Morphometric studies of Sargassum spp. (Sargassaceae, Phaeophyta) from Reunion Rocks, KwaZulu-Natal, South Africa. I. Receptacles

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Specimens of a mixed population of Sargassum spp. were collected from Reunion Rocks, KwaZulu-Natal, South Africa over a period of one year. Three general shapes of receptacle were recorded for Sargassum elegans, S. incisifolium and an undescribed species of Sargassum: i) terete, ii) three-cornered and iii) twisted receptacles respectively. The number of conceptacles on the receptacles was enumerated and related to the dry weight of the receptacles. It was found that conceptacle number per receptacle correlated well to the weight of the receptacle and that each receptacle type had a different number of conceptacles per unit weight. Relationships were found to vary from one season to the next, however, it was found that the three-cornered receptacle type developed a greater number of conceptacles per unit weight than the terete receptacle type. Reproductive somatic biomass ratios indicated that the three-cornered receptacle type had a lower reproductive expenditure than the terete receptacle type in terms of biomass. Ecological and possible taxonomic implications are discussed.

Keywords: Sargassum, receptacles, morphometric analysis.

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Introduction

The brown algal genus Sargassum has a tropical to subtropical distribution world-wide. The genus is credited with over 500 recorded species (Yoshida 1989), but the taxonomy of the genus is considered by several authors to be in need of revision (Tseng et al. 1985; Yoshida 1988, 1989; Abbott 1992). There have been many papers which have investigated the taxonomy of Sargassum spp. (e.g. Yoshida 1989; Kilat et al. 1992a,b; Trono 1992; Tseng & Lu 1992a,b; Ajisaka et al. 1994; Noro et al. 1994; Silva et al. 1996) and several papers have investigated aspects of the ecology of members of the genus (e.g. Ang 1987; Ang & de Wrede 1990; Trono & Tolentino 1993; Kendrick & Walker 1994 and Largo et al. 1994). Some papers have attempted to place a measure on the reproductive output of the species under investigation (Umezaki 1984) and others have highlighted the reproductive development of members of the genus (Okuda & Satoh 1989; Critchley et al. 1991). To our knowledge, few papers have related quantitative data on reproductive structures across different species/forms of Sargassum.

This paper forms part of a broader ecological study of the Sargassum spp. population at Reunion Rocks, KwaZulu-Natal (KZN), South Africa. Sargassum is a common genus of seaweed occurring on the coast of KZN and is a dominant alga of upper intertidal rock pools. The Sargassum population at Reunion Rocks (approximately 15 km south of Durban; 29°59'S, 30°58'E) consists of several forms, the taxonomy of which remain uncertain (Birkett 1984). Several taxonomic publications have included South African species of Sargassum (Simons 1976; Seagrief 1984), and nine species have been recorded from the South African coast (Silva et al. 1996), yet the variation present at Reunion Rocks is not adequately described by these works. Three forms of Sargassum, each with a different shape of receptacle, are discussed in this paper. One is Sargassum elegans Suhr, one has been commonly referred to as S. heterophyllum C. Agardh [=S. incisifolium (Turner) C. Agardh, Silva et al. 1996] and the third appears to be undescribed.

The reproductive structures of Sargassum are referred to as receptacles. In the forms found at Reunion Rocks, these structures occur in the axils of laminae of either secondary or tertiary branches of the main axis (nomenclature after Jensen 1974 and Yoshida 1989). Conceptacles (structures within the receptacle containing gametangia) occur in the receptacles and are visible on the receptacle surface as pores.

The number of conceptacles that can occur on a single receptacle is considerable and an accurate count of these conceptacles while rotating a receptacle under a microscope is both difficult and time consuming. This study presents an analysis of allometric relationships which allow estimation of conceptacle number from receptacle weight, while, at the same time presenting useful quantitative information of reproductive features of the genus, often considered to be conservative characters, across different species within the genus Sargassum. The potential application of a quantifiable taxonomic character and some ecological implications of the results are discussed.

