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Reconstructing change of benthic seascapes through temporal comparison of historical and present photographies

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Summary

Abstract

The lack of long-term historical data is generally considered one of the main obstacles to the development of adequate measures of conservation for marine ecosystems.

To improve our knowledge the field of marine historical ecology has emerged, with the aim of reconstruct historical baselines as far as possible in the past.

In this thesis the changes of some benthic hard-bottom communities of the Ligurian Sea (NW Mediterranean Sea) were reconstructed, integrating different methods (time series vs. temporal comparison), time scales (pluriannual vs. multidecadal), data sources (scientific vs. non scientific photography) and substrates (natural vs. artificial).

It has been possible to draw a picture of the main changes in marine communities of the last 30 years analysing old photos taken in the MPA of Portofino. The main taxa showing a clear decrease are *E. cavolini* and erect algae, while a sharp increase has been documented, among the others, for *P. clavata*, *C. rubrum*, encrusting and massive sponges and algal turf. Moreover, *C. cylindracea* and *W. setacea*, absent in the past photos, were observed in the current ones.

A more detailed approach but along a shorter time-scale has been performed at Gallinara Island, by a photosampling lasted almost ten years. Here was documented an extremely low temporal variability of the benthic communities, especially at higher depth. Furthermore, the largest component of horizontal spatial variation occured at the smallest spatial scale.

A third approach has taken in account old magazines dedicated to diving activities. A semiquantitative analysis of the most common taxa present in the old photos has been conducted from the 70's up today. In the past sponges, hexacorals, octocorals and bryozoans were present in the photos with an highest frequency respect nowadays.

The potential of non-scientific photography to serve as unconventional source of data for these communities has been documented, suggesting it is an effective tool to fill historical gaps of knowledge.

Riassunto

La mancanza di dati storici a lungo termine è generalmente considerata uno dei principali ostacoli allo sviluppo di adeguate misure di conservazione degli ecosistemi marini.

Per incrementare la nostra conoscenza in materia, è emerso il campo dell'ecologia storica, cui obiettivo principale è quello di ricostruire "baseline" di riferimento posizionate più possibile indietro nel tempo.

In questa tesi sono stati ricostruiti i cambiamenti nel tempo di alcune comunità bentoniche di fondo duro del Mar Ligure (Mediterraneo nord-occidentale), integrando differenti metodologie (serie temporali vs confronto temporale), scale temporali (pluriannuale vs multidecadale), fonti di dati (fotografia scientifica vs fotografia non scientifica) e substrati (naturale vs artificiale).

È stato possibile tracciare un quadro dei principali cambiamenti delle comunità marine dell'AMP di Portofino negli ultimi 30 anni analizzando vecchie fotografie subacquee. I principali taxa che mostrano un chiaro declino sono *E. cavolini* e le alghe erette, mentre è stato osservato un deciso aumento, tra gli altri, di *P. clavata*, *C. rubrum*, spugne incrostanti e massive e feltro algale. Inoltre, nelle foto attuali sono state osservate *C. cylindracea* e *W. setacea*, non presenti in quelle vecchie.

Un approccio più dettagliato ma lungo una scala temporale più breve, è stato applicato all'isola Gallinara, utilizzando un fotocampionamento durato quasi dieci anni. Qui è stata documentata una variabilità temporale estremamente limitata, specialmente in profondità. Inoltre, la componente più grande della variabilità spaziale orizzontale è stata osservata alla più piccola scala spaziale.

Un terzo approccio ha preso in considerazione vecchi numeri di riviste subacquee, su cui è stata svolta un'analisi semiquantitativa dei taxa più comunemente presenti nelle foto, dagli anni 70 a oggi. In passato spugne, esacoralli, ottocoralli e briozoi erano presenti nelle foto pubblicate più frequentemente rispetto a oggi.

In conclusione, questa tesi ha documentato il ruolo potenziale della fotografia subacquea non-scientifica come fonte non convenzionale di dati per le comunità bentoniche di fondo duro, suggerendo che possa essere uno strumento efficace nel colmare le lacune nella conoscenza della loro storia.

Introduction

Marine ecosystems are facing worldwide a vast array of anthropogenic disturbances (Halpern et al., 2008). Resource overexploitation, pollution, habitat alteration, introduction of alien species, climate change and related perturbation of ocean biogeochemistry are considered the major threats to marine biodiversity (Costello et al., 2010). Since the assessed relationship between biodiversity and ecosystem functioning (BEF; Mora et al. (2014) and references therein), biodiversity loss impairs dramatically the ecosystems capacity to furnish goods and services (Beaumont et al., 2007; Cardinale et al., 2012; Chapin et al., 2000; Salomidi et al., 2012).

For these reasons, the conservation of marine biodiversity and sustainable management of marine resources have become a global priority (Selig et al., 2014). To achieve an effective and good process of management, restoration and recovery of marine ecosystems, we need to know their history and the magnitude and drivers of their long-term changes (Lotze and Worm, 2009), and to understand how these changes have influenced their functioning and related services (Manez et al., 2014). Without this knowledge, in fact, we are not able to asses the ecological quality or integrity of an ecosystem (Borja et al., 2012) and verify its position along a disturbance gradient (Latimer et al., 2003). The measurement of ecosystems changes requires reference conditions (i.e. ecological baselines) to which compare the present status (Clark et al., 2001; Lotze and Worm, 2009; Roberts, 2003). These baselines should represent the undisturbed conditions of an ecosystem (or conditions of minimal human pressure, since it is now widely recognized that pristine conditions are virtually inexistent, Erlandson and Rick, 2010; Pinnegar and Engelhard, 2007), and should show the natural variability of communities and habitat quality (Borja et al., 2012).

Until recently, each generation of marine ecologists have fixed baselines that represented the conditions occurred at the beginning of their career, believing that these were the pristine or nearly pristine conditions (Hobday, 2011; Jackson, 2001). This erroneous belief has caused the gradual sliding of the baselines for marine ecosystems toward more degraded states (i.e. shifting baseline syndrome, Pauly, 1995), disguising biodiversity and habitat loss, and ecosystems goods and services decrease (Hobday, 2011; Pinnegar and Engelhard, 2007; Roberts, 2003). The awareness of this syndrome and of the fact that many ecosystems changes occurred well before the establishment of scientific monitoring programs (Jackson, 2001; Roberts, 2007), triggered an explosion in the studies about historical data to counteract the shifting baseline phenomenon (Hobday, 2011). The rising field of marine historical ecology, in fact, has born to reconstruct historical baselines and past changes in marine species (Lotze and Worm, 2009), through a vast plethora of data sources, like paleontological (e.g. McCulloch et al., 2003), archaeological (e.g. Rick and Erlandson, 2008) and historical records (e.g. Holm, 2005), fisheries (e.g. Myers and Worm, 2003), ecological monitoring

(e.g. Sandin et al., 2008) and molecular data (e.g. Alter et al., 2007), and anecdotal clues from living memory (e.g. Bunce et al., 2008). Since some of these data are unconventional in marine ecology but commonly used in other disciplines (e.g. history, anthropology), there is the need to borrow protocols for their collection and use (McClenachan et al., 2012). Consequently to this sources diversity, the timescale, resolution and kind of information extracted vary depending on the methodologies used (Thurstan et al., 2015). The fundamental ecological indicators that can be obtained from historical studies are changes in population abundance (i.e. increase/decrease of individual number, biomass, average size or age; expansion/contraction of distribution over time), presence/absence of a species in a ecosystem, trends in functional groups, changes in trophic habits and positions (Coll and Lotze, 2016). However, data from historical ecology have some inherent constraints, since they can be non-homogeneous or incomplete both in time and space, limited in quality and/or quantity and prone to subjective interpretations (Gatti et al., 2016); therefore a cautious and critical use of them is suggested (Baisre, 2016). Nevertheless, if taken in quantity and from a diversity of sources (e.g. Eddy et al., 2010; Ferretti et al., 2015), also unconventional historical data can be useful in reconstructing pictures of past ecosystems (Al-Abdulrazzak et al., 2012).

Since the seminal paper about the shifting baseline concept (Pauly, 1995), the vast majority of the historical studies on marine ecosystems has regarded commercially targeted species (or bycatch species), mainly large vertebrates (e.g. Ainsworth et al., 2008; Baum and Myers, 2004; Jackson et al., 2001; Johnson and Jackson, 2015; Roman and Palumbi, 2003; Sáenz-Arroyo et al., 2005), and shellfish, especially oyster reefs (e.g. Alleway and Connell, 2015; Kirby, 2004; Zu Ermgassen et al., 2012) but also other molluscs (e.g. Antczak and Cipriani, 2008). It is self-evident, in fact, that a vast part of the historical information findable are linked to organisms exploited in the past, also because most of these information came from fishery data or fishermen's accounts. For this reason, less attention has so far given to non-target species, which however have been affected by historical human activities mainly through habitat destruction and pollution (Lotze et al., 2006). Some authors (see Jackson, 2001 and references therein) tried to infer the changes caused by dredging and trawling on the benthic subtidal communities inhabiting soft bottoms using fishery data. Since they are not subjected to trawling, less is know about hard bottoms benthic communities, with the exceptions of some studies about coral reefs (e.g. Kittinger et al., 2011; Knowlton and Jackson, 2008; Pandolfi et al., 2003).

The Mediterranean Sea is particularly affected by human activities (Claudet and Fraschetti, 2010; Ferretti et al., 2008; Levin et al., 2014; Lotze et al., 2006; Micheli et al., 2013), since its peculiar physiographic and biological characteristics (Lejeusne et al., 2010) and its long history of anthropization (Hughes, 1996; Lotze et al., 2006). What is considered an hotspot of marine

biodiversity (Bianchi and Morri, 2000; Myers et al., 2000) and endemism (Coll et al., 2010), under the pressure of human-driven impacts is turning in one of the most degraded ecosystems in the world (Bianchi and Morri, 2000; Halpern et al., 2008). Reconstructions of the historical changes occurred showed that humans affected Mediterranean ecosystems mainly through overexploitation and habitat alteration since millennia (Lotze et al., 2006; Lotze et al., 2011), also modifying dramatically the shallow food-webs structure (Sala, 2004). Obviously, after the Industrial Revolution, with the technological advancement and the sudden growth of the population, the human pressure over this area increased tragically (Coll et al., 2010; Lotze et al., 2011).

Because of the ancientness and pervasiveness of human presence on its coasts, in the Mediterranean Sea the human footprints on marine ecosystems are particularly antique and deep but, contextually, even historical information are (Hughes, 1996; Lotze et al., 2006). Not only anecdotal and unconventional data are abundant, but also old ecological observations are more available in this basin than elsewhere, since the long history of environmental studies that characterizes it (Bianchi and Morri, 2000 and references therein). For these reasons, the Mediterranean Sea is one of the best scenario where try to turn back the clock of marine ecosystems history.

Even in this area most of the historical ecology studies were focused on species affected by fishery, mainly large vertebrates (e.g. Coll et al., 2014; Ferretti et al., 2008; Ferretti et al., 2015; Fortibuoni et al., 2010; Maynou et al., 2011), but also invertebrates (mainly sponges, red coral and molluscs; Lotze et al., 2011; Milanese et al., 2008; Pronzato and Manconi, 2008; Tsounis et al., 2010). For those organisms that are no directly exploited or indirectly affected by the fishing activities (i.e. bycatch), mainly benthic hard bottom species, the possibility to reconstruct their historical changes relies on old ecological observations, long-term series and documentary records (e.g. Bertolino et al., 2016; Bianchi et al., 2014; Gatti et al., 2015; Gatti et al., 2016). The impracticability to use other longer term methods (i.e. paleontological and archaeological data; old historical records), reduces the amount of time of which the baselines can be moved in the past to not more than some decades (Gatti et al., 2016). Notwithstanding, given the importance of these benthic hard bottom species (i.e. sponges; cnidarians; bryozoans; ascidians) as ecosystem engineers (sensu Jones et al., 1994) which form animal forests (Rossi, 2013), any clue regarding their past attributes can be crucial for the restoration processes (Thurstan et al., 2015).

The possible analytical approaches to reconstruct past changes of this kind of communities are time series analysis (e.g. Casas-Güell et al., 2013; Kersting et al., 2014; Teixidó et al., 2011) and temporal comparison (or then-now comparison; e.g. Bertolino et al., 2016; Bianchi et al., 2014; Gatti et al., 2016), while hindcasting (requires historical catch data) and space-for-time comparison (there are no pristine zone to serve as baseline for these communities) are not suitable (Lotze and Worm, 2009). Analysis of time series would be preferable, since allows to follow trends and

fluctuations over time (Sukhotin and Berger, 2013), but, as stated by Jackson (2001), those available for benthic communities are too short to detect completely the long-term variations. The then-now comparison, instead, doesn't take into account the temporal variability but can provide older information (Lotze and Worm, 2009), especially for the Mediterranean Sea where early ecologist began to collect descriptive data long before to arrange periodic monitoring program (Bianchi and Morri, 2000).

One potential source of historical data for hard bottom communities that was not yet fully explored is the underwater (uw) photography. Until now, in fact, it was used by marine scientists as sampling techniques, both collecting time series (e.g. Casas-Güell et al., 2013; Teixidó et al., 2011) and surveys scattered in time, providing the chance to perform temporal comparisons (e.g. Bertolino et al., 2016; Gatti et al., 2015). However, since the beginning of this field, the non-scientist uw photographers were much more than the marine biologist that used an uw camera. For this reason, the potential amount of data buried in photographic archives from private citizens, diving associations and sectorial magazines is potentially far greater than those contained in pictures taken for scientific purposes. This approach could be particularly effective in the Mediterranean Sea, which was perhaps the birth place of the SCUBA diving and uw photography (Romeo, 2009). Moreover, this data source could contribute to fill the gap about the history of hard bottom benthic communities, which are very often represented in uw pictures, both as subject and background.

Aims and structure of the thesis

The main aim of this thesis is to reconstruct changes of Mediterranean benthic seascapes through temporal comparison of historical and present photographs. This work explores the potential of non-scientific uw photography to serve as source of historical data about hard bottom benthic communities. It integrates different methods (i.e. time-series and temporal comparison), time scales (pluriannual and multidecadal), sources of images (i.e. private archives, diving magazines) and kind of substrates (i.e. natural and artificial) to assess the usefulness of this approach in counteracting the sliding of the baselines for the hard bottom benthic communities in the Mediterranean Sea.

The thesis is divided in three chapters:

Chapter 1 – Heterogeneity and variability in subtidal epibenthic assemblages at the Gallinara Island (northwestern Mediterranean Sea)

This chapter describes the variability of the subtidal hard-bottom assemblages at the Gallinara Island over multiple spatial scales throughout 7 years, analysing a time-series of uw pictures. The observed patterns of variability were put in relation with potential causative factors.

Chapter 2 – Long-term reconstruction of changes in hard-bottom seascapes

This chapter investigates the changes occured in the last decades in sessile communities inhabiting natural and artificial (i.e. wrecks) hard bottoms, through the development of an analysis protocol to extract information from old pictures of these assemblages. The results were put in relation with potential drivers of change. The reliability of the approach was discussed.

Chapter 3 – Can sectorial magazines offer an actual picture of historical trends of benthic assemblages?

This chapter tries to clarify if trends in subjects depicted in diving magazines could be useful as a sort of long-term time series for hard bottom benthic communities. This approach could virtually help to overcome the limitations of the temporal comparison, providing useful data, albeit rough, about temporal variability of these communities.

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CHAPTER 1: Heterogeneity and variability in subtidal epibenthic assemblages at the Gallinara Island (northwerstern Mediterranean Sea)

Introduction

The Mediterranean Sea experiences loss of biodiversity due to human activities since millennia (e.g. Lotze et al., 2011). The oldness of the anthropic impacts on marine ecosystems sharpens the severity of the shifting baseline syndrome (Pauly, 1995), making difficult to identify the real magnitude of the changes occurred (Lotze and Worm, 2009). This difficulty is particularly serious for the hard-bottom benthic communities, which are not directly exploited (with some exceptions, like red coral and bath sponges), but are, and have been, indirectly affected through habitat destruction and pollution (Lotze et al., 2006).

In this context it has became crucial the accessibility to historical information and long-term series, especially in areas with a long history of anthropization like the Mediterranean Sea (Lotze et al., 2011). Indeed, in this basin the human footprints on marine ecosystems are particularly ancient and deep (Hughes, 1996; Lotze et al., 2006) but, contextually, old ecological observations are more available in the Mediterranean Sea than elsewhere, since the long history of environmental studies that characterizes it (Bianchi and Morri, 2000, and reference therein).

For the benthic communities the possible analytical approaches to reconstruct the history of ecosystem changes are time-series analysis and temporal comparison (or then-now comparison, see Lotze and Worm (2009) for the description of further approaches). The first method theoretically would be the preferable since "Long-term series are the only way to follow ecological histories, […] they are crucial for understanding the history of ecological systems." (Boero, 2013). During the last 15 years, several studies have followed time-series for different kind of benthic habitats and different temporal spans. Given their importance as reservoir of biodiversity (Ballesteros, 2006) and long-lived/ high 3D complex species (Coma et al., 1998; Garrabou et al., 2002), many of these studies have taken into account the coralligenous (Bramanti et al., 2005; Casas-Güell et al., 2013; Casas-Güell et al., 2015; Coma et al., 2004; Cupido et al., 2009; Linares et al., 2005; Ponti et al., 2011; Teixidó et al., 2011; Teixidó et al., 2013; Teixidó et al., 2014) and other rocky reef assemblages (Cocito and Sgorbini, 2013; Coma et al., 2006; Fraschetti et al., 2013; Garrabou and Harmelin, 2002; Hereu et al., 2012; Kersting et al., 2014; Linares et al., 2012; Montero-Serra et al., 2015; Teixidó et al., 2009). The temporal scales ranging from 5 to 25 years, with a sampling

frequency of at least once a year, and the series date back not before the 1970s (only in one study, see Garrabou and Harmelin, 2002).

Analysing the results of these long-term studies, six main trends emerge clearly: 1) the benthic structural species that characterize coralligenous assemblages, and in general rocky reef communities (i.e. sponges, cnidarians, bryozoan), exhibit, as stated by Teixidó et al., 2011 "low dynamics, high longevity and persistence" (Bramanti et al., 2005; Cocito and Sgorbini, 2013; Garrabou and Harmelin, 2002; Kersting et al., 2014; Montero-Serra et al., 2015; Ponti et al., 2011; Teixidó et al., 2009; Teixidó et al., 2011); 2) consequently, the temporal variability of coralligenous assemblages is extremely low (Casas-Güell et al., 2013; Casas-Güell et al., 2015; Ponti et al., 2011); 3) extreme disturbance events, like dramatic storms or heat waves and related mass mortality events, represent a serious threat for these benthic communities, both with immediate and delayed effects (Cocito and Sgorbini, 2013; Coma et al., 2006; Cupido et al., 2009; Kersting et al., 2014; Linares et al., 2005; Teixidó et al., 2013; Teixidó et al., 2014); 4) the MPAs can provide protection to the rocky benthic communities, enhancing assemblages stability and restoring biodiversity (Fraschetti et al., 2013; Linares et al., 2012), but the consequent increase of diving pressure can impact negatively fragile benthic organisms (Coma et al., 2004; Linares et al., 2012); 5) the precious red coral *Corallium rubrum* exhibit a particularly low recruitment and growth rates, that are incompatible with the present exploitation practices and poaching events (Bramanti et al., 2005; Garrabou et al., 2002; Linares et al., 2012; Montero-Serra et al., 2015); 6) the long-term studies are crucial to provide actual baselines of biodiversity structure and variability patterns of benthic communities, to understand key ecological processes and ecosystem functioning, and to design long-term management and conservation strategies (Casas-Güell et al., 2013; Casas-Güell et al., 2015; Cocito and Sgorbini, 2013; Fraschetti et al., 2013; Hereu et al., 2012; Montero-Serra et al., 2015; Ponti et al., 2011; Teixidó et al., 2009; Teixidó et al., 2011).

In this study I investigated spatial and temporal variability of the subtidal assemblages of the Gallinara Island (Ligurian Sea, NW Mediterranean) throughout 7 years. The sampling design has allowed to verify the interactions among horizontal variability at local and small scale and depth gradients, and to compare temporal dynamics between a shallow subtidal community (10 m depth) and a coralligenous one (30 m depth).

Materials & Methods

Study site

The study was carried out at Gallinara (or Gallinaria) Island in the Ligurian Sea (north-western Mediterranean Sea). The island is located 0.75 nm from the coast and 1.5 nm northeast of the harbour of Alassio. It has a sub-triangular shape, a surface of 9.8 ha, emerges up 90 m above sea level, and is composed by quartzite rocks of the superior cretaceous period (Balduzzi et al., 1994). It has rocky shores all around, a small port in the northern tip, directed toward the mainland coast, and two promontories on the side exposed to the open sea: Punta Sciusciaù (44.02497° N 8.23034° E) and Punta Falconara (44.02252° N 8.22608° E). Sea bottoms towards mainland are characterised by a gentle slope and *Posidonia oceanica* meadows on sandy sediment, while those toward the open sea have steep rocky cliffs ending with detrital and muddy sediments (Fig. 1). The geomorphological profile of Punta Sciusciaù is characterized by two steep rocky walls from the surface to 6 m depth and from 12 to 24 m depth, separated by a wide sub-horizontal terrace, followed by a gentler rocky slope from 24 m depth and by a detrital plane from about 35 m depth. The profile of Punta Falconara, instead, shows the typical aspect of a landslide, with the alternation of rocky steps (the fallen boulders) and hollows full of coarse sediment (Balduzzi et al., 1994). Given their exposition to the open sea, in the shallowest bathymetric belts the two promontories present a biocenosis of photophilic algae adapted to high hydrodynamism. This is followed by a biocenosis of sciaphilous algae with an important animal component (e.g. sponges; bryozoans; tunicates) and, from 25 m depth, by the coralligenous assemblages (Ballesteros, 2006). Gallinara Island is a proposed Site of Community Importance since 1995 (SCI code IT1324908, European Habitats Directive, 92/43/CEE) and a designed national Marine Protected Area since 1991 (La Mesa et al., 2010; Tunesi et al., 2008).
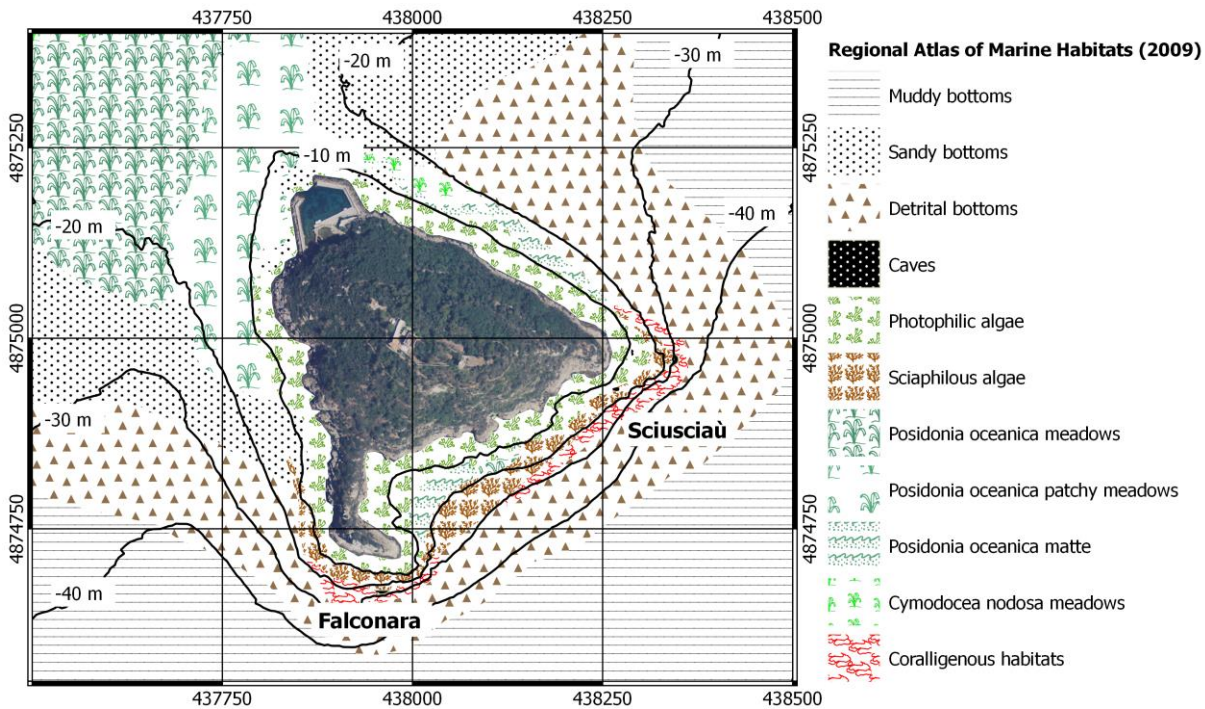
Figure 1. Bathymetric and habitats map of the study area (data from Liguria Region, 2009).

