Constancea 83, 2002
University and Jepson Herbaria
P.C. Silva Festschrift

Vegetative and Reproductive Phenology of *Chondrophycus perforatus* and *Laurencia viridis* (Rhodomelaceae, Rhodophyta) in Tenerife, Canary Islands

M.C. Gil−Rodríguez[1]* and R. Haroun[2]
[1]* Dpto. de Biología Vegetal (Botánica),
Universidad de La Laguna, E−38071 La Laguna, Islas Canarias, España.
[2] Dpto. de Biología, Fac. de Ciencias del Mar, Universidad de Las Palmas de Gran Canaria,
E−35017 Las Palmas, Islas Canarias, España.

* Corresponding author

E−mail: mcgil@ull.es
Fax: +34 922 318 447

ABSTRACT

Vegetative and reproductive phenology of two intertidal red macroalgae: *Chondrophycus perforatus* (Bory) Nam and *Laurencia viridis* Gil−Rodríguez & Haroun (Rhodomelaceae, Rhodophyta) were compared between sites on the northern and southern shore of Tenerife Island (Canary Islands). Several biometrical parameters were obtained over a period of 24 months. Physical and chemical characteristics of the two sites were determined. *Chondrophycus perforatus*, a perennial, reaches maximum size in early summer (June to July) in the north, winter (December to March) in the south. Tetrasporophytes are most abundant in the north during summer, while they are most abundant in the south in autumn and winter. Female gametophytes were not found; male gametophytes were rare. *Laurencia viridis*, an annual, appears in the north in autumn (September to December), reaches maximum size in spring and early summer (June), and disappears in July, while in the south, it carries out its life history one to two months earlier. Tetrasporophytes dominate in the spring to early summer at both sites. Male plants appear early at the southern site and continue growing throughout the winter at both sites. Cystocarpic plants are present during the period December to June in the north, November to May in the south. The differential growth of both species in the two locations are discussed in relation to key environmental parameters, such as temperature and light regime. The higher sea surface temperature and irradiance encountered in the southern site may explain the early development of the populations of both species.

INTRODUCTION

Members of the Rhodomelaceae, including among others the genera *Laurencia*, *Chondrophycus*, and *Osmundea*, are important components of the intertidal flora in warm temperate coasts. About twenty species belonging to these red algal genera are known from the Canary Islands (Gil−Rodríguez and Haroun 1993; Afonso−Carrillo and Sansón, 1999). Recently, Garbary and Harper (1998) proposed the elevation of the subgenus *Chondrophycus* to generic level based on a cladistic analysis of the *Laurencia* complex, while Nam (1999) gave several morphological and anatomical details to support that change and transferred among others, *Laurencia perforatus* (Bory) Montagne, to the new genus. In a previous paper, Haroun and Gil−Rodríguez (1995) described the vegetative growth process of *Chondrophycus perforatus* (as *L. perforata*), a widespread intertidal species in the Canarian coasts, as well as discussing spermatangia.

Taking into account climatological differences between the northern and southern intertidal shores of the Canary Islands, we decided to find out if differences existed between the structure and the dynamics of macroalgal populations growing at two sites with different oceanographic conditions. The present paper reports the results of a study on two rhodomelacean species, *Chondrophycus perforatus* and *Laurencia viridis*, in which growth, reproductive and seasonality are compared between two intertidal sites on Tenerife Island, one (site N) on the north coast, the other (site S) on the south coast.

MATERIAL AND METHODS

The location of the two study sites is shown in Figure 1. Site N is Punta del Hidalgo (28RCS707618 UTM) while site S is Pariso Floral (28RCS253117 UTM). Samples were collected (1500 in all) monthly from October 1988 to September 1990 by scraping off all organisms from a 25 cm^2 area, fixing them in a 4% formalin−seawater solution, and sorting them in the laboratory. Ten randomized plant replicates were collected at each site each month. Samples in the *Chondrophycus perforatus* zone were not taken at site N in October and November 1989 due to heavy surf. The study sites comprised intertidal areas with basaltic substratum of different degrees of inclination, moderately to highly exposed to the wave action. In the Canarian coasts, the tides are semi−diurnal, with a maximum tidal range of 2.8 m. Lower tides during noon time, which expose the target macroalgal species to bright sunlight, are more frequent in the summer months (July to September). Daylength varies from 9.5 h in winter (December) to 14.5 in summer (June) (Haroun, 2001).

In the laboratory, individuals of the two rhodomelacean species were separated from the rest of the scraped material, and some biometrical parameters such as total length and diameter of the main axes were measured with the aid of an electronic gauge (Trimes Sylvac®). The data were analyzed with computer programs (Lotus−1−2−3, v. 3.1®, and Microsoft® Powerpoint®97). For this study, the monthly maximum, minimum, and mean values of the thalli length were graphed. Additionally, the reproductive status of the specimens (sterile, male gametophyte, female gametophyte including carposporophyte, and tetrasporophyte) was noted.

To characterize the oceanographic conditions of the two sites, physico−chemical parameters were measured. Seawater temperature and salinity were measured using a microprocessor conductivity meter (MTW LF−196®). Density and pH were also determined (Wiss. Techn. Werkstätten D,812 Weilheim meter®). Photon flux density was measured with a spherical sensor LI−COR LI 1000® at similar times of day at both localities, choosing days with same weather conditions.

Chondrophycus perforatus **(Bory) Nam**

This species, which was originally described from the Canary Islands (Bory 1803: 305, pl.V: fig 1, as *Fucus perforatus* Bory), has been reported from warm−water coasts in all major oceans, including Brazil (Oliveira 1969), tropical West Africa (Lawson and John 1982), Marshall Islands (Taylor 1950), northeastern Australia (Cribb 1958, 1983), Ceylon (Durairatnam 1963), and Tanzania (Jaasund 1970, 1976). In the Canary Islands, it is quite common on intertidal platforms, growing in semi−exposed and exposed points, mainly in rock fissures where water movement is almost continuous (Haroun and Gil−Rodríguez 1995; Masuda et al., 1998).

The morphological features of *C. perforatus* were confirmed in this study: thallus perennial, cartilaginous, reddish purple to olive green when living, forming tightly intricate turf averaging 1.5–3.0 cm (range 0.7–5.2 cm) high; main axes attached to substrate by discoid holdfast; branches cylindrical, arcuate, and decumbent, creeping by apical rhizoidal attachments. Reproduction seems to be chiefly vegetative, as previously noted (Haroun and Gil−Rodríguez, 1995). Tetrasporophytes and male gametophytes with cup−shaped spermatangial receptacles were observed, but no female plants were found.

