

Natural History of the Sea Fan Blenny,
Emblemariopsis pricei
(Teleostei: Chaenopsidae), in the
Western Caribbean

JAMES C. TYLER
and
DIANE M. TYLER

SERIES PUBLICATIONS OF THE SMITHSONIAN INSTITUTION

Emphasis upon publication as a means of "diffusing knowledge" was expressed by the first Secretary of the Smithsonian. In his formal plan for the institution, Joseph Henry outlined a program that included the following statement: "It is proposed to publish a series of reports, giving an account of the new discoveries in science, and of the changes made from year to year in all branches of knowledge." This theme of basic research has been adhered to through the years by thousands of titles issued in series publications under the Smithsonian imprint, commencing with *Smithsonian Contributions to Knowledge* in 1848 and continuing with the following active series:

Smithsonian Contributions to Anthropology
Smithsonian Contributions to Botany
Smithsonian Contributions to the Earth Sciences
Smithsonian Contributions to the Marine Sciences
Smithsonian Contributions to Paleobiology
Smithsonian Contributions to Zoology
Smithsonian Folklife Studies
Smithsonian Studies in Air and Space
Smithsonian Studies in History and Technology

In these series, the Institution publishes small papers and full-scale monographs that report the research and collections of its various museums and bureaux or of professional colleagues in the world of science and scholarship. The publications are distributed by mailing lists to libraries, universities, and similar institutions throughout the world.

Papers or monographs submitted for series publication are received by the Smithsonian Institution Press, subject to its own review for format and style, only through departments of the various Smithsonian museums or bureaux, where the manuscripts are given substantive review. Press requirements for manuscript and art preparation are outlined on the inside back cover.

I. Michael Heyman
Secretary
Smithsonian Institution

Natural History of the Sea Fan Blenny,
Emblemariopsis pricei (Teleostei: Chaenopsidae),
in the Western Caribbean

James C. Tyler
and Diane M. Tyler



Smithsonian Institution Press

Washington, D.C.

1999

ABSTRACT

Tyler, James C., and Diane M. Tyler. Natural History of the Sea Fan Blenny, *Emblemariopsis pricei* (Teleostei: Chaenopsidae), in the Western Caribbean. *Smithsonian Contributions to Zoology*, number 601, 24 pages, 7 figures, color frontispiece, 6 tables, 1999.—The chaenopsid blenny *Emblemariopsis pricei* Greenfield presently is known only from waters off Belize and Honduras, where it occurs at depths of 1 to 30 m. It is unusual among Atlantic Ocean fishes in partitioning its microhabitat usage according to sex and age. During daylight, females, nonbreeding males, and immatures are found mostly on the surface of soft-coral sea fans (*Gorgonia ventalina* Linnaeus), whereas breeding males occupy cavities in live scleractinian corals. The cavities are the remains of serpulid worm (*Spirobranchus giganteus* (Pallas)) tubes, which are most often found in elkhorn coral (*Acropora palmata* (Lamarck)), but which also are found in species of several genera of globose mound corals. Breeding males are dark-headed and range from 17.5 to 28.6 mm standard length (SL). Adult females, adult nonbreeding males, and immatures are semitransparent; mature females attain up to 19.6 mm SL and nonbreeding males up to 24.3 mm SL. Approximately one in eight sea fans at a study reef at Carrie Bow Cay, Belize, has a blenny present. Pale adult males, presumably seeking tube cavities to occupy, frequently are found on the surface of live coral, especially in the vicinity of cavities occupied by dark-headed males. Pale males immediately enter any tube cavities that become vacant when resident dark-headed males are removed. Upon occupation, pale males turn dark headed overnight, although the full complement of dark pigment that remains evident in preserved specimens takes up to 10 days to develop. Females deposit their eggs in the tube cavities, where the resident breeding male fertilizes and incubates them. Mature females have 21 to 27 large ovarian eggs, and most tube cavities contain an average of about 300 eggs in various stages of development from multiple spawning deposits.

OFFICIAL PUBLICATION DATE is handstamped in a limited number of initial copies and is recorded in the Institution's annual report, *Annals of the Smithsonian Institution*. SERIES COVER DESIGN: The coral *Montastrea cavernosa* (Linnaeus).

Library of Congress Cataloging-in-Publication Data

Tyler, James C., 1935-

Natural history of the sea fan blenny, *Emblemariopsis pricei*
(Teleostei: Chaenopsidae), in the western Caribbean / James C. Tyler and Diane M. Tyler.
p. cm. — (Smithsonian contributions to zoology ; no. 601)

Includes bibliographical references.

1. *Emblemariopsis pricei*. I. Tyler, Diane M. II. Title. III. Series.

QL1.S54 no. 601

[QL638.C4]

590 s—dc21

[597:.77]

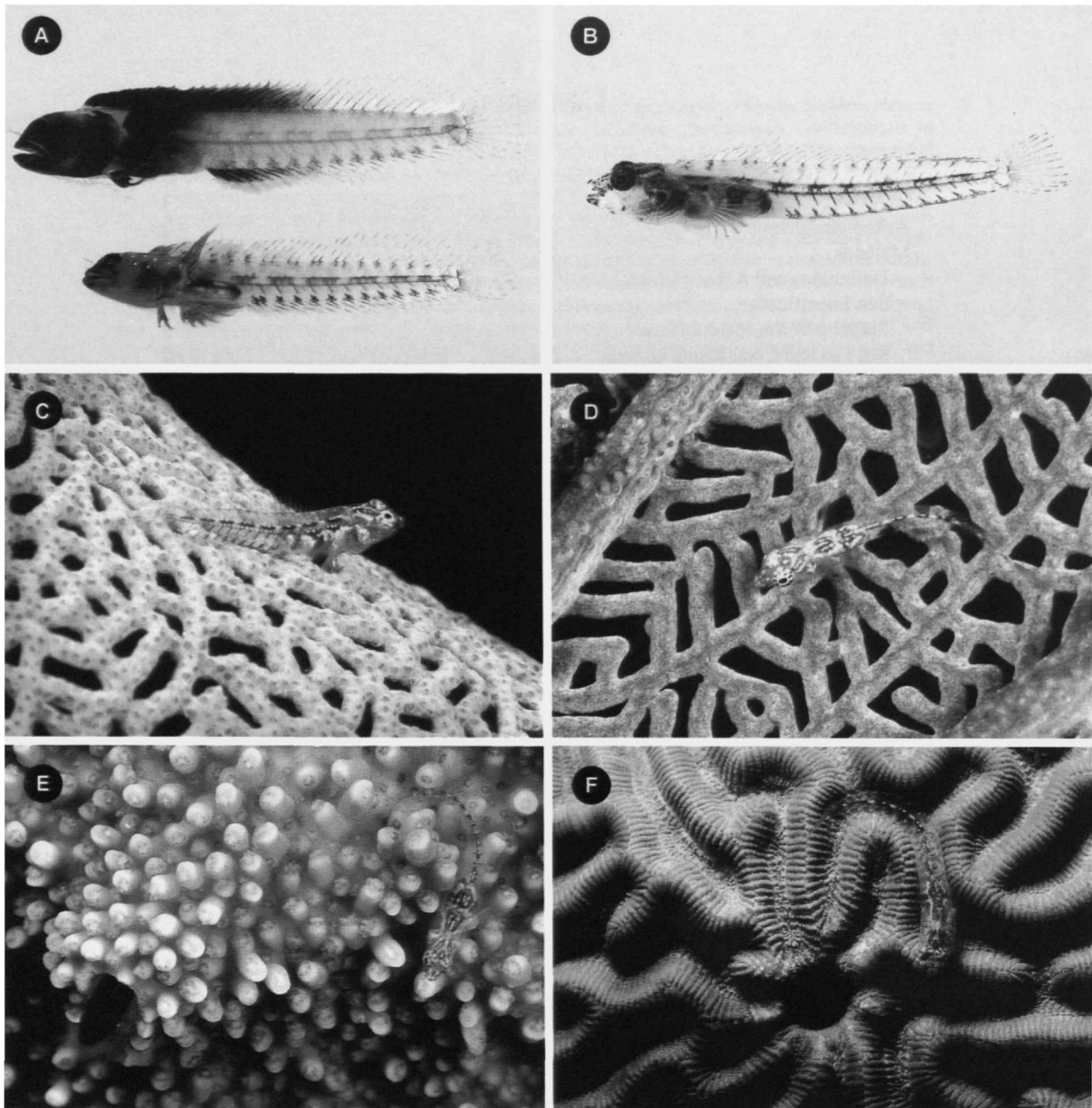
99-20380

CIP

© The paper used in this publication meets the minimum requirements of the American National Standard for Permanence of Paper for Printed Library Materials Z39.48—1984.

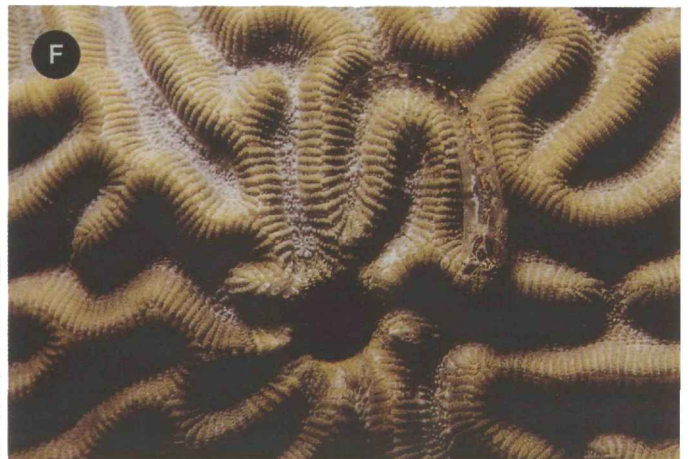
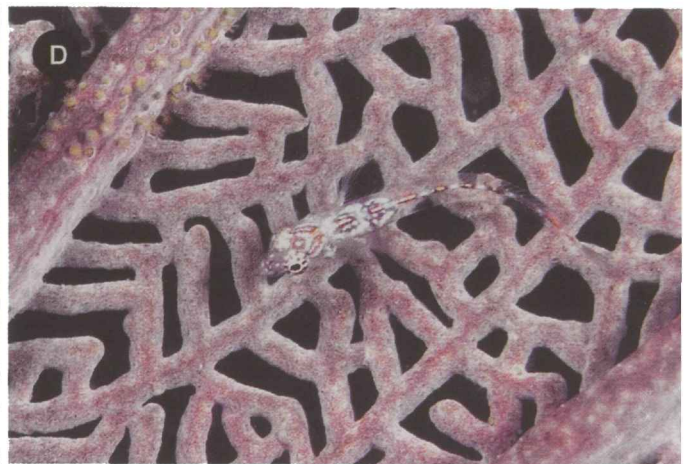
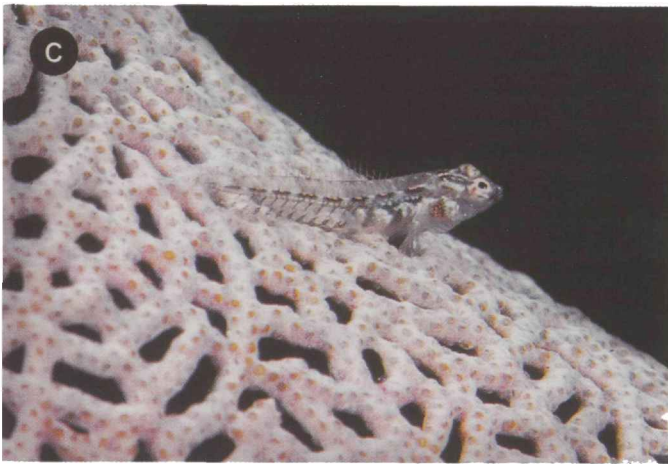
Contents

| | <i>Page</i> |
|--|-------------|
| Introduction | 1 |
| Acknowledgments | 2 |
| Methods | 2 |
| Definitions and Abbreviations | 2 |
| Sex Identification | 2 |
| Serpulid Worm Identification | 2 |
| Sea Fan and Coral Identifications | 3 |
| Collecting Techniques | 3 |
| Location of the Two Main Study Areas | 3 |
| Results | 3 |
| Systematics | 3 |
| Generic Allocation | 3 |
| Differences between <i>E. pricei</i> and <i>E. randalli</i> | 4 |
| Microhabitats of <i>Emblemariopsis pricei</i> | 6 |
| Sea Fans | 6 |
| Size and Sex of Sea-Fan Dwelling Pale Individuals | 6 |
| Constancy and Percentage of Occurrence on Sea Fans | 9 |
| Invertebrates on Same Sea Fans as <i>E. pricei</i> | 10 |
| Corals | 10 |
| Coral Species on which <i>E. pricei</i> Is Found | 10 |
| Size and Sex of Pale Individuals from Coral Surfaces | 10 |
| Size of Dark-Headed Males from Tube Cavities in Coral | 11 |
| Replacement Sequences Following Removal of Dark-Headed Males | 11 |
| Tube-Cavity Structure | 15 |
| Reproduction | 16 |
| Female Maturity Estimates and Ovarian Egg Numbers | 16 |
| Incubating-Egg Numbers | 16 |
| Discussion | 16 |
| Conclusion | 19 |
| Appendix: Specimens Examined | 20 |
| Literature Cited | 23 |



FRONTISPIECE.—Live specimens of *Emblemariopsis pricei* either anesthetized in the laboratory (A,B) or in situ (C–F). A, two dark-headed males (USNM 336744) of varying intensity and extent of darkening from a patch reef SW of Carrie Bow Cay (CBC), Belize, 8 m, 9 March 1994; larger specimen, 26.5 mm SL, from a tube cavity in living *Montastrea annularis*, smaller specimen, 21.9 mm SL, from a tube cavity in living *Porites astreoides*. B, female (USNM 336741), 19.6 mm SL, from surface of sea fan, patch reef SW of CBC, 8 m, 7 March 1994 (see D for same specimen in situ). C, female (USNM 336769), 17.1 mm SL, as seen obliquely parallel to surface near sea-fan edge and thus more conspicuous than usual, patch reef SW of CBC, 7 m, 16 March

1994. D, female (USNM 336741), 19.6 mm SL, as seen at right angle to broad surface of sea fan (see B for same specimen anesthetized in laboratory). E, dark-headed male, 19.3 mm SL, in its tube cavity in living *Acropora palmata*, and one of two pale males, 20.8 mm SL, 21.0 mm SL (all USNM 336768), on nearby surface (both pale males collected, but it is unknown which is in photograph), spur and groove study site just E of CBC, 8 m, 16 March 1994. F, tube cavity in living *Diploria strigosa* containing dark-headed male (USNM 336746, 23.1 mm SL) that withdrew after being disturbed, and pale individual of unknown length (it escaped collection) on nearby surface, spur and groove study site just E of CBC, 8 m, 12 March 1994.



FRONTISPICE.—Live specimens of *Emblemariopsis pricei* either anesthetized in the laboratory (A,B) or in situ (C–F). A, two dark-headed males (USNM 336744) of varying intensity and extent of darkening from a patch reef SW of Carrie Bow Cay (CBC), Belize, 8 m, 9 March 1994; larger specimen, 26.5 mm SL, from a tube cavity in living *Montastrea annularis*, smaller specimen, 21.9 mm SL, from a tube cavity in living *Porites astreoides*. B, female (USNM 336741), 19.6 mm SL, from surface of sea fan, patch reef SW of CBC, 8 m, 7 March 1994 (see D for same specimen in situ). C, female (USNM 336769), 17.1 mm SL, as seen obliquely parallel to surface near sea-fan edge and thus more conspicuous than usual, patch reef SW of CBC, 7 m, 16 March

1994. D, female (USNM 336741), 19.6 mm SL, as seen at right angle to broad surface of sea fan (see B for same specimen anesthetized in laboratory). E, dark-headed male, 19.3 mm SL, in its tube cavity in living *Acropora palmata*, and one of two pale males, 20.8 mm SL, 21.0 mm SL (all USNM 336768), on nearby surface (both pale males collected, but it is unknown which is in photograph), spur and groove study site just E of CBC, 8 m, 16 March 1994. F, tube cavity in living *Diploria strigosa* containing dark-headed male (USNM 336746, 23.1 mm SL) that withdrew after being disturbed, and pale individual of unknown length (it escaped collection) on nearby surface, spur and groove study site just E of CBC, 8 m, 12 March 1994.

Natural History of the Sea Fan Blenny, *Emblemariopsis pricei* (Teleostei: Chaenopsidae), in the Western Caribbean

James C. Tyler
and *Diane M. Tyler*

Introduction

In conjunction with ongoing ichthyological investigations at the Smithsonian Institution's research station at Carrie Bow Cay on the Belize Barrier Reef in the western Caribbean, a survey was undertaken to determine whether there were any small, cryptic fishes that might associate with gorgonian soft-coral sea fans and sea whips. Such associations are common among some species of certain goby genera in the Indo-Pacific (Davis and Cohen, 1969, for *Cottogobius*; Larson, 1985, 1990, and contained references, for *Bryaninops* and *Pleurosicya*) but are poorly known in the western Atlantic. During the survey at Carrie Bow Cay, no fishes were found on sea whips, but one species was found on sea fans.

About one of every eight sea fans carefully examined on patch reefs and in the spur and groove zone around the island laboratory had an inconspicuous little chaenopsid blenny on its surface. The collected voucher specimens were all relatively pale and semitransparent; these included mature females, males larger and males smaller than the mature females but with inactive testes, and immatures, but there were no sexually mature males. The latter subsequently were discovered with their heads protruding from holes in massive coral mounds to which

the sea fans were attached and in holes in elkhorn corals near sea fans. These sexually mature males were much more extensively pigmented than were females, immatures, or other males, and they had exceptionally dark heads.

The chaenopsid proved to be *Emblemariopsis pricei* Greenfield (1975), a species first described on the basis of two dark-headed males collected from holes in living elkhorn coral (*Acropora palmata* (Lamarck)) in the lagoon of Glovers Reef, Belize, only 25 km east of Carrie Bow Cay. Subsequent to the original description, Greenfield and Johnson (1981) re-described the species on the basis of a total of 10 specimens from Belize (including one from Carrie Bow Cay) and Honduras: six dark-headed males from holes in living *A. palmata* and four pale individuals found on the coral surface. Three of the semitransparent, pale individuals were male and one was female, and Greenfield and Johnson (1981) speculated that the cryptic specimens on the surface of the coral were nonterritorial and that dark-headedness was obtained only by territorial, hole-dwelling, breeding males.

