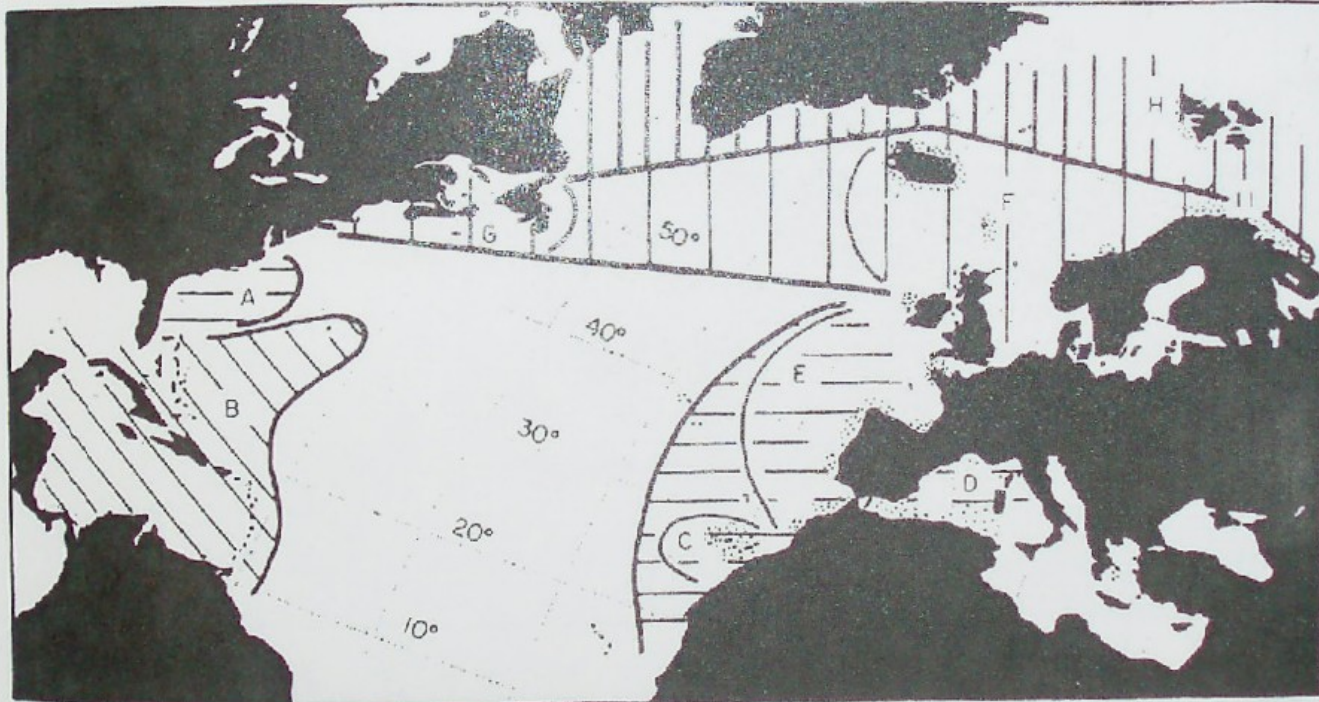


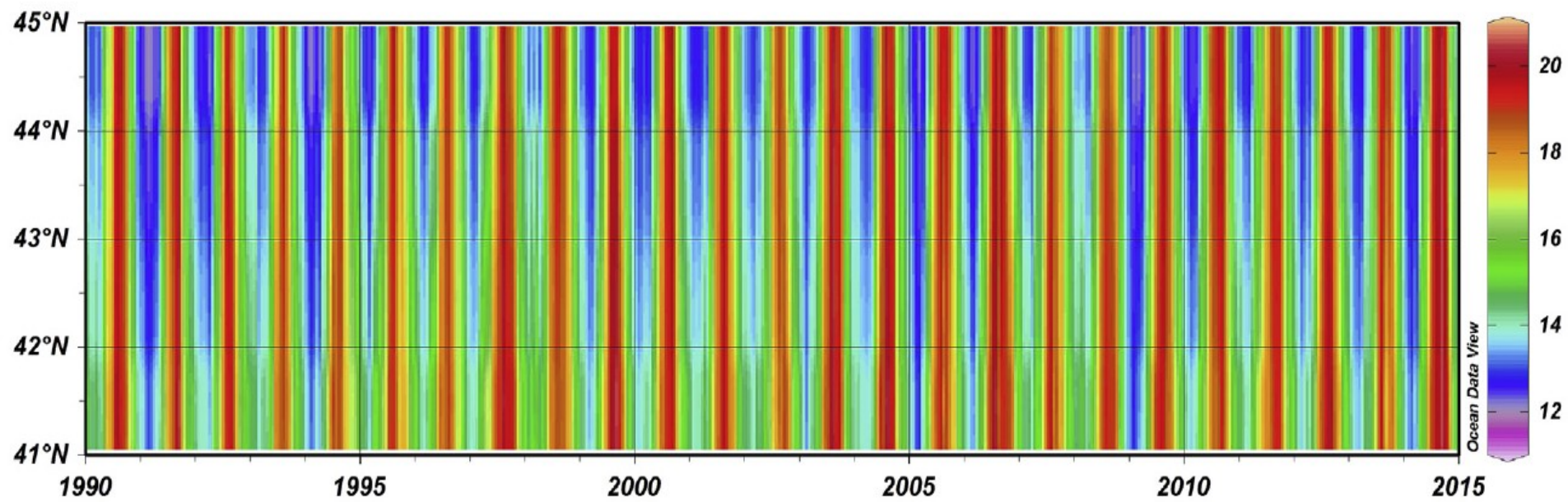
## European / NW African warm temperate Mediterranean-Atlantic region

from 10°C w.i. near western Ireland/Brittany to 25°C s.i. near Cape Verde

three phycogeographic provinces: **Lusitania province**, **Canary province**, **Mediterranean**



**Fig. 2.45** Phytogeographical regions and provinces in the North Atlantic. A = warm temperate Carolina region; B = western Atlantic tropical region; C,D,E = warm temperate Mediterranean-Atlantic region (C = Canary province; D = Mediterranean province, E = Lusitania province); F,G = cold temperate North Atlantic region (F = eastern province; G = western province), H = Arctic region. (From van den Hoek 1975.)



spatio-temporal variation in sea surface temperature across NW Spanish/Portuguese coast



