Distribution and morphological variation of colonies of the bryozoan Pentapora fascialis (Bryozoa: Cheilostomata) along the western coast of Italy

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Distribution and morphological variation of colonies of the bryozoan *Pentapora fascialis* (Bryozoa: Cheilostomata) along the western coast of Italy

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Bathymetric range, substrate, colony density, colony size, and some zoarial features (form of the colony and branches) of the carbonate reef building cheilostome bryozoan *Pentapora fascialis* (Pallas) were recorded from 15 localities along the western coast of Italy. A wide range in the depth distribution of colonies was observed (11 to 60 m). Colonies occurred on several different types of substrate including gorgonians, sponges, bedrock and rock boulders, in current swept areas. Density was approximately 1 colony/m\(^2\). The most frequent colony size-class was 10 to 20 cm in diameter and was typically found growing epizoically on gorgonians. Ellipsoidal colony forms with expanded, foliaceous laminae were characteristic of larger colonies; these frequently grew on rock substrates. Subspherical colonies with a diameter less than 20 cm grew as epizoans and had a narrow branches structure. This information will help to inform decisions on taxonomic discrepancies within the Pentaporidae. In addition the data provide a useful baseline for the future estimation of a carbonate budget in the region.

**Keywords:** distribution, morphological variation, colonies, *Pentapora fascialis*, western coast of Italy

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### INTRODUCTION

The erect, robust-branching bryozoan *Pentapora fascialis* (Pallas, 1766) is a conspicuous subtidal species colonizing hard rock substrates, cobble and boulder areas and also other living species (gorgonians) from 1 m depth down to 60 m or more (Hayward & McKinney, 2002; Novosel et al., 2004). It occurs along the western coast of Britain as far north as the Hebrides and St Kilda, and eastwards along the English Channel, towards its limit in Sussex. The species occurs southwards into the western Mediterranean, with records in the Adriatic and Ionian Seas and along the coast of Tunisia (Hayward & Ryland, 1999; Cocito & Ferdeghini, 2001; Mustapha et al., 2002).

Colonial growth of *P. fascialis* begins with a small encrusting patch that develops into bilaminal sheets (Hayward & Ryland, 1999). These then go on to develop into an erect foliose structure, 20–30 cm in diameter, occasionally up to 80 cm (Cocito et al., 1998). Growth occurs in one of two ways, either by the formation of slender dichotomous branches or by the development of fused laminae, thus corresponding to the adeoniform and eschariform morphotypes respectively (McKinney & Jackson, 1989). This may be a response to different water flow directions and velocities (Cocito & Ferdeghini, 2000) or it may be due to genetic makeup.

There have been some recent taxonomic issues concerning *Pentapora*. It was considered by Gautier (1962) to comprise two different species, namely, *Pentapora fascialis* (Pallas) and *Pentapora foliacea* (Ellis & Solander). Zabala & Maluquer (1988) relegated these to subspecies and in 1999 they were merged into a single species, *P. fascialis*, by Hayward & Ryland. In this study we will refer to it as the single species *P. fascialis* but it should be noted that genetic research is currently underway in order to clarify the systematics of the different morphological types.

*Pentapora fascialis* is a distinguishing species of the ‘facies with large branching Bryozoa’ among the ‘bioconesoses of the coastal detritic bottoms’ of the circalittoral zone (Habitat Directive 92/43 EEC). Together with other bryozoans, the species lives on both hard substrata and as an epizoan on gorgonians within different facies of coralligenous bioconesoses (Pérès & Picard, 1964; Bellan-Santini et al., 2002). The high vulnerability of the habitat provided by *P. fascialis* and also its abundant associated diversity make its protection a priority (Bardat et al., 1997).

As with many bryozoans, *Pentapora fascialis* produces a heavily calcified skeleton that withstands current flow. The colonies can develop into large reef-like constructions that provide living space for other species, thereby increasing the diversity of habitats where they occur. An interesting recent development has been the use of *P. fascialis* colonies as a bioindicator of seasonal variations in temperature through...
analysis of zooid size variation. This method has been applied
in two studies (O’Dea, 2005; Lombardi et al., 2006). When a
colony is damaged or eventually dies its skeleton is deposited
into the sediment, providing a source of carbonate (Smith
et al., 1998; Cocito, 2004).