Methods and materials

Thalli of Sargassum elegans, S. incisifolium and an, as yet, undescribed Sargassum species were collected from Reunion Rocks, KwaZulu-Natal, South Africa (29°59'S, 30°58'E) over a one year period (July, October 1995, January, May 1996). Each species develops receptacles of a different form, a consistent feature between the species. Stratified random sampling using seven 0.16 m² quadrats was used. From the material collected, a sub-sample of a minimum of five thalli (with receptacles) of each species present was chosen at random. From these thalli, all receptacles present were removed and preserved in 4% formalin-seawater. A sub-sample of receptacle clusters was taken from the thalli. A receptacle cluster being defined as all those receptacle branches (all three types of receptacle display branching) which arise from one axis in the axil of a lamina. The number of conceptacles that could be seen on a receptacle when looking down the microscope was counted for material collected during all sample times, i.e. one side of the three-cornered receptacles (receptacle placed on one apex of the 'triangle'); those conceptacles that were visible on the terete type without any movement of the receptacle, and those of the twisted receptacle were counted by following one of the three sides around a twist from the base to the apex. In addition to these data the total number of conceptacles per receptacle cluster was also counted for July 1995 so as to determine the relationship between 'surface' and total
conceptacles. The receptacles were examined using a Wild stereo dissecting microscope. The shape, number and dry weight of receptacles were recorded along with the weights of the associated thalli. The receptacles and thalli were dried at 45°C until constant weight. Regression analyses were performed to determine relationships between the various parameters.

Results
At least three species of Sargassum can be identified at Reunion Rocks, each with a different receptacle type. The receptacles are broadly described as follows (Figure 1):
- Terete (Sargassum elegans)
- Three-cornered (commonly referred to as S. heterophyllum = S. incisifolium), and
- Twisted (undescribed species).

These names refer to the general shape of the receptacles. This paper does not intend to describe the nature of the receptacles in detail, but rather indicate the different forms that do exist and which will be discussed. The terete form lacks ornamentation and is approximately circular in cross-section. The twisted type has three 'sides' with a spiral nature. This receptacle type has more ornamentation (in the form of pointed protuberances) than the three-cornered type, which, when cut in transverse section presents the form of a triangle. The three-cornered receptacle type lacks ornamentation, but for the corrugated surface which occurs as a result of the occurrence of conceptacles. All three receptacle types were found to contain oogonia throughout the year.

'Surface' conceptacle number was plotted against total conceptacle number for each receptacle type collected during July 1995. Correlation coefficients \( r \) of 0.997, 0.997 and 0.984 were obtained for the terete, three-cornered and twisted receptacle types respectively (Figure 2).

For subsequent analyses 'surface' conceptacles were counted and from this the total conceptacle number for each conceptacle type was estimated using the formulae presented in Figure 2. It was believed that this approach, while in addition to being more efficient, would also yield accurate results as counting receptacles around an entire receptacle can result in errors associated with recounting of conceptacles when rotating the receptacle to view all sides. This would be more noticeable when counting the terete and twisted receptacle types.

In general, the three-cornered receptacle type developed a greater number of conceptacles per receptacle than the other two receptacle types (Figure 2). The maximum number of conceptacles recorded from a three-cornered receptacle cluster exceeded that of the terete receptacle clusters for the four seasons studied. The greatest difference was recorded in July 1995, where a receptacle cluster of the three-cornered type had 1559 conceptacles, while the maximum number of conceptacles recorded from a terete receptacle cluster was 632. The significance of this became clearer when the number of conceptacles was related to receptacle weight (Figures 3–6). Regression analyses revealed a strong relationship between the number of conceptacles on a receptacle and receptacle weight. What is apparent from Figures 3–6 is that each of the receptacle types had a different relationship of conceptacle number to receptacle weight. As a rule, the twisted receptacle type had a lower number of conceptacles per weight of receptacle than the other two types. The three-cornered receptacle type had the highest number of conceptacles per weight of receptacle. The terete receptacle type is intermediate between the two. This is indicated by the slopes of the lines, \( m \) of \( y = mx + c \), presented in Figures 3–6.

