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CLUSTER ANALYSIS OF TRAWL COLLECTED DECAPOD CRUSTACEA FROM THE SOUTH ATLANTIC BIGHT

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INTRODUCTION

The decapod Crustacea of the Carolinian shelf province, extending from Cape Hatteras, North Carolina to Cape Canaveral, Florida (Briggs, 1974) have been the subject of numerous systematic and ecological accounts, although few species have been studied in detail (Williams,1965) and information on the spatial and temporal distributional patterns of multispecies assemblages of Decapoda from the South Atlantic Bight is lacking. This is not surprising in view of the extensive collecting efforts needed to reveal latitudinal as well as bathymetic patterns of distribution on a seasonal basis within such a large geographic area. Through samples collected as part of MARMAP (Marine Resources Monitoring Assessment and Prediction Program) we were able to collect data to supplement previously published information about the ecology of decapod Crustacea from the South Atlantic Bight.

We have prepared a manuscript (Seasonal Community Composition and Abundance of Decapod Crustacea from the South Atlantic Bight) in which we: 1) described the assemblages of decapod Crustacea collected within the South Atlantic Bight from both sand and live bottom habitats, 2) examined changes in these assemblages with depth, season and latitude, 3) provided estimates of relative decapod abundance and 4) correlated their abundance with biological and physical factors where possible. Due to journal restraints on publication of figures, we were not able to include complete results of cluster and nodal analyses in the manuscript. Our purpose in preparing this report is to present these results which otherwise would be unavailable in a published manuscript.

We gratefully acknowledge B.B. Boothe, Jr. (Smithsonian Institution) for his identification of the Reptantia on which the current study is based. A.B. Williams (National Marine Fisheries Service) and L. Pequegnat (Texas A & M University) also provided identifications and advice on systematic status of several species.

Programs for diversity and cluster analysis were kindly provided by D. Boesch and W. Blystone of the Virginia Institute of Marine Science. Analyses would not have been possible without the invaluable help of C. Brosseau, G. Gash, N. Kopacka and D. Machowski of the South Carolina Marine Resources Research Institute.

We also wish to thank C.A. Barans, V.G. Burrell, Jr. and R.K. Keiser for initiating the collection of invertebrates during MARMAP cruises. We are especially grateful to the crew of the R/V Dolphin and the scientific personnel who assisted with collection in the field.

This work is a result of research sponsored by the National Marine Fisheries Service (MARMAP Program Office) under Contract Number 6-35147 and by the South Carolina Wildlife and Marine Resources Department.

METHODS AND MATERIALS

Samples of decapod Crustacea were collected at 496 randomly located stations within depth zones of 9-18 m, 19-27 m, 28-55 m, 56-110 m, 111-183 m, 184-366 m, in the South Atlantic Bight between Cape Fear, North Carolina and Cape

Canaveral, Florida.

Wenner et al. (1979) indicated that these depth zones may be defined in terms of the continental shelf habitats described by Struhsaker (1969); i.e., the 9-18 m depth zone is equivalent to the coastal habitat, the 19-27 m and 28-55 m depth zones are equivalent to the open shelf habitat, and the 56-110 m and 111-183 m depth zones coincide with the shelf edge and lower shelf habitats.

All collections were made with a 3/4 scale version of a Yankee No. 36 trawl (Wilk and Silverman, 1976) which has a 16.5 m footrope, an 11.9 m headrope and a 1.3 m stretch mesh codend liner. Tows were made from the 32.6 m R/V Dolphin at a speed of 6.5 km/h and were 0.5-h in duration. Catches of Decapoda taken during tows in which the net was damaged, failed to reach bottom or became twisted during the tow were not included in analyses. At live bottom stations no quantitative collections of Decapoda were made of microhabitats, such as sponges. A station was considered to be in the live bottom habitat when the catch contained large amounts of sponges and/or corals and associated fish species (Wenner, et al., 1979).

All decapod Crustacea collected were preserved in 10% seawater formalin and returned to the laboratory where they were transferred to 40% isopropanol, identified to species or the lowest possible taxon and counted.

Numerical classification or cluster analysis was used to determine species associations and distributional patterns. Prior to analysis, the data were reduced by elimination of species which occurred at only one or two stations occupied during a sampling season. Similarly, stations were eliminated from analysis if they contained only one species prior to or after data reduction. These data reductions were necessary because species which occur at only one or two stations generally lack a detectable distribution pattern (Boesch, 1973) and stations which contain only one species augment confusion in interpretation of site cluster analysis and do not give a representative catch of the decapod fauna.

After data reduction, numerical classification analysis was performed on quantitative collections from each season using the program COMPAH. Algorithms used included a combination of square root transformation ($\sqrt{n}$), the Canberra metric similarity measure and flexible sorting with $\beta = -0.25$ (Clifford and Stephenson, 1975; Boesch, 1977). The Canberra metric similarity coefficient (Lance and Williams, 1967) was chosen because it is effective when organisms are contagiously distributed (common among benthic organisms) and because it gives rare species as much weight in determining similarity as abundant species (Boesch, 1977). Therefore, with the use of the Canberra metric similarity coefficient, an outstandingly abundant species does not dominate the index (Clifford and Stephenson, 1975). Because the Canberra metric measure is insensitive to large values and can be used with data which contains abundant as well as rare species, it may be used with a mild transformation such as square root (Clifford and Stephenson, 1975).

Post-clustering techniques of nodal analysis (Williams and Lambert, 1961; Lambert and Williams, 1962) were employed to examine species and site group coincidences in order to identify missclassifications and to describe site groups in terms of their characteristic species and species groups in terms of their occurrence within site groups. Nodal analysis interpretations were made using patterns of constancy (a measure of how consistently a species is found in a site group) and fidelity (a measure of how restricted a species group is to a site group). Both constancy and fidelity are qualitative measures and imply nothing about the abundance of species. Constancy has a value of one when all species occur in all collections in a site group and zero when none of the species occur in the collections in the group. The fidelity index ranges from values greater than 2, suggesting strong association of species with a site group, to less than 1, which suggests "negative" association of species with a site group (Boesch, 1977).

RESULTS

Fall

Normal classification showed six site groups which correspond to coastal (group 1), open shelf (groups 2 and 3), outer shelf (groups 4 and 5) and upper slope (group 6) areas (Fig. 1). The depths of the site groups overlapped, indicating that the fauna associated with these site groups are relatively homogenous with major differences of Decapoda occurring only between the open shelf and outer shelf groups. Two stations were misclassified in the fall site cluster: one station at 75 m within site group 1 contained *Portunus spinimanus*, *Ovalipes stephensoni*, *Calappa flammea* and *Anasimus latus*, species which were also found within other stations in site group 1; and a station at 38 m within site group 4 which contained *Portunus spincarpus*, a species found in the other stations in the site group also.

The inverse cluster showed six species groups whose distribution patterns also appear to be related to depth (Fig. 2). Group A consisted of species which are associated with the inner shelf: *Portunus gibbesii* (surface to 88 m on mud, sand and broken shell: Powers, 1977), *Portunus spinimanus* (surface to 90 m on sand, gravel, broken shell, mud: Williams, 1965; Powers, 1977), *Trachypenaeus constrictus* (to 59 m; Chace, 1972), *Penaeus duorarum* (mostly to 50 m on sand, shell, mud: Williams, 1965) and *Calappa flammea* (mostly 11-29 m on hard bottoms, primarily sand: Williams, 1965; Powers, 1977). Group B species were found in slightly deeper water: *Dardanus venosus* (to 90 m on sand and mud: Williams, 1965) and *Porcellana sayana* (shallow to 86 m among rocks of jetties and clusters of oyster shells: Williams, 1965). Group C species included *Metapenaeopsis goodei* (surface to 329 m on sand or shell: Chace, 1972), *Dardanus insignis* (27-223 m: Williams, 1965) and *Scyllarus chacei* (16-180 m; Williams, 1965) which are inhabitants of the mid-shelf. Group D species included *Anasimus latus* (47-158 m on sand, coral, mud and shell: Williams, 1965) and *Stenorynchus seticornis* (most common $\leq$ 180 m on rock, coral rock, sand, pebbles, sponges: Williams, 1965; Powers, 1977). Group E contained numerically-dominant decapods of the mid to outer continental shelf: *Solenocera atlantidis* (most abundant at < 75 m on mud, shells, sand, coral and sponges: Williams, 1965; Powers, 1977), *Mesopenaeus tropicalis* (30-915 m, most abundant near shelf edge: Perez Farfante, 1977), Sicyonia brevirostris (73-411 m on mud but also on shelly sand: Cobb et al., 1973; Chace 1972), and Portunus spinicarpus (9-540 m on sand, gravel, coral, broken shell and mud: Williams, 1965; Powers, 1977) Group F contained species found mostly on the outer shelf-upper slope: Munida irrasa (54-468 m: Williams, 1965), Calappa angusta (13-270 m: Williams, 1965), Parapenaeus longirostris (25-350 m on soft mud or muddy sand bottoms: Williams, 1965), and Processa profunda (185-348 m on mud: Manning and Chace, 1971).

Species Group A was relatively eurybathic, being consistently collected at stations within site group 1 and also occurring in groups 2 and 3 (Fig. 3). This group was not restricted to any site group, however (Fig. 4). Group B species were restricted to site group 2 but they did not occur at many stations within this site group as indicated by the moderate constancy value. Group C species were not frequently encountered or restricted to any site group, although these species did occur in groups 2 and 5. Group D species displayed moderate constancy and fidelity to stations in site group 5. Group E species were eurybathic, being found at stations in site groups 2, 4, 5 and 6. However, these species were consistently collected at stations in site group 5 but were not faithful to any site group. Group F species were mostly collected at the deepest stations (site group 6), and these species were also restricted to this site group.

Winter

Seven site groups were present during winter months: Groups 1 and 2 were located on the coastal continental shelf; groups 3 and 4 were located on the open shelf; groups 5 and 6 were located on the outer shelf and group 7 occurred at the deepest depths sampled on the upper slope (Fig. 5). Misclassifications included stations at 232 and 110 m which clustered with shallow mid-shelf stations in site group 5 because they had a few species in common with the other stations. The three shallow stations at 68, 79 and 24 m occurred with deeper stations in site group 6 because these 3 stations contained only 2 species, Sicyonia brevirostris and Mesopenaeus tropicalis.

Inverse cluster analysis showed six species groups were present: an inner shelf group (Group D), mid-shelf groups (A,B,C,E) and an outer shelf group (F) (Fig. 6).

Species group A consisted of eurybathic species which occurred from the coastal shelf to shelf edge. These species were not overly abundant within winter collections.

Species group B were infrequently-collected species found from the coastal habitat to 45 m.

Species group C contained species which are abundant at mid-shelf depths. Metapenaeopsis goodei, Sicyonia brevirostris, Scyllacus chacei, Solenocera atlantidis and Mesopenaeus tropicalis are particularly abundant mid-shelf species and occurred mostly on sand bottom. Petrochirus diogenes, Parthenope serrata, Portunus spinicapus and Processa vicina were less abundant species which also occurred on sand bottoms. Collodes trispinosus and Porcellana sayana occurred on rocks and gravel predominantly.

Species group D contained inner

shelf species as well as live bottom species. Predominant inshore sand species included *Trachypenaeus constrictus*, *Ovalipes stephensoni*, and *Portunus gibbesii*. Species associated with live bottom areas included *Stenorynchus seticornis*, *Parthenope fraterculus*, *Dromidia antillensis*, *Stenocionops furcata coelata*, *Synalpheus townsendi*, *Pilumnus sayi*, *Podochela sidneyi* and *Podochela gracilipes*.