Sampling design and data analyses

Sessile benthic assemblages living on rocky cliffs were investigated by means of photographic sampling in two areas 400 m away (Falconara and Sciusciaù), at two depths (10 and 30 m) and two randomly selected sites, about 40 m distant, for each area and depth. Sampling was repeated yearly, in the first decade of June, from 2007 to 2014, excepting 2009. Photographic samples (21 × 28 cm) were collected along sub-vertical seaward oriented rocky substrates using high-resolution digital cameras equipped with external strobe and a custom steel frame. Organisms were identified to the lowest possible taxonomic level by comparison with a species reference collection (voucher specimens and macro pictures) and assigned to morphological and ecological groups (Ponti et al., 2011). Percent cover of sessile organisms was estimated by superimposing a grid of 400 equal-sized cells (i.e. 0.25% each) using the PhotoQuad software (Trygonis and Sini, 2012). Areas of photos that were too dark, blurred or occupied by vagile organisms were excluded and percent cover was adjusted according to the total readable area of each image (Ponti et al., 2011). Percent cover of sediments was also estimated.

Species richness (number of taxa, S), species diversity (Shannon's index with log base 2, H') and the corresponding evenness component (Pielou index, J') were calculated for each replicate sample (Magurran, 2004).

Differences in assemblage structure, species percent cover, and diversity indices, among Areas (fixed factor, two levels), Depths (fixed factor, two levels), Years (fixed factor, seven levels), and Sites (random factor, two level nested in Areas × Depths × Years), including all possible interactions, were assessed by uni- and multivariate permutational analysis of variance (PERMANOVA; Anderson and Robinson, 2001; Anderson and ter Braak, 2003). Univariate tests were run on Euclidean distances calculated on untransformed data (Anderson and Robinson, 2001). Multivariate analyses were based on Bray-Curtis similarity of square root transformed data (Clarke, 1993). When no differences among sites were detected ($p > 0.25$) this source of variation was eliminated from the analyses and the mean squares pooled in order to increase the power of the other relevant tests (Clarke, 1993). Significant results were further analysed by '*a posteriori*' pair-wise tests. When less than 999 unique values in the permutation distribution were available, asymptotical Monte Carlo p-values (p_{MC}) were used instead of permutational p-values. Similarity patterns were displayed by unconstrained ordination plots using the principal coordinate analysis (PCoA, i.e. metric multidimensional scaling; Gower, 1966). Vectors superimposed on to the PCoA plot represented the correlations of the abundances of the most relevant taxa with the PCoA axes. Statistical analyses were performed using PRIMER 6 with PERMANOVA+ add-on package (Anderson et al., 2008), while boxplots were obtained using R (R Core Team, 2012).

Results

Epibenthic organisms found at Falconara and Sciusciaù, at 10 and 30 m depth, include 75 taxa (6 Chlorophyta, 4 Ochrophyta, 12 Rhodophyta, 34 Porifera, 5 Cnidaria, 2 Annelida, 1 Mollusca, 9 Bryozoa, 1 Chordata), 50 of them identified at species level and other 11 at genus level.

The taxa that showed significant spatial and/or temporal variability in terms of percent cover are: Dyctiotaceae, *Padina pavonica* (Linnaeus) Thivy*, Pseudochlorodesmis furcellata* (Zanardini) Børgesen*, Caulerpa cylindracea* Sonder*, Jania* spp. J.V.Lamoroux, 1812, *Peyssonnelia* spp. Decaisne, 1841, *Womersleyella setacea* (Hollenberg) R.E.Norris, encrusting calcareous Rhodophyta, algal turf, *Axinella* spp. Schmidt, 1862, *Parazoanthus axinellae* (Schmidt, 1862), and encrusting bryozoan sp. 1.

The percent cover of the brown filamentous algae belonging to the family Dictyotaceae showed a large variability at very local scale (i.e., among random sites) and was affected by the interaction of all the three main factors considered (i.e., area, year and depth), nevertheless these algae had a clear preference for the shallower depth (Table 1, fig. 2a). Also the percent cover of the invasive green algae *C. cylindracea* displayed great variability among random sites and was affected by the

interaction between depth and year; this species showed a clear preference for the 10 m depth (Table 1, fig. 2b). Instead, the percent covers of the brown algae *P. pavonica* and the red algae belongin to the genus *Jania* resulted homogeneous among sites and were affected by the interaction between depth and year; both taxa had a clear preference for the shallower depth (Table 1, fig. 2a; 2b).

The percent covers of the encrusting bryozoan sp. 1 and the sediment showed an high variability at very local scale; that of the bryozoan varied significantly among years, while that of the sediment was affected by the interaction between area and depth. Both categories displayed a preference for the deeper depth (Table 1, fig. 2c). The percent covers of the red algae belonging to the genus *Peyssonnelia* and the sponges belonging to the genus *Axinella* showed a lower variability among sites and are affected by the depth; both taxa displayed a preference for the 30 m depth, stronger for the algae (Table 1; fig. 2b; 2c) . Instead, the percent covers of the green algae *P. furcellata* and the encrusting calcareous Rhodophyta showed no significant variability at the very local scale; that of *P. furcellata* is affected by the interaction of all the three main factor considered (i.e., area, year and depth), while that of ECR varied significantly with depth. Both taxa had a strong preference, higher in the case of the green algae, for the 30 m depth (Table 1, fig. 2a). Also the percent covers the zoanthid *P. axinellae* is homogeneous among sites and was affected by the interaction between area and depth; this species showed a clear preference for the deeper depth (Table 1, fig. 2c).

The percent cover the invasive red algae *W. setacea* didn't vary significantly among sites nor with depth, while it was affected by the interaction between area and year and between depth and year (Table 1, fig. 2b).

The percent cover of the algal turf, instead, showed large variability only at very local scale (Table 1).
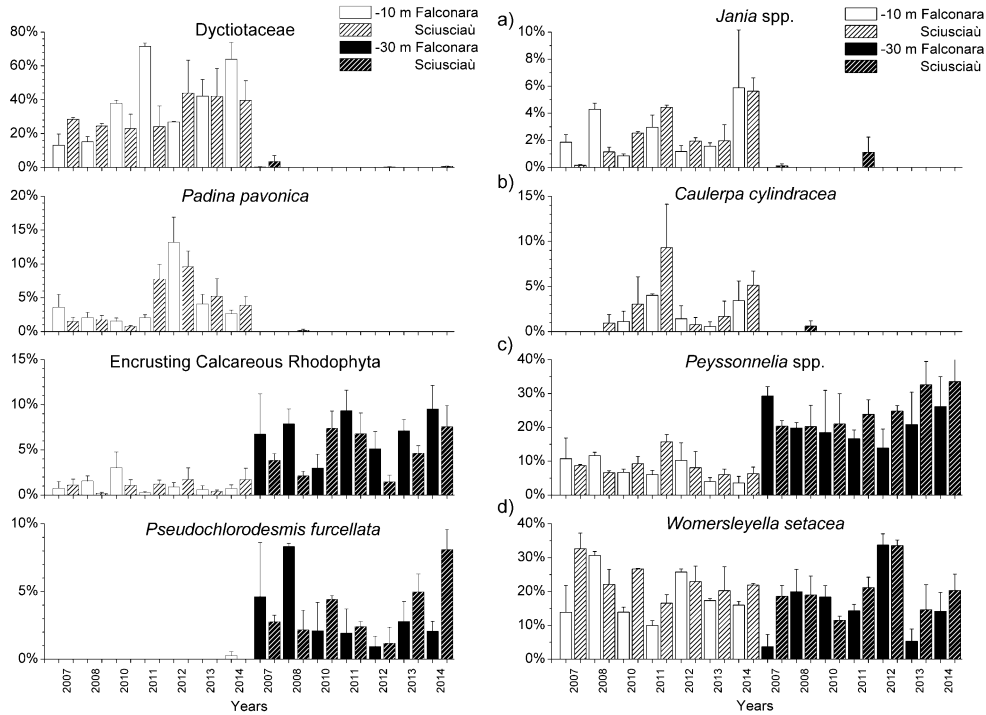
a)

b)
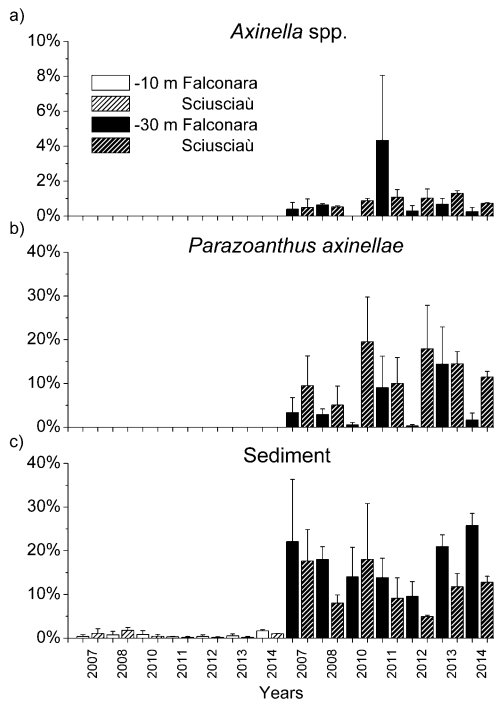
c)

Figure 2. Substratum percent cover of: a) Dictyotaceae, *P. pavonica*, ECR, *P. furcellata*; b) *Jania* ssp., *C. cylindracea*, *Peyssonnelia* spp, *W. setacea*; c) *Axinella* spp., *P. axinellae*, sediment.

Species richness (S) varied significantly only with the interaction between area and depth; it showed higher values at Sciusciaù than at Falconara at 30 m depth (Table 1, fig 3).

Species diversity (H') varied significantly with the interaction of all the three main factors considered (i.e., area, year and depth; Table 1, fig 3).

Evenness (J'), instead, showed significant differences among sites and with the with the interaction of all the three main factors considered (i.e., area, year and depth; Table 1).
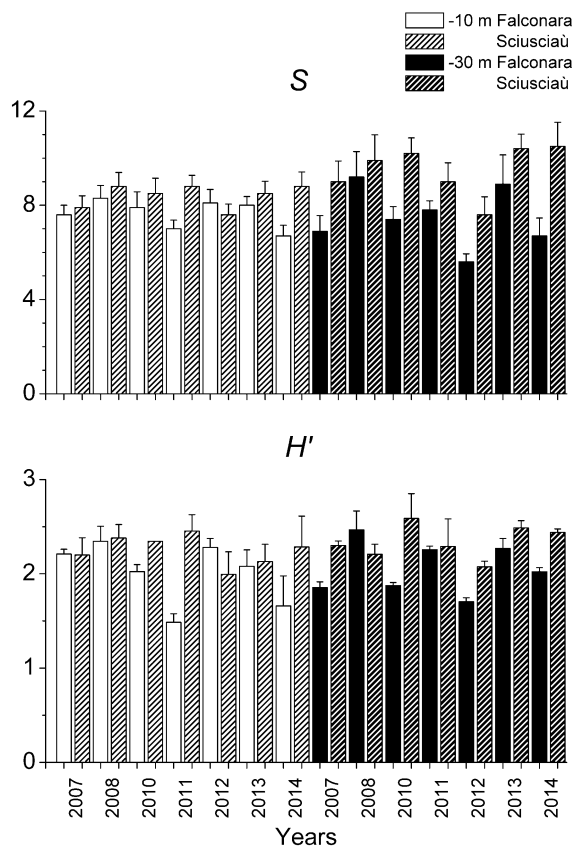
Figure 3. Spatio-temporal variation of species richness (S) and Shannon Index (H').

The assemblages structure varied significantly mainly at very local scale and with the depth, but also, with lower significance, with time and area (Table 2). These results are clearly showed by the PCO ordination plot, in which the first two axes explained 42.3% and 11.4% of the variability of thr assemblages respectively (fig. 4). The figure showed a clear differation between the assemblages at 10 m depth and those at 30 m.
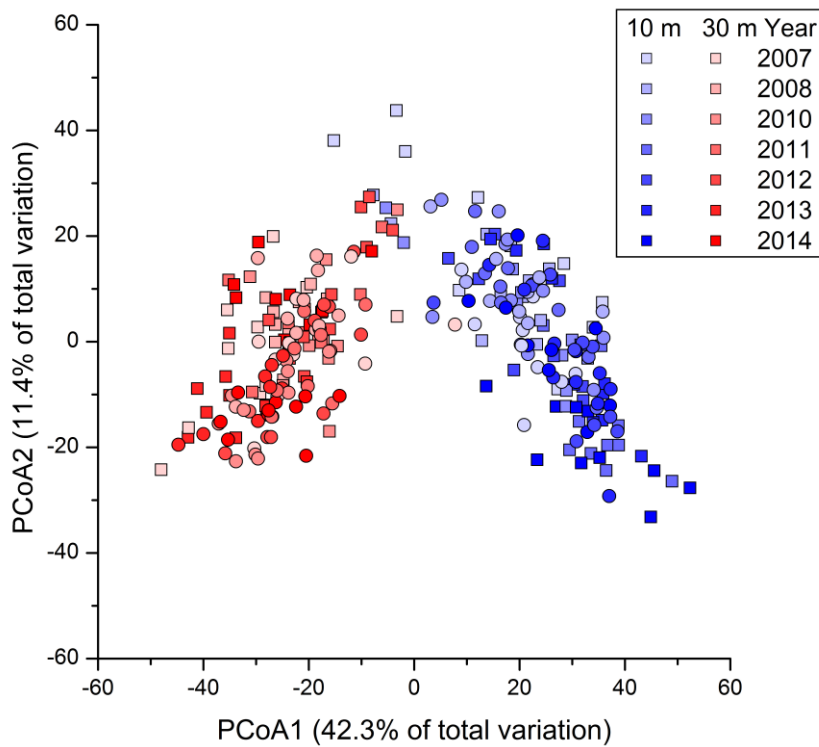
Figure 4. Unconstrained ordination plots (PCoA) of benthic assemblage data at two depths (blue = 10 m, red = 30 m), two areas (circle: Sciusciaù; square: Falconara) and seven dates (2007, 2008, 2010, 2011, 2012, 2013, 2014; gradient color). Square root-transformed percent cover data, Bray-Curtis coefficient.

The PERMDISP test (fig. 7) showed that the spatio-temporal variability of the assemblages is significantly greater at 30 m depth (PERMDISP: 33.29±0.82, Table 3) than at 10 m (PERMDISP: 27.84±0.72, Table 3).

Table 1. Results from Permanova on percent cover of the most significative taxa and diversity index (S: species richness; H': Shannon's index; J': Pielou's index). In case of mean squares pooling, the denominator *df* increases from 28 to 252.

Source	Stat	Dictyotaceae	*Padina pavonica*	*Pseudochlorodesmis furcellata*	*Caulerpa cylindracea*	*Jania* spp.	*Peyssonnelia* spp.	*Womersleyella setacea*	Encrusting calcareous Rhodophyta	Algal turf	*Axinella* spp.	*Parazoanthus axinellae*	Encrusting bryozoan sp. 1	Sediment	S	H' (log2)	J'
Depth (De)	MS	8,6297	0,1263	0,0842	0,0339	0,0442	1,5440	0,0642	0,1621	0,0507	0,0057	0,5166	0,0159	1,3841	15,5570	0,3355	0,0233
	Pseudo-$F_{1,28}$	34,8190	10,8580	33,5350	3,7504	16,5110	27,3210	1,3680	14,2200	1,2639	9,1861	4,3377	12,1910	17,1580	0,5362	2,2374	1,2249
	p	0,0003 ***	0,0092 **	0,0007 ***	0,0940	0,0021 **	0,0008 ***	0,3760	0,0049 **	0,4056	0,0145 *	0,0762	0,0093 **	0,0028 **	0,7263	0,2077	0,4138
Year (Yr)	MS	0,1514	0,0116	0,0023	0,0056	0,0029	0,0079	0,1032	0,0032	0,0970	0,0007	0,0113	0,0005	0,0224	16,1040	0,4763	0,0130
	Pseudo-$F_{6,28}$	1,0317	5,2529	0,6685	6,2204	3,0830	0,3106	2,1669	1,5710	3,2400	1,2799	0,7399	1,2324	2,9955	2,5673	0,7238	0,3392
	p	0,4755	0,0480 *	0,6796	0,0161 *	0,1032	0,9103	0,1948	0,3068	0,0927	0,3060	0,6249	0,4048	0,1139	0,1422	0,6653	0,8934
Area (Ar)	MS	0,0590	0,0001	0,0003	0,0043	0,0000	0,0547	0,1504	0,0084	0,0289	0,0000	0,1113	0,0012	0,0631	134,4100	4,7314	0,0661
	Pseudo-$F_{1,28}$	0,4020	0,0334	0,0904	4,7675	0,0092	2,1633	3,1591	4,1685	0,9641	0,0209	7,2823	2,9086	8,4320	21,4290	7,1897	1,7283
	p	0,5443	0,8621	0,7778	0,0638	0,9217	0,1934	0,1212	0,0902	0,3577	0,8686	0,0400 *	0,1370	0,0280 *	0,0047 **	0,0407 *	0,2392
De × Yr	MS	0,1659	0,0118	0,0022	0,0059	0,0026	0,0376	0,0577	0,0041	0,0719	0,0007	0,0113	0,0004	0,0183	7,2321	0,4689	0,0310
	Pseudo-$F_{6,28}$	1,2222	5,2840	0,5838	6,2492	3,1471	3,1113	3,4150	1,1254	0,9227	1,2799	0,7399	1,0054	2,3414	2,2968	0,6200	0,5753
	p	0,4078	0,0304 *	0,7340	0,0187 *	0,0086 **	0,0957	0,0099 **	0,4499	0,5272	0,3428	0,6389	0,5046	0,1608	0,1646	0,7130	0,7421
Ar × De	MS	0,0858	0,0000	0,0004	0,0034	0,0001	0,0194	0,0015	0,0076	0,0298	0,0000	0,1113	0,0009	0,0628	27,6570	0,0191	0,0320
	Pseudo-$F_{6,28}$	0,6320	0,0174	0,1183	3,5680	0,1751	1,6042	0,0914	2,0895	0,3829	0,0209	7,2823	2,2993	8,0322	8,7834	0,0252	0,5940
	p	0,4578	0,9040	0,7477	0,1041	0,6892	0,2485	0,7597	0,1959	0,5527	0,8855	0,0376 *	0,1827	0,0321 *	0,0257 *	0,8774	0,4711
Ar × Yr	MS	0,1468	0,0022	0,0035	0,0009	0,0010	0,0253	0,0476	0,0020	0,0300	0,0005	0,0153	0,0004	0,0075	6,2726	0,6581	0,0383
	Pseudo-$F_{6,28}$	3,2287	1,5614	2,8061	0,5205	1,1566	0,8978	2,8164	0,8419	0,6450	0,9676	0,9449	1,0448	0,3744	1,3360	2,6135	1,7891
	p	0,0143 *	0,1598	0,0272 *	0,8005	0,3507	0,5113	0,0257 *	0,5418	0,6960	0,5130	0,4810	0,4220	0,8945	0,2428	0,0401 *	0,1384
Ar × De × Yr	MS	0,1358	0,0022	0,0037	0,0009	0,0008	0,0121	0,0169	0,0036	0,0779	0,0005	0,0153	0,0004	0,0078	3,1488	0,7563	0,0540
	Pseudo-$F_{6,28}$	2,9870	1,5726	3,0114	0,5511	1,4270	0,4287	1,4722	1,5074	1,6782	0,9676	0,9449	1,0034	0,3915	0,6706	3,0034	2,5222
	p	0,0215 *	0,1505	0,0174 *	0,7792	0,0561	0,8540	0,0531	0,1812	0,1660	0,5038	0,4777	0,4410	0,8864	0,6702	0,0223 *	0,0460 *
Site (Ar × De × Yr)	MS	0,0455	pooled	0,0012	0,0017	pooled	0,0282	pooled	pooled	0,0464	0,0005	0,0162	0,0004	0,0200	pooled	0,2518	0,0214
	Pseudo-$F_{28,224}$	2,8771		1,2630	2,4735		1,7449			3,2013	1,4361	2,7687	1,8423	3,1391		1,4344	2,1004
	p	0,0001 ***		0,1733	0,0004 ***		0,0148 *			0,0001 ***	0,0320 *	0,0001 ***	0,0075 **	0,0001 ***	*	*	0,0014 **
Res	MS	0,0158	0,0014	0,0010	0,0007	0,0006	0,0161	0,0115	0,0024	0,0145	0,0004	0,0058	0,0002	0,0064	4,6952	0,1756	0,0102

Significant levels were indicated by the following symbols: ns = not significant, * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$

Table 2. Summary of PERMANOVA tests on differences of taxa abundances among Depths (fixed factor, two levels), Years (random factor, seven levels), Areas (random factor, two levels), and Sites (random factor, two level nested in Areas × Depths × Years) (square root-transformed percent cover data, Bray-Curtis coefficient).

Source	df	SS	MS	Pseudo-F	P(perm)	perms	
Depth (De)	1	160180	160180	19,0630	0,0009	9962	***
Year (Yr)	6	23301	3884	2,3768	0,0021	9930	**
Area (Ar)	1	4856	4856	2,9718	0,0371	9924	*
De × Yr	6	18809	3135	1,5798	0,0972	9931	
Ar × De	1	5372	5372	2,7070	0,0645	9921	
Ar × Yr	6	9804	1634	1,1283	0,2721	9883	
Ar × De × Yr	6	11906	1984	1,3702	0,0752	9891	
Site (Ar × De × Yr)	28	40548	1448	1,8825	0,0001	9691	***
Res	224	172320	769				
Total	279	447090					

Table 3. Distance-based test for homogeneity of multivariate dispersions (PERMDISP) between benthic assemblages at two depth (10 and 30 m).

Group	Size	Average	SE
10 m	140	27,837	0,71791
30 m	140	33,291	0,82477

Discussions

The structure of investigated hard bottom communities showed significant changes with depth and at the horizontal spatial scale of meters/dozen of meters, while exhibited low variability through years and at the horizontal spatial scale of hundreds of meters. The percent cover of many of the organisms observed changed significantly with depth, with some of them that resulted exclusive or almost exclusive of one sampling depth, determining a clear differentiation between the communities at 10 and 30 m, in agreement with previous studies (e.g. Balata et al., 2006; Garrabou and Harmelin, 2002; Terlizzi et al., 2007). The largest component of horizontal variation of percent cover occured at small spatial scales (i.e. replicates: meters; site: dozen of meters), especially at 30 m depth where the high topographical heterogeneity promotes the patchy distribution of the

organisms (Ferdeghini et al., 2000; Terlizzi et al., 2007), in agreement with results from previous studies (Casas-Güell et al., 2015 and reference therein). In term of community composition the studied assemblages showed only limited temporal variability, which seems to be more pronounced at the shallower depth, as showed by the PCO. Moreover, the only taxa that showed significant temporal fluctuations in their percent cover were non-reef-forming organisms (i.e. Dictyotaceae; *P. furcellata*; *P. pavonica; C. cylindracea*; *Jania* spp.; *W. Setacea*) that, with the exception of *P. furcellata and W. setacea*, were almost exclusive of the shallower sampling depth. This results, in agreement with those from Ponti et al. (2011), seem to confirm the reduction of the dynamics with depth in the hard bottom subtidal communities (Garrabou et al., 2002) and the high temporal stability of coralligenous (Casas-Güell et al., 2015). This habitat, in fact, being subjected to nearly stable physical conditions and hosting species with low population dynamics and long lifespan (Teixidó et al., 2011), is characterized by longer-term temporal variability than that considered in this study (Virgilio et al., 2006). The shallow subtidal assemblages, instead, are dominated by photophilous macroalgae (mainly Ochrophyta; Boudouresque, 1984), which exhibit stronger temporal dynamics than deeper algal assemblages (Piazzi et al., 2002).

