

Geographical Distribution, Habitat and Reproductive Phenology of the Genus *Kallymenia* (Gigartinales, Rhodophyta) from Catalonia, Spain

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The authors report the geographical distribution, habitat and reproductive phenology of the four species of the genus *Kallymenia* from Catalonia, Spain: *K. feldmannii* Codomier, *K. lacerata* J. Feldmann, *K. patens* (J. Agardh) Parkinson and *K. requienii* J. Agardh. The records confirm that these species are quite common in the western Mediterranean Sea, but are very rare in the eastern Mediterranean region, where only *K. lacerata* and *K. requienii* have been found once. In addition, the examination of different herbaria shows that *K. requienii* is present on the Atlantic coast of the north of Spain. The four species are sciophilous and live preferably in the coralligen or in the maerl, usually at depths of more than 30 m in the northern Mediterranean Sea or below 40 m in the central and southern Mediterranean Sea. All species are highly proterandrous. *Kallymenia feldmannii* and *K. lacerata* are annual and ensure survival in winter by developing incrusting discs from carpospores and tetraspores. *Kallymenia patens* and *K. requienii* are perennial, and ensure survival by maintaining only the basal part of the blade from one year to the other and developing new blades from it in spring. The perennial species, on aging, accumulate floridean starch in the intermediate cortical layers, which takes the form of whitish spots on the blade surface; the older thalli are totally whitish.

Introduction

The genus *Kallymenia* J. Agardh (Kallymeniaceae, Gigartinales, Rhodophyta) is composed of foliaceous species of multiaxial construction. All of them are characterized by having: (a) an essentially filamentous medulla, but with several lightly staining stellate or ganglionic cells remaining, (b) a cortex composed of layers of cells not arranged in distinct anticlinal filaments and diminishing in size towards the outside: the innermost cells are stellate and lie in the plane of flattening, (c) a triphasic life history with isomorphic gametophytes and tetrasporophytes, (d) a non-procarpic female reproductive structure, (e) a carpogonial branch system usually with a lobed supporting cell that gives rise to several sterile lobed (subsidiary) cells, and with one or more 2-celled carpogonial branches arising from the subsidiary cell, and (f) tetrasporangia scattered over the whole thallus, in the outer cortex. The contents of the tetrasporangia are cruciately or irregularly divided. The genus *Kallymenia* is well represented on the northwestern Mediterranean coasts of Spain, where 4 species are reported: *K. feldmannii* Codomier, *K. lacerata* J. Feldmann, *K. patens* (J. Agardh) Parkinson and *K. requienii* J. Agardh. Much has been said about the geographic distribution of these species and their possible presence on the Atlantic coast of Spain and France and in the Canary Islands, but hitherto no light has been shed on this. No data about their phenological behavior is available either.

In this work we report on: a) the geographic distribution of the four species of the genus *Kallymenia*, b) their habitat, and c) the most characteristic features of their phenological behavior.

Materials and Methods

This study was conducted on the basis of the examination of individuals present in the Phycological Herbaria of different Universities of Spain and from floristic surveys of subtidal algal communities made between January 1996 and September 1999 at many points on the coast of the Iberian Peninsula, Balearic Islands and France. Collections were made by SCUBA diving always on sublittoral bottoms at depths of between 10 and 50 m. The species were found only in pristine areas. The sampling was carried out all the year round to allow the observation of the phenology of the different species, but due to their strong seasonality, sampling was intensified in spring and summer. Specimens were deposited in the Phycological Herbarium of the University of Girona, Spain (HGI-A). The other herbaria examined are those of the Universities of Santiago de Compostela (SANT), Barcelona (BCF), Complutense de Madrid (MAF), La Laguna (TFC), Las Palmas de Gran Canaria (BCM), Málaga (MGC) and Valencia (VAB).

The different species of *Kallymenia* were determined to species level and the reproductive status of each one was reported (sterile, male gametophyte, fe-

male gametophyte including carposporophyte and tetrasporophyte).

Results

Kallymenia feldmannii Codomier

Kallymenia feldmannii Codomier 1971: 36, figs 20–24; Codomier 1972: fig. 30 (e–f), fig. 46 (e–r, w–z), fig. 52, fig. 53 bis, fig. 54 (a–c), fig. 55 (a–b), figs 56–62, Vergés 2000: 21–35, figs 2–12.

Geographical distribution: *Kallymenia feldmannii* has been collected only from the western Mediterranean Sea (Table I, Fig. 1). It has been found on the northern coast of Spain (Ballesteros i Sagarra 1980) and in the Balearic Islands (Ballesteros 1992a, 1993). In France it is known from Banyuls de la Marenda (Codomier 1968, 1971, Knoepffler *et al.* 1990), Marseilles (Huvé and Passelaigue 1970), and Corsica (Coppejans 1979, 1982, Verlaque 1987). In Italy it has been collected from the Tuscan archipelagos (Papi *et al.* 1992), from several places in Sicily and the Strait of Messina (Codomier and Giaccone 1972, Giaccone and Rizzi-Longo 1976, Furnari *et al.* 1977, Cormaci *et al.* 1978, 1985, Giaccone and Di Martino 1996, Marino *et al.* 1998) and from the Sicily channel (Giaccone *et al.* 1972). Finally, Codomier and Giaccone (1972) reported this species had been found by J. Feldmann in Algeria. After a bibliographic revision of the J. Feldmann publications, no citations of *K. feldmannii* were found for Algeria, and we think that the report of Codomier and Giaccone (1972) is due to a confusion with *K. lacerata*, a species described on the basis of a specimen from Algeria.

In this work we report on some new localities from the northeast of Spain, from the Balearic Islands and from the Alboran Sea (Table I, Fig. 1). The specimen from the Alboran Sea is in the Herbarium of the University of Málaga (MGC 3336 Phyc) and was misidentified as *K. requienii*.

Habitat: *Kallymenia feldmannii* grows in the coralligen [organic concretion consisting basically of the incrustated red algae *Mesophyllum alternans* (Foslie) Cabioch *et* Mendoza and *Lithophyllum frondosum* (Dufour) Furnari, Cormaci *et* Alongi], and in maerl. It is present usually at depths of more than 30 m; the maximum depth at which it has been found being 93 m, at Cabrera, Balearic Islands (Ballesteros 1993). Nevertheless, some individuals have been found living at shallower depths, i. e. the individuals HGI-A 4035, 4064 and 4065, were found at a depth of 10 m at the entrance to the Cova Blava cave (Cabrera, Balearic Islands), and the individual collected by Codomier and Giaccone (1972) at the Esc. dels Ciclopi (Catania, Italy) was from a depth of only 1 m. Associated species in its habitat include different species of *Peyssonnelia*, other *Kallymenia* spp. (*K. lacerata* and *K. requienii*) and *Contarinia squamariae* (Meneghini) Denizot.

