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Distribution of the Epiphytes along the Leaves of *Cymodocea nodosa* in the Canary Islands

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The distribution of the epiphytes along the oldest leaf of shoots of *Cymodocea nodosa* was studied during a two-year cycle, from June 1990 to May 1992, in terms of number of species and cover. The difference in age between the base (the youngest part) and the apex (the oldest part) of the leaves allowed a study of the effect of the age of the host on the epiphyte community. A continuous increase in the number of species was observed along the oldest leaf of each shoot, from basal to apical segments. While the permanent epiphyte species were present everywhere, the seasonal and the occasional species were concentrated on the apical segments of the leaves and the occasional epiphytes showed their highest abundance in winter. The greatest development of the individuals, the high number of species as well as the high densities found towards the apical segments resulted in remarkable differences of cover along the leaves, from 0% at the basal segments to more than 600% reached at the apical segments in some months during the study period. The highest mean percentage cover by epiphytes on the oldest leaf of a shoot was detected in winter while the lowest was obtained in spring-summer. The Rhodophyta showed a quantitative dominance of more than 90% of cover in relation to the rest of the algal divisions, the Ceramiales and the Corallinales being the epiphytes which mainly contributed throughout the year. Results on cover and number of species of epiphytes permitted the distinguishing of three stages of development of the epiphytic community along the leaves: initiation, transition and maturity. Annual variations in the number of species as well as in the cover of the epiphytes along the oldest leaves were directly related to the growth rate and life-time of the leaves of *Cymodocea nodosa*. During the life-time of the leaves there was no succession of species in the epiphytic community but, from basal to apical segments, the epiphyte species were more developed and abundant, and the epiphytic community became more diverse.

Introduction

The ephemeral character of seagrasses leaves, because of the continuous production of new leaves and the loss of the oldest ones, determines the floristic composition of the epiphytic algal community, generally consisting of specific epiphytes that have a higher turn-over rate than the leaves (Heijs 1985 a). According to Heijs (1985 a), the growth of the leaves of most of seagrasses from the base produce a difference in age between the youngest part and the oldest – first exposed – part of a leaf, which results in more heavily epiphytized leaf apices. Van den Ende and Haage (1963) were the first to study the distribution of epiphytes along the leaves of a cold temperate seagrass, the eelgrass *Zostera marina* Linnaeus, in relation to the gradient of age between leaf segments. Later, the distribution of the epiphyte community has been studied along the leaves of several tropical seagrasses, such as *Thalassia hemprichii* (Ehrenberg) Ascherson (Heijs 1985 a), *Cymodocea rotundata* Ehrenberg *et* Hemprich, *Cymodocea serrulata* (R. Br.) Ascherson *et* Magnus, *Halodule uninervis* (Forsskal) Ascherson and *Syringodium isoetifolium* (Ascherson) Dandy (Heijs 1985 b). However, little is known about the distribution of epiphytes along the leaves of *Cymodocea nodosa* (Ucria) Ascherson, a warm temperate seagrass widely distributed in the Mediterranean, along the Atlantic coast of North Africa and in the Canary Islands (den Hartog 1970).

Studies on different aspects of the epiphyte community on leaves of *Cymodocea nodosa* from the Canary Islands have been carried out recently, mainly in an attempt to determine the importance of these epiphytes in a widely distributed marine ecosystem on the Canarian sandy bottomed ecosystems (Reyes *et al.* 1995 a). Reyes and Afonso-Carrillo (1995) described the morphology and phenology of the epiphytic crustose Corallinaceae and their distribution in terms of density, cover and fertility. Reyes and Sansón (1996) described the process of colonization by epiphytes of the leaves and reported 53 species on both leaves and rhizomes of this seagrass. The temporal distribution and reproductive phenology of the epiphytes during a two-year cycle was described by Reyes and Sansón (1997), who distinguished three groups of epiphyte flora on leaves of *Cymodocea nodosa*: the permanent epiphytes (present throughout the year), the seasonal epiphytes (present only at certain periods of year) and the occasional epiphytes

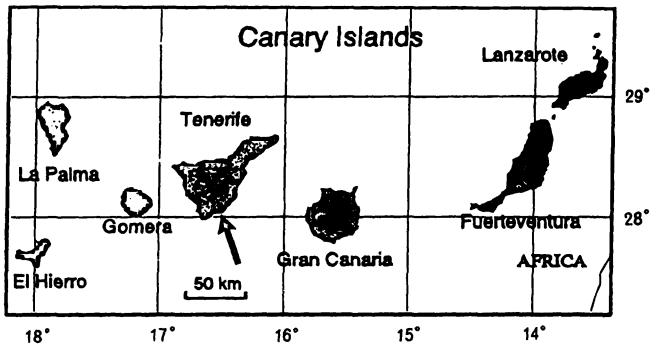

Fig. 1. Geographical location of the sampling site: El Médano (arrow), at South of Tenerife, Canary Islands.