Current knowledge on the extent and distribution of car-
bonate build-ups and carbonate production by P. fascialis is
limited. The eastern Ligurian Sea and the karstic freshwater
springs in the north-eastern Adriatic Sea are the only
Mediterranean regions to have been studied so far (Cocito &
Ferdeghini, 2001; Cocito et al., 2004).

Analysis of the occurrence of P. fascialis and its growth
habits, along with an indication of how the morphology of
the species responds to different environmental conditions,
should increase our current understanding of its ecological
variability. Contemporary knowledge of the distribution of
this large carbonate producing bryozoan will provide new
data for the re-evaluation of the carbonate budget of the
Mediterranean.

The aim of our study was therefore to map the distribution
and morphology of the species P. fascialis along the western
coast of Italy. Observations were made of bathymetric range,
the substrates on which colonies develop, colony density and
size, and colony morphology (form of the colony and branches).

MATERIALS AND METHODS
The study was carried out during the period 2001 to 2003 in
15 localities along the western coast of Italy, extending from
the Ligurian Sea in the north to Sicily in the south (Figure 1).

SCUBA divers recorded a variety of data including the depth
range of P. fascialis colonies, the type of substrate on which
colonies lived (hard, artificial and other organisms), colony
size in diameter (<10 cm, 10–20 cm, >20 cm), colony
density (<1/m², 1–2/m², >2/m²), colony morphology
(sub-spherical or ellipsoidal) and the branching form
(expanded, foliaceous laminae or slender, dichotomous
branches) of colonies. The collection of this data was facilitated
by the setting out of three transect lines at each location. Five
replicate quadrats (1 m²) were randomly placed along each
transect line, then the number and size of colonies present
within each quadrat was recorded by pairs of divers on an
underwater recording slate.

Voucher colonies of P. fascialis with the different growth
forms and branching types were collected from each location
in order to establish a baseline for accurate taxonomic identi-
cation. These colonies were preserved by air drying following
careful transportation to the laboratory.

Frequency distribution graphs were constructed from the
data to analyse: (a) the size-classes of P. fascialis colonies
growing on different substrate types; (b) the size-classes of
colonies in relation to colony morphology; (c) the type of sub-
strate in relation to colony morphology; and (d) the colony
morphology in relation to branching type.

A multivariate descriptive method, the multiple correspon-
dence analysis (MCA), was used to analyse correlation
between variables. Data on colony size, colony density,
colony form and branch type were converted to a 0–1
matrix and treated separately for the two types of substrate
more frequently used by P. fascialis, organic and hard. As all
colonies growing on organic substrate displayed dichotomous
branches, branch form was not considered as a variable in the
MCA. Analogously, colony form was not considered in the
MCA on hard substrate, where all colonies had the ellipsoidal
form.

RESULTS
Distribution of P. fascialis colonies
The distribution of Pentapora fascialis colonies on western
Italian coasts was documented by SCUBA surveys. 517 colo-
nies were recorded in total, from a depth of 11 to 60 m
(Table 1). The shallowest colonies (11 deep) were found at
Tino Island and Cape Tegge, whereas at the Formiche
Islands and Cape Barbi P. fascialis occurred down to 60 m
depth.