Phenology: This species has been collected mainly in spring and summer. The first individuals appear in March–April, and the last before the autumn storms. Records for later in the year (i. e. in December) seem to be exceptional. The young individuals (from April–May) were usually sterile or male gametophytes, whereas in adult individuals the female structures were increasingly more common (Table II).

Kallymenia lacerata J. Feldmann

Kallymenia lacerata Feldmann 1942: 10, fig. 2; Huvé and Passelaigue 1970: 47, pl. 2 (b); Codomier 1971: 44, figs 25–28; Cinelli and Codomier 1974: fig. 1 (a); Athanasiadis 1987: 46; Vergés 2000: 61–73, figs 13–21.

Geographical distribution: *Kallymenia lacerata* is known mainly from the western Mediterranean Sea but has also been reported from Sithonia, Greece, in the eastern Mediterranean Sea (Athanasiadis 1987) (Table I, Fig. 1). In Spain, references to it are rare and it has been only found on the northern coast (Ballesteros i Sagarra 1983, 1984) and in the Balearic Islands (Ballesteros *et al.* 1997). In France it is known from Banyuls de la Marenda (Codomier 1968, 1971, Cinelli and Codomier 1974, Knoepffler *et al.* 1990), Marseilles (Huvé and Passelaigue 1970), Port-Cros (Belsher *et al.* 1976) and Corsica (Coppejans 1979, 1982, Verlaque 1990, Rodríguez-Prieto *et al.* 1993). In Italy it is known from Naples (Cinelli and Codomier 1974) and from Sicily and the Strait of Messina (Codomier and Giaccone 1972, Giaccone and Rizzi-Longo 1976, Furnari *et al.* 1977, Cormaci *et al.* 1985, Marino *et al.* 1998). Finally, it is also known from Algeria, where J. Feldmann collected the type in 1938 at Borj-el-Bahri (Feldmann 1942). Since then, there have been no further citations from this country.

In this work we give some new records from the northeast of Spain, the Balearic Islands and the Columbrets Islands (Table I, Fig. 1).

Habitat: *Kallymenia lacerata* appears to be common in the coralligen or even in maerl, usually at depths of more than 30 m in the northwestern Mediterranean Sea and at more than 40 m in the central and southern Mediterranean Sea. The greatest depth at which it has been found is 71 m (Ballesteros *et al.* 1997). Nevertheless, it can also develop at shallower depths, in dark places. The shallowest depth at which it has been found is 10 m (HGI-A 4000, entrance to the Cova Blava cave, Cabrera, Balearic Islands). Associated species in its habitat are the same as for *K. feldmannii*.

Phenology: This species has been collected from spring until early autumn and once in December. The first individuals appear in April and, while we found one individual in December, usually the latest appear before the autumn storms. The young individuals

Table I. Geographical distribution of the different species of *Kallymenia* studied grouped by localities. Data, number of individuals and reproductive status of each one (in square brackets) and collector and/or bibliographical reference are indicated. The number indicated before each locality corresponds to the geographical distribution shown in Figure 1.

| Localities | <i>Kallymenia feldmannii</i> | <i>Kallymenia lacerata</i> | <i>Kallymenia patens</i> | <i>Kallymenia requienii</i> |
|--|---|---|---|--|
| Cap de Creus (E) | | | 1 20-6-1996 [1 s], CRP | 1 14-7-1998 [2 s], CRP and AV |
| L'Estartit and Medes I. (E) | 1 18-6-1998 [2 s], CRP and AV 10-7-1998 [1 s], CRP and AV 10-8-1998 [3 s], CRP and AV | 1 26-6-1998 [1 s], CRP and AV | 2 10-7-1998 [1 s], CRP and AV | 2 Ballesteros i Sagarra and Romero Martinengo 1982 Ballesteros <i>et al.</i> 1984 14-8-1989, Verlaque 1990 June 1998 [2 s, 2 f, 2 t], CRP and AV 10-7-1998 [3 s], CRP and AV |
| Begur (E) | | | 3 3-8-1999 [1 s], CRP | 3 5-6-1998 [1 s], CRP and AV 3-8-1998 [1 s], CRP 24-5-1999 [1 f], L Lavelli, BCF 12306 |
| Els Ullastres, Llafranc (E) | | 2 25-7-1999 [1 m], CRP | | |
| Formigues I., Món del Padró, La Llosa and Món de Fora, Palamós (E) | 2 8-6-1997 [1 s], May 1998 [6 s], 28-6-1998 [2 s, 1 f], 30-8-1998 [4 s, 4 f, 2 ft], CRP 6-12-1998, [1 mt], CRP April 1999 [4 s, 1 m], CRP 23-5-1999 [1 s], CRP | 3 6-12-1998, [1 f], CRP April 1999 [2 s], CRP 24-5-1999 [1 s], CRP 1-8-1999 [2 s, 1 mf], CRP 30-8-1998 [6 s], CRP | 4 17-5-1998 [1 s], CRP June 1999 [5 s, 1 t], CRP | 4 May 1997 [2 s, 1 t], CRP 8-6-1997 [2 s], CRP May 1998 [2 s], CRP June 1998 [6 s], CRP 6-12-1998 [1 s, 1 t], CRP 28-3-1999 [1 s], CRP April 1999 [6 s, 1 m, 1 t], CRP May 1999 [2 s], CRP |
| Tossa de Mar (E) | 3 Ballesteros i Sagarra 1980 | 4 [1 s], Ballesteros i Sagarra 1983 4-10-1983, Ballesteros i Sagarra 1984 | 5 30-7-1983 [1 s], Ballesteros i Sagarra 1984 | 5 Ballesteros i Sagarra 1983 17-10-1982, 14-7-1983, September 1983 [2], October 1983 [3], Ballesteros i Sagarra 1984 |
| Mallorca, Balearic I. (E) | 4 18-5-1991 [2 s], Ballesteros 1992a | | | 6 23-6-1987, Ballesteros 1992b |
| Minorca, Balearic I. (E) | 5 28-7-1994 [1 s], EB and NS | 5 22-7-1994 [1 s], Ballesteros <i>et al.</i> 1997 28-7-1994 [1 s], EB and NS | 6 28-11-1887, 7-7-1888, Rodríguez y Femenías 1889 [7], Rodríguez y Femenías 1889 18-8-1887, 5-6-1888, 8-11-1890, Seoane-Camba 1969 3-9-1887, Codomier 1971 Codomier 1972 28-12-1994 [1 s], EB and NS | 7 3-9-1887, 21-6-1888, 22-9-1889, 18-6-1888, 20-7-1888, 5-10-1888, 11-10-1895, 14-10-1895, Seoane-Camba 1969 11-10-1895 [1 f], Codomier 1971 27-6-1986, 28-6-1986, 2-7-1986, Ballesteros 1994 28-7-1994 [3 s], EB and NS 26-7-1996 [3 s], CRP 25-5-1997 [2 s], CRP 25-6-1997 [6 s, 1 f], CRP 26-7-1996 [1 s], CRP |
| Cabrera, Balearic I. (E) | 6 Ballesteros 1993 May 1996 [5 s], CRP 11-6-1996 [1 t], NS | 6 May 1996 [12 s], CRP | | 8 18-10-1986, Ballesteros 1992b [2], Ballesteros 1993 12-5-1985, June 1996 [2], July 1986, Ballesteros 1994 May 1996 [8 s, 1 f], CRP |