late February sea surface temperature minimum

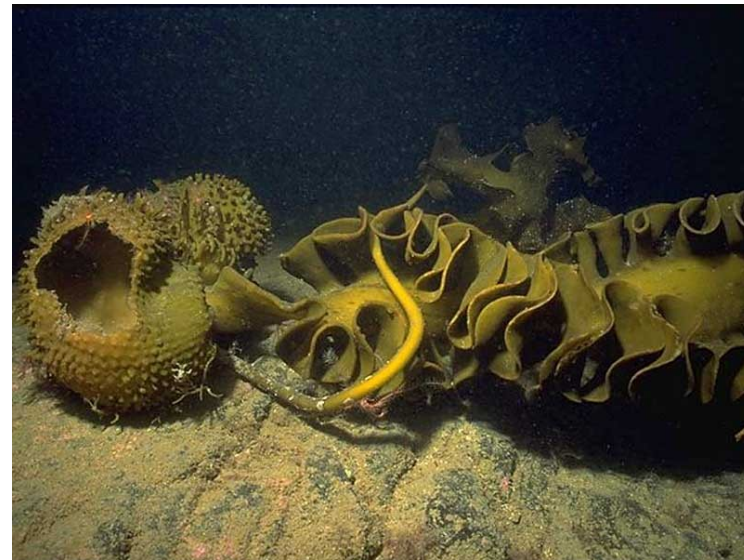


*Pineiro-Corbeira et al., 2016, Mar. Env. Res.*

# Lusitania province

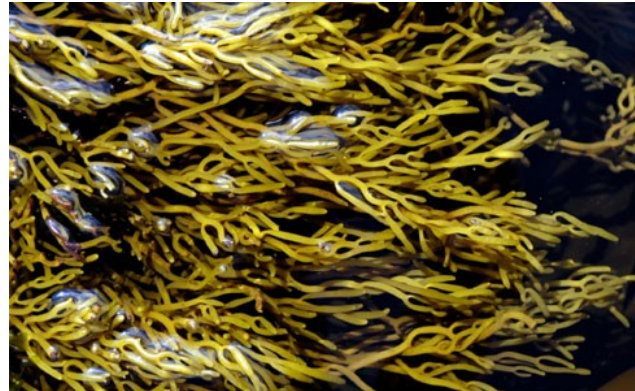
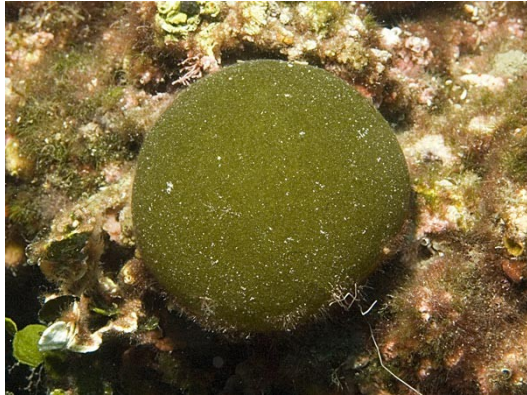
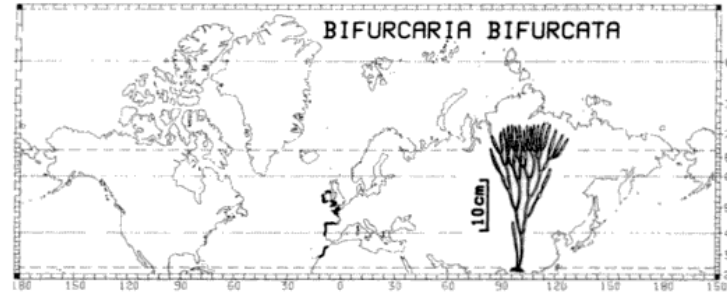
*Alaria esculenta* and *L. digitata* do not reach below W Ireland/Bretagne; but additional cold temperate seaweeds reach up to mid Portugal (e.g., *L. hyperborea*, *Saccharina latissima*)

typical ancestral species: *Saccorhiza polyschides*, *L. ochroleuca*  
(they mix with the cold temperature species on Bretagne coast)



southern species reaching the northern limits in Lusitanian province

*Codium bursa*, *Bifurcaria bifurcata*, *Cystoseira* spp., *Padina pavonica*, *Halopteris filicina*, *Dictyopteris membranacea*, *Dictyota dichotoma*



many species - distributional gap along the French Atlantic coast south of the Loire to north Spain (e.g. *L. saccharina*, *F. seratus*, *A. nodosum*, *Ch. crispus*)



inhospitable soft substrate...

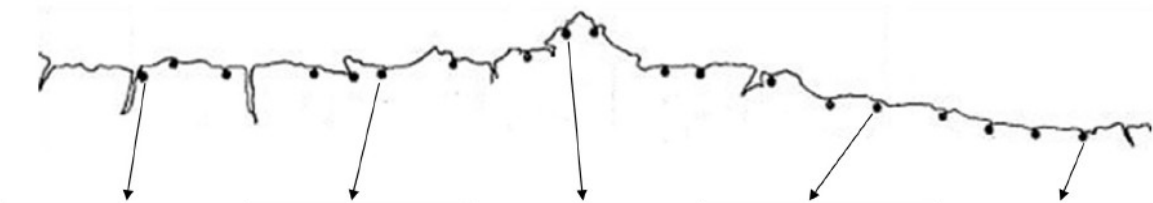
but on Basque coast: 22°C in August (as in Mediterranean and Morocco); too much for laminariacean cold temperate species

Basque coast: *Cystoseira tamariscifolia*, *Gelidium sesquipedale*, *C. officinalis*  
*F. spiralis*



Northern and NW coasts of Iberian peninsula are quite variable due to the temperature heterogeneity

