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# 17. IMAGE-ANALYSIS COMPARISON OF HOLOTYPES OF THE CALCAREOUS NANNOFOSSIL GENUS *SCYPHOSPHAERA*[1]

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## ABSTRACT

Some scyphosphaerids have species names that have been erected based on relatively minor differences in the shape of the lopadolith wall. We have attempted to compare the holotypes of these species quantitatively, using an image-analysis computer program. Comparison is made by superimposing the images of two different holotypes and calculating the amount of deviation between the two. A Similarity Index (Ψ) for each compared pair of holotypes is derived; a psi value of <6 Ψ suggests a close relationship and possible conspecificity.


## INTRODUCTION

Paleontologists group fossils together on the basis of similar skeletal characteristics. This may be done with considerable objectivity at higher taxonomic levels, where defining features are distinctly different. At the species level, however, where much more subtle differences in skeletal features are used to differentiate species, taxonomy becomes more subjective.

The decision to subdivide a population into different morphospecies is, in itself, a subjective matter, and the differing philosophies of "splitters" and "lumpers" are well known. New species are erected by selecting a single specimen (the holotype), whose characteristics are considered sufficiently different from related fossils to merit a separate taxonomic category. Once a holotype is chosen, its particular characteristics become the defining standard for the species, and all other specimens subsequently identified as belonging to that species must correspond to the holotype.

An obvious problem is that many species in the population from which the holotype was selected will possess features very close to, but not *exactly* corresponding to, the defining characteristics of the holotype. Assignment of these specimens to the species in question then becomes a subjective determination based on the investigator's personal concept of how much intraspecific variation of the defining characteristics is allowable for this species. Two related questions are at the heart of practical species taxonomy: "What should be the limits of a defining characteristic, or set of characteristics, of a species?," and, "When do features of specimens differ enough from the holotype to require assignment to a different species?"

There are no ready answers to these questions. For most species, the degree to which an individual specimen may deviate from the holotype is merely the opinion held by each investigator. Biometric studies that quantitatively define species and their limits of variation are clearly the answer to this problem, and such studies are increasingly being published for calcareous nannofossils (e.g., Backman, 1980; Firth, 1989; Young, 1990; Young and Westbroek, 1991; Wei, 1992; Wei et al., 1993; Bralower and Parrow, 1996). The purpose of our paper is to investigate biometrically the inter- and intraspecific variation of another of the calcareous nannofossils, the Cenozoic genus *Scyphosphaera,* which occurs as a frequent component in Leg 161 sediments (Siesser and de Kaenel, Chap. 16, this volume).

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## *SCYPHOSPHAERA* BIOMETRICS

Fifty-three scyphosphaerid species and one variety have been previously named, some on the basis of very minor shape differences. A cursory examination of a scyphosphaerid-rich slide will, however, reveal an inordinate number of specimens that do not correspond exactly with any of the previously named species. This wide intraspecific variation is probably the main reason why, out of frustration, so many investigators list this group simply as "*Scyphosphaera* spp." on range charts.

Most previous biometric studies of nannofossils have involved measuring size (length and width) of placoliths and their parts, or counting the numbers of discoaster rays. These are all readily measurable characteristics. A biometric study of the scyphosphaerids faces a very different problem. Size has not been used as a primary defining characteristic for any scyphosphaerid species, although a few have been partially defined by their length:width ratio (e.g., *S. brevisa, S. columella, S. praeglobulata, S. pseudorecurvata*), together with other characteristics. Size of the distal opening and the presence or absence of pores in the basal plate are also supplementary characteristics that have been used, but the primary defining characteristic of most scyphosphaerid species is the overall shape of the lopadolith as seen in plan view. The walls of scyphosphaerids may rise straight up, or angle upward, from the base; they may swell or constrict at different positions along the body; they may flare, recurve, or terminate simply at the distal end. No simple set of length:width measurements is able to quantify and define scyphosphaerids in a morphospecies context. For that reason, we have used a computer-driven image-analysis program (Sigmascan Pro) to quantify the overall shape of scyphosphaerids.

## METHODS

We have attempted to quantify the degree of difference or similarity among some of the more closely similar (in shape) scyphosphaerids that bear different species names. For reference, we have also compared some holotypes that are clearly different. Our method entails superimposing the shape of one holotype over that of another holotype and calculating the difference in the two shapes in terms of a "Similarity Index." Because scyphosphaerids are essentially symmetrical as seen in plan view, only half of the lopadolith, divided longitudinally, need be used. This half becomes a line in space, over which the line representing the shape of another species may be superimposed and compared (Figs. 1–5). In our study, we scanned the published image of the holotype of each scyphosphaerid species (using the Deskscan program), and transferred this image to the Sigmascan Pro image-analysis program. Data were then graphed using the Excel program. *Scyphosphaera apsteinii* is the exception to the "single holotype" image. Because Lohmann (1902) presented a coccosphere containing several lopadoliths as the biological type specimen, we scanned lopadoliths from this coccosphere as well as those presented by Deflandre (1942) to provide a composite image for our *S. apsteinii* "holotype."