(without apparent temporal pattern of occurrence). In this paper, results on the distribution of epiphytes along the leaves of the main seagrass in the Canary Islands are presented, in terms of number of epiphyte species and their cover during a two-year study.

Materials and Methods

The meadows of *Cymodocea nodosa* studied are situated at El Médano (South of Tenerife, Canary Islands) (Fig. 1). A detailed description of this locality was given by Reyes *et al.* (1995 a).

Monthly, 50 shoots of *Cymodocea nodosa* were randomly harvested from June 1990 to May 1992 at 5–7 m depth by SCUBA diving and preserved in a 4% formaldehyde-seawater solution. To ensure standardization and examination of the mature stages of the epiphytic community, one face of the oldest (outermost) leaf of each of 5 selected shoots was chosen for every sample, following the procedure outlined in Reyes and Sansón (1997). For each leaf, eight segments of the same length were cut from the point of insertion of the blade-sheath to the blade apex (Fig. 2a). A list of algal epiphytes was obtained for each segment and a cover index for each epiphyte species was assigned using a Zeiss binocular macroscope. For crustose species the cover index was estimated as the percentage of the leaf surface occupied by the species (Boudouresque 1971, Nédélec 1979) (Fig. 2b) and for erect filamentous or laminar species it was estimated as the percentage of the leaf surface covered by the horizontal projection of the species (Ballesteros 1992). Branched filamentous species were cut into small fragments that were disposed in geometrical forms and measured on millimetric paper (Fig. 2c). For each of these species, a cover value was obtained from a representative specimen at each segment of the leaf and extrapolated to the number of individuals of that species. The cover index was estimated according to a scale: 1 = 0–2%; 2 = 2–5%; 3 = 5–10%; 4 = 10–20%; 5 = 20–40%; 6 = 40–60%; 7 = 60–80%; and 8 = 80–100%. The mean cover, by segment of leaf, as well as the maximum value of cover, by leaf, were obtained from the 5 leaves studied. Diatoms and sessile or sedentary epiphytic fauna were not considered.

Results

The number of epiphyte species growing along the oldest leaf of a shoot of *Cymodocea nodosa* increased from the basal to the apical segments (Fig. 3), although a stabilization could be observed at the apical segments 7 and 8 in several months of the two years studied. The mean number of species at the basal segment 1 varied from 1 (October 1990) to 8 (February 1992) species, increasing progressively along the leaf to 19 species observed at the apical segment 8 in January 1992 and May 1992 (Fig. 3). The progressive increase in the number of species between successive leaf segments (from S1 to S8) was relatively similar throughout the two years studied, when a regular annual pattern was not detected (Fig. 4). About the 50%

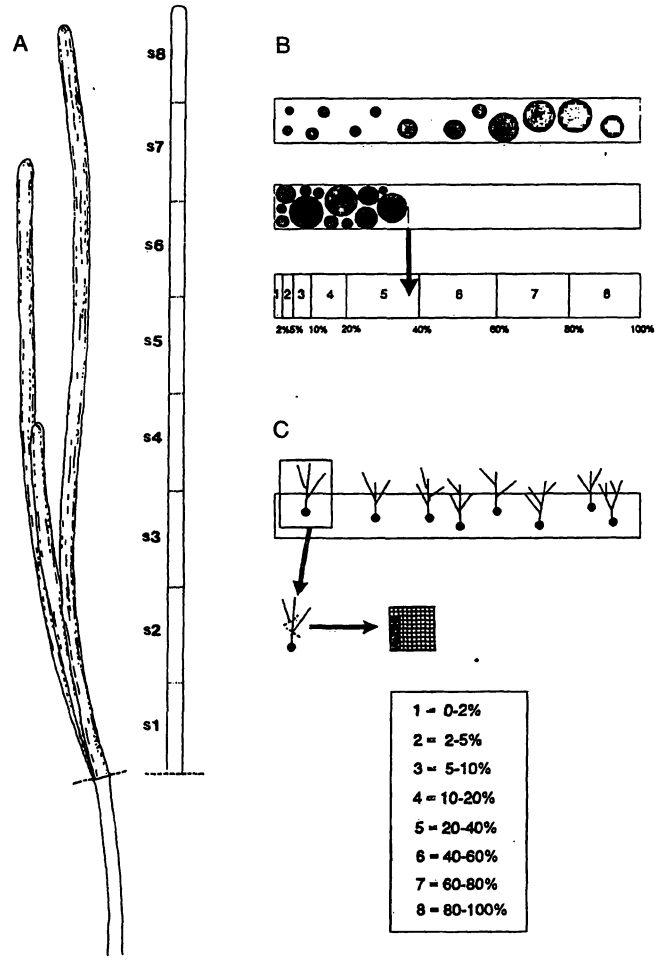

Fig. 2. Scheme of the method employed to estimate the cover by the epiphytes on the oldest leaf of a shoot of *Cymodocea nodosa*. (A) Shoot of *Cymodocea nodosa*. The scheme shows the eight segments, from segment 1 (S1) to segment 8 (S8), cut off starting from the point of insertion of the leaf-sheath (dotted line). (B) Leaf segment showing the method employed to estimate the cover by the crustose epiphyte species. (C) Leaf segment showing the method employed to estimate the cover by the erect epiphyte species.