Although the regression analyses revealed a relationship of conceptacle number to receptacle weight for each of the seasons, the relationship for each receptacle type and the relationship of one receptacle type to another did not remain constant for each season as indicated by the different regression equations for each season (Figures 3–6). A general relationship was identified, i.e. per unit of receptacle weight the three-cornered receptacle type

**Figure 1** Line drawings illustrating the three receptacle forms investigated and shape in transverse section. A. Terete receptacle (scale bar = 1.3mm). B. Three-cornered receptacle (scale bar = 1.7mm) and C. Twisted receptacle (scale bar = 1.8mm).
developed a greater number of conceptacles than the terete receptacle type; \( m \) for the three-cornered receptacle types was consistently above \( m \) for the terete receptacle type. It is difficult to make statements concerning the twisted receptacle type as data for this receptacle type is limited. Although thalli with these receptacles were found, their numbers throughout the sample period were low (< 3), making it difficult to attain a suitable sample size. The twisted receptacle type developed the lowest number of conceptacles per unit weight of all three receptacle types investigated.

An analysis of the reproductive:somatic biomass ratio for each of the receptacle types over the four seasons revealed that those

**Figure 2** Correlation of ‘surface’ conceptacle number against total conceptacle number for three receptacle types sampled during July 1995.

**Figure 3** Regression of conceptacle number against receptacle weight for receptacles collected during July 1995.
thalli which developed three-cornered receptacles produced receptacles which constituted a smaller proportion of the somatic biomass than the other receptacle types (Figure 7).

**Discussion**

Chapman (1995) warns that the estimation of fertility from reproductive or vegetative biomass is prone to error. From an allometric point of view the relationships identified make it possible to estimate the number of conceptacles per receptacle from receptacle weight. Thus, for estimating potential reproductive output, of which conceptacle number is a starting point, it is possible to only measure receptacle weights, thereby saving time expenditure on counting of conceptacles. It appears that thalli

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**Figure 4** Regression of conceptacle number against receptacle weight for receptacles collected during October 1995.

**Figure 5** Regression of conceptacle number against receptacle weight for receptacles collected during January 1996.
Figure 6  Regression of receptacle number against receptacle weight for receptacles collected during May 1996.

Figure 7  Graph of reproductive:somatic biomass ratios (+S.E.) for each receptacle type sampled at four different times (twisted receptacles only collected during July 1995).
which develop the twisted receptacle type (*Sargassum* sp.) put more energy into developing receptacles with fewer conceptacles. Thalli which develop the three-cornered receptacle type (*S. incisifolium*) invest the least energy in receptacle production than the other receptacle types in terms of associated somatic biomass. However, the receptacles have a greater number of conceptacles, the units of gametangia production, per unit of receptacle weight. Observations indicated that thalli with the twisted receptacle type were the least abundant at Reunion Rocks, while *S. incisifolium* and *S. elegans* seemed to be more balanced in terms of abundance (unpublished observations). The two species can grow alongside each other, however, thalli with large receptacles (*Sargassum elegans*) tend to occur in more wave exposed habitats than thalli with three-cornered receptacles (*S. incisifolium*). The differences in conceptacle number per unit receptacle weight have a possible ecological significance and may represent different reproductive strategies. It is possible that more conceptacles are produced per unit receptacle weight to ensure a greater chance of fertilization under conditions of greater wave action. De Paula and De Oliveira (1982) found that the receptacles of *S. cuneatum* were more branched in areas of greater surf exposure and suggested that this in combination with short leaves may increase the possibility of fertilization under surf conditions.

Birkett (1984) revealed that of the forms of *Sargassum* at Reunion Rocks, published descriptions of South African species of *Sargassum* could not be confidently applied to all of those present. Observations of herbarium specimens and study of the descriptions have not led to the positive identification of all the forms present at Reunion Rocks and it has been suggested that several of the forms present may be undescribed species (Birkett 1984) and some may be morphological variants of a single species. Three species of *Sargassum* are discussed in this paper, *S. elegans*, *S. incisifolium* and an, as yet, undescribed species. Although thalli with different receptacle types appear to dominate in different micro-habitats at Reunion Rocks, possibly related to wave exposure, they can be found growing alongside each other separated by distances of only a few centimetres. The differences identified, in terms of several relationships discussed, between *S. incisifolium* and *S. elegans* appear to be relatively temporarily stable. The differences identified may be an indication that the thalli are separate taxonomic entities and these quantifiable features of reproduction warrant further investigation as taxonomic characters.

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