Laurencia viridis Gil−Rodríguez and Haroun

This species was described (Gil−Rodríguez and Haroun 1992) from the Macaronesian Region (Azores, Madeira, Selvages, Canaries, and Cape Verd). It is mainly restricted to exposed low intertidal sites, growing on rocks with strong wave action.

The morphological features of this species are the following: thallus annual, cartilaginous, mainly greenish with pink tips, with erect axes averaging 4–8 cm (range 2–15 cm) long, having alternate or helicoid branching only in the upper 2/3 of the thallus; ovoid spermatangia produced in cup−shaped receptacles; cystocarps urceolate and sessile; tetrasporangia in parallel abaxial rows.

RESULTS

Physical and chemical measurements

Mean values of the oceanographic parameters analyzed at the two sites are given in Table I. There are only two significant differences, both of which favor site S for growth of warm−water organisms. At site S irradiance is twice that at site N, while surface seawater temperature are 2–3°C higher at site S than at site N.

Chondrophycus perforatus

Site N

The highest value of the mean size of *C. perforatus* was attained in June to July: 3.1–3.9 cm (a maximum size of 5.2 cm was reached during early summer, June 1990), but most of the year the mean thallus size was about 2–3 cm (Fig. 2a). Plant abrasion occurs during the autumn (October to November), leaving short turfs in December and January. Growth resumes in the spring (March to May). Vegetative thalli were present throughout the year.

Reproductive effort (Fig. 2b): Tetrasporophytes were found in the warmest months of the year (not observed between November and February), and peaked in late summer, while male gametophytes were found only in summer months (June to August) with the exception of one collection in February 1990. No female gametophytes were detected. There was a steady increase of tetrasporophytes from late winter to summer months.

Site S

In this location, the greatest mean size of *C. perforatus* was attained during the winter months: 3.2–3.4 cm (the maximum size 4.4 cm was reached in December 1988 and January 1990), but most of the year the mean size was about 2.4–2.5 cm (Fig. 3a). Due to high insolation in spring months, plants started to die, and remained small until next autumn (September to November), when the growth began again.

Reproductive effort (Fig. 3b): The maximum numbers of fertile plants was observed after the summer months. There was a clear increase of tetraspore formation towards late autumn (August to December). Only 34% of the total samples collected were tetrasporophytes, the remainder were sterile plants. In this site, no male or female gametophytes were detected despite a careful check of all specimens collected.

Comparing the two sites, maximum size is reached in the summer (June to September) at site N, whereas at site S reached it was in winter (December to March). In relation to the reproductive status of the plants, tetrasporophytes dominate at site N in summer (June to August) but are most abundant at site S during autumn (September to November). Male plants were found only at site N, and only at low frequencies. Female plants and carposporophytes were never found at either site.

Laurencia viridis Gil−Rodríguez and Haroun

Site N

Discernible thalli appeared in the autumn (November), grew slowly in winter, and reached a maximum size of 8.3–9.2 cm in spring (April) and early summer (June) (Fig. 4a). They disappeared by the end of August. Tetrasporophytes peaked in the spring and early summer (August) .

Reproductive effort (Fig. 4b): Male and female plants were found earlier than tetrasporangial plants. Sexual plants started to appear in late autumn and female plants lasted until late spring (May 1989); tetrasporophytes were found two months later. In summer, only tetrasporophytes were found. Of the total samples from site N, 23% were tetrasporophytes, 5% male gametophytes, 6% female gametophytes, and 66% sterile plants.

Site S

Thalli appeared at the beginning of September and grew rapidly during autumn and winter, reaching a maximum size of 12–15 cm in spring (March to May). They began to disappear at the beginning of July, with a new annual cycle starting at the beginning of September (Fig. 5a).

Reproductive effort (Fig. 5b): Tetrasporophytes were first detected in January and persisted until the end of June, reaching maximum size in the spring (March to June). Spermatangia develop in autumn (November) and winter (December to February), reaching a maximum in December to January. Female gametophytes were first detected during November, peaked in March, and persisted throughout April and May. Of the total sample from site S, 40% were tetrasporophytes, 8% male gametophytes, 9% female gametophytes, and 43% sterile plants.

There are some clear differences between the two sites. Thalli appeared in autumn (November) at site N, growing continuously through the winter (January) and spring (April), reaching maximum size in early summer (June), and disappearing at the end of summer (August). At site S, the growth cycle of the thalli started and finished earlier, appearing at the end of summer (September), attaining maximum size in spring (March to May), and started to disappear at early summer (July).

DISCUSSION

Laurencia viridis is an annual species which disappears in summer months. This species apparently responds favorably to the greater light and warmth of site S, running the course of its life history about a month earlier than at site N. By contrast, *C. perforata*, which is a perennial species, reproduces mostly by vegetative means at the two sites. In the southern site the plant regression during the spring months may be explained by the higher irradiance rate in that coastal area. in that period of the year. The marked difference in time of maximum thallus size (summer at site N and winter at site S) seems to be related to the light conditions at the two sites, but this aspect remains to be elucidated.

The relevance of vegetative propagation has already been remarked by other authors for diverse intertidal macroalgae (Lobban and Harrison, 1994). In *Laurencia crustiformans* McDermid which is also a intertidal and shallow subtidal (down to −1.5 m) species, sexual plants are rather uncommon (McDermid, 1989); only a few female plants have been observed. In another rhodomelacean species, *Acantophora spicifera* (Vahl) Børgesen, Kilar and McLachlan (1986) showed that fragmentation in this species was an effective mechanism of plant propagation in a wave exposed zone. Also, Braga (1990) described turf−forming populations of *Gigartina teedii* (Roth) Lamouroux on the subtropical coast of Brazil that persisted mainly through vegetative propagation. In our study, after two years' monthly sampling of the two intertidal macroalgae, vegetative propagation of *C. perforatus* is confirmed (Haroun and Gil−Rodríguez, 1995).