The scanned images were plotted on an x:y graph, with the point where the wall begins to rise from the scyphosphaerid basal plate located at the origin of the graph, and the distal end of the lopadolith at the far right along the x-axis. All specimens were scaled to the same height (i.e., length along the x-axis, 0–100). Values for "y" were calculated for each of the 100 points along the x-axis, and the square of the deviation between the y-points at each x-point was then calculated to determine a measure we call the "Similarity Index" (Ψ). This may be expressed as:

$$\Psi = (y_2 - y_1)^2/1000,$$

where Ψ = Similarity Index (smallest number equals the greatest degree of similarity):

$y_1$ = species image one,

$y_2$ = species image two.

## RESULTS AND DISCUSSION

Results of the holotype comparisons are presented in Table 1. Graphs of a few of the comparisons are presented in Figs. 1–4.

A number of specimens of *S. abelei, S. apsteinii, S. conica, S. deflandrei*, *S. intermedia,* and *S. pulcherrima* were routinely identified during the biostratigraphic study of Holes 974B, 975B, and 978A (Siesser and de Kaenel, Chap. 16, this volume). These specimens were identified using what we believe to be conservative species concepts (i.e., close enough to the holotype illustrations to be readily acceptable identifications to most biostratigraphers). Randomly chosen specimens of species from Hole 975B, supplemented by specimens from ODP Hole 762B (Exmouth Plateau), were scanned and compared to the holotype of each species (e.g., Figs. 4, 5). *S. abelei* (mean Ψ = 5.0), *S. apsteinii* (mean Ψ = 5.7), *S. conica* (mean Ψ = 5.0), and *S. intermedia* (mean Ψ = 5.0) showed the least deviation from their holotypes (Table 2). As examples with wide intraspecific variation, specimens assigned to *S. deflandrei* (Ψ = 21.4) and *S. pulcherrima* (Ψ = 30.7) showed the most deviation from their holotypes.

Application of the Similarity Index to this natural population provides some guidelines as to how the index should be viewed. If Ψ values within a species population average 6 Ψ or less (intraspecific variation) for specimens conservatively identified as belonging to a given species, interspecific values of <6 Ψ should suggest conspecificity (Table 1). Caution is urged, however, in interpreting the Similarity Index in terms of synonymy. In some species, other characteristics may overrule the high similarity of wall shapes. For example, *S. graphica* and *S. apsteinii* (Fig. 2) have a high Similarity Index (Ψ = 1.5), but the dominant horizontal ribbing of *S. graphica* (only known on this species) primarily distinguishes it from small forms of *S. apsteinii.* As other examples, the sharp "edge" near the base of the lower part of the margin of *S. campanula* appears as a minor variation in the overall comparison of the shapes of the two curves of *S. campanula* and *S. amphora* (Fig. 1), so a high Similarity Index results (Ψ = 0.9). This edge is, however, a defining characteristic separating the two species. *S. columella* and *S. cylindrica* holotypes also have a high Similarity Index (Ψ = 2.1), but *S. columella* is distinguished by its tall height.

With these constraints in mind, we use this Similarity Index as complementary evidence suggesting that certain scyphosphaerid species may be conspecific. We do not believe the index, by itself, is as yet a sufficiently accurate measurement to classify biometrically the scyphosphaerids, but it is a first step toward developing a biometric technique suitable for application to scyphosphaerids.

## SUMMARY

Holotypes of a number of scyphosphaerids that appear to the eye to be closely related have been compared quantitatively using an image-analysis program. The method used here scales and superimposes holotype images and calculates the square of the deviation between the shapes. This gives an index of similarity for the two species. A Similarity Index of <6, suggests (but does not prove) conspecificity.