The results of the present study confirm the perceptive surmises of Greenfield and Johnson (1981) and provide additional knowledge of the life history of this blenny and its association with both sea fans and hard corals.

A search of the literature on the habitats of the many species of *Emblemariopsis* and their relatives revealed that the pioneering underwater observer of the behavior and ecology of American tropical reef fishes, William H. Longley, had long ago mentioned (in Longley and Hildebrand, 1940:269) that *E. diaphana* Longley, found at Dry Tortugas, Florida, lives on both globose coral heads of *Montastrea* sp. (as *Orbicella*) and sea fans. Thus, the sea-fan habitat is not unique to *E. pricei*. This single reported observation from the better-studied eastern Caribbean and Florida Keys, however, suggests that the western Caribbean *E. pricei* may have a greater number of individuals

James C. Tyler, National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560-0106. Diane M. Tyler, Smithsonian Institution Press, 470 L'Enfant Plaza, Suite 7100, Washington, D.C. 20560-0950.

Review Chairperson: Stanley H. Weitzman, Smithsonian Institution, Washington, D.C. 20560-0159.

Reviewers: Raymond D. Clarke, Sarah Lawrence College, Bronxville, New York, 10708; Philip A. Hastings, University of Arizona, Tucson, Arizona, 85721-0088; Richard H. Rosenblatt, Scripps Institute of Oceanography, La Jolla, California, 92093-0208.

and a larger proportion of its life history associated with sea fans than do species such as *E. diaphana*.

ACKNOWLEDGMENTS

The field work for this study at Carrie Bow Cay, Belize, was often greatly aided by the following individuals: R.D. and K. Clarke, Sarah Lawrence College; C.L. Smith, American Museum of Natural History; A. Sundberg, University of Delaware; R.E. Clark, Jr., Smithsonian Institution; K.S. Cole, Bishop's University; and M.K. Tyler, Chappaqua, New York.

We thank R.E. Clark, Jr., for photography of living specimens at Carrie Bow Cay, and C.C. Hansen, Smithsonian Institution, for photography of preserved specimens and for composition of the color frontispiece.

Information on the systematics or behavior of other chaenopsids relevant to this study was received from R.D. Clarke; C.L. Smith; P.A. Hastings, University of Arizona; D.W. Greenfield, University of Hawaii; H. Andreyko, Hudson River Foundation for Science and Environmental Research; F. Cervigon, Fundacion Museo del Mar; A. Acero P., Universidad Nacional de Colombia; J.T. Williams and V.G. Springer, Smithsonian Institution; and P.H. Humann, Davie, Florida.

Much information on the biology and systematics of serpulid worms, especially *Spirobranchus*, was given to us by J.R. Marsden, McGill University and the Bellairs Research Institute in Barbados, and by E. Nishi, Natural History Museum and Institute, Chiba, Japan.

Identifications of invertebrates in this paper were generously provided by a number of scientists. From the Smithsonian Institution we thank S.D. Cairns (stony corals); F.M. Bayer (sea fans); R.B. Manning (crustacea); T.E. Coffey (echinoderms); and B.F. Kensley, K. Fauchald, R.B. Manning, and M.G. Harasewych (identifications of invertebrates that form cavities inhabited by chaenopsids), with special thanks to K. Fauchald for much information on serpulid worms. We also thank A.B. Williams, United States National Marine Fisheries Service, and S. Spotte, University of Connecticut (caridean shrimps); and G. Hendler, Los Angeles County Museum of Natural History (echinoderms).

Loans, cataloging, and radiographs of specimens examined were expeditiously processed by K.A. Murphy, D.G. Smith, L.F. Palmer, and S.J. Raredon, Smithsonian Institution; M.A. Rogers, Field Museum of Natural History; E.B. Böhlke and W.G. Saul, Academy of Natural Sciences of Philadelphia; and H. Nijssen, Zoölogisch Museum, Amsterdam.

At the Smithsonian Press, we thank Cheryl Roesel for editorial assistance that improved the paper and R. Schelin for financial support for the color frontispiece.

The manuscript benefited greatly from the suggestions received from P.A. Hastings, R.D. Clarke, S.H. Weitzman (Smithsonian Institution), and R.H. Rosenblatt (Scripps Institute of Oceanography) during the review process.

This is Contribution 492 from the Smithsonian Institution's Caribbean Coral Reef Ecosystem Program, directed by K. Rützler.

METHODS

DEFINITIONS AND ABBREVIATIONS.—Length is always standard length (SL). CBC refers to Carrie Bow Cay (Ellen Cay), on the Belize Barrier Reef, 16°48.15'N, 88°04.91'W, 18 km off the nearest point (Sittee Point, south of Dangriga) of mainland Belize. The use of the word coral refers to scleractinian hard corals. Institutional abbreviations follow Leviton et al. (1985). In statistical statements, *P* is probability, and *T* is test statistic for the Mann-Whitney rank sum test. GPS is global positioning system.

SEX IDENTIFICATION.—The sex of large pale specimens (over 20 mm) of *E. pricei* was relatively easily determined by external examination. Pale males have a genital papilla (although less prominent than that of dark-headed, hole-dwelling males), whereas females lack a papilla and have a higher and more distally scalloped anal mound. We were, however, occasionally uncertain of our sex determinations of smaller pale specimens. To test our ability to ascertain sex based on the external characteristics of papilla and anal-mound condition, 15 pale specimens were collected from sea fans (USNM 336788). These specimens represented an unbiased sample (all encountered specimens collected) from sea fans, and they ranged in length from 13.8 mm to 21.6 mm. The specimens were preserved in Dietrich's solution for histological preparation, numbered, and then sexed on the basis of papilla and anal-mound development. We were confident about our sex determinations based on external anatomy for three putative males of 17.8–21.6 mm and nine putative females of 13.8–18.5 mm, but we were less confident in our determinations for three specimens of 15.0–17.6 mm that we judged to be one female and two males. Histological examinations proved that all 15 determinations were correct.

Even though the large pale males from sea fans had developing spermatogenic tissue visible in the testes, none had free mature sperm cells, which indicated that they were not in breeding condition. We did not histologically examine the testes of dark-headed males resident in tube cavities in coral because they obviously were sexually mature based on the prominence of the genital papilla, the relative plumpness of the testes, and the brooding of eggs in all of the several cavities examined from which they had been extracted.

The initial, externally based determination of sex in pale specimens often was supplemented by opening the abdominal cavity for gross microscopic examination of the gonads, which was usually helpful in specimens over about 17 mm when the determination was otherwise in doubt. Specimens that could not be sexed confidently by a combination of external and gross gonadal examination were considered immature.

SERPULID WORM IDENTIFICATION.—The organism that creates the cavities occupied by dark-headed males of *E. pricei* is *Spirobranchus giganteus* (Pallas), a common species at Carrie Bow Cay and the only common solitary species of the genus in the Caribbean (J.R. Marsden, pers. comm., 25 April 1996). Its identification was based on (1) the structure of the cavity found

in elkhorn coral, including the cavity's entrance hole, and (2) the collection and identification of four serpulid worms within their tubes, which were near dark-headed males of *E. pricei* in cavities of similar shape on the same coral.

For information on the biology of *Spirobranchus giganteus* see the following: Smith (1985) for work on the Great Barrier Reef; the series of papers by Hunte, Conlin et al. (1990), Hunte, Marsden et al. (1990), and Marsden et al. (1990) for work at Barbados in the Caribbean; and Nishi (1995a, 1995b), Nishi and Nishihira (1996, in press), and Nishi et al. (1996) for work at Okinawa.

For information on the systematics of *Spirobranchus* see Hove (1970) and Hove and Nishi (1996), who recognized two subspecies of the "Christmas tree worm," *S. giganteus giganteus* (Pallas) in the western Atlantic (Florida to Brazil and the Caribbean) and eastern Pacific (California to Mexico and the Galapagos Islands) and *S. giganteus corniculatus* (Grube) in the Indo-Pacific (Red Sea to mid-Pacific islands).

Larval *S. giganteus* settle on a coral and begin secreting a tube. As the tube lengthens, the coral continues to grow, surrounding the tube with calcium up to the tube's aperture. The growth of the worm tube and the coral continues in unison, and ultimately the worm tube is almost entirely buried within the coral. The opening's rim remains slightly raised above the coral surface, and only the calcareous, sharp-pointed, ventral tooth-spike of the rim protrudes prominently (Hunte, Conlin et al., 1990). The tube may be buried either relatively deeply, at a right angle to the coral surface, or more superficially, parallel to it. There are a wide variety of tube structures in other genera and species of serpulid worms; the tubes of some species are much less embedded in coral and are more coiled than those of *S. giganteus* at CBC, whereas other species occur in colonial bunches.

We refer to the space occupied in a coral by dark-headed males of *E. pricei* as the "tube cavity," the "cavity," or more simply the "hole," because the lower region beyond the aperture is often eroded and no longer resembles the smooth-lined tube that once housed the *Spirobranchus* worm.

We have initiated studies on the rate of occupancy by *E. pricei* of *Spirobranchus* tubes after removal of the worms and on the rate at which *A. palmata* overgrows the opening of the tubes that remain unoccupied (e.g., tubes with opening diameters of 5 mm and larger, which may be too large for *E. pricei*). Preliminary results include the occupancy of vacated *Spirobranchus* tubes by dark-headed *E. pricei* (and also by species of *Acanthemblemaria*) within a week of our removal of the worm.

SEA-FAN AND CORAL IDENTIFICATIONS.—The specimens of *E. pricei* collected on sea fans are all from *Gorgonia ventalina* Linnaeus, the most common sea fan at CBC. Sea-fan identification was based on seven samples from various locations around CBC.

Identifications of all of the corals mentioned below were verified from photographs or from samples.

COLLECTING TECHNIQUES.—Specimens of *E. pricei* obtained from sea fans or coral surfaces were collected in clear plastic bags with an opening diameter of ~30 cm. The bag opening was placed over the blenny and the fish was teased into the bag, which was then quickly sealed. The specimens from tube cavities in coral were trapped in clear plastic tubes placed upright over the openings of the holes. The specimens were driven into the tubes by squirting a weak solution of quinaldine sulfate (1 g per 500 ml water) into the hole, which partially narcotized and disoriented the specimens.

LOCATION OF THE TWO MAIN STUDY AREAS.—Many of the specimens collected between 1993 and 1996 were from two locations. One was a patch reef about 1 km southwest of CBC that was buoyed and visited many times for observations and subsequent collections because of its richness in sea fans (GPS coordinates: 16°47.859'N, 88°05.350'W). This reef was about 50 m long and 20 m wide, ranged from 1 to 2.5 m in height, and was surrounded by a white sandy bottom in 8 m depth; it is referred to below as the "patch reef site." There were many globose corals on this patch reef but no *Acropora palmata*. Collections also were made on other adjacent patch reefs in this general area southwest of CBC, and complete data are listed for these collections.

The other main study area was just east of the laboratory on CBC in the spur and groove region that extends from the reef crest to about 20 m depth. This region had a wide variety of corals and numerous sea fans (see Rützler and MacIntyre, 1982). The spur and groove formation study site (GPS recordings: 16°48.128'N, 88°04.792'W) was buoyed at 8 m depth, and the region between 7 and 9 m depth was visited frequently, especially for the study of replacement sequences of dark-headed males in cavities in the locally abundant colonies of *Acropora palmata*; this region is referred to below as the "spur and groove site." Much collecting for male replacement studies also was done along the sides of the several spurs just north and south of the buoyed site. Because the spur and groove formation is continuous along all of the east and north sides of CBC, complete data are listed only for those collections made beyond about 30 m distance and 1 m depth of the buoyed site. On the north side of CBC, the spur and groove zone is along the south side of the channel between CBC and the island to the north, South Water Cay. Greenfield and Johnson (1990) noted the high frequency of occurrence of *E. pricei* in spur and groove formations off Belize.

Results

SYSTEMATICS

GENERIC ALLOCATION.—Although Acero (1987) synonymized *Emblemaropsis* with *Coralliozetus*, which was followed by Robins et al. (1991), we accept the ongoing cladistics-based results of the revisions by Hastings (e.g., 1992a) and Hastings and Springer (1994) of various chaenopsids in recognizing the

distinctiveness of *Emblemariopsis* within a *Coralliozetus*-like clade.

Ten species currently are placed in *Emblemariopsis*: the seven species recognized by Stephens (1970); *E. pricei* Greenfield, 1975; *E. ruetzleri* Tyler and Tyler, 1997; and *E. tayrona* (Acero), referred to *Emblemariopsis* by Hastings (1992a, MS).

Of the five species of *Emblemariopsis* without supraorbital cirri, three (*diaphana*, *bottomei* Stephens, *bahamensis* Stephens) have 13 pectoral-fin rays, whereas the other two species (*pricei* and *randalli* Cervigon) have 14 pectoral-fin rays. Of the five species of *Emblemariopsis* with supraorbital cirri, four (*tayrona*, *signifera* (Ginsberg), *occidentalis* Stephens, *leptocirris* Stephens) have 13 pectoral-fin rays (Stephens, 1970:284–285; Hastings, 1992a), and one (*ruetzleri*) has 14 pectoral-fin rays. The proper generic allocation of *E. pricei* is assured by its possession of the following derived character states delineated by Hastings (1992a, MS) for the genus based on four other species of *Emblemariopsis*. *Emblemariopsis pricei* has a short neural spine on the penultimate vertebra, a feature unique to this genus among chaenopsids (Hastings, MS); the mesopterygoid is absent; the pelvic-fin rays are prolonged beyond the membranes in both males and females; the nasals are separate, with ridges present; and the third basibranchial is unossified.

The phylogenetic relationships among the species of *Emblemariopsis* are unknown. Of the two features of similarity of *E. pricei* and *E. randalli*, the absence of a supraorbital cirrus may be a synapomorphy (see Hastings, 1992a) for these two

species and three others, whereas the 14 pectoral-fin rays found in these two species and *E. ruetzleri* is of unknown polarity.

DIFFERENCES BETWEEN *E. pricei* AND *E. randalli*.—Previous descriptions of *E. pricei* were based on 10 specimens, two in the original description (Greenfield, 1975) and eight obtained subsequently (Greenfield and Johnson, 1981). Nine of these specimens were from either Glovers Reef (the type locality) or Carrie Bow Cay, Belize, and the tenth specimen was from Big Hog Island, Honduras. Previous descriptions of *E. randalli* were based on 17 specimens, 10 in the original description (Cervigon, 1965) and seven obtained subsequently (Cervigon, 1966), all from Bahia de Charagato, Isla Cubagua, Venezuela.

With 174 newly acquired specimens of *E. pricei* from Carrie Bow Cay and seven unreported specimens of *E. randalli* now available, we provide a fuller differentiation of the two species than previously possible.

In general proportions, the head and body of the examined specimens of *E. randalli* appear to be deeper than those of *E. pricei*, and this seems apparent in Table 1. Because, however, the relatively few specimens of *E. randalli* are, on average, about 7 mm longer than those of *E. pricei* and because of the relatively small overlap in their length (in the 21–24 mm SL range), these data are only suggestive of proportional differences between them and are insufficient for statistical testing.

The two species clearly differ (Table 2) in the average number of soft anal-fin rays (21.0 in *randalli* versus 22.6 in *pricei*) and in the usual total number of vertebrae (38.0 in *randalli* versus 39.0 in *pricei*). The number of abdominal vertebrae usually

TABLE 1.—Selected proportional measurements of *Emblemariopsis pricei* and *E. randalli*.

| Species | Number | Size range (mm SL) | Average size (mm SL) | Head length (% SL) | | Head depth (% SL) | | Body depth (% SL) | |
|---------------------------------|--------|--------------------|----------------------|--------------------|---------|-------------------|---------|-------------------|---------|
| | | | | Range | Average | Range | Average | Range | Average |
| <i>E. pricei</i> [*] | 59 | 10.3–24.3 | 16.7 | 23.0–31.1 | 26.6 | 12.6–16.5 | 14.5 | 11.0–14.9 | 13.0 |
| <i>E. randalli</i> [†] | 7 | 21.4–27.2 | 23.9 | 26.1–29.0 | 27.7 | 15.7–18.8 | 17.6 | 15.4–18.7 | 16.3 |

^{*} Data from materials collected for this study at Carrie Bow Cay, Belize.

[†] Data from material reported herein from Venezuela.

TABLE 2.—Meristics of *Emblemariopsis pricei* and *E. randalli*.

| Species | Dorsal-fin spines | | | Soft dorsal-fin rays | | | | | Total dorsal-fin elements | | | | | Soft anal-fin rays ^a | | | | | Pectoral-fin rays ^b | | | Total vertebrae ^c | | | | Interorbital pores | | | | |
|---------------------------------|-------------------|----|----|----------------------|----|----|----|----|---------------------------|----|----|----|----|---------------------------------|----|----|----|----|--------------------------------|----|----|------------------------------|----|----|----|--------------------|---|----|---|---|
| | 20 | 21 | 22 | 10 | 11 | 12 | 13 | 14 | 31 | 32 | 33 | 34 | 35 | 20 | 21 | 22 | 23 | 24 | 13 | 14 | 15 | 37 | 38 | 39 | 40 | 1 | 2 | 3 | 4 | 5 |
| <i>E. pricei</i> ^d | 8 | 47 | 3 | – | – | 3 | 46 | 10 | – | – | 6 | 46 | 7 | – | 1 | 22 | 32 | 1 | 9 | 21 | 1 | – | 3 | 18 | 2 | 2 | 6 | 15 | 2 | – |
| <i>E. pricei</i> ^e | 2 | 8 | – | – | – | 2 | 6 | 2 | – | – | 3 | 6 | 1 | – | – | 6 | 4 | – | – | 20 | – | – | – | 8 | – | – | – | – | – | – |
| <i>E. randalli</i> ^f | 3 | 4 | – | 1 | – | 4 | 2 | – | 1 | 1 | 5 | – | – | 1 | 6 | 1 | – | – | – | 16 | – | 1 | 6 | 1 | – | – | – | – | 1 | 7 |
| <i>E. randalli</i> ^g | 2 | 15 | – | – | – | 7 | 10 | – | – | 2 | 5 | 10 | – | 5 | 7 | 5 | – | – | – | 33 | 1 | – | – | – | – | – | – | – | – | – |

^a All specimens with two anal-fin spines; total count of anal-fin elements two more than that of soft rays.