Our failure to detect female gametophytes of *C. perforatus* probably indicates that they are absent or rarely fertile. Male gametophytes (although presumably less conspicuous than female ones) were detected in several months. It seems unlikely that the female gametophytic stages would appear and disappear in the short intervals between the sampling times, but this possibility cannot be ruled out. In the literature, spermatangial branches were described for this species only twice (Cribb 1958; Haroun and Gil−Rodríguez 1995) and no other fertile gametophytic material has been described yet. Another possibility, suggested by Dyck et al., (1985) in their study of the reproductive phenology of *Iridaea cordata* (Turner) Bory along the Pacific Coast of North America and also by Braga (1990) with *Gigartina teedii* (Roth) Lamouroux in the subtropical Brazilian coast, is that a successful vegetative reproduction of any life−history stage on the available substrate may preclude the development of other stages. Only local catastrophes or the senescence of the dominant life−history stage would allow the growth of the other stage.

ACKNOWLEDGEMENTS

We would like to express our gratitude to Dr Paul C. Silva for his critical review of the manuscript. We feel also indebted to Drs. M. Chacana and M. Medina, and Lcda. M. C. Hernández−González for their help with the field work, as well as Dr F. Valdés.

REFERENCES

Afonso−Carrillo, J. and Sansón, M. 1999.
Algas, hongos y fanerógamas marinas de las Islas Canarias. Clave analítica. Materiales Didácticos Universitarios. Serie Biología /2. Servicio de Publicaciones de la Universidad de La Laguna. Santa Cruz de Tenerife. 254 pp.

Bory de Saint Vincent, J.B.G.M. 1803.
Essais sur les Isles Fortunées et l'antique Atlantide, ou Précis de l'histoire générale de l'Archipel des Canaries. Baudouin, París. i−viii, 522 pp.

Braga, M.R.A. 1990.
Reproductive characteristics of *Gigartina teedii* (Roth) Lamouroux (Rhodophyta, Gigartinales), a turf−forming species: field and laboratory culture. *Botanica Marina* 33: 401–409.

Cribb, A.B. 1958.
Records of marine algae from south−eastern Queensland—III. *Laurencia* Lamx. *University of Queensland Papers, Department of Botany* 3: 159−–191, including 13 pls.

Cribb, A.B. 1983.
Marine Algae of the Southern Great Barrier Reef. Part. I. Rhodophyta. Australian Coral Reef Society Handbook 2. 173 pp.

Durairatnam, M. 1963.
Some marine algae from Ceylon 2. *Laurencia* Lamouroux. *Fisheries Research Station, Ceylon, Bulletin* 16(2): 19–28.

Dyck, L., De Wreede, E.R., and Garbary, D. 1985.
Life history phases in *Iridea cordata* (Gigartinaceae): relative abundance and distribution from British Columbia to California. *Journal of Phycology* 33: 225–232.

Garbary, D.J. and Harper, J.T. 1998.
A phylogenetic analysis of the red algae belonging to the *Laurencia* complex (Rhodomelaceae). *Cryptogamie: Algologie* 19: 185–200.

Gil−Rodríguez, M.C. and Haroun, R. 1992.
Laurencia viridis sp. nov. (Ceramiales, Rhodomelaceae) from the Macaronesian Archipelagos. *Botanica Marina* 35: 227–237.

Gil−Rodríguez, M.C. and Haroun, R. 1993.
The genus *Laurencia* (Rhodomelaceae, Rhodophyta) in the Canary Islands. *Courier Forschungsinstitut Senckenberg* 159: 113–117.

Haroun, R. 2001.

El mar canario. In Fernandez−Palacios, J.M. and Martín−Esquivel, J.L. (eds). *Ecología y Conservación en las Islas Canarias*. Ed. Turquesa, Santa Cruz de Tenerife. Pp. 48–56.

Haroun, R. and Gil−Rodríguez, M.C. 1995.
Reproductive strategies of *Laurencia perforata* (Bory) Montagne in the Canary Islands. *Nova Hedwigia* 61: 269–274.

Jaasund, E. 1970.
Marine algae in Tanzania II. *Botanica Marina* 13: 59–64.

Jaasund, E. 1976.
Intertidal seaweeds in Tanzania. University of Tromsø. 160 pp.

Kilar, J.A. and McLachlan, J. 1986.
Ecological studies of the alga, *Acantophora spicifera* (Vahl) Boerg. (Ceramiales, Rhodophyta): vegetative fragmentation. *Journal of Experimental Marine Biology and Ecology* 104: 1–21.

Lawson, G.M. and John D. 1982.
The Marine Algae and Coastal Environment of Tropical West Africa. J. Cramer, Berlin. 455 pp.

Lobban, C.S. and Harrison, P.J. 1994.
Seaweed Ecology and Physiology. Cambridge Univ. Press, Cambridge. 366 pp.

Masuda, M., Kogame, K., Arisana, S., and Suzuki, M. 1998.
Morphology and halogenated secondary metabolites of three Gran Canarian species of *Laurencia* (Ceramiales, Rhodophyta). *Botanica Marina* 41: 265–277.

McDermid, K.J. 1989.
Laurencia crustiformans sp. nov. (Ceramiales, Rhodophyta) from the Hawaiian Islands. *Phycologia* 28: 352–359.

Nam, K.W. 1999.
Morphology of *Chondrophycus undulata* and *C. parvipapillata* and its implications for the taxonomy of the *Laurencia* (Ceramiales, Rhodophyta) complex. *European Journal of Phycology* 34: 455–468.

Oliveira, E.C., 1969.
Algas marinhas do sul do Estado do Espírito Santo (Brasil) I. Ceramiales. *Boletim de Faculdade de Filosofia, Ciências e Letras, Universidade de São Paulo, Botânica* 26: 1–277.

Taylor, W.R. 1950.
Plants of Bikini and other Northern Marshall Islands. Univ. Michigan Press, Ann Arbor. 227 pp.

FIGURES 1 – 5; TABLE 1

Fig. 1. Location of the two study sites in Tenerife Island (Canary Islands).– Site N: Punta del Hidalgo. Site S: Paraíso Floral.