Table I. Continued.

| Localities | <i>Kallymenia feldmannii</i> | <i>Kallymenia lacerata</i> | <i>Kallymenia patens</i> | <i>Kallymenia requienii</i> | | |
|--|------------------------------|---|---|---|--|--|
| Columbrets I. (E) | 7 | June 1996 [5 s], EB | 7-7-1985 [1], Boisset López 1987 23-6-1996 [3 s], EB 18-9-1998 [1 s], F Boisset, VAB-A1975 | 9 | 7-7-1985, Boisset López 1987 7-7-1985, Boisset and García-Carrascosa 1987 June 1996 [5 s], EB | |
| Múrcia (E) | | | 8 | 10-8-1987 [1 s], Soto Moreno 1992 | 10 | Xàbia, Alicante (E) 15-7-1984, Boisset López 1987 |
| Alboran Sea (E) | 7 | 30-6-1995 [1 s], EB, MGC 3336 Phyc | 9 | October 1971, Giaccone 1972 | 11 | October 1971, Giaccone 1972 30-6-1995 [1 f], EB, MGC 3358 Phyc |
| Banyuls and Cerbère de la Marendà (F) | 8 | 13-9-1965 [1 f, 1t], Codomier 1968 [1 m], Codomier 1968 Codomier 1971 Knoepffler <i>et al.</i> 1990 | 8 | 14-9-1966 [1 s], Codomier 1968 3-9-1965 [1 t], September 1970, Codomier 1971 10-10-1973, [1 f], Cinelli and Codomier 1974 Knoepffler <i>et al.</i> 1990 | 10 | Codomier 1968 1-1-1969, Boudouresque 1970 17-7-1992 [1 s], CRP July 1995 [1 s], CRP |
| Port-Cros (F) | | 9 | Belsher <i>et al.</i> 1976 | 13 | 21-6-1969, Boudouresque 1970 Belsher <i>et al.</i> 1976 February, Coppejans 1976-1977 June 1976, Augier and Boudouresque 1978 | |
| Provence (F) | | | 11 | J. G. Agardh 1851-1863 | 14 | [1 f], J. G. Agardh 1842 Mouret 1911 June 1952, August 1952, April 1953, Huvé and Passelaigne 1970 Codomier 1971 [1 f, 1 t], Codomier 1971 |
| Marseille region (F) | 9 | June 1968 [1 s], Huvé and Passelaigne 1970 | 10 | August 1967 [1 t], Huvé and Passelaigne 1970 | 15 | J. Feldmann 1942 |
| Villefranche sur Mer (F) | | | 11 | August 1977, Coppejans 1979 Coppejans 1982 Verlaque 1990 August 1992, Rodríguez- Prieto <i>et al.</i> 1993 | 16 | Molinier 1960 Coppejans 1979 Verlaque 1987 August 1992 [1 s], CRP |
| Corsica (F) | 10 | July 1977, August 1977 [2], September 1977, Coppejans 1979 Coppejans 1982 Verlaque 1987 | 13 | May-June 1976, Verlaque <i>et al.</i> 1977 July 1977, Coppejans 1979 Coppejans 1982 | 17 | Boudouresque 1980 16-5-1985, Frick <i>et al.</i> 1986 |
| Lavezzi I. (F) | | | 11 | Papi <i>et al.</i> 1992 | 18 | Papi <i>et al.</i> 1992 |
| Montecristo I., Tuscan archipelago (I) | | | | | | |

| | | | | | | | | |
|--|----|---|----|---|----|---|----|---|
| Naples region (I) | 12 | 29-9-1972 [1 f], Cinelli and Codomier 1974 | 14 | July 1970 [1 s], Feoli and Bressan 1972 | 19 | [1 t], Cinelli and Codomier 1974 | | |
| Sardinia (I) | | | 15 | Brambati <i>et al.</i> 1980 | 20 | Brambati <i>et al.</i> 1980 | | |
| Sicily and Strait of Messina (I) | 12 | August 1968, May 1969, Codomier and Giaccone 1972 Giaccone and Rizzi-Longo 1976 Furnari <i>et al.</i> 1977 [2], Cormaci <i>et al.</i> 1978 21-3-1980, Cormaci <i>et al.</i> 1985 Giaccone and Di Martino 1996 May 1996, Marino <i>et al.</i> 1998 | 13 | August 1970, Codomier and Giaccone 1972 Giaccone and Rizzi-Longo 1976 Furnari <i>et al.</i> 1977 Cormaci <i>et al.</i> 1985 May 1996, October 1996, Marino <i>et al.</i> 1998 | 16 | Mazza 1904 January 1966, July 1968, Codomier and Giaccone 1972 August 1970, April 1971, Giaccone 1972 Furnari and Scammacca 1973 Giaccone and Rizzi-Longo 1976 Furnari <i>et al.</i> 1977 Cormaci and Furnari 1979 Battiato <i>et al.</i> 1980 Spring and Autumn 1983, Giaccone <i>et al.</i> 1985 October 1996, Marino <i>et al.</i> 1998 | 21 | Lagenbach 1873 Ardissone 1883 [3], Mazza 1904 Spinelli 1905 Codomier 1969 May, August 1970, Codomier and Giaccone 1972 August 1970, April 1971, Giaccone 1972 April-May [2 m, 2 f], Furnari and Scammacca 1973 Furnari <i>et al.</i> 1977 Cormaci and Furnari 1979 Battiato <i>et al.</i> 1980 23-1-1980, 28-2-1980, 28-3-1980, 13-9-1982, Cormaci <i>et al.</i> 1985 Spring and Autumn 1983, Giaccone <i>et al.</i> 1985 |
| Sicily channel (I) | 13 | 24-9-1971, Giaccone <i>et al.</i> 1972 | 17 | September 1971 [2], Giaccone <i>et al.</i> 1972 Giaccone <i>et al.</i> 1973 May 1972, Giaccone and Sortino 1974 [1 f], Cinelli <i>et al.</i> 1976 | 22 | September, Codomier and Giaccone 1972 September 1971 [2], Giaccone <i>et al.</i> 1972 Giaccone <i>et al.</i> 1973 May 1972, June 1972, Giaccone and Sortino 1974 [1 f], Cinelli <i>et al.</i> 1976 | | |
| Tabarka (TUN) | | | | | 23 | 24-4-1969, Boudouresque 1970 | | |
| Bordj-El-Bahri (ALG) | 14 | 20-10-1938 [1 f], J. Feldmann 1942 | | | 24 | Alger (ALG) [1 f], Montagne 1846 Debray 1897 17-5-1939 [1 f], J. Feldmann 1942 | | |
| Sithonia (Gr) | 15 | Athanasiadis 1987 | | | | | | |
| Akkuyu, Messin (TUR) | | | | | 25 | Cirik 1991 | | |
| Comillas, Santander (E) | | | | | 26 | 5-10-1994, BCF 10568 | | |
| Xové, Lugo (E) | | | | | 27 | 8-9-1994 [1 f, 1 t], J. Cremades and I. Bárbara, SANT 6161 18-8-93 [1 f], J. Cremades, I. Bárbara and A. Granja, SANT 6164 8-9-1994 [1 s], J. Cremades, I. Bárbara, A. Granja and A. J. Veiga, SANT 6164 8-9-1994 [1 f], J. Cremades, I. Bárbara, A. Granja and A. J. Veiga, SANT 6190 | | |
| Malpica and Punta Aruela, A Coruña (E) | | | | | 28 | 27-3-1994 [1 f], J. Cremades, I. Bárbara, A. Granja and A. J. Veiga, SANT 6464 27-3-1994 [1 f], J. Cremades, I. Bárbara, A. Granja and A. J. Veiga, SANT 6465 27-3-1994 [1 f], J. Cremades, I. Bárbara, A. Granja and A. J. Veiga, SANT 6466 28-2-1998 [1 s], J. Cremades, SANT 9674 | | |
| Cangas, Pontevedra (E) | | | | | 29 | 15-4-97 [3 f, 1 t], I. Bárbara, A. Granja and A. J. Veiga, SANT 5602 | | |