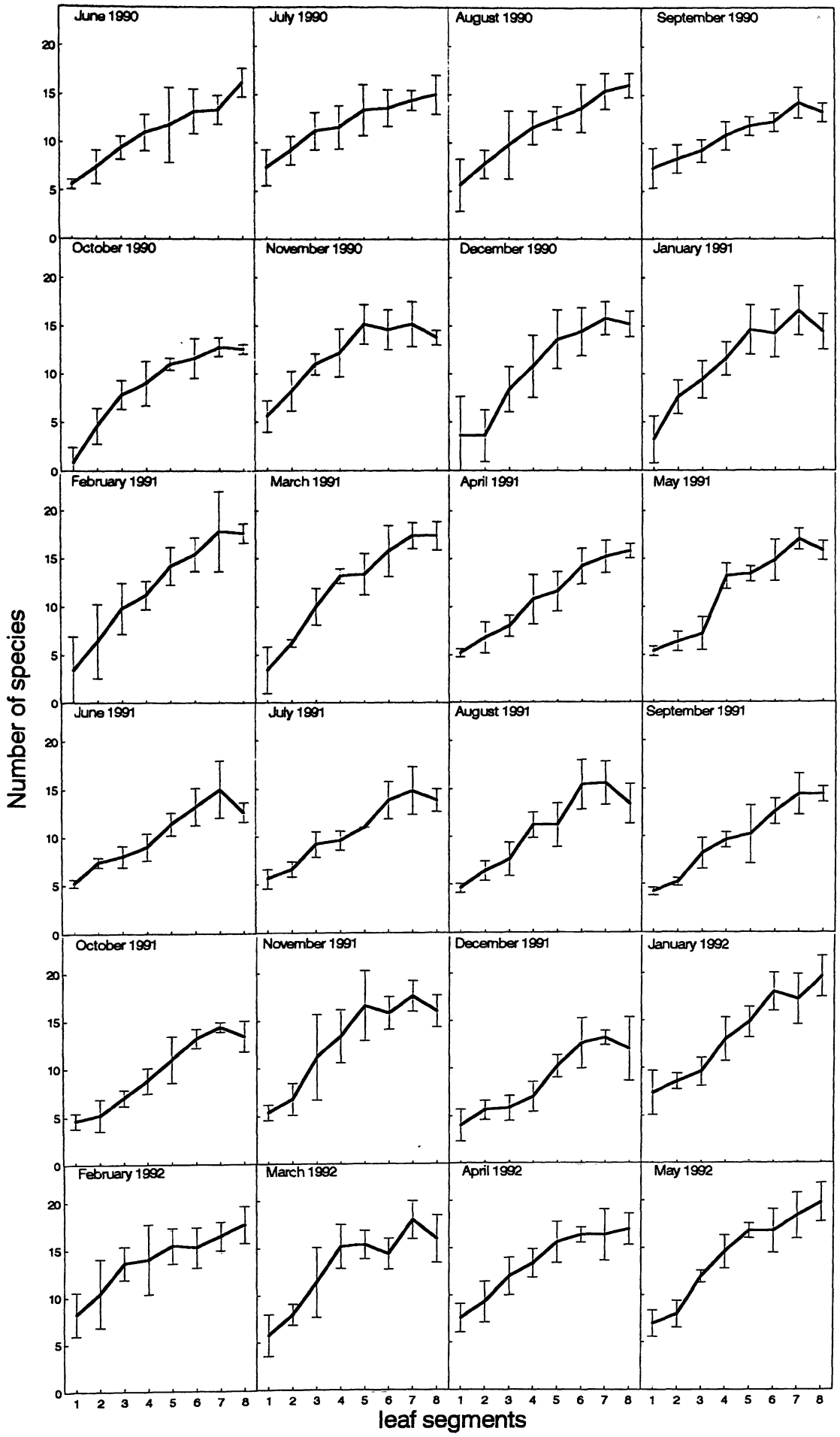

Fig. 3. Variations of the mean number of epiphyte species along the oldest leaves of *Cymodocea nodosa*, from segment 1 to segment 8 (June 1990 to May 1992). Vertical lines indicate standard deviation.