Size-class distribution of colonies in relation
to substrate and colony morphology
The modal size-class of colonies recorded was the 10 to 20 cm
category of colony diameter with 87.7% of colonies being
assigned to this category (see Table 1). In 10 of the localities
surveyed, this size-class of colony was found commonly
growing as epizoans on gorgonians and, to a lesser extent,
colonizing hard substrates (Figure 2A). Colonies were
occasionally observed on artificial substrates. When growing
epizoically, the main substrate for attachment of colonies
of P. fascialis was provided by the living branches and the
bare axial skeleton of branches, specifically those affected by
necrosis on the gorgonian Paramuricea clavata (Risso).
Colonies were also recorded on living gorgonians of the
species Eunicella singularis (Esper) and Leptogorgia sarmen-
tosa (Linnaeus) and on the sponge Cucospongia scalaris
(Schmidt). These substrate preferences were recorded at
both Tino Island and Carega Shoal at Portofino. Hard
bedrock and rocky blocks were also common substrates for
Table 1. Study localities, number of colonies observed, depth-range of distribution, type of substrate (o, other organisms; h, hard; a, artificial), colony size, density, form (s, sub-spherical; e, ellipsoidal) and branch form (d, dichotomous; f, folicaceous). Li, Ligurian Sea; Ty, Tyrrhenian Sea; Sa, Sardinian Sea; Si, Sicily Channel.

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<th>Locality</th>
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<th>Substrate</th>
<th>Colony size (cm)</th>
<th>Density (m$^{-2}$)</th>
<th>Colony form</th>
<th>Branch form</th>
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<tr>
<td>1) Allassio Bay (Li)</td>
<td>17–22</td>
<td>o</td>
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<td>2) Carega Shoal (Li)</td>
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<td>3) Tino Island (Li)</td>
<td>11–25</td>
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<td>4) Cape Civitata (Ty)</td>
<td>15–38</td>
<td>h</td>
<td>&gt;20</td>
<td>&gt;2</td>
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<td>5) Formiche Islands (Ty)</td>
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<td>6) Cape Fenaio (Ty)</td>
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<td>7) Cape Tegge (Ty)</td>
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<td>10–20</td>
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<td>8) Cape Marargiu (Sa)</td>
<td>12–30</td>
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<td>10–20</td>
<td>1–2</td>
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<td>9) Osalla Bank (Ty)</td>
<td>15–24</td>
<td>h</td>
<td>10–20</td>
<td>&gt;2</td>
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<td>10) Cape Aniello (Ty)</td>
<td>15–40</td>
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<td>10–20</td>
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<td>11) Cape Barbì (Ty)</td>
<td>18–60</td>
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<td>12) Cape S. Paolo (Ty)</td>
<td>30–40</td>
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<td>10–20</td>
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<td>13) Toro Shoal (Ty)</td>
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<td>&gt;20</td>
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<tr>
<td>14) Bassana Point (Ty)</td>
<td>20–30</td>
<td>o</td>
<td>10–20</td>
<td>&lt;1</td>
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<td>15) Scoglitti (Si)</td>
<td>20–24</td>
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The small size-category of *P. fascialis* colonies (<10 cm) with the bryozoan species *P. fascialis* along the western coast of Italy. This study was necessary for the collection of detailed morphological and ecological data which can be used to supplement detailed analysis to study the taxonomic systematics of the *Pentapora* species. The colonies were typically small, less frequently developed, dichotomous branches were less frequently developed in ellipsoidal colonies, being dominant in smaller subspherical colonies.

**Colony density and growth form of *P. fascialis***

At Allassio Bay, Tino Island, Cape Tegge, Osalla Bank, Scoglitti, where colony density was high (Table 1), ellipsoidal colonies often had subcircular expansions at the colony edge, formed by the fusion of satellite colonies. The narrow branched, sub-spherical *P. fascialis* colonies growing on other organisms or fishing nets and lines occurred at lower densities of <1 colony/m$^2$, and less frequently, 1–2 colony/m$^2$. These colonies did not appear to have undergone any fusion events.

**DISCUSSION**

The aim of this study was to investigate the distribution and morphology of the bryozoan species *P. fascialis* along the western coast of Italy. This study was necessary for the collection of detailed morphological and ecological data which can be used to supplement detailed analysis to study the taxonomic systematics of the *Pentapora* species. The colonies were typically small, less frequently developed, dichotomous branches were less frequently developed in ellipsoidal colonies, being dominant in smaller subspherical colonies.

Small colonies of *P. fascialis* (<10 cm) usually occurred as epizoans and were scarce (Figure 2A). These colonies tended to exhibit a subspherical growth form, which was dominant in small colonies of *P. fascialis* (10–20 cm in diameter or less) (Figure 2B).