This low temporal variability has two main effects: 1) the assemblages considered are particularly vulnerable to a large plethora of threats (e.g. Balata et al., 2007; Cebrian et al., 2012; Piazzi et al., 2011), especially extreme disturbance events (e.g. heat waves; dramatic storms; Cerrano et al., 2000; Garrabou et al., 2009; Teixidó et al., 2013); 2) in absence of catastrophic events, temporal changes of these assemblages are extremely hard to detect, with the risk to not recognize slow regime shifts (Hughes et al., 2013). In this context, the results of this study stress the need of longer-term monitoring protocol for coralligenous, since even an almost decadal time-series of observations is ineffective to intercept the temporal variability of these assemblages. Indeed, a then-now comparison performed at Gallinara Island in 2006 (Tunesi et al., 2006) respect to 1988-1992 (Balduzzi et al., 1994) allowed to notice the disappearance of the gorgonian *Eunicella singularis* (Esper, 1791) and the arrival of two invasive green algae, *Caulerpa taxifolia* (M.Vahl) C.Agardh and *C. cylindracea* Sonder. In turn, Balduzzi et al. (1994) were unable to find *Corallium rubrum* (Linnaeus, 1758) and *Savalia savaglia* (Bertoloni, 1819), reported for Gallinara Island in the previous decades (Marchetti, 1965). Some of these changes can be put in relation with specific anomalous events occured in that temporal span. The benthic assemblages at Gallinara Island, as well as many other sites along the Ligurian Sea coast, experienced sponges bleaching (e.g. in 1998; Cerrano et al., 2001) and mass mortality of both sponges and gorgonian (e.g. in 1999; Cerrano et al., 2000), which were associated to stress due to temporary changes in the environmental parameters (decrease of salinity consequent to autumnal rainfalls and increase of seawater

temperature respectively). My results confirmed the absence of *C. rubrum*, *E. singularis* and *S. savaglia*, and attested the disappearance/regression of *C. taxifolia* and the expansion of *C. cylindracea* from just the soft bottoms (Tunesi et al., 2006) to also the vertical hard bottoms (first appearance in 2008). Then, this work can represents a further "stepping-stone" in the reconstruction of long-term changes of subtidal assemblages at Gallinara Island, providing new data for temporal comparison approach and, at the same time a baseline for future monitoring activities.

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CHAPTER 2: Long-term reconstruction of changes in hard-bottom seascapes

Introduction

In a world in which marine ecosystems are threatened by anthropogenic activities (Halpern et al., 2008), it has became crucial to reconstruct how these activities affected marine biodiversity, and related ecosystem functioning, in the past (Manez et al., 2014). Indeed, only knowing the history of their past changes we will able to manage properly the processes of management, restoration and recovery of marine ecosystems (Borja et al., 2012; Lotze and Worm, 2009).

This work of reconstruction can be particularly challenging for hard-bottom sessile communities, for which historical data are scarce and fragmentary (Gatti et al., 2017). The applicable approaches of historical ecology for these organisms are time-series analysis (see chapter 1 for a review about the use of this technique in Mediterranean Sea) and temporal comparison (Lotze and Worm, 2009). Although the first one would be preferable, since allows to follow trends and fluctuations over time (Sukhotin and Berger, 2013), for benthic communities available time-series are too short to detect correctly and completely the long-term variations (Jackson, 2001). Instead, temporal comparison (or then-now comparison), which consists to confront ecological information about one locality in two (rarely more) moments in time, allows to obtain older information, especially for the Mediterranean Sea where early ecologists began to collect descriptive data long before to arrange periodic monitoring programs (Bianchi and Morri, 2000).

Several studies using this approach were conducted in the Mediterranean Sea during the last 20 years, focalised on macroalgal forests (Bianchi et al., 2014; Cormaci and Furnari, 1999; Perkol-Finkel and Airoldi, 2010; Thibaut et al., 2005), sessile communities on rocky reefs (Bianchi et al., 2014; Parravicini et al., 2013), coralligenous assemblages (Bourcier, 1996; Gatti et al., 2015), *Posidonia oceanica* meadows (Ardizzone et al., 2006; Bourcier, 1996), and soft bottoms (Bianchi et al., 2014; Bourcier, 1996; Grémare et al., 1998). The average temporal span is 45 years, with a maximum of 90 years (Thibaut et al., 2005). Remarkably, the studies regarding hard-bottom communities have the shortest temporal span (Bianchi et al., 2014; Bourcier, 1996; Parravicini et al., 2013), with the exception of Gatti et al. (2015), where the authors built a chronological chain of events for a coralligenous assemblages over 70 years combine old descriptive information (since the 30') with more recent quantitative data (since 60'). In some cases the comparison was made only between two moments in time (Bianchi et al., 2014; Bourcier, 1996; Cormaci and Furnari, 1999;

Grémare et al., 1998; Parravicini et al., 2013), while in other was made among a 4/5 moments scattered throughout the entire temporal span (Ardizzone et al., 2006; Bourcier, 1996; Gatti et al., 2015; Perkol-Finkel and Airoldi, 2010; Thibaut et al., 2005). Where past quantitative or semi-quantitative data were available, the authors have compared them with present data obtained with the same methodologies (Ardizzone et al., 2006; Bianchi et al., 2014; Bourcier, 1996; Cormaci and Furnari, 1999; Grémare et al., 1998; Parravicini et al., 2013). The longest temporal comparison studies, however, are based on past descriptive information inferred by scientific literature, like species composition of the communities, distribution data, and environmental information (Perkol-Finkel and Airoldi, 2010; Thibaut et al., 2005).

The results can be summarised in the following points: 1) in the last 30/40 years, macroalgal forests on rocky reefs have suffered a drastic decline, both in terms of distribution and diversity, caused mainly by pollution, eutrophication and natural and human-induced habitat instability (Bianchi et al., 2014; Cormaci and Furnari, 1999; Perkol-Finkel and Airoldi, 2010; Thibaut et al., 2005); 2) in a comparable time span, *Posidonia oceanica* meadows have seen a reduction of their extension and their lower bathymetric limits and an increase of the extension of dead matte, due to the increase of turbidity, bottom trawling and other human activities (Ardizzone et al., 2006; Bianchi et al., 2014; Bourcier, 1996); 3) overall, benthic sessile communities in different areas of the Mediterranean Sea have faced phase shifts, with disappearance (or dramatic reduction) of formerly abundant species, biotic homogenization and appearance of alien species, caused by the interaction of local human pressure and global climate change (Bianchi et al., 2014; Bourcier, 1996; Gatti et al., 2015; Parravicini et al., 2013). The obvious limit of then-now approach is that comparing two (or little more) moments distant in time does not take into account temporal variability (Lotze and Worm, 2009) and does not allow to understand precisely when a phase shift in communities (Montefalcone et al., 2011) has occurred (Spencer et al., 2012).

In this study I applied the temporal comparison approach to sessile benthic communities of natural (rocky reefs) and artificial (wrecks) hard bottoms, using past underwater (hereafter uw) photographs stored in private archives or published in grey literature as unconventional data sources (Al-Abdulrazzak et al., 2012), and comparing them to current pictures of the same localities.

Materials & methods

Study sites

The uw pictures of natural hard bottoms depict the rocky reefs of the Portofino Promontory, located about 30 km eastward to Genoa (Ligurian Region, Italy). It is a squared rocky cape that protrudes 5

km into the sea, whose exposed side is about 6 km long vertical cliff (fig. 1) This is composed of Oligocenic puddingstone and continues underwater until 50-60 m depth (Tortonese, 1958). In the 1999 was established the Marine Protected Area (MPA) of Portofino, but only in 2001 the protection was successfully enforced.

The pictures of artificial hard bottoms depict 6 different wrecks (Table 1) scattered along the Italian and French coast of the Ligurian Sea (fig. 2).
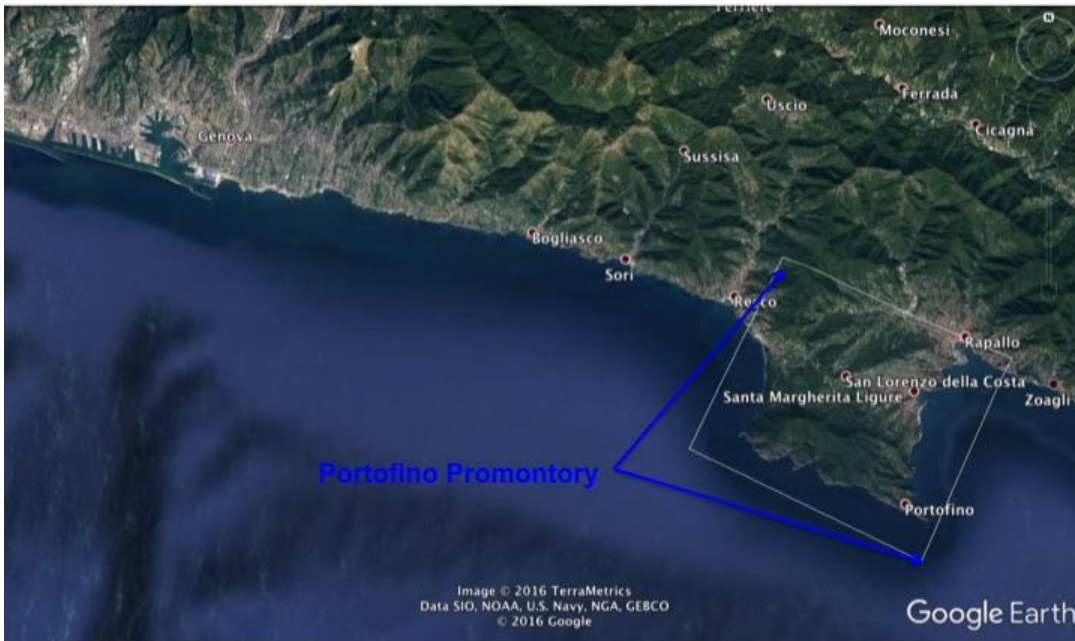

Figure 1. Portofino Promontory.
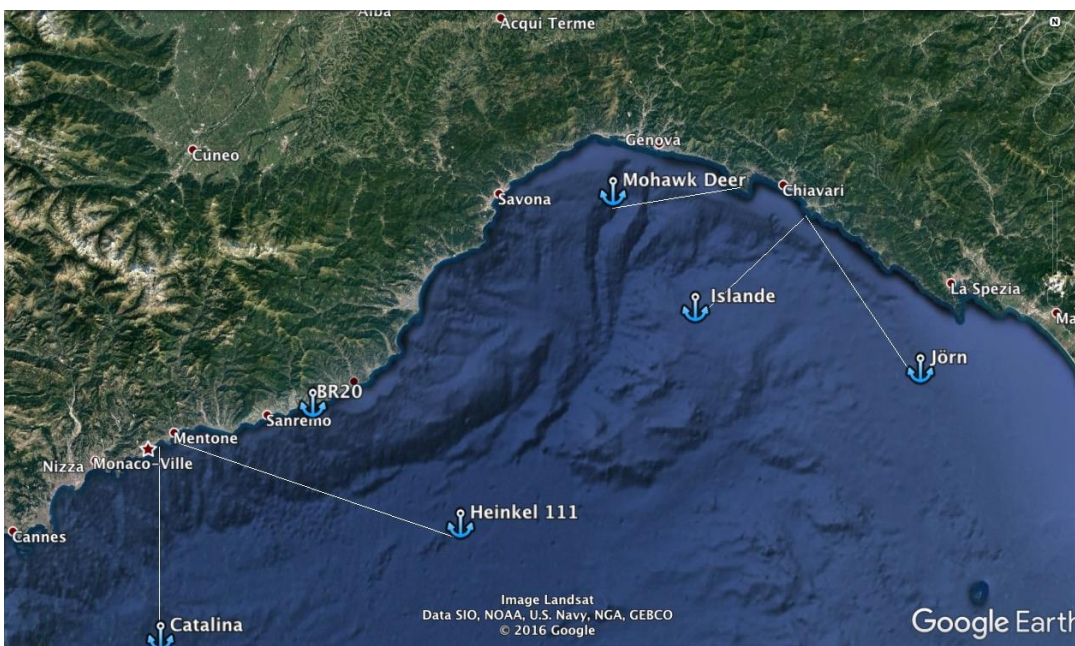
Figure 2. Position of the wrecks considered.

Table 1. Wrecks considered.

Wreck	Latitude	Longitude	Depth (m)
BR20	43°48'23.55"N	7°54'32.83"E	47
Catalina	43°44'20.26"N	7°27'4.98"E	54-58
Heinkel 111	43°45'13.44"N	7°29'42.99"E	58-60
Islande	44°15'6.88"N	9°23'1.65"E	36
Jöern	44°15'4.09"N	9°23'6.09"E	26-32
Mohawk Deer	44°18'27.72"N	9°11'28.68"E	20-50

Data sources

The historical pictures of natural hard bottoms of Portofino (a total of 40 photos) were collected from the private archive of the uw photographer Armando Tommei, and date back to the 1980's. A comparable number of current pictures of the same area (taken between 2013 and 2016) were gathered from several photographers and were.

The historical pictures of wrecks (3 for BR20, 2 for Catalina, 1 for Islande and Jöern) were extrapolated from the books "Navi e Relitti tra Montecarlo e il promontorio di Portofino" and "Navi e Relitti tra Sestri Levante e La Spezia", and were taken by the photographer Adriano Penco during the 1990's. The current pictures were gathered from the web and were taken from 2010 and 2016, with the exception of the wreck of Mohawk Deer in Portofino, for which was possible to track a sort of long-term series, with pictures dating back to 1990, 2001, 2008, 2013 and 2016 (1 picture for each year).

Data management and analysis

Since the pictures were not taken for scientific purposes, they were not orthogonal to the substratum and the calculation of the percent cover of the sessile organisms was not feasible. For this reason, an analysis protocol was developed to extrapolate semi-quantitative data (fig. 3). This protocol

provides to distinguish among different typology of substratum inclination in each picture and to analyse them separately, since this factor is considered as a major determinant of habitat heterogeneity in hard-bottom habitats (Glasby, 2000; Glasby and Connell, 2001), in particular for coralligenous assemblages (Virgilio et al., 2006). Four typology of substratum inclination were described, in order of increasing slope: lower bank shelf, mid deep depression, open slope, overhang structures (fig. 4; Verfaillie et al., 2007). The analysis consists of identifying each sessile organism depicted at the lowest taxonomic level feasible and storing presence/absence data (through a binary system: 1=present; 0=absent) and abundance data. The last ones are quantified using two different measurement scales: 1) the numerical system, based on the number of the specimens (for organisms that can be easily counted); 2) the alphabetical system, relying on the degree of the substratum cover (for organisms that can't be counted, like encrusting sponges, algal turf, etc.) (Table 2). Where was not possible to discern among similar organisms, taxonomic categories were used (e.g. algal turf; encrusting sponges; erect bryozoans; etc.). The presence/absence data are expressed as the frequency of the pictures in which a certain species/taxonomic category is present on the total number of pictures for each typology of substratum inclination. The abundance data for a certain species/taxonomic category are expressed as the frequency of the different abundance categories on the total number pictures in which that species/taxonomic category is present. The changes in presence and abundance over time of each species/taxonomic category for each typology of substratum were assessed. On the basis of these changes, an overall evaluation of the temporal changes was performed and the species/taxonomic categories were classified in "winners" if they increase or appear in current pictures respect to the past ones and "losers" if they decrease or disappear (Baskin, 1998).

This protocol was applied to the pictures of Portofino, taking care to discern between landscape and close-up pictures, since the different spatial scale covered (Terlizzi et al., 2007) and the different accuracy in the organisms identification that the two techniques allow.
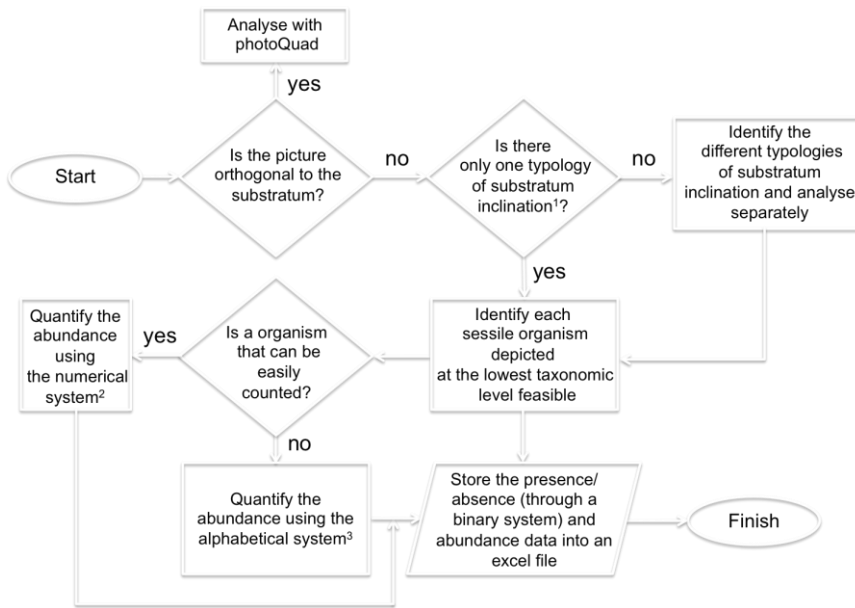
Figure 3. Flow chart of the analysis protocol for historical pictures.

Degrees of inclination:

0-10°   lower bank shelf
11-45° mid-deep depression
46-90° open slope
>90°   overhang structure

Mid-Deep Depression
Open Slope
Overhang Structures
Lower Bank Shelf
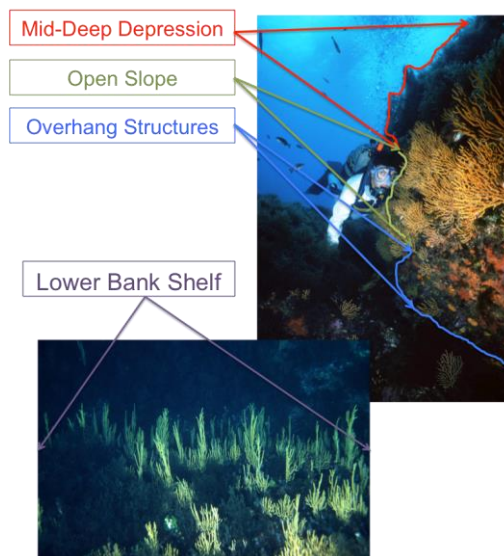
Figure 4. Typology of substratum inclination.

Table 2. Abundance quantification systems.

Numerical system	Alphabetical system
1-3 specimens	**A:** one isolated specimen
4-10 specimens	**B:** some scattered specimens
11-50 specimens	**C:** several scattered specimens
>50 specimens	**D:** one crowded area
	E: some crowded areas
	F: several crowded areas

Since wrecks provide fixed reference point that make easier to recognize the framed area, current pictures with the same frame (or almost the same) of the past ones were chosen for each wreck to be compared. Therefore, the analysis protocol was applied without distinguishing between close-up and landscape pictures and among the different typology of substratum inclination. The temporal changes for each wreck were assessed comparing each past picture with its present counterpart in terms of presence and abundance of species/taxonomic categories.

Results

Pictures of Portofino

Presence/absence data

Considering overall the close-up pictures, the species/morphological categories that showed the greater temporal changes in frequency of presence are the cnidarians *Eunicella cavolini* (Kock, 1887) that passed from 85% in past pictures to 20% in present ones, *Paramuricea clavata* (Risso, 1826) that passed from 20% to 55%, *Corallium rubrum* (Linnaeus, 1758) that passed from 15% to 45%, *Parazoanthus axinellae* (Schmidt 1862) that passed from 40% to 15%, the erect bryozoans that passed from 30% to 50%, the erect algae that passed from 40% to 25%, and the encrusting calcareous Rhodophyta (hereafter ECR) that passed from 25% to 45%. Moreover, the bryozoan *Turbicellepora avicularis* (Hincks, 1860) and filamentous red algae *Womersleyella setacea* (Hollenberg) R.E.Norris 1992, appeared only in the present pictures, both with a frequency by 20%,

while the green algae *Halimeda tuna* (J. Ellis & Solander) J.V. Lamouroux 1816, which showed a frequency of presence by 15% in the past pictures, disappeared in the present ones (fig. 5).
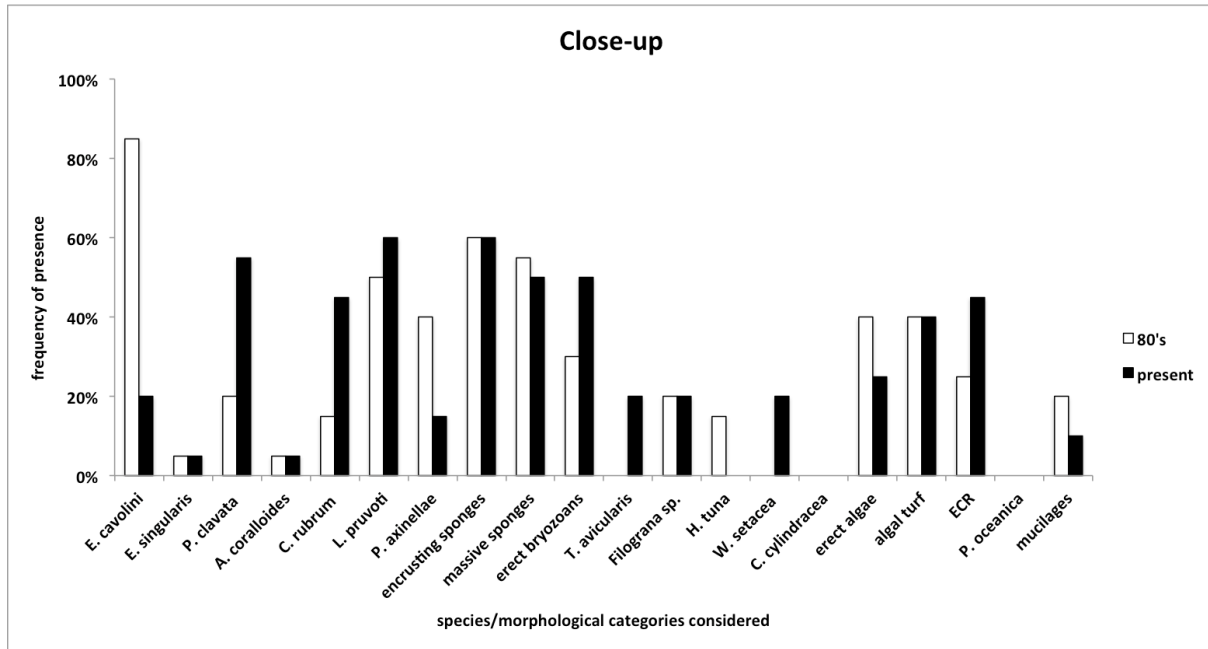
Figure 5. Presence/absence data for the close-up pictures.