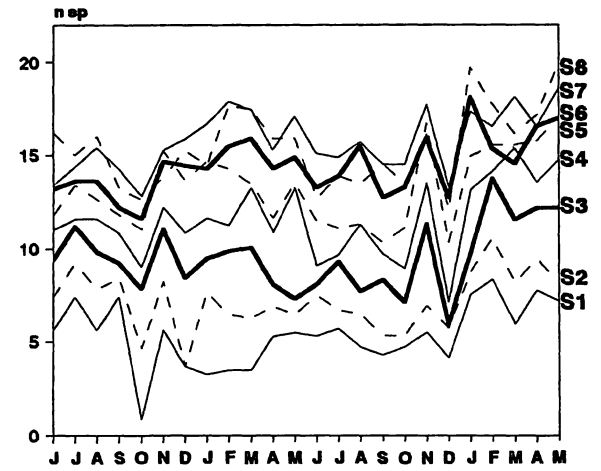

Fig. 4. Variations of the mean number of epiphyte species on leaf segments of *Cymodocea nodosa*, from segment 1 (S1) to segment 8 (S8) (June 1990 to May 1992).

of the species of epiphytes observed on *Cymodocea nodosa* leaves during the study period were recognized sometime at the basal segment 1, while more than the 80% were detected at the apical segments 7 and 8.

Of the 22 permanent epiphyte species observed on *Cymodocea nodosa* leaves, 21 (39.6% of the total number of epiphytes) were present from the basal to the apical segments (Fig. 5), all except *Callithamnion corymbosum* (Smith) Lyngbye that appeared only from the segment 4 to the apices. However, as shown in Figure 5, the seasonal and the occasional species were gradually incorporated towards the apical segments.

The distribution of permanent, seasonal and occasional species on the successive segments of the leaf

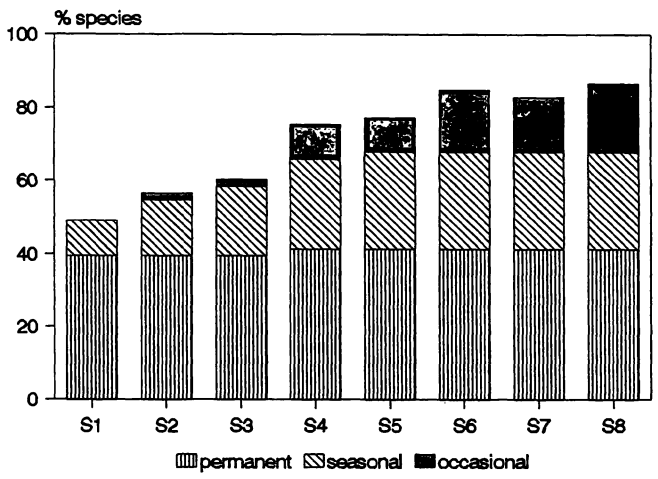

Fig. 5. Total species percentage of the permanent, the seasonal and the occasional epiphyte species on leaf segments of *Cymodocea nodosa*, from segment 1 (S1) to segment 8 (S8). Note: Species percentages are referred to the total number of epiphyte species (53 species) observed on the leaves during the study period.

during the two-year cycle is illustrated in Figure 6, in terms of percentage of the total number of epiphyte species observed throughout the two years studied. These results show the progressive increase of species of the three temporal groups of epiphytes from segments 1 to 8, the incorporation of seasonal species mainly from mid- to apical segments, and the highest abundance of occasional species in winter.

A gradient of development of individuals of permanent and seasonal epiphytes was recognized along the oldest leaf of a shoot throughout the study period, the earliest stages of development of these species, such as propagules or young plants, being more common at the basal segments whereas the mature plants were observed mainly at the apical ones. The greatest development of individuals together with the highest number of species and the highest densities found towards the apical segments resulted in remarkable differences of cover along the leaves. The mean percentage cover by epiphytes at the basal segment 1 varied from 0% (October 1990 and December 1991) to about 50% (November 1990), increasing progressively along the leaf to more than 600%, at the apical segments 7 and 8 in December 1990, November 1991, December 1991 and February 1992 (Fig. 7). As presented in Figure 7, the increase in the percentage cover by epiphytes at the successive leaf segments (from S1 to S8) showed annual variations, with the highest percentages in winter and the lowest ones in spring–summer. The contribution of the apical segments 7 and 8 to the total percentage cover of the leaf was considerably higher than that of the remainder of the segments in all months. The mean annual percentage cover by leaf was of 167%, with the highest value of 307% observed in November 1991 and the lowest of 83% in June 1990 (Fig. 8).

Red algae were quantitatively dominant in relation to the rest of the divisions of the algae, with a contribution of 90.5–99.2% of the cover. This dominance was due to 9 species of the Ceramiales [*Ceramium diaphanum* (Lightfoot) Roth, *Ceramium flaccidum* (Kützing) Ardissone, *Ceramium* sp., *Champia parvula* (C. Agardh) Harvey, *Chondria mairei* G. Feldmann, *Herposiphonia secunda* (C. Agardh) Ambronn, *Laurencia minuta* Vandermeulen, Garbary *et* Guiry, *Polysiphonia sphaerocarpa* Børgesen and *Polysiphonia* sp.] and 4 species of the Corallinales [*Hydrolithon boreale* (Foslie) Chamberlain, *Hydrolithon cruciatum* (Bressan) Chamberlain, *Hydrolithon* sp. and *Pneophyllum fragile* Kützing]. The percentage cover by leaf of the Ceramiales varied from about 50% (June 1990) to 225% (November 1991) and that of the Corallinales ranged between 29% (June 1990) and 81% (November 1990), the contribution of the rest of the algae being very low (Fig. 9).