^b Counted on both sides of most specimens.

^c All specimens with 11 abdominal vertebrae except single specimens of *E. pricei*, with 10 and 12 abdominal vertebrae.

^d Data from materials collected for this study at Carrie Bow Cay, Belize.

^e Data from Greenfield and Johnson (1981) for specimens from Belize and Honduras.

^f Data from materials reported herein from Venezuela.

^g Data from Cervigon (1965, 1966) for specimens from Venezuela.

is 11 in both species, with the difference between them being in the caudal series (defined herein as beginning with the vertebra whose haemal spine is most closely associated with the dorsal tips of the shafts of the first two anal-fin basal pterygiophores). Another meristic difference is in the number of anterofrontal cephalic pores (sensu Hastings, 1992a) in the interorbital region between the posterior halves of the eyes: in *E. randalli* there are usually five pores, a median commissural pore (sensu Stephens, 1963, 1970; Hastings and Springer, 1994) and usually two pores on each side anterolaterally and posterolaterally (one of which is occasionally absent); in *E. pricei* there are usually only three pores, the median commissural and one pore to each side anterolateral to it (between the frontal and nasal bones), although one of these is sometimes absent, and one or both of the anterofrontal pores posterolateral to it sometimes is present.

Inspection of the number of soft dorsal-fin rays between the two species as represented in Table 2 does not suggest an obvious difference in these meristics, which, like the others, failed to pass tests for normality ($P < 0.001$). Thus, the nonparametric Mann-Whitney rank sum test was used to test the null hypothesis of no difference in soft dorsal-fin rays. It was found that the difference in the median values of the population samples of the two species is statistically significant ($T = 699$, and

$P < 0.001$). No statistically significant differences were found between the number of dorsal-fin spines or the number of pectoral-fin rays of the two species. The total number of dorsal-fin elements was statistically significantly different, but this is simply an expression of the difference in the number of soft dorsal-fin rays and therefore a redundant measure of this difference.

The two species differ strikingly in preserved color pattern in at least moderate- to large-sized specimens of both sexes. In *E. randalli* there is a prominent, oval, median, dark blotch along all of the surface of the anal mound in both sexes, but this is not present in either sex of *E. pricei* (for the latter, see Figures 1 and 2 for dark-headed and pale males and Figure 3 for females). In *E. randalli*, females are lightly speckled with dark pigment on the top of the back of the head and all over the body, and males are heavily speckled and moderately dark on the head and all of the body. In *E. pricei*, only preserved territorial (cavity dwelling) males are dark and then only on the head and anterior part of the body. Male *E. randalli* have a chalky white region distal to the otherwise darkened membrane in the anterior part of the spinous-dorsal fin; this whitish band is relatively deep anteriorly, occupying the distal one-third of the membrane between the first few spines, but it decreases gradually in depth posteriorly to terminate between the fifth

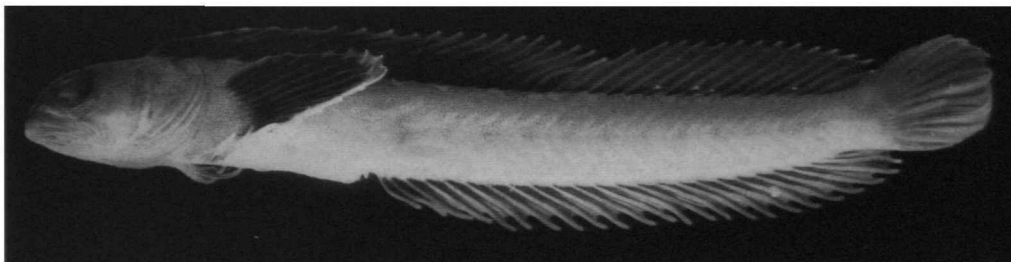


FIGURE 1.—Typical preserved appearance of a moderately dark-headed male of *Emblemariopsis pricei*, USNM 336764, 22.7 mm SL, from a tube cavity in living *Acropora palmata*, spur and groove east of Carrie Bow Cay, Belize, 5 m, 15 March 1994.

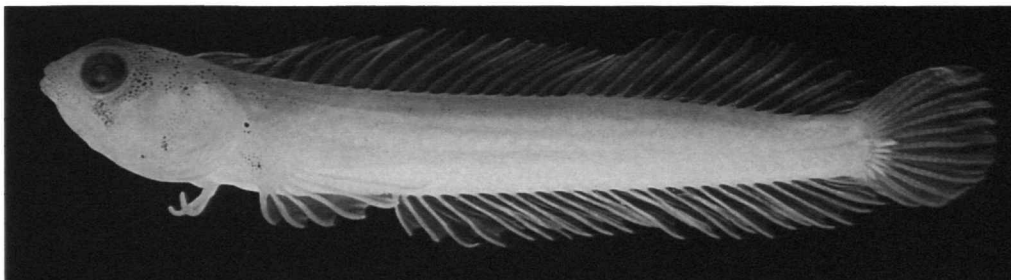


FIGURE 2.—Typical preserved appearance of a pale male of *Emblemariopsis pricei*, USNM 325443, 21.9 mm SL, from a sea fan (marked sea fan no. 14), patch reef study site 1 km southwest of Carrie Bow Cay, Belize, 8 m, 9 February 1993.

and sixth (smaller specimens) to tenth spines. Female *E. randalli* have a distal whitish band similar to that of males, but below it the membrane is not uniformly dark; rather, it bears dark blotches between the first to fourth dorsal-fin spines. In *E. pricei*, the dorsal-fin membranes are only lightly speckled with melanophores in all specimens except territorial males, the spinous dorsal-fin membrane of which is uniformly darkened and without a whitish distal band (Figures 4–7). In *E. randalli*, males have five or six dark spots along the base of the spinous-dorsal fin, spaced at about every third or fourth spine, beginning at about the sixth to eighth spine and ending under the last few spines or first few rays; females have fewer and less intensively pigmented spots under the spinous-dorsal fin. In *E. pricei* there are no such spots along the dorsal-fin base in preserved specimens, even though in life there is internal dark coloration that gives much the same effect as spots (Figure 4 and Frontispiece A,B). The anal fin in *E. randalli* has a more intense pigment band than it does in *E. pricei*. Based on the description of the color of fresh specimens of *E. randalli* by Cervigon (1965, 1966), at least the males of this species are far more colorful than those of *E. pricei*.

Although adults of *E. randalli* and *E. pricei* are distinctive, the postlarvae of the two species may be difficult to distinguish. Birdsong and Emery (1968) listed two postlarval specimens from Lighthouse Reef, Belize, as *E. diaphana*. Stephens (1970) found that these specimens have 14 pectoral-fin rays and tentatively identified them as *E. randalli*, the only then-known species of *Emblemariopsis* with more than 13 pectoral-fin rays (counts confirmed by P.A. Hastings, pers. comm., 3 May 1995). Because the more recently described *E. pricei* also has 14 pectoral rays, the record from Lighthouse Reef could apply to either *E. pricei* or *E. randalli*. *Emblemariopsis pricei*,

however, is definitely known to occur on the Belize Barrier Reef and *E. randalli* is not; thus, we think it more likely that the Lighthouse Reef specimens are *E. pricei*.

Humann's (1994) reef fish identification guide includes two photographs under the name *Coralliozetus bahamensis*, a species that lacks a supraorbital cirrus. One photograph is of a dark-headed individual partially protruding from a cavity opening in apparently dead coral at Dry Tortugas, Florida, and the other photograph is of a semitransparent individual on a sea fan at Lighthouse Reef, Belize (the stated locality in Humann, 1994:269, of Culebra, Puerto Rico, is incorrect, P.H. Humann, pers. comm., 23 July 1991). Without voucher specimens it is impossible to be sure of the identification of these individuals. Indeed, these two photographs may not be of the same species. The semitransparent individual on a sea fan at Lighthouse Reef, Belize, may be *E. pricei* because of its known sea-fan habitat on the Belize Barrier Reef. The dark-headed individual may be *E. diaphana*, the only species of the genus known from the Florida Keys (and one that is known to have individuals on coral surfaces and sea fans; Longley and Hildebrand, 1940; Butter et al., 1980).

MICROHABITATS OF *Emblemariopsis pricei*

Sea Fans

SIZE AND SEX OF SEA-FAN DWELLING PALE INDIVIDUALS.—A total of 77 specimens were collected on sea fans. These specimens represent a relatively unbiased sample because an attempt (usually successful) was made to collect every individual seen during a collecting dive (with the exception of those on tagged sea fans during constancy of occurrence obser-



FIGURE 3.—Typical preserved appearance of females of *Emblemariopsis pricei*, USNM 325450, specimen of 18.6 mm SL above a 17.5 mm SL specimen, both from sea fans in a cumulative composite collection on patch reefs southwest of Carrie Bow Cay, Belize, and in the spur and groove along the east and north sides of the cay, 5–10 m, 2–10 March 1992.

vations in January–February 1993, when collecting was delayed until the final day). Of these, 41 (53%) were females of 11.7–19.6 mm (average 16.6 mm), 20 (26%) were males of

13.9–24.3 mm (average 20.1 mm), and 16 (21%) were immatures of 10.3–16.7 mm (average 12.9 mm). Thus, on sea fans males were only about one-half as numerous as females but

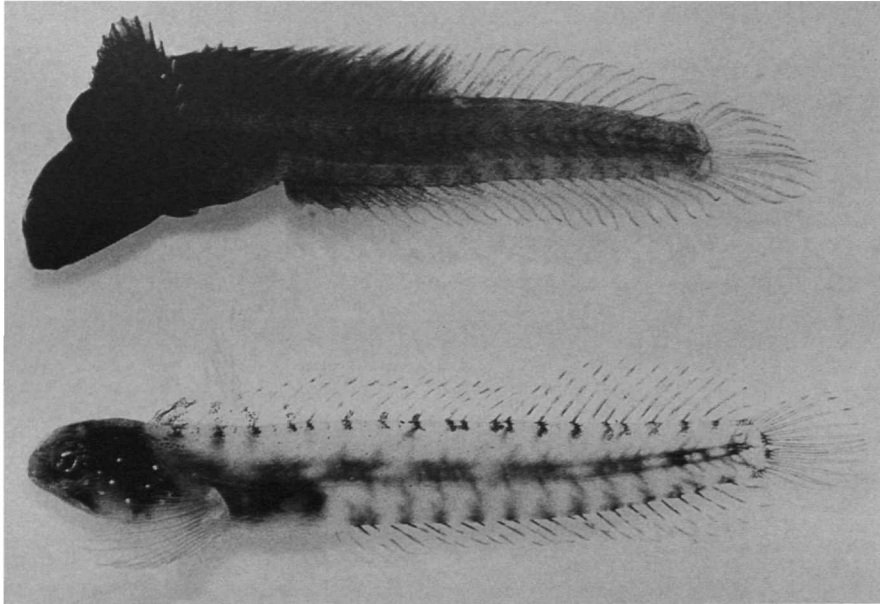


FIGURE 4.—Live specimens of *Emblemariopsis pricei*, USNM 336740, anesthetized in the laboratory. The dark-headed male, 19.8 mm SL, is from a tube cavity in a dead section of an otherwise living *Montastrea annularis*; the pale male, 20.3 mm SL, replaced it from the nearby surface of the living coral. The pale male replacement was collected about 45 minutes after the removal of the dark-headed male and perhaps already shows a slight darkening of the head and anterior region of the spinous-dorsal fin. Both from patch reef southwest of Carrie Bow Cay, Belize, 8 m, 7 March 1994 (see Figure 5 for these two specimens preserved).



FIGURE 5.—Preserved appearance of the same two specimens (the 19.8 mm SL dark-headed male above the 20.3 mm SL replacement) of *Emblemariopsis pricei* shown alive (anesthetized) in the laboratory in Figure 4.

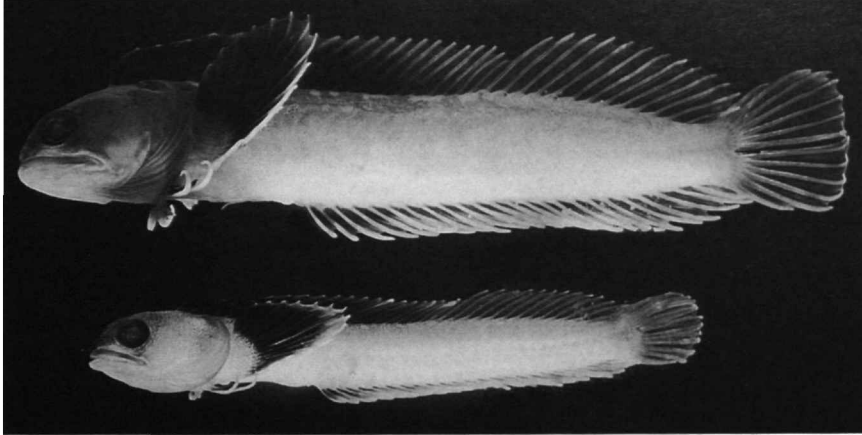


FIGURE 6.—Typical amount of variation in the darkness of preserved, smaller- and larger-sized dark-headed males of *Emblemariopsis pricei*, USNM 336746 (specimen above, 23.1 mm SL; specimen below, 17.9 mm SL). The larger specimen is from a tube cavity in living *Diploria strigosa* and the smaller one is from a tube cavity in a dead section of an otherwise living *Porites astreoides*, spur and groove study site just east of Carrie Bow Cay, Belize, 8 m, 12 March 1994.

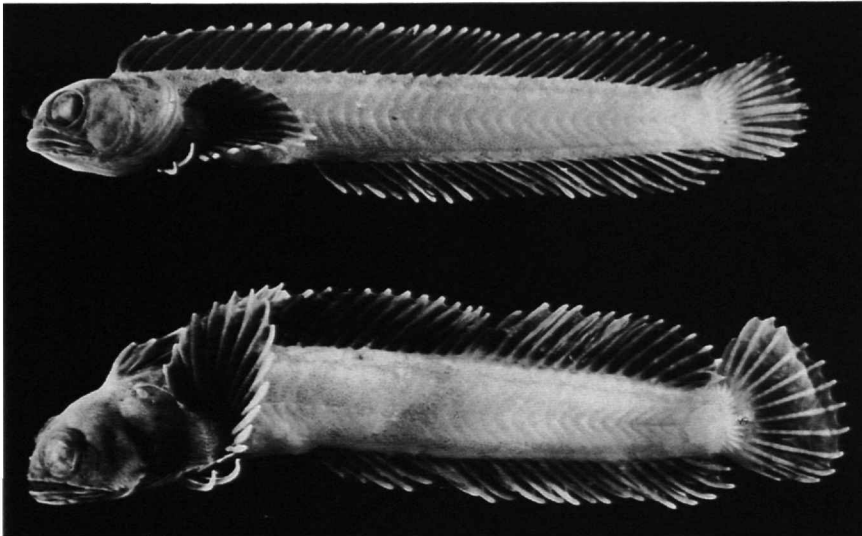


FIGURE 7.—Preserved dark-headed males of *Emblemariopsis pricei*. The upper specimen, 21.6 mm SL, is typical of the five individuals (USNM 341517, 21.6–23.8 mm SL) removed from tube cavities in living *Acropora palmata* in the spur and groove study area just east of Carrie Bow Cay, Belize, 8 m, on 16 March 1996, and the lower specimen, 21.6 mm SL, is typical of four of the five replacement individuals (USNM 341518, 19.7–22.2 mm SL) removed from these same cavities 10 days later, 26 March (one of the five replacement specimens was significantly less darkly pigmented than the other four; see text and Table 6).

were significantly larger in average size. Some of these females were ripe or approaching ripeness, but none of the males had sexually active testes (see “Sex Identification” and “Reproduc-

tion”). All of the sea-fan dwelling specimens were pale in preservation (Figures 2, 3), whereas in life they were semitransparent, with only a few surface melanophores but many internal

markings (Frontispiece B–D) of orange, silver, golden brown, and chalk that blend into the sea fan background and render them very inconspicuous. The most prominent of the internal markings seen through the semitransparent flesh are the eight or nine orangish blotches along the neural arches (separated by less-well-defined chalky blotches), the brown and chalk bands on the abdomen, the golden brown and silver stripes and spots on the top of the head and around the eyes, and the golden brown spots at the bases of every few dorsal- and anal-fin elements, which extend inward along the pterygiophores, especially in the anal fin. The most prominent dark marks on the surface of the body are a bar below the eye, a spot on the pectoral-fin base, irregular blotchy speckling on the opercular region and on the top of the head behind the eye, and spotting along sections of the dorsal-fin spines.

The sea-fan dwelling individuals often were overlooked during the first few days at the beginning of this study in 1991 because the sea fans were examined perpendicular to their surface. It was rapidly learned that the blenny was more readily seen when the sea fan was inspected along its edge parallel to the broad surface; this examination often was aided by holding an edge of the fan with fingers to partially arrest its swaying in the currents.

These blennies are extremely agile and are adept at escaping capture, moving from one side of a sea fan to the other by darting around the sea fan's edges or through its surface apertures. They also dart onto coral, algae, or other substrate around the base of the sea fan, where they are nearly impossible to find.

CONSTANCY AND PERCENTAGE OF OCCURRENCE ON SEA FANS.—In an effort to obtain some approximation of the relative degree of constancy of occupancy of a blenny on a particular sea fan, a patch reef about 1 km southwest of CBC that had

numerous sea fans was selected for daily examination (for specifications of this reef, see "Location of the Two Main Study Areas"). A survey of the entire reef led to an estimate of about 160 sea fans more or less evenly distributed over the reef, but those on the southeastern cavernous 20% of the reef were not further considered because of the presence of an especially large and assertive green moray in that region. Therefore, there were approximately 130 sea fans in the effective study area.

On the first day (31 January 1993) of assessment of blennies on sea fans, the approximately 50 sea fans in the more western region of the reef were closely examined during a 1.3 hour search by two divers; six sea fans were found to have a blenny present on the surface. These sea fans were tagged with numbered ribbons. On the following day (1 February), the first 15 minutes of the dive were devoted to examining these same six sea fans and noting whether a blenny was present (P) or absent, or at least not seen (NS). If a blenny was present, its approximate size in terms of small (about 10–16 mm), medium (about 17–20), or large (about 21–24 mm) was noted. The remaining one hour of the dive was spent looking for other sea fans with blennies, and five more were found and numbered, most of them to the northeast of the area assessed on the preceding day. Table 3 summarizes these and subsequent days' inspection of sea fans on which blennies had been previously seen and of new sea fans on which additional blennies were found.