summer upwelling affects the Northwest coast of the Iberian Peninsula



| Arnao (20)                   |                                | C. Artedo (14)                |                             | Bañugues (11)                |                              | Caravia (5)                   |                                 | Buelna (1)                     |                                |
|------------------------------|--------------------------------|-------------------------------|-----------------------------|------------------------------|------------------------------|-------------------------------|---------------------------------|--------------------------------|--------------------------------|
| 1977                         | 2007                           | 1977                          | 2007                        | 1977                         | 2007                         | 1977                          | 2007                            | 1977                           | 2007                           |
| Yellow lichens               | Yellow lichens                 | Yellow lichens                | Yellow lichens              | Yellow lichens               | Yellow lichens               | Yellow lichens                | Yellow lichens                  | Yellow lichens                 | Yellow lichens                 |
| <i>Verrucaria Melaraphe</i>  | <i>Verrucaria - Melaraphe</i>  | <i>Verrucaria Melaraphe</i>   | <i>Verrucaria-Melaraphe</i> | <i>Verrucaria-Melaraphe</i>  | <i>Verrucaria-Melaraphe</i>  | <i>Verrucaria Melaraphe</i>   | <i>Verrucaria Melaraphe</i>     | <i>Verrucaria Melaraphe</i>    | <i>Verrucaria Melaraphe</i>    |
| <i>Chthamalus Littorina</i>  | <i>Chthamalus Phorcus</i>      | <i>Chthamalus Littorina</i>   | <i>Chthamalus Phorcus</i>   | <i>Chthamalus Littorina</i>  | <i>Chthamalus Phorcus</i>    | <i>Chthamalus Gibbula</i>     | <i>Chthamalus Phorcus</i>       | <i>Chthamalus Gibbula</i>      | <i>Chthamalus Phorcus</i>      |
| <i>Pelvetia canaliculata</i> | <i>Lichina</i>                 | <i>Patella-Gibbula</i>        | <i>Lichina</i>              | <i>Pelvetia canaliculata</i> | <i>Pelvetia canaliculata</i> | <i>Chthamalus Patella</i>     | <i>Chthamalus Patella</i>       | <i>Chthamalus Patella</i>      | <i>Chthamalus Patella</i>      |
| <i>Fucus spiralis</i>        | <i>Chthamalus Patella</i>      | <i>Lichina</i>                | <i>Chthamalus Patella</i>   | <i>Fucus spiralis</i>        | <i>Fucus spiralis</i>        | <i>Lithophyllum tortuosum</i> | <i>Lithophyllum tortuosum</i>   | <i>Lithophyllum tortuosum</i>  | <i>Lithophyllum tortuosum</i>  |
| <i>Fucus vesiculosus</i>     |                                | <i>Fucus vesiculosus</i>      | <i>Ellisolandia</i>         | <i>Fucus vesiculosus</i>     | Ephemerals                   | <i>Ellisolandia elongata</i>  | <i>Ellisolandia elongata</i>    | <i>Ellisolandia elongata</i>   | <i>Ellisolandia Gellidium</i>  |
| <i>Fucus serratus</i>        | <i>Ellisolandia Ephemerals</i> | <i>Bifurcaria Himanthalia</i> | <i>Bifurcaria bifurcata</i> | <i>Bifurcaria bifurcata</i>  | <i>Bifurcaria bifurcata</i>  | <i>Bifurcaria Stypocaulon</i> | <i>Bifurcaria Stypocaulon</i>   | <i>Bifurcaria Ellisolandia</i> | <i>Bifurcaria Ellisolandia</i> |
| <i>Himanthalia elongata</i>  | <i>Bifurcaria Lithophyllum</i> | <i>Chondrus crispus</i>       | Ephemerals                  | <i>Gelidium</i>              | <i>Gelidium</i>              | <i>Gelidium-Ellisolandia</i>  | <i>Lithophyllum Stypocaulon</i> | <i>Gelidium Ellisolandia</i>   | <i>Gelidium-Ellisolandia</i>   |
| <i>Laminaria Chondrus</i>    | <i>Sargassum</i>               | <i>Saccorhiza Cystoseira</i>  | <i>Cystoseira</i>           | <i>Saccorhiza Cystoseira</i> | <i>Cystoseira</i>            | <i>Saccorhiza Cystoseira</i>  | <i>Cystoseira</i>               | <i>Saccorhiza Cystoseira</i>   | <i>Cystoseira</i>              |

