberg, 1820	2
GEVO	2017 IV 11	Canacidae Jones, 1906	3
GEVO	2017 IV 11	Heleomyzidae Westwood 1840	2
GEVO	2017 IV 11	Hybotidae, Falln, 1816	1
GEVO	2017 V 11	Calliphoridae	1
GEVO	2017 V 11	Canacidae Jones, 1906	2
GEVO	2017 V 11	Drosophilidae ,Rondani, 1856	1
GEVO	2017 V 11	Ephydridae Zetterstedt, 1837	1
GEVO	2017 V 11	Heleomyzidae Westwood 1840	1
GEVO	2017 V 11	Sciaridae Billberg, 1820	1
GEVO	2017 IX 28	Canacidae Jones, 1906	2
GEVO	2017 IX 28	Scatopsidae Newman, 1834	1
GEVO	2017 IX 28	Sciaridae Billberg, 1820	1
GEVO	2017 X 19	Canacidae Jones, 1906	1
GEVO	2017 X 19	Chironomidae Newman, 1836	1
GEVO	2017 X 19	Limoniidae Speiser, 1909	1
GEVO	2017 XI 15	Canacidae Jones, 1906	3
GEVO	2017 XI 15	Drosophilidae Rondani, 1856	1
GEVO	2017 XI 15	Microphridae Latreille, 1809	1
GEVO	2017 XI 15	Tephritidae Newman, 1834	1
SVTM	2017 XI 29	Anthomyzidae Czerny, 1903	1

SVTM	2017 XI 29	Coelopidae Hendel, 1910	1
SVTM	2017 XI 29	Heleomyzidae Westwood 1840	1
SVTM	2017 XI 29	Syrphidae Latreille, 1802	1
SVPP	2017 XI 29	Canacidae Jones, 1906	3
SVPP	2017 XI 29	Drosophilidae Rondani, 1856	12
SVPP	2017 XI 29	Helcomyzidae Hendel, 1924	1
SVPP	2017 XI 29	Heleomyzidae Westwood 1840	2
SVPP	2017 XI 29	Hybotidae Falln, 1816	1
SVPP	2017 XI 29	Scatophagidae Robineau-Desvoidy, 1830	2
SVPP	2017 XI 29	Sciaridae Billberg, 1820	1
GEVO	2017 III 22	Chironomidae Newman, 1836	1
GEVO	2017 III 22	Hybotidae Falln, 1816	1
GEVO	2017 III 22	Sciaridae Billberg, 1820	3
GEVO	2017 III 22	Sepsidae Walker, 1833	1
GEVO	2017 V 17	Chironomidae Newman, 1836	1

Table 5.88: Driftwoods. Diptera families (adult stage) collected among all investigated sites. GEVO = Genova Voltri; SVTM = Savona Torre del Mare; SVPP = Savona Punta Predani.

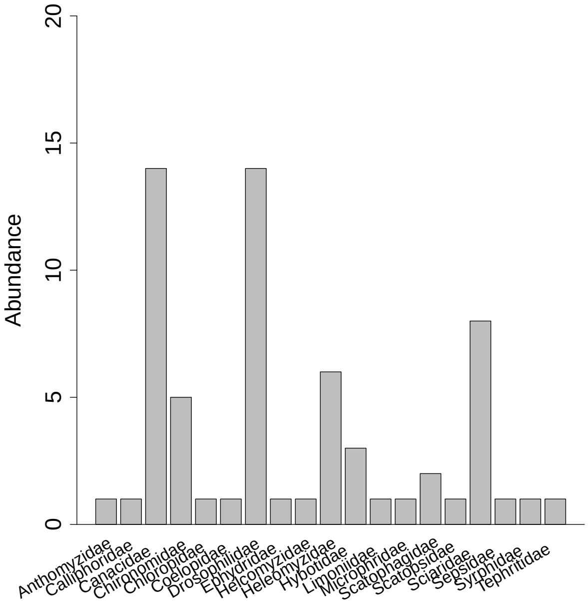

Figure 5.33.a: Absolute

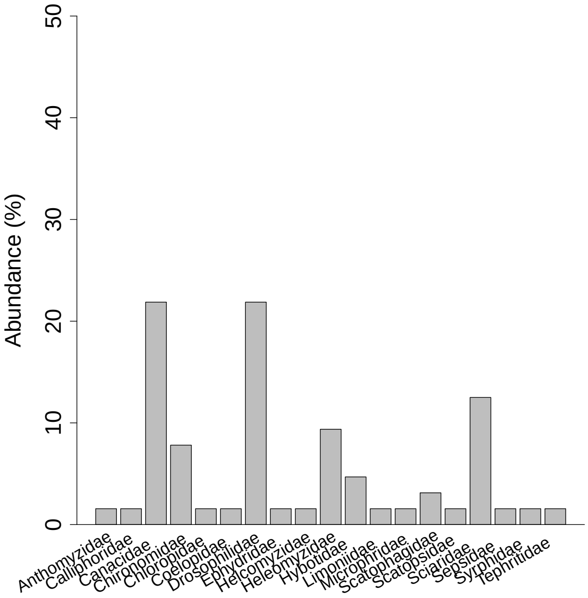

Figure 5.33.b: Relative

Figure 5.33: Driftwoods. Diptera families (adults) absolute (a) and relative percentage abundance (b).

Chapter 6

Discussions

Discussed results aim to connect the different applied approaches to give a meaningful description of *P. oceanica* and drifwoods communities. Proposed models seem to confirm what reported in previous works (Barboza et al., 2012; Colombini et al., 2008) about the importance of physical parameters (e.g. pH and Mz) as driving factors in determining richness and abundance.

6.0.1 The rarer the richer

Results confirm the renowned structure according which, in multispecies communities most of the detected diversity only comes from some common species. A lot of research enlightens the important patterns linking species abundance, number of individuals and singletons and doubletons. Most species-rich sites are usually characterized by high numbers of so called *rare species* with particular emphasis of those sampled as doubletons while individual abundance only marginally account: Bergeggi host almost twice the species richness than Recco. However the number of individuals collected greatly differs among sites. On the other hand, several test show that individual abundance only marginally account to taxonomic richness.

6.1 ***Posidonia oceanica*** banquettes

6.1.1 Environmental variables

Within the study of the banquettes-associated arthropods, the analysis of environmental variables describe their variation in space: wordclim data provide a general geographic discrimination based on climatic data at regional scale, describing site according different climatic conditions. Field collected variables provide a measure of the habitats at a fine scale resolution, describing micro-environmental conditions in sampled site. These variables have been considered descriptors of processes influencing physical and chemical alteration that involve *P. oceanica* such as temperature and pH changes together with the sea action and the management of the investigated beach.

6.1.2 Arhtropods communities

P. oceanica banquette related communities greatly change in terms abundance an composition between sites. Even if MDS and ANOSIM do not show consistent differences among levels and sites, the taxonomy allowed the identification of a total of 34 taxa differently adapted to the beach environment. These faunal assemblages are mainly composed by Collembola, Diptera and Coleoptera, both immature and adults, which complete their life cycle in the banquettes. Most of the described taxa for *P. oceanica* wracks are represented by detritovours organisms related to decaying matter. This guild can be further splitted into two groups: true grazers such as Collembola and some Diptera larvae and macro-detritivorous forms like many adult Coleoptera. Other taxa such as many adult Brachycera exploit biofilm that covers sand grains or fungi which growth inside decaying *P. oceanica*. Some anthropogenic and disturbed environments - related species are represented by different ant genera. Thanks to the identification carried out by specialists, it has been possible to record one new coleoptera species for Liguria (*Cartodere bifasciata*) and one new spider species for Italy (*Chaerea maritimus*). These records are examples of the low degree of knowledge of these environment.

6.1.3 Asymptotic estimation

Asymptotic estimators within sample based workframe give a satisfactory overview of *P. oceanica* related-arthropods for all sampled banquettes as in most cases at least one of them reaches a clear monotonic trend. For every sampling site according to asymptotic estimation, species richness is generally underestimated.Nevertheless some differences in estimating species richness within the same site are related to the formulation of the estimator itself: to provide a more precise estimation the use of incidence-based estimators is recommended to mitigate possible biasses coming from overall abundant taxa, such as mite and Collembola. According to observed community composition, Jackkinfe estimators are the most regular in reaching the asymptote: this class of estimators provides higher richness values for those sampling sites that are characterized by many rare species (singletons and doubletons) and by lower level of dominance, though not consistent in terms of abundance. The use of ICE estimators can sometimes lead to some strange behaviour imputable to the difficulty to set a proper cut-off value to discriminate rare and common species and its use is not recommended in exploratory surveys like this one. Also in this case, however, the so called rare species (singletons and doubletons) play a relevant role in the observed taxonomical richness, and such issue must be kept in mind before choosing the most suitable estimator.

6.1.4 Diversity in space

Differences in calculated indices express differences between sites according climatic and environmental conditions. Low values of Shannon diversity for Recco *P. oceanica* banquette can be interpreted according an ecological and taxonomical point of view: low values can potentially infer to simple foodwebs (low entropy) or highly disturbed habitats, where few taxa - sometimes abundant - are present. The variation in terms of richness, structure and composition highlights the importance of taxonomical contribution to solve ecological questions. Communities greatly change among sampling sites in response to several factors: highly anthropogenic impacted beaches are not strictly related to low diversiy values. The asymptotic estimation for the site of Nervi lead to a number raging from 24.70 to 26.78, comparable to values estimated for Cipressa (2017: from 32.45 to 44.09; 2018: from 13.70 to 24 taxa). This resemblance can be misunderstood without looking to other analysis such as Simper that compared Nervi with the other two communities. Significant contribution are given by ant genus *Plagiolepis*, and Diptera Families Sciaridae and Psychodidae, which are two taxa typically related to anthropogenic environments.

6.1.5 Diversity in time

The same community can also experience great changes across time in terms of consistence and composition, as can be observed within the comparison of Cipressa sampling site in two consecutive years: surveys collected a total of 1,013 individuals for 2017 and only 477 for 2018. Non parametric asymptotic estimation, performed on a even reference sample of 20 coils, seems to confirm what stated with a clear asymptote of both class of estimators (abundance based and incidence based) for the analysed communities estimating from 32.45 to 44.09 species for the year 2017, and from 13.70 to 24 species supported by significance test.