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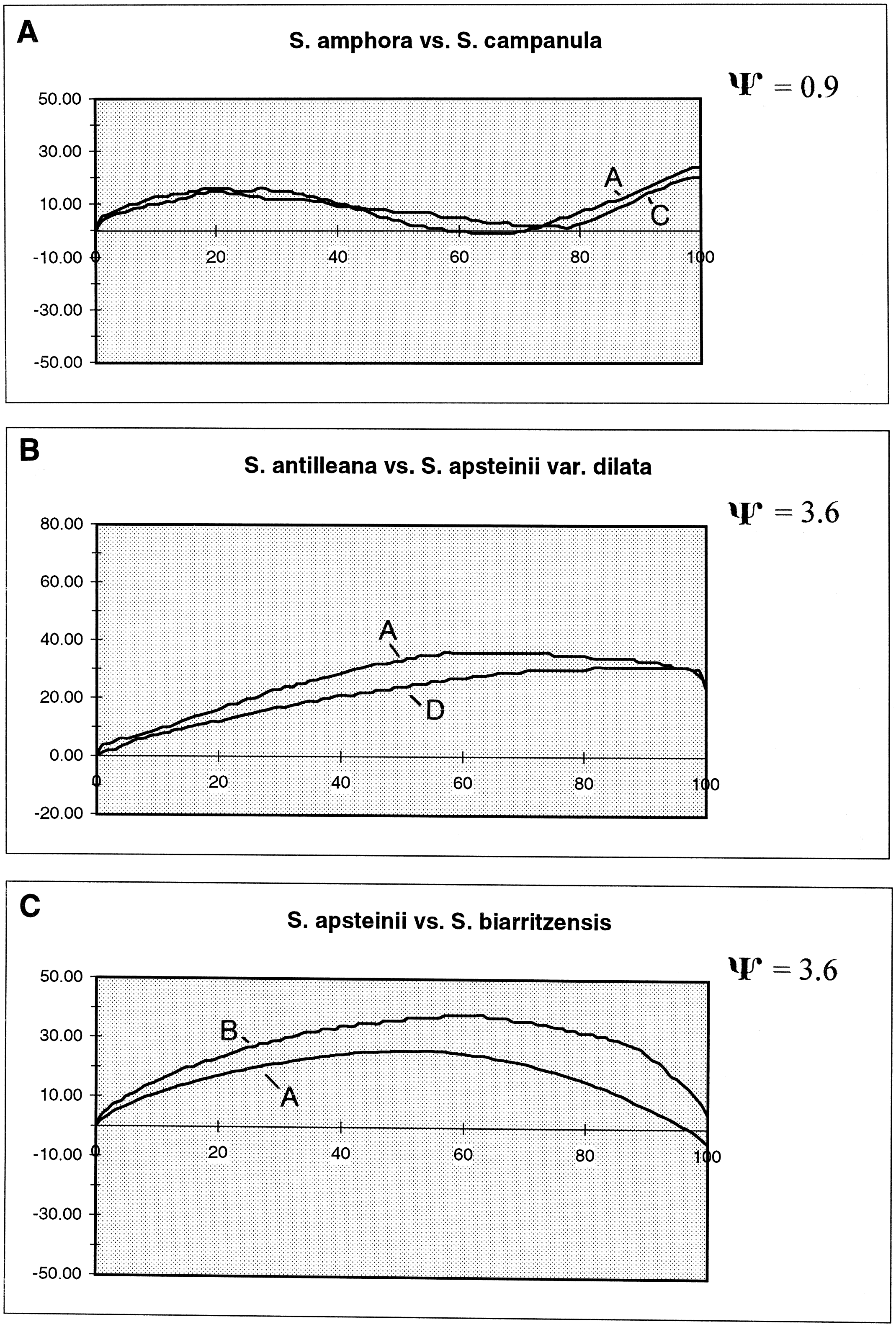


Figure 1. Comparison of holotypes of (**A**) *S. amphora* (A) vs. *S. campanula* (C); (**B**) *S. antilleana* (A) vs. *S. apsteinii* var. *dilata* (D); (**C**) *S. apsteinii* (A) vs. *S. biarritzensis* (B).