Fig. 1

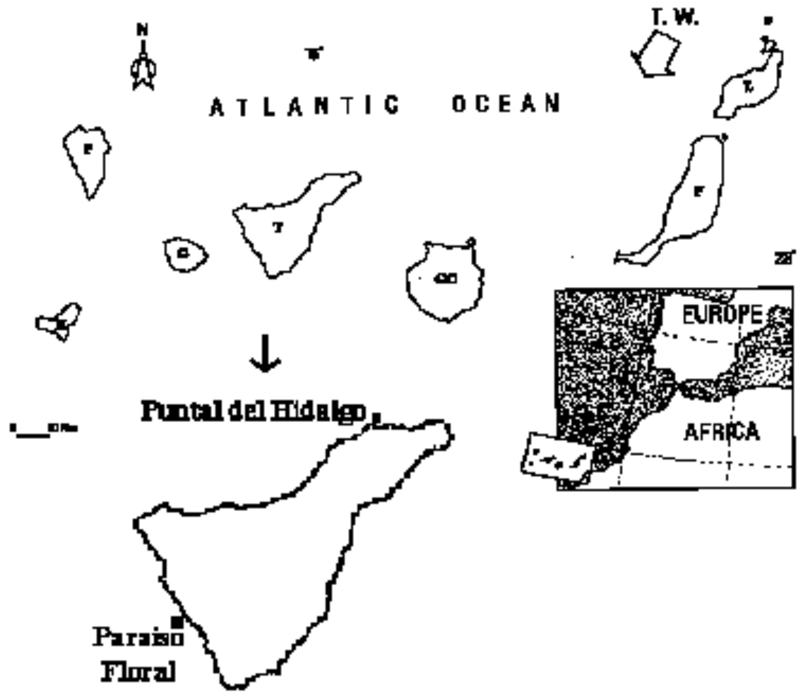
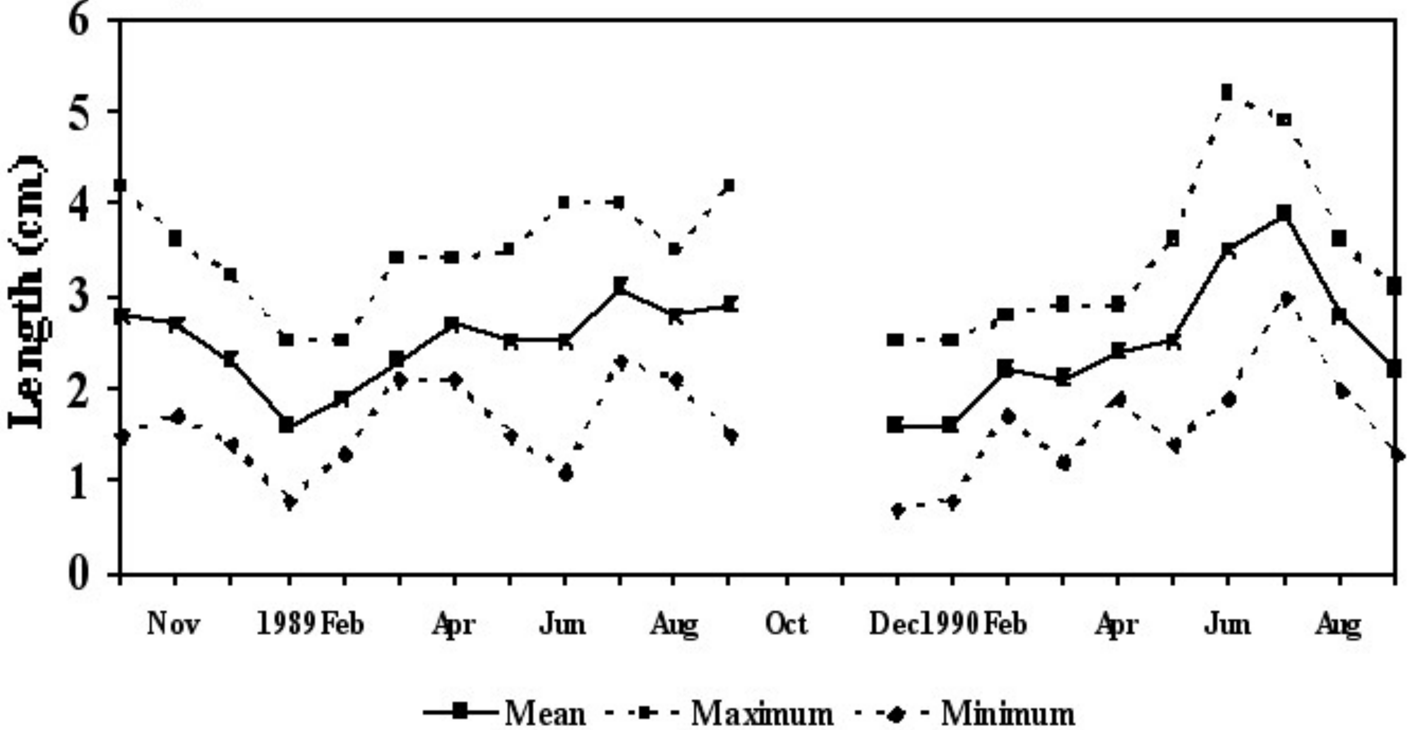


Fig. 2. C. perforatus from Site N, October 1988 – September 1990.
2a: Biometry.
2b: Percentage of sterile/fertile plants.

Fig.2a


6
5
4
3
2
1
0
Length (cm)
Nov
1989 Feb
Apr
Jun
Aug
Oct
Dec1990 Feb
Apr
Jun
Aug
Mean
Maximum
Minimum