Species group E consisted of Decapoda which were found on the open shelf. *Pachycheles rugimanus*, *Pseudomedaeus agassizi* and *Mithrax forceps* were primarily found on rocks or coral and in sponges, whereas *Scyllarus depressus*, *Dardanus venosus* and *Portunus spinimanus* occurred on sandy substrates.

Species in Group F occurred on the outer continental shelf and upper continental slope. These species were restricted to these deeper depths.

Species in group A were collected infrequently but were restricted to site group 4 (Fig. 7 and 8). Group B species were collected infrequently but were found exclusively at site group 2. Species in group C were eurybathic, being found in site groups 2, 4 and 6; however, these species were not frequently caught at stations in any of these site groups, and they showed only moderate constancy to site group 4. Species group D was collected at few stations in site groups 1 and 2 and was not restricted to any site group. Species group E was restricted to site group 3 where it was caught infrequently. Species group F was most faithful to stations in site group 7 but was found infrequently at stations in site groups 6 and 7.

Spring

Normal classification analysis showed that 5 groups of stations were present in the spring: coastal shelf groups (1 and 2) open-outer shelf groups (3 and 4) and an upper slope group (5) (Fig. 9). Groups 1-4 showed a large amount of overlap with regard to depth while group 5 was relatively discreet bathymetrically and faunistically from these other groups. Several stations appeared to be misclassified: in group 2 a station at 124 m contained only *Sicyonia brevirostris* and *Ovalipes stephensoni* which grouped it with shallower stations also containing these species; in group 3 stations at 33 and 22 m occurred with those deeper because they contained similar species, *Collodes trispinosus* and *Sicyonia brevirostris*; in group 4, two deep stations at 124 and 144 m occurred with shallower stations because they all contained species such as *Solenocera atlantidis* and *Mesopenaeus tropicalis*; a station at 126 m occurred with those deeper because it contained *Cancer irroratus* and *Rochinia crassa* which were abundant at the deeper stations, also.

The inverse cluster indicated that 5 species assemblages were present on the continental shelf (Fig. 10) during the spring. Group A consists of species which were found on the inner continental shelf on a variety of bottom types: *Trachypenaeus constrictus* is found from estuaries to 59 m (Williams, 1965); *Sicyonia typica* is found from tidal marks to 68 m (Chace, 1972); *Scyllarus chacei* occurs from 16-180 m (Williams, 1965); *Coelocerus spinosus* occurs on sand, rock and coral at depths from 23-63 m (Williams, 1965; Powers, 1977), and *Pilumnus sayi* occurs on sand, shell, rock, coral and gravel from low water to 88 m (Williams, 1965; Powers, 1977).

Group B contains the portunid crabs Portunus spinimanus, Portunus gibbesii and Ovalipes stephensoni. Group C contains eurybathic species found on a variety of bottoms at mid-shelf depths. Some of these species are frequently associated with live bottom habitats: Parthenope serrata occurs mostly on sand and mud, although it is found on coral also, from shallow water to 108 m, (Williams, 1965); Stenocionops furcata coelata occurs on coarse bottoms and on shelly reefs in shallow water to 108 m (Williams, 1965); Stenorynchus seticornis; Parthenope agona is found on sand, broken shell, mud, at 45-385 m (Williams, 1965); Petrochirus diogenes; and Collodes trispinosus which is found on sands of varying coarseness, shell, gravel at 7-148 m (Williams, 1965). Group D contains abundant eurybathic mid-shelf species Anasimus latus, Portunus spinicarpus, Sicyonia brevirostris, Mesopenaeus tropicalis, Solenocera atlantidis and Calappa flammea. Group E contains species which were associated with deeper water and were found on the shelf edge to upper slope: Cancer irroratus (usually coarse substrates, deeper south of Cape Hatteras, out to 565 m) and Rochinia crassa (128-860 m, on mud, sand and coral ooze).

Patterns of nodal constancy (Fig. 11) and fidelity (Fig. 12) indicated that species in group A were not consistently collected in site group 1 but were restricted to that site group on the inner shelf. These species are apparently stenobathic. Species in group B were most frequently collected at stations in site group 2 and were restricted to this site group. Species in group C are eurybathic, being found at stations in site groups 1 and 3; these species, however, were not consistently collected at these site groups as shown by moderate to low constancy values, but they were highly faithful to site group 3. Species in group D were also eurybathic, being found in site groups 1, 3 and 4; these species were most consistently collected at stations in site group 4 but were not restricted to any site group. Group E species were consistently collected at and restricted to the deepest site group (5).

Summer

Normal cluster analysis showed that the six site groups present in summer corresponded to areas on the coastal (group 1), open shelf (groups 2-4), outer continental shelf (group 6) and upper slope (group 5) (Fig. 13). The depths associated with stations in these site groups overlapped broadly (Fig. 13). Some of this overlap is due to 3 misclassified stations: one station at 247 m occurred in site group 4 because it contained only 3 species (1 individual each); one station at 16 m occurred in site group 5 because it contained Solenocera atlantidis and Cancer irroratus which are deeper dwelling species; one station at 17 m occurred with deeper stations in site group 6 because it contained only 2 species (1 individual each). These collections with few species and individuals have low similarity with other stations in other groups and were simply placed within a station group which contained stations with these species.

Inverse cluster analysis showed that 6 species groups were present (Fig. 14). Groups A, B and C consisted of species which are located on the inner shelf. Among group A species, Synalpheus townsendi, occurs in large sponges, turtle grass flats and eroded dead coral at low water to 102 m (Chace, 1972); Pseudomedaeus agassizi is found in sponges, sand, shell, rock, coral from 11-81 m (Williams, 1965); Carpoporus papulosus occurs on sand, shell, coral at 32-112 m (Williams, 1965; Powers, 1977); and Micropanope sculptipes occurs on sand, coral, shell and gravel from 9-306 m (Powers, 1977). These species are found on a variety of bottoms but are primarily associated with the inshore sponge-coral habitat or live bottom. Munida iris iris is a eurybathic species (70-730 m) which is mostly associated with sand or shell bottoms (Williams, 1965). Dardanus insignis and Parthenope fraterculus are also eurybathic species which were found on a variety of substrates.

Group B species were eurybathic and not overly abundant anywhere. These species occurred on predominantly sand or shell bottoms.

Species in group C generally occurred only at inner shelf depths and were numerically abundant there. Trachypenaeus constrictus, Ovalipes stephensoni, Portunus spinimanus and Portunus gibbesii were the most frequently encountered and abundant decapod species on the inner shelf. Calappa flammea, Sicyonia typica, Callinectes sapidus and Podochela sidneyi were much less abundant but were associated with these near shore depths.

Species in group D occurred on the open shelf and were primarily associated with the rocky outcrop habitat, an area with hard bottom and epifaunal growth. Species which we found to be associated with this offshore hard bottom habitat were Dromidia antillensis, Macrocoeloma trispinosum, Porcellana sayana, Mithrax pleuracanthus, and Pilumnus sayi.

Group E species were frequently encountered at depths on the mid to outer continental shelf and were mostly found on sand bottoms. Sicyonia brevirostris, Metapenaeopsis goodei, Scyllarus chacei and Solenocera atlantidis were abundant at depts < 110 m on the continental shelf. The other species in group E were not as numerically important but were nevertheless characteristic of the open shelf habitat.

Group F species were mostly found on the outer continental shelf and upper continental slope. These species formed a tight group which was clearly separated by cluster distance from shallower species groups.

Species group A was not collected at many stations in site group 4, although it was restricted to this site group (Fig. 15 & 16). Species group B was infrequently collected although it showed moderate fidelity to site group 4. Species group C was eurybathic and found at site groups 1-4. Species in group C were not consistently collected at stations in any site group and showed only moderate faithfulness to group 1. Group D species were infrequently collected and showed no restriction to any one site group. Group E species were most consistently located in site group 2 and were restricted to this site group also. Group F species were entirely associated with site group 5 although species in this group were not collected at many stations in that site group.

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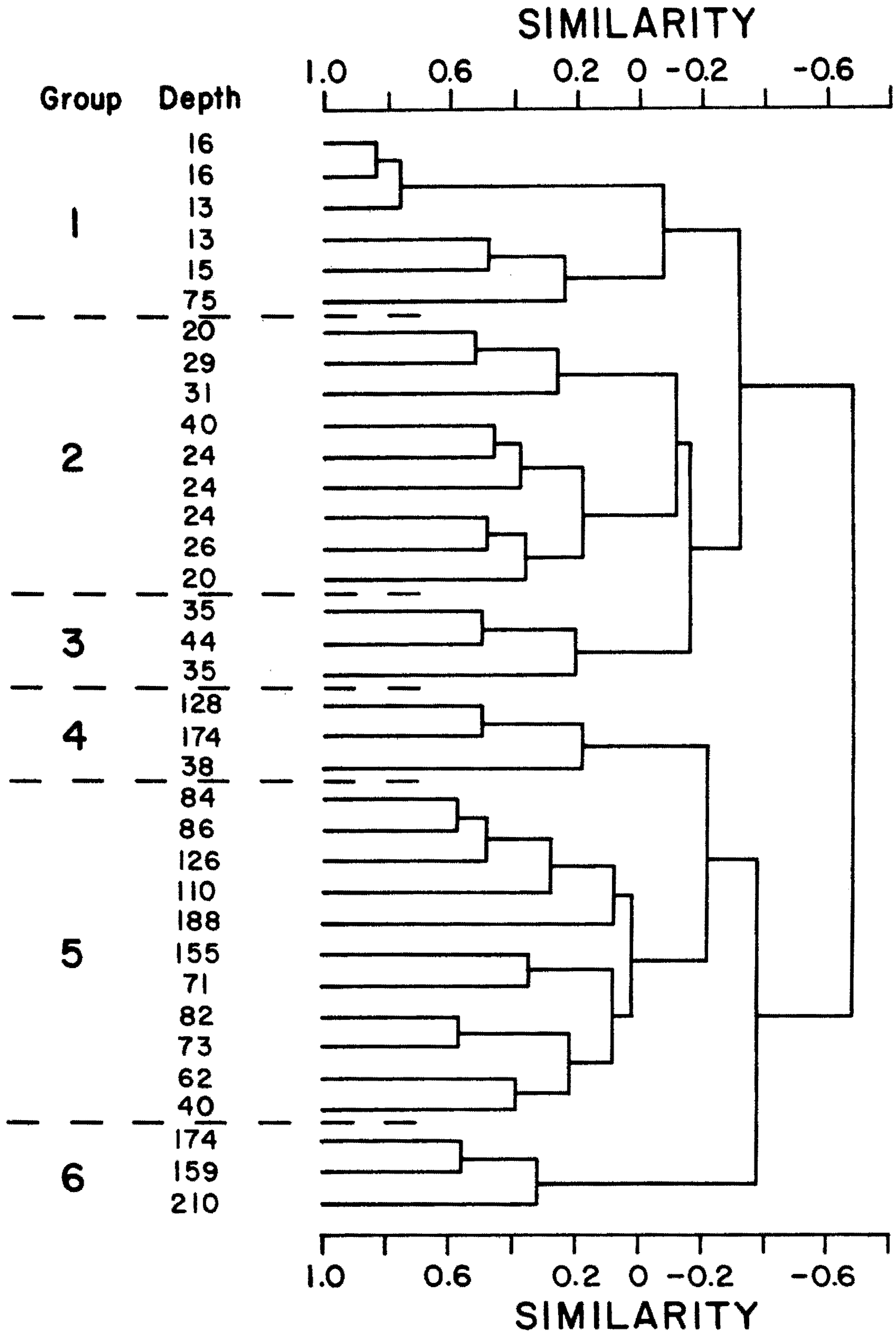


FIGURE 1. DENDROGRAM OF STATIONS FROM FALL SAMPLING PRODUCED BY NORMAL ANALYSIS USING SQUARE ROOT TRANSFORMATION, FLEXIBLE SORTING AND THE CANBERRA METRIC COEFFICIENT.