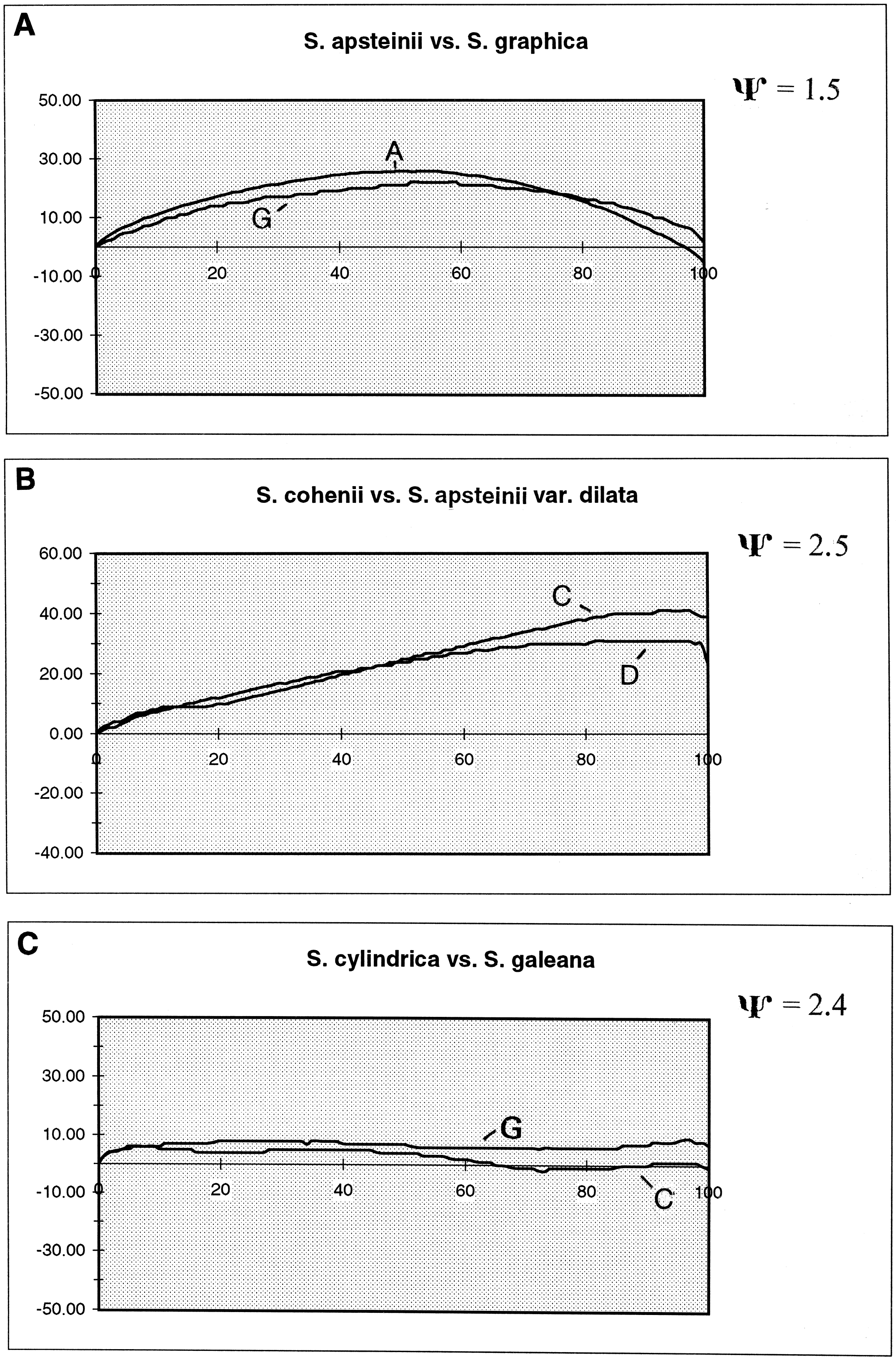


Figure 2. Comparison of holotypes of (**A**) *S. apsteinii* (A) vs. *S. graphica* (G); (**B**) *S. cohenii* (C) vs. *S. apsteinii* var. *dilata* (D); (**C**) *S. cylindrica* (C) vs. *S. galeana* (G).