Abbreviations: f = female gametophyte; ft = female gametophyte and tetrasporophyte at the same time; m = male gametophyte; mf = male and female gametophyte at the same time; mt = male gametophyte and tetrasporophyte at the same time; s = sterile; t = tetrasporophyte; AV = A. Vergés; CRP = C. Rodríguez-Prieto; EB = E. Ballesteros; NS = N. Sant.

(from April to June) were usually sterile or male gametophytes and adults frequently bear female reproductive structures (Table II).

Kallymenia patens (J. G. Agardh) Parkinson

Halymenia patens J. G. Agardh 1851–1863: 203; Kützing 1866: pl. 94.

Halarachnion patens (J. G. Agardh) De Toni 1905: 1654; Preda 1908–1909: 65.

Kallymenia patens (J. G. Agardh) Codomier 1971: 27, figs 15–17; Huvé and Passelaigue 1970: 47, pl. 1b.

Kallymenia patens (J. G. Agardh) Parkinson 1980: 16; Vergés 2000: 95–106, figs 22–28.

Geographical distribution: *Kallymenia patens* is known only from the western Mediterranean Sea (Table I, Fig. 2). In Spain it is widespread: it has been collected on the northeastern coast (Ballesteros i Sagarra 1984), in the Balearic Islands, where it was found several times in Minorca at the end of the 19th century by J. J. Rodríguez y Femenías (Rodríguez y Femenías 1889, Seoane-Camba 1969, Codomier 1971, 1972), in the Columbrets Islands (Boisset López 1987), in Murcia, (Soto Moreno 1992) and in the Alboran Sea (Giaccone 1972). In France it has been found at Banyuls