The distribution of the Ceramiales, the Corallinales and the remainder of the epiphytes on the leaf segments during the two years studied is illustrated in Figure 10, in terms of percentages of cover. These

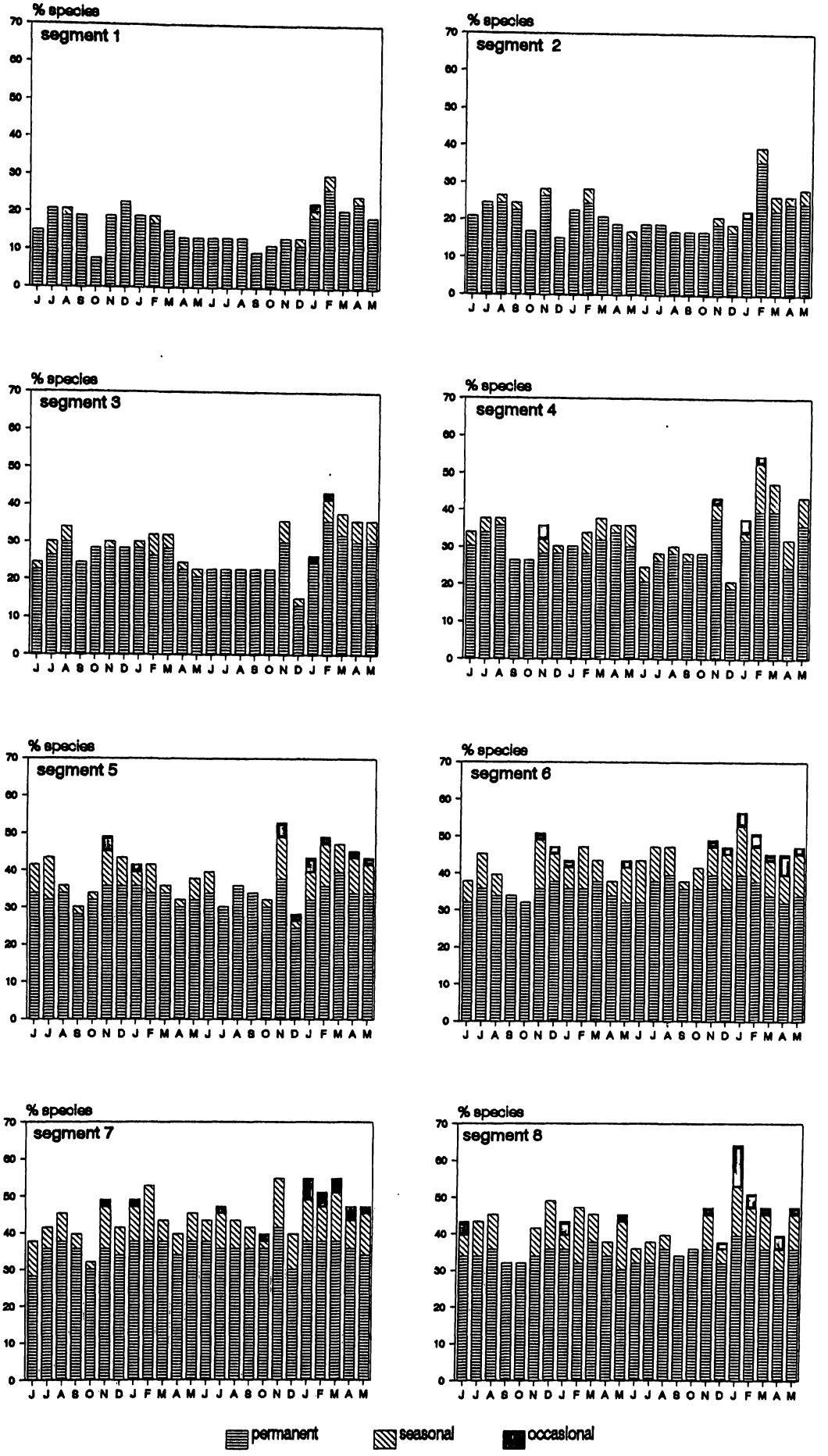

Fig. 6. Species percentage of the permanent, the seasonal and the occasional epiphyte species on leaf segments of *Cymodocea nodosa*, from segment 1 to segment 8 (June 1990 to May 1992). Note: Species percentages are referred to the total number of epiphyte species (53 species) observed on leaves during the study period.

results show the highest contribution in cover by the crustose Corallinales at the basal segments 1 and 2,