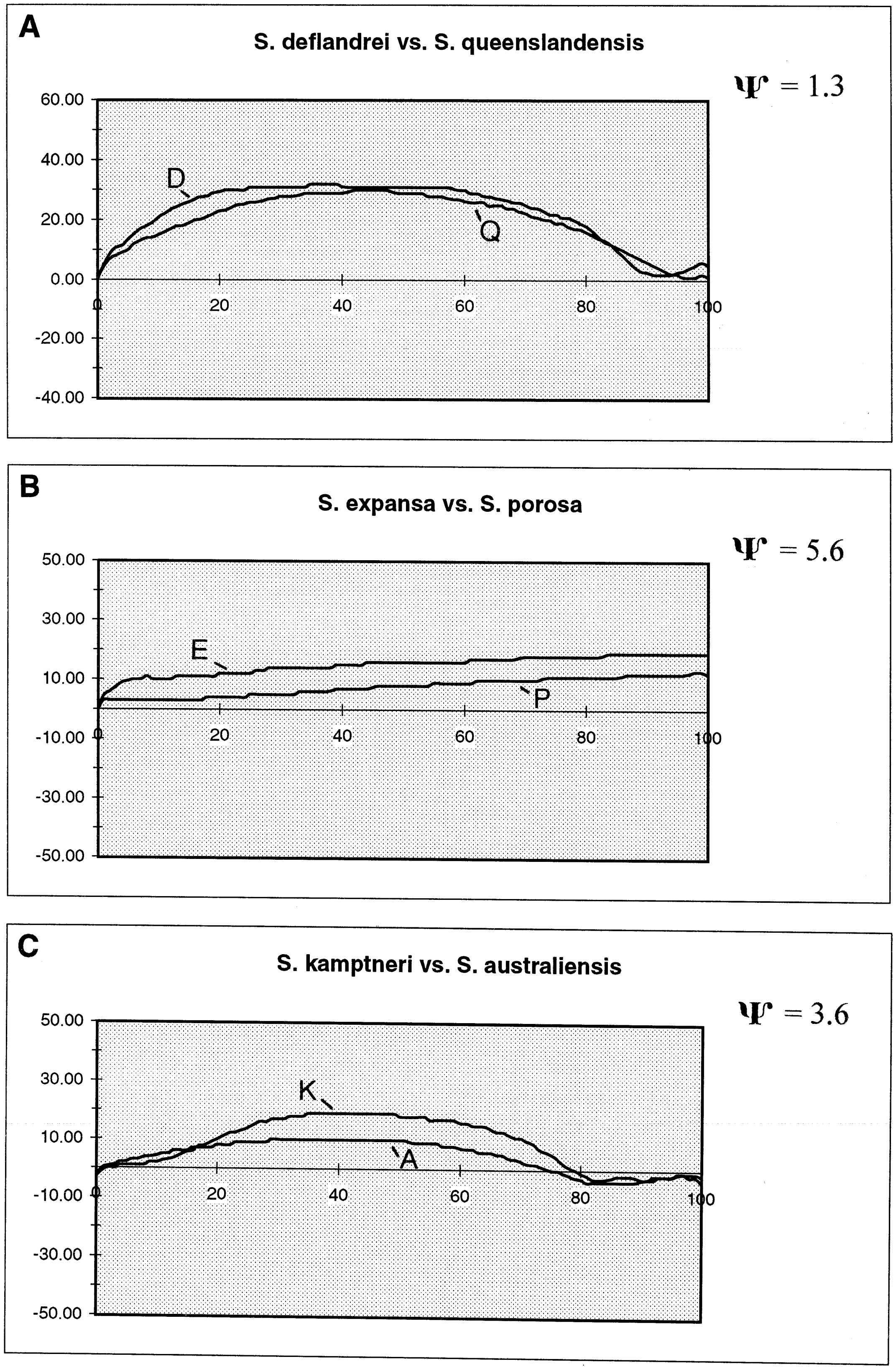


Figure 3. Comparison of holotypes of (**A**) *S. deflandrei* (D) vs. *S. queenslandensis* (Q); (**B**) *S. expansa* (E) vs. *S. porosa* (P); (**C**) *S. kamptneri* (K) vs. *S. australiensis* (A).