The frequency of presence for each species/morphological categories considered varied in time in different ways depending on the inclination of substratum. Some of those that didn't show changes in the overall analysis of the close-up pictures, like *Leptopsammia pruvoti* Lacaze-Duthiers, 1897, showed changes when the typologies of substratum inclination were considered separately. *E. cavolini* passed from 100% of presence in past pictures to 40% in present ones for lower bank shelf, from 100% to 50% for mid-deep depression, from 100% to 0% for open slope, and from 66.7% to 0% in overhang structures. *P. clavata* passed from 20% to 80% for lower-bank shelf, from 66.7% to 100% for mid-deep depression, from 16.7% to 40% for open slope, and from 0% to 16.7% for overhang structures. *C. rubrum* passed from 0% to 25% for mid-deep depression, from 0% to 40% for open slope, from 50% to 100% for overhang structures, while it was not present both in past and present pictures for lower banks shelf. *L. pruvoti* passed from 0% to 40% for lower-bank shelf, from 33.3% to 50% for mid-deep depression, from 50% to 80% for open slope, and from 100% to 66.7% for overhang structures. *P. axinellae* passed from 60% to 20% for lower-bank shelf, from 100% to 20% for mid-deep depression, from 33.3% to 20% for open slope, and from 16.7% to 0% for overhang structures. The erect bryozoans passed from 0% to 40% for lower-bank shelf, from 0% to

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75% for mid-deep depression, from 50% to 60% for open slope, and from 50% to 33.3% for overhang structures. *T. avicularis* passed from 0% to 75% for mid-deep depression and from 0% to 16.7% for overhang structures, while it was not present both in past and present pictures for lower-bank shelf and open slope. The erect algae passed from 80% to 20% for lower-bank shelf, from 66.7% to 25% for mid-deep depression, from 33.3% to 60% for open slope, and from 16.7% to 0% for the overhang structures. The ECR passed from 0% to 60% for lower-bank shelf, from 33.3% to 100% for mid-deep depression, from 50% to 40% for open slope, and from 16.7% to 0% for overhang structures. *W. setacea* passed from 0% to 20% for lower-bank shelf, from 0% to 25% for mid-deep depression, from 0% to 40% for open slope, while it was not present both in past and present pictures for overhang structures. *H. tuna* passed from 50% to 0% for open slope, while it was not present bot in past and present pictures for lower-bank shelf, mid-deep depression and overhang structures (fig. 6a, b c, d).

a)

Close-up - mid-deep depression

b)

Close-up - open slope

c)

Close-up - overhang structures
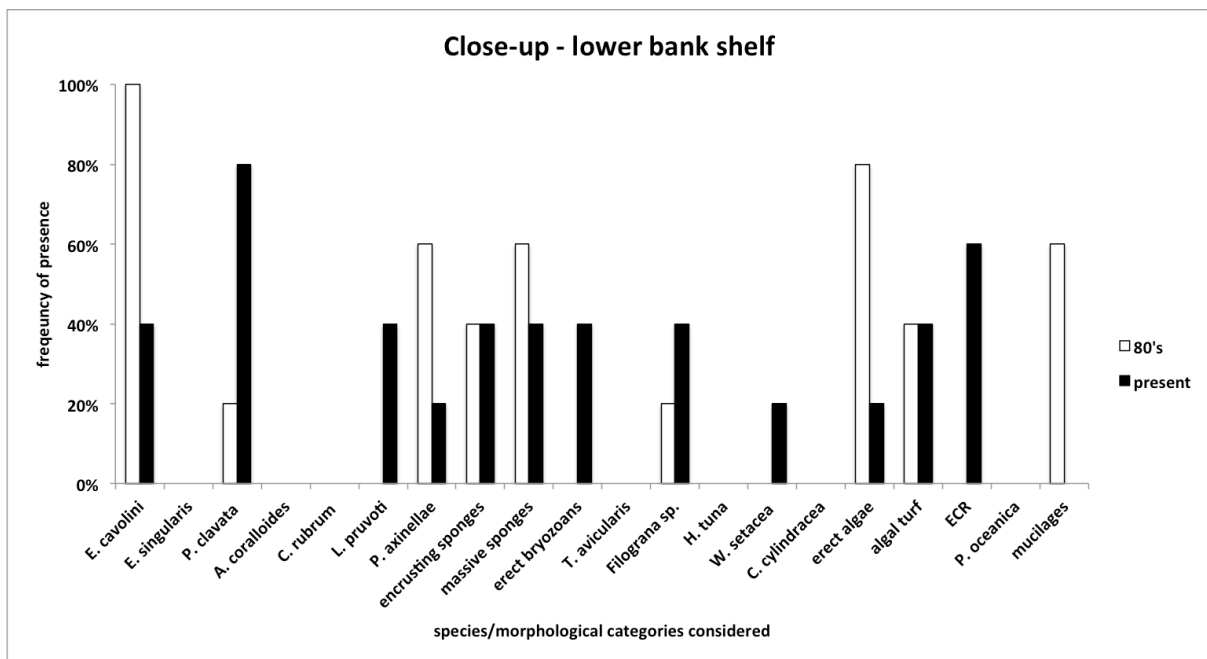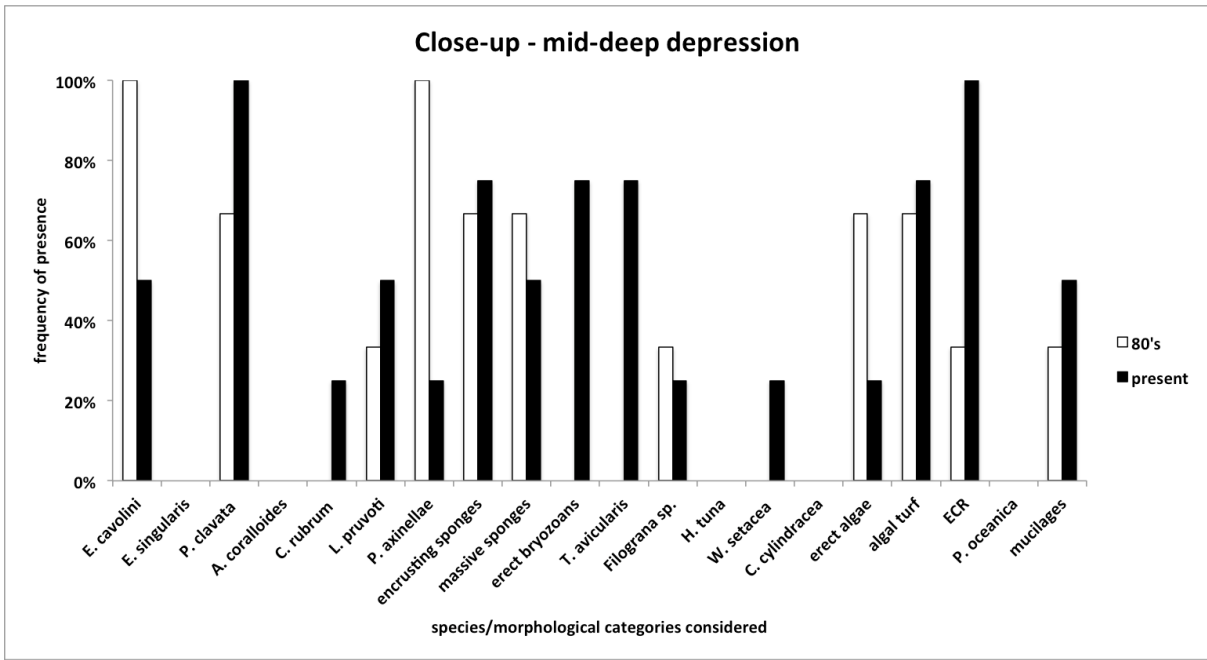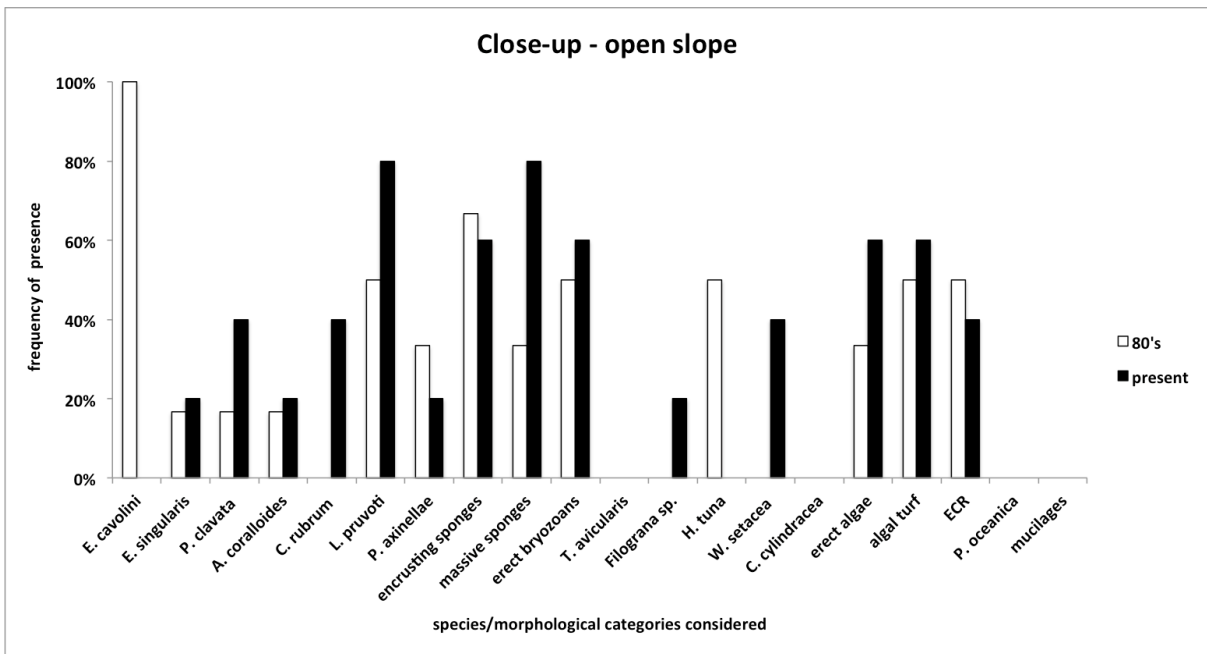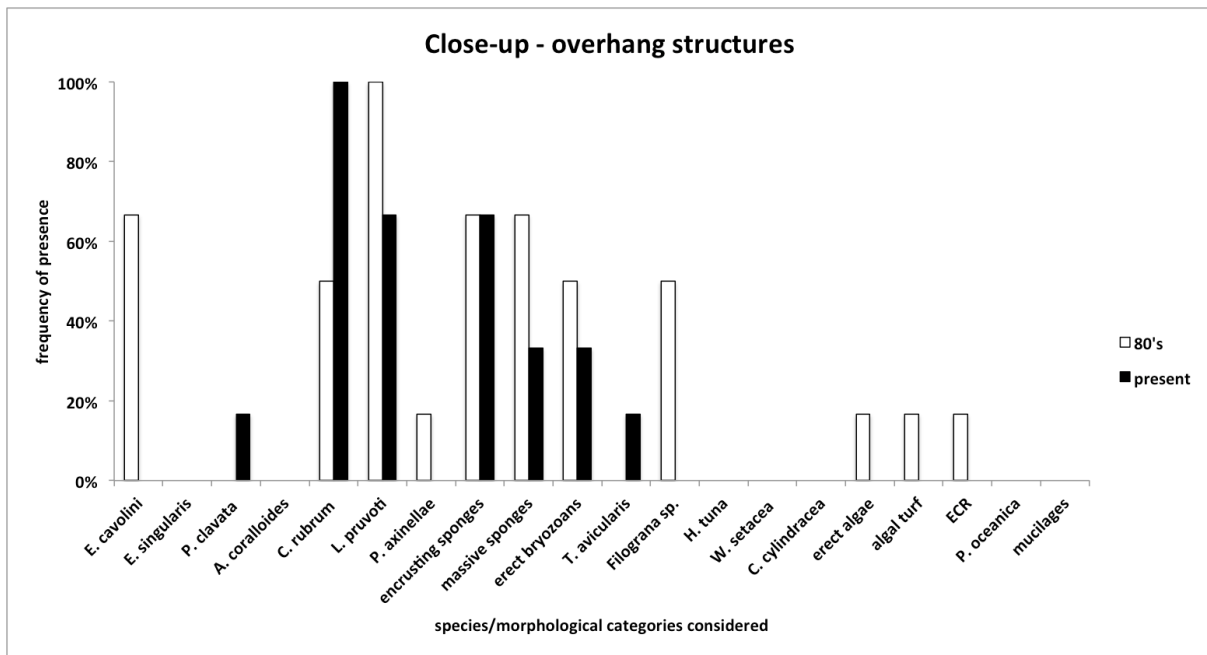
d)

Figure 6. Presence/absence data for the different typology of substratum inclination of the close-up pictures: a) lower-bank shelf; b) mid-deep depression; c) open slope; d) open slope.

Considering overall the landscape pictures, the species/morphological categories that showed the greater temporal changes in frequency of presence are the cnidarians *E. cavolini* that passed from 73.9% in the past pictures to 50% in the present ones, *P. clavata* that passed from 4.3% to 47.7%, *C. rubrum* that passed from 8.7% to 27.3%, *P. axinellae* that passed from 10.9% to 29.5%, the encrusting and massive sponges that passed respectively from 52.2% to 77.3% and 32.6% to 72.7%, the erect bryozoans that passed from 4.3% to 34.1%, the erect algae that passed from 60.9% to 45.5%, the algal turf that passed 43.5% to 70.5%, and the ECR that passed from 23.9% to 72.7%. Moreover, the green algae *Caulerpa cylindracea* Sonder, *W. setacea* and *T. avicularis* appeared only in the present pictures, with a frequency of presence respectively of 15.9%, 38.6% and 22.7% (fig 7)
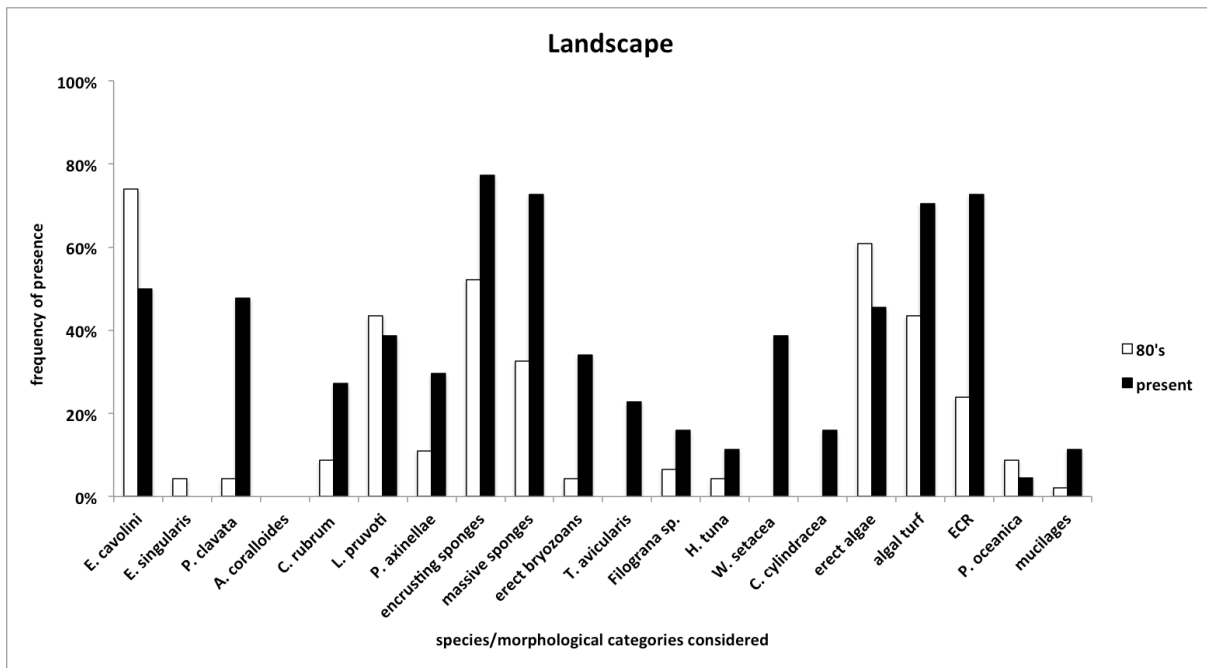
Figure 7. Presence/absence data for the landscape pictures.

The frequency of presence for each species/morphological categories considered varied in time in different ways depending on the inclination of substratum. Some of those that didn't show changes in the overall analysis of the close-up pictures, like the erect bryozoans, showed changes when the typologies of substratum inclination were considered separately. *E. cavolini* passed from 41.7% of presence in past pictures to 61.5% in present ones for lower bank shelf, from 55.6% to 75% for mid-deep depression, from 100% to 47.1% for open slope, and from 100% to 14.3% in overhang structures. *P. clavata* passed from 0% to 53.8% for lower-bank shelf, from 0% to 62.5% for mid-deep depression, from 11.1% to 47.1% for open slope, and from 0% to 14.3% for overhang structures. *P. axinellae* passes from 0% to 41.2% for lower-bank shelf, from 22.2% to 12.5% for mid-deep depression, from 16.7% to 43.8% for open slope, while it was not present both in past and present pictures for overhang structures. The encrusting sponges passed from 16.7% to 15.4% for lower-bank shelf, from 11.1% to 75% for mid-deep depression, from 83.3% to 87.5% for open slope and from 85.7% to 100% for overhang structures. The massive sponges passed from 11.1% to 53.8% for lower-bank shelf, from 0% to 75% for mid-deep depression, from 50% to 82.4% for open slope, and from 71.4% to 85.7% for overhang structures. The erect bryozoans passed from 0% to 23.1% for lower-bank shelf, from 0% to 12.5% for mid-deep depression, from 5.6% to 50% for open slopes, and from 14.3% to 28.6% for overhang structures. *T. avicularis* passed from 0% to 7.7% for lower-bank shelf, from 0% to 17.6% for open slope, from 0% to 14.3% for overhang

structures, while it was not present both in past and present pictures for mid-deep depression. *W. setacea* passed from 0% to 30.8% for lower-bank shelf, from 0% to 75% for mid-deep depression, from 0% to 29.4% for open slope, and from 0% to 14.3% for overhang structures. *C. cylindracea* passed from 0% to 7.7% for lower-bank shelf, from 0% to 25% for mid-deep depression, from 0% to 6.3% for open slope, while it was not present both in past and present pictures for overhang structures. The erect algae passed from 91.7% to 30.8% for lower-bank shelf, from 77.8% to 37.5% for mid-deep depression, from 55.6% to 56.3% for open slope, and from 0% to 14.3% for overhang structures. The algal turf passed from 25% to 61.5% for lower-bank shelf, from 11.1% to 87.5% for mid-deep depression, from 61.1% to 75% for open slopes, and from 71.4% to 42.9% for overhang structures. The ECR passed from 16.7% to 53.8% for lower-bank shelf, from 0% to 87.5% for mid-deep depression, from 38.9% to 81.3% for open slope, and from 28.6% to 57.1% for overhang structures (fig. 8).

a)

Landscape - mid-deep depression

b)

Landscape - open slope

c)

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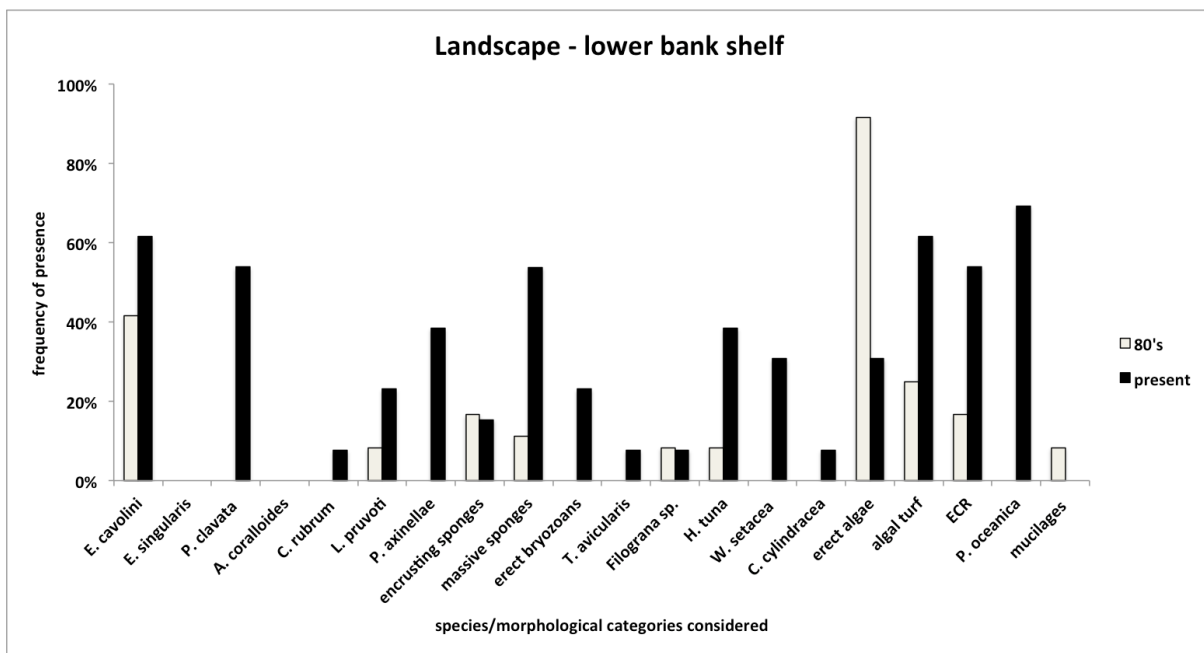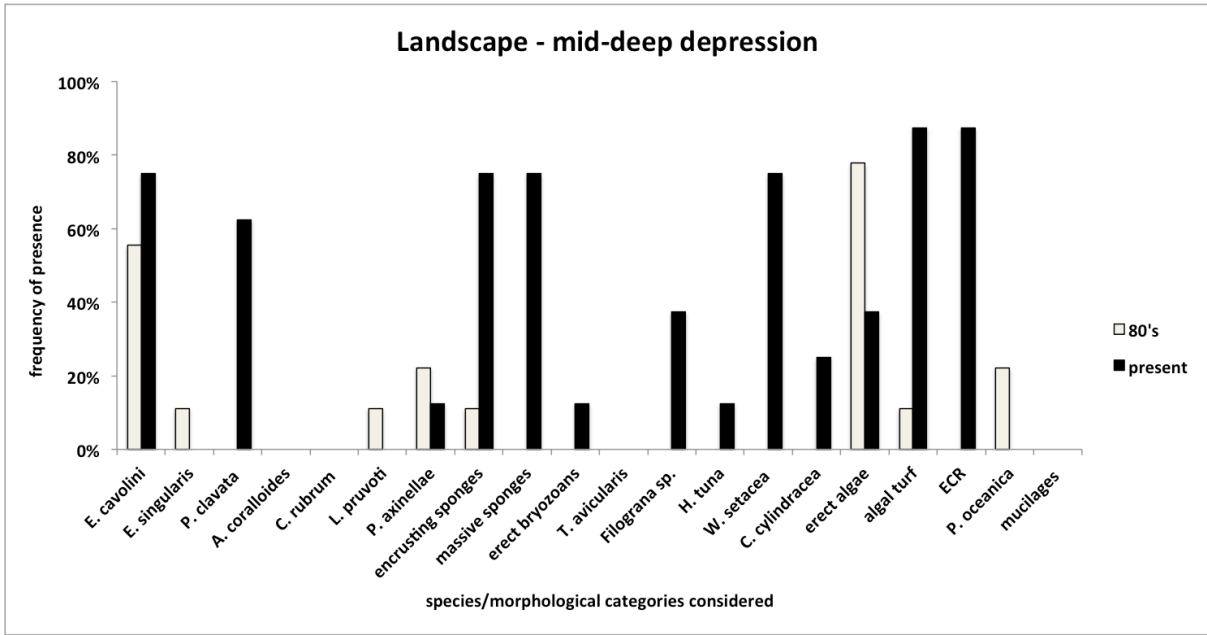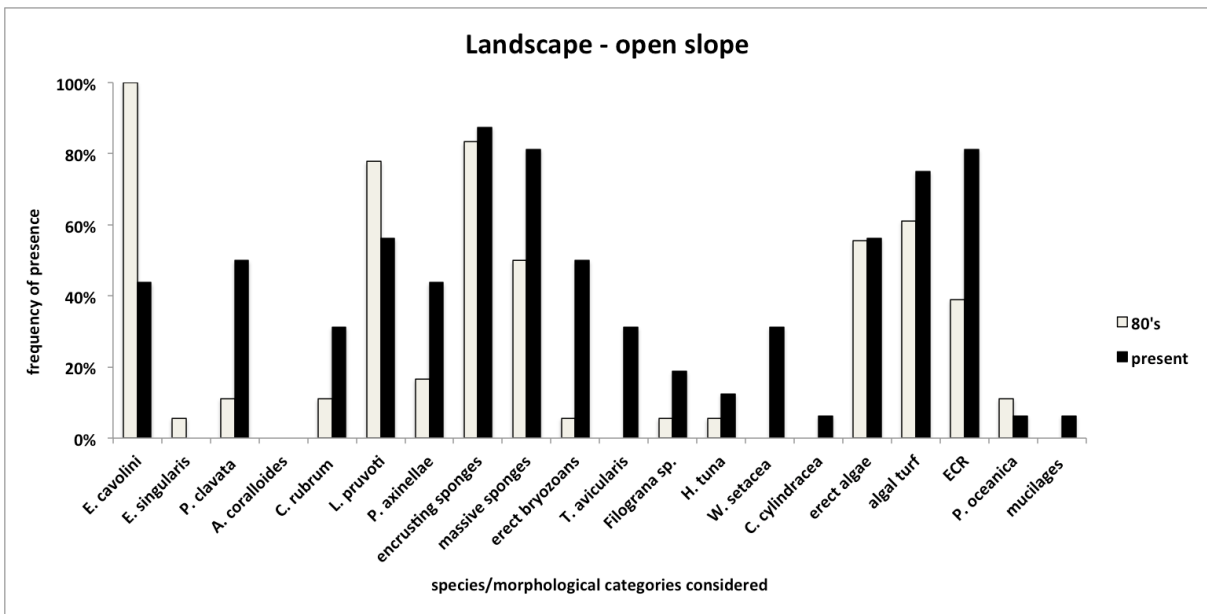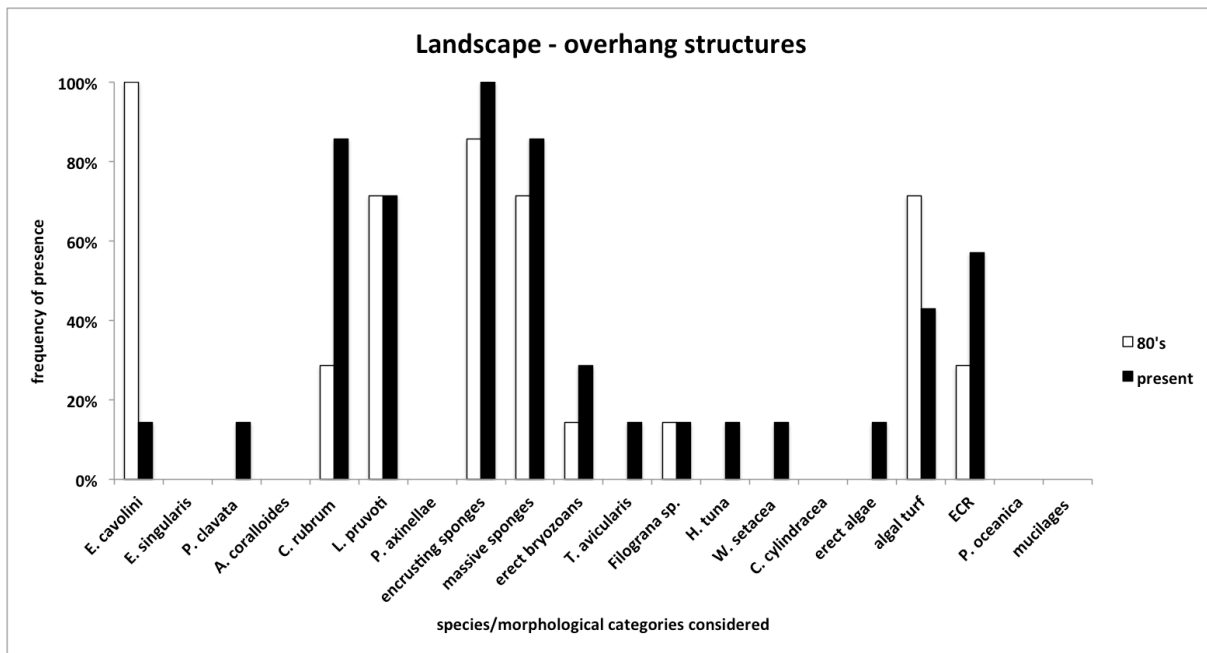
d)