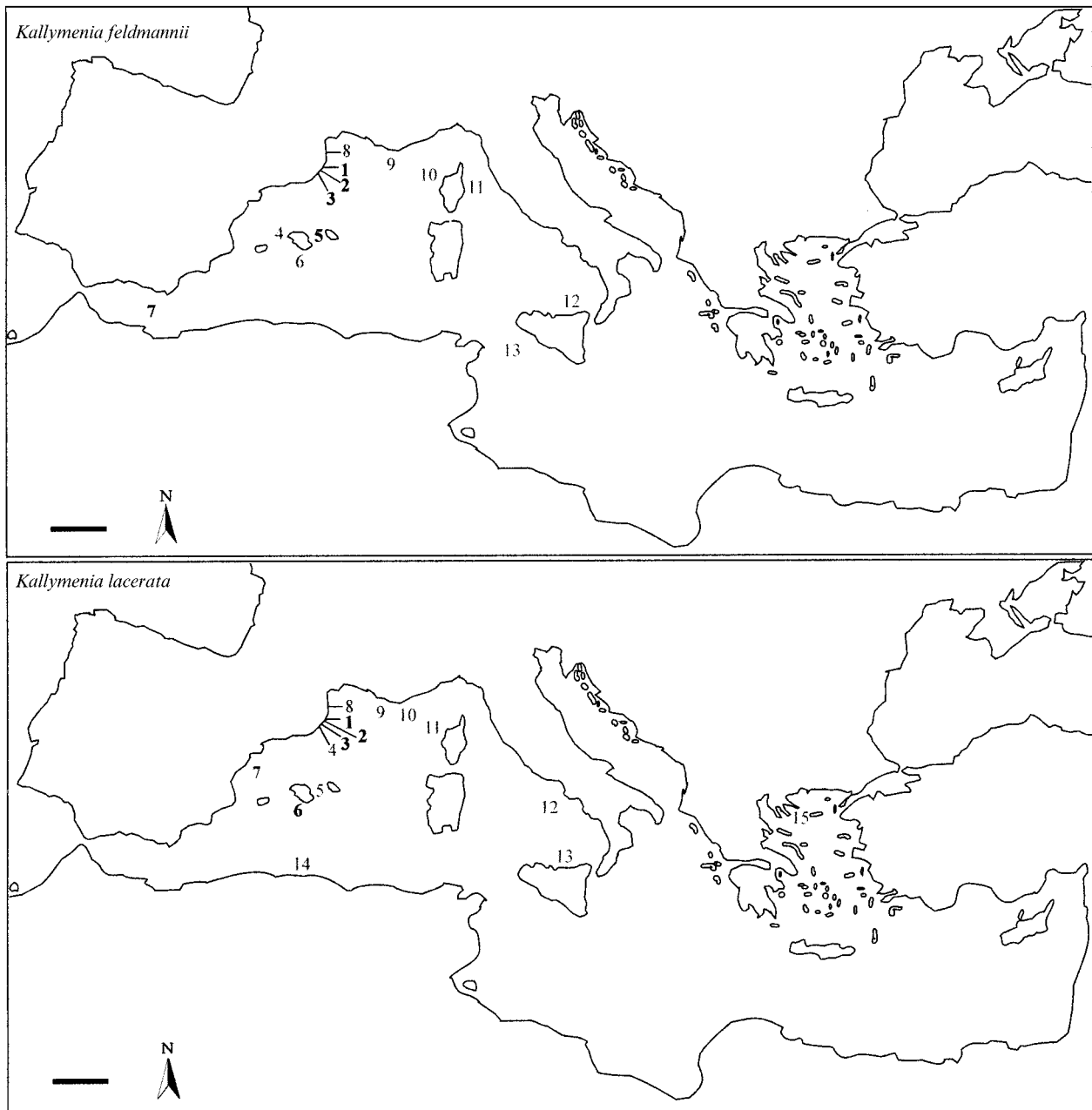


Fig. 1. Geographical distribution of *Kallymenia feldmannii* and *K. lacerata* grouped by localities. Numbers correspond to Table I. New localities are in bold. Bar = 200 km.

de la Marena (Codomier 1968, Boudouresque 1970), in Provence (J. G. Agardh 1851–1863), at Marseilles (Huvé and Passelague 1970) and in Corsica (Verlaque *et al.* 1977, Coppejans 1979, 1982). In Italy it has been found at Naples (Feoli and Bressan 1972), in Sardinia (Brambati *et al.* 1980), in Sicily and in the Strait of Messina (Mazza 1904, Codomier and Giaccone 1972, Giaccone 1972, Furnari and Scamaccia 1973, Giaccone and Rizzi-Longo 1976, Furnari *et al.* 1977, Cormaci and Furnari 1979, Battiato *et al.* 1980, Giaccone *et al.* 1985, Marino *et al.* 1998). Finally, it is also known from the Strait of Sicily (Giaccone *et al.* 1972, 1973, Giaccone and Sortino 1974, Cinelli *et al.* 1976).

In this work we report on some new records from the northeast coast of Spain, the Minorca Channel and the Columbrets Islands (Table I, Fig. 2).

Habitat: Like the other species of the genus, *Kallymenia patens* lives in the coralligen. It is common in communities dominated by *Rhodymenia ardissoni* J. Feldmann, with which it can be easily confused. It has also been found in other habitats, as on the rhi-

zomes of *Posidonia oceanica* (Linné) Delile (Codomier 1971).

Phenology: This species is present all year round, but has been always found sterile, except in June when it bore tetrasporangia. The female gametophyte was found on one occasion in the Island of Linosa, Italy (Cinelli *et al.* 1976) (Table II).

Kallymenia requienii J. G. Agardh

Rhodomenia requienii J. G. Agardh 1841: 12.

Kallymenia requienii J. G. Agardh 1842: 99; J. G. Agardh 1851–1863: 289; J. G. Agardh 1876: 220; Codomier 1971: 14, figs 8–14; Codomier 1972: fig. 30 (a–d), fig. 49 (b–d), figs 50–51, fig. 53, fig. 54 (e–f), fig. 55 (c–f); Ribera Siguán 1983: pl. 20 (a–b); Vergés 2000: 123–140; figs 29–38.

Euhymenia requienii Kützing 1843: 400; Kützing 1849: 743; Kützing 1867: pl. 81.

Kallymenia demissa J. G. Agardh 1892: 67; Preda 1908–1909: 342 [as *Callymenia demissa*].

Table II. Annual reproductive behavior of the Catalan species of the genus *Kallymenia*, according to bibliographic data and our own observations.

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | UD |
|--|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|
| <i>Kallymenia feldmannii</i> | | | | | | | | | | | | | |
| Sterile | | | | 4 | 14 | 7 | 2 | 7 | | | | | |
| Male gametophyte | | | | 1 | | | | | | | | | 1 |
| Female gametophyte | | | | | | 1 | | 4 | 1 | | | | |
| Tetrasporophyte | | | | | | 1 | | | 1 | | | | |
| Male gametophyte and tetrasporophyte | | | | | | | | | | | | 1 | |
| Female gametophyte and tetrasporophyte | | | | | | | | 2 | | | | | |
| Phenological data unknown | | | 1 | | 2 | | 1 | 3 | 2 | | | | 12 |
| <i>Kallymenia lacerata</i> | | | | | | | | | | | | | |
| Sterile | | | | 2 | 13 | 6 | 2 | 8 | 1 | | | | 1 |
| Male gametophyte | | | | | | | 1 | | | | | | |
| Female gametophyte | | | | | | | | | 1 | 2 | | 1 | |
| Male and female gametophyte | | | | | | | | 2 | | | | | |
| Tetrasporophyte | | | | | | | | 1 | 1 | | | | |
| Phenological data unknown | | | | | 1 | | | 2 | 1 | 2 | | | 9 |
| <i>Kallymenia patens</i> | | | | | | | | | | | | | |
| Sterile | | | | | 1 | 9 | 6 | 2 | 1 | | | 1 | |
| Female gametophyte | | | | | | | | | | | | | 1 |
| Tetrasporophyte | | | | | | 1 | | | | | | | |
| Phenological data unknown | 2 | | | 1 | 1 | 1 | 4 | 3 | 3 | 2 | 2 | | 21 |
| <i>Kallymenia requienii</i> | | | | | | | | | | | | | |
| Sterile | | | 1 | 1 | 6 | 16 | 22 | 12 | 2 | 2 | | 1 | 2 |
| Male gametophyte | | | | | 2 | 1 | | | | | | | |
| Female gametophyte | | | 3 | 4 | 4 | 3 | | 2 | 2 | 1 | | | 3 |
| Tetrasporophyte | | | | 2 | 1 | 2 | | | 1 | | | 1 | 1 |
| Female gametophyte and tetrasporophyte | | | | | | | | | | | | | 1 |
| Phenological data unknown | 1 | 2 | 1 | 3 | 5 | 9 | 7 | 4 | 9 | 10 | | | 32 |

UD: undated specimens

Callymenia tenuifolia (Rodríguez Femenías manuscript) J. Feldmann 1935: 368; J. Feldmann 1939: 327, figs 24–25.

Kallymenia rigida J. Feldmann 1942: 13, fig. 4.