It is also interesting to observe from a diversity perspective that the analysed communities show relatively closer values of richness (Shannon) and dominance (Simpsons), but uneven values in composition, as evenness differs significatively for the two years, suggesting that in the last survey community was more homogeneous being represented by a reduced yet abundant number of taxa. Thus, it is possible to hypothesize through collected information some kind of dynamics according which the first two indices are rather constant, while the relative-abundance of each taxa is a more time-related value. This dynamics can be achieved with some taxa overall present along the year, while some others are replaced along a temporal gradient, together with the ecological need of each group, as can be observed in Simper analysis comparing the two investigated communities.

6.1.6 Modelling diversity in space

P. oceanica banquette models aim to describe - with their limits - diversity across site: Shannon entropy model, related to overall organism abundance, shows increasing values for smaller size sediment that can be linked to increasing trophic availability or pattern of movement also for immature instars such as Coleoptera or Diptera. Entropy tends to increase with higher pH values. Increasing rainfall contributes to keep high level of moist, which are essential for the survival of many taxa, such as the above mentioned larvae or Collembola, the latter mostly related to the proliferation of fungi on decaying material. Simpson Dominance model is quite interesting: it shows that diversity decreases as the diurnal range, increases indicating that these community are related to less-xeric condition. Moreover, the diversity increases with the increase of the maximum temperature which probably promote organisms life cycles or movements, and the development of fungi responsible for the degradation of organic matter. Also for this model, rain meaning may be related to the moisture conditions of the banquette.

6.2 Driftwoods

6.2.1 Environmental variables

Within the study of driftwoods, the environmental variables address a seasonal-related dynamics: wordclim data provide climatic information for the sampling months. Field collected variables measure the abiotic factors of the environments influencing the arthropods communities. Mean grains size differences between two consecutive years provide a useful element to describe the set up modifications, while surface temperature describes at fine scale the influence upon arthropod assemblages.

6.2.2 Arhtropods communities

Driftwood-related fauna accounts for the site of Voltri more than 40 species, where the number of singletons and doubletons is rather high. Community analysis across two consecutive sampling seasons through MDS, PERMANOVA and Simper do not give meaningful results. Within this site, community it's composed mainly by adult lifeforms, but this is due to the sampling technique itself. The presence of a highly diverse xylophagous Coleoptera community shows the importance of driftwoods in increasing biodiversity. It's interesting to observe some kind of trend among months: while Shannon index and Simpson Dominance increase their values towards warmer periods, Pielou's evenness shows a rather straight trend. Simpson index reaches is higher values in September. Going towards the hot season, community faces more stress and only more thermopilous- erebic taxa increase their dominance within the community.

6.2.3 Diversity towards time & space

The use of Hills number trough a R/E (rarefaction and extrapolation) framework represents a powerful tool to infer meaningful comparisons in terms of completeness rather than in size between taxonomic richness and community composition, also in those cases with large differences among sampling observations . Rarefaction highlights how the driftwood contributes to increase species richness even in a more disturbed context (Voltri), compared to a less disturbed site not interested by driftwood provision (Predani). Extrapolation shows that even doubling minimum sample size, sites free from conspicuous driftwoods or heavily managed for turistical purpose cannot account for the same biodiversity compared to more abandoned one. The same framework allow to observe richness variation along time: the rarefaction of the 2017 sampling season to allow comparison with 2018 surveys show for the first year a more rich community. The extrapolation of the 2018 data survey to the size of the 2017 confirm once more higher estimated values for the latter. This difference related to two sampling seasons across the same site could be addressed to the different status and the type of the stranded materials as well as by its position across the beach.

6.2.4 Pitfall Collembola GLMs

Springtail lifeforms exhibit differential sensitiveness to environmental variables. Because models describing collembola lifeforms abundance have been fitted trough almost the same variables, a comparison can be made to assess which parameter has more weight on the abundance of a given lifeforms according to its degree of adaptation to below-ground life. As Euedaphic models have been rejected, only Epedaphic, Hemiedaphic and Atmobiotic models could be discussed. Atmobiotic Collembola abundance was modelled through five variable parameters, of which only one shows evident effects. The relationship of these lifeforms to above ground environment can be described by their preference for fine sediment (increased mobility) and the relative distance from the wrack which probably interferes with dwelling activities. Within the epedaphic lifeforms the first full-averaged model shows a quite positive influence of the measured T. The second more complex model, shows the multiple effect of five parameters (three of which highly significant) on the estimated abundance: as these organisms tend to be more upper-surface dwellers, the wind accounts for a negative effect as probably discourages movements, which will expose these animals to its dangerous power. As more related to the surface, these Collembola show thermophilous attitude that explains the great positive effect of the temperature. The positive effect of the increasing grain size can be explained according mobility patterns and trophic behaviour related to the vegetal detritus and biofilm on which these Collembola rely on. Emiedaphic lifeform has been described trough a six parameter model: all variables included, with the exception of the distance from the swash line, account for significative and meaningful values. The negative weight of the diurnal range can be interpreted in relation to the more below-ground attitude of these springtails. The detrimental effect of the increasing grain size support the hypothesis of the adaptation to below ground preferences. The huge effect of the wind is quite doubtful and the only hyphotesis that can be addressed is its dispersal effect and its drying action.

6.2.5 Modelling diversity in time

Pielou's evenness (J') has been described by two averaged models. The first diurnal range-related model has been fitted through five variables, three of which have significant values in estimating evenness: higher temperatures promote increasing estimated values as well as grain size. These two factors potentially could describe the change toward more termophilous communities, more related to fine incoherent substratum. The second model give further consistence to the previous hypothesis with T and Mz coefficient highly meaningful in estimating evenness. The wind effect, even if significant marginally affects predicted values.

Chapter 7

Conlusions

7.1 Methodological approach

From a methodological point of view, best results come from pit-fall trapping surveys that allow to collect several data with a relatively low sampling effort: differently from *P. oceanica* coil-sampling, this technique is not related to the presence of the vegetal necromasses. On the other hand, coil-sampling and the following Berlese-Tullgren extraction turn to be very useful to collect immature instars and smaller arthropods like Acarina and Collembola.

The analysis through presence-absence results highly useful to compare sampling sites attenuating extreme values coming from highly disturbed situations. Abundance data are more likely to be used within the same site as they preserve a better descriptive power.

A good option as emerged by between-sites comparisons is represented by the use of indices, with particular reference to the Simpson (D) index which provide information more related to community composition and therefore it represents a good proxy of the status of the investigated community. The weakness of some models may be caused mainly by the rarefied chronological continuum of the sampling activity and by the large-scale variables such as monthly mean rainfall: more fine scale measurements could provide better predictive models and estimation.

7.2 Biological value

The current work is far to be an extensive account of the great biological diversity which characterizes the ephemeral habitats as already pointed out by several works (Munari, 2010; Audisio & Taglianti, 2010). However it represents the first multilevel study which tries to relate - even if partially - the taxonomical aspect to the ecological context of these peculiar ecotones. Collected specimens belong to taxa observed also for more natural context (Colombini et al., 2005) even if with more consistent populations.

Both driftwoods and banquettes represent true biodiversity hotspot hosting quite complex arthropods communities described by a consistent species density and several specialized taxa as emerged by richness estimation and community composition analysis. Nevertheless, the asymptotic approach leaves space for greater species richness values. The discover of unknown species at local or national level that belongs to different taxa such as *Anthicus genei* La Fert-Snectre, 1849 and *Chaerea maritimus* Simon, 1884 are just example of what stated.

7.3 Raising concerns

The presence of *P. oceanica* banquettes and driftwoods greatly increases the coastal biodiversity. The increasing anthropogenic pressure on the coastal area - to which the investigated habitats belong to - represents without any doubt a huge threat for the biodiversity of these environments.

The vital relationship between the wracks on which these communities rely on is the measure of the fragility of these environments where dozens of species depend just on these allochthonous inputs coming from the sea. Concerns have to be addressed against recreational-only management strategies which can ruin the biodiversity of these habitats and the well-functioning of the related environment. Oculated management strategies are required to protect and preserve the high biological values of these ephemeral habitat both in protected (Onori et al., 2009) and urbanized areas (Borriello et al., 2010).

Appendices

.1 Tables Appendix

.1.1 Simper Tables

Taxa	**Average**	**Ratio**	**ava**	**avb**	**cumsum**	**p-val.**
Anthomyiidae larva	0.126	0.73	0.67	0.8	0.17	0.63
Plagiolepis	0.099	0.76	0.39	0.0	0.30	$1.99 \times 10^{-3}*$
Sphaeroceridae adult	0.051	0.53	0.22	0.0	0.37	0.33
Sciaride adult	0.051	0.51	0.22	0.0	0.44	0.18
Coleoptera larva	0.048	0.53	0.22	0.0	0.51	0.10
Psychodidae adult	0.041	0.53	0.22	0.0	0.56	0.06
Staphylinidae	0.039	0.33	0.11	0.0	0.62	0.99
Zygentomata	0.038	0.38	0.06	0.1	0.67	0.07 .
Hemiptera	0.037	0.32	0.11	0.0	0.72	0.08
Chironomidae larva	0.037	0.32	0.11	0.0	0.77	0.10
Cryptophagidae	0.030	0.32	0.00	0.1	0.81	0.15
Ponera	0.028	0.34	0.11	0.0	0.85	0.11
Psocoptera	0.022	0.32	0.00	0.1	0.88	0.49
Dermestidae	0.022	0.32	0.00	0.1	0.92	0.37
Heleomyzidae adult	0.013	0.24	0.06	0.0	0.94	0.53
Sespidae adult	0.013	0.24	0.05	0.0	0.95	0.16