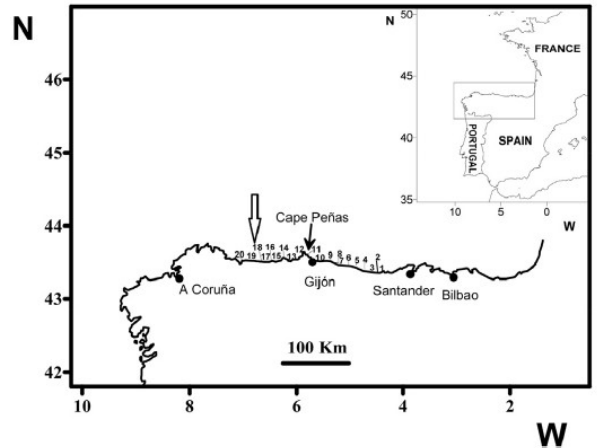


Fig. 1. The North coast of Spain and the situation of the studied shores. (1: Buelna, 2: Llanes, 3: San Antolín, 4: Ribadesella, 5: Caravia 6: La Griega, 7: Rodiles, 8: Playa España, 9: Peñarrubia, 10: Luanco, 11: Bañugues, 12: Verdicio, 13: Sta. María del Mar, 14: Concha de Artedo, 15: Cadavedo, 16: Cueva, 17: Barayo, 18: Cartavio, 19: Punta Arenales, 20: Arnao). The main arrow shows the biogeographic border in 1977 and the second indicates the situation of Cape Peñas as the limit of the influence of the summer upwelling.

Fig. 2. Patterns of zonation at five selected localities Arnao (shore 20), Concha de Artedo (shore 14), Bañugues (shore 11), Caravia (shore 5) and Buelna (shore 1) in 1977 and 2007.

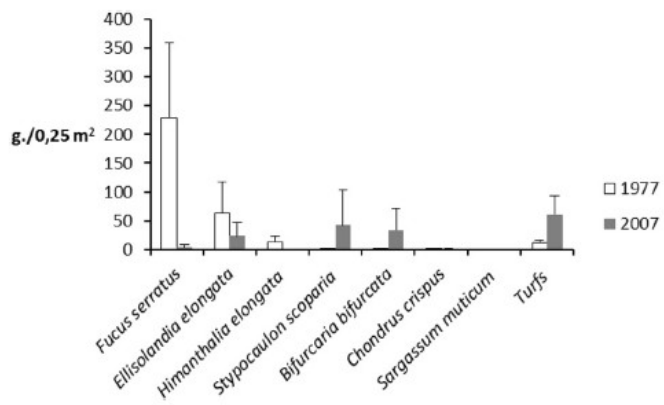


Fig. 7. Mean biomass (g dry weight/2500 cm²) of the main species characterizing the assemblage of the level 3 in 1977 and 2007. Bars indicate S.D. Shores considered were 20, 19 and 18.

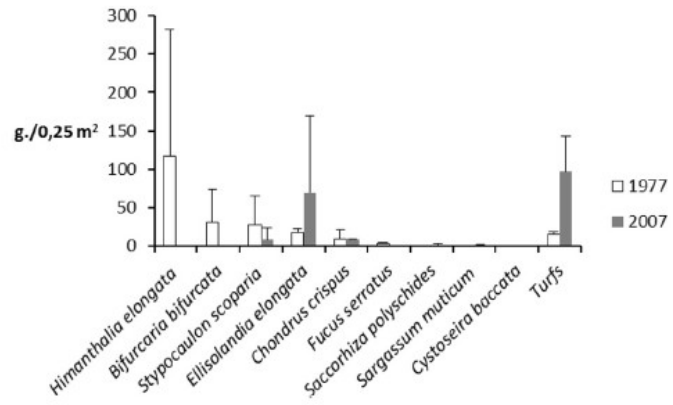


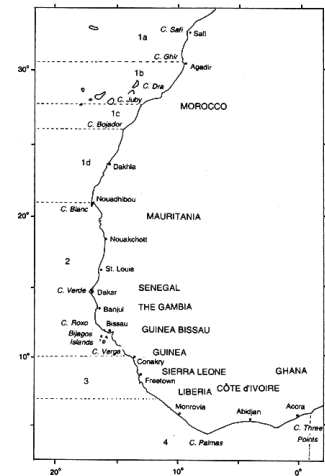
Fig. 6. Mean biomass (g dry weight/2500 cm²) of the main species characterizing the assemblage of the level 2 in 1977 and 2007. Bars indicate S.D. Shores considered were 20, 19 and 18.

Cold-temperate canopy species such as kelps (*L. hyperborea*, *L. ochroleuca* and *S. polyschides*), fucoids (*Fucus serratus*, *F. vesiculosus*, *Himanthalia elongata*) and *Chondrus crispus* have almost disappeared and replaced by warm temperate species such as *Cystoseira baccata*, *C. tamariscifolia*, *Bifurcaria bifurcata* and coralline algae (*Ellisolandia elongata*, *Lithophyllum incrustans* and *Mesophyllum lichenoides*).