Geographical distribution: *Kallymenia requienii* has been found on many occasions in the western Mediterranean Sea, where it is quite common, and once in the eastern Mediterranean Sea, in the Bay of Akkuyu, Mersin, Turkey (Cirik 1991) (Table I, Fig. 2). In Spain it is known from the northeastern coast (Ballesteros i Sagarra and Romero Martinengo 1982, Ballesteros i Sagarra 1983, 1984, Ballesteros *et al.* 1984, Verlaque 1990), from the Balearic Islands (Seoane-

Camba 1969, Codomier 1971, Ballesteros 1992b, 1993, 1994), from the Columbrets Islands (Boisset López 1987, Boisset and García-Carrascosa 1987), from the coast of Alicante (Boisset López 1987) and from the Alboran Sea (Giaccone 1972). In France, it has been found at Banyuls and in Cerbère de la Merenda (Feldmann 1935, 1939, Codomier 1968, Boudouresque 1970, Coppejans 1976–1977), in the region of Marseille (J. G. Agardh 1842, Mouret 1911, Huvé and Passelaigue 1970, Codomier 1971), in the National Park of Port-Cros (Boudouresque 1970, Belsher *et al.* 1976, Coppejans 1976–1977, Augier and Boudouresque 1978), at Villefranche sur Mer, Alpes-Maritimes (Feldmann 1942), at different sites

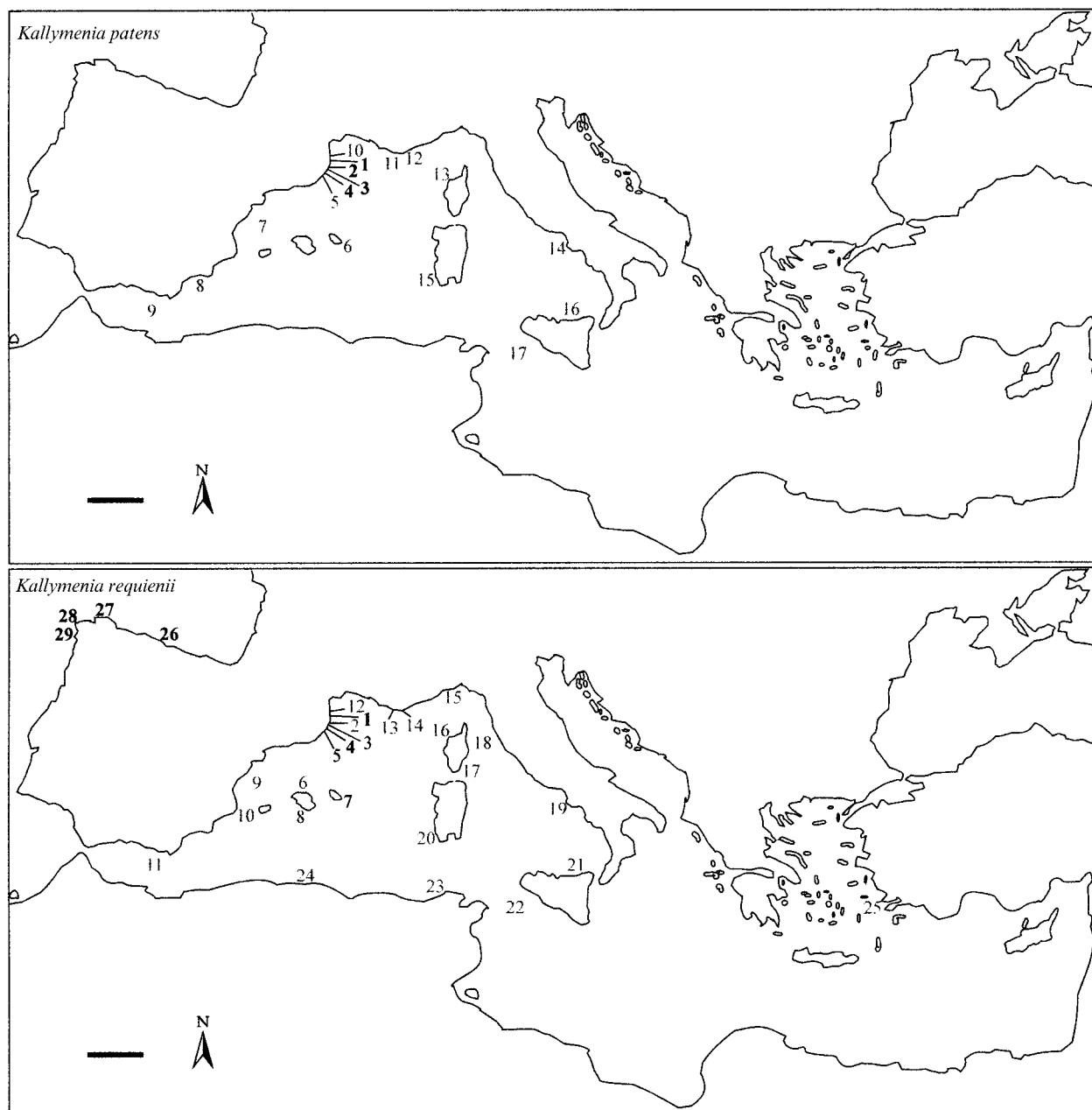


Fig. 2. Geographical distribution of *Kallymenia patens* and *K. requienii* grouped by localities. Numbers correspond to Table I. New localities are in bold. Bar = 200 km.

in Corsica (Molinier 1960, Coppejans 1979, Verlaque 1987) and in the Lavezzi Islands (Boudouresque 1980, Frick *et al.* 1986). In Italy it is known from the Island of Montecristo, Tuscany (Papi *et al.* 1992), from Naples (Cinelli and Codomier 1974), from Sardinia (Brambati *et al.* 1980), from different points in Sicily and from the Strait of Messina (Lagenbach 1873, Ardissonne 1883, Mazza 1904, Spinelli 1905, Giaccone 1969, 1972, Codomier and Giaccone 1972, Furnari and Scammacca 1973, Furnari *et al.* 1977, Cormaci and Furnari 1979, Battiato *et al.* 1980, Cormaci *et al.* 1985, Giaccone *et al.* 1985) and from the channel of Sicily (Codomier and Giaccone 1972, Giaccone *et al.* 1972, 1973, Giaccone and Sortino 1974, Cinelli *et al.* 1976). In Algeria it has been found at Alger (Montagne 1846, Debray 1897) and at Borj-el-Bahri (Feldmann 1942). Finally, in Tunisia it is known from Tabarka (Boudouresque 1970). *Kallymenia requienii* has been also recorded from Kabaena, Indonesia, as *Kallymenia requienii* var. *indica* (Weber-van Bosse 1928), but due to the great distance of this site from the Mediterranean Sea and to the incomplete description of the specimen, we suspect it was a misidentification.