Sixteen sea fans were tagged between 31 January and 3 February. During the four periods of diving observation between 4–9 February, the 16 tagged sea fans were examined during the first 20–30 minutes of each dive. The remaining approximately one hour of observation time was spent looking for blennies on

TABLE 3.—Relative constancy of subsequent presence of *Emblemariopsis pricei* on 16 marked sea fans observed to have a blenny present during surveys of a study patch reef from 31 January to 3 February 1993. The patch reef is located ~1 km southwest of Carrie Bow Cay, Belize, has a dimension of ~50 × 20 m, and rises 1–2.5 m off a white sand bottom in 8 m depth. There are estimated to be 160 sea fans on this patch reef, with about one in eight having a blenny present. All sea fans on which blennies were observed were marked, but one area representing about 20% of the reef was not included in the blenny search. (P=present; NS=none seen, presumably absent at time of observation. When size of specimens was noted, this is indicated by sm=small, med=medium, lg=large.)

| Sea-fan number | 31 Jan | 1 Feb | 2 Feb | 3 Feb | Feb 4 | 5 Feb | 6 Feb | 9 Feb |
|----------------|--------|---------|---------|-----------|-----------|---------|-----------------|-----------------|
| 1 | P | P (sm) | P (sm) | NS | NS | P (sm) | NS | NS |
| 2 | P | P (med) | P (med) | P (med) | P (med) | P (lg) | P (med) | P (1 med, 1 lg) |
| 3 | P | NS | P (sm) | P (sm) | P (sm) | P (sm) | NS | NS |
| 4 | P | P (sm) | P (med) | P (sm) | P (2 med) | P (med) | NS | P (med) |
| 5 | P | P (med) | P | P (med) | NS | P (med) | P (1 med, 1 lg) | P (med) |
| 6 | P | P (med) | P (med) | P (sm) | P (sm) | P (med) | P (med) | P (med) |
| 7 | – | P | P (med) | P | P (lg) | P (lg) | P (med) | P (med) |
| 8 | – | P | P (med) | NS | NS | P (med) | NS | P |
| 9 | – | P | P (med) | P (sm) | NS | NS | P (med) | NS |
| 10 | – | P | P (sm) | P | NS | NS | NS | NS |
| 11 | – | P | P (med) | NS | P (med) | NS | NS | NS |
| 12 | – | – | P (sm) | NS | NS | NS | P | NS |
| 13 | – | – | P (lg) | P (med) | P (med) | P (sm) | P | P (lg) |
| 14 | – | – | P (med) | P (2 med) | P (med) | P (med) | P (lg) | P (med) |
| 15 | – | – | – | P | P (med) | P (med) | P (med) | NS |
| 16 | – | – | – | P | P (med) | P (med) | P (sm) | P (med) |

untagged sea fans in the areas previously assessed, but none were found. A large minority (7 of 16) of the tagged sea fans had blennies absent or at least not seen on two or more of the subsequent days of observation, but more than one-half had a blenny present either on all of the subsequent assessment days (6 of 16, including 2 of the original 6 sea fans tagged on 31 January) or on all but one of the subsequent days (3 of 16).

Although we could not recognize individual blennies on sea fans from one day to the next, in most cases it seems that the same individual was not necessarily present over many days on a particular sea fan because of differences in the estimated sizes of the blennies present on various days. Nevertheless, the combination of consistently not finding blennies on most of the sea fans in the effective study area over the four day assessment period of 4–9 February and the consistency of finding blennies on most days of observation on 9 of the 16 tagged sea fans, leads to the conclusion that some sea fans are far more likely to have blennies on them than are others. No gross morphological differences were noted between those sea fans with and those without blennies.

The greater percentage of occurrence on certain sea fans probably has nothing to do with the sea fan itself. It could be related to the suitability of the region around the base of the sea fan for off-fan foraging and other functions (including nocturnal quiescence; see below) or to the presence of cavity-dwelling males within an appropriate distance from the sea fans for females to visit for breeding and for nonterritorial males to have the opportunity to occupy vacated cavities. Also, there is probably an element of chance to multiple occurrence on particular sea fans, with whichever sea fan that happens to attract one blenny perhaps becoming a site of attraction for others.

No correlation was evident between the size of the sea fans and the size of the blennies on them or between the position of the blennies on one side or the other of the sea fan relative to current direction.

Table 3 shows that two blennies were sometimes present on one sea fan, and on several other occasions after the observation period three blennies were seen on a single sea fan.

Between 2–4 February 1993, five sea fans and the single blennies on each of them were removed from another patch reef southwest of CBC and transported to large aquaria at the laboratory. These sea fans were observed at numerous times of the day and night for one week. During daylight hours, the blennies were usually on the sea fans and were less frequently on the live coral, coralline algae, and rubble surfaces that covered the bottom of the aquaria; at night, blennies were never seen on the sea fans but could usually be located (with the aid of a flashlight) on the surface of the substrates near the base of the sea fans. Although we did not verify this by night observations in the reef habitats, we presume that the blennies' association with sea fans is diurnal and that they have their nighttime quiescent period on the reef structures below the sea fans.

One of these five blennies died in poor condition after a few days and two others could not be easily located among the rubble in which they took refuge when the aquaria were too hur-

riedly dismantled at the end of a research period; thus, only two of them were preserved (USNM 325441, a 16.5 mm female and a 17.4 mm male).

INVERTEBRATES ON SAME SEA FANS AS *E. pricei*.—The two most common invertebrates found on sea fans along with *E. pricei* around CBC were the flamingo tongue gastropod, *Cyphoma gibbosum* (Linnaeus), and juveniles of the basketstar, *Astrophyton muricatum* (Lamarck). Less frequently encountered were the green clinging crab, *Mithraculus sculptus* (Lamarck), and the caridean shrimp, *Periclimenes patae* Heard and Spotte (the latter a recently described gorgonian-dwelling member of the *P. iridescens* Lebour complex, see Heard and Spotte, 1991). No interactions were seen between the blennies and these invertebrates.

Corals

CORAL SPECIES ON WHICH *E. pricei* IS FOUND.—Most of our specimens of *E. pricei*, other than those collected from sea fans, were from the surface of, or from tube cavities in, living elkhorn coral, *Acropora palmata*. This may be a reflection of concentrating our work on dark-headed males in the close-by spur and groove study site just to the east of CBC and to the ease of seeing both the dark-headed males in cavities in, and the nonterritorial males on the surface of, elkhorn coral. Although we did not systematically assess what percentage of clusters of elkhorn corals had dark-headed *E. pricei* present in cavities, we estimate that about one in every three coral clusters in the spur and groove study site had a dark-headed male present. Usually there was only one dark-headed male in a cluster, but occasionally two and, in two cases, three were present in one cluster.

In addition to living *A. palmata*, *E. pricei* also was collected in tube cavities in living colonies of *Colpophyllia natans* (Houttuyn), *Diploria strigosa* (Dana), *Porites astreoides* Lamarck, and *Montastrea annularis* (Ellis and Solander). All of the specimens of *E. pricei* collected on coral from patch reefs southwest of CBC, where there is little *A. palmata*, were found on these four species of corals.

Although *E. pricei* usually occurs in association with live coral, it occasionally was collected in cavities in dead coral (*A. palmata*, *P. astreoides*, *M. annularis*), but usually in dead areas near otherwise living parts of a colony. Of the 45 collections of resident (nonreplacement) dark-headed males in tube cavities, seven collections (15%) were from dead coral. This, however, is a false representation of the frequency of occurrence in dead coral because a conscious effort was made to collect all dark-headed blennies resident in dead coral (both for this study and for that of the recently described *Emblemariopsis ruetzleri*) and because many dark-headed males of *E. pricei* were observed in living coral but were not collected during the course of the study.

SIZE AND SEX OF PALE INDIVIDUALS FROM CORAL SURFACES.—Fifty-two specimens were collected either directly from the surface of corals or from tube cavities

that had been reoccupied shortly after a dark-headed male had been removed. Most of the specimens removed from vacated cavities had been observed on the surface of the corals in the vicinities of the cavities before the resident dark-headed males were removed. Therefore, we think it reasonable to record all of the specimens that entered vacated cavities as being from nearby coral surfaces. Of these 52 surface specimens, 38 were pale males of 14.9–22.3 mm (average 19.5 mm), 10 were females of 14.8–18.1 mm (average 16.4 mm), and 4 were immatures of 10.0–13.6 mm (average 11.6 mm). Of the 38 pale males, 7 (14.9–21.0 mm) were collected directly on the surface of corals and 31 (15.8–22.3 mm) were collected after they replaced dark-headed males that had been removed (see Tables 4–6 for sizes of all of the replacements). Of the 10 females, 6 (14.8–18.1 mm) were collected directly on the surface of corals and 4 (15.0–16.2 mm) were in cavities from which dark-headed males had been removed.

Of the six females collected on the surface, only one (16.6 mm) was judged to be very ripe, having ovaries with eggs of up to 0.7 mm diameter, which was slightly larger than any eggs measured for any other *E. pricei* female. Given what is known about the life history in most chaenopsids, it is reasonable to assume that this 16.6 mm female was in transit for purposes of depositing eggs in a cavity occupied by a dark-headed male. Of the other five females (14.8–18.1 mm) collected on the surface, three had ovarian eggs of 0.3 mm diameter, one had eggs of 0.4 mm diameter, and one had eggs of 0.45 mm diameter. These five females were not considered to be ripe enough to lay eggs because the size of eggs incubated in cavities was 0.6–0.7 mm diameter (see “Incubating-Egg Numbers”). Therefore, we presume that these five females collected on coral surfaces were on excursions from sea fans for feeding or for some other nonbreeding-related activity.

Of the four females collected in vacated cavities, only one (15.8 mm) was judged to be very ripe, with eggs up to 0.65 mm diameter, the second largest diameter of ovarian eggs measured in any specimen. We presume that this female entered the cavity to seek temporary refuge rather than to deposit eggs, based on aquarium observations of behavior in *Acanthemblemaria spinosa* Metzelaar and *A. aspera* (Longley) (R.D. Clarke, pers. comm., 14 May 1996), whose females only enter male occupied cavities for egg laying after courtship. Of the other three females (15.0–16.2 mm) collected in vacated cavities, two had developing ovaries with 0.3–0.45 mm eggs and one was approaching maturity with 0.5 mm eggs but was not yet ripe enough to lay eggs. We presume that these three females also had entered the vacated cavities for temporary refuge. We guess that the four immatures collected on coral surfaces were on foraging excursions from the sea-fan habitat, although coral surfaces may be an alternate habitat for them.

SIZE OF DARK-HEADED MALES FROM TUBE CAVITIES IN CORAL.—Forty-five dark-headed specimens resident in undisturbed tube cavities in coral (i.e., excluding originally pale

specimens that occupied cavities made available by the removal of a resident specimen) were collected, all of which were males with a prominent genital papilla. These specimens represent an unbiased sample because very little difference in size can be detected from the anterior part of the head, which protrudes from the opening of the cavity, and because during dives devoted to specimen collection, nearly all encountered individuals were taken. The cavity-dwelling males ranged from 17.5 mm to 28.6 mm (average 22.1 mm). All but one were very dark-headed in life and more or less fully retained the dark-headed coloration in preservative (in contrast to the pale males that usually replaced them in the cavities, which become dark-headed overnight but which do not retain much of this darkening in preservative after only a day or two in the cavity; see “Replacement Sequences”). The one exception was an 18.4 mm male specimen that was noted at the time of collection to be only moderately dark-headed, less so than all of the others collected as original occupants of tube cavities. Its testes were long and thin rather than at least moderately plump, as was the condition for all of the more fully dark-headed individuals. Its cavity was collected (along with a 20.0 mm pale male specimen that replaced the 18.4 mm dark-headed specimen), and it did not contain eggs. Because this specimen was only moderately dark headed in life (some of which was not retained in preservative) and had thin testes, and because there were no eggs in the cavity, we speculate that it had taken up residence in the cavity within no more than the previous day or two, had not yet obtained breeding condition, and had not yet developed a full complement of melanophores on the head. All five of the other cavities that were collected after removal of the dark-headed residents had eggs (see “Structure of Tube Cavity” and “Incubating-Egg Numbers”).

There is great variation in the degree of dark coloration among cavity-dwelling males. Although intensity of head darkening and extension of dark coloration along the body tends to be greater in the largest territorial males (as typified in Frontispiece A, illustrating 21.9 mm and 26.5 mm specimens), some smaller cavity-dwelling males are almost as dark (as typified in Figure 6 illustrating 23.1 mm and 17.9 mm specimens). The implication that the degree of darkening is directly related to length of time spent in the tube-cavity habitat is confirmed by the data given in the section on “Replacement Sequences.” It seems reasonable to assume that there is a gradual increase both in specimen length, which on average is about 20 mm, and in degree of darkening following initial residence in a cavity.

The testes of the dark-headed males (with the exception noted above) resident in cavities are nearly all noticeably plumper than those of the pale males collected on sea fans and on the surface of corals; this distinction is especially apparent between the testes of resident males removed from cavities and those of the pale males that replaced them.

REPLACEMENT SEQUENCES FOLLOWING REMOVAL OF DARK-HEADED MALES.—In the spur and groove study site, pale individuals of *E. pricei* frequently were noted on the coral surface near the holes containing dark-headed males. These

pale individuals darted into, or in and out of, the cavities within minutes after the removal of a dark-headed individual. How quickly they settled into the cavities seemed to depend on how rapidly the quinaldine that was used to extract the dark-headed males dissipated, usually within two or three minutes but sometimes as long as 10 minutes. These observations led to an effort to collect a number of dark-headed males from cavities and revisit the same cavity to remove the replacement individuals to determine their size and sex.

If there were several semitransparent individuals on the surface within about one meter of the vacated cavity, it was found that a series of replacement individuals could be collected from the same cavity (see Figures 4, 5 for typical live and preserved

appearance of an original occupant and a replacement collected later during the same dive). In two sets of short-term experiments (less than 24 hours), 18 dark-headed males were removed from their cavities (16 in March 1994 and 2 in February 1995). Each cavity was marked with a numbered ribbon. These cavities were then checked either during the same dive (dive durations usually 60–90 minutes), a subsequent dive the same day, or, in one case, the following morning. Fifteen of these 18 cavities had replacements (see Table 4). During a longer experiment (more than one week) conducted in February 1995, four dark-headed males were removed from their cavities, but only two cavities had replacement specimens (Table 5). Thus, replacement sequences were observed in 17 out of 22 cavities.

TABLE 4.—Replacement sequences following removal of resident dark-headed territorial male *Emblemariopsis pricei* from their holes (exclusive of those from numbered holes given in Table 5), with notation of when the replacement individuals were collected. Same dive means that the replacement was collected during the one-hour length typical scuba dive during which the original occupant was removed (typically within a few to 15 minutes, or sufficient time for the quinaldine to be washed out of the hole). See "Materials" for detailed specimen data, but the majority of collections are from the spur and groove formation just east of Carrie Bow Cay, Belize, 5–9 m depth, in 1994 and 1995, and are mostly from holes in living *Acropora palmata*.

| Catalog no. | Original occupant | 1 st replacement | 2 nd replacement | 3 rd replacement | 4 th replacement | 5 th replacement |
|---------------------|--|--|---|---|--|--|
| USNM 336740 | 19.8 mm dark-headed male | 20.3 mm pale male, removed same dive | | | | |
| USNM 336743 | 27.8 mm dark-headed male | 22.1 mm pale male, removed same dive | | | | |
| USNM 336748 | 18.4 mm moderately dark-headed male | 20.0 mm pale male, removed same dive | | | | |
| USNM 336751 | 20.4 mm dark-headed male | 18.4 mm pale male, removed same dive | | | | |
| USNM 336752 | 20.9 mm dark-headed male | 19.0 mm pale male, removed same dive | | | | |
| USNM 336754–336756 | 23.6 mm dark-headed male, removed 14 March | 17.5 mm pale male, removed AM 15 March | 18.8 mm pale male, removed PM 15 March | 16.0 mm female with 0.5 mm diameter eggs, removed same PM dive 15 March | | |
| USNM 336757, 336758 | 23.1 mm dark-headed male, removed AM dive | 20.0 mm pale male, removed PM dive, same day | 18.7 mm pale male, removed same PM dive | | | |
| USNM 336759, 336760 | 25.5 mm dark-headed male, removed AM dive | 20.6 mm pale male, removed same AM dive | 18.5 mm pale male, removed same AM dive | 15.0 mm female with 0.3 mm diameter eggs, removed same AM dive | 18.9 mm pale male, removed PM dive, same day | 15.8 mm pale male, removed PM dive, same day |
| USNM 336762 | 24.4 mm dark-headed male | 19.7 mm pale male, removed same dive | 19.7 mm pale male, removed same dive | | | |
| USNM 336763 | 21.5 mm dark-headed male | 18.8 mm pale male, removed same dive | 19.4 mm pale male, removed same dive | | | |
| USNM 336766 | 20.4 mm dark-headed male | 16.2 mm female with 0.45 mm diameter eggs, removed same dive | | | | |
| USNM 336767 | 25.0 mm dark-headed male | 15.8 mm female with 0.65 mm diameter eggs, removed same dive | | | | |
| USNM 336778, 336779 | 22.4 mm dark-headed male | 22.3 mm pale male, removed same dive | | | | |
| USNM 336780 | 20.1 mm dark-headed male | 21.5 mm pale male, removed same dive | | | | |
| USNM 336782, 336783 | 23.8 mm dark-headed male | 20.3 mm pale male, removed same dive | | | | |

TABLE 5.—Replacement sequences beginning on 23 February 1995 when four resident dark-headed territorial male *Emblemariopsis pricei* were removed from marked holes in four clumps of living *Acropora palmata* in the spur and groove study site just east of Carrie Bow Cay, Belize, 7–8 m depth. Pale individuals (presumably mostly nonbreeding males) were seen on the surface of the coral in the vicinity of each of the holes when the original occupants were removed. Note that after the first five days, observations and collections are more distantly spaced; of the two holes that had no replacements take up residence, one apparently was damaged during the removal of the original occupant and became slimy by 27 February. All but one of the replacement individuals were very dark-headed males in life, but they were only slightly dark in preservative; the exception is the pale male replacement (apparently a very recent resident) in hole 35 on 1 March 1995. See “Materials” for details of specimen data for USNM 336770–336777.

| Date | Hole number | | | |
|-----------------|--|---|---|---|
| | 23 | 29 | 31 | 35 |
| 23 February, AM | 20.6 mm original dark-headed male removed (USNM 336770) | 20.0 mm original dark-headed male removed (USNM 336770) | 20.2 mm original dark-headed male removed (USNM 336770) | 28.6 mm original dark-headed male removed (USNM 336770) |
| 24 February, PM | No new dark head in hole; pale individuals in and out of vacant hole | Hole empty, no pale individuals seen on surface | Hole empty, no pale individuals seen on surface | 20.7 mm replacement dark head removed (USNM 336771) |
| 25 February, AM | 18.0 mm replacement dark head removed (USNM 336773) | " | " | 21.9 mm replacement dark head removed (USNM 336772) |
| 26 February, AM | pale individual in hole, not removed | " | " | 19.3 mm replacement dark head removed (USNM 336774) |
| 27 February, AM | pale individual in hole, not removed | grayish slime in hole | grayish slime in hole | pale individual in hole, not removed |
| 1 March, AM | hole empty, no pale individuals seen on surface | " | " | 18.0 mm replacement pale male removed (USNM 336775) |
| 7 March, AM | " | " | " | 20.1 mm replacement dark head removed (USNM 336776)* |

* Two additional dark-headed males (USNM 336777; 21.9 and 23.5 mm) were discovered and collected from holes on the underside of the basal region of this clump of coral.