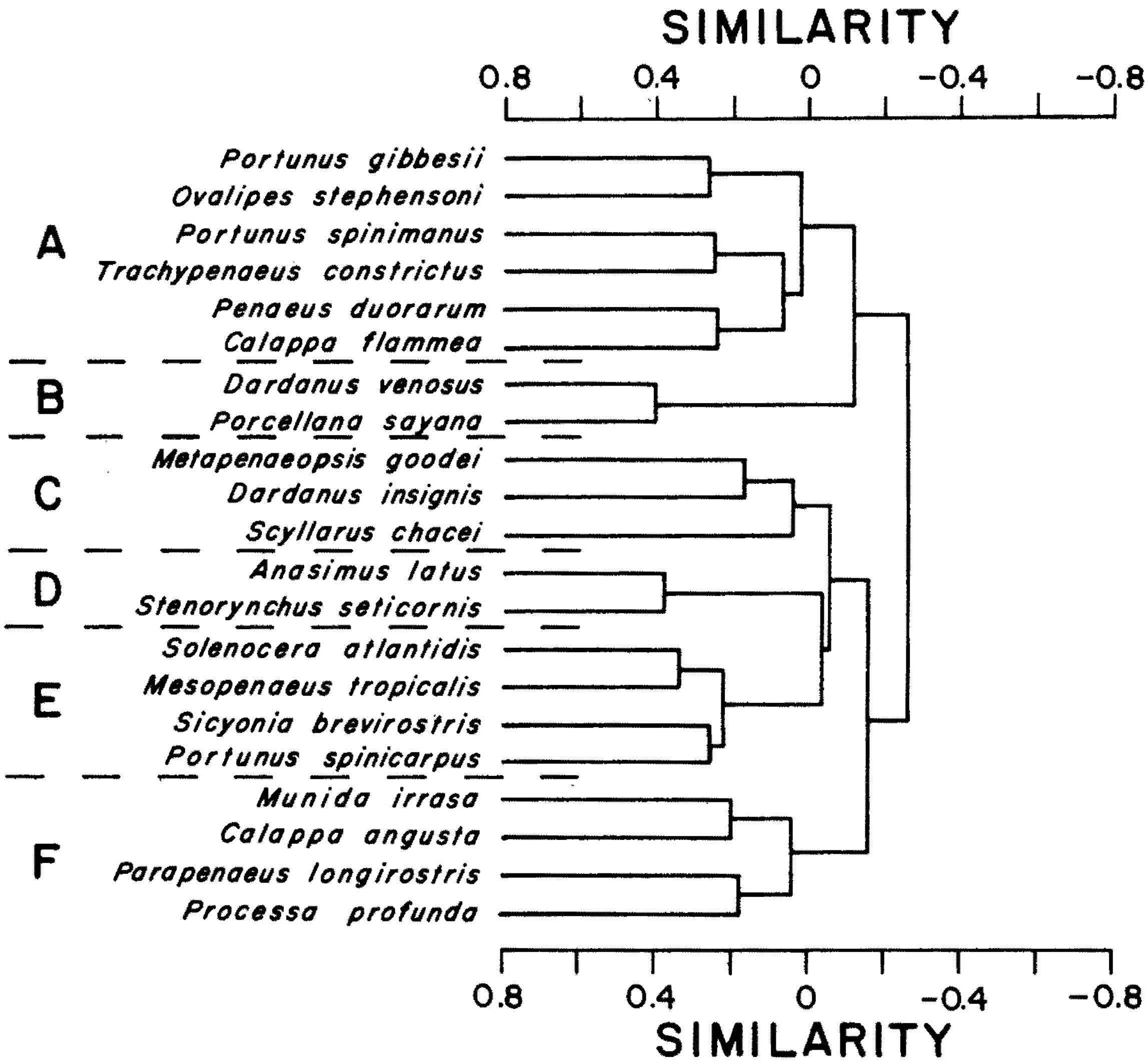
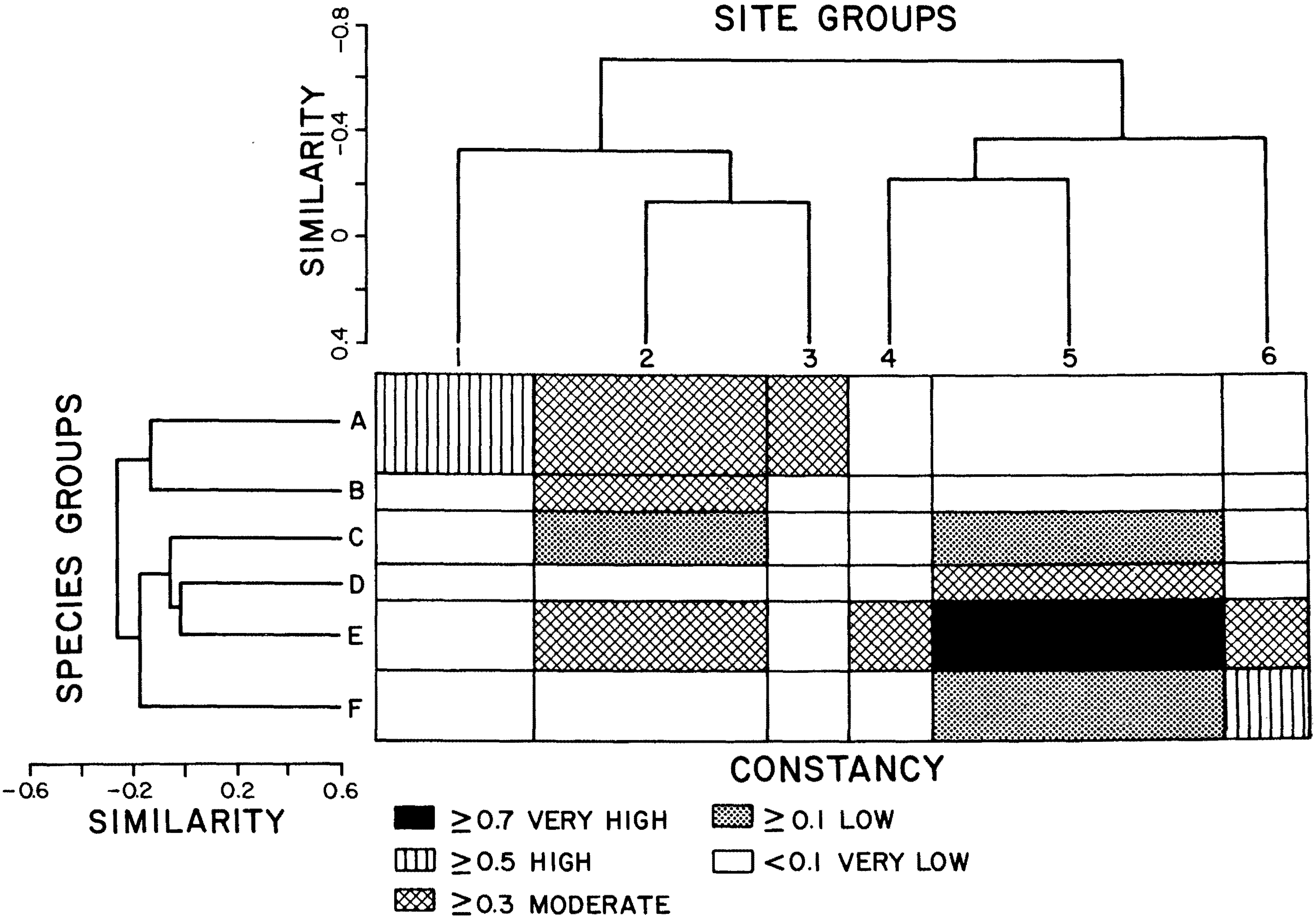


FIGURE 2. DENDROGRAM OF SPECIES FROM FALL SAMPLING PRODUCED BY INVERSE CLUSTER ANALYSIS.



IGURE 3. SPECIES GROUP CONSTANCY WITHIN SITE GROUPS DEPICTED IN A TWO-WAY TABLE FOR FALL COLLECTIONS.

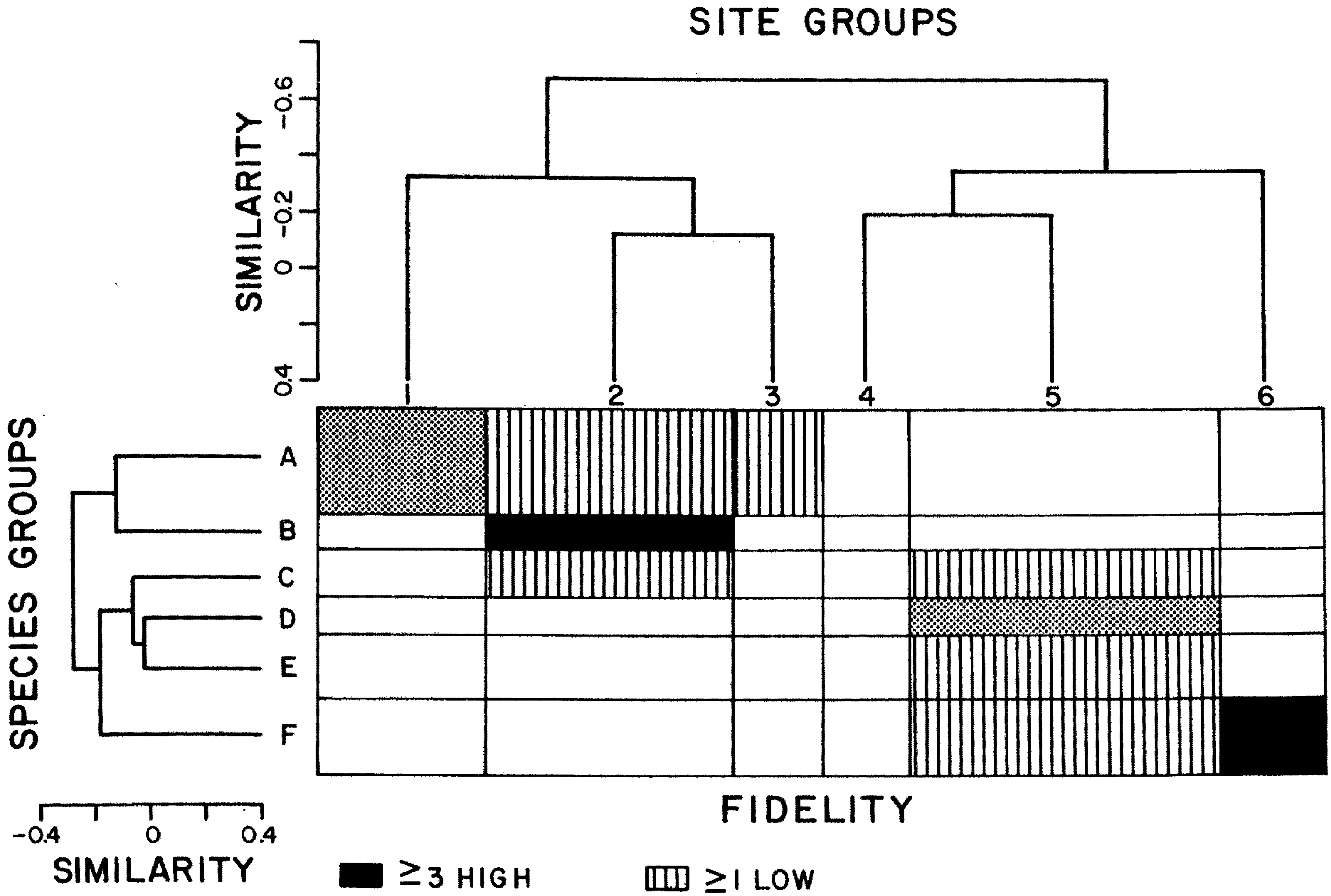


FIGURE 4. SPECIES GROUP FIDELITY WITHIN SITE GROUPS DEPICTED IN A TWO-WAY TABLE FOR FALL COLLECTIONS.