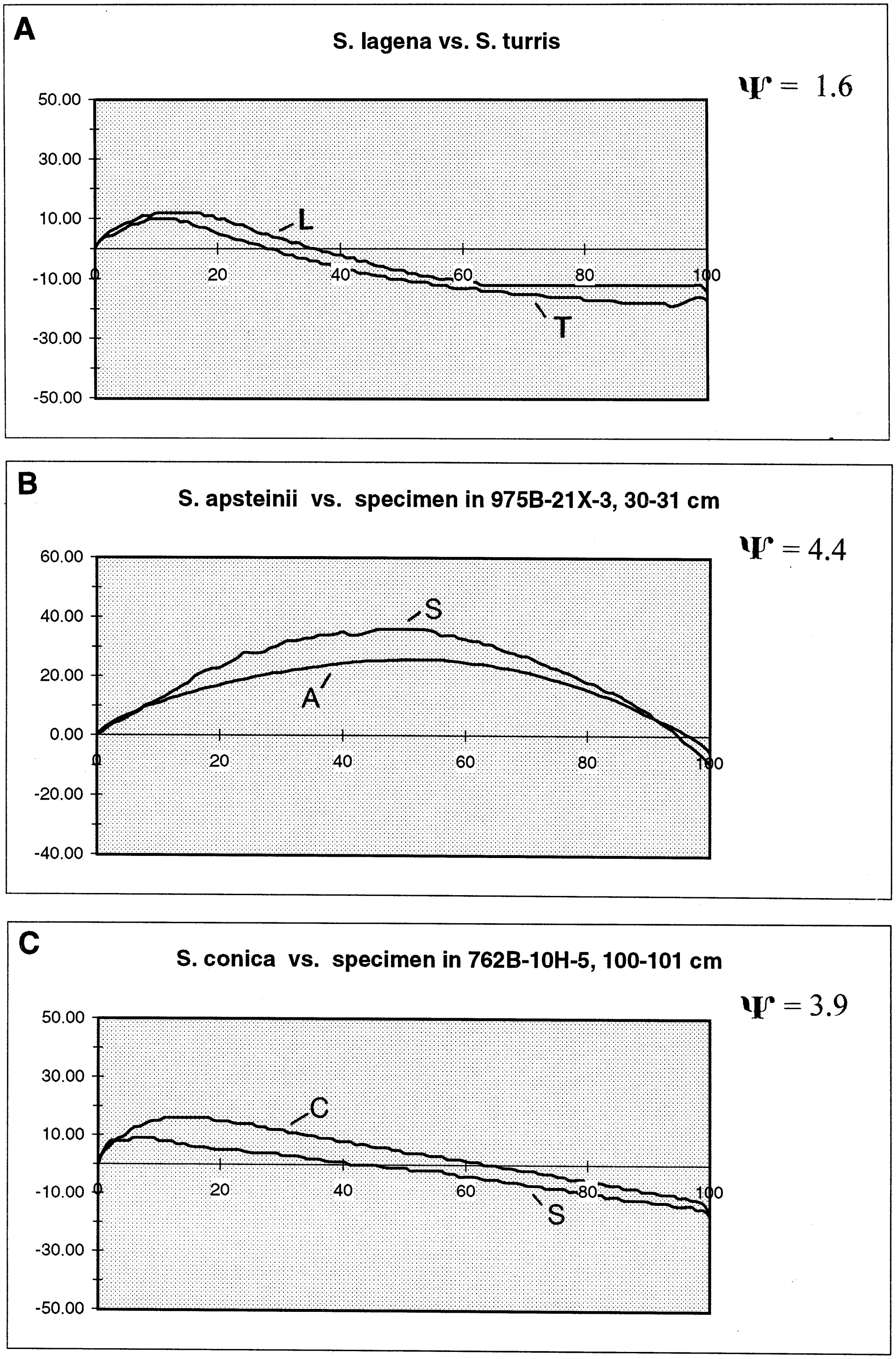


Figure 4. Comparison of holotypes of (**A**) *S. lagena* (L) vs. *S. turris* (T). Comparison of holotype to a randomly chosen specimen of the species (**B**) *S. apsteinii* (A) vs. specimen (S) in Sample 161-975B-21X-3, 30–31 cm; (**C**) *S. conica* (C) vs. specimen (S) in Sample 122-762B-10H-5, 100–101 cm.