Figure 8. Presence/absence data for the different typology of substratum inclination of the landscape pictures: a) lower-bank shelf; b) mid-deep depression; c) open slope; d) open slope.

Abundance data

Considering overall the close-up pictures, the species/morphological categories that showed the greater temporal changes in abundance are *E. cavolini*, *P. clavata*, *C. rubrum*, *L. pruvoti*, erect bryozoans and *T. avicularis* for those that used the numerical abundance quantification system, while are *P. axinellae,* encrusting sponges, *W. setacea* and algal turf for those that used the alphabetical abundance quantification system. The frequencies of presence of the different abundance categories of *E. cavolini* passed from 13.3% for 1-3 specimens ("1-3" hereafter), 46.7% for 4-10 ("4-10" hereafter) specimens and 40% for 11-50 ("11-50" hereafter) specimens in the past pictures to 100% for "1-3" in the present ones. For *P. clavata* the frequencies passed from 50% for "1-3" and 25% both for "4-10" and "11-50" in the past pictures to 9.1% for "1-3", 72.7% for "4-10" and 18.2% for "11-50" in the present ones. For *C. rubrum* the frequencies passed from 33.3% for 4-10 and 66.7% for 11-50 in the past pictures to 20% for "1-3" and 40% both for "4-10" and "11-50" in the past ones. For *L. pruvoti* the frequencies passed from 10% for "1-3", 50% for "4-10" and 20% both for "11-50" and >50 specimens (">50" hereafter) in the past pictures to 10% for "1-3", 30% for "4-10" and 60% for "11-50" in the present ones. For the erect bryozoans the frequencies passed from 16.7% for "1-3" and 83.3% for "4-10" in the past pictures to 70% for "1-3", 20% for

"4-10" and 10% for "11-50" in the present ones. For *T. avicularis*, which was not present in the past pictures, the frequencies in the present ones were 50% both for "1-3" and "4-10". For *P. axinellae* the frequencies passed from 50% for category B (B hereafter), 37.5% for category C (hereafter C) and 12.5% for category D (D hereafter) in the past pictures to 66.7% for B and 33.3% for category E (E hereafter) in the present ones. For the encrusting sponges the frequencies passed from 8.3% for category A (A hereafter), 75% for B and 16.7% for C in the past pictures to 16.7% for A, 58.3% for B and 25% for C in the present ones. For *W. setacea,* which was not present in the past pictures, the frequencies in the present ones were 75% for B and 25% for D. For the algal turf the frequencies passed from 30% for D to 70% for E in the past pictures to 37.5% for both B and D and 12.5% for both C and E in the present ones (fig. 9).
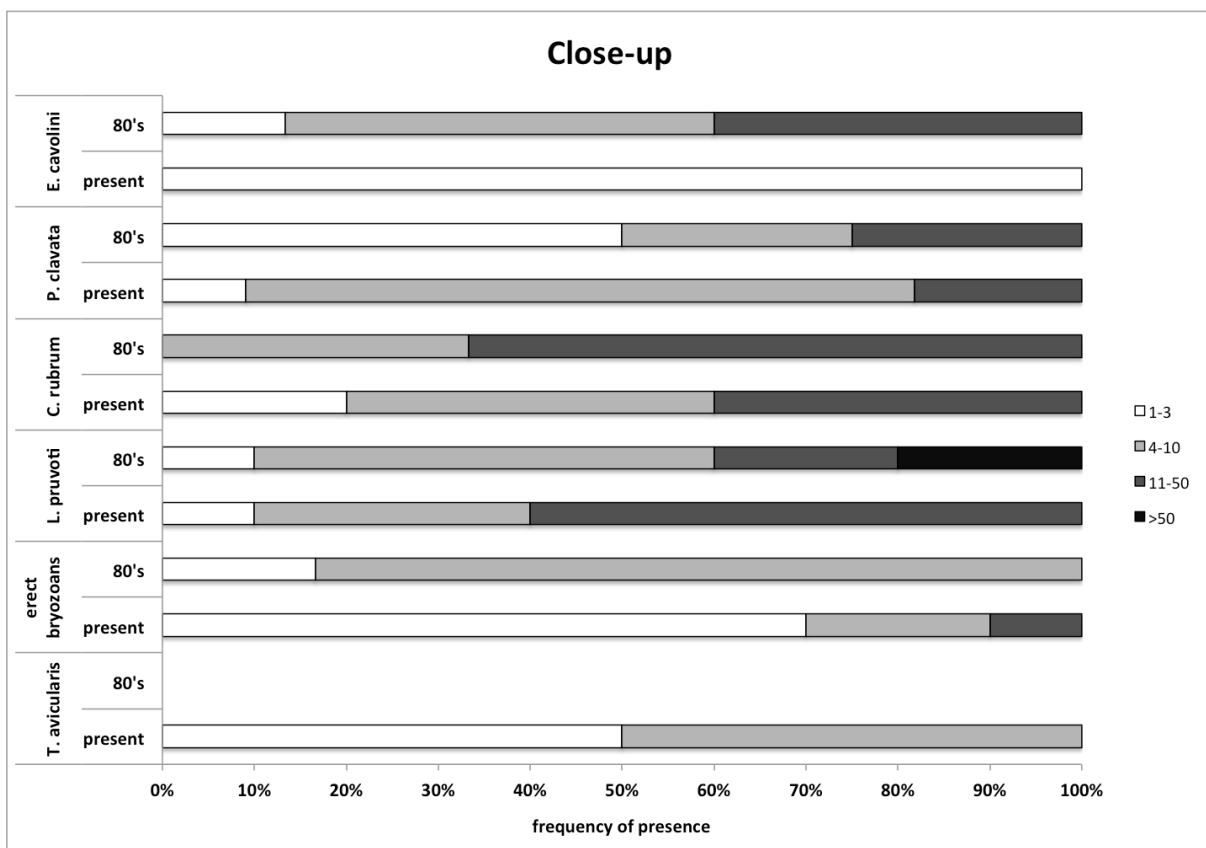
a)
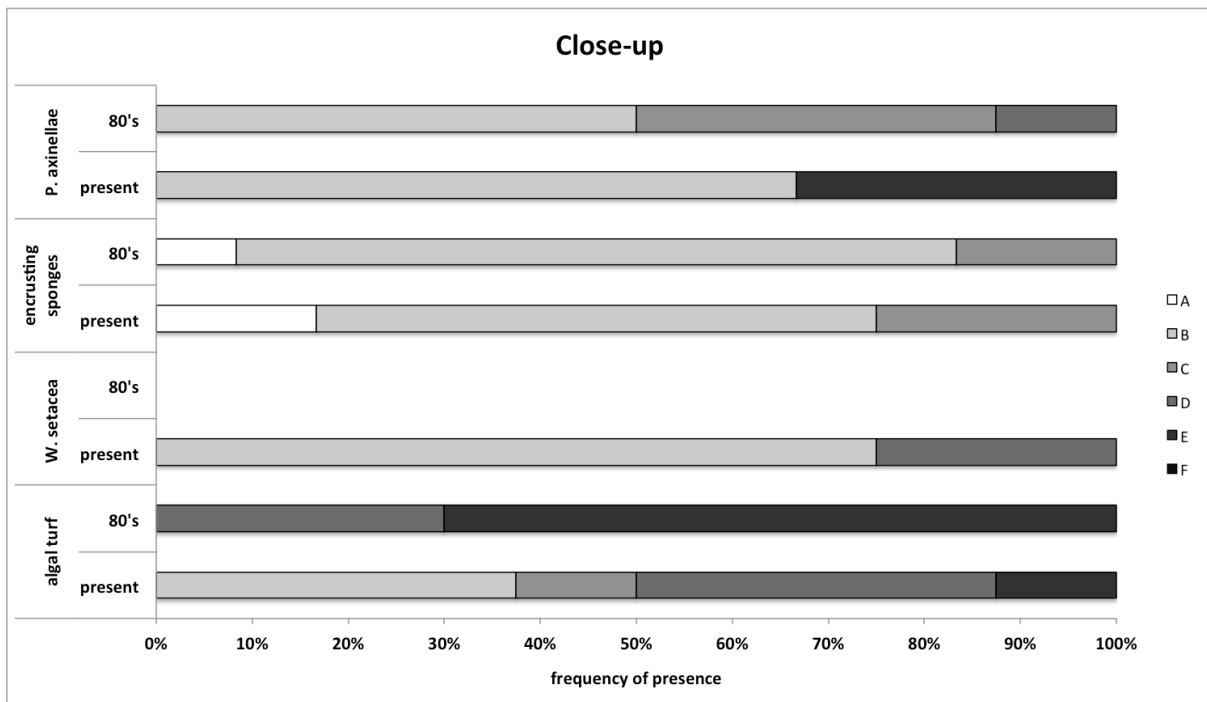
b)

Figure 9. Abundance data for the close-up pictures: a) species/morphological categories that used the numerical system; b) species/morphological categories that used the alphabetical system. Legend: A – one isolated specimen; B – some scattered specimens; C – several scattered specimens; D – one crowded area; E – some crowded areas; F – several crowded areas.

The frequency of presence of the different abundance categories for each species/morphological categories considered varied in time in different ways depending on the inclination of substratum. The frequencies of *E. cavolini* varied in these ways: from 50% for both "1-3" and "4-10" in the past pictures to 100% for "1-3" in the present ones of lower bank shelf; from 33.3% for "1-3", "4-10" and "11-50" in the past pictures to 100% for "1-3" in the present ones of mid-deep depression; from 33.3% for "4-10" and 66.7% for "11-50" in the past pictures of open slope, not found in the present ones; 75% for "4-10" and 25% for "11-50" in the past pictures of overhang structures, not found in the present ones. The frequencies of *P. clavata* varied in these ways: from 100% for "1-3" in the past pictures to 100% for "4-10" in the present ones for lower bank shelf; from 50% both for "4-10" and "11-50" in the past pictures to 50% for "11-50" and 25% for both "1-3" and "4-10" in the present ones for mid-deep depression; from 100% for "1-3" in the past pictures to 100% for "4-10" in the present ones for open slope; 100% for "4-10" in the present pictures of overhang structures, not found in the past ones. The frequencies of *C. rubrum*, which was not found at all in pictures of

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lower bank shelf, varied in these ways: 50% both for "1-3" and "11-50" in the present pictures of mid-deep depression, not found in the present ones; 50% for both "1-3" and "4-10" in the present pictures of open slope, not found the past one; from 33.3% for "4-10" and 66.7% for "11-50" in the past pictures to 50% both for "4-10" and "11-50" in the present ones of overhang structures. The frequencies of *L. pruvoti* varied in these ways: 50% for both "1-3" and "4-10" in the present pictures of lower-bank shelf, not found in the past ones; 100% for "4-10" in the past pictures of mid-deep depression, not found in the present ones; from 33.3% for "1-3", "4-10", "11-50" in the past pictures to 25% for "4-10" and 75% for "11-50" in the present ones for open slope; from 50% for "4-10", 16.7% for "11-50" and 33.3% for ">50" in past pictures to 25% for "4-10" and 75% for "11-50" in the present ones for overhang structures. The frequencies of the erect bryozoans varies in these ways: 100% for "1-3" in the present pictures of lower-bank shelf, not found in the past ones; from 100% for "1-3" in the past pictures to "66.7%" for "1-3" and 33.3% for "11-50" in the present ones for mid-deep depression; from 100% for "4-10" for the past pictures to 100% for "1-3" in the present ones for open slope; no variation for overhang structures, 100% for "4-10" both in past and present pictures. The frequencies of *T. avicularis*, which was not found at all in pictures of overhang structures, varied in these ways: 100% for "4-10" in the present pictures of lower-bank shelf, not found in the past ones; 100% for "1-3" in the present pictures of mid-deep depression, not found in the past ones; 100% for "1-3" in the present pictures of open slope, not found in the past ones. The frequencies of *P. axinellae* varied in these ways: from 100% for B in the past pictures to 100% for E in the present ones of lower-bank shelf; from 66.7% for B and 33.3% for C in the past pictures to 100 % for B in the present ones; from 100% for C in the past pictures to 100% for B in the present ones of open slope; 100% for D in the past pictures of overhang structures, not found in the present ones. The frequencies of *W. setacea*, which was not found at all in the pictures of overhang structures, varied in these ways: 100% for B in the present pictures of lower-bank shelf, not found in the past ones; 100% for D in the present pictures of mid-deep depression, not found in the past ones; 100% for B in the present pictures of open slope, not found in the past pictures. The frequencies of the encrusting sponges varies in these ways: from 100% for B in the past pictures to 50% for both A and B in the present ones of lower-bank shelf; from 100% of B in the past pictures to 66.7% for B and 33.3% for C in the present ones of mid-deep depression; from 75% for B and 25% for C in the past pictures to 33.3% for A, B and C in the present ones of open slope; from 50% for B and 25% for both A and C in the past pictures to 75% for B and 25% for C in the present ones of overhang structures. The frequencies of the algal turf varied in these ways: from 50% for both D and E in the past pictures to 50% for both B and E in the present ones for lower-bank shelf; from 33.3% for D and 66.7% for E in the past pictures to 33.3% for B, C and D in the present pictures of

mid-deep depression; from 50% for both D and E in the past pictures to 33.3% for B and 66.7% for D in the present ones of open slope; 100% for E in the past pictures of overhang structures, not found in the present ones (fig. 10).
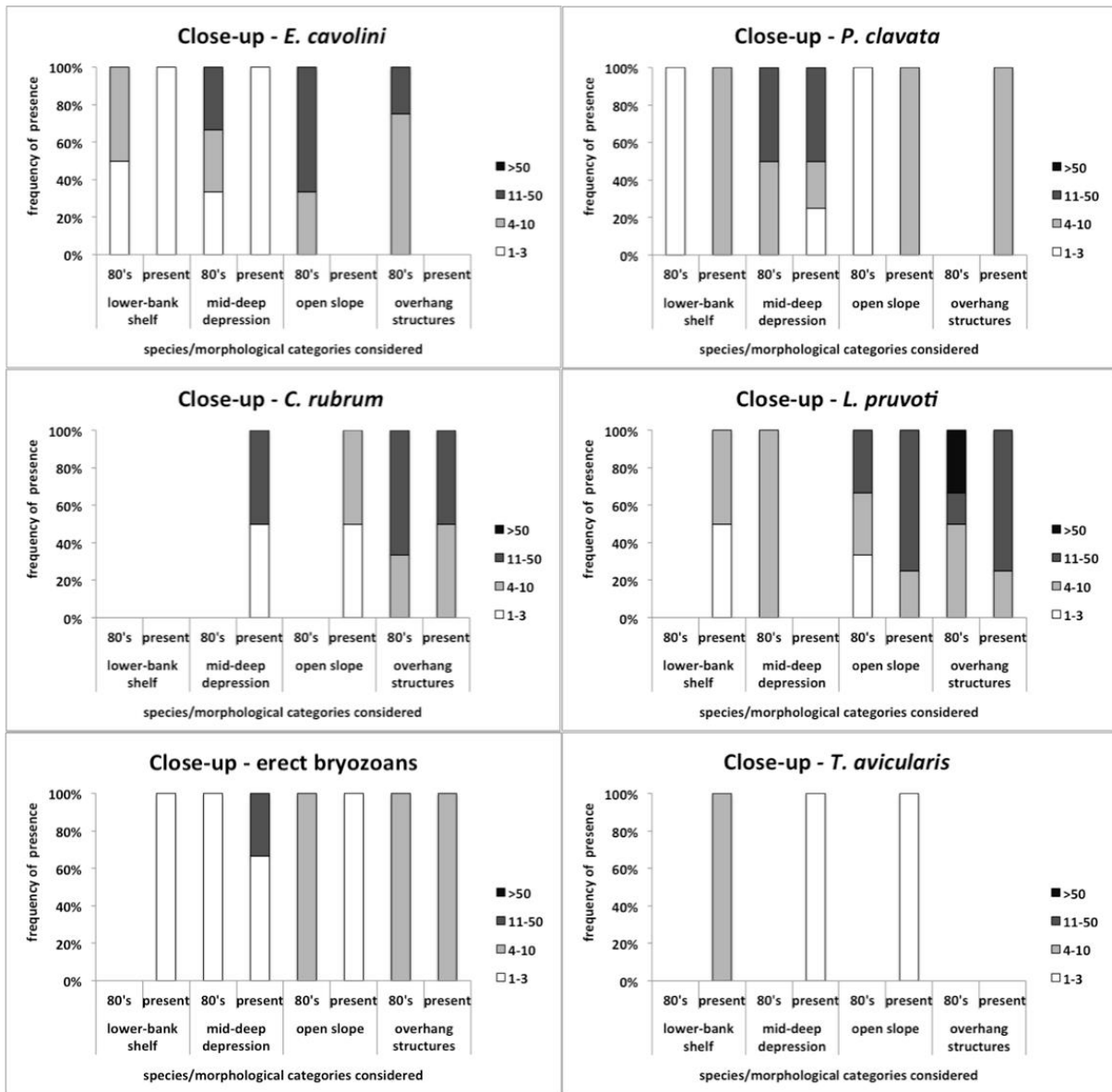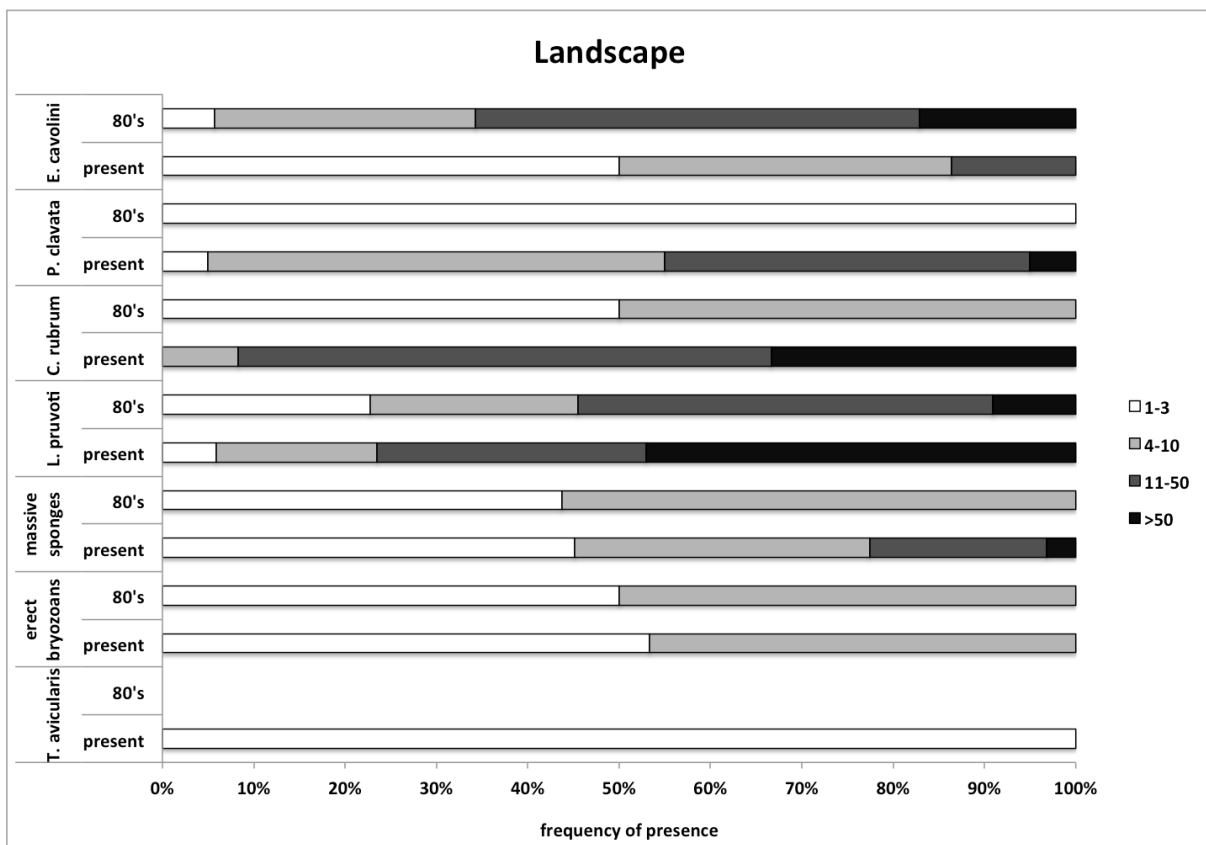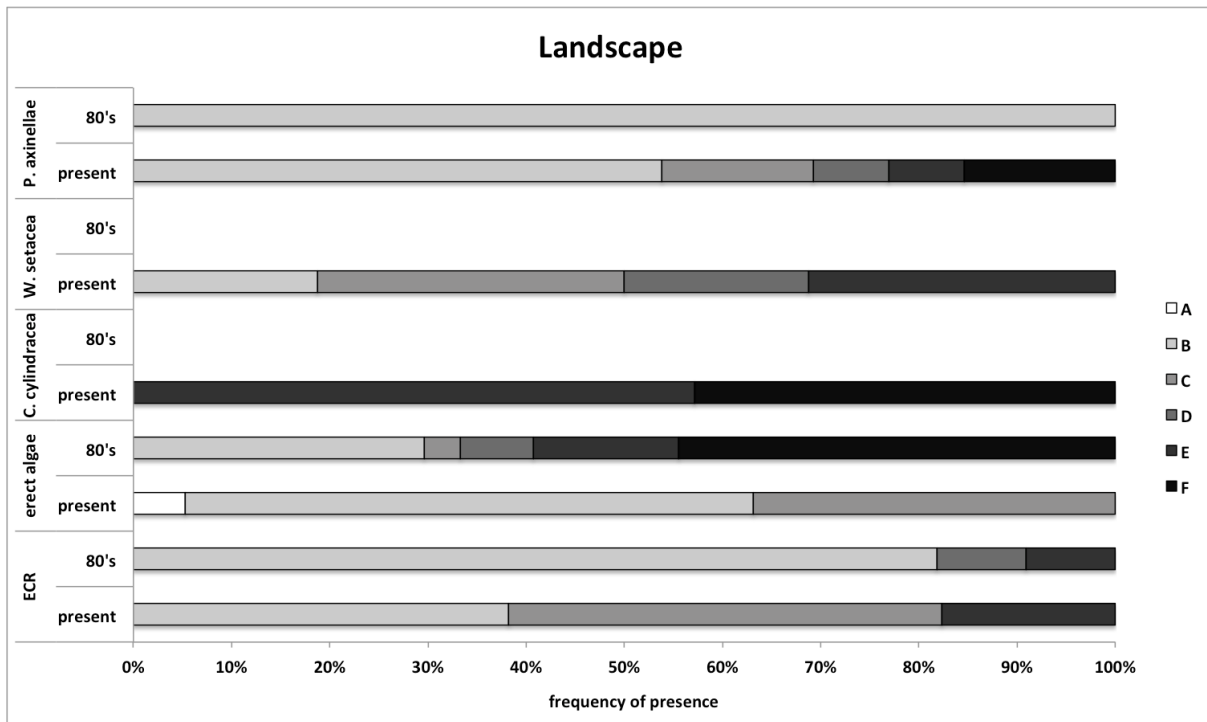