Table 1: Simper: contrast between Nervi and Recco (= significative p-value).*

Taxa	**Average**	**Ratio**	**ava**	**avb**	**cumsum**	**p-val.**
Anthomyiidae larva	0.117	0.95	0.67	0.33	0.14	0.92
Coleoptera larva	0.099	0.95	0.22	0.53	0.26	0.49
Plagiolepis	0.079	0.74	0.39	0.00	0.35	$2.99 \times 10^{-3}*$
Sphaeroceridae adult	0.054	0.54	0.22	0.07	0.41	0.24
Staphylinidae	0.049	0.47	0.11	0.13	0.47	0.97
Psychodidae adult	0.041	0.58	0.22	0.07	0.52	$4.09 \times 10^{-2}*$
Sciaride adult	0.041	0.50	0.22	0.00	0.57	0.32
Ephydridae larva	0.041	0.57	0.00	0.27	0.62	0.22
Talitridae	0.033	0.44	0.06	0.13	0.66	0.59
Ptiliidae	0.030	0.38	0.00	0.13	0.69	0.50
Hemiptera	0.027	0.31	0.11	0.00	0.72	0.25
Chironomidae larva	0.027	0.31	0.11	0.00	0.76	0.23
Psocoptera	0.027	0.38	0.00	0.13	0.79	0.31
Ponera	0.022	0.33	0.11	0.00	0.82	0.23
Chironomidae adult	0.020	0.25	0.00	0.07	0.84	0.31
Dolichopodidae larva	0.018	0.36	0.00	0.13	0.86	0.06
Dermestidae	0.015	0.26	0.00	0.07	0.88	0.52
Histeridae	0.012	0.26	0.00	0.07	0.89	0.24
Heleomyzidae adult	0.011	0.24	0.06	0.00	0.91	0.75
Sespidae adult	0.011	0.24	0.06	0.00	0.92	0.45
Latridiidae	0.011	0.24	0.06	0.00	0.93	0.45
Muscidae larva	0.010	0.26	0.00	0.07	0.94	0.22
Zygentomata	0.001	0.24	0.06	0.00	0.95	0.73

Table 2: Simper: contrast between Nervi and Cipressa (2017) (= significative p-value).*

Taxa	**Average**	**Ratio**	**ava**	**avb**	**cumsum**	**p-val.**
Staphylinidae	0.125	1.08	0.11	0.67	0.15	$2.99 \times 10^{-3}*$
Anthomyiidae larva	0.112	0.99	0.67	0.33	0.28	0.97
Coleoptera larva	0.093	0.95	0.22	0.53	0.39	0.67
Plagiolepis	0.074	0.73	0.39	0.00	0.48	$1.99 \times 10^{-3}*$
Talitridae	0.041	0.42	0.06	0.13	0.52	0.39
Sphaeroceridae adult	0.039	0.51	0.22	0.00	0.57	0.62
Sciaride adlt.	0.039	0.50	0.22	0.00	0.62	0.35
Chaerea maritimus	0.037	0.58	0.00	0.27	0.66	$5.99 \times 10^{-3}*$
Psychodidae adult	0.033	0.52	0.22	0.00	0.70	0.22
Stenophiloscia glarearum	0.029	0.48	0.00	0.20	0.73	$1.69 \times 10^{-2}*$
Ptiliidae	0.027	0.33	0.00	0.13	0.76	0.55
Hemiptera	0.026	0.31	0.11	0.00	0.79	0.28
Chironomidae larva	0.026	0.31	0.11	0.00	0.83	0.26
Chaerea maritimus	0.025	0.49	0.00	0.20	0.86	$1.99 \times 10^{-2}*$
Ephydridae larva	0.024	0.38	0.00	0.13	0.88	0.71
Ponera	0.021	0.33	0.11	0.00	0.91	0.27
Simphyla	0.019	0.35	0.06	0.06	0.93	0.22
Pauropoda	0.010	0.26	0.00	0.06	0.94	0.39
Coleopidae larva	0.010	0.26	0.00	0.06	0.95	0.25

Table 3: Simper: contrast between Nervi and Bergeggi (= significative p-value).*

Taxa	**Average**	**Ratio**	**ava**	**avb**	**cumsum**	**p-val.**
Anthomyiidae larva	0.178	1.04	0.8	0.33	0.22	$9.992 \times 10^{-3}*$
Coleoptera larva	0.126	0.99	0.0	0.53	0.38	0.032∗
Psocoptera	0.055	0.49	0.1	0.13	0.45	0.017∗
Ephydridae larva	0.052	0.57	0.0	0.27	0.51	0.104
Ptiliidae	0.042	0.39	0.0	0.13	0.57	0.250
Dermestidae	0.042	0.41	0.1	0.07	0.62	0.029∗
Talitridae	0.037	0.38	0.0	0.13	0.70	0.476
Staphylinidae	0.037	0.38	0.0	0.13	0.71	0.980
Zygentomata	0.033	0.31	0.1	0.00	0.75	0.208
Cryptophagidae	0.033	0.31	0.1	0.00	0.80	0.117
Sphaeroceridae adult	0.031	0.26	0.0	0.07	0.83	0.694
Chironomidae adult	0.031	0.26	0.0	0.07	0.87	0.164
Dolichopodidae larva	0.023	0.36	0.0	0.13	0.90	0.067
Histeridae	0.016	0.27	0.0	0.07	0.92	0.170
Muscidae larva	0.013	0.27	0.0	0.07	0.94	0.155
Psychodidae adult	0.013	0.27	0.0	0.07	0.95	0.771

Table 4: Simper: contrast between Recco and Cipressa 2017 (= significative p-value).*

Taxa	**Average**	**Ratio**	**ava**	**avb**	**cumsum**	**p-val.**
Staphylinidae	0.184	1.19	0.0	0.67	0.21	$9.992 \times 10^{-3}*$
Anthomyiidae larva	0.182	1.04	0.8	0.33	0.42	$7.992 \times 10^{-3}*$
Coleoptera larva	0.118	0.97	0.0	0.53	0.56	0.08 .
Talitridae	0.052	0.38	0.0	0.13	0.61	0.22
Chaerea maritimus	0.047	0.58	0.0	0.27	0.67	$6.99 \times 10^{-3}*$
Ptiliidae	0.040	0.33	0.0	0.13	0.72	0.30
Stenophiloscia glarearum	0.036	0.48	0.0	0.20	0.76	0.02*
Ephydridae larva	0.032	0.39	0.0	0.13	0.79	0.50
Chaerea maritimus	0.031	0.50	0.0	0.20	0.83	0.01*
Zygentomata	0.030	0.31	0.1	0.00	0.86	0.24
Cryptophagidae	0.031	0.31	0.1	0.00	0.90	0.14
Psocoptera	0.023	0.32	0.1	0.00	0.93	0.47
Dermestidae	0.023	0.32	0.1	0.00	0.95	0.33

Table 5: Simper: contrast between Recco and Bergeggi (= significative p-value).*

Taxa	**Average**	**Ratio**	**ava**	**avb**	**cumsum**	**p-val.**
Anthomyiidae larva	0.313	1.39	0.8	0.2	0.37	$9.99 \times 10^{-4}*$
Sciaride adult	0.093	0.49	0.0	0.2	0.48	0.02*
Sphaeroceridae adult	0.093	0.49	0.0	0.2	0.59	0.07
Heleomyzidae adult	0.093	0.49	0.0	0.2	0.70	$7.992 \times 10^{-3}*$
Coleoptera larva	0.093	0.49	0.0	0.2	0.80	0.60
Zygentomata	0.050	0.33	0.1	0.0	0.86	0.10
Cryptophagidae	0.050	0.33	0.1	0.0	0.92	0.08

Table 6: Simper: contrast between Recco and Cipressa 2018 (= significative p-value).*

Taxa	**Average**	**Ratio**	**ava**	**avb**	**cumsum**	**p-val.**
Staphylinidae	0.135	1.06	0.13	0.67	0.17	$7.992 \times 10^{-3}*$
Coleoptera larva	0.105	0.92	0.53	0.53	0.30	0.26
Anthomyiidae larva	0.101	0.77	0.33	0.33	0.42	0.99
Canacidae larva	0.057	0.65	0.27	0.13	0.50	$1.29 \times 10^{-2}*$
Talitridae	0.057	0.50	0.13	0.13	0.56	0.10
Ptiliidae	0.052	0.48	0.13	0.13	0.63	0.07
Chaerea maritimus	0.039	0.57	0.00	0.27	0.68	$3.996 \times 10^{-3}*$
Stenophiloscia glarearum	0.030	0.47	0.00	0.20	0.72	$1.99 \times 10^{-2}*$
Psocoptera	0.027	0.37	0.13	0.00	0.75	0.44
Chaerea maritimus	0.026	0.49	0.00	0.20	0.79	$1.59 \times 10^{-2}*$
Sphaeroceridae adult	0.020	0.25	0.07	0.00	0.81	0.92
Chironomidae adult	0.020	0.25	0.07	0.00	0.84	0.43
Dolichopodidae larva	0.019	0.36	0.13	0.00	0.86	0.19
Pauropoda	0.016	0.36	0.07	0.06	0.88	0.20
Dermestidae	0.015	0.26	0.07	0.00	0.90	0.67
Simphyla	0.013	0.26	0.00	0.07	0.91	0.41
Histeridae	0.012	0.26	0.07	0.00	0.93	0.47
Coleopidae larva	0.011	0.26	0.00	0.07	0.94	0.38
Muscidae larva	0.010	0.26	0.07	0.00	0.96	0.46

Table 7: Simper: contrast between Cipressa 2017 and Bergeggi (= significative p-value).*

Taxa	**Average**	**Ratio**	**ava**	**avb**	**cumsum**	**p-val.**
Coleoptera larva	0.145	0.92	0.53	0.2	0.16	0.02*
Anthomyiidae larva	0.143	0.75	0.33	0.2	0.33	0.31
Sphaeroceridae adult	0.086	0.52	0.07	0.2	0.42	0.09
Sciaride adlut	0.066	0.46	0.00	0.2	0.50	0.12
Heleomyzidae adult	0.066	0.46	0.00	0.2	0.60	0.08
Ephydridae larva	0.054	0.57	0.27	0.0	0.63	0.15
Ptiliidae	0.044	0.39	0.13	0.0	0.69	0.28
Talitridae	0.039	0.39	0.13	0.0	0.73	0.45
Psocoptera	0.039	0.39	0.13	0.0	0.77	0.24
Staphylinidae	0.039	0.39	0.13	0.0	0.82	0.93
Chironomidae adult	0.033	0.27	0.07	0.0	0.86	0.08
Dolichopodidae larva	0.024	0.36	0.13	0.0	0.88	0.10
Dermestidae	0.022	0.27	0.07	0.0	0.91	0.22
Histeridae	0.017	0.27	0.07	0.0	0.93	0.08
Muscidae larva	0.013	0.27	0.07	0.0	0.94	0.08
Psychodidae adlut	0.013	0.27	0.07	0.0	0.96	0.59