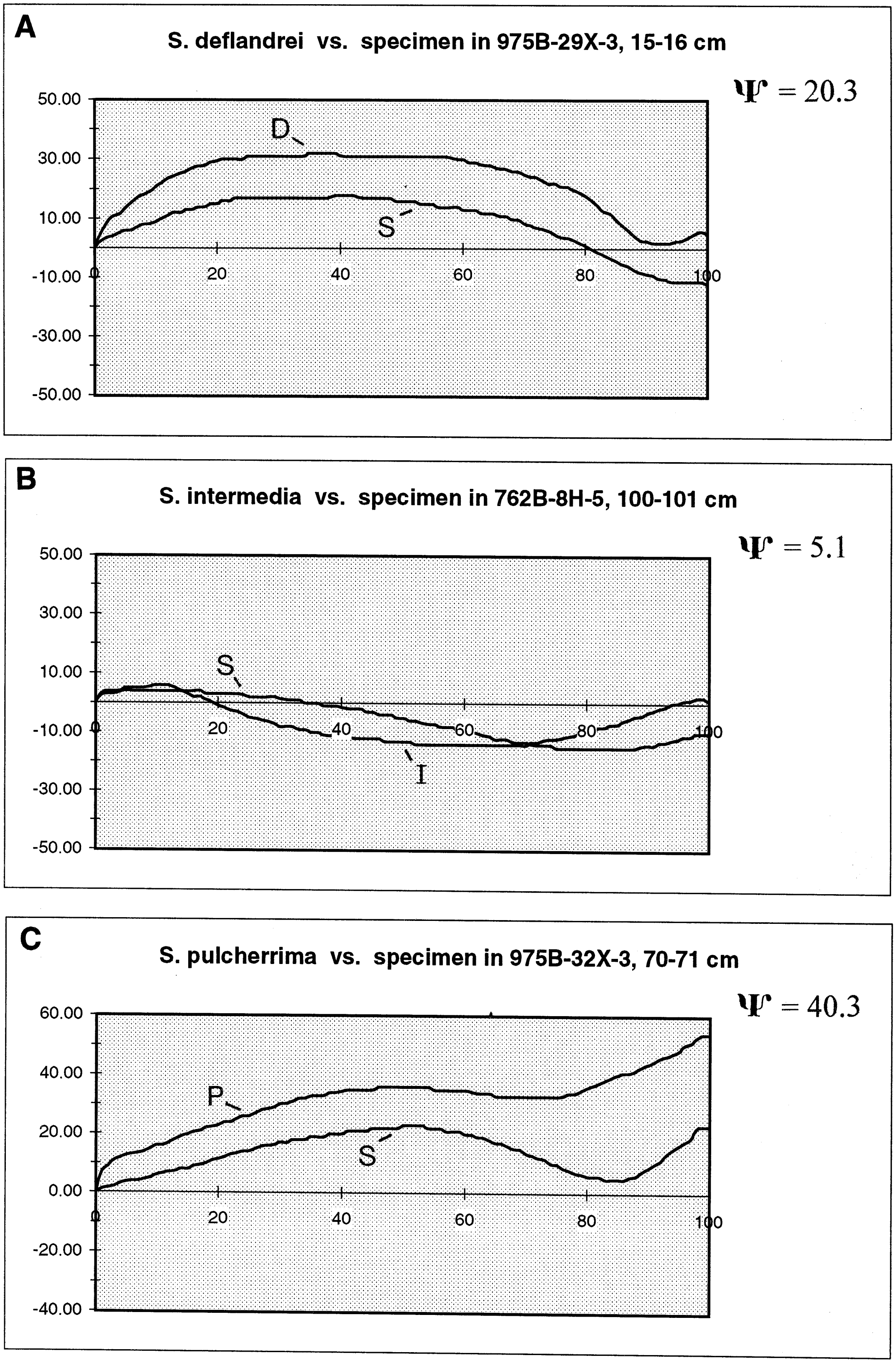


Figure 5. Comparison of holotype to a randomly chosen specimen of the species (**A**) *S. deflandrei* (D) vs. specimen (S) in Sample 161-975B-29X-3, 15–16 cm; (**B**) *S. intermedia* (I) vs. specimen (S) in Sample 122-762B-8H-5, 100–101 cm; (**C**) *S. pulcherrima* (P) vs. specimen (S) in Sample 161-975B-32X-3, 70–71 cm.

**Table 1. Similarity index comparison of *Scyphosphaera* holotypes.**

| Holotypes | Similarity index (Ψ) |
|---|---|
| *S. aequatorialis: S. abelei* | 10.6 |
| *S. aequatorialis: S. australiensis* | 6.4 |
| *S. aequatorialis: S. cantharellus* s.l. | 4.4 |
| *S. aequatorialis: S. pacifica* | 25.2 |
| *S. aequatorialis: S. queenslandensis* | 38.8 |
| *S. amphora: S. campanula* | 0.9 |
| *S. amphora: S. darraghi* | 10.6 |
| *S. amphora: S. halldalli* | 16.4 |
| *S. amphora: S. intermedia* | 28.0 |
| *S. amphora: S. pulcherrima* | 63.9 |
| *S. ampla*: *S. globulata* | 55.3 |
| *S. ampla*: *S. globulosa* | 36.3 |
| *S. antilleana: S. apsteinii* var. *dilata* | 3.6 |
| *S. apsteinii: S. antilleana* | 20.0 |
| *S. apsteinii: S. aranta* | 1.6 |
| *S. apsteinii: S. biarritzensis* | 3.6 |
| *S. apsteinii: S. brevisa* | 8.3 |
| *S. apsteinii: S. cohenii* | 22.1 |
| *S. apsteinii: S. apsteinii* var. *dilata* | 14.9 |
| *S. apsteinii: S. graphica* | 1.5 |
| *S. australiensis*: *S. pacifica* | 8.5 |
| *S. canescens*: *S. columella* | 9.8 |
| *S. canescens*: *S. cylindrica* | 3.4 |
| *S. cantharellus* s.s.: *S. cantharellus* s.l. | 0.5 |
| *S. cohenii*: *S. apsteinii* var. *dilata* | 2.5 |
| *S. cohenii*: *S. antilleana* | 4.5 |
| *S. conica: S. lagena* | 6.6 |
| *S. cylindrica: S. columella* | 2.1 |
| *S. cylindrica: S. galeana* | 2.4 |
| *S. cylindrica: S. graphica* | 20.4 |
| *S. cylindrica: S. hemirana* | 9.3 |
| *S. cylindrica: S. penna* | 3.7 |
| *S. deflandrei*: *S. abelei* | 15.3 |
| *S. deflandrei*: *S. gladstonensis* | 18.0 |
| *S. deflandrei*: *S. kamptneri* | 13.1 |
| *S. deflandrei*: *S. queenslandensis* | 1.3 |
| *S. deflandrei: S. rottiensis* | 20.9 |
| *S. deflandrei: S. ventriosa* | 11.2 |
| *S. expansa: S. inversiconica* | 9.7 |
| *S. expansa: S. porosa* | 5.6 |
| *S. galeana: S. columella* | 7.8 |
| *S. halldalli: S. campanula* | 19.1 |
| *S. halldalli: S. darraghi* | 10.4 |
| *S. intermedia: S. campanula* | 26.8 |
| *S. intermedia: S. magna* | 8.5 |
| *S. intermedia: S. quasitubifera* | 2.6 |
| *S. kamptneri: S. australiensis* | 3.6 |
| *S. kamptneri: S. gladstonensis* | 6.1 |
| *S. kamptneri: S. pacifica* | 2.1 |
| *S. kamptneri: S. queenslandensis* | 7.2 |
| *S. lagena: S. martinii* | 14.5 |
| *S. lagena: S. tubicena* | 25.2 |
| *S. lagena: S. tubifera* | 4.3 |
| *S. lagena: S. turris* | 1.6 |
| *S. magna: S. quasitubifera* | 14.6 |
| *S. pacifica: S. gladstonensis* | 8.0 |
| *S. porosa: S. inversiconica* | 28.9 |
| *S. praeglobulata: S. pseudorecurvata* | 30.0 |
| *S. pulcherrima: S. campanula* | 63.9 |
| *S. pulcherrima: S. darraghi* | 34.8 |
| *S. pulcherrima: S. halldalli* | 22.2 |
| *S. tubifera: S. martinii* | 6.5 |
| *S. tubifera: S. tubicena* | 15.9 |
| *S. tubifera: S. turris* | 4.3 |
| *S. turris: S. martinii* | 8.5 |
| *S. turris: S. tubicena* | 16.0 |