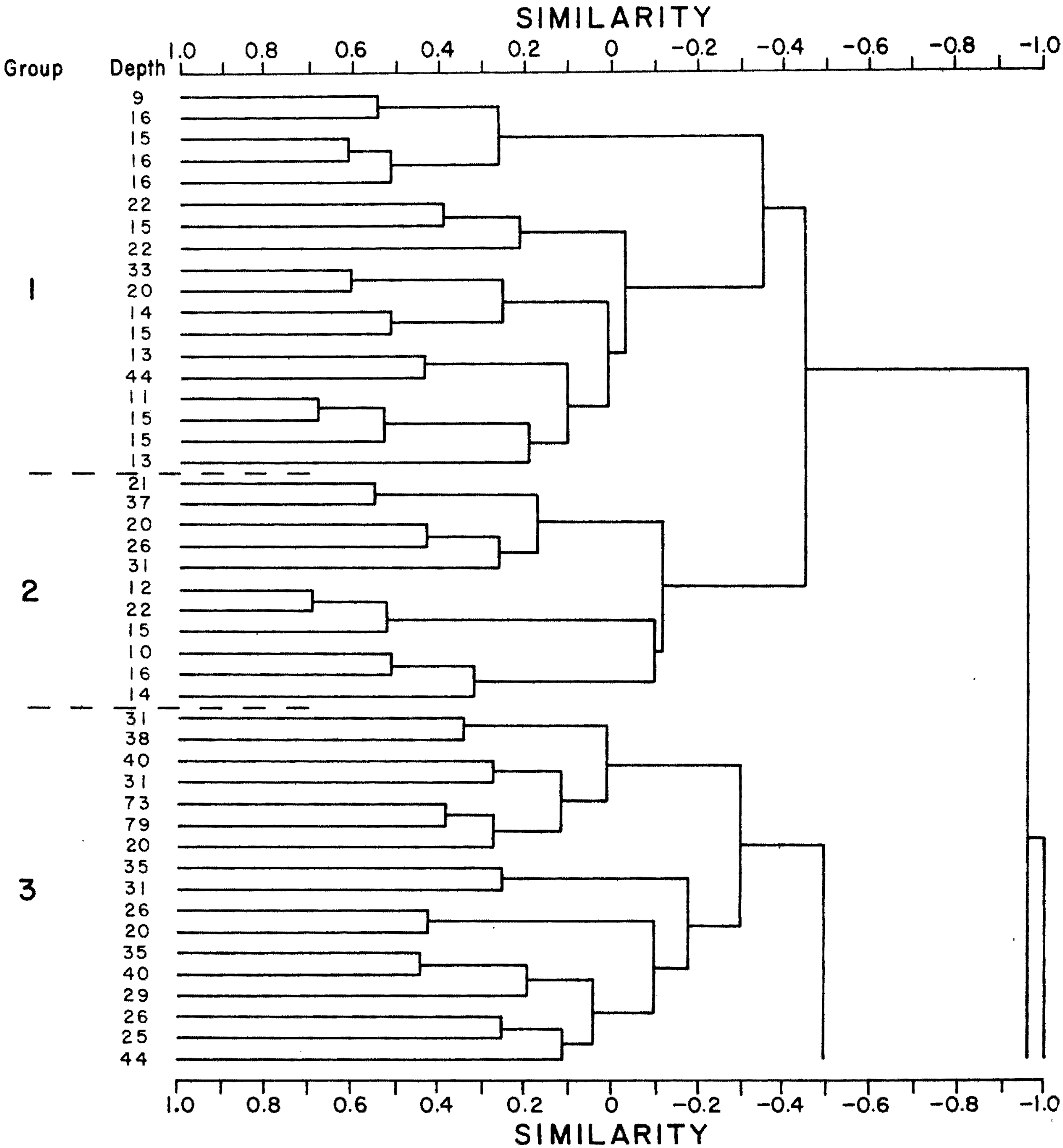


FIGURE 5. DENDROGRAM RESULTING FROM NORMAL ANALYSIS OF STATIONS FROM WINTER SAMPLING.

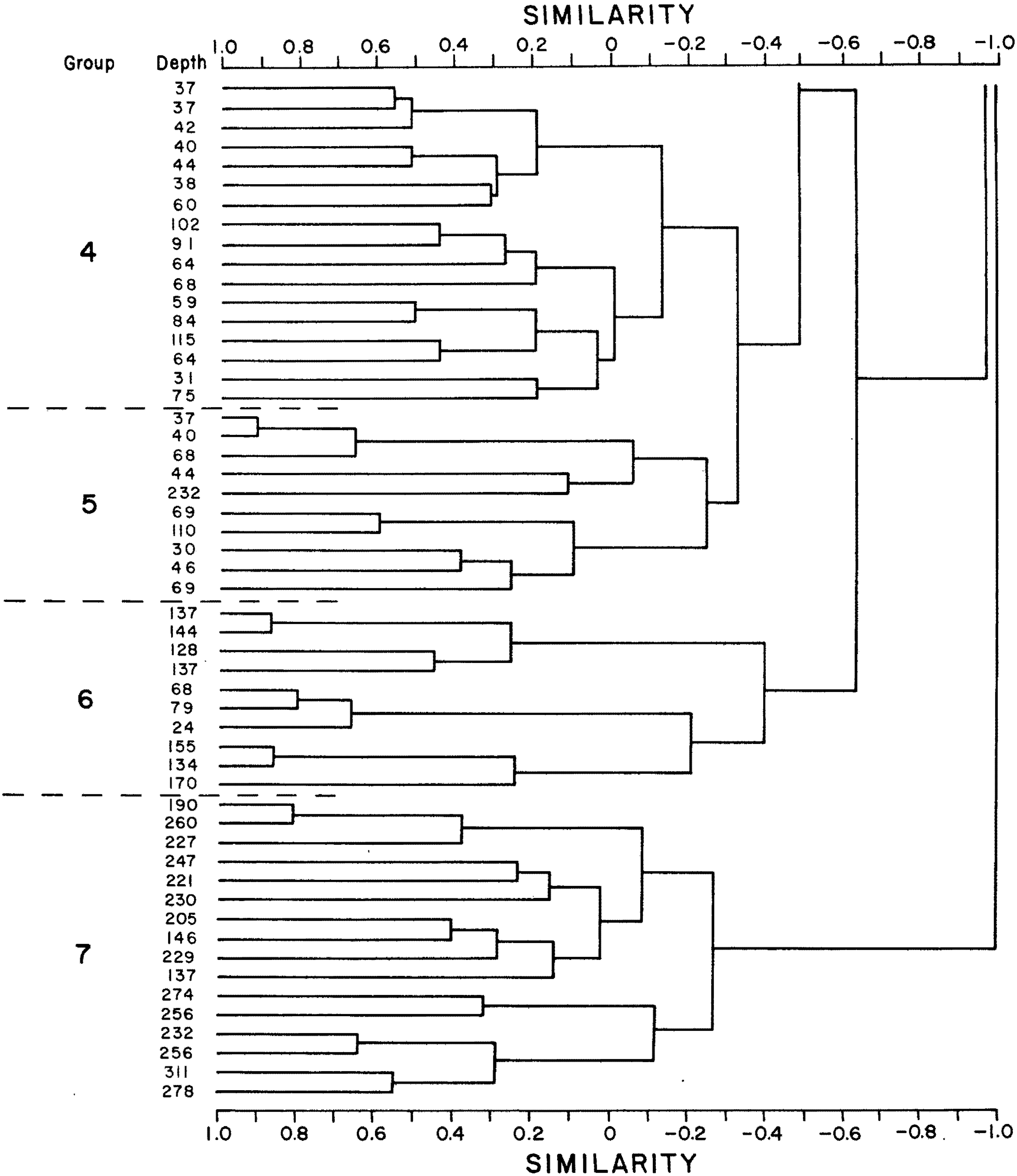


FIGURE 5. (continued).