Table 8: Simper: contrast between Cipressa 2017 and Cirpessa 2018 (= significative p-value).*

Taxa	**Average**	**Ratio**	**ava**	**avb**	**cumsum**	**p-val.**
Staphylinidae	0.192	1.19	0.67	0.0	0.21	$1.99 \times 10^{-3}*$
Coleoptera larva	0.135	0.91	0.53	0.2	0.36	0.06
Anthomyiidae larva	0.113	0.74	0.33	0.2	0.48	0.80
Sciaride adlt.	0.061	0.46	0.00	0.2	0.55	0.14
Sphaeroceridae adult	0.061	0.46	0.00	0.2	0.61	0.27
Heleomyzidae adult	0.061	0.46	0.00	0.2	0.68	0.09
Talitridae	0.056	0.38	0.13	0.0	0.74	0.25
Chaerea maritimus	0.048	0.58	0.27	0.0	0.79	0.05
Ptiliidae	0.043	0.33	0.13	0.0	0.84	0.30
Stenophiloscia glarearum	0.037	0.48	0.20	0.0	0.88	0.11
Ephydridae larva	0.033	0.39	0.13	0.0	0.92	0.47
Chaerea maritimus	0.032	0.50	0.20	0.0	0.95	0.09

Table 9: Simper: contrast between Bergeggi and Cirpessa 2018 (= significative p-value).*

Bibliography

Akaike, H. (1998). Information theory and an extension of the maximum likelihood principle. In *Selected papers of hirotugu akaike* (pp. 199–213). Springer.

Alexander, K. N. (2006). The habitat preferences of polyxenus lagurus (linné). *Bulletin of the British Myriapod and Isopod Group*, *21*, 12–13.

Anderson, M. J. (2001). A new method for non-parametric multivariate analysis of variance. *Austral ecology*, *26*(1), 32–46.

Annuario dei dati ambientali. (2010). Via Brancati, 48 - 00144 Roma: ISPRA. Retrieved from `https://annuario.isprambiente.it/pdf/tematiche-2010`

Arnett, R. H., Frank, J. H., Thomas, M. C., Skelley, P. E., et al. (2002). *American beetles, Volume II: Polyphaga: Scarabaeoidea through C urculionoidea.* CRC press.

Arnett Jr, R. H., & Thomas, M. C. (2000). *American beetles, Volume I: Archostemata, Myxophaga, Adephaga, P olyphaga: Staphyliniformia.* CRC Press.

Audisio, P. (1993). Coleoptera Nitidulidae-Kateretidae. *Fauna d'Italia*, *32*.

Audisio, P. (2002). Litorali sabbiosi e organismi animali. *Quaderni Habitat: Dune e spiagge sabbiose*, 63–117.

Audisio, P. (2003). Sandy shores and their animals. In *Sand dunes and beaches:*

environments between land and sea (pp. 59–111).

Audisio, P., & Taglianti, A. V. (2010). Insecta Coleoptera. *Biol. Mar. Mediterr*, *17*(1), 547–571.

Bächli, G. (2015). Taxodros: The database on taxonomy of Drosophilidae. *Database*, *3*(25).

Backlund, H. (1944). The ability of the shore beetle, *Cafius xantholoma* Grav. to evade seadrift. *Kungliga Fysiografiska Sällskapets Lund Förhandlingar*, *14*, 1–14.

Balogh, J., & Balogh, P. (1992). *The oribatid mites genera of the world* (2nd ed., Vol. 1). Hungarian Natural History Museum.

Barber, H. (1931). Traps for cave-inhabiting insects. *Journal of the Elisha Mitchell Scientific Society*, *46*(2), 259–266.

Barboza, F. R., Gómez, J., Lercari, D., & Defeo, O. (2012). Disentangling diversity patterns in sandy beaches along environmental gradients. *PLoS One*, *7*(7), e40468.

Barros, F. (2001). Ghost crabs as a tool for rapid assessment of human impacts on exposed sandy beaches. *Biological Conservation*, *97*(3), 399–404.

Barton, K. (2016). Mumin: multi-model inference. r package version 1.40. 4. *CRAN Retrieved from https://cran. r-project. org/package= MuMIn.*

Bellinger, P., Christiansen, K., & Janssens, F. (2007). *2008. checklist of the collembola of the world.* Retrieved from `http://www.collembola.org`

Ben-Dor, E., & Banin, A. (1989). Determination of organic matter content in arid-zone soils using a simple loss-on- ignition method. *Communications in Soil Science and Plant Analysis*, *20*(15-16), 1675–1695.

Berlese, A. (1905). Apparecchio per raccogliere presto ed in gran numero piccoli arthropodi. *Redia, Vol. 2*, 85-89.

Bernabeu, A., De la Fuente, M. N., Rey, D., Rubio, B., Vilas, F., Medina, R., & González, M. (2006). Beach morphodynamics forcements in oiled shorelines: coupled physical and chemical processes during and after fuel burial. *Marine Pollution Bulletin*, *52*(10), 1156–1168.

Bernini, F., Castagnoli, M., & Nanneli, R. (1995). *Arachnida acari.* Calderini.

Bianchi, C. N., & Peirano, A. (1995). *Atlante delle fanerogame marine della liguria.* ENEA. Retrieved from `https://books.google.it/books?id=OsLJoAEACAAJ`

Binaghi, G. (1951). *Coleotteri d'italia.* Briano Ed.

Blake, J. G., & Loiselle, B. A. (2000). Diversity of birds along an elevational gradient in the Cordillera Central, C osta Rica. *The Auk: Ornithological Advances*, 663–686.

Bodin, P. (1988). Results of ecological monitoring of three beaches polluted by the amoco cadiz oil spill: development of meiofauna from 1978 to 1984. *Marine Ecology Progress Series. Oldendorf*, *42*(2), 105–123.

Borriello, P., De Angelis, R., Pallottini, E., & Saccomandi, F. (2010). Formazione e gestione delle banquettes di posidonia oceanica sugli arenili. *Istituto Superiore per la Protezione Ambientale (ISPRA), Manuali e linee guida*, *55*, 1–138.

Boudoresque, C., Ponel, P., Astruch, P., Barcelo, A., Blanfuné, A., Geoffroy, D., & Thibaut, T. (2017). The high heritage value of the Mediterranean sandy beaches, with a particular focus on the *Posidonia oceanica* "banquettes": A review. *Sci. Rep. Port-Cros Natl. Park*, *31*, 23–70.

Boudouresque, C., & Meinesz, A. (1982). Decouverte del l'herbier de Posidonie. *Sci. Rep. Port-Cros Natl. Park*, *4*, l–79.

Boudouresque, C. F., Bernard, G., Bonhomme, P., Charbonnel, E., Diviacco, G., Meinesz, A., Pergent, G., Pergent-Martini, C., Ruitton, S., Tunesi, L., et al. (2006). *Préservation et conservation des herbiers à emphPosido-*

nia oceanica. RAMOGE. Retrieved from `http://www.ramoge.org/filesfr/guideposidonie/posidonia_oceanica.pdf`

Bovina, G. (2001). Programma di indagine sulle banquettes di posidonia oceanica come indicatore dello stato diconservazione delle praterie. In *Convenzione associazione ambientalista marevivo/ministero dellambiente - relazione illustrativa finale.* Ministero dellAmbiente 2002.

Brazeiro, A., & Defeo, O. (1996). Macroinfauna zonation in microtidal sandy beaches: is it possible to identify patterns in such variable environments? *Estuarine, Coastal and Shelf Science*, *42*(4), 523–536.

Brewer, M. S., Sierwald, P., & Bond, J. E. (2012). Millipede taxonomy after 250 years: classification and taxonomic practices in a mega- diverse yet understudied arthropod group. *PLoS One*, *7*(5), e37240.

Brocher, F. (1912). Recherches sur la respiration des insectes aquatiques adultes. Les Haemonia. *Ann. Biol. Lacust*(5), 6–26.

Brose, U., & D. Martinez, N. (2004). Estimating the richness of species with variable mobility. *Oikos*, *105*(2), 292–300.

Brose, U., Martinez, N. D., & Williams, R. J. (2003). Estimating species richness: sensitivity to sample coverage and insensitivity to spatial patterns. *Ecology*, *84*(9), 2364–2377.

Brown, A., & McLachlan, A. (2002). Sandy shore ecosystems and the threats facing them: some predictions for the year 2025. *Environmental Conservation*, *29*(1), 62–77.

Brown, V. D. R. L. (1976). Other intertidal air-breathing arthropods. *Marine insects*, 119.

Brusca, R. C. (1973). *Common intertidal invertebrates of the gulf of california.*

Bunge, J., & Fitzpatrick, M. (1993). Estimating the number of species: a review. *Journal of the American Statistical Association*, *88*(421), 364–

373.

Burnham, K. P., & Anderson, D. R. (2014). *Model selection and multimodel inference: a practical information-theoretic approach.* Springer Science & Business Media.

Burnham, K. P., & Overton, W. S. (1978). Estimation of the size of a closed population when capture probabilities vary among animals. *Biometrika*, *65*(3), 625–633.

Butler, B. J., & Chazdon, R. L. (1998). Species richness, spatial variation, and abundance of the soil seed bank of a secondary tropical rain forest. *Biotropica*, *30*(2), 214–222.

Buuren, S. v., & Groothuis-Oudshoorn, K. (2010). mice: Multivariate imputation by chained equations in r. *Journal of statistical software*, 1–68.

Campbell, J. (1991). Family Oedemeridae, false blister beetles. *Checklist of Beetles of Canada and Alaska, ed. Bousquet Y*, 1–266.

Castillo, C., Mantecón, A., Sotillo, J., Benedito, J., Abuelo, A., Gutiérrez, C., & Hernández, J. (2014). The use of banquettes of *Posidonia oceanica* as a source of fiber and minerals in ruminant nutrition. an observational study. *Animal*, *8*(10), 1663–1666.