**Table 2. Similarity index comparison of species holotype to randomly chosen specimens of the species.**

| Species in sample: | | Similarity index (Ψ) |
|---|---|---|
| *S. abelei* | | |
| 161-975B- | | |
| 26X-3, 28-29 | | 13.4 |
| 26X-3, 28-29 | | 0.6 |
| 122-762B- | | |
| 9H-5, 100-101 | | 3.3 |
| 11H-6, 100-101 | | 1.0 |
| 11H-6, 100-101 | | 2.2 |
| 11H-6, 100-101 | | 9.7 |
| | Range: | 0.6-13.4 |
| | Mean: | 5.0 |
| *S. apsteinii* | | |
| 161-975B- | | |
| 17X-3, 40-41 | | 13.3 |
| 21X-3, 30-31 | | 1.3 |
| 21X-3, 30-31 | | 4.4 |
| 25X-3, 19-20 | | 0.8 |
| 25X-3, 19-20 | | 8.7 |
| 29X-3, 15-16 | | 0.2 |
| 29X-3, 15-16 | | 3.4 |
| 32X-3, 70-71 | | 1.8 |
| 32X-3, 70-71 | | 11.7 |
| 122-762B- | | |
| 3H-3, 100-101 | | 2.4 |
| 3H-3, 100-101 | | 16.5 |
| 4H-3, 100-101 | | 3.1 |
| 7H-3, 100-101 | | 6.0 |
| 9H-5, 100-101 | | 0.7 |
| 10H-5, 100-101 | | 18.6 |
| 11H-1, 100-101 | | 4.7 |
| 11H-1, 100-101 | | 10.0 |
| 11H-6, 100-101 | | 1.4 |
| 15H-2, 100-101 | | 4.6 |
| 18H-1, 100-101 | | 0.8 |
| | Range: | 0.2-16.5 |
| | Mean: | 5.7 |
| *S. conica* | | |
| 122-762B- | | |
| 8H-5, 100-101 | | 14.2 |
| 10H-5, 100-101 | | 0.3 |
| 10H-5, 100-101 | | 3.9 |
| 10H-5, 100-101 | | 6.9 |
| 11H-1, 100-101 | | 1.9 |
| 11H-1, 100-101 | | 3.6 |
| 11H-1, 100-101 | | 4.3 |
| | Range: | 0.3-14.2 |
| | Mean: | 5.0 |
| *S. deflandrei* | | |
| 161-975B- | | |
| 19X-3, 79-80 | | 16.9 |
| 22X-3, 40-41 | | 12.2 |
| 26X-3, 28-29 | | 31.9 |
| 26X-3, 28-29 | | 33.8 |
| 29X-3, 15-16 | | 1.4 |
| 29X-3, 15-16 | | 20.3 |
| 29X-3, 15-16 | | 31.6 |
| 122-762B- | | |
| 3H-3, 100-101 | | 4.6 |
| 9H-5, 100-101 | | 55.0 |
| 10H-5, 100-101 | | 9.1 |
| 10H-5, 100-101 | | 29.5 |
| 11H-1, 100-101 | | 10.7 |
| | Range: | 1.4-55.0 |
| | Mean: | 21.4 |
| *S. intermedia* | | |
| 161-975B- | | |
| 31X-3, 47-48 | | 13.8 |
| 122-762B- | | |
| 8H-5, 100-101 | | 5.1 |
| 9H-5, 100-101 | | 4.2 |
| 11H-6, 100-101 | | 3.8 |
| 12H-2, 100-101 | | 2.4 |
| 12H-2, 100-101 | | 4.6 |
| 13H-1, 100-101 | | 1.3 |
| | Range: | 1.3-13.8 |
| | Mean: | 5.0 |
| *S. pulcherrima* | | |
| 161-975B- | | |
| 17X-3, 40-41 | | 50.5 |
| 32X-3, 70-71 | | 40.3 |
| 122-762B- | | |
| 3H-3, 100-101 | | 32.8 |
| 5H-5, 100-101 | | 4.9 |
| 7H-3, 100-101 | | 41.1 |
| 9H-5, 100-101 | | 59.5 |
| 10H-5, 100-101 | | 5.9 |
| 12H-2, 100-101 | | 14.6 |
| 12H-CC | | 18.9 |
| 18H-1, 100-101 | | 38.4 |
| | Range: | 4.9-59.5 |
| | Mean: | 30.7 |