**Colony form of *P. fascialis* in relation to substrate and branching form**

The small size-category of *P. fascialis* colonies (<10 cm) with subspherical growth form frequently grew either on other organisms or on artificial substrates such as fishing nets and lines (Figure 2C). Larger ellipsoidal colony forms were dominant on hard substrates (Figure 2C) where they commonly developed folicaceous laminae that were convoluted and fused to varying degrees (Figures 2D & 3B). On the other hand, dichotomous branches were less frequently developed in ellipsoidal colonies, being dominant in smaller subspherical colonies.
70 m depth from the top of a shoal off Mazara del Vallo (TP), southern Sicily (M. Gristina, personal communication).

Colonies of *P. fascialis* were typically an important component of the zoobenthos in the transition zone between the infralittoral and the circalittoral, specifically in the ‘circalittoral sciaphilic algal community’. This type of community, fully developed in most of the locations, occurred either at the foot of cliffs, or on rocky surfaces emerging from the sediment. *Pentapora fascialis* was also a common epizoan in facies that were characterized by gorgonians within the coralligenous biocoenoses on rocky cliffs with high hydrodynamics. This is in accord with previous studies on the French coasts (Augier, 1982; Bellan-Santini et al., 2002) and in the northeastern Adriatic Sea, where the most common distribution patterns observed for the species refer to rocky walls and gorgonian stalks attached to cobbles and boulders on flat soft-sediment (Hayward & McKinney, 2002; McKinney, 2007). Around the British Isles, *P. fascialis* colony morphologies are only of the fused laminar morphology. The species is distributed from as far north as the Shetland Isles, around the west coast of the UK, with occasional records around the west coast of Ireland, through the Irish Sea and Cardigan Bay and up through the English Channel as far east as Beachy Head (NBN gateway). In UK coastal waters, *P. fascialis* colonies are found attached to bedrock, large boulders, cobbles and pebbles, they have not been recorded living on seafans.

Substrate is one of the main environmental parameters that controls bryozoan colonization, settlement and growth (Hageman et al., 1997; Taylor & Wilson, 2003; Amini et al., 2004). Natural marine hard substrates both biogenic (live and partially dead gorgonians, sponges) and abiotic materials (rocks, cobbles and boulder) represent the preferred substrate for *P. fascialis* colonization compared to unconsolidated sediments, on which the taxon has never been found. Large, long-lived gorgonians, such as *Paramuricea clavata*, *Eunicella singularis* and *Leptogorgia sarmentosa*, and large sponges offer, analogously to rocky substrata and boulders, relatively stable habitats, even in moderately exposed sites, for the rigidly erect species that rises from sediment avoiding being covered with mud. According to previous observations

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**Fig. 2.** Frequency distribution of *Pentapora fascialis* colonies in the 15 localities: (A) size-classes type of substrate; (B) size-class colony form; (C) type of substrate colony form; (D) branch colony form.

**Fig. 3.** *Pentapora fascialis* growth forms: (A) depressed globular colony with an elliptic perimeter and expanded, foliaceous laminae; (B) detail of slender, dichotomous branches of a subspherical colony growing on the gorgonian *Paramuricea clavata*. 
(Cocito & Ferdeghini, 2000), the species only developed dichotomous branches when living on an organic substrate, which could represent a limiting factor for the development of large colonies and for high colony densities to occur. In contrast, on hard substrates ellipsoidal colonies were found bearing both foliaceous laminae and dichotomous branches. Foliaceous laminae were associated with the highest density of colonies in contrast to the Atlantic environment where colonies, typically displaying foliaceous morphology, are usually smaller in size and characterized by low densities (Lombardi personal observation; MarLIN website).