Most of these records involved only a single replacement individual that was removed during the same dive as the removal of the resident dark-headed male. This is because most holes were not revisited during that or a subsequent dive to determine whether a second replacement individual had taken up residence after removal of the first.

Of the 17 replacement sequences, 15 cavities had a pale male and two had a female as the first individual to enter the cavity. The pale replacement males were, on average, somewhat smaller than the original resident dark-headed breeding males (dark-headed resident males: 18.4–28.6 mm, average 22.7 mm; pale male replacements: 17.5–22.3 mm, average 19.9 mm); however, three pale male replacements were slightly larger than the resident dark-headed male. The average size of pale males on sea fans was 20.1 mm, which was essentially the same as the average size of first pale male replacements. This was not surprising because pale males apparently move freely between sea fans and coral surfaces. The two females were substantially smaller than the dark-headed males they replaced. This was as expected because resident males are, on average, larger than mature females.

There were six cases in which a pale-male first replacement was itself removed and another pale male replaced it. The second suite of replacement males ranged from 18.5 to 21.9 mm (average 19.5 mm), which was about the same average size as the first suite of replacement pale males.

The most extensive replacement sequence involved the removal of a 25.5 mm dark-headed male and its subsequent replacement by four pale males of 15.8–20.6 mm (average 18.4 mm) and one female of 15.0 mm. The resident male was removed at the beginning of a morning dive and all replacements were collected during morning and afternoon dives on the same day. This hole was not revisited on subsequent days; thus, we do not know how long this replacement sequence might have been prolonged.

None of the replacement pale males in these sequences had testes as well developed as those of resident dark-headed males. Presumably the replacement males would not have become sexually active until some period of time had been spent in the cavity, during which time the amount of pigment on the head would have increased.

Three approaches were used to determine the time required for the head to darken after a pale male occupies a vacated cavity. In the first experiment, a dark-headed male from 8 m depth in the spur and groove zone was removed from a cavity in a branch of living *A. palmata* and a pale replacement individual was seen to enter and remain in the cavity. The branch was detached, brought back to the laboratory, and placed in an aquarium on 26 February 1995. The replacement individual was observed throughout the daylight hours. It remained in the cavity with the front of the head protruding, with no noticeable darkening until about 1800 hr, at which time the exposed part of the head seemed slightly darker. By sunset that day it had retreated

into the cavity, and at 2000 hr it could no longer be observed. It remained within the cavity throughout the night and when next observed at 0700 hr on 27 February, its head was very dark and appeared to be about as fully dark as the heads of resident males in cavities on the reef. This specimen was maintained in the aquarium for one more full day and was fed fresh plankton each evening.

When sacrificed after two days in the aquarium, this now dark-headed specimen (USNM 336783) of 20.3 mm blanched considerably. It showed only a moderate but uniform speckling of small dark spots on the head and between the first few dorsal-fin spines. The melanophores in this speckling must have been much expanded in life to have created the dark-headed appearance, which mostly disappeared in preservative. This leads to the conclusion that the full pigmentary basis of dark-headedness, as seen in nearly all of the preserved dark-headed males removed from cavities on the reef (for an exception see "Size of Dark-Headed Males"), takes many days to develop. A previous attempt on 24 February had been unsuccessful in establishing a pale replacement (USNM 336779) in a tube cavity in *A. palmata*. After nosing in and out of the hole before the branch of coral was collected, the specimen never settled into the hole but remained pale for the four days it was maintained in the aquarium, usually resting on the surface of the live coral and sometimes on the coral rubble present in the aquarium.

In the second experiment (summarized in Table 5), in the same spur and groove zone, four dark-headed males in holes in four separate clumps of living *A. palmata*, each about 1 m wide, were marked with numbered ribbons. Only a single dark-headed male was seen per coral clump, but each clump was seen to have at least two pale individuals on the coral surface. Each resident male was removed on the morning of 23 February 1995. Two of the holes developed a grayish slime within a few days, probably because the quinaldine solution used to remove the residents was too strong and damaged the eggs in the holes. Of the two remaining holes, one (number 23) was located in 7 m water depth and the other (number 35) was in 9 m water depth, about 35 meters away.

The two holes were next observed on the afternoon of 24 February. Cavity 23 was empty but had two pale individuals on the surface, one of which was darting in and out of the cavity. Cavity 35 had a dark-headed individual within it, which we promptly removed. The latter specimen proved to be a 20.7 mm male, whereas the original occupant had been 28.6 mm (the largest specimen collected during this study). This 20.7 mm dark-headed replacement male blanched significantly in preservative and was obviously just beginning to form the permanent pigmentary basis for dark-headedness.

When observed the following morning (25 February), both cavities had a dark-headed individual present. These specimens were removed and were determined to be an 18.0 mm male in cavity 23 (whose original dark-headed occupant was 20.6 mm) and a 21.9 mm male in cavity 35 (replacing a 20.7 mm replacement). Like the previous replacement from cavity 35, these two

replacements were dark-headed in life but blanched in preservative and now have only a speckling of dark pigment on the head.

On the morning of 26 February, cavity 23 contained a pale individual that was not removed, and cavity 35 had a dark-headed 19.3 mm male that was removed (replacing a 21.9 mm replacement). Like the other dark-head replacements of one-day duration, it blanched in preservative.

On the morning of 27 February, cavity 23 had a pale individual in it, which was not collected. It is not known whether this was the same individual from the previous day that had not become dark-headed overnight or if it was a different individual that less than a day before had exchanged places with the pale individual seen on 26 February. Cavity 35 also contained a pale individual that was not collected; this individual also could have been either a pale individual from the previous day that did not become dark-headed overnight or one that only just that day had entered the vacant cavity.

After a one day operational hiatus, observations on the morning of 1 March showed that cavity 23 was empty and no pale individuals were seen on the surface, as was the case six days later on the last day of observation. Cavity 35 had a pale 18.0 mm male in it that was removed, and, because of the lack of head pigment, we presume that it had within hours gone into the cavity.

On the last day of observation, the morning of 7 March, only cavity 35 was occupied. It held a dark-headed, 20.1 mm male, which was removed. We do not know how many days this last specimen had been in residence, but it did not blanch extensively in preservative. After preservation it had about the same degree of moderate speckling of melanophores on the head as the preserved one-day residents, but there was much more pigment on a greater extent of the spinous dorsal-fin membranes and on the pectoral-fin basal regions and abdomen than in the one-day residents. Thus, we presume that this 20.1 mm specimen had been in cavity 35 for at least several days.

When the last observations of these two clumps of coral were made on 7 March, we found two additional dark-headed males of 21.9 mm and 23.5 mm in the elkhorn clump containing cavity 35. These two males were in holes on the underside of two of the more basal coral branches near the coral's central axis. All of our previous observations had led us to believe that resident males occurred on the upper surfaces of the elkhorn branches, although as often toward the central axis as toward the middle of the branches (and less frequently more peripherally). Because this day of observation was near the termination of most of the field work of the several-year study, we do not know how often we had overlooked dark-headed males on undersurfaces of elkhorn coral because most of our effort was directed to upper surfaces. In any case, the presence of these two other males in cavities on the same clump with cavity 35 may be a factor in the large number (5 or 6) of surface individuals that replaced the original dark-headed male of cavity 35, which was on the upper surface of a higher branch.

In the third experiment to determine length of time for head darkening (summarized in Table 6), five dark-headed males (USNM 341517) were removed on 16 March 1996 from tube cavities in three clumps (one large clump had three dark-headed males) of living *A. palmata* in the same spur and groove study area as the other two experiments. When these five cavities were next observed the following day, all five were occupied by dark-headed replacement individuals. These cavities were left undisturbed (and unobserved) thereafter until 26 March, 10 days after the original occupants had been removed. The preserved melanophore pigmentation of the five original occupants of 16 March was well developed on the head and anterior parts of the body and spinous-dorsal fin. Of the five replacement dark-headed males collected on 26 March, four had the melanophore pigmentation just as well developed as that of the original occupants (see Figure 7 for an example of a typical original occupant and one of the four equally dark replacements). We presume these four were the individuals we had seen in the cavities on 17 March; thus, they had a ten-day residency when collected on 26 March. One of the five replacements, however, had only a moderate development of melanophores, much less than the other four replacements. The melanophore development in this relatively pale, preserved replacement (21.8 mm) had more extensive speckling posteriorly on the body and spinous-dorsal fin than the specimen kept in an aquarium for one day after its transformation overnight from pale to dark-headed (USNM 336783). Interestingly, it had almost exactly the same degree of speckling as that developed by the pale replacement male that had turned dark-headed after an indeterminate number of days (up to six) in residence in marked cavity 35 of the preceding experiment (USNM 336776, Table 5).

We think it likely that one of the dark-headed replacement individuals left its cavity sometime during the subsequent nine days and was itself replaced by the relatively pale individual collected on 26 March. Given that at least four of the five replacements in this experiment presumably had 10 days of growth in the cavities, the difference in average size (1.8 mm) between them and the original occupants is expectedly less than the difference (2.8 mm) between original occupants and their replacements in all previous such collections made during same-day periods or within one day of a replacement entering a cavity (see Table 4).

In summary, the tube cavity tagging experiments substantiate (1) the overnight head darkening of pale males that occupy vacant cavities, (2) the overnight darkening is superficial, (3) a longer residency in a cavity (but not more than 10 days) is required for more general darkening and full pigment development, and (4) the plenitude in some cases, such as for cavity 35, of available replacements, which are usually pale males from the nearby surface.

TUBE-CAVITY STRUCTURE.—The aperture diameters of 13 *Spirobranchus* cavities occupied by *E. pricei* in living *A. palmata* were measured. All the resident males were collected, and

TABLE 6.—Size and pigmentation of five resident dark-headed territorial male *Emblemaripis pricei* and of the five males extracted from the same holes 10 days later. Specimens are from the spur and groove study site just east of Carrie Bow Cay, Belize, in 7–8 m water depth. Dark-headed replacement individuals were seen in the five holes one day after removal of the original occupants, but the holes and their new occupants were left undisturbed thereafter until the terminal collection. All 10 specimens were dark-headed in life when collected. See Figure 7 for preserved pigmentation and “Materials” for details of specimen data for USNM 341517 and 341518.

| Date | Size range | Average size | Preserved pigmentation |
|----------|--------------|--------------|--|
| 16 March | 21.6–23.8 mm | 22.8 mm | Head and anterior regions of body and spiny dorsal fin darkly pigmented (USNM 341517) |
| 26 March | 19.7–22.2 mm | 21.0 mm | Four individuals just as darkly pigmented as the original occupants of the holes (above), but one, 21.8 mm, much less darkly pigmented (USNM 341518) |

six of the 13 cavities also were collected. The openings were all circular and slightly upraised from the coral surface, with diameters ranging from 2.9 mm to 4.0 mm (average 3.4 mm). The males collected from these cavities ranged from 18.4 mm to 24.4 mm. All were dark headed with the exception of the 18.4 mm specimen, which was only moderately dark headed (see “Size of Dark-Headed Males”). There was no correlation between cavity opening diameter and specimen size in this sample (e.g., the largest male, 24.4 mm, came from a 3.0 mm diameter opening, and the largest opening, 4.0 mm diameter, contained a 21.3 mm male). Tube-cavity openings of 3–4 mm equated with the maximum depth of the blenny body (3–4 mm in adults with the median fins depressed), so adults nearly filled the opening.

Below the circular opening the six *Spirobranchus* cavities had a relatively uniform tubular region of 4–18 mm length, with the lower end slightly greater in diameter than the opening. Just below this tubular portion, the cavities had an irregularly eroded, larger, egg-incubation region (see below) of 16–30 mm length and 7–14 mm width; the overall length of the cavity from aperture to bottom of the large lower region ranged from 25 mm to 48 mm.

In the course of our studies, no vacant *Spirobranchus* tubes were observed in living *Acropora palmata*. We presume that when *Spirobranchus* worms die, the tube cavities with the appropriate 3–4 mm diameter opening rapidly become occupied by *E. pricei* males as soon as the dead worm’s remains are emptied from the cavity by decay and by detritus feeders. Cavities of any size that do not become occupied by *E. pricei* or other organisms apparently are overgrown by the living coral (experiments on this are ongoing at CBC).

Although the diameters of the openings of the tube cavities in the globose species of coral from which dark-headed males were removed were not measured, they seemed to be of the same 3–4 mm diameter as those in living *A. palmata*. No cavities were collected from the large mounds of *Montastrea*,

Porites, *Colpophyllia*, and *Diploria*, however, because of the difficulty of doing so. Therefore, it is not certain whether the cavities in these massive corals are of similar structure and serpulid origin as those in the branches of *A. palmata*.

REPRODUCTION

FEMALE MATURITY ESTIMATES AND OVARIAN EGG NUMBERS.—Eggs contained in the tube cavities occupied by dark-headed males were 0.6–0.7 mm in diameter. Of the 51 females collected from all sources, only three were judged to be fully mature. One of these, 19.2 mm, collected on a sea fan, had large spent ovaries with only a few scattered small eggs remaining; we presumed they had been emptied very shortly before the individual was collected. Another of the females, 16.6 mm, collected on a coral surface, had eggs of 0.7 mm diameter and seemed especially ripe. The third mature female, 15.8 mm, collected in a cavity just vacated by a dark-headed male, had eggs of 0.65 mm diameter.

Ten other females (15.9–18.2 mm) had eggs of 0.5–0.6 mm diameter, and we judged them to be almost ripe but not yet on the point of egg laying. Of these, all but one were collected on sea fans. The exception, 16.0 mm, was the third replacement individual in a tube cavity from which we had removed the original dark-headed male and two successive pale male replacements; we do not believe that this female, with 0.5 mm eggs, was on the verge of spawning. Thirty-seven females (12.7–19.6 mm), collected mostly on sea fans but also on coral surfaces and in recently vacated cavities in corals, had eggs of 0.1–0.45 mm diameter; we considered these females to be ripening, but far from egg laying. One of the females, 11.7 mm, had only oocytes and could have been considered immature.

The two females (15.8–16.6 mm) with the largest eggs (0.65–0.7 mm diameter) had 11 to 15 eggs in each ovary, for a total of 24 to 27 large eggs, and they had about an equal or slightly larger number of very small (about 0.1 mm) eggs. Four other females (15.9–17.0 mm) with eggs of 0.4–0.6 mm diameter had egg numbers similar to those of the even riper individuals: 10 to 15 large eggs in each ovary, for a total of 21 to 27 large eggs, plus a usually slightly larger number of very small eggs.

These data indicate that only a small minority of females are in spawning condition at any given time; however, the cavities of dark-headed males nearly always have 10 or more clutches of incubating eggs, suggesting that it may require only a day or two for females with eggs of 0.5–0.6 mm diameter to become ready for spawning.

A pale individual was never observed entering or leaving the cavity of an undisturbed dark-headed territorial male in what could be interpreted as the spawning sequence, even though we postulate that this occurs frequently. We speculate that female visits to the cavity for egg laying probably take place just after sunrise, based on observations made of other chaenopsids maintained in aquaria, namely *Acanthemblemaria spinosa* and

A. aspera (R.D. Clarke, pers. comm., 7 March 1995) and *Emblemaria pandionis* Evermann and Marsh (Andreyko, MS).

INCUBATING-EGG NUMBERS.—The incubating eggs were all contained in the lower, irregularly eroded region of the tube cavity occupied by the dark-headed male. The eggs were 0.6–0.7 mm in diameter (average 0.65 mm). Of the five cavities collected with eggs, four contained 180 to 400 (actual count of eggs plus an additional 10% to 20% depending on how many were estimated to have been lost in sawing open the cavity), with an average of about 300. There were both eyeless and eyed eggs in these four cavities, and in some cases there seemed to have been at least two stages of development among both categories of eggs. Because ripe and almost ripe females have a total of only 21–27 large eggs in the ovaries, it is obvious that the eggs in the cavities represent many different spawnings. Three of the four cavities had more than 150 eyed and eyeless eggs; therefore, 10 or more spawning events must have been responsible for the average number of eggs in these cavities. The fourth cavity had fewer eggs than the others, and all were eyeless; however, so many eggs were lost in opening this cavity that an estimate of about 100 eggs is only approximate. Nonetheless, 100 eggs represents a minimum of three or four spawning events.