We have found this species in some new places on the northeastern coast of Spain, in the Balearic Islands and in the Columbrets Islands. We have also located this species for the first time on the Atlantic coasts, in specimens from the herbarium of the University of Santiago de Compostela. These specimens came from Santander, A Coruña, Pontevedra and Lugo (Table I, Fig. 2).

Habitat: The Mediterranean individuals of *Kallymenia requienii* grow in the coralligen or, less commonly, in maerl. The maximum depth where they have been found is 95 m, in Minorca, where it was found in the 19th century by J. J. Rodríguez y Femenías (Seoane-Camba 1969). Associated species in its habitat are the same as for *K. feldmannii* and *K. lacerata*. The Atlantic specimens are usually found in the low sublittoral level, attached to rocky bottoms.

Phenology: This species has been collected all year round, except in November, and it is fertile from spring to autumn, bearing female reproductive structures throughout this period and tetraspores in spring. Male reproductive structures have only been found in April and May (Table II).

Discussion

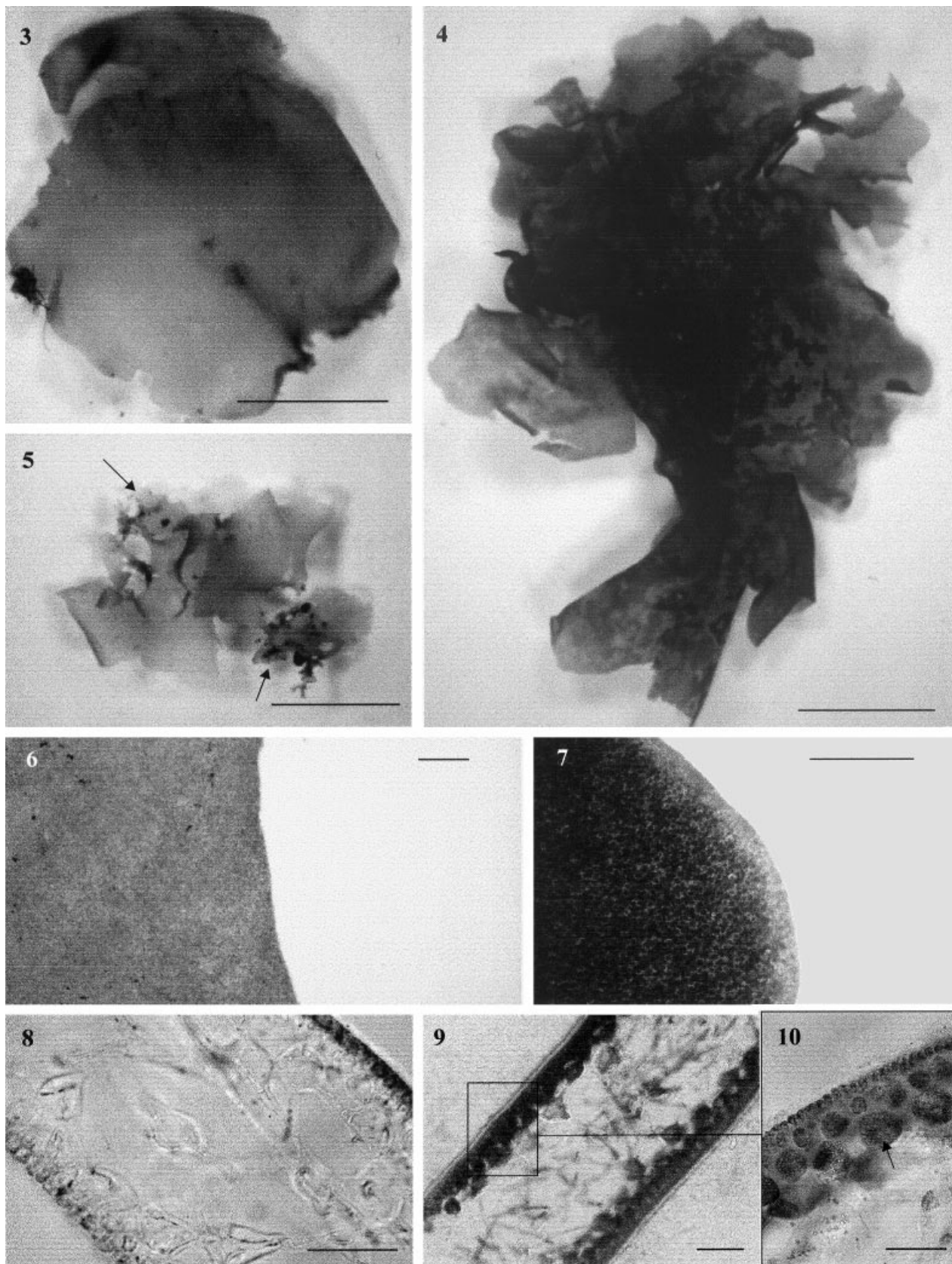
The genus *Kallymenia* from Catalonia is represented only by four species (*K. feldmannii*, *K. lacerata*, *K. patens* and *K. requienii*). *Kallymenia feldmannii* and *K. patens* are found exclusively in the western Mediterranean Sea; *K. lacerata* is known from the western Mediterranean Sea and from Greece; and *K. requienii* is the most widespread species, being present in the

western Mediterranean Sea, in Turkey, and also on the Atlantic coast of the Iberian Peninsula. After examination of the herbaria from the University of Las Palmas de Gran Canaria (BCM) and from the University of la Laguna (TFC), there is no record of these species in the Canary Islands. The individuals of *K. feldmannii* (BCM 1898) and *K. requienii* (BCM 634, BCM 1000, BCM 1892 and BCM 1893) in these herbaria were misidentified and in our opinion they belong to other species of the genus from the Macaronesian area or to other genera. The other specimens of the genus *Kallymenia* in this herbaria were also examined but did not belong to any of the four species studied.

The genus *Kallymenia* is sciophilous. In the Mediterranean Sea it is common in the coralligen, but it may also be present in maerl, usually at depths of more than 30 m. Sometimes it can be found at shallower depths, albeit usually in dark places (entrances to caves, etc.). On the Atlantic coast, *K. requienii* is found in low sublittoral zones, attached to rocky bottoms.