Catenazzi, A. (2006). *The importance of marine subsidies for terrestrial consumers in coastal peru* (dissertation). Florida International University.

Chao, A. (1984). Nonparametric estimation of the number of classes in a population. *Scandinavian Journal of statistics*, *11*(4), 265–270.

Chao, A. (1987). Estimating the population size for capture-recapture data with unequal catchability. *Biometrics*, 783–791.

Chao, A., & Chiu, C.-H. (2016). Nonparametric estimation and comparison of species richness. *eLS. John Wiley & Sons, Ltd: Chichester*, 1–11.

Chao, A., Gotelli, N. J., Hsieh, T., Sander, E. L., Ma, K., Colwell, R. K., &

Ellison, A. M. (2014). Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. *Ecological Monographs*, *84*(1), 45–67.

Chao, A., Hwang, W.-H., Chen, Y., & Kuo, C. (2000). Estimating the number of shared species in two communities. *Statistica sinica*, *10*(1), 227–246.

Chao, A., & Jost, L. (2012). Coverage-based rarefaction and extrapolation: standardizing samples by completeness rather than size. *Ecology*, *93*(12), 2533–2547.

Chao, A., & Lee, S.-M. (1992). Estimating the number of classes via sample coverage. *Journal of the American Statistical Association*, *87*(417), 210–217.

Chazdon, R. L., Colwell, R. K., Denslow, J. S., & Guariguata, M. R. (1998). Statistical methods for estimating species richness of woody regeneration in primary and secondary rain forests of northeastern Costa Rica. In *Man and the biosphere series* (Vol. 20).

Chelazzi, G., Chelazzi, L., & Focardi, S. (1983). Dynamic zonation of staphylinoid beetles (Coleoptera: Staphylinoidea) on a sandy beach in East Africa. In *Sandy beaches as ecosystems* (pp. 405–412). Springer.

Chelazzi, L., & Colombini, I. (1989). Zonation and activity patterns of two species of the genus *Phaleria* Latreille (Coleoptera Tenebrionidae) inhabiting an equatorial and a mediterranean sandy beach. *Ethology Ecology & Evolution*, *1*(4), 313–321.

Cheng, L. (1976). *Marine insects.* North-Holland Publ. Company.

Chessa, L. A., Fustier, V., Fernandez, C., Mura, F., Pais, A., Pergent, G., Serra, S., & Vitale, L. (2000). Contribution to the knowledge of'banquettes' of *Posidonia oceanica* (L.) delile in sardinia island. *Biologia Marina Mediterranea*, *7*(2), 35–38.

Chvála, M. (1983). Hybotidae, Atelestidae and Microphoridae. In *The Empididae (Diptera) of Fennoscandia and Denmark, Part II.* BRILL.

Clarke, K. R. (1993). Non-parametric multivariate analyses of changes in community structure. *Australian journal of ecology*, *18*(1), 117–143.

Coleman, B. D., Mares, M. A., Willig, M. R., & Hsieh, Y.-H. (1982). Randomness, area, and species richness. *Ecology*, *63*(4), 1121–1133.

Colombini, I., Aloia, A., Fallaci, M., Pezzoli, G., & Chelazzi, L. (2000). Temporal and spatial use of stranded wrack by the macrofauna of a tropical sandy beach. *Marine Biology*, *136*(3), 531–541.

Colombini, I., Bouslama, M. F., El Gtari, M., Fallaci, M., Scapini, F., & Chelazzi, L. (2005). Study of the community structure of terrestrial arthropods of a Mediterranean sandy beach ecosystem of Morocco. *Ecosystèmes côtiers sensibles de la Méditerrané: cas du littoral de Smir. Trav. Inst. Sci. série générale*, *4*, 43–54.

Colombini, I., Chaouti, A., Fallaci, M., Gagnarli, E., Bayed, A., & Chelazzi, L. (2008). An assessment of sandy beach macroinvertebrates inhabiting the coastal fringe of the Oued Laou river catchment area (Northern Morocco). *Du bassin versant vers la mer: Analyse multidisciplinaire pour une gestion durable. Trav. Inst. Sci, série générale*, *5*, 81–91.

Colombini, I., Chelazzi, L., Gibson, R., & Atkinson, R. (2003). Influence of marine allochthonous input on sandy beach communities. *Oceanography and Marine Biology: An Annual Review*, *41*, 115–159.

Colwell, R. K. (2013). Estimates: statistical estimation of species richness and shared species from samples. version 9.0. User's guide and application. *http://purl. oclc. org/estimates*.

Colwell, R. K., Chao, A., Gotelli, N. J., Lin, S.-Y., Mao, C. X., Chazdon, R. L., & Longino, J. T. (2012). Models and estimators linking individual-based and sample-based rarefaction, extrapolation and comparison of assemblages. *Journal of plant ecology*, *5*(1), 3–21.

Colwell, R. K., & Coddington, J. A. (1994). Estimating terrestrial biodiversity through extrapolation. *Phil. Trans. R. Soc. Lond. B*, *345*(1311), 101–118.

Colwell, R. K., Mao, C. X., & Chang, J. (2004). Interpolating, extrapolating, and comparing incidence-based species accumulation curves. *Ecology*, *85*(10), 2717–2727.

Cotana, F., Buratti, C., Barbanera, M., Cavalaglio, G., Foschini, D., Nicolini, A., & Pisello, A. (2016). Driftwood biomass in italy: estimation and characterization. *Sustainability*, *8*(8), 725.

Coupland, G. T., Duarte, C. M., & Walker, D. I. (2007). High metabolic rates in beach cast communities. *Ecosystems*, *10*(8), 1341–1350.

Czarnecka, M. (2016). Coarse woody debris in temperate littoral zones: implications for biodiversity, food webs and lake management. *Hydrobiologia*, *767*(1), 13–25.

Dahl, E. (1952). Some aspects of the ecology and zonation of the fauna on sandy beaches. *Oikos*, *4*(1), 1–27.

Dallai, R., Cicconardi, F., & Fanciulli, P. P. (2010). Insecta Collembola. *Biol. Mar. Mediterr*, *17*(1), 538–544.

Davies, B. E. (1974). Loss-on-ignition as an estimate of soil organic matter 1. *Soil Science Society of America Journal*, *38*(1), 150–151.

de Alava, A., & Defeo, O. (1991). Distributional pattern and population dynamics of *Excirolana armata* (Isopoda: Cirolanidae) in a uruguayan sandy beach. *Estuarine, Coastal and Shelf Science*, *33*(5), 433–444.

De Falco, G., Simeone, S., & Baroli, M. (2008). Management of beach-cast *Posidonia oceanica* seagrass on the island of Sardinia (Italy, Western

Mediterranean). *Journal of Coastal Research*, *24*(sp3), 69–75.

Defeo, O., & McLachlan, A. (2013). Global patterns in sandy beach macrofauna: Species richness, abundance, biomass and body size. *Geomorphology*, *199*, 106–114.

Defeo, O., McLachlan, A., Schoeman, D. S., Schlacher, T. A., Dugan, J., Jones, A., Lastra, M., & Scapini, F. (2009). Threats to sandy beach ecosystems: a review. *Estuarine, coastal and shelf science*, *81*(1), 1–12.

Defeo, O., & Rueda, M. (2002). Spatial structure, sampling design and abundance estimates in sandy beach macroinfauna: some warnings and new perspectives. *Marine Biology*, *140*(6), 1215–1225.

Deharveng, L., DHaese, C. A., & Bedos, A. (2008). Global diversity of springtails (collembola; hexapoda) in freshwater. In *Freshwater animal diversity assessment* (pp. 329–338). Springer.

Dhooria, M. S. (2016). Acarology and its importance. In *Fundamentals of applied acarology* (pp. 1–7). Springer.

Diviacco, G., & Coppo, S. (2006). *Atlante degli habitat marini della Liguria.* Grafiche Amadeo.

Dormann, C. F., Elith, J., Bacher, S., Buchmann, C., Carl, G., Carré, G., Marquéz, J. R. G., Gruber, B., Lafourcade, B., Leitão, P. J., et al. (2013). Collinearity: a review of methods to deal with it and a simulation study evaluating their performance. *Ecography*, *36*(1), 27–46.

Doyen, J. T. (1976). Marine beetles (Coleoptera excluding Staphylinidae). *Marine insects*, 497–519.

Dugan, J. E., Hubbard, D. M., McCrary, M. D., & Pierson, M. O. (2003). The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern california. *Estuarine, coastal and shelf science*, *58*, 25–40.

Dugan, J. E., Hubbard, D. M., Page, H. M., & Schimel, J. P. (2011). Marine macrophyte wrack inputs and dissolved nutrients in beach sands. *Estuaries and Coasts*, *34*(4), 839–850.

Dugan, J. E., Hubbard, D. M., Rodil, I. F., Revell, D. L., & Schroeter, S. (2008). Ecological effects of coastal armoring on sandy beaches. *Marine Ecology*, *29*, 160–170.

Edwards, C. A. (1991). The assessment of populations of soil-inhabiting invertebrates. *Agriculture, Ecosystems & Environment*, *34*(1-4), 145–176.

Enghoff, H. (1983). Adaptive radiation of the millipede genus cylindroiulus on madeira: habitat,body size and morphology (diplopoda, julida: Julidae). *Rev. Ecol. Biol Sol*, *20*(3), 403–415.

Enghoff, H. (1985). The millipede family nemasomatidae. with the description of a new genus, and a revision of orinisobates (diplopoda: Julida). *Insect Systematics & Evolution*, *16*(1), 27–67.

Enghoff, H. (1994). Geographical parthenogenesis in millipedes (diplopoda). *Biogeographica*, *70*(1), 25–31.

Enghoff, H., Petersen, G., & Seberg, O. (2011). Phylogenetic relationships in the millipede family julidae. *Cladistics*, *27*(6), 606–616.

Escher, S. A., Ekenstedt, J., Pakalniškis, S., Rimšaitė, J., & Saura, A. (2004). The Drosophilidae (Diptera) of Lithuania. *Acta Zoologica Lituanica*, *14*(2), 48–55.

Evans, G. O. (1992). Principles of acarology.