Discussion

The only fish around Carrie Bow Cay, Belize, utilizing the *Gorgonia* sea-fan habitat is *Emblemaria pricei*. Semitransparent immatures, females, and nonbreeding males are found on approximately one in every eight sea fans, with usually only one but occasionally two and rarely three blennies per sea fan. Breeding males of this species are the only fishes around CBC utilizing empty *Spirobranchus* worm tubes in live corals, and about one in every three clumps of *Acropora* elkhorn coral has a dark-headed male present, with sometimes two or three such males present in the same clump. Because we have never seen any unoccupied *Spirobranchus* tubes (i.e., without the living worm or a fish) in these living elkhorn corals, we believe that this habitat is fully occupied by breeding males of *E. pricei*. This is concordant with our replacement experiments, in which vacated cavities, formerly occupied by dark-headed males, are usually rapidly (within minutes) occupied by pale, nonbreeding males lurking on the surface nearby, and these males become dark-headed overnight.

We presume that the same thing happens when natural mortality of *Spirobranchus* worms creates vacant tubes of the appropriate 3–4 mm diameter opening, for which *E. pricei* may also have to compete with various invertebrates. Because many sea fans are not utilized by *E. pricei* but empty *Spirobranchus* tubes in live coral are apparently fully occupied, we presume that the availability of tube cavities in live coral in which dark-headed males of *E. pricei* can live and incubate eggs is the limiting factor for population abundance in this blenny.

It is often presumed that at least the smaller species of chaenopsids, especially those of the genera *Acanthemblemaria* and *Emblemariopsis* that can mature at less than about 20 mm SL during the first year of life, typically have a life span of no more than two or three years. This notion is not well documented, and aquarium observations indicate that *Acanthemblemaria aspera* and *A. spinosa* can live to between three and a half and four years (R.D. Clarke, pers. comm., 23 May 1996).

By contrast, *Spirobranchus* worms are relatively long-lived. Estimated ages (based on growth rings of the coral surrounding the worm tube) for large (up to 14 mm diameter aperture) *S. giganteus* at Okinawa are mostly between 10 and 20 years, with some as old as 30 to 40 years (Nishi, 1995a; Nishi and Nishihira, 1996), whereas on the Great Barrier Reef ages of large specimens are around 20 years (Smith, 1985). Growth rates recorded by Nishi and Nishihira (1996) indicate that tube-aperture diameter increases 0.2–1.0 mm per year, with an average increase of 0.6 mm. If the growth rate of *S. giganteus* at CBC is similar to this, then the tube cavities of 3–4 mm diameter opening occupied by *E. pricei* became available through the death of worms of about five to seven years of age.

It seems reasonable to presume that far more *Spirobranchus* tube cavities become available to pale male *E. pricei* through mortality of dark-headed males that already occupy a former *Spirobranchus* tube than through the death of the worms themselves. This suggests that an interesting future experiment would be the removal of living *Spirobranchus* from tubes of a variety of opening diameters and subsequent observation on the rapidity of occupancy of the tubes by nonbreeding males of *E. pricei*, followed by long-term monitoring. It likewise would be of interest to determine how rapidly the openings of *Spirobranchus* tubes in the 3–4 mm size occupied by *E. pricei* lose their distinctive upright spike along the ventral aperture edge and, if not occupied, how quickly the apertures become overgrown by coral and disappear. We note that large *Spirobranchus* in the two main study areas at CBC can have tube openings of up to 10 mm diameter; thus, these worms may be about 15 years of age. We have not found any *Spirobranchus* in the study areas with apertures as large as those recorded from Okinawa (14 mm diameter).

Although dark-headed males of *E. pricei* are found far more often in tube cavities in living coral than in dead coral, there are several other chaenopsids found in the same general areas around CBC that almost always inhabit holes in dead coral, coral rubble, or pavement rock. These are *Emblemariopsis ruetzleri*, *Acanthemblemaria paula* Johnson and Brothers, *A. greenfieldi* Smith-Vaniz and Palacio, and, less frequently, *A. maria* Böhlke, which are all found in the shallow waters from the reef crest to the back reef and lagoon at CBC, and *A. spinosa* and *A. aspera*, which are found in relatively deeper waters, especially in dead *A. palmata* in the spur and groove zone just east of the CBC reef crest (Greenfield and Greenfield, 1982; Johnson and Brothers, 1989; and, most comprehensively, Clarke, 1994).

Acanthemblemaria paula is a diminutive species, attaining less than 20 mm versus more than 30 mm for the other species of *Acanthemblemaria* at CBC (Johnson and Brothers, 1989), and it occupies cavities with openings ranging from only 2 mm to slightly less than 3 mm diameter (we measured 10 openings in the back reef areas west of CBC: five in pavement rock immediately off the southwest edge of the island and five in dead coral in the lagoon to the northwest of the island). *Acanthemblemaria spinosa* probably is typical of all other species of *Acanthemblemaria* at CBC in that it occupies cavities with openings of up to a little more than 5 mm diameter (R.D. Clarke, pers. comm., 15 June 1994).

Only the breeding males of *E. pricei* occupy cavities in coral, but all individuals of the species of *Acanthemblemaria* are cavity dwelling. The only fishes that we have found consistently in tube-like cavities in living corals around CBC are dark-headed males of *E. pricei*. Although *Acanthemblemaria spinosa* is much more common in cavities in dead coral, we have occasionally found individuals in tube cavities in living *Acropora palmata*, in more peripheral locations on the branches than where *E. pricei* usually is found.

We presently are studying the life history of the recently described *Emblemariopsis ruetzleri* at CBC; it is very similar morphologically to *E. pricei* (including 14 pectoral-fin rays), but it is smaller and has a short supraorbital cirrus. In contrast to *E. pricei*, the dark-headed males of *E. ruetzleri* are almost always found in cavities in dead coral, with only one of dozens of specimens collected from a cavity in a living coral (*A. palmata*). Females and immatures of *E. ruetzleri* are found on coral surfaces and algal turf. There is an undescribed species of *Emblemariopsis* (with 13 pectoral-fin rays and a moderately long supraorbital cirrus) with dark-headed males that also are found in holes in dead coral in shallow water around CBC, but we know too little as yet about it for further comment.

Among chaenopsids, behavioral ecology is best known in the species of *Acanthemblemaria*. Shelter availability has been shown to be a potentially limiting resource for species in the Gulf of California (Hastings, 1984; Lindquist, 1985) and the Caribbean (Clarke, 1989, 1994, 1996; Buchheim and Hixon, 1992). This limitation applies to all individuals (i.e., settled juveniles and older) in the populations of the species of *Acanthemblemaria*, unlike the situation for *E. pricei*, in which shelter availability is limiting only for dark-headed males. Even when there is an abundance of tube cavities in dead coral suitable for occupancy by species of *Acanthemblemaria*, competition can still occur based on the quality of the cavity in relation to food availability (Clarke, 1992, 1994, and ongoing research at CBC); this is not evident in *E. pricei* because dark-headed males seem to occupy all available cavities, from upper surfaces on high branches of *Acropora palmata* to lower surfaces on basal branches and from shallow-water reef crests down to 30 m depth on drop-offs of the Belize Barrier Reef (the 30 m record from Greenfield and Johnson, 1981).

Clarke (1989) found that the removal of *Acanthemblemaria spinosa* from cavities in dead coral in the Virgin Islands led to reoccupation of 86% of the cavities within two days, with a lower rate of reoccupation in *A. aspera*, and that competition for cavities was sometimes intense, leading to fighting over cavities. The reoccupation rate following removal of dark-headed *E. pricei* is as high as that for *A. spinosa* and no less rapid, usually within minutes.

Many fishes (and alpheid shrimps) are potential competitors for tube-like cavities in dead coral around CBC. The shelter resource of cavities (originally formed by mollusks, shrimps, sponges, and several families of worms), is finely partitioned for all individuals of the species of *Acanthemblemaria* by factors of water depth, cavity size, orientation of the cavity opening relative to the surrounding matrix, and zooplankton availability in the water column at various depths above the bottom substrate (Greenfield and Greenfield, 1982; Johnson and Brothers, 1989; Clarke, 1992, 1994, 1996, and ongoing research at CBC). The primary fishes competing for the shelter resource in dead coral around CBC are the five species of *Acanthemblemaria* (Clarke, 1994) and the two species of *Emblemariopsis* mentioned above that are found in the same areas as *E. pricei*.

Because so few individuals of dark-headed *E. pricei* are found in tube cavities in dead coral, they are unlikely to be active competitors for the finely partitioned dead coral shelter resources. Instead, they appear to be the only fishes in the western Caribbean able to routinely exploit tube cavities in live coral. Likewise, the females, nonbreeding males, and immatures of *E. pricei* on sea fans apparently have no competition from other fishes for these gorgonian surfaces.

To what extent the sea fan and live-coral tube-cavity habitats are occupied elsewhere in the Caribbean by species of *Emblemariopsis* other than *E. pricei* remains to be seen. In the Florida Keys, *E. diaphana* sometimes is known to be present on sea fans as well as on the surface of globose heads of living *Montastrea* (Longley and Hildebrand, 1940). A detailed study of *E. diaphana* at Curaçao indicated that this species has a close relationship with the surface of living heads of *Meandrina*, as well as those of *Eusmilia* and *Colpophyllia* (Butter et al., 1980). Field observations in the above study were mainly at night, and fewer fishes were seen on coral surfaces during daylight than at night when coral tentacles are extended. There was no mention of sea fans or tube cavities in coral as habitat for this species (its correct identification was confirmed from voucher specimens; see "Appendix"); however, because the study was focused on live globose coral surfaces at night, it is possible that no attention was given to sea fans and that cavity-dwelling males could have been overlooked. Ripe females were mentioned in the Butter et al. (1980) study, but not males of any age.

Although *E. diaphana* may be associated mostly with the surface of living globose corals and may have breeding males in tube cavities like most other species of chaenopsids, we suspect its association with sea fans is probably less substantial

than it is for *E. pricei*. This is because a fish consistently present on sea fans is unlikely to have gone unnoticed in the Florida Keys, which have been relatively well studied by diving naturalists.

In addition to *E. pricei*, *E. ruetzleri*, and *E. sp.*, two other species of *Emblemariopsis* are known to have both pale- and dark-headed males (the wide-spread *E. bahamensis* and *E. bottomei*, known only from Venezuela). One of these, *E. bahamensis*, has been found in serpulid tubes in eroded dead coral (Luckhurst and Luckhurst, 1978). The precise habitats occupied by individuals other than dark-headed males of *E. bahamensis* is unknown, but it remains possible that this species, which is found in the Bahamas and throughout the Antilles to the northern coast of South America and the western Caribbean (Stephens, 1970; Luckhurst and Luckhurst, 1978; Birdsong and Emery, 1967; the identification of the specimen listed in the latter paper from off Nicaragua confirmed by P.A. Hastings, pers. comm., 3 May 1995), has individuals on sea fans. In another species, *E. signifera*, males have somewhat darker heads and anterior regions of the dorsal fin than do females, but both sexes of this species are found on the surface of living corals and encrusting sponges (Smith and Tyler, 1972) and not in tube cavities in living coral.

Our data on the rapidity in obtaining ripeness and the frequency of spawning in *Emblemariopsis pricei* are in keeping with what is known for a similar cavity-dwelling chaenopsid at CBC, *Emblemaria pandionis*. In the latter species, spawnings take place every three to five days in aquaria, with hatching times of seven to nine days. All ripe eggs are deposited in a single male-occupied cavity during each spawning event (Andreyko, MS). Thus, female *E. pandionis* do not split their clutches with several males, as is the case in some species of *Acanthemblemaria* (Stephens et al., 1966; Hastings, 1988b). There are about 100 large ovarian eggs in ripe female *E. pandionis* and about that same number (usually 60–150) deposited per spawning. Yet *E. pandionis* males have, on average, only about 170 eggs in their coral-rubble cavities, with six developmental stages often represented. This implies that there is substantial egg mortality associated with spawning in *E. pandionis*, perhaps from males eating a significant minority of the eggs of a clutch just after deposition in at least these aquarium observations at the American Museum of Natural History on materials collected at CBC (Andreyko, MS; Smith et al., 1998). Eggs are known to be eaten by the incubating males of *Emblemaria hypacanthus* (Jenkins and Evermann) (Hastings, 1992b) and *Acanthemblemaria spinosa* (R.D. Clarke, pers. comm., 18 May 1995), but in the former case this may have been related to disturbance under aquarium conditions (Hastings, 1992b) and in the latter from the manipulations of glass tubes on artificial reefs (Clarke, 1992). In *Emblemaria hypacanthus*, spawning (every 2–3 days) and hatching (4–5 days) are even more frequent and rapid (Hastings, 1992b) than in *E. pandionis*.

Among chaenopsids other than some of the species of *Emblemariopsis*, patterns of habitat usage with resource-defense polygyny (Hastings, 1986, 1988a) most analogous to that of *E.*

pricei may occur in some of the species of *Emblemaria* and *Coralliozetus*, behaviors of which have been studied in detail by P.A. Hastings in the Gulf of California. In these chaenopsids, males and females of some species often have different patterns of habitat usage. These two genera are in different clades (Hastings and Springer, 1994) within the Chaenopsidae; *Emblemaria* is one of five genera in the *Chaenopsis* clade, and *Coralliozetus* is in the clade of that name, along with *Emblemariopsis* and *Protemblemaria*.

Hastings (1991) reported a difference in shelter use among different populations of one of the signal blennies, *Emblemaria hypacanthus*. Among populations inhabiting areas in which there is a relatively low risk from predation, male *E. hypacanthus* spend most of their time in shelters (*Turbo* gastropod shells), whereas females are more out in the open and move about frequently. By contrast, in high-risk predation areas, both sexes of *E. hypacanthus* spend most of their time in shelters (see also Hastings, 1992b, for nest-site size as a constraint on reproductive success in this species).

This different utilization of habitats by *E. hypacanthus* in low-risk areas, with dark-colored breeding males in shelters and pale females and pale nonbreeding males more active and out on the surface of the substrate, has obvious analogies to the even more distinctively different habitats in *Emblemariopsis pricei*.

The only species of signal blenny in the shallow waters around CBC is *Emblemaria pandionis*. It is similar to the low-predation risk populations of *E. hypacanthus* in having dark-colored breeding males exclusively resident in cavities (usually in coral rubble) and nonbreeding pale males and pale females much less tied to particular pieces of coral rubble for shelter sites and much more active out on the sandy substrate in the rubble zone (Smith et al., 1998).

Three other species of *Emblemaria* have been reported from Belize or Honduras: *E. caldwelli* Stephens, *E. piratula* Ginsberg and Reed (both found at CBC), and *E. hyltoni* Johnson and Greenfield; however, these are deeper water species (Greenfield and Johnson, 1981), and nothing is known of their behavior.

Hastings (1986) has shown that, during the breeding season, most males of *Coralliozetus angelica* (Böhlke and Mead) are resident in empty barnacle (*Megabalanus*) tests and rarely venture far from them, whereas females spend most of their time foraging in the open, again similar to the situation in *E. pricei*.

Conclusion

Females, nonbreeding males, and juveniles of *E. pricei* are semitransparent and are difficult to see on the sea fans (*Gorgonia ventalina*) on which they are found during daylight. Based on aquarium observations, these individuals retreat to the coral reef substrate at the base of the sea fans at night. Females on sea fans reach 19.6 mm (average 16.6 mm) and include very ripe individuals on the verge of egg laying, whereas nonbreeding males on sea fans attain up to 24.3 mm (average 20.1 mm) but do not have active sperm in the testes.

Breeding males of 17.5–28.6 mm (average 22.1 mm) inhabit former serpulid worm (*Spirobranchus giganteus*) tubes in a variety of corals (usually living corals; frequently *Acropora* elkhorn coral but also massive mounds of *Montastrea*, *Porites*, *Diploria*, and *Colpophyllia*). Unlike pale individuals on sea fans and coral surfaces, the dark-headed males, whose heads partially protrude from their holes, are easily noticed against the pale-colored corals.

Females, nonbreeding males, and immatures all spend some time on coral surfaces as well as on sea fans, perhaps in foraging activity for crustaceans (remains found in a few stomachs). Mature females also must transit coral surfaces in order to lay eggs in the tube cavities of breeding males, and some nonbreeding males are nearly always present on coral surfaces in the vicinity of the cavities of the territorial dark-headed males, awaiting the opportunity to occupy the cavity if it becomes vacant.

In replacement experiments, the average size of resident dark-headed males that were removed from cavities was 22.7 mm and that of the first pale males that replaced them within one day was 19.9 mm, about the same as pale males on sea fans. If the first replacement male was itself removed, subsequent male replacements were not much different in size from the first replacements.

Dark-headedness is achieved overnight by pale nonbreeding males that occupy vacated cavities, but the full pigmentation of the head, anterior body, and median fins takes several more days to develop. The overnight darkening seen in recent occupants of tube cavities mostly fades in preservative, whereas that of longer term residents mostly remains.

Territorial dark-headed males incubate an average of about 300 eggs in their tube cavities, and these are in various stages of development. Very ripe females have between 21 and 27 eggs of 0.65–0.7 mm diameter and, assuming that essentially all of these are deposited (as evidenced by one spent female without any large eggs), there must be a minimum of 10 spawnings represented in most of these cavities. Circumstantial evidence indicates frequent spawning and rapid change in females from almost fully ripe to running ripe.

Although there are similarities in differential habitat usage between *E. pricei* and several other chaenopsids of varying degrees of phylogenetic relationship to it, with dark-colored breeding males in one kind of microhabitat and pale nonbreeding males, females, and immatures in another, the degree of distinctiveness of these habitats is more extreme in *E. pricei*, with breeding males in tube cavities in live coral and all other individuals on sea fans or moving about on the surface of corals. Habitat for breeding males of *E. pricei* is restricted to vacant tube cavities of *Spirobranchus* worms, and this also is probably more specific and more limited than habitats for breeding males in many other species of chaenopsids. The limitation on availability of *Spirobranchus* tubes for breeding-male habitat and egg incubation probably controls population size in *E. pricei*.

Appendix

Specimens Examined

Male sea fan blennies are specified below as either dark headed (always resident in tube cavities in coral) or pale (from sea fans or coral surfaces, or as recent replacements in cavities from which dark-headed males were removed). Because females and immatures are always pale (semitransparent), color is not specified. If the aperture diameter of the tube cavity from which an individual was collected was noted, it is given in parenthesis after the first mention of the cavity. Replacement specimens are those that occupied the same cavity from which another individual was removed. All specimens collected at the patch reef site and the spur and groove site were from 8 m depth.