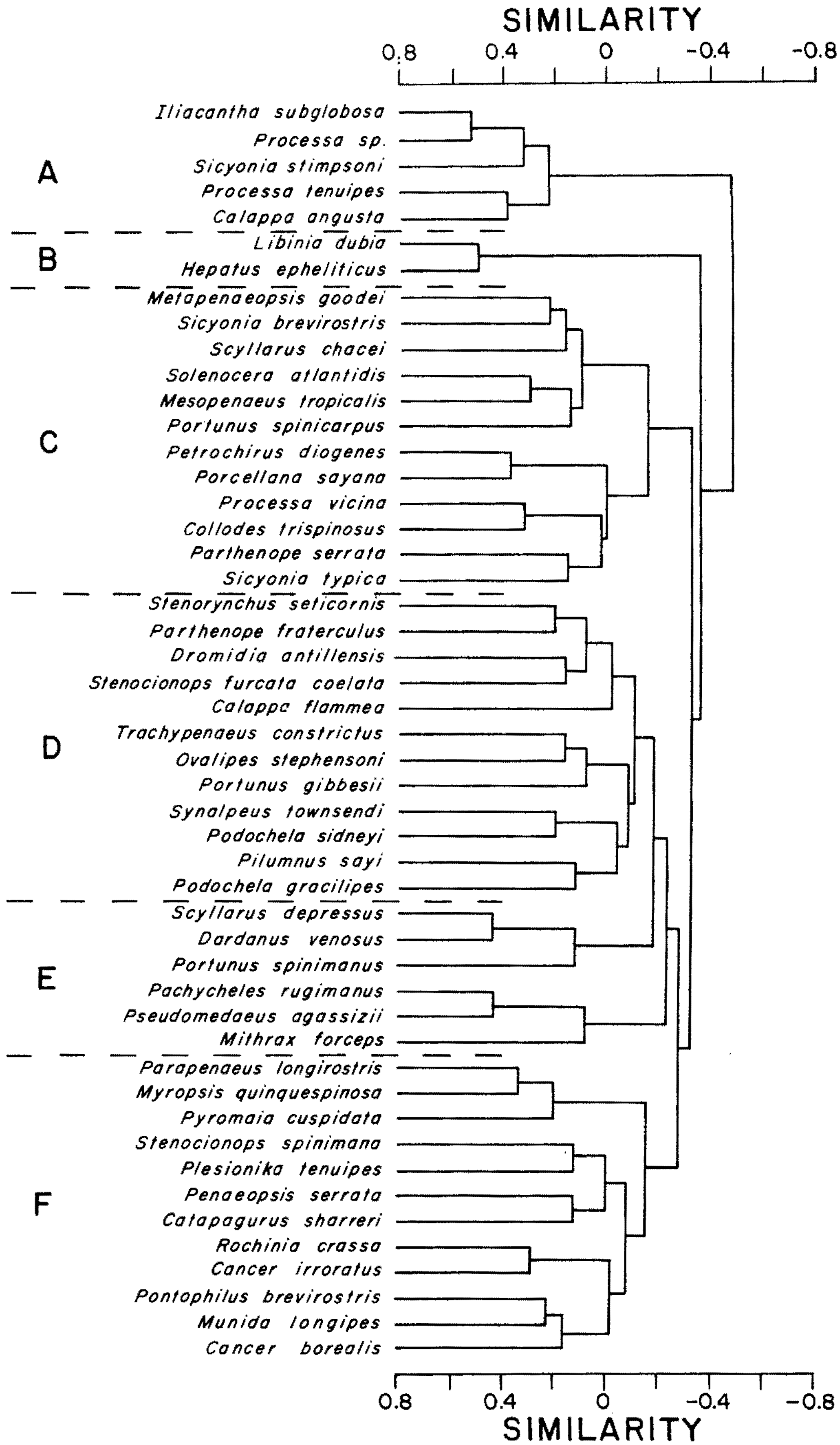


FIGURE 6. DENDROGRAM OF SPECIES FROM WINTER SAMPLING PRODUCED BY INVERSE CLUSTER ANALYSIS.

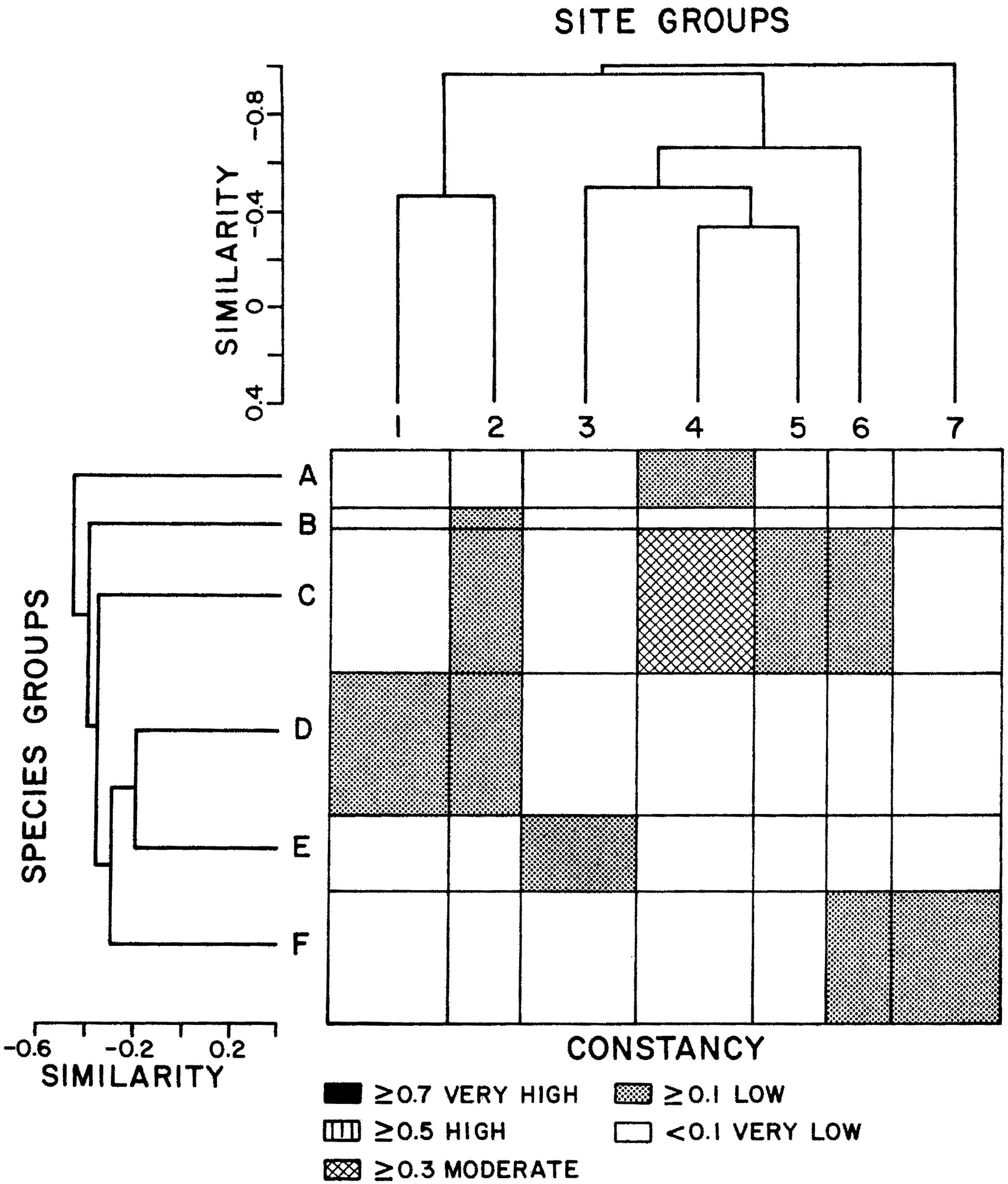


FIGURE 7. SPECIES GROUP CONSTANCY WITHIN SITE GROUPS DEPICTED IN A TWO-WAY TABLE FOR WINTER COLLECTIONS.

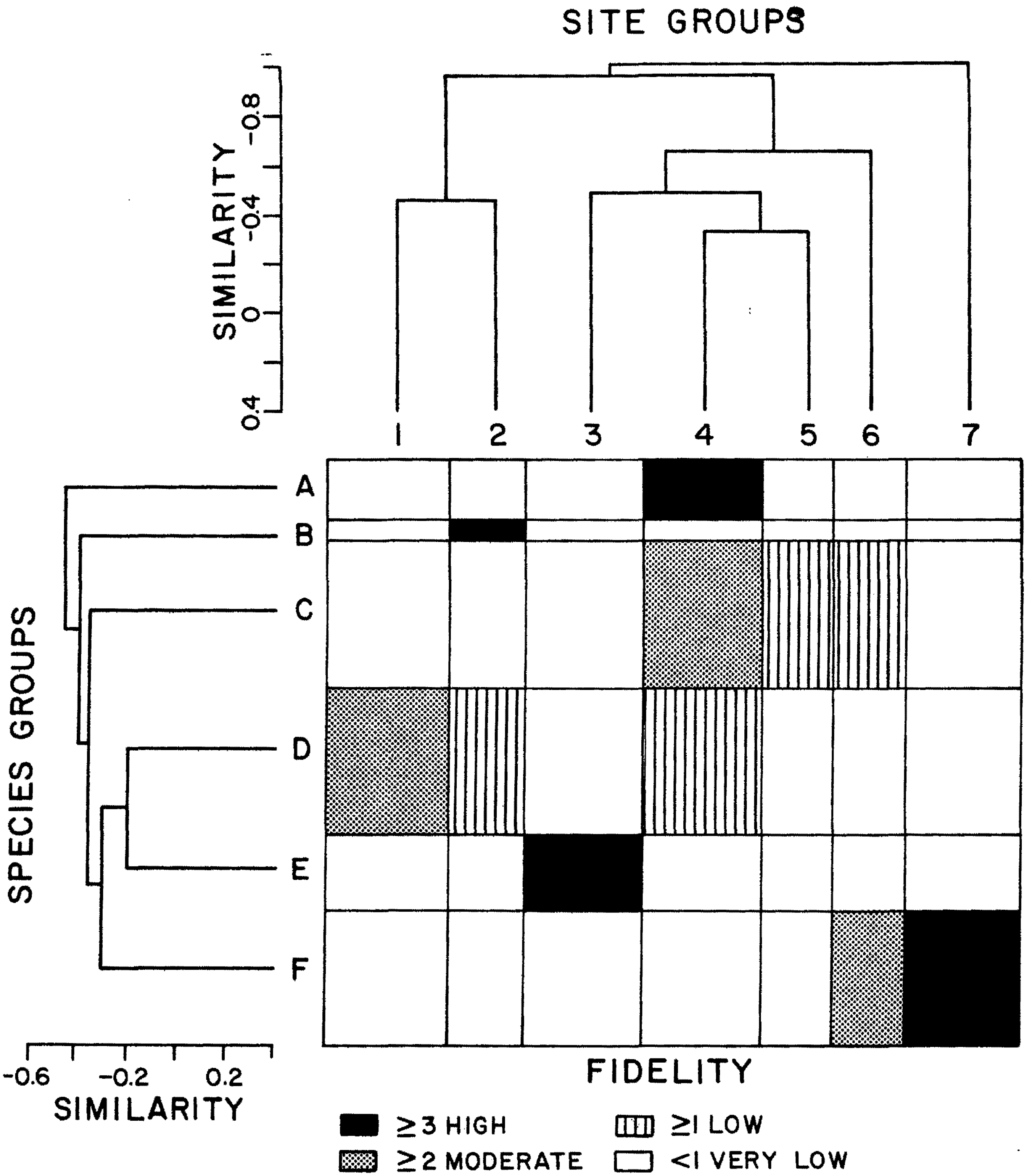


FIGURE 8. SPECIES GROUP FIDELITY WITHIN SITE GROUPS DEPICTED IN A TWO-WAY TABLE FOR WINTER COLLECTIONS.