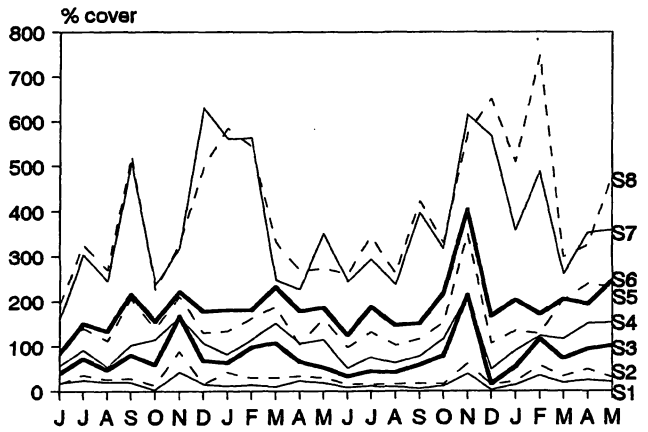

Fig. 7. Variations of the mean percentage cover by epiphytes on the successive leaf segments of *Cymodocea nodosa*, from segment 1 (S1) to segment 8 (S8) (June 1990 to May 1992).

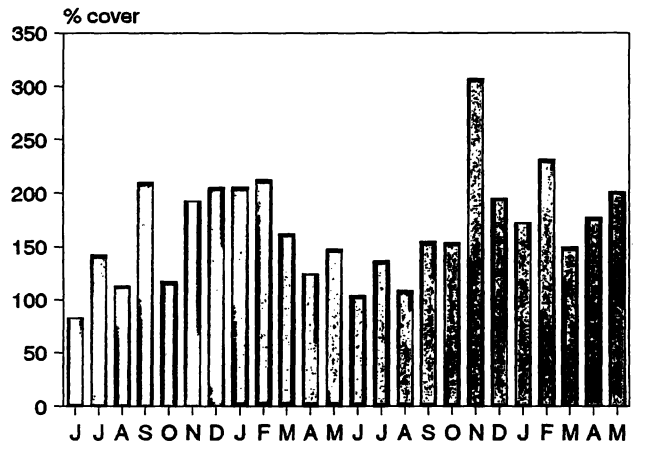

Fig. 8. Variations of the mean percentage cover by epiphytes on the oldest leaf of shoots of *Cymodocea nodosa* (June 1990 to May 1992).

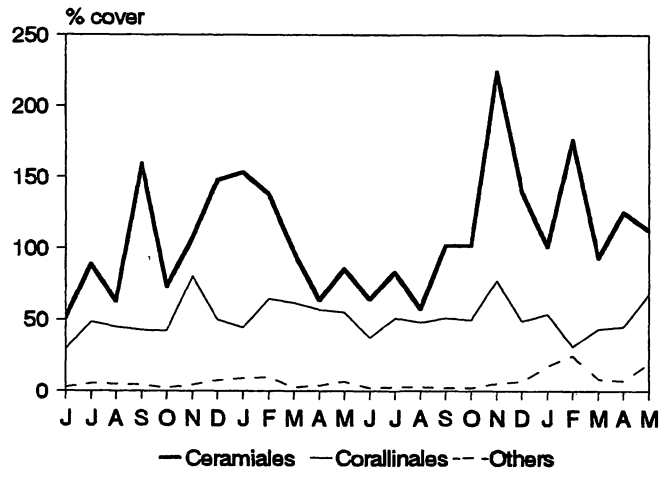

Fig. 9. Variations of the mean percentage cover by the Ceramiales, the Corallinales and the remainder of the epiphytes (others) on the oldest leaf of shoots of *Cymodocea nodosa* (June 1990 to May 1992).

the progressive increase of the percentage cover of the erect Ceramiales at the mid-segments 3 to 6, exceeding gradually that of the Corallinales, and the highest contribution in cover by the Ceramiales at the apical segments 7 and 8, especially in winter (Fig. 10).

Discussion

The increase in the number of epiphyte species observed along the oldest leaves of *Cymodocea nodosa* from the Canary Islands, from the basal to the apical segments, is in line with the tendency reported along the leaves of different seagrasses by several authors [e. g. van der Ben 1971, in *Posidonia oceanica* (Linnaeus) Delile; Jacobs *et al.* 1983, in *Zostera marina* Linnaeus; Heijs 1985 a, in *Thalassia hemprichii* (Ehrenberg) Ascherson; Heijs 1985b, in four Cymodoceoideae species]. However, a slight stabilization in the number of epiphyte species was detected sometimes at the apical segments, that may be partly explained by the natural detachment of the longest erect epiphytes observed because of the friction with the seawater.

Heijs (1985a) showed that colonizing species found on the youngest segments of the leaves of the tropical seagrass *Thalassia hemprichii* were persistent through to the oldest segments, becoming more abundant towards the apices, and the epiphytic community more diverse. This was observed on the leaves of *Cymodocea nodosa* studied by Reyes and Sansón (1997). They described the permanent epiphyte species as those which were present everywhere along the leaves throughout the study period, although during the life-time of the leaves they were joined by the remainder of the epiphytes (seasonal and occasional species).