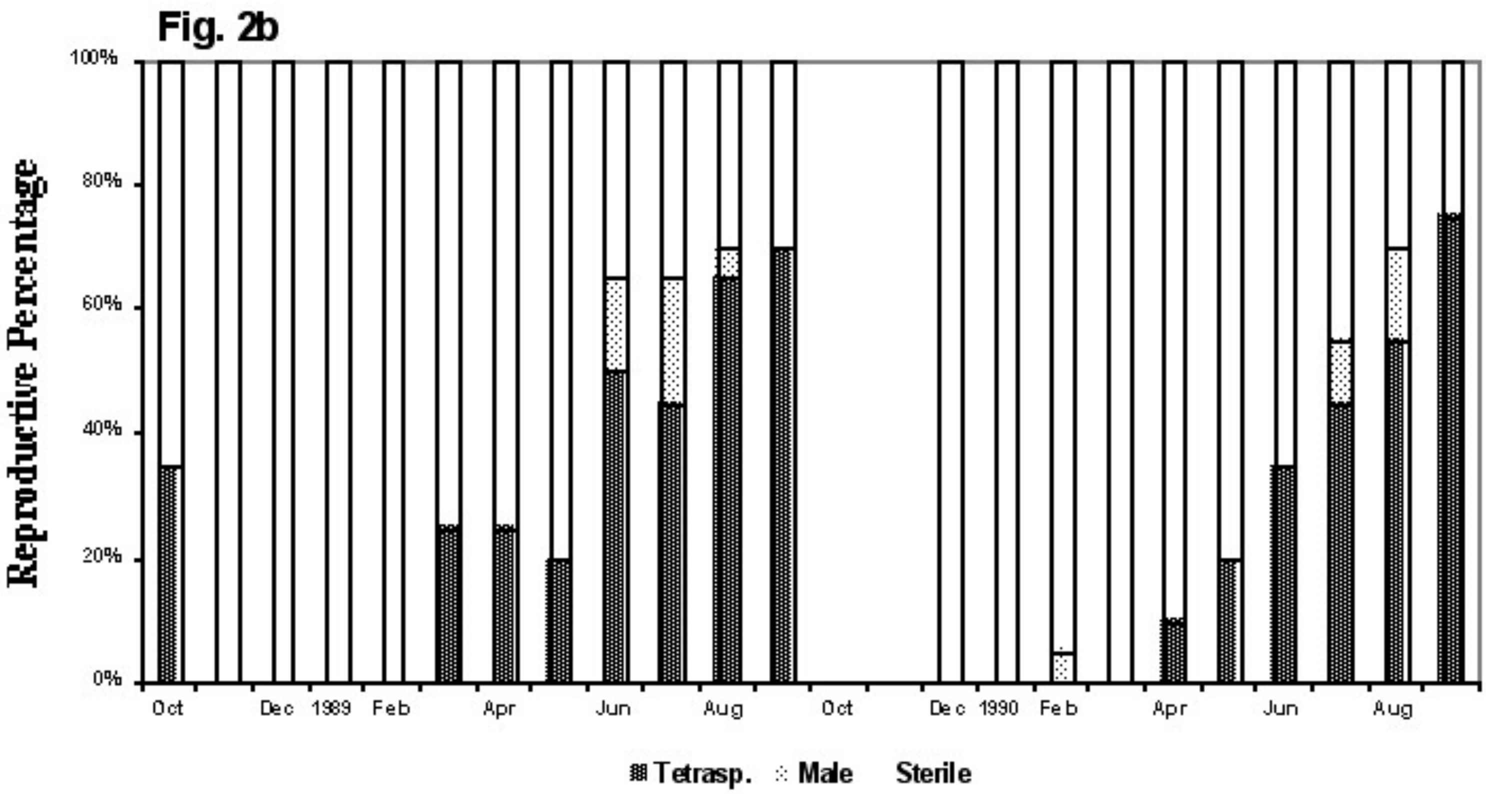
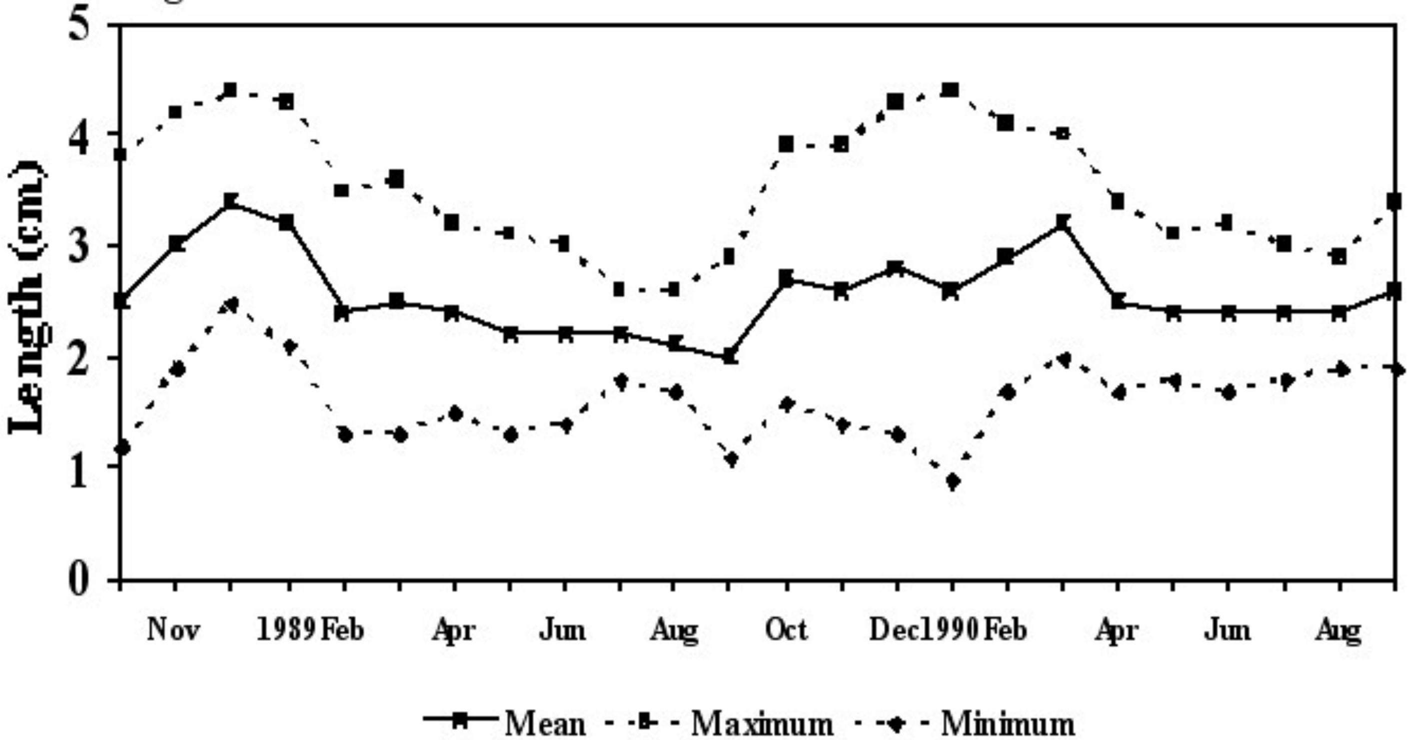


Fig. 3. C. perforatus from Site S, October 1988 – September 1990.
3a: Biometry.
3b: Percentage of sterile/fertile plants.