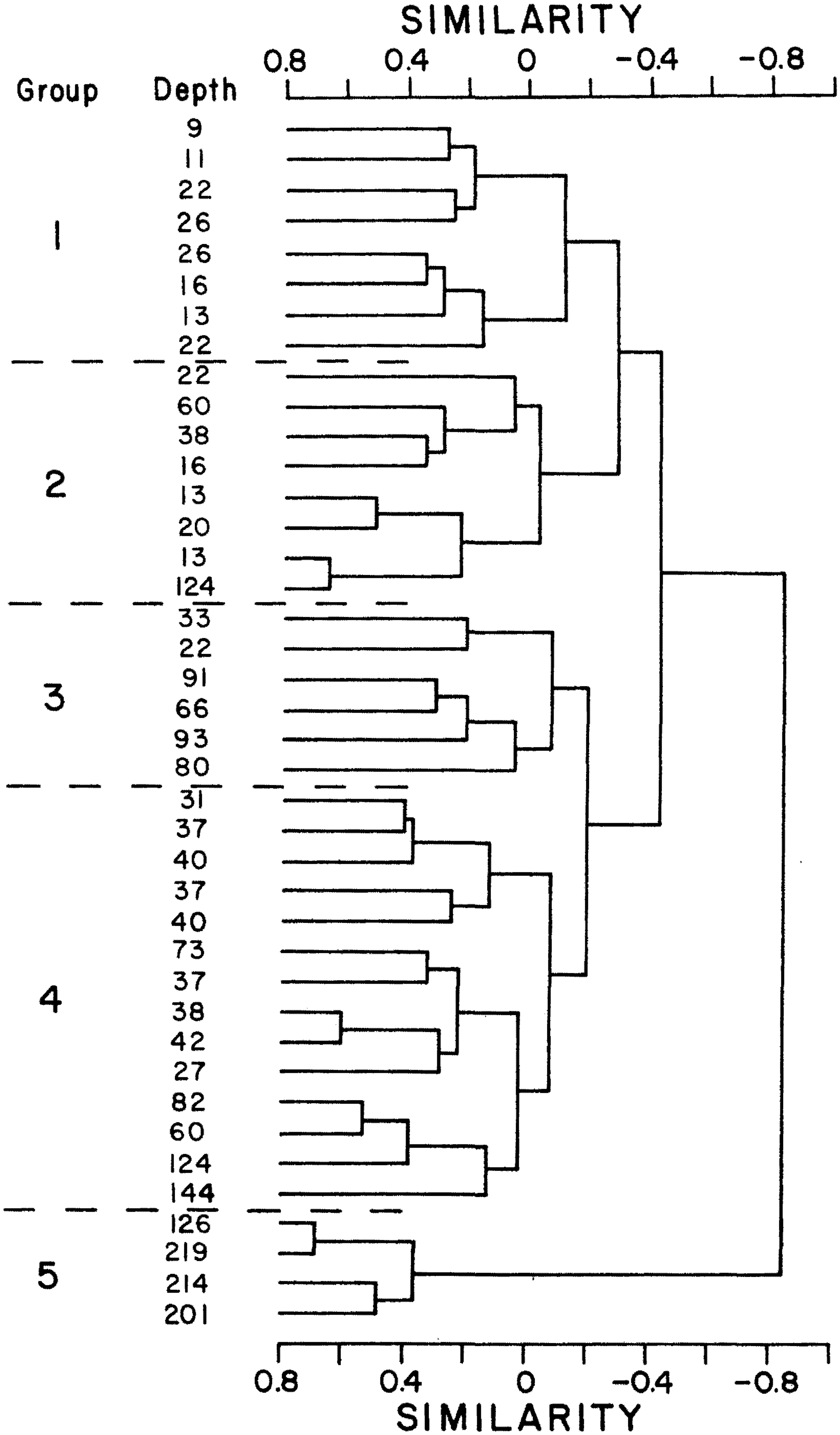


FIGURE 9. DENDROGRAM RESULTING FROM NORMAL ANALYSIS OF STATIONS FROM SPRING SAMPLING.

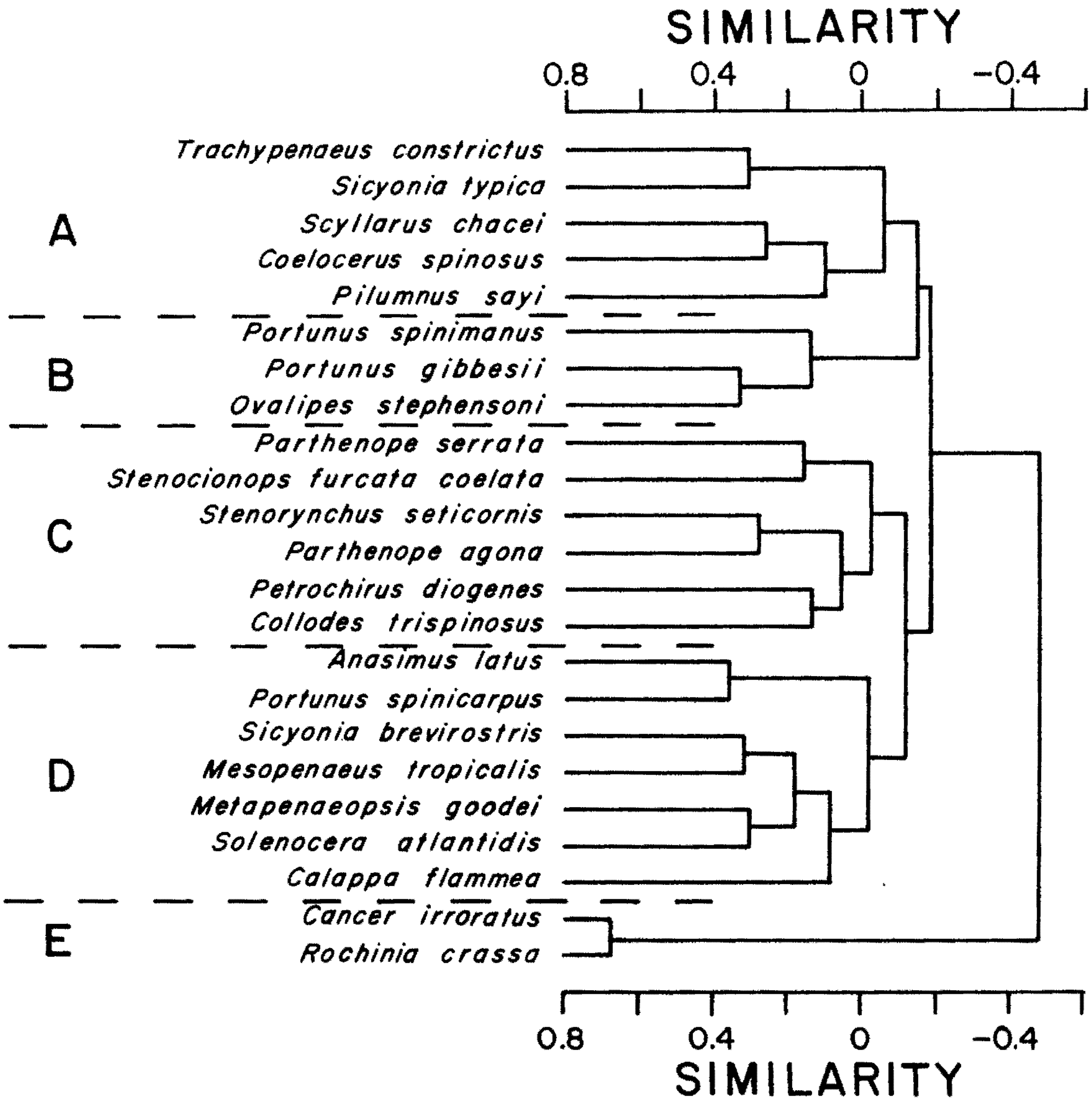


FIGURE 10. DENDROGRAM OF SPECIES FROM SPRING SAMPLING PRODUCED BY INVERSE CLUSTER ANALYSIS.

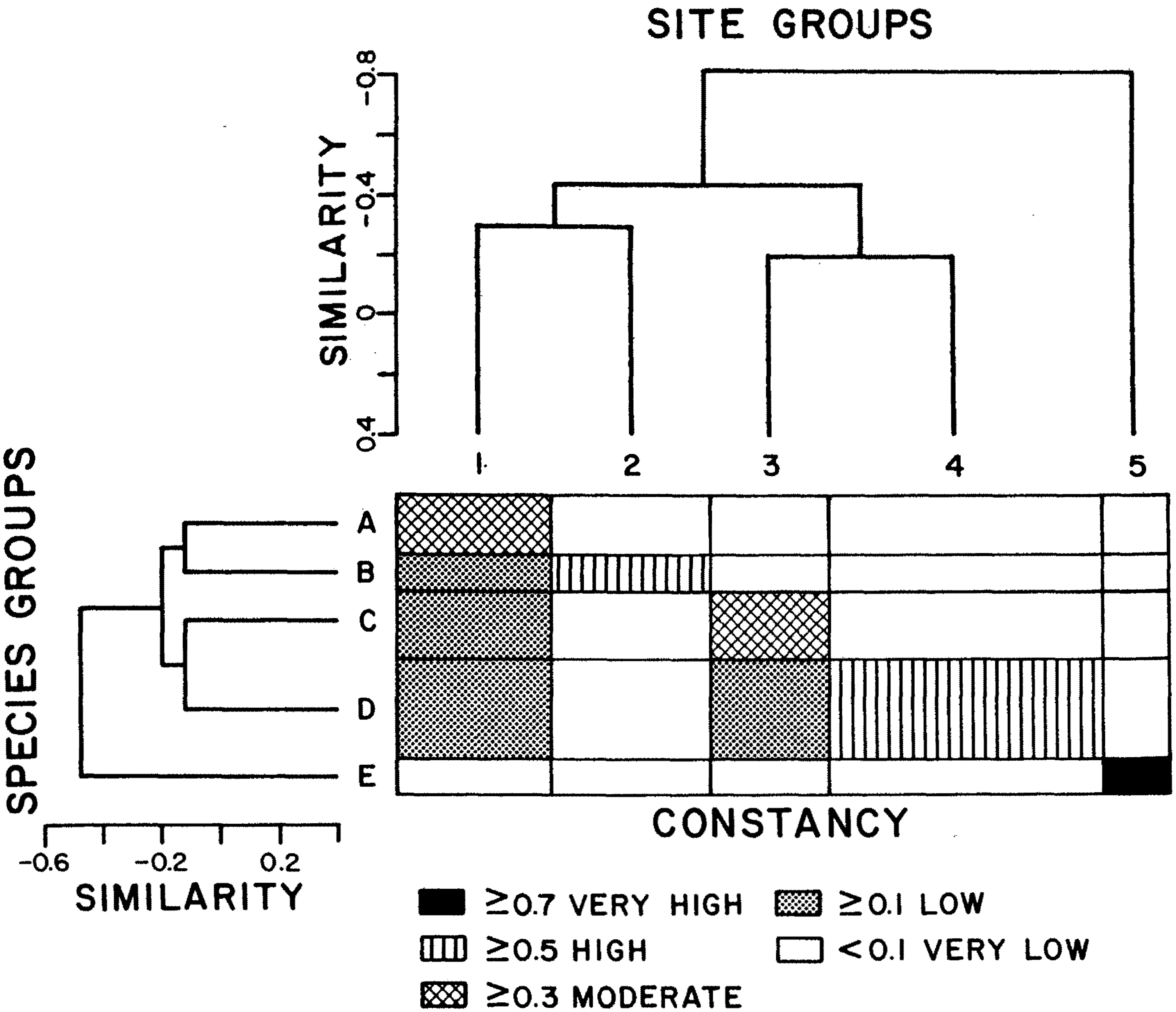


FIGURE 11. SPECIES GROUP CONSTANCY WITHIN SITE GROUPS DEPICTED IN A TWO-WAY TABLE FOR SPRING COLLECTIONS.