a)
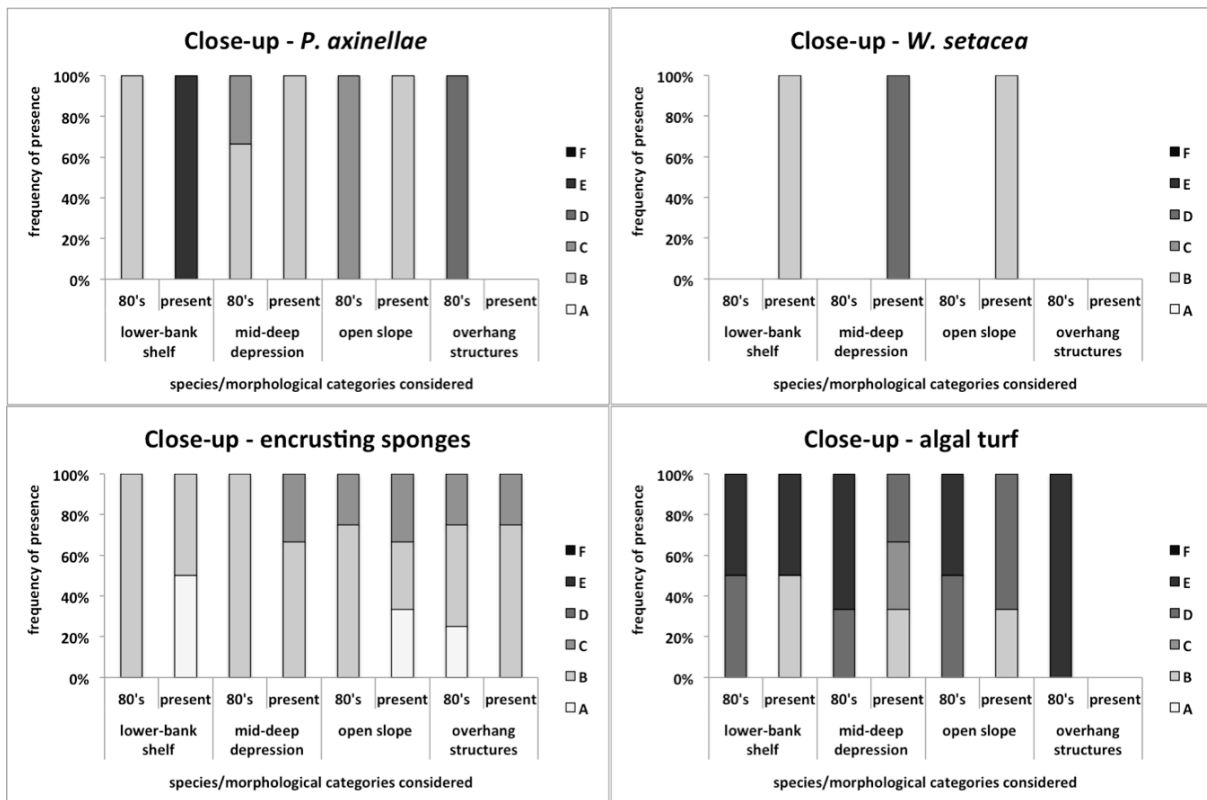
b)

Figure 10. Abundance data of each species in every substratum inclination for the close-up pictures: a) species/morphological categories that used the numerical system; b) species/morphological categories that used the alphabetical system. Legend: A – one isolated specimen; B – some scattered specimens; C – several scattered specimens; D – one crowded area; E – some crowded areas; F – several crowded areas.

Considering overall the landscape pictures, the species/morphological categories that showed the greater temporal changes in abundance are *E. cavolini*, *P. clavata*, *C. rubrum*, *L. pruvoti*, massive sponges, erect bryozoans, *T. avicularis* for those that used the numerical abundance quantification system, while are *P. axinellae*, *W. setacea*, *C. cylindracea*, erect algae and ECR for those that used the alphabetical abundance quantification system. For *E. cavolini* the frequencies passed from 5.7% for "1-3", 28.6% for "4-10", 48.6% for "11-50" and 17.1% for ">50" in the past pictures to 50% for "1-3", 36.4% for "4-10" and 13.6% for "11-50" in the present ones. For *P. clavata* the frequencies passed from 100% for "1-3" in the past pictures to 50% for "4-10", 40% for "11-50" and 5% both for "1-3" and ">50" in the present ones. For *C. rubrum* the frequencies passed from 50% for both "1-3" and "4-10" in the past pictures to 8.4% for "4-10", 58.3% for "11-50" and 33.3% for ">50" in the present ones. For *L. pruvoti* the frequencies passed from 22.7% for both "1-3" and "4-10", 11-

50% for 45.5% and 9.1% for ">50" in the past pictures to 5.9% for "1-3", 17.6% for "4-10", 29.4% for "11-50" and 47.1% for ">50" in the present ones. For the massive sponges the frequencies passed from 43.8% for "1-3" and 56.2% for "4-10" in the past pictures to 45.2% for "1-3", 32.3% for "4-10", 19.4% for "11-50" and 3.2% for ">50" in the present ones. For the erect bryozoans the frequencies passed from 50% both for "1-3" and "4-10" in the past pictures to 53.3% to "1-3" and 46.7% to "4-10" in the present ones. For *T. avicularis*, which was not present in the past pictures, the frequency in the present ones was 100% for "1-3". For *P. axinellae* the frequencies passed from 100% for B in the past pictures to 53.8% for B, 15.4% both for B and for category F (F hereafter) and 7.7% both for D and E in the present ones. For *W. setacea*, which was not present in the past pictures, the frequencies in the present ones were 18.8% both for B and D and 31.2% both for C and E. For *C. cylindracea*, which was not present in the past pictures, the frequencies in the present ones were 57.1% for E and 42.9% for F. For the erect algae the frequencies passed from 29.6% for B, 3.7% for C, 7.4% for D, 14.8% for E and 44.5% for F in the past pictures to 5.3% for A, 57.9% for B and 36.8% for C in the present ones. For the ECR the frequencies passed from 81.8% for B and 9.1% both for D and E in the past pictures to 38.2% for B, 44.2% for C and 17.6% for E in the present ones (fig. 11).
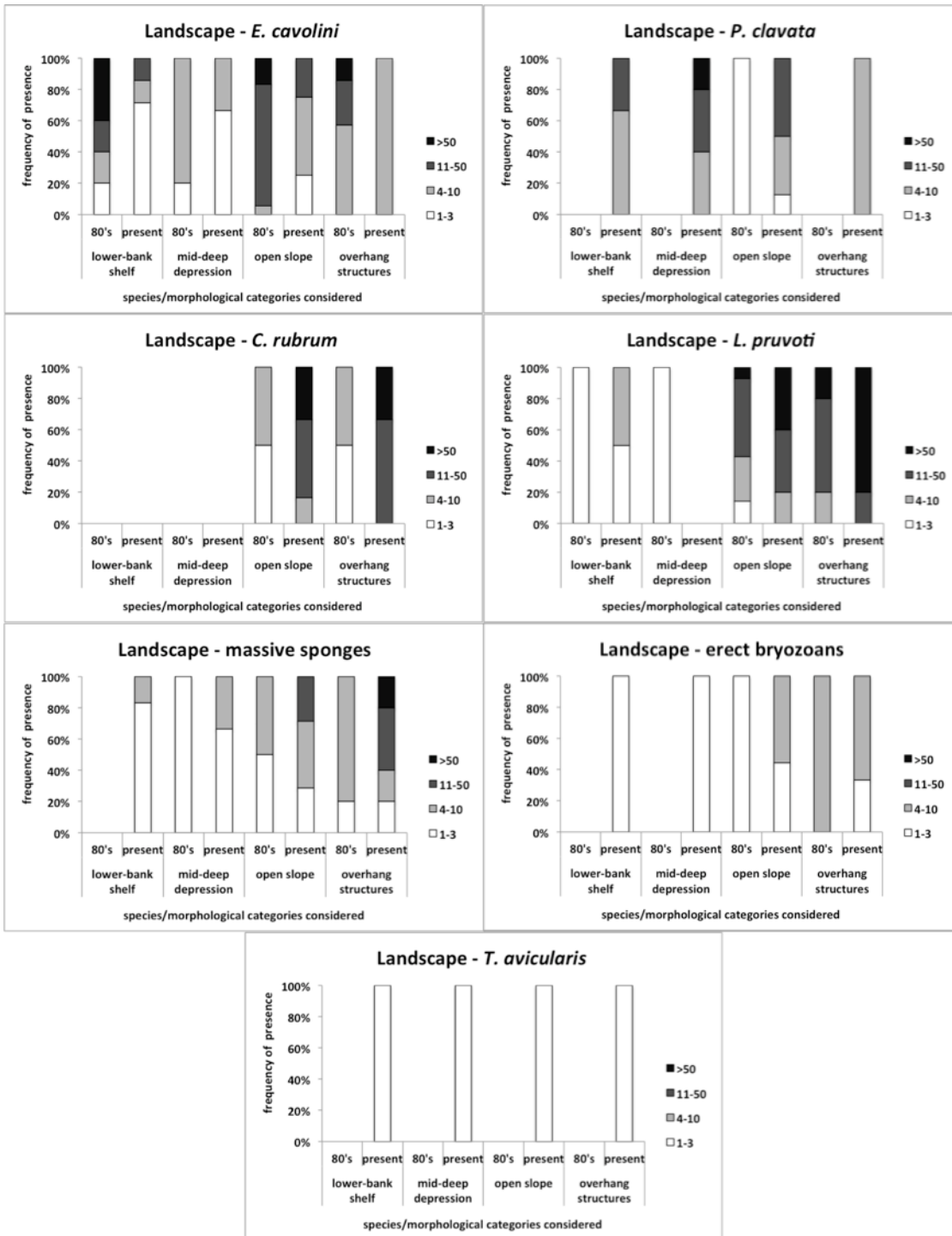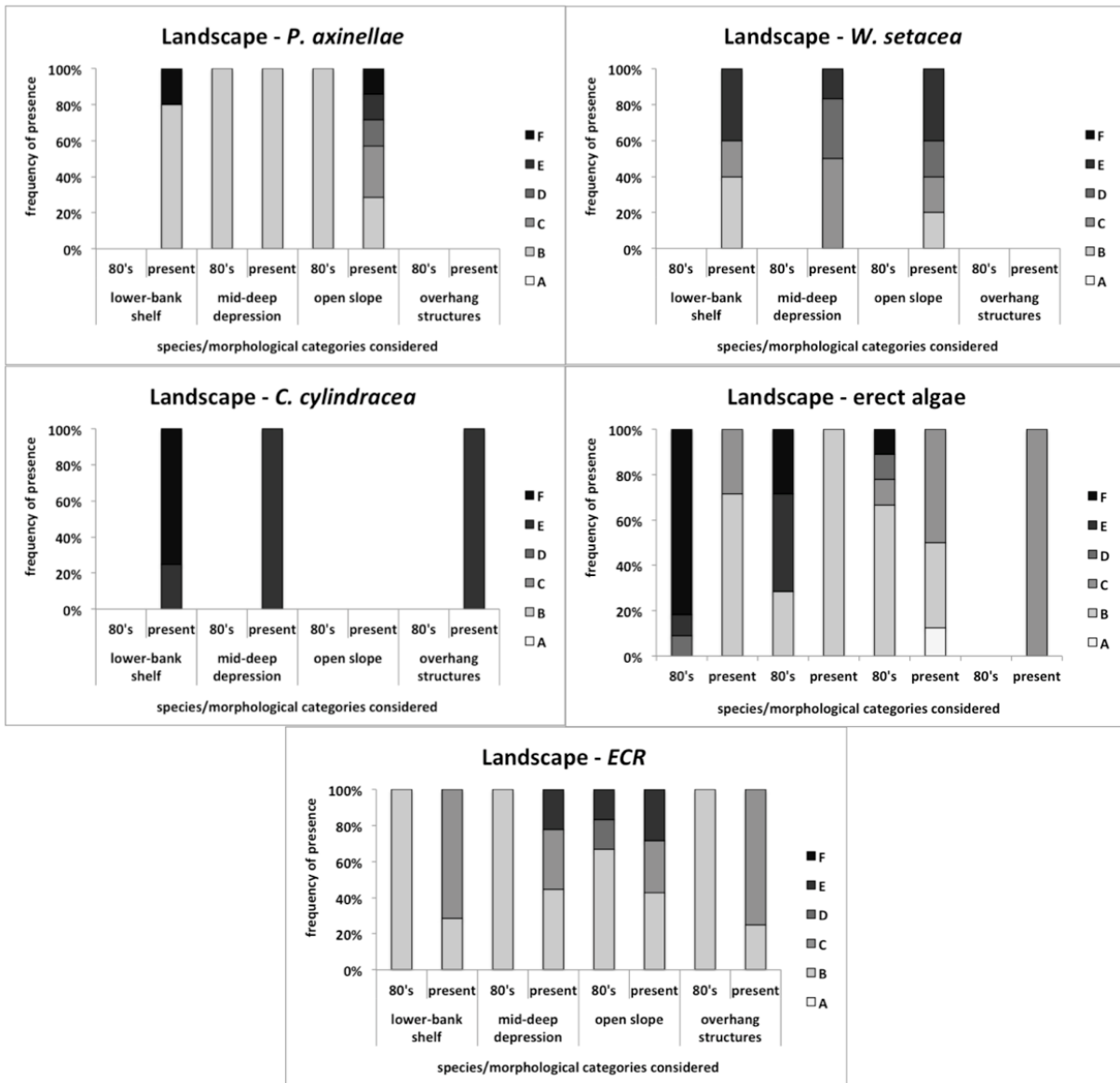
Figure 11. Abundance data for the landscape pictures: a) species/morphological categories that used the numerical system; b) species/morphological categories that used the alphabetical system. Legend: A – one isolated specimen; B – some scattered specimens; C – several scattered specimens; D – one crowded area; E – some crowded areas; F – several crowded areas.

The frequency of presence of the different abundance categories for each species/morphological categories considered varied in time in different ways depending on the inclination of substratum. The frequencies of *E. cavolini* varied in these ways: from 20% for "1-3", "4-10" and "11-50" and 40% for ">50" in the past pictures to 71.4% for "1-3", 14.3% both for "4-10" and "11-50" in the present ones of lower-bank shelf; from 20% for "1-3" and 80% for "4-10" in the past pictures to 66.7% for "4-10" and 33.3% for "11-50" in the present ones of mid-deep depression; from 5.6% for "4-10", 77.8% for "11-50" and 16.7% for ">50" in the past pictures to 50% for "4-10" and 25% for both "1-3" and "11-50" in the present ones of open slope; from 57.1% for "4-10", 28.6% for "11-50" and 14.3% for ">50" in the past pictures to 100% for "4-10" in the past ones of overhang structures. The frequencies of *P. clavata* varied in these ways: 66.7% for "4-10" and 33.3% for "11-50" in the present pictures of lower-bank shelf, not found in the past ones; 20% for ">50" and 40%

for both "4-10" and "11-50" in the present pictures of mid-deep depression, not found in the past ones; from 100% for "1-3" in the past pictures to 12.5% for "1-3", 37.5% for "4-10" and 50% for "11-50" in the past ones of open slope; 100% for "4-10" in the present pictures, not found in the past ones. The frequencies of the massive sponges varied in these ways: 83.3% for "1-3" and 16.7% for "4-10" in the present pictures of lower-bank shelf, not found in the past ones; from 100% for "1-3" in the past pictures to 66.7% for "1-3" and 33.3% for "4-10" in the present ones of mid-deep depression; from 50% for both "1-3" and "4-10" in the past pictures to 42.8% for "4-10" and 28.6% for both "1-3" and "11-50" in the present ones of open slope; from 20% for "1-3" and 80% for "4-10" in the past pictures to 20% for "1-3", "4-10" and ">50" and 40% for "4-10" in the present ones of overhang structures. The frequencies of the erect bryozoans varied in these ways: 100% for "1-3" in the present pictures of lower-bank shelf, not found in the past ones; 100% for "1-3" in the present pictures of mid-deep depression, not found in the past ones; from 100% for "1-3" in the past pictures to 44.4% for "1-3" and 55.6% for "4-10" in the present ones of open slope; from 100% for "4-10" in the past pictures to 33.3% for "1-3" and 66.7% for "4-10" in the present ones of overhang structures. The frequencies of *T. avicularis* were 100% for "1-3" in the present pictures of lower-bank shelf, mid-deep depression, open slope and overhang structures, not found in the present ones. The frequencies of *P. axinellae*, which was not found at all in the pictures of overhang structures, varied in these ways: 80% for B and 20% for F in the present pictures of lower-bank shelf, not found in the past ones; no variation for mid-deep depression, 100% for B both in past and present pictures; from 100% for B in the past pictures to 28.5% both for B and C, 14.3% both for D and E and 14.4% for F in the present pictures of open slope. The frequencies of *W. setacea*, which was not found at all in the pictures of overhang structures, varied in these ways: 20% for C and 40% both for B and E in the present pictures of lower-bank shelf, not found in the past ones; 50% for C, 33.3% for D and 16.7% for E in the present pictures of mid-deep depression, not found in the past ones; 20% for B, C and D and 40% for E in the present pictures of open slope, not found in the past ones. The frequencies of *C. cylindracea*, which was not found at all in the present pictures of open slope, varied in these ways: 25% for E and 75% for F in the present pictures of lower-bank shelf, not found in the past ones; 100% for E in the present pictures of mid-deep depression and overhang structures, not found in the past ones. The frequencies of the ECR varied in these ways: from 100% for B in the past pictures to 28.6% for B and 71.4% for C in the present ones of lower-bank shelf; from 100% for B in the past pictures to 44.4% of B, 33.3% of C and 22.3% for E in the present ones of mid-deep depression; from 66.6% for B and 16.7% for D and E in the past pictures to 42.8% for B and 28.6% both for C and E in the present ones of open slope; from 100% for B in the past pictures to 25% for B and 75% to C in the present ones of overhang structures (fig. 12).

a)

b)

Figure 12. Abundance data of each species in every substratum inclination for the landscape pictures: a) species/morphological categories that used the numerical system; b) species/morphological categories that used the alphabetical system. Legend: A – one isolated specimen; B – some scattered specimens; C – several scattered specimens; D – one crowded area; E – some crowded areas; F – several crowded areas.

Winners and losers

Based on changes of their frequency of presence and abundance with time in the landscape pictures, 14 species/morphological categories were labelled as winners; most of them were present also in the old pictures (i.e. *P. clavata*; *C. rubrum*; *P. axinellae*; encrusting sponges; massive sponges; erect

bryozoans; *Filograna* sp.; *H. tuna*; algal turf; ECR; mucilages), while *T. avicularis*, *W. setacea* and *C. cylindracea* appeared only in the current pictures. Losers included *E. cavolini* and erect algae), while *E. singularis* and *L. pruvoti* and P. *oceanica* were labelled "little or no changes" (Table 3).

Table 3. Winners and losers

Species/morph. cat.	Label
E. cavolini	∇
E. singularis	< >
P. clavata	Δ
C. rubrum	Δ
L. pruvoti	< >
P. axinellae	Δ
encrusting sponges	Δ
massive sponges	Δ
erect bryozoans	Δ
T. avicularis	Δ
Filograna sp.	Δ
H. tuna	Δ
W. setacea	Δ
C. cylindracea	Δ
erect algae	∇

algal turf	Δ
ECR	Δ
P. oceanica	< >
mucilages	Δ

Pictures of wrecks

Presence/absence data

In the pictures taken at the BR20 wreck there were not differences between the species/morphological categories observed in past pictures and those observed in the current ones; both in past and current pictures, *Aplysina* sp. Nardo 1834, *Scalarispongia scalaris* (Schmidt, 1862), encrusting sponges, massive sponges, encrusting bryozoans, and ECR were observed.

At the Catalina wreck, *Eunicella verrucosa* (Pallas, 1776), *P. axinellae*, *Axinella* sp., encrusting sponges, algal turf and ECR were observed both in past and current pictures; instead, *Leptogorgia sarmentosa* (Esper, 1789) and *Sabella spallanzanii* (Gmelin, 1791) were found only in the past pictures, while massive sponges were found only in the current ones.

In the pictures taken at the Heinkel 111 wrecks, *Aplysina* sp., *S. scalaris*, encrusting sponges, encrusting bryozoans, *Halocynthia papillosa* (Linnaeus, 1767) and ECR were observed both in past and current pictures, while *L. pruvoti* was observed only in the past pictures.

At the Islande wreck, encrusting sponges, massive sponges, algal turf and ECR were observed both in past and present pictures, while *Filograna* sp. was found only in the present ones.

In the pictures taken at the Jöern wreck there were not differences between the species/morphological categories observed in past pictures and those observed in the current ones; both in past and current pictures, encrusting sponges, encrusting bryozoans, algal turf and ECR were observed (tab 4).

At the Mohawk Deer wreck, *L. pruvoti,* encrusting bryozoans, algal turf and ECR were observed in all the years considered (i.e. 1990, 2001, 2008, 2013, 2016), while *E. cavolini* was observed only in the pictures from 1990 (tab. 5).

Table 4. Presence/absence data for the wrecks of BR20, Catalina, Heinkel 111, Islande, Jöern.