Fig. 3a


5
4
3
2
1
0
Length (cm)
Nov
1989 Feb
Apr
Jun
Aug
Oct
Dec 1990 Feb
Apr
Jun
Aug
Mean
Maximum
Minimum

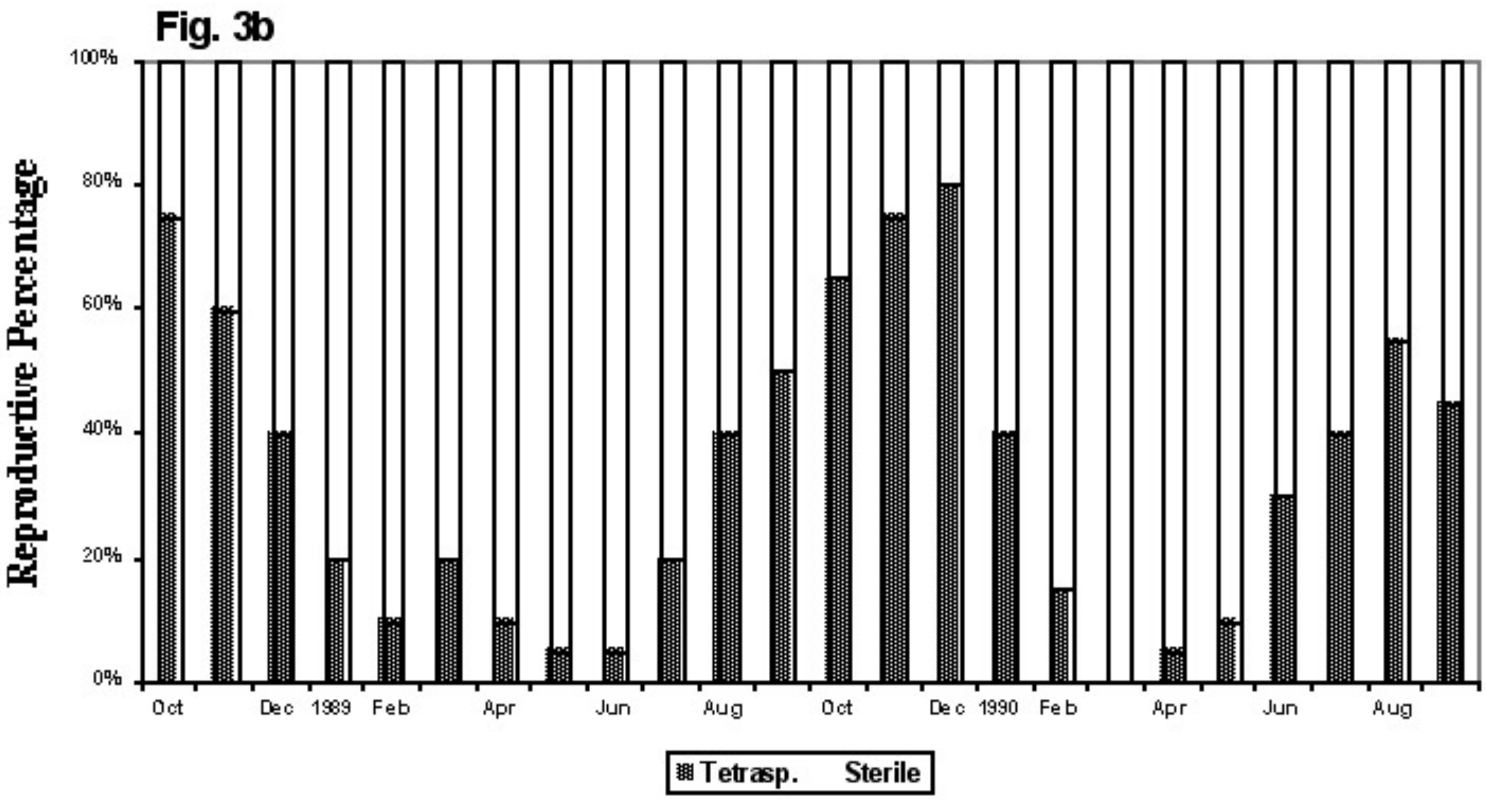
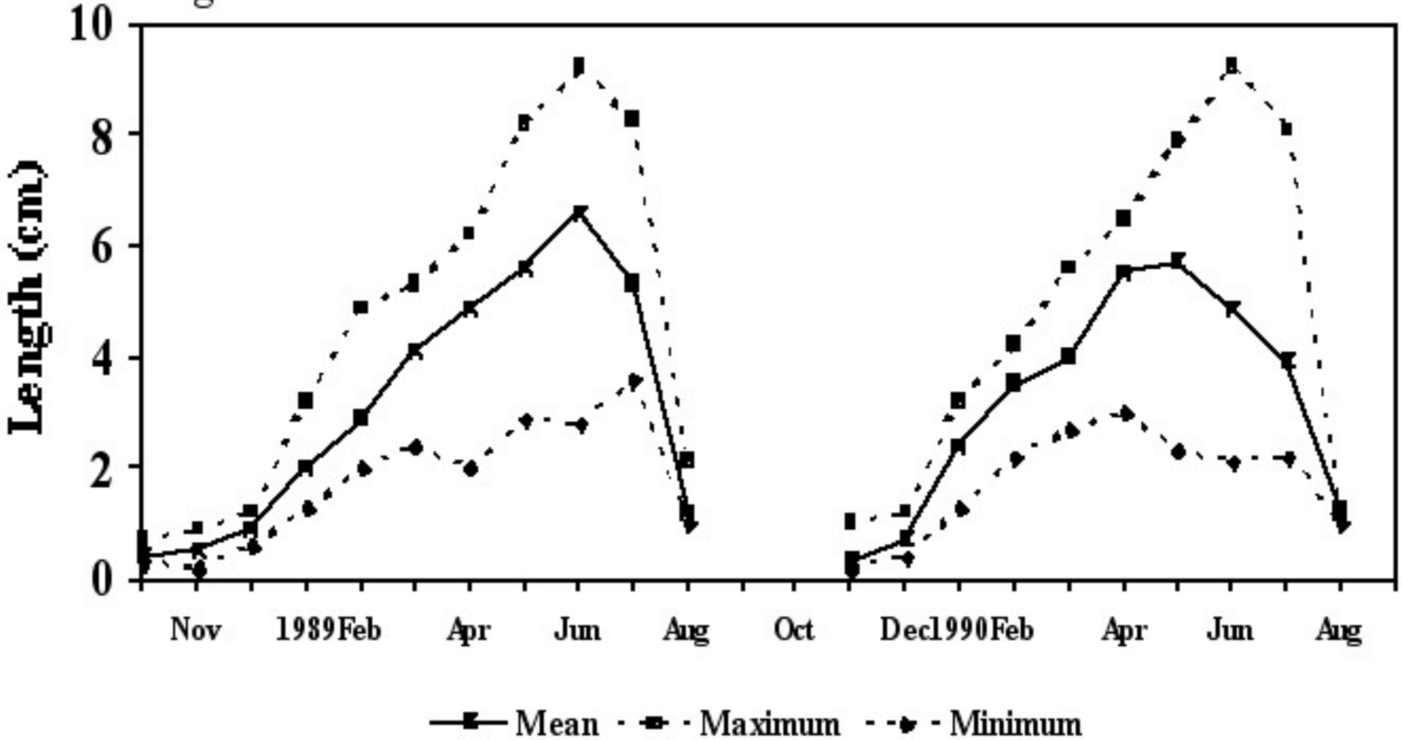


Fig. 4. Laurencia viridis from Site N, October 1988 – September 1990.
4a: Biometry.
4b: Percentage of sterile/fertile plants.