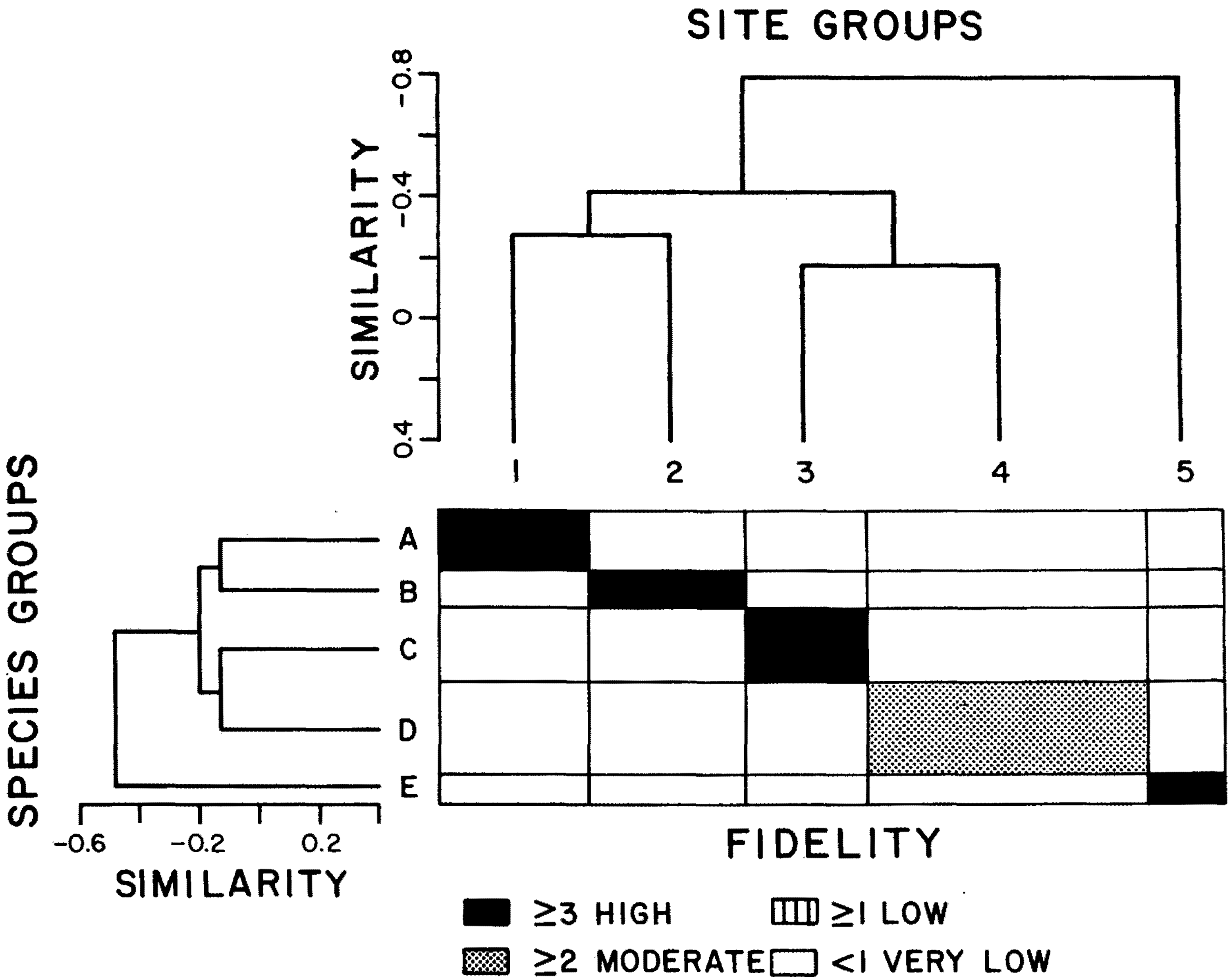


FIGURE 12. SPECIES GROUP FIDELITY WITHIN SITE GROUPS DEPICTED IN A TWO-WAY TABLE FOR SPRING COLLECTIONS.

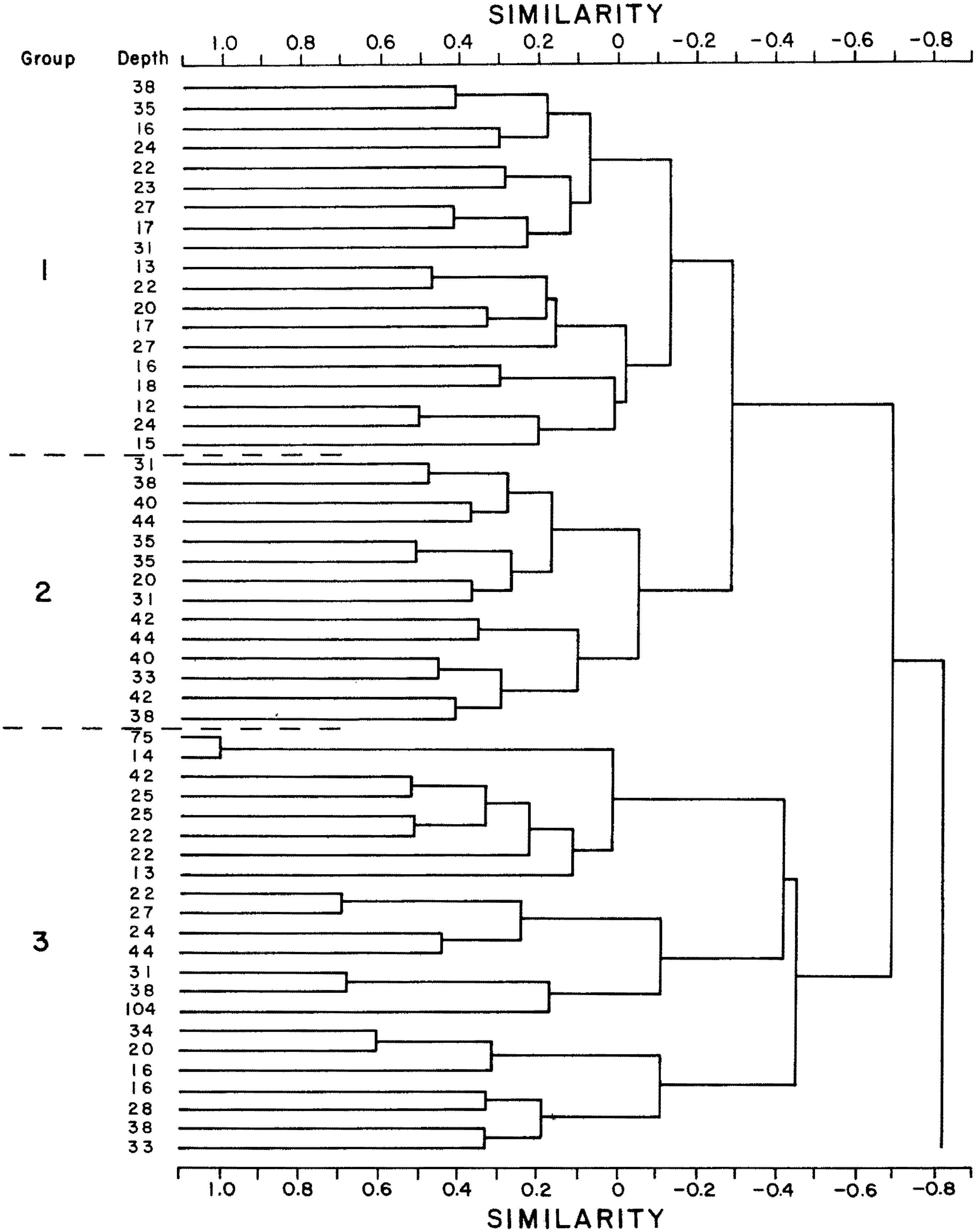


FIGURE 13. DENDROGRAM RESULTING FROM NORMAL ANALYSIS OF STATIONS FROM SUMMER SAMPLING.

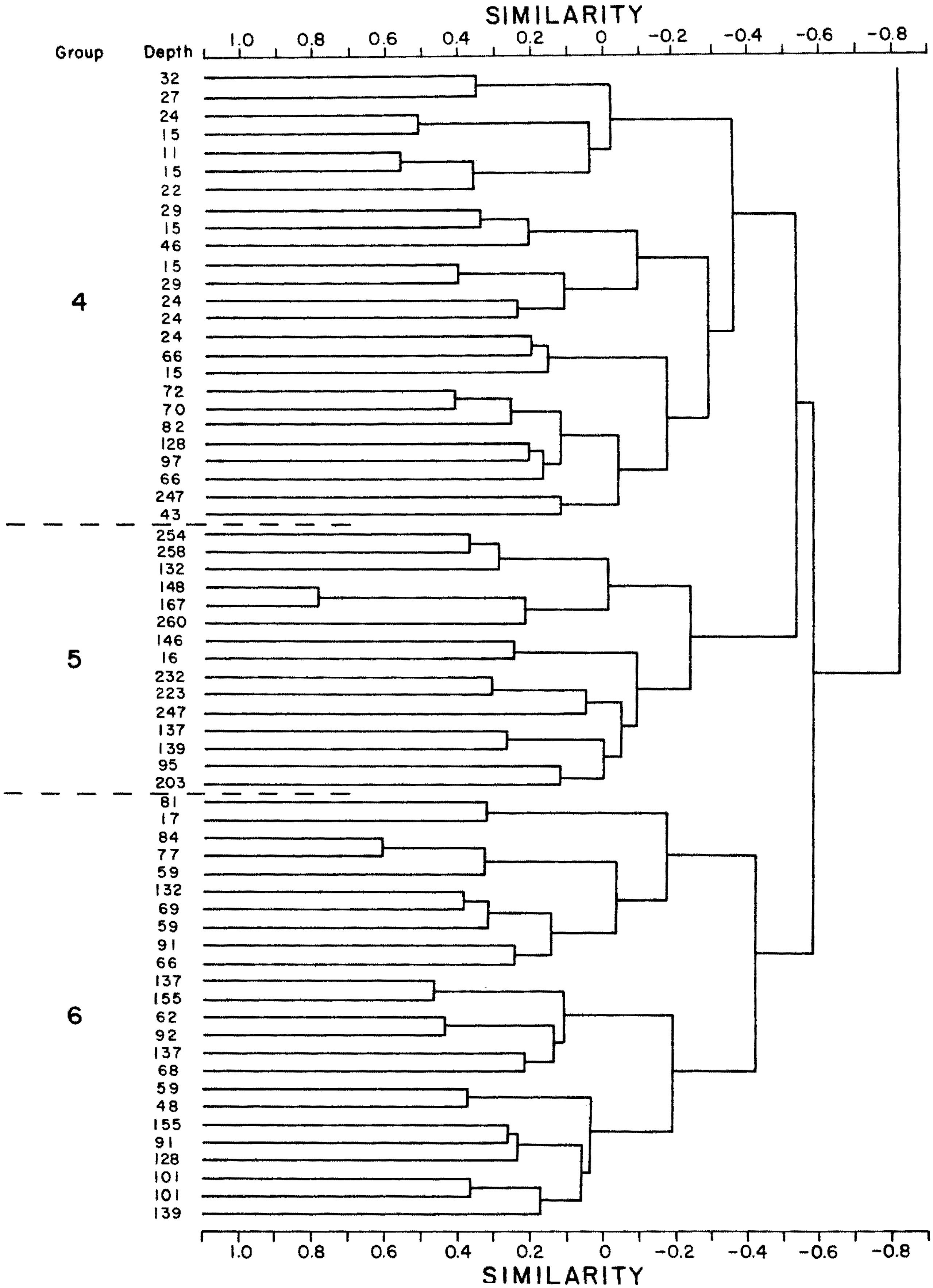


FIGURE 13. (continued).