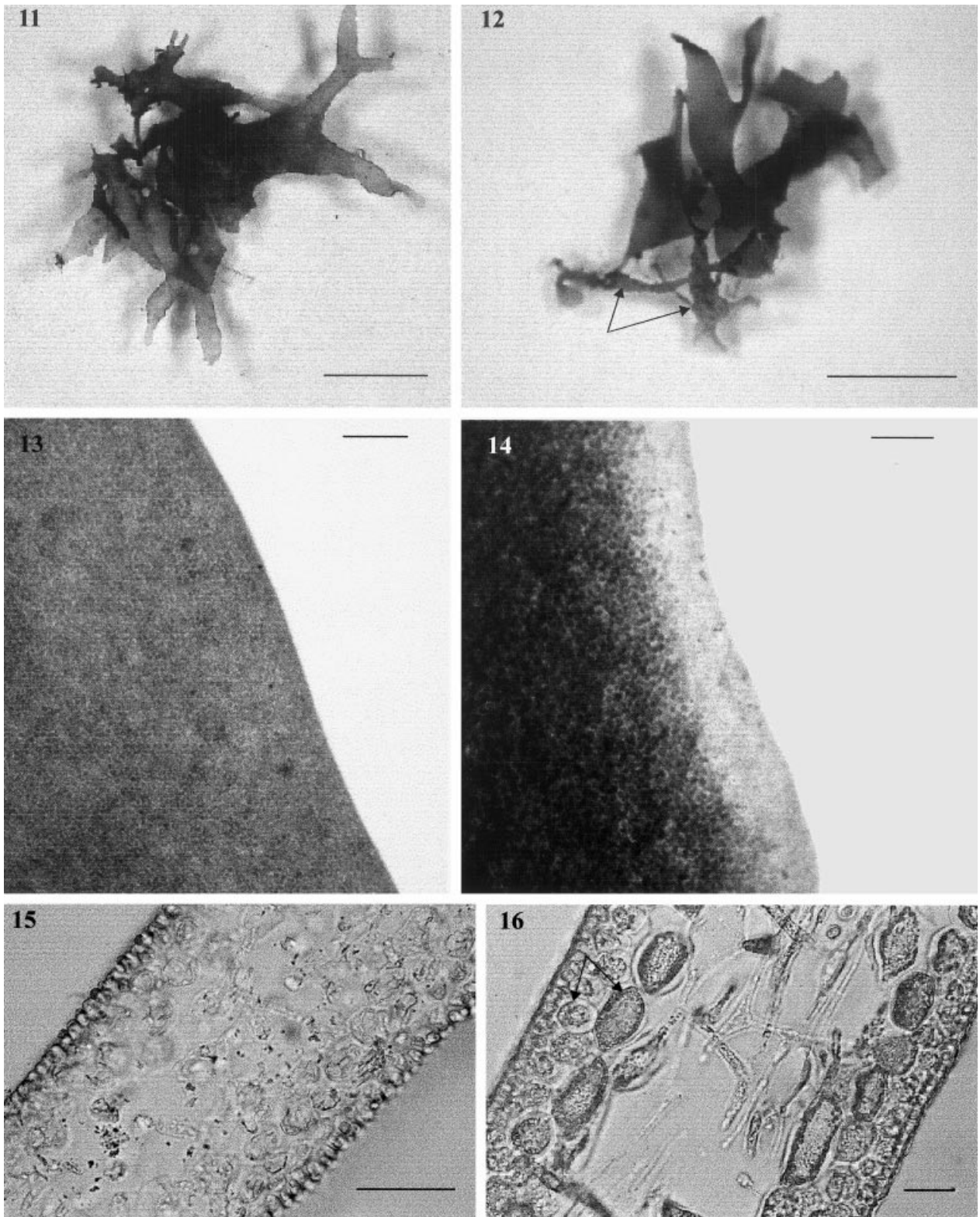
Kallymenia feldmannii and *K. lacerata* seem to be annual because they have never been collected in winter (Table II). The culture of carpospores and tetraspores of *K. feldmannii* (Codomier 1972) shows that this species is able to develop incrusting discoid structures that can survive for long periods of time (some months in our own cultures) and in this way ensure survival in winter. The development of erect vegetative structures is stimulated from the discs with increasing light and temperature. On the other hand, *K. patens* and *K. requienii* seem also to be able to develop incrusting discs from carpospores (i. e. culture of carpospores of *K. requienii*, Codomier 1972), but erect fronds have been found all year round. Young individuals are present in spring and are small and pink. From spring to autumn they grow and accumulate floridean starch in the intermediate layers of cortical cells (never in the first layer or the outer one), with the plant showing whitish spots on the blade surface. Older individuals are totally whitish when viewed macroscopically (Figs 3–5, 11–12). The blade is destroyed during the autumn storms and, during winter, only the basal part of the frond is present in nature. This strategy is another way to ensure survival in winter. In spring, some new blades, pink-colored, without floridean starch and well distinguishable from the old ones, are developed over the old whitish and well epiphytised ones (Figs 5, 12).

The accumulation of floridean starch is very apparent in light microscope surface view of old individuals, as the margin, occupied by younger cells (growth is marginal), is optically less dense than the inner part of the blade, where older cells have accumulated the floridean starch (Figs 6–7; 13–14). This is also apparent in cross sections, because the inner cortical cells of young individuals



Figs 3–10. *Kallymenia requienii*.

Fig. 3. Young individual. Fig. 4. Individual showing whitish spots on the blade surface. Fig. 5. Individual more than one year old showing new blades developed over the old whitish ones (arrows). Fig. 6. Margin of the thallus of a young individual in surface view. Fig. 7. Margin of the thallus of an old individual in surface view. The accumulation of floridean starch in the adult cells makes the inner part of the blade optically dense. Fig. 8. Transverse section of the thallus of a young individual. Fig. 9. Transverse section of the thallus of an old individual. Fig. 10. Enlargement of part of Fig. 9 showing floridean starch in the intermediate cortical cells (arrows). Bars: Figs 3–5 = 1 cm; Figs 6–7, 9 = 100 μ m; Figs 8, 10 = 50 μ m.



Figs 11–16. *Kallymenia patens*.

Fig. 11. Young individual. Fig. 12. Individual more than one year old showing new blades developed over the old whitish ones (arrows). Fig. 13. Margin of the thallus of a young individual in surface view. Fig. 14. Margin of the thallus of an old individual in surface view. The accumulation of floridean starch in the adult cells makes the inner part of the blade optically dense. Fig. 15. Transverse section of the thallus of a young individual. Figs. 16. Transverse section of the thallus of an old individual showing floridean starch in the intermediate cortical cells (arrows). Bars: Figs 11–12 = 1 cm; Figs 13–14 = 100 μ m; Fig. 15 = 50 μ m; Fig. 16 = 25 μ m.

are hyaline, whereas in the old individuals there is a dark and optically dense intermediate cortical layer (Figs 8–10, 15–16). We think that the accumulation of floridean starch is not related to the irradiation of the site as was suggested by Codomier (1972), but is related to the age of the plant as we have shown here.

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