Fig. 4a


10
8
6
4
2
0
Length (cm)
Nov
1989Feb
Apr
Jun
Aug
Oct
Dec1990Feb
Apr
Jun
Aug
Mean
Maximum
Minimum

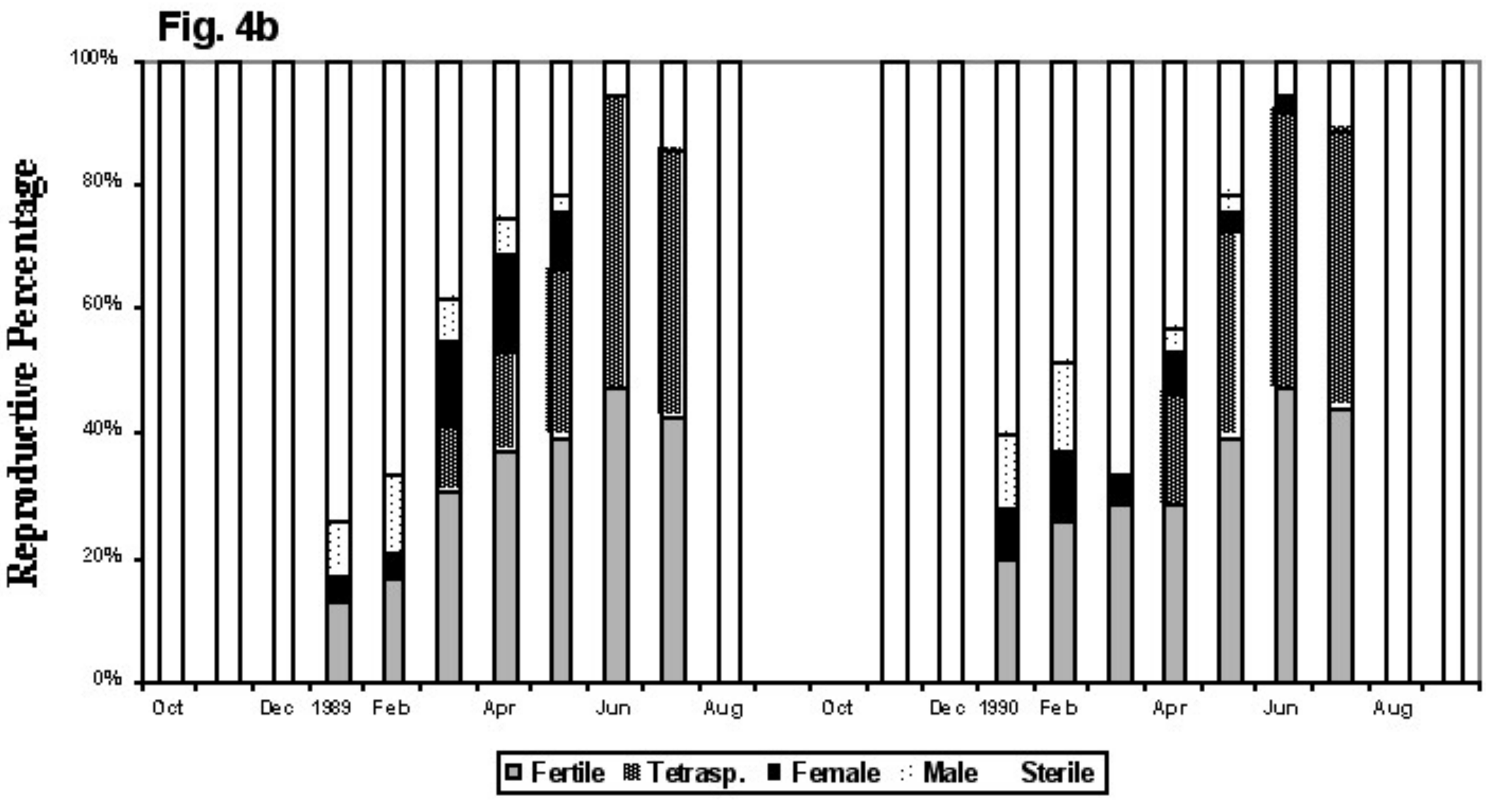


Fig. 5. Laurencia viridis from Site S, October 1988 – September 1990.
5 a: Biometry.
5b: Percentage of sterile/fertile plants.