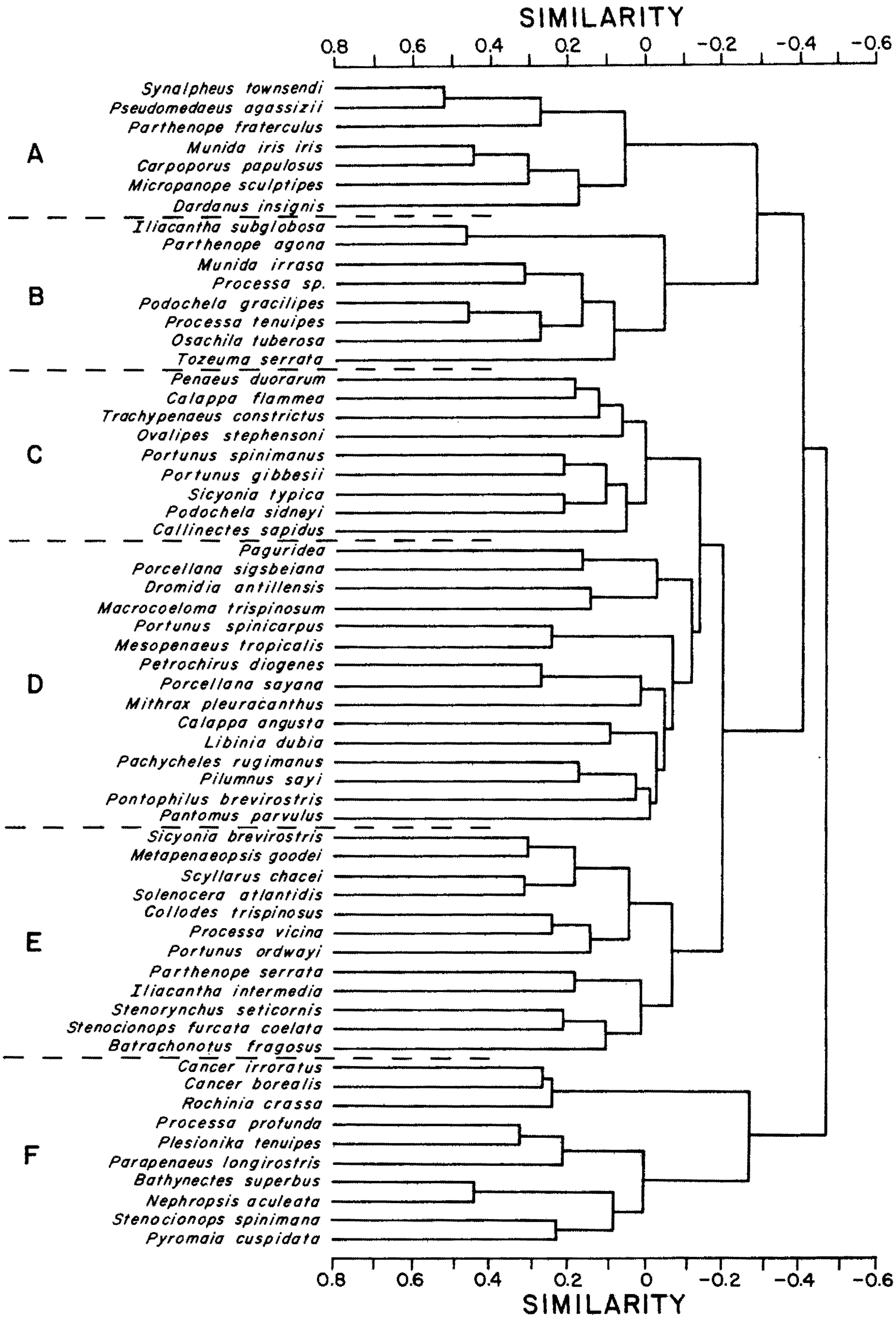


FIGURE 14. DENDROGRAM OF SPECIES FROM SUMMER SAMPLING PRODUCED BY INVERSE CLUSTER ANALYSIS.

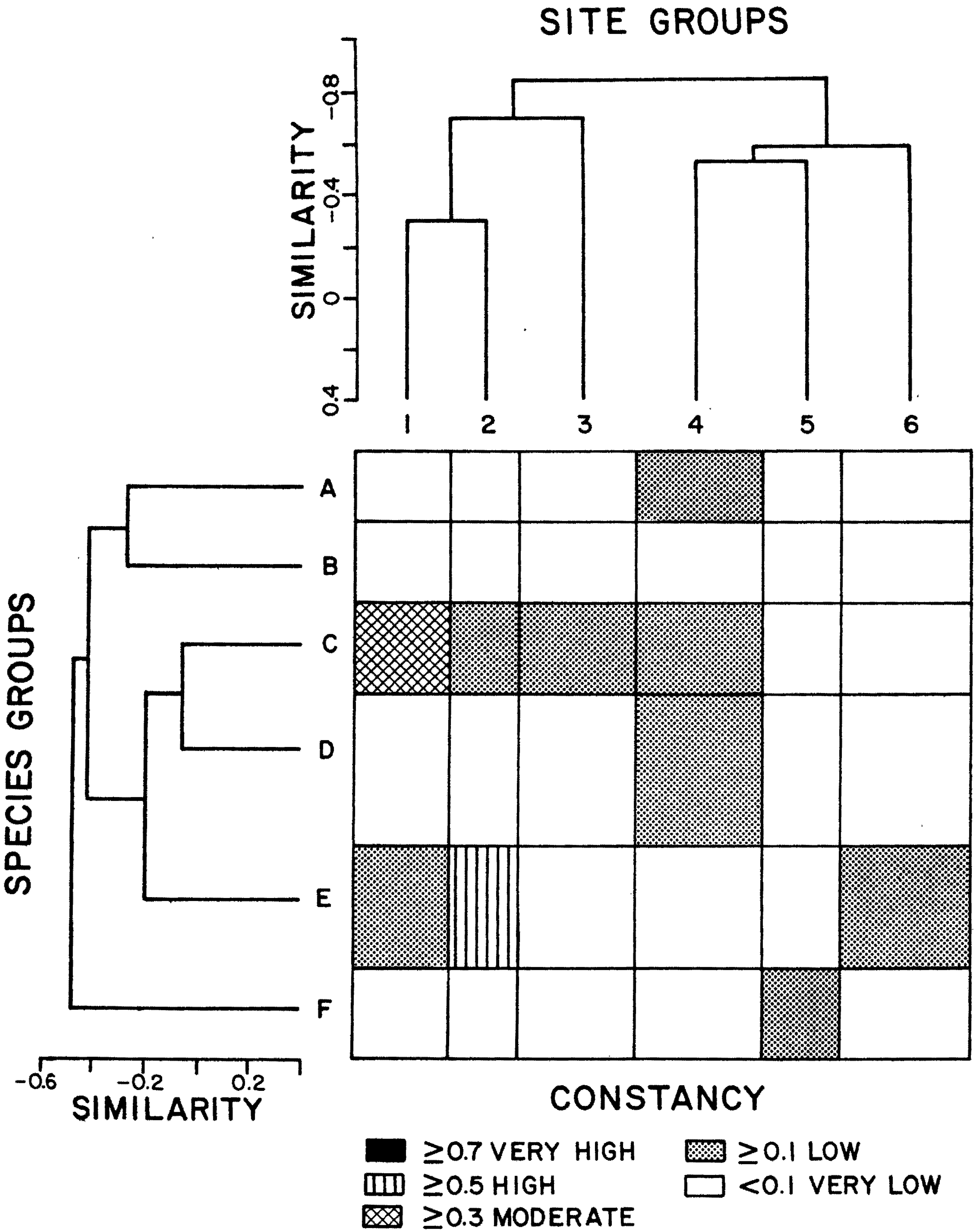


FIGURE 15. SPECIES GROUP CONSTANCY WITHIN SITE GROUPS DEPICTED IN A TWO-WAY TABLE FOR SUMMER COLLECTIONS.

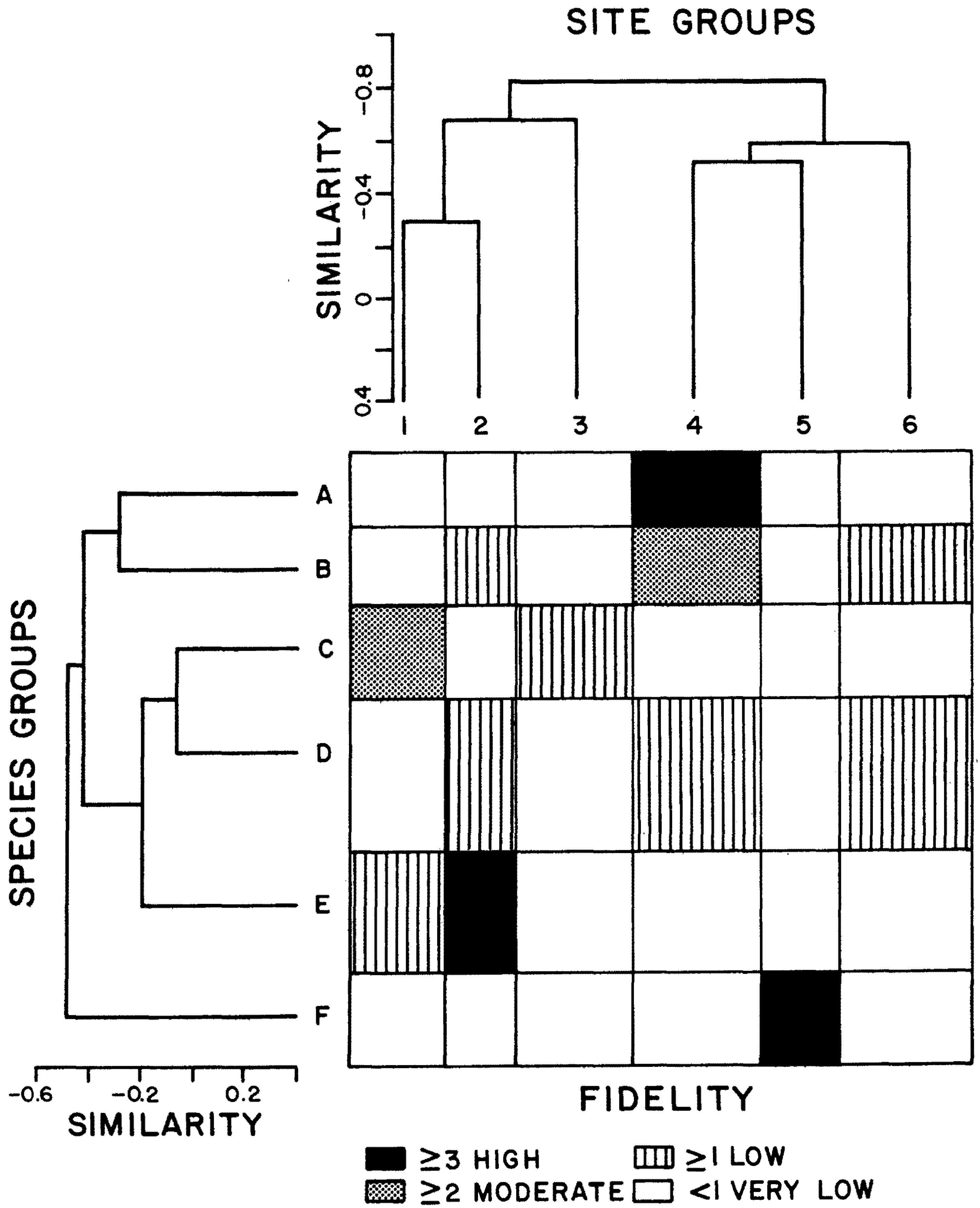


FIGURE 16. SPECIES GROUP FIDELITY WITHIN SITE GROUPS DEPICTED IN A TWO-WAY TABLE FOR SUMMER COLLECTIONS.