northern Spain – many cold temperate species again (*L. hyperborea*, *L. saccharina*)

northwestern Spain – upwelling area – cold water (in August max. 18-19°C)  
e.g., *L. hyperborea*, *L. saccharina*, *Fucus vesiculosus*, *F. spiralis*,  
*F. serratus*, *Ch. crispus*

southern and central Portugal - 20°C s.i., 15°C w.i. - end of cold temperate kelps...  
(*Saccharina latissima* and *L. hyperborea* gametophytes cannot mature in comparatively warm  
winter conditions)  
about 20 tropical species reach northern limit here (e.g. *Valonia utricularis*)



Moroccan coast – southern limit of *F. vesiculosus*, *F. spiralis*  
in upwellings – still Lusitanian species (*S. polyschides*, *B. bifurcata*, *L. ochroleuca*)

many tropical species have northern limit on Cape Blanc...

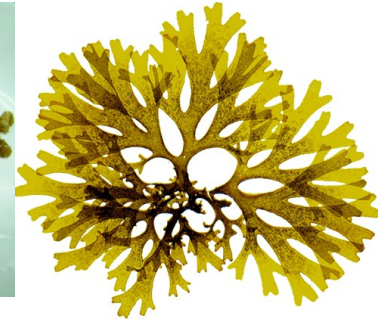
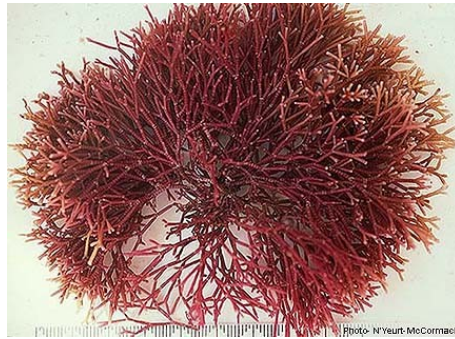
# Canary province



80% of macroalgae here is common with Lusitanian and Mediterranean shores

some characteristic taxa are missing (*B. bifurcata*, *S. polyschides*)  
some are extremely rare (*L. ochroleuca*)

water temperature: 17-23°C, tropical elements are frequent  
- e.g. *Valonia utricularis*, *Caulerpa* spp., *Galaxaura* spp., *Zonaria*, *Padina*, *Dictyota*, *Gelidium* (endemic *G. arbuscula*, *G. canariensis*), *Cystoseira abies-marina*, *Stypocaulon scoparium*