As Heijs (1985 a) has pointed out, the formation of the new leaves growing primarily from the base between the older leaves on a shoot of most seagrasses means that the leaves apices have always been exposed longer than the basal segments for the settlement of epiphytes. The permanent epiphyte species have been observed growing on the surface of leaves of *Cymodocea nodosa* since the surface has been exposed out of the sheaths of the older leaves that firstly protect it. All permanent epiphyte species on different seagrasses seem to be well adapted to live on their leaves, growing rapidly to reach their characteristic small size and to form their reproductive structures a few days after their settlement and before the leaves fall out (Ducker and Knox 1984, Reyes and Afonso-Carrillo 1995, Reyes and Sansón 1997).

The seasonal species have also being observed growing along the leaves of *Cymodocea nodosa*, from the basal to the apical segments. However, in contrast to the permanent epiphytes, the different seasonal species were only present on the leaves for a certain period of the year. Amongst the seasonal epiphytes

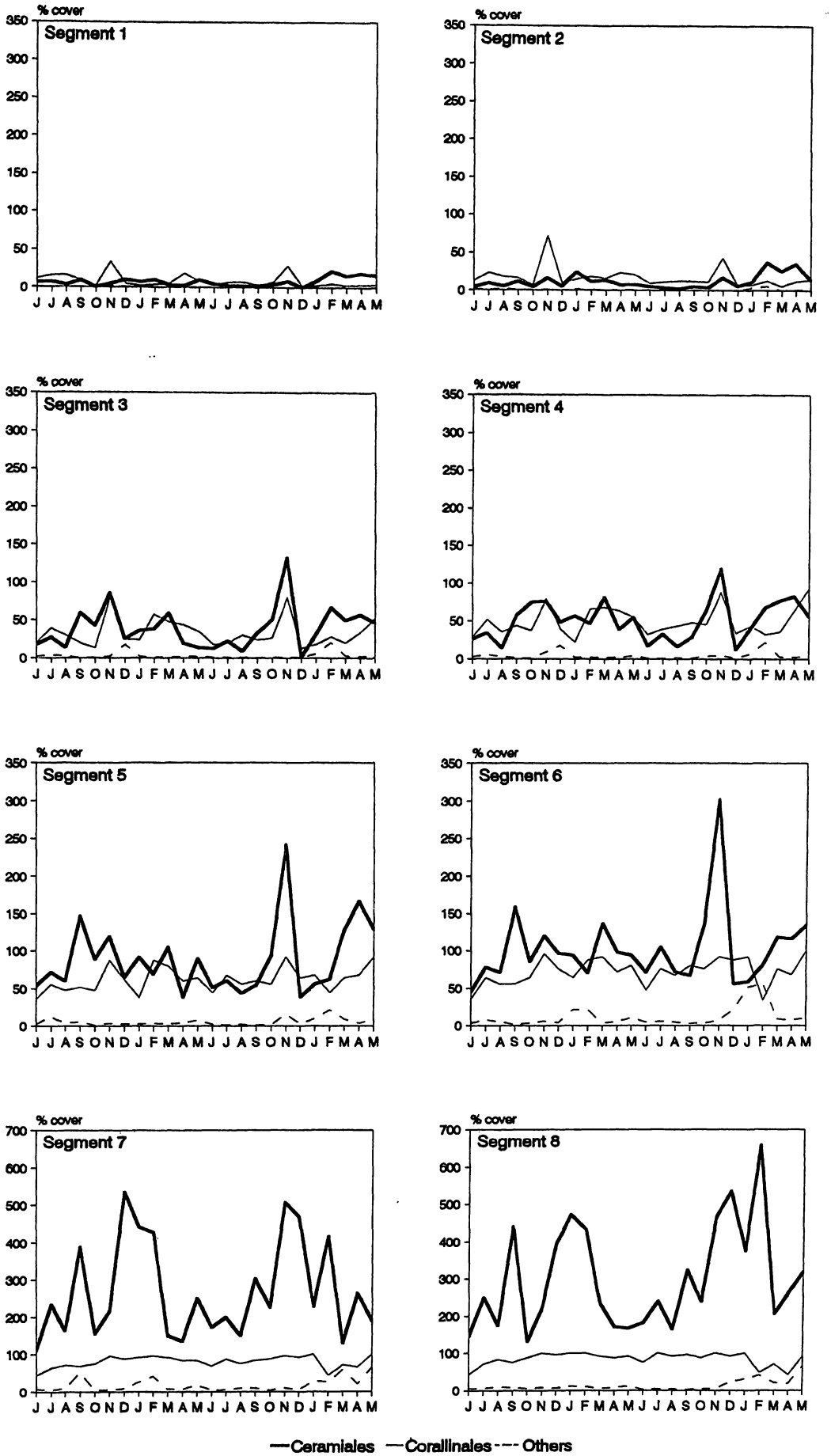

Fig. 10. Variations of the mean percentage cover by the Ceramiales, the Corallinales and the remainder of the epiphytes (others) on leaf segments of *Cymodocea nodosa*, from segment 1 to segment 8 (June 1990 to May 1992).

three different groups of species were recognized on *Cymodocea nodosa* leaves (Reyes and Sansón 1997) depending on the months they were present, each group has been observed to contribute to the apical concentration of seasonal species at the different periods of the year.