	BR20		Catalina		Heinkel 111		Islande		Jöern	
	90's	2013	90's	2014	90's	2012	2000	2015	2000	2010
E. cavolini										
E. verrucosa			✓	✓						
L. sarmentosa			✓							
L. pruvoti					✓					
P. axinellae			✓	✓						
Axinella sp.			✓	✓						
Aplysina sp.	✓	✓			✓	✓				
encr. sponges	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
mass. sponges	✓	✓		✓			✓	✓		
S. scalaris	✓	✓								
encr.bryoz.	✓	✓			✓	✓			✓	✓
Filograna sp.								✓		
S. spallanzanii			✓							
H. papillosa					✓	✓				
algal turf			✓	✓			✓	✓	✓	✓
ECR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 5. Presence/absence data for the wreck of Mohawk Deer

	Mohawk Deer				
	1990	**2001**	**2008**	**2013**	**2016**
E. cavolini	✓				
E. verrucosa					
L. sarmentosa					
L. pruvoti	✓	✓	✓	✓	✓
P. axinellae					
Axinella **sp.**					
Aplysina sp.					
encr. sponges					
mass. sponges					
S. scalaris					
encr. bryoz.	✓	✓	✓	✓	✓
Filograna sp.					
S. spallanzanii					
H. papillosa					
algal turf	✓	✓	✓	✓	✓
ECR	✓	✓	✓	✓	✓

Abundance data

Changes of abundance are negligible for all wrecks considered but one, that of Mohawk Deer. Here the abundances of algal turf and encrusting bryozoans didn't change over time, ramaining respectively 100% for "E" and 100% for "B" in all years considered. Abundance of ECR remained 100% for "C" in 1990, 2001, 2008 and 2013, and passed to 100% for "B" in 2016. Abundance of *L.*

pruvoti passed from 100% for "4-10" in 1990 to 100% for ">50" in 2001, 2008, 2013 and 2016. *E. cavolini* had an abundance of 100% for "11-50" in 1990 and vanished completely in all the following years considered (fig. 12).

Mohawk Deer

1990 L. pruvoti
2001
2008
2013
2016

1990 E. cavolini
2001
2008
2013
2016

Legend:
- 1-3
- 4-10
- 11-50
- >50

X-axis: 0%, 20%, 40%, 60%, 80%, 100% — frequency of presence

a)

b)
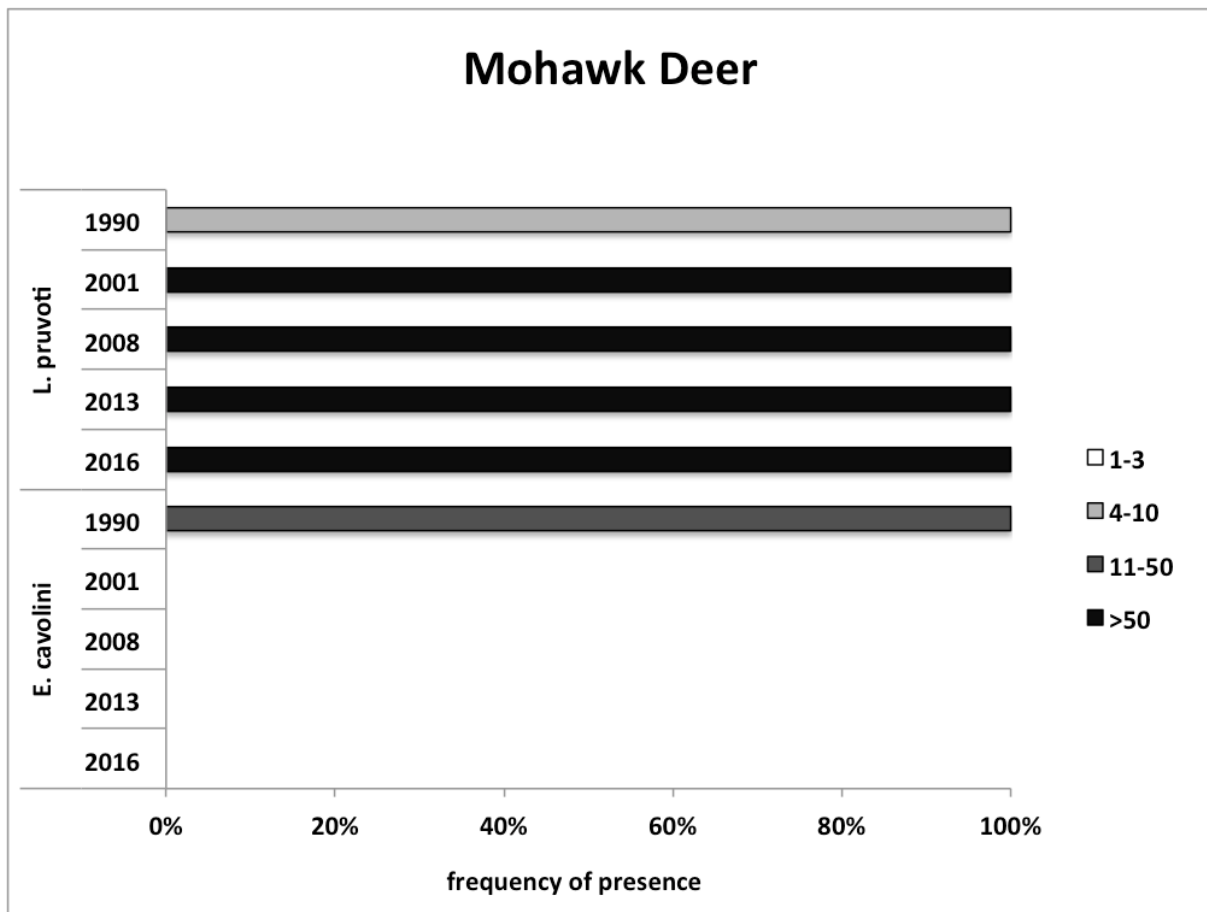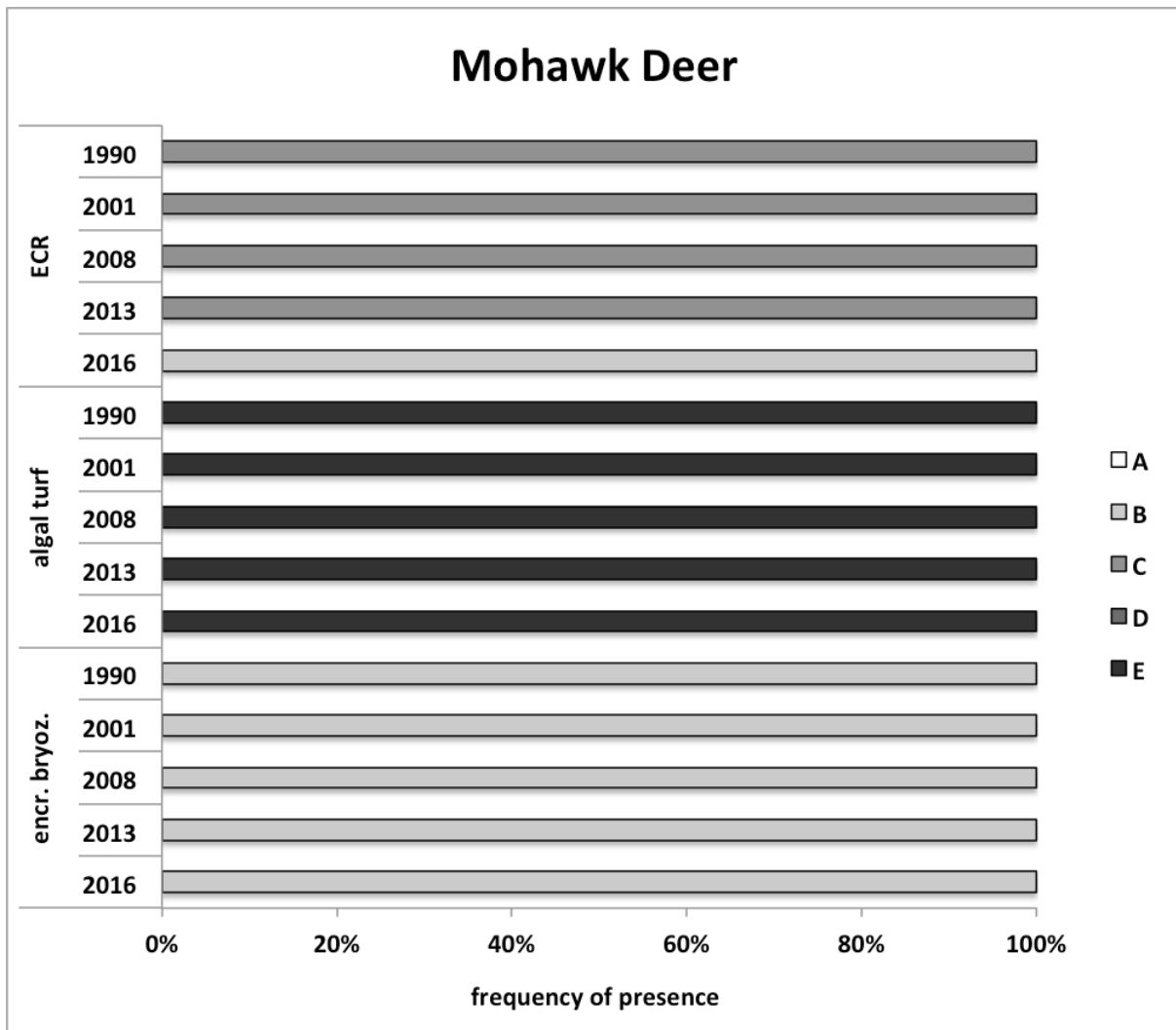
Figure 12. Abundance data for Mohawk Deer wreck: a) species/morphological categories that used the numerical system; b) species/morphological categories that used the alphabetical system. Legend: A – one isolated specimen; B – some scattered specimens; C – several scattered specimens; D – one crowded area; E – some crowded areas; F – several crowded areas.

Discussion

In this work, the comparison between past and current underwater photographs allowed to reconstruct the changes, if any, occurred in the community structure of natural (i.e. Portofino's rocky reefs) and artificial (wrecks) hard bottom assemblages across 20/30 years.

Our data confirmed the strong influence of substratum inclination on community structure in coralligenous habitat (Virgilio et al., 2006). Substrates with different inclination, in fact, host

assemblages that are clearly diverse among them, especially regarding species/taxa relative abundance (Zapata-Ramírez et al., 2016). Moreover, there are clear differences between landscape and close-up pictures both in term of presence/absence and abundance, confirming that the patterns of variability, in subtidal assemblages, are affected by the considered spatial scale (Terlizzi et al., 2007). Since the small spatial scale covered by the close-up pictures resulted non suitable to describe properly the benthic communities, I have chosen to use only the landscape pictures to evaluate their temporal changes.

The analysis of presence/absence and abundance data extrapolated from the pictures of Portofino permitted to identify species/morphological categories that apparently increased in present pictures respect to those ones from 1980's (i.e. winners), species/morphological categories that conversely decreased (i.e. losers), and those ones that showed no substantial changes (i.e. little or no changes). The "losers" include the gorgonian *E. cavolini* and the erect algae. In particular, *E. cavolini* showed a great reduction, both in term of frequency of presence in the pictures and abundance. These results are in agreement with findings from Bertolino et al. (2016) and could be related to the mass mortality events that affected the Portofino Promontory in 1999 (Cerrano et al., 2000) and 2003 (Garrabou et al., 2009). Indeed, in both cases this gorgonian showed high percentage of affected colonies and high mortality rates (Cerrano et al., 2000; Garrabou et al., 2009). Moreover, since Mediterranean gorgonians are characterized by slow population dynamics (Coma et al., 1998; Linares et al., 2008), it is plausible that our data reflected the long-term effects of these catastrophic events.

The historical reduction of erect algae is a well-known phenomenon for the Portofino Promontory, with several works that documented a severe depletion compared to 1980s and early 1990s (Bertolino et al., 2016; Gatti et al., 2017; Parravicini et al., 2013). Furthermore, earlier descriptive records allowed to understand that the macroalgal cover was already greatly reduced in 1980s respect to 1950s, in particular for the canopy-formers species *Dictyopteris popypodioides* (A.P.De Candolle) J.V.Lamoroux and *Sargassum vulgare* C.Agardh 1920 (Parravicini et al., 2013 and references therein). This trend was already described in others areas of the Mediterranean (e.g. Bianchi et al., 2014; Thibaut et al., 2005) and of the world (e.g. Lamela-Silvarrey et al., 2012; Raybaud et al., 2013; Wernberg et al., 2010). In parallel to the decrease of erect algae, our results described also the increase of algal turf (included among the "winners"), in a co-tendency toward the homogenisation of the assemblages reported also by other authors for this area (Bertolino et al., 2016; Parravicini et al., 2013). The transition from assemblages dominated by erect algae to assemblages dominated by algal turf has been probably the result of complex synergistic interactions among climatic and human pressures (Parravicini et al., 2013) The sea-water warming

is known to be detrimental for canopy-forming macroalgae, also through the extreme climatic events provoked (Smale and Wernberg, 2013; Wernberg et al., 2013), and to foster the expansion of thermophilic alien species (Galil, 2008), some of which (e.g. *W. setacea*) are turf-forming algae. Furthermore, the presence of anthropogenic stressors may have made the benthic assemblages more susceptible to invasive species (MacDougall and Turkington, 2005). For instance, the eutrophication caused by sewage outfalls (Claudet and Fraschetti, 2010) and the increase in sedimentation and turbidity produced by coastal activities (Mangialajo et al., 2008) may have jeopardized the more sensitive erect macroalgae and favoured the increase of algal turf. Moreover, also the protection effect of the MPA (established in 1999) might have promoted this shift determining an increase in the herbivorous fish *Sarpa salpa* (Linnaeus, 1758; Guidetti et al., 2008), able to favour the dominance of turf in algal assemblages (Ruitton et al., 2000). By contrast, the creation of the MPA has not caused a significant decrease of the sea urchins and their grazing activity through an increase in the carnivorous fishes (Parravicini et al., 2013; Sala et al., 1998). The group of the "winners" is the most numerous and includes both organisms that were already present in the 80s (e.g. *P. clavata, C. rubrum, P. axinellae*, encrusting and massive sponges, algal turf, etc.) and some that appeared only in the current pictures (i.e. *C. cylindracea*; *W. setacea*; *T. avicularis*). Among the last ones, *C. cylindracea* and *W. setacea* are considered the most invasive macroalgae in the Mediterranean Sea (Boudouresque and Verlaque, 2002; Meinesz et al., 2001). They both have a tropical origin and the warming trend of the Mediterranean Sea could be a factor to explain their successful invasion (Raitsos et al., 2010). The first record in the Mediterranean Sea for *C. cylindracea* was in Libya in 1990 (Nizamuddin, 1991), while for the Ligurian was in Quinto (near Genoa) in 1995 (Bussotti et al., 1996). This algae is able to reproduce itself efficiently by fragmentation and stolonization (Ceccherelli and Piazzi, 2001) and to spread quickly on all kind of non-living substratum and sessile organisms (Piazzi and Cinelli, 2001; Piazzi et al., 2005; Ruitton et al., 2005). Hence, it shows an high invasiveness and affects the native macroalgal assemblages, reducing their biodiversity and substratum cover (Balata et al., 2004). *W. setacea*, instead, was originally reported for the Mediterranean Sea as *Polysiphonia setacea* Hollenberg 1968 in 1987 (Verlaque, 1989). It is a filamentous turf-forming algae, producing thick turfs and affecting the biodiversity of invaded assemblages (Piazzi and Cinelli, 2003). These two species can co-occur at the same sites, leading to complex interactions and synergism (Piazzi et al., 2003b; Piazzi et al., 2003a), although *C. cylindracea* grows faster at higher irradiance levels (Capiomont et al., 2005), while *W. setacea* dominates deeper (Piazzi et al., 2007). The recent appearance and increase of *C. cylindracea* in the bottoms of the Portofino Promontory was reported also by Gatti et al. (2017), who described the substitution of canopy forming macroalgae from a group of ubiquitous

photophilic macroalgae that include also this species. Moreover, a temporal comparison performed by Gatti et al. (2015) for the coralligenous of an area about 35 km from Portofino, Mesco Reef (Ligurian Sea, NW Mediterranean), documented the appearance of *W. setacea* and *C. cylindracea* respectively in 1996 and 2008, with the former become dominant in 2008 and the latter in fast expansion in the following years. As suggested by these authors, anthropogenic and climatic stress could be the other side of the coin in determining the success of these invasions, altering the native ecosystems and making them more prone to the spread of alien species (MacDougall and Turkington, 2005). Instead, *T. avicularis* is a bryozoan known to colonize the denuded branches of *P. clavata* (Bavestrello et al., 1997) and its appearance could be a signal of an increase in damaged gorgonians, likely due to fishing activities (Bavestrello et al., 1997), diving impacts (Linares et al., 2010) and climate change (Coma et al., 2009).

Particularly relevant is the presence among the "winners" of the two alcyonaceans *C. rubrum* and *P. clavata*. Since they were two of the most affected species by the mass mortality events in 1999 (Cerrano et al., 2000) and 2003 (Garrabou et al., 2009), these findings could seems surprising. However, Bavestrello et al. (2014) argued than the end of the harvesting in the late 1970's allowed the population of *C. rubrum* to develop, around the early 1990's, a "bushy" structure with high density of small colonies (Tsounis et al., 2006). The mass mortality events, instead, reduced the intra-specific competition for the survivors, allowing the population to return to the pristine "forest-like" structure, with bigger colonies and lower density (Bavestrello et al., 2014). In this scenario, our historical pictures (taken in 1980's) depicted a population of *C. rubrum* yet severely depleted by harvesting and this may explain the higher frequency of presence and abundance of this species in current pictures respect to those ones from 1980's. For what concern *P. clavata*, some works revealed that this species showed unexpected recovery 3 or more years after the mass mortality events (Cerrano et al., 2005; Cupido et al., 2009), with lower average size but higher density as a result of successful recruitment. Cupido et al. (2009) hypothesized that, through this process of recovery, a clear-cut population could re-establish the canopy some years after the high-mortality event.

Beside the capability of some species to overcome the negative effects of mass mortality events, the observed increase in the abundances of many components of the coralligenous assemblages respect to those noticed in 1980s (i.e. *C. rubrum*, *P. clavata*, *P. axinellae*, encrusting and massive sponges, erect bryozoans) may be related to the MPA establishment in 1999. In fact, two of the main threats to the coralligenous communities are fishing (i.e. fishing line, trawling) and boat anchoring (Ballesteros, 2006; Bavestrello et al., 1997; Salomidi et al., 2012), two activities that have been regulated with the creation of the MPA: artisanal fishing is allowed in zones B and C only for

resident and involves 35 small vessels (<10 m in length), recreational fishing is allowed only under authorization, in zones B and C for resident, in zone C for –non resident, while trawling is forbidden everywhere in the MPA (Prato et al., 2016); anchoring is banned in zones A and B (the southern front of Portofino Promontory, where both past and current pictures were taken; Venturini et al., 2016). Therefore, despite the high number of divers that frequent the MPA (Lucrezi et al., 2017) and their potential negative impact on the benthic communities (e.g. Coma et al., 2004; Linares et al., 2010; Luna-Pérez et al., 2009), it is plausible to suppose a positive effect of the MPA establishment as partial explanation of the observed patterns for these component of the coralligenous assemblages. Moreover, an higher abundance in 2000-10s respect to 1980-90s for *P. clavata*, *C. rubrum*, sponges (i.e. *Axinella damicornis* (Esper 1794); *Agelas oroides* (Schmidt, 1864); *Ircinia* spp. Nardo 1883) and erect bryozoans (i.e. *Myriapora truncata* (Pallas, 1766); *Smittina cervicornis* (Pallas, 1766)) was reported also by Gatti et al. (2017).

The temporal comparison performed on the pictures of wrecks, revealed that the benthic communities depicted remained quite stable over the temporal span considered (comprised between 10 and 26 years, depending on the wreck). Both in term of presence/absence and abundance, in fact, very few changes occurred in each wreck. These results are consistent with the high temporal stability of hard bottom subtidal communities found by Garrabou et al. (2002), especially at relevant depths. Moreover, the average depth of the wrecks considered (-45 m) may have protected, at least partially, the assemblages from the detrimental effects of the heat waves occurred in the region in 1999 and 2003 (Cerrano et al., 2000; Garrabou et al., 2009), which maximum depths in most parts of the affected areas were respectively 40 (Cerrano et al., 2000; Coma et al., 2006) and 30 m (Garrabou et al., 2009). Not surprisingly the greatest temporal variation was found in the shallowest communities, those inhabiting the Mohawk Deer bow, placed at about 20 m depth in the Portofino Promontory. The availability for this wreck of pictures from more than two moments in time (i.e. 1990, 2001, 2008, 2013, 2016) allowed to track a more detailed history of the changes occurred. Here the gorgonian *E. cavolini*, abundant in pictures from 1990 (about 40 specimens), vanished completely in pictures of 2001 and didn't reappear in the following years. It is reasonable to hypothesize that the population of this species living on the Mohawk Deer bow was affected by the mass-mortality event of the 1999 (Cerrano et al., 2000). The sudden and total mortality that is possible to deduce from the pictures, in fact, was too abrupt to reflect the natural mortality of these kind of organisms (Linares et al., 2008). Conversely, from 1990 to 2001 the abundance of the solitary madreporarian *L. pruvoti* increased of at least one order of magnitude and remained quite constant in the following years, likely taking advantage to the space freed by the gorgonians (Giannini et al., 2003).

Conclusions

The new approach used in this work (i.e. to compare past and present non scientific uw pictures to reconstruct historical changes of hard-bottom benthic communities) presents some intrinsic weakness. First of all, comparing just two (more only in the case of Mohawk Deer wreck) moments in time didn't allow to take into account the temporal variability (Lotze and Worm, 2009). Furthermore, since these pictures were not taken for scientific purposes, and in particular with the aim to quantitatively describe benthic communities, they rarely were orthogonal to the substrate. Thus, the calculation of percent cover of the sessile organisms was not feasible (as done in the Chapter 1; Ponti et al., 2011) and I was able to obtain only a semi-quantitative description of the communities. Moreover, the parallax error and the lowest image quality of the past pictures made harder to distinguish properly some species, forcing to use morphological categories (e.g. massive and encrusting sponges; erect bryozoans) with a low resolution power. The lack of knowledge about the precise shooting location for the pictures of Portofino (I knew only that they came all from the southern front of the Promontory) curtailed the precision of the temporal comparison, preventing me to re-visit the same place and obtain a circumstantial description of the changes (e.g. Bertolino et al., 2016; Gatti et al., 2015). I was then obliged to compare the past and present pictures of the area as a whole, making the description of the communities prone to be impaired by differences in location and depth at which the pictures were taken (Garrabou et al., 2002; Terlizzi et al., 2007). Moreover, the results may have been partially influenced even by the changes in sensibility and knowledge of the uw photographs occurred in these time span (Cerrano et al., 2016), which could have modified the subjects of their pictures, altering the relative frequencies of presence of benthic organisms. To work on pictures of wrecks allowed me to avoid this problem, since the easily recognisable three-dimensional structure of wrecks gave the opportunity to compare past and current photos with the same framing and reconstruct in detail the changes occurred over time. However, unfortunately was not possible to find more than a few pictures for each wreck, since they came from grey literature.

Despite these limitations and intrinsic bias, this approach might be the only able to provide some insights about the long-term changes of hard-bottom benthic communities in certain areas. Indeed, where there is not a long history of environmental studies (Bianchi and Morri, 2000), the critical use (Baisre, 2016) of unconventional source of data (Al-Abdulrazzak et al., 2012) is the only viable option for these communities. Testing this approach in an area well studied since XIX century like the Portofino Promontory (Gatti et al., 2017 and references therein), gave me the opportunity to compare my results with those derived by the use of old ecological observations as source of historical data (Bertolino et al., 2016; Gatti et al., 2017). Through this comparison I found many

similar temporal trends and this seems to confirm the reliability of the approach in describing long-term dynamics of benthic communities, since also the potential amount of non-scientific uw photographies available for the Mediterranean Sea (Romeo, 2009).

Given the paramount importance of hard-bottom communities (Rossi, 2013), this work stresses the potentiality of the temporal comparison using non-scientific photos in reconstructing their past changes to help the restoration processes (Thurstan et al., 2015).

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CHAPTER 3: Diving magazines. A neglected tool to draw historical trends of benthic assemblages

Introduction

In the last few years, the historical ecology field rose quickly to contrast the "shifting baseline syndrome" (Pauly, 1995) and to reconstruct past changes of marine species (Lotze and Worm, 2009). To do this, historical ecologists use a vast plethora of data sources, including unconventional and anecdotal ones (Al-Abdulrazzak et al., 2012), which require to develop protocols for their collection and use (McClenachan et al., 2012). These sources are particularly useful for those species for which the conventional data are scarce because they are not exploited species, although they have however been affected by human activities, mainly through habitat destruction and pollution (Lotze et al., 2006).