Fanini, L., Cantarino, C. M., & Scapini, F. (2005). Relationships between the dynamics of two *Talitrus saltator* populations and the impacts of activities linked to tourism. *Oceanologia*, *47*(1).

Fattorini, S. (2002). The Tenebrionidae (Coleoptera) of a Tyrrhenian coastal area: diversity and zoogeographical composition. *Biogeographia: The Journal of Integrative Biogeography*, *23*(1).

Feranec, J., Soukup, T., Hazeu, G., & Jaffrain, G. (2016). *European landscape dynamics: Corine land cover data*. CRC Press.

Fichter, E. (1941). Apparatus for the comparison of soil surface arthropod populations. *Ecology*, *22*(3), 338–339.

Fierro, G., Berriolo, G., & Ferrari, M. (2010). *Le spiagge della Liguria occidentale: analisi evolutiva*. Regione Liguria.

Fierro, G., Berriolo, G., & Ferrari, M. (2015). *Le spiagge della liguria orientale-analisi evolutiva*. Regione Liguria.

Folk, R. L., Andrews, P. B., & Lewis, D. (1970). Detrital sedimentary rock classification and nomenclature for use in New Z ealand. *New Zealand journal of geology and geophysics*, *13*(4), 937–968.

Folk, R. L., & Ward, W. C. (1957). Brazos river bar (Texas); a study in the significance of grain size parameters. *Journal of Sedimentary Research*, *27*(1), 3–26.

Foote, B. (1995). Biology of shore flies. *Annual Review of Entomology*, *40*(1), 417–442.

Frank, J. H., & Ahn, K.-J. (2011). Coastal Staphylinidae (Coleoptera): A worldwide checklist, biogeography and natural history. *ZooKeys*(107), 1–98.

Gacia, E., & Duarte, C. M. (2001). Sediment retention by a mediterranean posidonia oceanica meadow: the balance between deposition and resuspension. *Estuarine, coastal and shelf science*, *52*(4), 505–514.

Giudice, G. L., & Woźnica, A. J. (2013). An updated checklist of the Italian Heleomyzidae (Diptera: Sphaeroceroidea). *Genus*, *24*(3-4), 439–458.

Golovatch, S. I., & Kime, R. D. (2009). Millipede (Diplopoda) distributions:

A review. *Soil Organisms*, *81*(3), 565–597.

Good, I., & Toulmin, G. (1956). The number of new species, and the increase in population coverage, when a sample is increased. *Biometrika*, *43*(1–2), 45–63.

Good, I. J. (1953). The population frequencies of species and the estimation of population parameters. *Biometrika*, *40*(3–4), 237–264.

Gotelli, N. J., & Colwell, R. K. (2001). Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. *Ecology letters*, *4*(4), 379–391.

Green, E. P., Short, F. T., Frederick, T., et al. (2003). *World atlas of seagrasses*. Univ of California Press.

Griffiths, C., Stenton-Dozey, J., & Koop, K. (1983). Kelp wrack and the flow of energy through a sandy beach ecosystem. In *Sandy beaches as ecosystems* (pp. 547–556). Springer.

Guala, I., Simeone, S., Buia, M. C., Flagella, S., Baroli, M., & De Falco, G. (2006). *Posidonia oceanica* banquettes removal: environmental impact and management implications. In B. M. C. D. C. G. P.-M. C. P. G. P. G. Gambi M. C Borg J. A (Ed.), *Proceedings of the mediterranean seagrass workshop* (Vol. 13, pp. 149–153). SIBM.

Gullan, P. J., & Cranston, P. S. (2014). *The insects: an outline of entomology*. John Wiley & Sons.

Hall, S. J. (1994). Physical disturbance and marine benthic communities: life in unconsolidated sediments. *Oceanogr. Mar. Biol. Ann. Rev.*, *32*, 179–239.

Hammond, P. (1990). Insect abundance and diversity in the Dumoga-Bone National Park, N. Sulawesi, with special reference to the beetle fauna of lowland rain forest in the Toraut region. *Insects and the rain forests of*

South East Asia (Wallacea), 197–254.

Hashimoto, H. (1976). Non-biting midges of marine habitats (diptera: Chironomidae). *Marine insects*, *1*, 377–414.

Hayes, W. B. (1970). The accuracy of pitfall trapping for the sand-beach isopod tylos punctatus. *Ecology*, *51*(3), 514–516.

Hertz, M. (1927). Huomioita petokuoriaisten olinpaikoista. *Luonnon Ystävä*, *31*(218-222).

Hijmans, R. J., Cameron, S. E., Parra, J. L., Jones, P. G., & Jarvis, A. (2005). Very high resolution interpolated climate surfaces for global land areas. *International journal of climatology*, *25*(15), 1965–1978.

Hill, M. O. (1973). Diversity and evenness: a unifying notation and its consequences. *Ecology*, *54*(2), 427–432.

Hinton, H. (1966). Plastron respiration in marine insects. *Nature*, *209*(5019), 220.

Hopkin, S. P., Read, H. J., et al. (1992). *The biology of millipedes.* Oxford: Oxford University Press.

Hortal, J., Borges, P. A., & Gaspar, C. (2006). Evaluating the performance of species richness estimators: sensitivity to sample grain size. *Journal of Animal Ecology*, *75*(1), 274–287.

Hsieh, T., Ma, K., & Chao, A. (2016). inext: an r package for rarefaction and extrapolation of species diversity (h ill numbers). *Methods in Ecology and Evolution*, *7*(12), 1451–1456.

Hsu, T.-W., Lin, T.-Y., & Tseng, I.-F. (2007). Human impact on coastal erosion in Taiwan. *Journal of Coastal Research*, *23*(4), 961–973. doi: 10.2112/04-0353R.1

Ince, R., Hyndes, G. A., Lavery, P. S., & Vanderklift, M. A. (2007). Marine macrophytes directly enhance abundances of sandy beach fauna through provision of food and habitat. *Estuarine, Coastal and Shelf Science*, *74*(1-2), 77–86.

Inglis, G. (1989). The colonisation and degradation of stranded *Macrocystis pyrifera* (l.) c. ag. by the macrofauna of a new zealand sandy beach. *Journal of Experimental Marine Biology and Ecology*, *125*(3), 203–217.

Jacquemart, S., & Jacques, J. (1980). A propos d'un collembole entomobryen a la fois marin et désertique. *Annales de la Société royale zoologique de Belgique*, *109*(1), 9–18.

Jaramillo, E., & Gonzalez, M. (1991). Community structure and zonation of the macroinfauna along a dissipative-reflective range of beach category in southern chile. *Studies on Neotropical Fauna and Environment*, *26*(4), 193–212.

Jarosik, V. (1992). Pitfall trapping and species-abundance relationships: a value for carabid beetles (C oleoptera, Carabidae). *Acta Entomologica Bohemoslovaca (CSFR)*, *51*, 1–12.

Jennings, R., & Shulmeister, J. (2002). A field based classification scheme for gravel beaches. *Marine Geology*, *186*(3–4), 211–228.

Jeon, M.-J., & Ahn, K.-J. (2007). Descriptions of late instars of three littoral *Cafius* species (Coleoptera: Staphylinidae) by association of life stage with dna sequences. *Florida Entomologist*, 465–474.

Jocqué, R., Dippenaar-Schoeman, A. S., & Zoologin, S. (2006). Spider families of the world.

Karl, O. (1930). Thalassobionte und thalassophile Diptera Brachycera. In *Die tierwelt der nord- und ostsee* (p. 33-34). Akademische Verlagsgesellschaft, Becker & Erler.

Kejval, Z. (1998). Review of Oriental and some Palaearctic species of the genus *Endomia* (C oleoptera: Anthicidae). *European Journal of Entomology*, *95*, 99–132.

Kensler, C. B. (1967). Desiccation resistance of intertidal crevice species as a factor in their zonation. *The Journal of Animal Ecology*, *36*(2), 391–406.

Kime, R. D., & Enghoff, H. (2017). Atlas of european millipedes 2: Order julida (class diplopoda). *European Journal of Taxonomy*(346), 1–299.

Kirkman, H., & Kendrick, G. A. (1997). Ecological significance and commercial harvesting of drifting and beach-cast macro-algae and seagrasses in australia: a review. *Journal of Applied Phycology*, *9*(4), 311–326.

Krantz, G., & Walter, D. (1978). *A manual of acarology* (Ed. 2 ed.). Texas Tech University Press.

Lapresa, A., Angelici, P., & Festari, I. (2004). Gli habitat secondo la nomenclatura eunis: manuale di classificazione per la realtà italiana. *APAT, Roma*.

Leather, S. R. (2008). *Insect sampling in forest ecosystems.* John Wiley & Sons.

Legner, I. M. F. (1976). Intertidal rove beetles (Coleoptera: Staphylinidae). *Marine insects*, *1*, 521–552.

Lele, S. R., Keim, J. L., Solymos, P., Solymos, M. P., & Imports, M. (2019). Package resourceselection.

Leschen, R. A. (1996). Phylogeny and revision of the genera of cryptophagidae (coleoptea: Cucujoidea). *The University of Kansas Science Bulletin*, *55*, 594–634.

Liebowitz, D. M., Nielsen, K. J., Dugan, J. E., Morgan, S. G., Malone, D. P., Largier, J. L., Hubbard, D. M., & Carr, M. H. (2016). Ecosystem connectivity and trophic subsidies of sandy beaches. *Ecosphere*, *7*(10).

Löbl, I., & Smetana, A. (2004). Catalogue of Palaearctic Coleoptera. Vol. 2: Hydrophiloidea, Histeroidea, Staphylinoidea. , 122–131.

Löbl, I., & Smetana, A. (2008). Distributional information. In *Tenebrionoidea* (pp. 11–15). BRILL.

Longcore, T., & Rich, C. (2004). Ecological light pollution. *Frontiers in Ecology and the Environment*, *2*(4), 191–198.

Macfadyen, A. (1962). Soil arthropod sampling. In *Advances in ecological research* (Vol. 1, pp. 1–34). Elsevier.

MacMillan, M. R., & Quijón, P. A. (2012). Wrack patches and their influence on upper-shore macrofaunal abundance in an Atlantic Canada sandy beach system. *Journal of Sea Research*, *72*, 28–37.