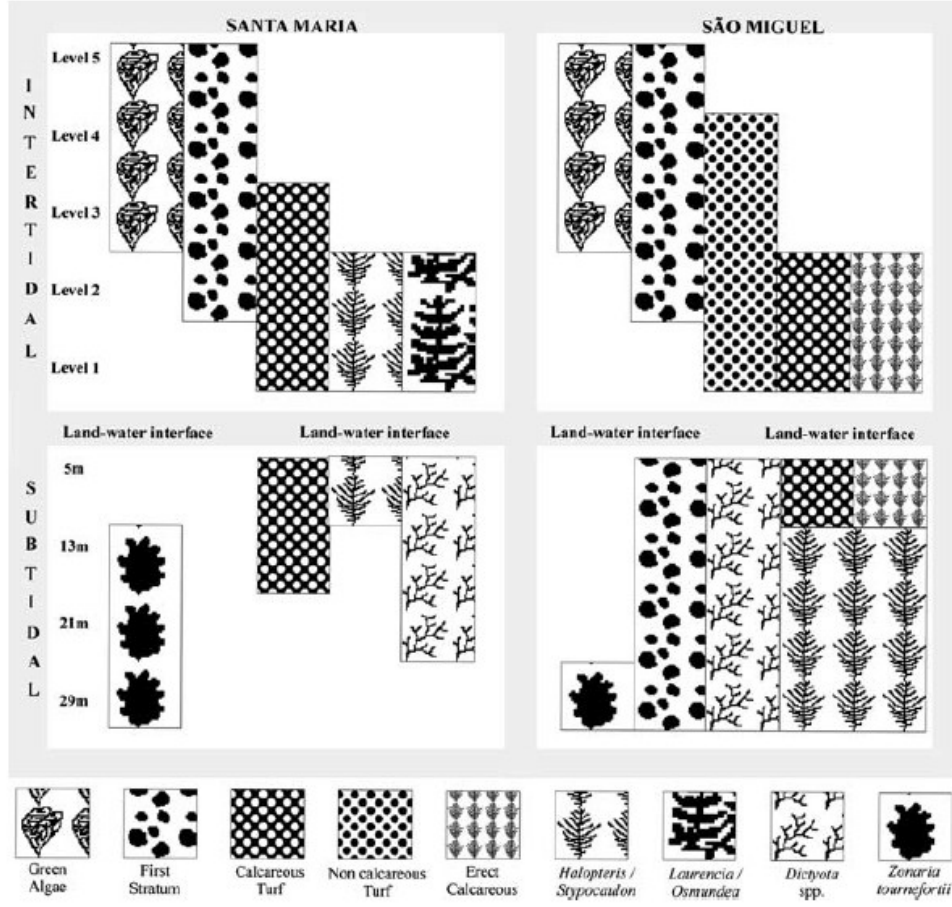
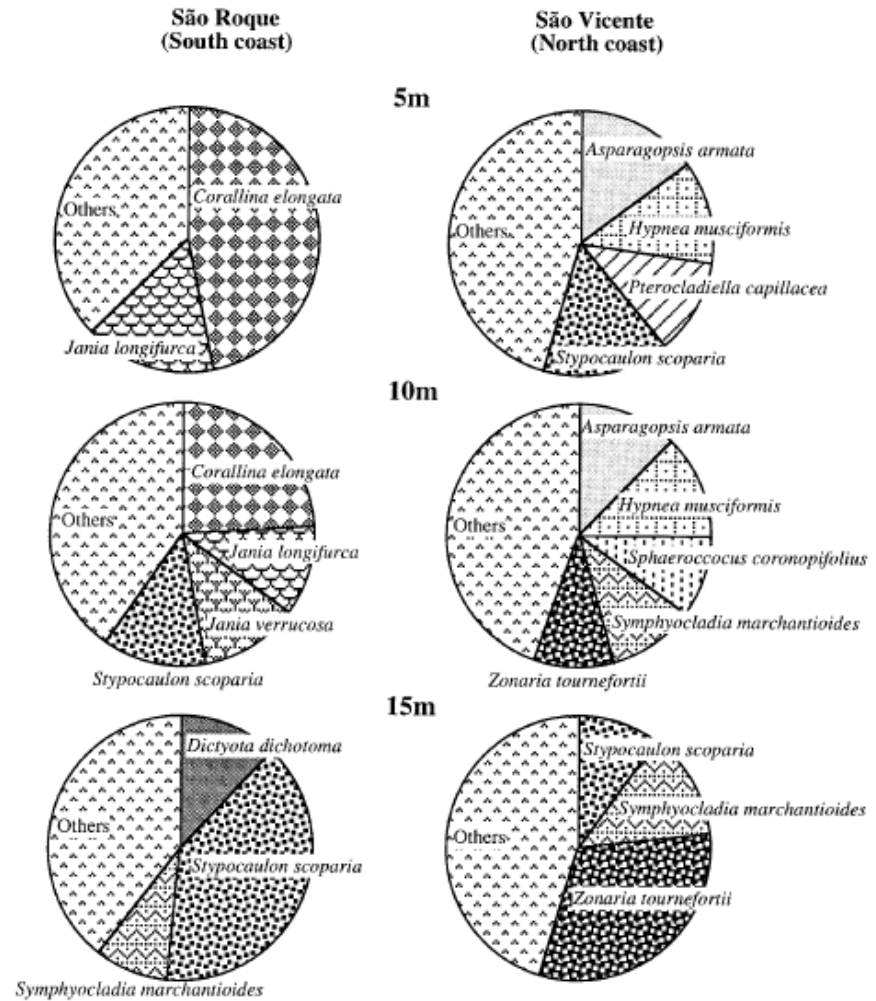
Azores – more Lusitanian and less tropical species;  
almost none American taxa  
BUT: *Asparagopsis armata* !

*C. abies-marina* (Canarias)



Subtidal algal biotopes of Azores Islands are characterised by warm temperate taxa such *Dictyota* spp., *Halopteris filicina*, *Ellisolandia elongata*, invasive *Asparagopsis armata*, *Sphaerococcus coronopifolius* and, most commonly, ***Zonaria tournefortii***.

Fig. 2 Distribution of intertidal and subtidal *taxal* ecological categories of Santa Maria and São Miguel Islands



Neto, 2001, *Helgol. Mar. Res.*  
 Tittley & Neto, 2000, *Hydrobiologia*  
 Wallenstein et al., 2009, *Aquat. Ecol.*