In the Mediterranean Sea, particularly affected by human pressures (Claudet and Fraschetti, 2010; Micheli et al., 2013) since historical time (Lotze et al., 2006), little is know about the past changes of the hard bottom sessile communities; given the importance of these organisms (i.e. sponges, cnidarians; bryozoans; ascidians) as ecosystem engineers (sensu Jones et al., 1994) which form animal forests (Rossi, 2013), each clue regarding their past attributes can be crucial for the restoration processes (Thurstan et al., 2015). One possible source of historical data for these communities, which was not yet fully explored, is the non-scientific underwater (uw) photography, since they are very often represented in uw pictures, both as subject and background. The amount of information buried in photographic archives from private citizens, diving association and sectorial magazines is potentially huge, especially for the Mediterranean Sea, which was perhaps the birth place of the SCUBA diving and uw photography (Romeo, 2009).

In this work, we explore the possibility to use the uw pictures published on diving magazines for historical ecology studies about hard bottom benthic communities. Our hypothesis is that trends of subjects depicted in diving magazines could reflect actual alteration and that, consequently, they could be used as a sort of long-term time series for these communities. Moreover, we propose the use of diving magazines as a source of anecdotal evidence of "what we have lost", borrowing an approach used by Guidetti and Micheli (2011) for the ancient art. Magazines contain photos with high visual impact (e.g. high abundance of species now very rare; specimens of exceptional size; etc.) that can help to create the perception of changes occurred in these communities in the last

50/60 years, thus contributing to counteract the sliding of the baselines through the awareness of the common people.

Materials & methods

We collected 90 numbers from 5 different Italian magazines (i.e. Mondo Sommerso; Scubazone; Sesto Continente; Sub; Subaqua), covering the period from 1979 to 2013. We selected all the pictures from Mediterranean Sea and, for each of them, we collected information about shooting locality (whenever specified) and year, typology of frame (landscape or close-up), and inclination of substrate. Then, we proceed to the identification of the organisms depicted in each picture to the lower taxonomic level feasible.

Once completed the data matrix, we gathered the organisms identified in large taxa and chose sponges, hexacorals, octocorals and bryozoans to perform the analysis. Then, we calculated the occurrence frequency for each of these taxa per year, as the ratio between the number of pictures in which each taxon appears and the total number of pictures analysed for that year. We calculated the average occurrence frequency for the following three periods: 1979-1989; 1990-2000; 2001-2013.

Preliminary Results

We analysed a total of about 1000 pictures for the Mediterranean Sea, 233 pictures for the period 1979-1989, 434 for the period 1990-2000 and 366 for the period 2001-2013.

The average occurrence frequency of the sponges is 18.4% in 1979-1989, 12.4% in 1990-2000 and 7% in 2001-2013 (fig. 1).
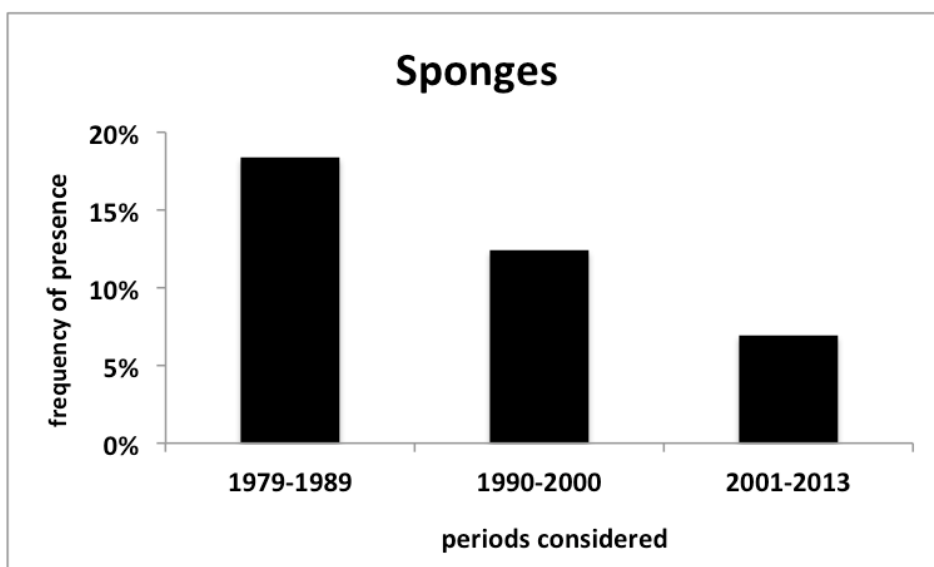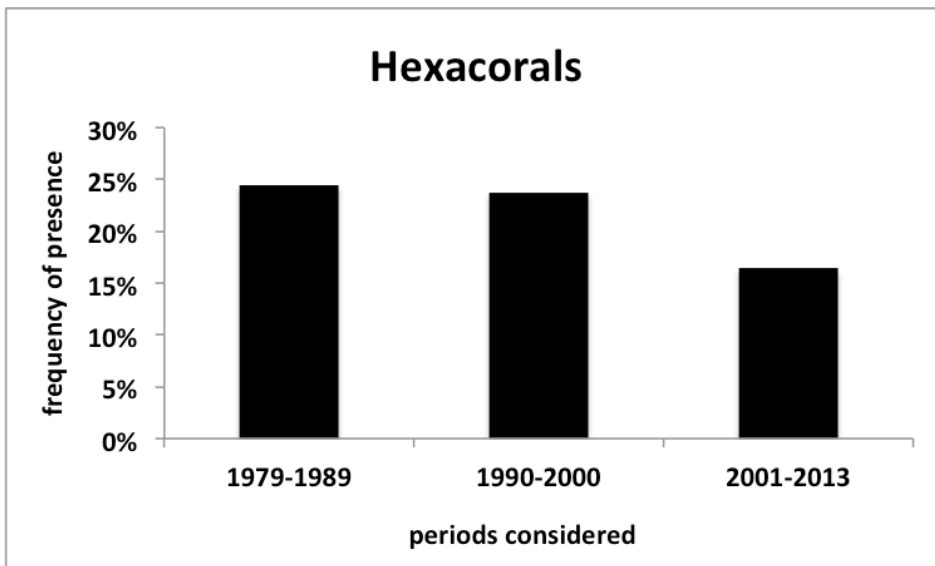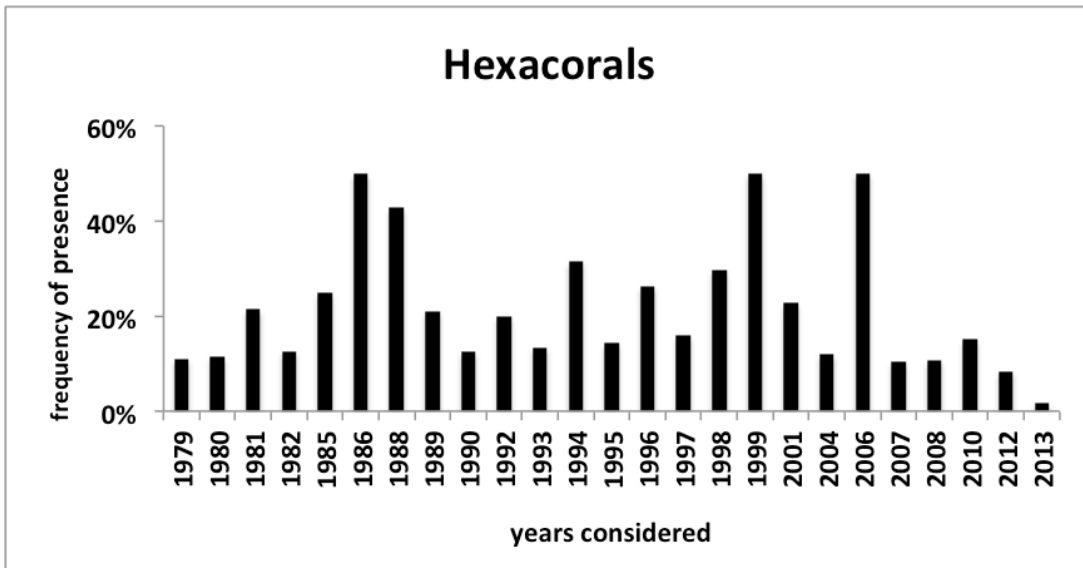
a)
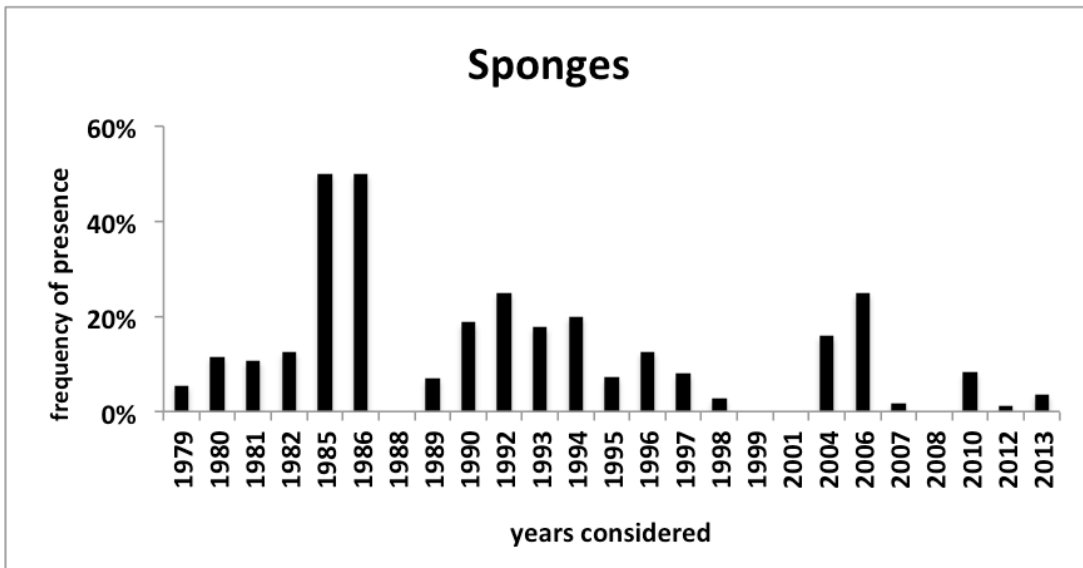
b)

Figure 1. Average occurrence frequencies of the sponges: a) for decades; b) for years.

The average occurrence frequency of the hexacorals is 24.4% in 1979-1989, 23.7% in 1990-2000 and 16.4% in 2001-2013 (fig. 2).
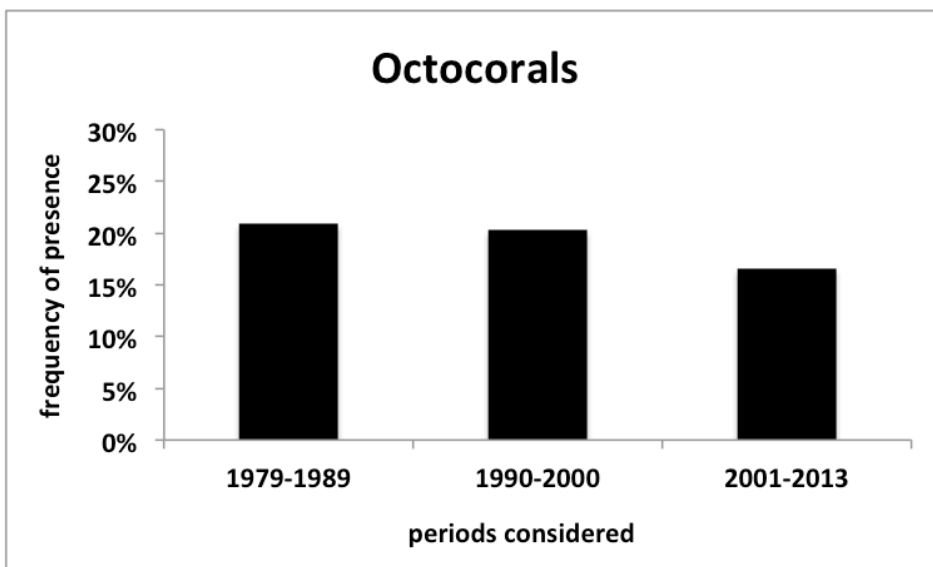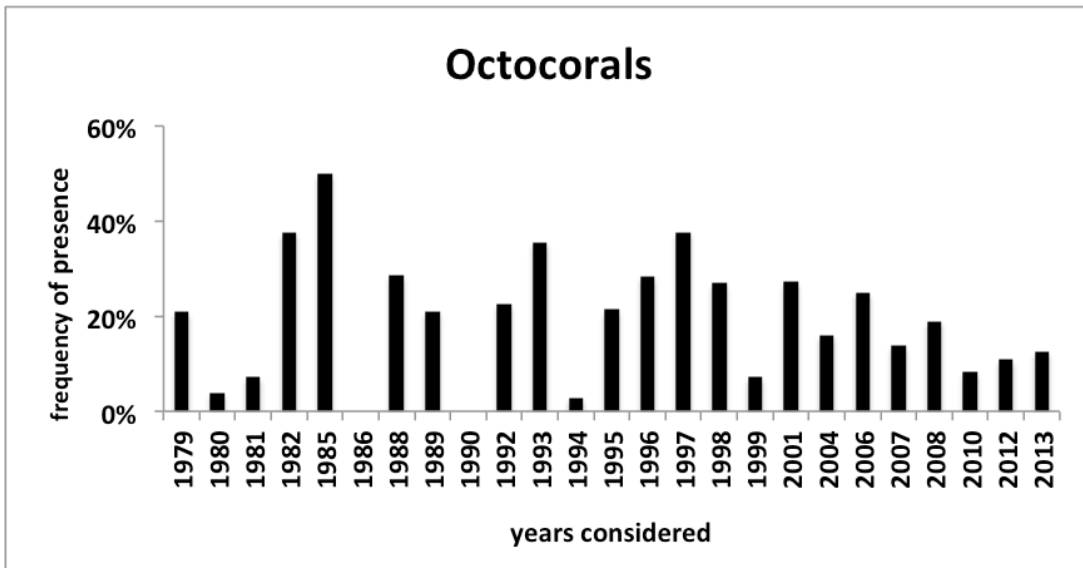

a)

b)

Figure 2. Average occurrence frequencies of the hexacorals: a) for decades; b) for years.

The average occurrence frequency of the octocorals is 21.11% in 1979-1989, 20.3% in 1990-2000 and 16.7% in 2001-2013 (fig. 3).
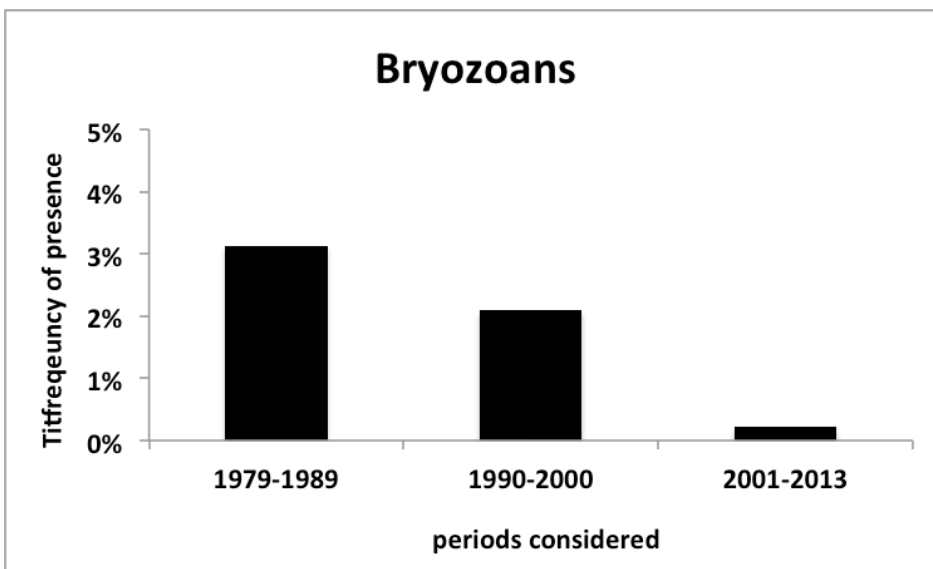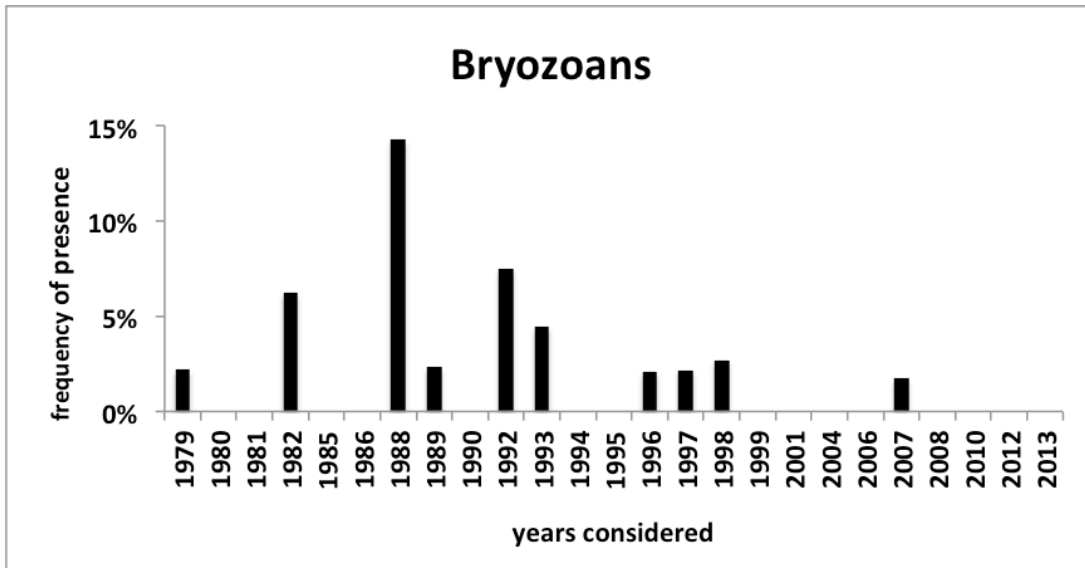

a)

b)

Figure 3. Average occurrence frequencies of the octocorals: a) for decades; b) for years.

The average occurrence frequency of the bryozoans is 3.1% in 1979-1989, 2.1% in 1990-2000 and 0.2% in 2001-2013 (fig. 4).

a)

b)

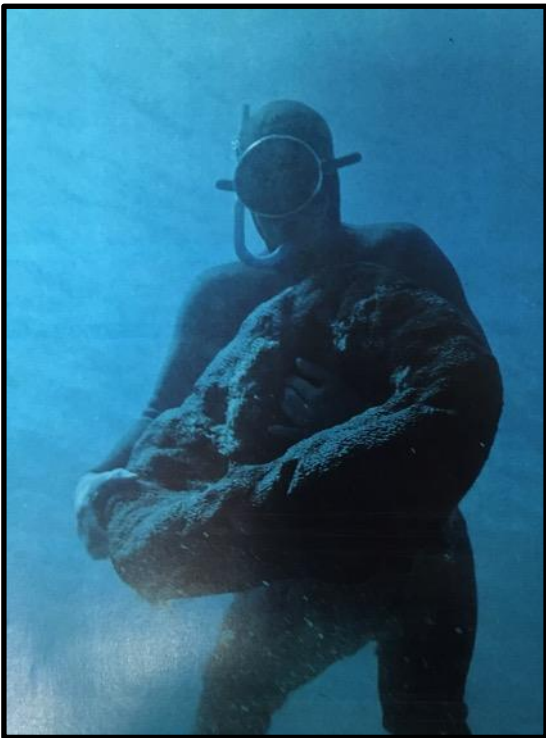**Figure 4. Average occurrence frequencies of the bryozoans: a) for decades; b) for years.**

We found several photos with high visual impact, depicting high abundance of species now rare and/or specimens with exceptional size (fig. 5).

a)

b)

c)

Figure 5. Some example of anecdotal evidence of "what we have lost": a) *Corallium rubrum*, **1966; b) bath sponges, 1966; c) bath sponge, 1979.**

Discussion

The preliminary results suggest a constant downward trend in the occurrence frequency of the taxa analysed, from the decades 1979-1989 and 1990-2000 to the period 2001-2013, more pronounced for sponges and bryozoans.

This trend could be related on one side to a change in the interest of underwater photographers and in the photographic techniques. In fact, the passage from film to digital (in the late 90s/early 2000s), made the techniques of macro-photography cheaper and simpler, making other subjects (nudibranchs over all) really intriguing for many photographers. Nevertheless, on the other side the trend might reflect an actual alteration occured in the benthic sessile communities. Indeed, most of the organism considered exhibit "low dynamics, high longevity and persistence" (Teixidó et al., 2011). They are therefore sensitive to extreme disturbance events, like heat waves and related mass-mortality events (Cerrano et al., 2000; Garrabou et al., 2009), which are able to cause partial and total mortality through immediate and delayed effects (e.g. Linares et al., 2005; Teixidó et al., 2014).

Moreover, the diving magazines have the potential to provide photos with high visual impact (i.e. organisms with exceptional size or abundance) that might help to create in the common people the awareness of the change occurred and to contrast the shifting baseline syndrome.

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General conclusions

To reconstruct the historical changes of marine ecosystems is necessary to counteract the shifting baseline syndrome (Pauly, 1995) and perform effective management, restoration and recovery processes (Lotze and Worm, 2009). This is especially true in the Mediterranean Sea, since its long history of anthropization and the ancientness of human impacts (Lotze et al., 2006; Lotze et al., 2011). In particular, coastal ecosystems are experiencing structural and functional changes (Barange et al., 2010), due to synergistic interactions (Crain et al., 2008) between direct human activities (Claudet and Fraschetti, 2010) and climate change (Hughes et al., 2003). Among them, the hard-bottom benthic communities are threatened by pollution (Hong, 1983), sedimentation (Piazzi et al., 2011), fishing (Bavestrello et al., 1997), anchoring (Lloret et al., 2008), SCUBA diving (Coma et al., 2004; Linares et al., 2010), biological invasion (Piazzi et al., 2007; Piazzi and Balata, 2009), climate change (Coma et al., 2009) and related mass mortality events (Cerrano et al., 2000; Garrabou et al., 2009). However, the changes of these communities are particularly difficult to detect since they are almost not directly exploited, thus risking to be unrecognized (Al-Abdulrazzak et al., 2012). The chance to reconstruct their history rely on old ecological observations (e.g. Bertolino et al., 2016; Gatti et al., 2015) and on a critic use (Baisre, 2016) of unconventional/non-scientific data sources (Al-Abdulrazzak et al., 2012).

In this scenario, the main aims of this work were to reconstruct the changes of some benthic seascapes and investigate the potential of the non-scientific uw photography to serve as unconventional source of data for hard-bottom benthic communities. To di this, I integrated different methods (time series vs. temporal comparison), time scales (pluriannual vs. multidecadal), data sources (scientific vs. non scientific photography) and substrates (natural vs. artificial). The conclusion can be summarised as follow:

- time-series analysis, where available, is the preferable method because takes into account the temporal variability and fluctuations over time (Sukhotin and Berger, 2013), allowing to identify possible phase shifts (Montefalcone et al., 2011; Spencer et al., 2012);

- the temporal variability of hard-bottom benthic communities is extremely low, making them notably vulnerable to threats and especially to extreme disturbance events (e.g. Cerrano et al., 2000; Teixidó et al., 2013), and it is negatively correlated with the depth (Garrabou et al., 2002); this slow dynamics stress the need to longer-term monitoring program, indispensable to identify slow regime shift (Hughes et al., 2013)

- in absence of time-series of scientific data, temporal comparison using non-scientific uw photography can be a reliable approach, despite its intrinsic limitations; since to work with unconventional sources requires to develop protocols to extract the data (McClenachan et al., 2012), this study proposes a suitable ones to derive semi-quantitative data from non scientific photos;

- diving magazines might represent an additional tool to reconstruct changes of benthic communities through the interpretation of trends in organisms depicted in the pictures published; moreover, they can provide visual evidence of "what we have lost", helping to build in the common people the awareness of the changes occurred and to contrast the shifting of the baselines;

- since the inherent constraints of the historical ecology, the only way to increment the trustworthiness of reconstructed changes is to integrate data from a diversity of sources.

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