At the 15 localities studied, most of the bryozoan colonies were found in current swept areas, particularly at capes, shoals and banks where food availability to benthic suspension feeders is guaranteed by the hydrodynamic regime (Gili & Ros, 1985). Many bryozoans display a diversity of colony morphologies that interact with water flow affecting resistance to current action and food capture (McKinney & Jackson, 1989). A relationship between morphology of *P. fascialis* colonies and the local environment was proposed by Cocito & Ferdeghini (2000), who considered variations in colony morphology to be an important adaptive mechanism of suspension feeders to their local environment. Small colonies of *P. fascialis* with slender, dichotomous branches may represent an adaptive response to conditions where colonies grow in a multidirectional flow. In contrast, large colonies with expanded thick laminae, may be a response to the increased capacity of colonies to withstand flow stress, allowing colonies

![Fig. 4](image-url)

Fig. 4. (A) Relationships among colony size, colony density and colony form for *Pentapora fascialis* growing on organic substrate according to the multiple correspondence analysis (MCA); (B) Relationships among colony size, colony density and branch form for *P. fascialis* growing on hard substrata. Variable categories are given in Table 1. Both graphs show the first and second factorial planes.
to take advantage of strong laminar currents. In our study, for
colonies growing on an organic substrate, the MCA analysis
divided ellipsoidal forms from large, high-density colonies
(Figure 4A). For colonies growing on hard substrata, colonies
with dichotomous branches were separated from those occurring
at highest density (>2 colony/m²), and medium size
colonies weakly clustered together with low density distribu-
tion away from large colonies at intermediate
density (1–2 colony/m²) (Figure 4B). These results therefore
provide further support for the hypothesis of Cocito &
Fredeghini (2000).

Further functional analyses of different morphotypes
across a wider range of environments are required to charac-
terize more accurately the relationship between colony mor-
phology and ecology, particularly with respect to
hydrodynamic regime. One possibility would be to grow colo-
nies of Pentapora in flow tanks of different regimes, or to
transplant young colonies into different regimes in the
natural environment.

Considerable phenotypic plasticity is exhibited by P. fascia-
lis in terms of variation in the size and morphology of the
colony, and branching pattern. Genetic studies and detailed
morphometrics at the zooid level are currently underway.
This approach will further clarify the taxonomic relationships
between different colony morphologies and the level of genetic
differentiation between branching and foliaceous colonies.

In accordance with previous reports (Gautier, 1962;
Hayward & Ryland, 1999), we found the most frequent size-
class to be 10 to 20 cm in colony diameter. However, colonies
growing on hard bedrocks and rocky bottoms frequently
reached some 50 cm across. Apart from one record of a
colony of 1 m in diameter in the Adriatic Sea (Cocito et al.,
2004), larger sized colonies (80 cm in diameter, 50 cm in
height) were previously described only from the Ligurian
Sea (Cocito et al., 1998). The fragility of the carbonate skeleton
of the colony makes the species very sensitive to damage by
human activities, in particular dredging and diving activities.
In one study, a reduction in the average size of P. fascialis col-
onies was reported in areas where frequent diving and dredging
activities were taking place (Sala et al., 1996). Other threats
such as water pollution, changes in sedimentation rate, fine
sediment input and trawl fishing have been reported for
large, erect bryozoans (Harmelin & Capo, 2002). Due to
recent increases of water turbidity and sewage, large, erect
ramose bryozoan colonies have been reduced in number or
have even disappeared in several urban coastal areas of the
Mediterranean Sea. Losses of colonies due to anthropogenic
activities, clearly has repercussions for the overall levels of
biodiversity of these coralligenous bicoenosens.

In summary our study brings useful new information
regarding the large-scale distribution and growth habits of
the conspicuous reef constructing bryozoan species, P. fascia-
lis. We advocate further studies of this type, particularly in
other areas of the Mediterranean and also into the Atlantic
to establish the distribution of colony morphologies and
growth types throughout the range of the species. Such data
will be of considerable importance in calculating the com-
ponent that these organisms contribute to regional carbon
sinks. These regional sinks are a highly significant component
of the global carbon cycle. A basic knowledge of the biogeo-
graphical distribution of major current carbon producing
organisms is essential to further our understanding of the
impacts (e.g. ocean acidification) of climate change in relation
to carbon cycling. This is necessary both to clarify events from
the past (through the fossil record) and also to inform for the
future (for modelling the effects of climate change).

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