The highest abundance of the occasional species at the apical segments in winter can probably be attributed to the lowest growth rate as well as the longest life-time of the leaves of *Cymodocea nodosa* in these months (Reyes *et al.* 1995 b), the time available for the fortuitous establishment of these epiphytes being much longer in winter.

The increase in the epiphyte cover observed along the oldest leaves of *Cymodocea nodosa*, from the basal to the apical segments, is in agreement with the tendency reported along the leaves of different seagrasses (Humm 1964, on *Thalassia testudinum* Banks *ex* König; van der Ben 1971, on *Posidonia oceanica*; Jacobs *et al.* 1983, on *Zostera marina*; and Heijs 1985 a, b, on *Thalassia hemprichii*).

The qualitative dominance of the Rhodophyta observed on the leaves of *Cymodocea nodosa*, where they contribute more than 50% to the epiphytic community, has previously been reported on leaves of other seagrasses (van der Ben 1971, Panayotidis 1980, Ballesteros *et al.* 1984, Heijs 1985 a, 1987). The importance of the Ceramiales has been pointed out by Battiato *et al.* (1982), Buia *et al.* (1985) and Heijs (1985 a, 1987), with *Ceramium*, *Laurencia*, *Polysiphonia*, *Herposiphonia* and *Chondria* being the genera with the highest number of species on leaves of different seagrasses. The crustose Corallinales, especially members of the genera *Hydrolithon* and *Pneophyllum*, have been considered the most ubiquitous of the seagrasses epiphytes (Humm 1964, Chamberlain 1977, 1983, Harlin 1980, Bramwell and Woelkerling 1984, Jones and Woelkerling 1984, Harlin *et al.* 1985), contributing markedly to the epiphytic community. Bramwell and Woelkerling (1984) observed that species of these two crustose genera exhibited significantly high cover percentages and densities on the oldest leaves of shoots of *Amphibolis antarctica* (Labillardière) Sonder *et* Ascherson. Reyes and Afonso-Carrillo (1995) observed the same pattern on the leaves of *Cymodocea nodosa*.

On *Cymodocea nodosa* leaves from the Canary Islands, the Ceramiales contributed more than the Corallinales to the total epiphyte cover, mainly due to the relative larger size, the higher degree of branching and the larger number of specimens of the Ceramiales on the apical segments of leaves. Cover by the Corallinales never exceeded 100% of the leaf surface, while the Ceramiales reached cover percentages, as horizontal projection of the species, higher than 200%, the quantitative contribution of the rest of epiphytes being insignificant.

Variations observed in percentage cover by epiphytes along the oldest leaves of *Cymodocea nodosa* throughout the year could be interpreted according to the growth rate and the life-time of the leaves. The highest percentages of cover were observed in winter, when *Cymodocea nodosa* presented the lowest growth rate of 0.8 mg dw shoot^{-1} and the longest life-time of up to 90 days for leaves, while the lowest ones were observed in summer, when the growth rate was of 1.9 mg dw shoot^{-1} and the life-time of leaves up to 45 days (Reyes *et al.* 1995 b). During the life-time of the leaves studied, neither a succession of epiphyte species nor exclusive species for any segment of that leaves were detected, aspects that were also observed by Heijs (1985 a) on leaves of *Thalassia hemprichii*.

In conclusion, an analysis of the tendency observed in the number of epiphyte species together with that detected in the percentage cover by the Ceramiales, the Corallinales and the rest of the epiphytes along the oldest leaves of *Cymodocea nodosa* permitted the distinguishing of three stages of development of the epiphytic community:

(1) Stage of initiation; recognized at basal segments 1 and 2, where the number of epiphyte species was low (< 10 species) and cover was mainly due to the crustose Corallinales.

(2) Stage of transition; recognized at mid-segments 3 to 6, where there was a gradual increase in the number of species (to 17 species) as well as in the percentage cover, and where the cover by the crustose species was gradually exceeded by that of the erect species.

(3) Stage of maturity; recognized at apical segments 7 and 8, where the number of species was high (17–20 species) and cover was mainly due to the erect Ceramiales.

Thus, as pointed out by Heijs (1985 a) for *Thalassia hemprichii*, along a leaf of *Cymodocea nodosa* it is possible to observe the evolution of an ephemeral epiphytic community directly influenced by the growth-rate and the life-time of the leaf.

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