Fig. 5a

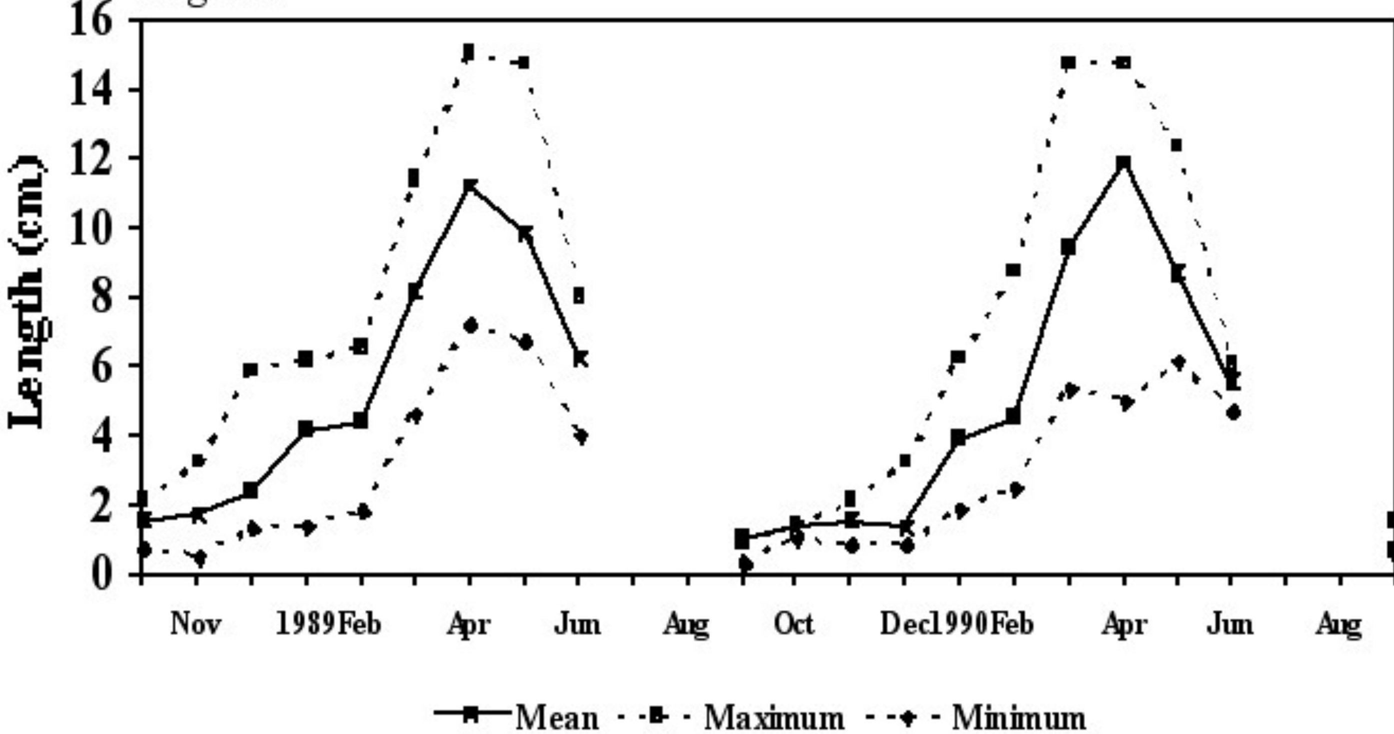

16
14
12
10
8
6
4
2
0
Length (cm)
Nov
1989Feb
Apr
Jun
Aug
Oct
Dec1990Feb
Apr
Jun
Aug
Mean
Maximum
Minimum

Fig. 5b

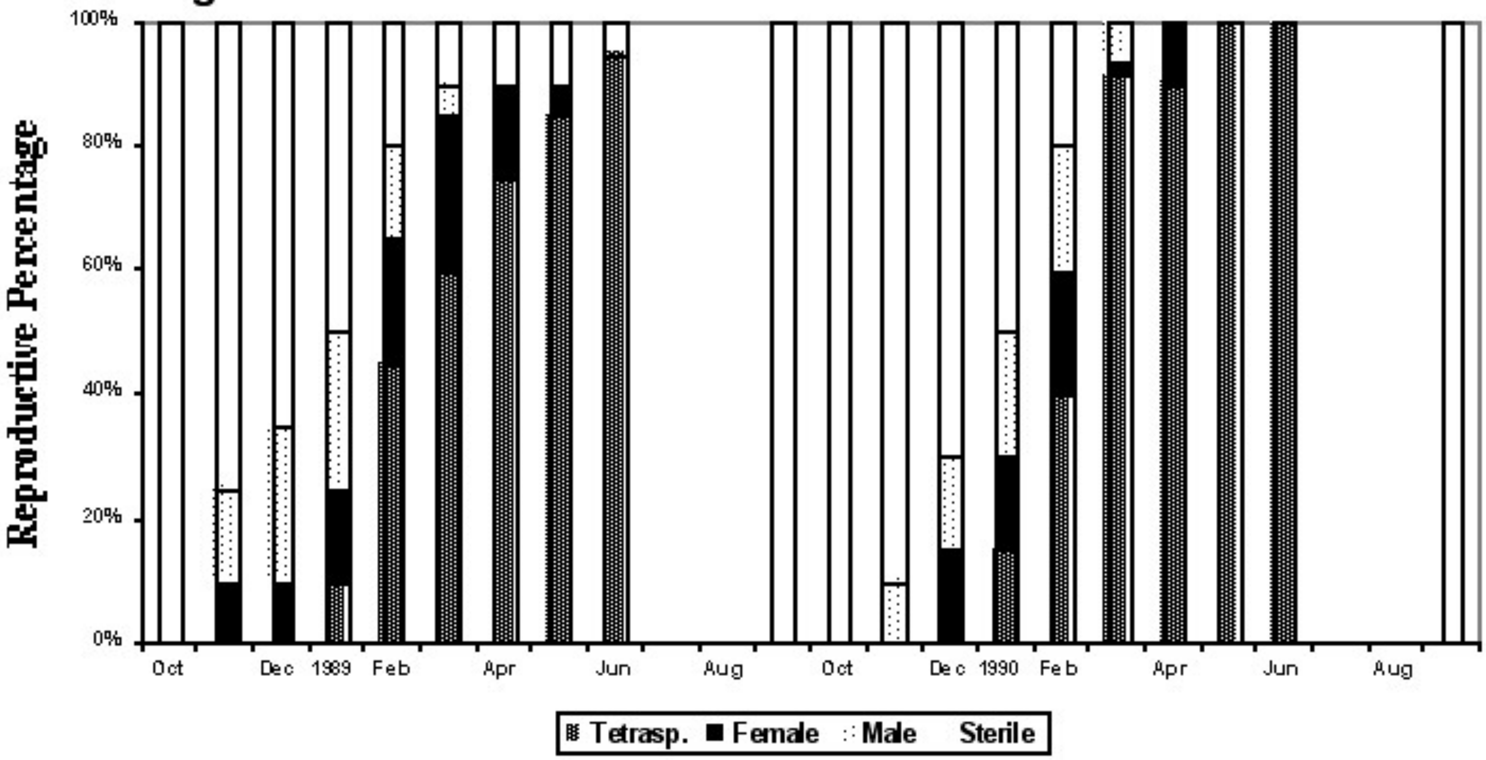


Table I. Physico−chemical parameters at the two intertidal sites.

	Northern Site	Southern Site
Irradiance	50 µmol $m^{-2}sec^{-1}$	100 µmol $m^{-2}sec^{-1}$
Water temperature, Winter	17–19 ºC	19–21 ºC
Water temperature, Summer	21–22 ºC	22–25ºC
Salinity	37 ‰	38 ‰
pH	8.2	8.1