Magistretti, M. (1967). Catalogo degli Oedemeridae italiani (Coleoptera). *Memorie della Società Entomologica italiana*, *46*, 181–200.

Magurran, A. E. (2013). *Measuring biological diversity.* John Wiley & Sons.

Magurran, A. E., & McGill, B. J. (2011). *Biological diversity: frontiers in measurement and assessment.* Oxford University Press.

Majer, J. (1978). An improved pitfall trap for sampling ants and other epigaeic invertebrates. *Australian Journal of Entomology*, *17*(3), 261–262.

Mallet, J., & Willmott, K. (2003). Taxonomy: renaissance or tower of babel? *Trends in Ecology & Evolution*, *18*(2), 57–59.

Maser, C., Tarrant, R. F., Trappe, J. M., & Franklin, J. F. (1988). *From the forest to the sea: a story of fallen trees.* Pacific Northwest Research Station: US Department of Agriculture, Forest Service.

Mateo, M.-Á., Sanchez-Lizaso, J.-L., & Romero, J. (2003). *Posidonia oceanica* "banquettes": a preliminary assessment of the relevance for meadow carbon and nutrients budget. *Estuarine, Coastal and Shelf Science*, *56*(1), 85–90.

McLachlan, A. (1977). Effects of ore dust pollution on the physical and chemical features, and on the meiofauna and microfauna, of a sandy beach. *African Zoology*, *12*(1), 73–88.

McLachlan, A. (1985). The biomass of macro-and interstitial fauna on clean and wrack-covered beaches in western australia. *Estuarine, Coastal and Shelf Science*, *21*(4), 587–599.

McLachlan, A. (1990). Dissipative beaches and macrofauna communities on exposed intertidal sands. *Journal of coastal research*, *6*(1), 57–71.

McLachlan, A., & Brown, A. (2006). *The ecology of sandy shores* (3rd ed.). Academic Press.

McLachlan, A., & Jaramillo, E. (1996). Zonation on sandy beaches. *Oceanographic Literature Review*, *12*(43), 12–47.

McLachlan, A., Wooldridge, T., & Dye, A. H. (1981). The ecology of sandy beaches in southern africa. *African Zoology*, *16*(4), 219–231.

McNeely, J. A. (2002). The role of taxonomy in conserving biodiversity. *Journal for Nature Conservation*, *10*(3), 145–153.

Melbourne, B. A. (1999). Bias in the effect of habitat structure on pitfall traps: an experimental evaluation. *Australian Journal of Ecology*, *24*(3), 228–239.

Minchin, P. R. (1987). An evaluation of the relative robustness of techniques for ecological ordination. In *Theory and models in vegetation science* (pp. 89–107). Springer.

Moffett, M., McLachlan, A., Winter, P., & De Ruyck, A. (1998). Impact of trampling on sandy beach macrofauna. *Journal of Coastal Conservation*, *4*(1), 87–90.

Morris, E. K., Caruso, T., Buscot, F., Fischer, M., Hancock, C., Maier, T. S., Meiners, T., Müller, C., Obermaier, E., Prati, D., et al. (2014). Choosing and using diversity indices: insights for ecological applications from the german biodiversity exploratories. *Ecology and evolution*, *4*(18), 3514–

3524.

Munari, L. (2010). Insecta diptera. *Biol. Mar. Mediterr*, *17*(1), 572–583.

Nardi, G., & Háva, J. (2013). Italian Dermestidae: notes on some species and an updated checklist (C oleoptera). *ZooKeys*(360), 45–81.

Nartshuk, E. (2014). Grass-fly larvae (Diptera, Chloropidae): diversity, habitats, and feeding specializations. *Entomological Review*, *94*(4), 514–525.

Nelson, W. G. (1989). An overview of the effects of beach nourishment on the sand beach fauna. In L. S. Tait (Ed.), *Beach preservation technology* (Vol. 88, pp. 295–310). 864 East Park Avenue, Tallahasse, Florida 32301.

Nguyen, B. N. (2015). Effects of wrack composition, age, and cover on the spatial distribution of beach arthropods. In *Explorations: The uc davis undergraduate research journal* (Vol. 17, pp. 1–16).

Niemelä, J., Halme, E., Pajunen, T., & Haila, Y. (1986). Sampling spiders and carabid beetles with pitfall traps: the effect of increased sampling effort. In *Annales entomologici fennici* (Vol. 52, pp. 109–111).

Noble, M., Xu, J., Robertson, G., & Rosenfeld, L. (2006). Distribution and sources of surfzone bacteria at huntington beach before and after disinfection on an ocean outfall: a frequency-domain analysis. *Marine environmental research*, *61*(5), 494–510.

Ochieng, C. A., & Erftemeijer, P. L. (1999). Accumulation of seagrass beach cast along the kenyan coast: a quantitative assessment. *Aquatic Botany*, *65*(1-4), 221–238.

O'Hara, T. (2002). Endemism, rarity and vulnerability of marine species along a temperate coastline. *Invertebrate Systematics*, *16*(4), 671–684.

Oksanen, J., Blanchet, F. G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P. R., O'Hara, R. B., Simpson, G. L., Solymos, P., Stevens, M. H. H., Szoecs, E., & Wagner, H. (2017). vegan: Community ecology package [Computer software manual]. Retrieved from `https://CRAN.R-project.org/package=vegan` (R package version 2.4-5)

Olabarria, C., Lastra, M., & Garrido, J. (2007). Succession of macrofauna on macroalgal wrack of an exposed sandy beach: effects of patch size and site. *Marine Environmental Research*, *63*(1), 19–40.

Onori, L., Cornelini, P., & Sauli, G. (2009). *Il ripristino degli ecosistemi marino costieri e la difesa delle coste sabbiose nelle Aree protette* (Vol. 100). Via Vitaliano Brancati, 48 00144 Roma: ISPRA Istituto Superiore per la Protezione e la Ricerca Ambientale.

Oosterbroek, P. (2006). *The European Families of the Diptera: Identification-diagnosis-biology.* Brill.

Ott, J., & Maurer, L. (1977). Strategies of energy transfer from marine macrophytes to consumer levels: the *Posidonia oceanica* example. In *Biology of benthic organisms* (pp. 493–502). Elsevier.

Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., Church, J. A., Clarke, L., Dahe, Q., Dasgupta, P., et al. (2014). *Climate change 2014: synthesis report. contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change.* Geneva, Switzerland: IPCC.

Pape, T., Beuk, P., Pont, A. C., Shatalkin, A. I., Ozerov, A. L., Woźnica, A. J., Merz, B., Bystrowski, C., Raper, C., Bergström, C., et al. (2015). Fauna europaea: Diptera–Brachycera. *Biodiversity Data Journal*(3).

Penati, F. (2009). An updated catalogue of the histeridae (coleoptera) of sardinia, with faunistic, zoogeographical, ecological and conservation remarks. *Zootaxa*, *2318*(1), 197–280.

Pennings, S. C., Carefoot, T. H., Zimmer, M., Danko, J. P., & Ziegler, A. (2000). Feeding preferences of supralittoral isopods and amphipods. *Ca-*

nadian Journal of Zoology, *78*(11), 1918–1929.

Pergent, G., Boudouresque, C., & Crouzet, A. (1983). Variations cycliques dans les écailles des rhizomes orthotropes de *Posidonia oceanica*. *Trav. sci. Parc. nation. Port-Cros*, *9*, 107–148.

Peterson, B., McAlpine, J., Shewell, G., Teskey, H., Vockeroth, J., & Wood, D. (1981). *Manual of Neartic Diptera* (No. Vol. I). Agriculture Canada.

Peterson, B., McAlpine, J., Shewell, G., Teskey, H., Vockeroth, J., & Wood, D. (1987). *Manual of Neartic Diptera* (No. Vol. II). Agriculture Canada.

Peterson, C. H., & Bishop, M. J. (2005). Assessing the environmental impacts of beach nourishment. *AIBS Bulletin*, *55*(10), 887–896.

Platia, G. (1994). *Coleoptera: Elateridae*. Calderini.

Platnick, N. (2007). The world spider catalog version 7.5 american museum of natural history online. Retrieved from `http://research.aninh.org/entomology/spiders/catalog81-87/index.html`

Pohlert, T. (2014). The pairwise multiple comparison of mean ranks package (pmcmr). *R package*, *27*.

Polis, G. A., Anderson, W. B., & Holt, R. D. (1997). Toward an integration of landscape and food web ecology: the dynamics of spatially subsidized food webs. *Annual review of ecology and systematics*, *28*(1), 289–316.

Polis, G. A., & Hurd, S. D. (1996). Allochthonous input across habitats, subsidized consumers, and apparent trophic cascades: examples from the ocean-land interface. In *Food webs* (pp. 275–285). Springer.

Polis, G. A., Power, M. E., & Huxel, G. R. (2004). *Food webs at the landscape level.* University of Chicago Press. Retrieved from `https://books.google.it/books?id=OsLJoAEACAAJ`

Pollet, M. A., Brooks, S. E., & Cumming, J. M. (2004). Catalog of the Dolichopodidae (Diptera) of America north of Mexico. *Bulletin of the*

American Museum of Natural History, *283*, 1–114.

Pont, A., & Meier, R. (2002, 01). The Sepsidae (Diptera) of Europe. *Fauna Entomologica Scandinavica*, *37*, 1–221.

Potapov, A. A., Semenina, E. E., Korotkevich, A. Y., Kuznetsova, N. A., & Tiunov, A. V. (2016). Connecting taxonomy and ecology: Trophic niches of collembolans as related to taxonomic identity and life forms. *Soil Biology and Biochemistry*, *101*, 20–31.

Pranzini, E. (2004). *La forma delle coste: geomorfologia costiera, impatto antropico e difesa dei litorali.* Zanichelli. Retrieved from `https://books.google.it/books?id=khZNAQAAIAAJ`

R Core Team. (2017). R: A language and environment for statistical computing [Computer software manual]. Vienna, Austria. Retrieved from `https://www.R-project.org/`

Raffaelli, D. (1991). Zonation schemes on sandy shores: a multivariate approach. *J. Exp. mar. Biol. Ecol*, *148*, 241–253.