With the exception of the last two entries, all of the specimens with USNM numbers were collected by the authors, frequently with the help of either C.L. Smith and M.K. Tyler, or R.D. and K. Clarke, or A. Sundberg, and these collectors names are not listed below.

Emblemariopsis pricei

USNM SPECIMENS.—All of the 174 specimens examined, ranging in length from 10.0–28.6 mm SL (11.5–32.5 mm total length), were individually collected at various locations within the immediate vicinity (no more than 1 km distance) of the Smithsonian marine laboratory on the Belize Barrier Reef at Carrie Bow Cay. There were 51 females, of which 41 were from sea fans, 6 were from coral surfaces, and 4 were from cavities in coral from which dark-headed males had been removed. There were 103 males, of which 45 dark-headed individuals were resident occupants from cavities in coral, 38 pale individuals were from coral surfaces (including 31 pale replacements that became dark-headed upon residence in vacated cavities), and 20 pale individuals were from sea fans. There were 20 immatures (no external sexual dimorphism and gonads too small for macroscopic sex determination), of which 16 were from sea fans and 4 were from coral surfaces.

USNM 325440, 2, immature 12.3 mm on surface of living *Montastrea annularis* and ♀ 15.9 mm on sea fan, spur and groove region along north side of CBC, 13–15 m, 18 Mar 1991. USNM 325449, 7, 2 pale ♂ 13.9 mm, 21.2 mm, 3 ♀ 12.7–14.5 mm, and 2 immatures 11.0 mm, 14.4 mm, on sea fans, spur and groove region along north side of CBC, 12–17 m, 19 Mar 1991. USNM 325446, 3, 2 ♀ 16.5 mm, 16.6 mm, and 1 immature 13.6 mm on sea fans, spur and groove region along north side of CBC, 17–20 m, 20 Mar 1991 (all 3 cleared and stained). USNM 325445, 1, ♀ 15.0 mm on sea fan, patch reef just north of CBC, 1.5 m, 24 Mar 1991. USNM 325450, 39, 9 pale ♂ 16.2–24.3 mm, 18 ♀ 11.7–18.6 mm, and 12 imma-

tures 10.3–16.7 mm on sea fans, cumulative composite collection of specimens from sea fans on patch reefs southwest of CBC and in spur and groove regions along east and north sides of CBC, 5–10 m, 2–10 Mar 1992. USNM 325447, 1, immature 13.6 mm on surface of living *Colpophyllia natans*, patch reef site, 5 Mar 1992. USNM 325448, 2, ♀ 14.9 mm and immature 14.4 mm on same sea fan, spur and groove region along north-east side of CBC, 12 m, 5 Mar 1992. USNM 325442, 1, ♀ 18.4 mm on surface of living *Diploria strigosa* at base of sea fan, patch reef on northwest side of CBC, 2 m, 10 Mar 1992. USNM 325441, 2, pale ♂ 17.4 mm and ♀ 16.5 mm on sea fans, spur and groove site, 2 Feb 1993, specimens brought back to laboratory with sea fans on which they were found and maintained in aquaria until sacrificed on 8 Feb 1993. USNM 325439, 1, pale ♂ 20.6 mm on sea fan, patch reef site, 9 Feb 1993. USNM 325443, 1, pale ♂ 21.9 mm on marked sea fan number 14, patch reef site, 9 Feb 1993. USNM 325444, 3, pale ♂ 20.9 mm on marked sea fan number 3, and 2 ♀ 16.6 mm, 17.1 mm, on surface of unrecorded species of globose coral at base of the sea fan (it being possible that the females were on the sea fan but moved to the coral surface during the disturbance of collecting the male), patch reef site, 9 Feb 1993. USNM 336738, 1, dark-headed ♂ 18.3 mm in cavity in dead part of otherwise living *Porites astreoides*, just inside reef crest on east side of CBC, 1 m, 6 Mar 1994. USNM 336739, 2, ♀ 17.7 mm, 19.2 mm (larger one spent), on sea fans, patch reef on north side of CBC, 1 m, 6 Mar 1994. USNM 336740, 2, dark-headed ♂ 19.8 mm from cavity in dead part of otherwise living *M. annularis* and pale ♂ 20.3 mm replacement, patch reef southwest of CBC, 8 m, 7 Mar 1994. USNM 336741, 1, ♀ 19.6 mm on sea fan, patch reef southwest of CBC, 8 m, 7 Mar 1994. USNM 336742, 1, dark-headed ♂ 19.7 mm in cavity in living *A. palmata*, spur and groove region along north side of CBC, 4 m, 7 Mar 1994. USNM 336744, 2, dark-headed ♂ 21.9 mm, 26.5 mm, smaller one from cavity in living *P. astreoides* and larger one from cavity in living *M. annularis*, patch reef southwest of CBC, 8 m, 9 Mar 1994. USNM 336745, cavity only (2.9 mm diameter opening; moderate-sized, dark-headed male escaped) in living *A. palmata*, channel into south end of back reef along east side of CBC, 1 m, 11 Mar 1994. USNM 336746, 4, all dark-headed ♂, 22.1 mm from cavity in living *A. palmata*, 23.1 mm from cavity in living *D. strigosa* (pale individual close-by on surface not collected), 20.8 mm from cavity in living *P. astreoides*, 17.9 mm from cavity in dead part of otherwise living *P. astreoides*, spur and groove site, 12 Mar 1994. USNM 336747, 1, pale ♂ 18.1 mm on surface of living *A. palmata*, spur and groove site, 12 Mar 1994. USNM 336748, 2, moderately dark-headed ♂ 18.4 mm from cavity (2.9 mm diameter opening) in living *A. palmata* and pale ♂ 20.0 mm replacement, spur and groove site, 12 Mar 1994 (cavity also collected;

first male with such minimal dark coloration retained in preservative that it had probably taken up residence only within previous several days, and no eggs in cavity). USNM 336749, 1, dark-headed ♂ 21.3 mm from cavity (4.0 mm diameter opening) in living *A. palmata*, spur and groove site, 13 Mar 1994 (cavity also collected). USNM 336750, 1, dark-headed ♂ 21.7 mm from cavity (3.1 mm diameter opening) in living *A. palmata*, spur and groove site, 13 Mar 1994 (cavity also collected). USNM 336751, 2, dark-headed ♂ 20.4 mm from cavity (3.8 mm diameter opening) in living *A. palmata* and pale ♂ 18.4 mm replacement, spur and groove east of CBC, 5 m, 14 Mar 1994 (cavity also collected). USNM 336752, 2, dark-headed ♂ 20.9 mm from cavity (3.0 mm diameter opening) in living *A. palmata* and pale ♂ 19.0 mm replacement, spur and groove east of CBC, 5 m, 14 Mar 1994. USNM 336753, 1, dark-headed ♂ 23.0 mm from cavity (3.9 mm diameter opening) in living *A. palmata*, spur and groove east of CBC, 5 m, 14 Mar 1994 (cavity also collected). USNM 336754, 1, dark-headed ♂ 23.6 mm from cavity (4.0 mm diameter opening) in living *A. palmata*, spur and groove east of CBC, 5 m, 14 Mar 1994 (see next two entries for replacements). USNM 336755, 1, pale ♂ 17.5 mm replacement from cavity in which USNM 336754 was removed one day earlier (see that entry for data), 15 Mar 1994 in morning. USNM 336756, 2, pale ♂ 18.8 mm replacement from cavity in which USNM 336755 was removed about five hours previously and ♀ 16.0 mm replacement that occupied the cavity within about 15 minutes after removal of the ♂ 18.8 mm specimen (see previous entry), 15 Mar 1994 in afternoon. USNM 336757, 1, dark-headed ♂ 23.1 mm from cavity (3.6 mm diameter opening) in living *A. palmata*, spur and groove east of CBC, 5 m, 15 Mar 1994 in morning (see next entry for replacements). USNM 336758, 2, pale ♂ 20.0 mm replacement from cavity in which USNM 336757 was removed about five hours previously and pale ♂ 18.7 mm that occupied the cavity within about 15 minutes after removal of the ♂ 20.0 mm specimen (see previous entry), 15 Mar 1994 in afternoon. USNM 336759, 4, dark-headed ♂ 25.5 mm from cavity (3.5 mm diameter opening) in living *A. palmata* and three replacement individuals that occupied the cavity within a period of one hour, in sequence pale ♂ 20.6 mm, pale ♂ 18.5 mm, ♀ 15.0 mm, spur and groove east of CBC, 5 m, 15 Mar 1994 in morning (see next entry for subsequent replacements). USNM 336760, 2, pale ♂ 18.9 mm replacement from cavity in which last specimen of USNM 336759 was removed about five hours previously and pale ♂ 15.8 mm that occupied the cavity within about 30 minutes after removal of the 18.9 mm specimen (see previous entry), 15 Mar 1994 in afternoon. USNM 336761, 5, 2 pale ♂ 17.0 mm, 18.3 mm, 2 ♀ 14.8 mm, 17.3 mm, 1 immature 10.5 mm, from surface of living *A. palmata*, spur and groove east of CBC, 5 m, 15 Mar 1994. USNM 336762, 3, dark-headed ♂ 24.4 mm from cavity (3.0 mm diameter opening) in living *A. palmata* and two replacement individuals that occupied the cavity within a period of one hour, in sequence both pale ♂ 19.7 mm, spur and groove east of CBC, 5 m, 15 Mar 1994. USNM

336763, 3, dark-headed ♂ 21.5 mm from cavity (3.0 mm diameter opening) in living *A. palmata* and two replacement individuals that occupied the cavity within a period of one hour, in sequence pale ♂ 18.8 mm and pale ♂ 19.4 mm, 5 m, 15 Mar 1994. USNM 336764, 1, dark-headed ♂ 22.7 mm from cavity (3.0 mm diameter opening) in living *A. palmata*, spur and groove east of CBC, 5 m, 15 Mar 1994. USNM 336765, 2, ♀ 16.6 mm and immature 10.0 mm from surface of living *A. palmata*, spur and groove east of CBC, 5 m, 15 Mar 1994. USNM 336766, 2, dark-headed ♂ 20.4 mm from cavity in living *A. palmata* and ♀ 16.2 mm replacement, spur and groove site, 16 Mar 1994. USNM 336767, 3, dark-headed ♂ 25.0 mm from cavity in living *A. palmata* and ♀ 15.8 mm replacement, and pale ♂ 14.9 mm on nearby surface of same coral, spur and groove site, 16 Mar 1994. USNM 336768, 3, dark-headed ♂ 19.3 mm from cavity in living *A. palmata* and 2 pale ♂ 20.8 mm, 21.0 mm, on nearby surface of same coral, spur and groove site, 16 Mar 1994. USNM 336769, 1, ♀ 17.1 mm on sea fan, patch reef southwest of CBC, 7 m, 16 Mar 1994. USNM 336770, 4, dark-headed ♂ 20.0–28.6 mm from marked (with numbered ribbons) cavities in four clumps of living *A. palmata* for replacement head-darkening study, 20.0 mm specimen from cavity 29, 20.2 mm specimen from cavity 31, 20.6 mm specimen from cavity 23, and 28.6 mm specimen from cavity 35 (cavity 23 with one subsequent replacement, see USNM 336773 below; cavity 35 with five subsequent replacements, see USNM 336771, 336772, and 336774–336776 below; other two cavities without replacements; data on these four dark-headed males and their replacements summarized in Table 5), spur and groove site, 23 Feb 1995. USNM 336771, 1, dark-headed ♂ 20.7 mm from cavity 35 (above) one day after removal of original dark-headed ♂, 24 Feb 1995. USNM 336772, 1, dark-headed ♂ 21.9 mm from cavity 35 (above) one day after removal of first replacement (USNM 336771), 25 Feb 1995. USNM 336773, 1, dark-headed ♂ 18.0 mm from cavity 23 (above) two days after removal of original dark-headed ♂, 25 Feb 1995. USNM 336774, 1, dark-headed ♂ 19.3 mm from cavity 35 one day after removal of second replacement (USNM 336772), 26 Feb 1995. USNM 336775, 1, dark-headed ♂ 18.0 mm from cavity 35 three days after removal of third replacement (USNM 336774), 1 Mar 1995. USNM 336776, 1, dark-headed ♂ 20.1 mm from cavity 35 six days after removal of fourth replacement (USNM 336775), 7 Mar 1995. USNM 336777, 2, dark-headed ♂ 21.9 mm, 23.5 mm, from cavities in same living *A. palmata* with marked cavity 35 (above), with cavity 35 being in about the middle of the upper surface of one of the upper branches but the cavities for these two additional males being in the basal regions on the underside of two of the lower branches, 7 Mar 1995. USNM 336778, 1, dark-headed ♂ 22.4 mm from cavity in living *A. palmata*, spur and groove site, 24 Feb 1995 (see next entry for replacement). USNM 336779, 1, pale ♂ 22.3 mm that went in and out of cavity immediately after it had been vacated by removal of dark-headed ♂ from USNM 336778 (above), branch of this coral with the pale ♂ pu-

tative replacement brought back to aquarium at laboratory, but this pale specimen did not take up residence in the cavity and did not darken in color during four days in the aquarium; sacrificed 28 Feb 1995. USNM 336780, 2, dark-headed ♂ 20.1 mm from cavity in living *A. palmata* and pale ♂ 21.5 mm replacement within 10 minutes, spur and groove site, 27 Feb 1995. USNM 336781, 2, dark-headed ♂ 19.7 mm, 26.7 mm, from cavities in living *A. palmata*, spur and groove site, 27 Feb 1995. USNM 336782, 1, dark-headed ♂ 23.8 mm from cavity in living *A. palmata*, spur and groove site, 26 Feb 1995 in morning (see next entry for replacement). USNM 336783, 1, pale ♂ 20.3 mm replacement that entered cavity vacated by removal of dark-headed male from USNM 336782 (above), branch of this coral with the pale replacement in the cavity brought back to aquarium at laboratory where it remained in the cavity until sacrificed two days later on 28 Feb 1995 in morning, the pale male having become dark-headed overnight, as observed on morning of 27 Feb 1995. USNM 341517, 5, dark-headed ♂ 21.6–23.8 mm, all from cavities in living *A. palmata*, spur and groove site, 16 Mar 1996 (see next entry for replacements). USNM 341518, 5, dark-headed ♂ 19.7–22.2 mm, replacements collected 26 Mar 1996 from cavities vacated 10 days previously by five dark-headed ♂ (see previous entry and Table 6). USNM 341519, 2, dark-headed ♂ 21.5 mm from cavity in dead part of otherwise living *A. palmata* and pale ♂ 19.5 mm from close-by living surface of same coral, spur and groove site, 26 Mar 1996. USNM 341520, 1, dark-headed ♂ 17.5 mm from cavity in dead part of otherwise living *M. annularis*, spur and groove site, 24 Mar 1996. USNM 336788, 15, 5 pale ♂ 15.0–21.6 mm and 10 ♀ 13.8–18.5 mm, cumulative composite collection of specimens from sea fans on patch reefs 1 km southwest of CBC (adjacent to the patch reef site), 8 m, 6–16 Mar 1994; these specimens were preserved in Dietrich's solution for histological preparation in order to examine gonadal condition and to verify correctness of external determination of sex based on papilla and anal-mound development.

The following specimens were collected by R.D. and K. Clarke incidental to their studies of *Acanthemblemaria* habitat partitioning and feeding behavior at CBC and generously made available along with their field observations. USNM 325438, 1, dark-headed ♂ 19.9 mm from cavity in living *A. palmata*, patch reef off north end of CBC on permanent transect line, 1 m, 14 Mar 1991. USNM 336743, 3, 2 dark-headed ♂ 22.0 mm, 27.8 mm, from cavities about 45 mm apart in dead part of otherwise living *M. annularis* and pale ♂ 22.1 mm replacement from cavity from which larger dark-headed male was removed, spur and groove site, 7 Mar 1994.

FMNH SPECIMENS.—The following specimens are the only ones previously reported for this species (Greenfield, 1975; Greenfield and Johnson, 1981). FMNH 77481, dark-headed ♂ 27.0 mm, holotype, and FMNH 77482, dark-headed ♂ 26.0 mm, paratype, from cavities in living *A. palmata* (extracted from cavity by hand after rotenone failed to dislodge them), patch reef near Long Cay, in lagoon of Glovers Reef, Belize (about 22 km east of CBC and 40 km off the coast), 1–1.5 m, 3 Aug 1973, D.W. and T.A. Greenfield. FMNH 86180, 2, dark-headed ♂ 25.0 mm, 25.6 mm, from cavities in living *A. palmata* using quinaldine, patch reef near Long Cay, in lagoon of Glovers Reef, Belize, 1–3 m, 9 Jul 1974, D.W. and T.A. Greenfield. FMNH 86181, 2, dark-headed ♂ 18.2 mm, 25.7 mm, from cavities in living *Montastrea* sp. using quinaldine, drop-off reef at Long Cay, Glovers Reef, Belize, 15 m, 9 Mar 1976, D.W. and T.A. Greenfield. FMNH 86182, 1, pale ♂ 23.1 mm from surface of living *Montastrea* sp. using quinaldine, drop-off reef at Long Cay, Glovers Reef, Belize, 27–30 m, 9 Mar 1976, D.W. and T.A. Greenfield. FMNH 89419, 1, ♀ 18.6 mm, patch reef 46 m southwest of CBC, Belize (rotenone station without microhabitat data for *E. pricei*), 1–2 m, 16 May 1977, D.W. and T.A. Greenfield. FMNH 89420, pale ♂ 16.8 mm, coral ridges (mainly *Agaricia*) 90 m east of CBC (rotenone station without microhabitat data for *E. pricei*), 9 m, 31 Dec 1977, D.W. and T.A. Greenfield and C. Rakocinski. FMNH 84580, 1, pale ♂ 20.7 mm, 46 m off west side of Big Hog Island, Honduras (rotenone station without microhabitat data for *E. pricei*), 1–3 m, 21 May 1975, R.R. and F. Miller and D.W. and T.A. Greenfield.

Emblemariopsis randalli

USNM 325431, 5, 4 darkened ♂ 21.4–27.2 mm and 1 pale ♀ 23.4 mm, Bahia de Charagato, Isla de Cubagua, Venezuela, 11 Mar 1973, F. Cervigon (gift from Prof. Cervigon of specimens from the type locality). ANSP 103055, 2, pale ♀ 21.7 mm, ~23 mm (larger specimen in poor condition), 90 m off Laguna Grande, Peninsula de Araya, Golfo de Cariaco, Estado Sucre, Venezuela, 20 May 1961, W.A. Lund, Jr. ANSP 142952, 1, 25.5 mm of undetermined sex (specimen in poor condition), ledge of rock and sand on north side of bay, Cubagua, Isla Margarita, Venezuela, 5 m, 24 Jan 1965, J.E. Randall.