Rahbek, C., & Graves, G. R. (2001). Multiscale assessment of patterns of avian species richness. *Proceedings of the National Academy of Sciences*, *98*(8), 4534–4539.

Rieske, L., & Raffa, K. (1993). Potential use of baited pitfall traps in monitoring pine root weevil, *Hylobius pales*, *Pachylobius picivorus*, and *Hylobius radicis* (Coleoptera: C urculionidae) populations and infestation levels. *Journal of Economic Entomology*, *86*(2), 475–485.

Robertson, H. G. (2002). Comparison of leaf litter ant communities in woodlands, lowland forests and montane forests of north-eastern Tanzania. *Biodiversity & Conservation*, *11*(9), 1637–1652.

Rodil, I. F., Olabarria, C., Lastra, M., & López, J. (2008). Differential effects of native and invasive algal wrack on macrofaunal assemblages inhabiting exposed sandy beaches. *Journal of Experimental Marine Biology and Ecology*, *358*(1), 1–13.

Rohácek, J. (1999). Taxonomy and distribution of West Palaearctic Anthomyzidae (Diptera), with special regard to the Mediterranean and Macaronesian faunas. *Bollettino del Museo Regionale di Scienze Naturali di Torino*, *16*, 189–224.

Roháček, J. (2006). A monograph of Palaearctic Anthomyzidae (Diptera) part I. *Časopis Slezského Zemského Muzea, Opava (A)*, *55*(Supplement 1), 1–328.

Roháček, J., Marshall, S. A., Norrbom, A. L., Buck, M., Quiros, D. I., & Smith, I. (2001). *World catalog of Sphaeroceridae (Diptera).* Slezské zemské muzeum Opava.

Ruiz-Delgado, M. C., Reyes-Martínez, M. J., Sánchez-Moyano, J. E., López-Pérez, J., & García-García, F. J. (2015). Distribution patterns of supralittoral arthropods: wrack deposits as a source of food and refuge on exposed sandy beaches (SW Spain). *Hydrobiologia*, *742*(1), 205–219.

Rusek, J. (2007). A new classification of Collembola and Protura life forms. *Contributions to soil zoology in Central Europe II*, *5*, 109–115.

Ryan, P., & Moloney, C. (1990). Plastic and other artefacts on South African beaches: Temporal trends in abundance and composition. *S. Afr. J. Sci./S.-Afr. Tydskr. Wet.*, *86*(7), 450–452.

Sa'idane, A., De Waele, N., & Van de Velde, R. (1979). Contribution à l'étude du compostage de plantes marines en vue de la pré paration d'un amendement organique et d'un substrat horticole. *Bull. Oceanogr. Peche Salammbo*, *6*, 133–150.

Salvat, B. (1967). *La macrofaune carcinologique endogee des sediments meubles intertidaux (tanaidaces, isopodes et amphipodes), ethologie, bionomie et* *cycle biologique* (Vol. 45). Muséum national d'Histoire Naturelle.

Scapini, F., Chelazzi, L., Colombini, I., & Fallaci, M. (1992). Surface activity, zonation and migrations of talitrus saltator on a mediterranean beach. *Marine Biology*, *112*(4), 573–581.

Schlünz, B., & Schneider, R. (2000). Transport of terrestrial organic carbon to the oceans by rivers: re-estimating flux-and burial rates. *International Journal of Earth Sciences*, *88*(4), 599–606.

Schooler, N. K., Dugan, J. E., Hubbard, D. M., & Straughan, D. (2017). Local scale processes drive long-term change in biodiversity of sandy beach ecosystems. *Ecology and evolution*, *7*(13), 4822–4834.

Shannon, C. E. (1948). A mathematical theory of communication. *Bell system technical journal*, *27*(3), 379–423.

Shepard, F. P. (1950, 7). *Beach cycles in southern california* (Tech. Rep.). Corps of Engineers Washington DC Beach Erosion Board.

Sierwald, P., & Bond, J. E. (2007). Current status of the myriapod class diplopoda (millipedes): taxonomic diversity and phylogeny. *Annu. Rev. Entomol.*, *52*, 401–420.

Simeone, S., & De Falco, G. (2013). *Posidonia oceanica* banquette removal: sedimentological, geomorphological and ecological implications. *Journal of Coastal Research*, *65*(special issue), 1045–1050.

Simeone, S., De Muro, S., & De Falco, G. (2013). Seagrass berm deposition on a Mediterranean embayed beach. *Estuarine, Coastal and Shelf Science*, *135*, 171–181.

Simmons, C., Pedigo, L., & Rice, M. (1998). Evaluation of seven sampling techniques for wireworms (Coleoptera: Elateridae). *Environmental Entomology*, *27*(5), 1062–1068.

Sinclair, B. J., & Cumming, J. M. (2006). *The morphology, higher-level phylo-*

geny and classification of the Empidoidea (D iptera). Citeseer.

Smith, E. P., & van Belle, G. (1984). Nonparametric estimation of species richness. *Biometrics*, 119–129.

Smith, K. (1989). An introduction to the immature stages of British flies. *Handbooks for the identification of British insects*, *10*(14), 1–280.

Spence, J. R., & Niemelä, J. K. (1994). Sampling carabid assemblages with pitfall traps: the madness and the method. *The Canadian Entomologist*, *126*(3), 881–894.

Speybroeck, J., Bonte, D., Courtens, W., Gheskiere, T., Grootaert, P., Maelfait, J.-P., Mathys, M., Provoost, S., Sabbe, K., Stienen, E. W., et al. (2006). Beach nourishment: an ecologically sound coastal defence alternative? a review. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *16*(4), 419–435.

Steyskal, G. (1957). A revision of the family Dryomyzidae (Diptera, Acalyptratae). *Michigan Academy of Science, Arts and Letters*, *43*, 133–143.

Stoch, F. (2005). Crisi o rinascita? i nuovi orizzonti della tassonomia in italia. *Studi Trentini di Scienze Naturali, Acta Biologica*, *81*, 23–29.

Stoev, P., & Lapeva-Gjonova, A. (2005). Myriapods from ant nests in bulgaria (chilopoda, diplopoda). *Peckiana*, *4*, 131–142.

Taiti, S. (2017). Biologia e biogeografia degli isopodi terrestri (crustacea, isopoda, oniscidea). *Accademia Nazionale Italiana di Entomologia.*

Team, Q. D. (2018). Qgis geographic information system [Computer software manual]. Retrieved from `http://qgis.osgeo.org`

Terborgh, J., Lopez, L., Nuñez, P., Rao, M., Shahabuddin, G., Orihuela, G., Riveros, M., Ascanio, R., Adler, G. H., Lambert, T. D., et al. (2001). Ecological meltdown in predator-free forest fragments. *Science*, *294*(5548), 1923–1926.

Thorpe, W. (1950). Plastron respiration in aquatic insects. *Biological Reviews*, *25*(3), 344–390.

Topp, W., & Ring, R. A. (1988). Adaptations of Coleoptera to the marine environment. I. observations on rove beetles (Staphylinidae) from sandy beaches. *Canadian journal of zoology*, *66*(11), 2464–2468.

Trotta, A. (2004). Introduzione ai ragni italiani (Arachnida Araneae). *Memorie della Società Entomologica Italiana*, *83*(1), 3–178.

Trotta, A. (2010). Araneae. *Biol. Mar. Mediterr*, *17*(1), 389.

Tullgren, P. A. (1918). Ein sehr einfacher ausleseapparat für terricole tierformen. *Zeitschrift für angewandte Entomologie*, *4*(1), 149–150.

Usinger, R. L. (1957). Marine insects. *Geological Society of America Memoirs*, *67*(1), 1177–1182.

Vacchi, M., De Falco, G., Simeone, S., Montefalcone, M., Morri, C., Ferrari, M., & Bianchi, C. N. (2017). Biogeomorphology of the Mediterranean *Posidonia oceanica* seagrass meadows. *Earth Surface Processes and Landforms*, *42*(1), 42–54.

van der Hammen, L. (1989). *An introduction to comparative arachnology.* SPB Academic Pub.

Vienna, P. (1980). *Fauna d'Italia: Coleoptera, Histeridae.* Ed. Calderini.

Vigna Taglianti, A. (2005). Checklist e corotipi delle specie di Carabidae della fauna italiana. Appendice B. *I Coleotteri Carabidi per la valutazione ambientale e la conservazione della biodiversità. Manuale operativo. APAT, Manuali e Linee Guida*, *34*, 186–225.

Vigna Taglianti, A. (2010). Insecta Dermaptera. *Biol. Mar. Mediterr*, *17*(1), 545–546.

Vigna Taglianti, A. (2011). I Dermatteri di Sardegna (Dermaptera). *Biod-*

iversity of Marganai and Montimannu (Sardinia). Research in the framework of the ICP forests network., *5*, 269–285.

Wagner, R., Barták, M., Borkent, A., Courtney, G., Goddeeris, B., Haenni, J.-P., Knutson, L., Pont, A., Rotheray, G. E., Rozkošný, R., et al. (2008). Global diversity of dipteran families (Insecta Diptera) in freshwater (excluding Simulidae, Culicidae, Chironomidae, Tipulidae and Tabanidae). *Hydrobiologia*, *595*(1), 489–519.

Wentworth, C. K. (1922). A scale of grade and class terms for clastic sediments. *The Journal of Geology*, *30*(5), 377–392.

Woodcock, B. A. (2005). Pitfall trapping in ecological studies. *Insect sampling in forest ecosystems*, 37–57.

Yeates, D. K., Wiegmann, B. M., Courtney, G. W., Meier, R., Lambkin, C., & Pape, T. (2007). Phylogeny and systematics of Diptera: two decades of progress and prospects. *Zootaxa*, *1668*(1), 565–590.

Yerbury, C. J. (1919). Seashore diptera. *Journal of the Marine Biological Association of the United Kingdom*, *12*(1), 141–145.

Zatwarnicki, T. (1992). A new classification of Ephydridae based on phylogenetic reconstruction (Diptera: Cyclorrhapha). *Genus*, *2*(3), 65–119.

Zhang, Z.-Q. (2013). *Animal biodiversity: An outline of higher-level classification and survey of taxonomic richness* (Vol. 3703).