Emblemariopsis diaphana

ZMA 114.495, 6, 14.1–18.7 mm, 1 km east of Piscadera Bay, off southwest end of Curaçao, 5–20 m, 12 May 1977, on living *Meandrina meandrites* (Linnaeus), voucher materials for the behavioral study by Butter et al. (1980).

Literature Cited

- Acero P., A.
1987. The Chaenopsine Blennies of the Southwestern Caribbean (Pisces, Clinidae, Chaenopsinae), III: The Genera *Chaenopsis* and *Coralliozetus*. *Boletín Ecotropical*, 16:1–21.
- Andreyko, H.
MS Reproductive Behavior of the Sailfin Blenny, *Emblemaria pandionis*, in Captivity, with Notes on Eggs and Development.
- Birdsong, R.S., and A.R. Emery
1968 ("1967"). New Records of Fishes from the Western Caribbean. *Quarterly Journal of the Florida Academy of Sciences*, 30(3):187–196. [Date on title page is 1967; actually published in 1968.]
- Buchheim, J.R., and M.A. Hixon
1992. Competition for Shelter Holes in the Coral-Reef Fish *Acanthemblemaria spinosa* Metzelaar. *Journal of Experimental Marine Biology and Ecology*, 164:45–54.
- Butter, M.E., M. Wapstra, and E. Van Dijk
1980. *Meandrina meandrites* and *Emblemaria diaphana*, First Record of an Association between a Stony Coral and a Fish, Similar to Anemone/Fish Relationships. *Bijdragen tot de Dierkunde*, 50(1):87–95.
- Cervigon, F.
1965. *Emblemaria randalli* nov. sp., una nueva especie de Chaenopsidae de las costas de Venezuela. *Novedades Científicas, Contribuciones Ocasionales del Museo de Historia Natural La Salle, Serie Zoológica*, 33:1–4.
1966. Los peces marinos de Venezuela, tomo II. *Monografía, Estacion de Investigaciones Marinas de Margarita*, 12:449–951.
- Clarke, R.D.
1989. Population Fluctuation, Competition and Microhabitat Distribution of Two Species of Tube Blennies, *Acanthemblemaria* (Teleostei: Chaenopsidae). *Bulletin of Marine Science*, 44(3):1174–1185.
1992. Effects of Microhabitat and Metabolic Rate on Food Intake, Growth and Fecundity of Two Competing Coral Reef Fishes. *Coral Reefs*, 11:199–205.
1994. Habitat Partitioning by Chaenopsid Blennies in Belize and the Virgin Islands. *Copeia*, 1994(2):398–405.
1996. Population Shifts in Two Competing Fish Species on a Degrading Coral Reef. *Marine Ecology Progress Series*, 137:51–58.
- Davis, W.P., and D.M. Cohen
1969 ("1968"). A Gobiid Fish and a Palaemonid Shrimp Living on an Antipatharian Sea Whip in the Tropical Pacific. *Bulletin of Marine Science*, 18(4):749–761. [Date on title page is 1968; actually published in 1969.]
- Greenfield, D.W.
1975. *Emblemaria pricei*, a New Species of Chaenopsid Blenny from Belize. *Copeia*, 1975(4):713–715.
- Greenfield, D.W., and T.A. Greenfield
1982. Habitat and Resource Partitioning Between Two Species of *Acanthemblemaria* (Pisces: Chaenopsidae), with Comments on the Chaos Hypothesis. In Klaus Rützler and Ian G. Macintyre, editors, *The Atlantic Barrier Reef Ecosystem at Carrie Bow Cay, Belize, I: Structure and Communities*. *Smithsonian Contributions to the Marine Sciences*, 12:499–507.
- Greenfield, D.W., and R.K. Johnson
1981. The Blennioid Fishes of Belize and Honduras, Central America, with Comments on Their Systematics, Ecology, and Distribution (Blenniidae, Chaenopsidae, Labrisomidae, Tripterygiidae). *Fieldiana, Zoology*, new series, 8:1–106.
1990. Community Structure of Western Caribbean Blennioid Fishes. *Copeia*, 1990(2):433–448.
- Hastings, P.A.
1984. Resource Limitation in a Coral-Dwelling Blennioid Fish. *American Zoologist, Abstracts*, 24(3):128A.
1986. Habitat Selection, Sex Ratio and Sexual Selection in *Coralliozetus angelica* (Blennioidea: Chaenopsidae). In T. Uyeno, R. Arai, T. Taniuchi, and K. Matsuura, editors, *Indo-Pacific Fish Biology: Proceedings of the Second International Conference on Indo-Pacific Fishes*, pages 785–793. Tokyo: Ichthyological Society of Japan.
1988a. Female Choice and Male Reproductive Success in the Angle Blenny, *Coralliozetus angelica* (Teleostei: Chaenopsidae). *Animal Behavior*, 36:115–124.
1988b. Correlates of Male Reproductive Success in the Browncheek Blenny, *Acanthemblemaria crockeri* (Blennioidea: Chaenopsidae). *Behavioral Ecology and Sociobiology*, 22:95–102.
1991. Flexible Responses to Predators in a Marine Fish. *Ethology, Ecology and Evolution*, 3:177–184.
1992a. Phylogenetic Relationships of *Tanyemblemaria alleni*, a New Genus and Species of Chaenopsid (Pisces: Blennioidei) from the Gulf of Panama. *Bulletin of Marine Science*, 51:147–160.
1992b. Nest-Site Size as a Short-Term Constraint on the Reproductive Success of Paternal Fishes. *Environmental Biology of Fishes*, 34:213–218.
- MS Phylogenetic Relationships and Biogeography of *Coralliozetus* and *Prothemblemaria* Species, with Descriptions of a New Genus (Teleostei, Blennioidei).
- Hastings, P.A., and V.G. Springer
1994. Review of *Stathmonotus*, with Redefinition and Phylogenetic Analysis of the Chaenopsidae (Teleostei: Blennioidei). *Smithsonian Contributions to Zoology*, 558: 48 pages.
- Heard, R.W., and S. Spotte
1991. Pontonin Shrimps (Decapoda: Caridea: Palaemonidae) of the Northwest Atlantic, II: *Periclimenes patae*, New Species, a Gorgonian Associate from Shallow Reef Areas off the Turks and Caicos Islands and Florida Keys. *Proceedings of the Biological Society of Washington*, 104(1):40–48.
- Hove, H.A. ten
1970. Serpulinae (Polychaeta) from the Caribbean, I: The Genus *Spirobranchus*. *Studies on the Fauna of Curaçao and Other Caribbean Islands*, 32:1–57.
- Hove, H.A. ten, and E. Nishi
1996. A Redescription of the Indo-West Pacific *Spirobranchus corrugatus* Straughan, 1967 (Serpulidae, Polychaeta), and an Alternative Hypothesis on the Nature of a Group of Middle Miocene Microfossils from Poland. *Beaufortia*, 46(5):83–96.
- Humann, P.
1994. *Reef Fish Identification: Florida, Caribbean, Bahamas*. Second edition, 396 pages. Jacksonville, Florida: New World Publications.
- Hunte, W., B.E. Conlin, and J.R. Marsden
1990. Habitat Selection in the Tropical Polychaete *Spirobranchus giganteus*, I: Distribution on Corals. *Marine Biology*, 104:87–92.
- Hunte, W., J.R. Marsden, and B.E. Conlin
1990. Habitat Selection in the Tropical Polychaete *Spirobranchus giganteus*, III: Effects of Coral Species on Body Size and Body Proportions. *Marine Biology*, 104:101–107.
- Johnson, G.D., and E.B. Brothers
1989. *Acanthemblemaria paula*, a New Diminutive Chaenopsid (Pisces: Blennioidei) from Belize, with Comments on Life History. *Proceedings of the Biological Society of Washington*, 102(4):1018–1030.

- Larson, H.K.
 1985. A Revision of the Gobiid Genus *Bryaninops* (Pisces), with a Description of Six New Species. *The Beagle, Occasional Papers of the Northern Territory Museum of Arts and Sciences*, 2(1):57-93.
 1990. A Revision of the Commensal Gobiid Fish Genera *Pleurosicya* and *Luposicya* (Gobiidae), with Descriptions of Eight New Species of *Pleurosicya* and Discussion of Related Genera. *The Beagle, Occasional Papers of the Northern Territory Museum of Arts and Sciences*, 7(1):1-53.
- Leviton, A.E., R.H. Gibbs, Jr., E. Heal, and C.E. Dawson
 1985. Standards in Herpetology and Ichthyology, Part 1: Standard Symbolic Codes for International Resource Collections in Herpetology and Ichthyology. *Copeia*, 1985(3):802-832.
- Lindquist, D.G.
 1985. Depth Zonation, Microhabitat, and Morphology of Three Species of *Acanthemblemaria* (Pisces: Blennioidea) in the Gulf of California, Mexico. *Marine Ecology*, 6(4):329-344.
- Longley, W.H., and S.F. Hildebrand
 1940. New Genera and Species of Fishes from Tortugas, Florida. *Papers from the Tortugas Laboratory, Carnegie Institution*, 32(517):223-285.
- Luckhurst, B.E., and K. Luckhurst
 1978. Diurnal Space Utilization in Coral Reef Fish Communities. *Marine Biology*, 49:325-332.
- Marsden, J.R., B.E. Conlin, and B.E. Hunte
 1990. Habitat Selection in the Tropical Polychaete *Spirobranchus giganteus*, II: Larval Preferences for Corals. *Marine Biology*, 104:93-99.
- Nishi, E.
 1995a. [Biology of a Tropical Serpulid Worm Living in a Tube Embedded in a Coral.] *Iden* (Tokyo), 49(9):72-74. [In Japanese.]
 1995b. [Tropical Tube Worm *Spirobranchus* (Polychaeta, Serpulidae) from Japan.] *I.O.P. Diving News*, 7(1):4-6. [In Japanese.]
- Nishi, E., and M. Nishihira
 1996. Age-Estimation of the Christmas Tree Worm *Spirobranchus giganteus* (Polychaeta, Serpulidae) Living Buried in the Coral Skeleton from the Coral-Growth Band of the Host Coral. *Fisheries Science*, 62(2):400-403.
- In press. Use of Annual Density Banding to Estimate Longevity of Infauna of Massive Corals. *Fisheries Science*, 65.
- Nishi, E., T. Yamasu, and T. Kikuchi
 1996. Preliminary Observations of the Tropical Serpulid *Spirobranchus giganteus corniculatus* Pallas. *Publications from the Amakusa Marine Biological Laboratory, Kyushu University*, 12(2):45-54.
- Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott
 1991. Common and Scientific Names of Fishes from the United States and Canada, Fifth Edition. *American Fisheries Society, Special Publication*, 20:1-183.
- Rützler, K., and I.G. Macintyre
 1982. The Habitat Distribution and Community Structure of the Barrier Reef Complex at Carrie Bow Cay, Belize. In Klaus Rützler and Ian G. Macintyre, editors, *The Atlantic Barrier Reef Ecosystem at Carrie Bow Cay, Belize, I: Structure and Communities. Smithsonian Contributions to the Marine Sciences*, 12:9-45.
- Smith, C.L., and J.C. Tyler
 1972. Space Resource Sharing in a Coral Reef Fish Community. In Bruce B. Collette and Sylvia A. Earle, editors, *Results of the Tektite Program. Bulletin of the Natural History Museum of Los Angeles County*, 14:125-170.
- Smith, C.L., J.C. Tyler, H. Andreyko, and D.M. Tyler
 1998. Behavioral Ecology of the Sailfin Blenny, *Emblemaria pandionis* (Pisces: Chaenopsidae) in the Caribbean off Belize. *American Museum Novitates*, 3232:1-40.
- Smith, R.
 1985. Photoreceptors of Serpulid Polychaetes. 670 pages. Doctoral thesis, James Cook University of North Queensland, Townsville.
- Stephens, J.S., Jr.
 1963. A Revised Classification of the Blennioid Fishes of the American Family Chaenopsidae. *University of California Publications in Zoology*, 68:1-165.
 1970. Seven New Chaenopsid Blennies from the Western Atlantic. *Copeia*, 1970(2):280-309.
- Stephens, J.S., Jr., E.S. Hobson, and R.K. Johnson
 1966. Notes on Distribution, Behavior, and Morphological Variation in Some Chaenopsid Fishes from the Tropical Eastern Pacific, with Descriptions of Two New Species, *Acanthemblemaria castroi* and *Coralliozetus springeri*. *Copeia*, 1966(3):424-438.
- Tyler, D.M., and J.C. Tyler
 1997. A New Species of Chaenopsid Fish, *Emblemaropsis ruetzleri*, from the Western Caribbean off Belize (Blennioidei), with Notes on Its Life History. *Proceedings of the Biological Society of Washington*, 110(1):24-38.

REQUIREMENTS FOR SMITHSONIAN SERIES PUBLICATION

Manuscripts intended for series publication receive substantive review (conducted by their originating Smithsonian museums or offices) and are submitted to the Smithsonian Institution Press with Form SI-36, which must show the approval of the appropriate authority designated by the sponsoring organizational unit. Requests for special treatment—use of color, foldouts, case-bound covers, etc.—require, on the same form, the added approval of the sponsoring authority.

Review of manuscripts and art by the Press for requirements of series format and style, completeness and clarity of copy, and arrangement of all material, as outlined below, will govern, within the judgment of the Press, acceptance or rejection of manuscripts and art.

Copy must be prepared on typewriter or word processor, double-spaced, on one side of standard white bond paper (not erasable), with 1 1/4" margins, submitted as ribbon copy (not carbon or xerox), in loose sheets (not stapled or bound), and accompanied by original art. Minimum acceptable length is 30 pages.

Front matter (preceding the text) should include: **title** page with only title and author and no other information; **abstract** page with author, title, series, etc., following the established format; table of **contents** with indents reflecting the hierarchy of heads in the paper; also, **foreword** and/or **preface**, if appropriate.

First page of text should carry the title and author at the top of the page; **second page** should have only the author's name and professional mailing address, to be used as an unnumbered footnote on the first page of printed text.

Center heads of whatever level should be typed with initial caps of major words, with extra space above and below the head, but no other preparation (such as all caps or underline, except for the underline necessary for generic and specific epithets). Run-in paragraph heads should use period/dashes or colons as necessary.

Tabulations within text (lists of data, often in parallel columns) can be typed on the text page where they occur, but they should not contain rules or numbered table captions.

Formal tables (numbered, with captions, boxheads, stubs, rules) should be submitted as carefully typed, double-spaced copy separate from the text; they will be typeset unless otherwise requested. If camera-copy use is anticipated, do not draw rules on manuscript copy.

Taxonomic keys in natural history papers should use the aligned-couplet form for zoology and may use the multi-level indent form for botany. If cross referencing is required between key and text, do not include page references within the key, but number the keyed-out taxa, using the same numbers with their corresponding heads in the text.

Synonymy in zoology must use the short form (taxon, author, year:page), with full reference at the end of the paper under "Literature Cited." For botany, the long form (taxon, author, abbreviated journal or book title, volume, page, year, with no reference in "Literature Cited") is optional.

Text-reference system (author, year:page used within the text, with full citation in "Literature Cited" at the end of the text) must be used in place of bibliographic footnotes in all Contributions Series and is strongly recommended in the Studies Series: "(Jones, 1910:122)" or "...Jones (1910:122)." If bibliographic footnotes are

required, use the short form (author, brief title, page) with the full citation in the bibliography.

Footnotes, when few in number, whether annotative or bibliographic, should be typed on separate sheets and inserted immediately after the text pages on which the references occur. Extensive notes must be gathered together and placed at the end of the text in a notes section.

Bibliography, depending upon use, is termed "Literature Cited," "References," or "Bibliography." Spell out titles of books, articles, journals, and monographic series. For book and article titles use sentence-style capitalization according to the rules of the language employed (exception: capitalize all major words in English). For journal and series titles, capitalize the initial word and all subsequent words except articles, conjunctions, and prepositions. Transliterate languages that use a non-Roman alphabet according to the Library of Congress system. Underline (for italics) titles of journals and series and titles of books that are not part of a series. Use the parentheses/colon system for volume (number):pagination: "10(2):5-9." For alignment and arrangement of elements, follow the format of recent publications in the series for which the manuscript is intended. Guidelines for preparing bibliography may be secured from Series Section, SI Press.

Legends for illustrations must be submitted at the end of the manuscript, with as many legends typed, double-spaced, to a page as convenient.

Illustrations must be submitted as original art (not copies) accompanying, but separate from, the manuscript. Guidelines for preparing art may be secured from the Series Section, SI Press. All types of illustrations (photographs, line drawings, maps, etc.) may be intermixed throughout the printed text. They should be termed **Figures** and should be numbered consecutively as they will appear in the monograph. If several illustrations are treated as components of a single composite figure, they should be designated by lowercase italic letters on the illustration; also, in the legend and in text references the italic letters (underlined in copy) should be used: "Figure 9b." Illustrations that are intended to follow the printed text may be termed **Plates**, and any components should be similarly lettered and referenced: "Plate 9b." Keys to any symbols within an illustration should appear on the art rather than in the legend.

Some points of style: Do not use periods after such abbreviations as "mm, ft, USNM, NNE." Spell out numbers "one" through "nine" in expository text, but use digits in all other cases if possible. Use of the metric system of measurement is preferable; where use of the English system is unavoidable, supply metric equivalents in parentheses. Use the decimal system for precise measurements and relationships, common fractions for approximations. Use day/month/year sequence for dates: "9 April 1976." For months in tabular listings or data sections, use three-letter abbreviations with no periods: "Jan, Mar, Jun," etc. Omit space between initials of a personal name: "J.B. Jones."

Arrange and paginate sequentially every sheet of manuscript in the following order: (1) title page, (2) abstract, (3) contents, (4) foreword and/or preface, (5) text, (6) appendices, (7) notes section, (8) glossary, (9) bibliography, (10) legends, (11) tables. Index copy may be submitted at page proof stage, but plans for an index should be indicated when the manuscript is submitted.

