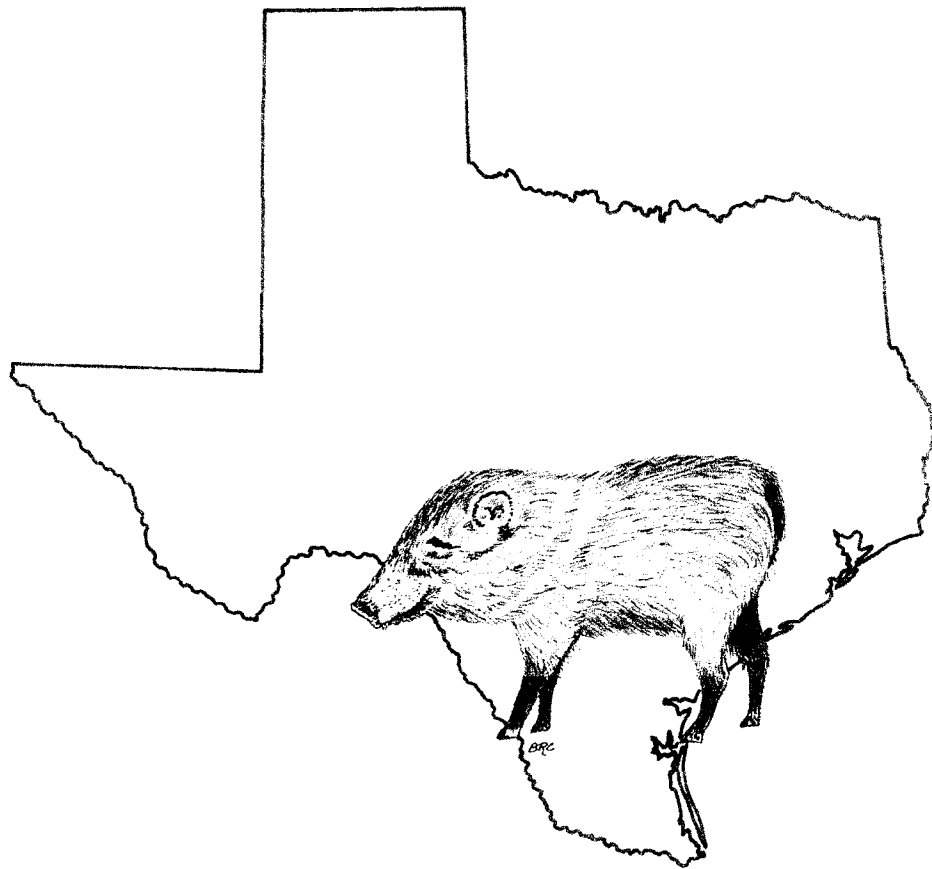


South Texas Fauna

A Symposium Honoring Dr. Allan H. Chaney



Brian R. Chapman
John W. Tunnell, Jr.
Co-Editors

Caesar
Kleberg
Wildlife Research Institute

**SOUTH TEXAS FAUNA -
A SYMPOSIUM HONORING DR. ALLAN H. CHANEY**

**Texas A&I University
Kingsville, Texas**

21 - 22 December 1977

**Brian R. Chapman
John W. Tunnell, Jr.
Co-Editors**

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EDITOR'S COMMENTS

The original idea for this symposium belongs to Brian W. Cain. However, the desire, enthusiasm, and involvement belongs to all who participated as has been so very well stated by Eric G. Bolen in the FOREWARD of this volume. The editors must extend our sincere appreciation to all the symposium participants and reviewers for their commitment to an excellent publication and especially for their patience with us. Our increased involvement with other activities, such as local organization for several regional and national meetings, American Malacological Union, 1979, Wilson/Cooper Ornithological Societies, 1980, and Texas Academy of Sciences, 1980, plus almost total emersion in the effects of the IXTOC I-Mexican oil spill on South Texas barrier island beaches, greatly slowed editing responsibilities. For these time-delays we apologize to our colleagues, but we rejoice with all at its completion, the contribution we believe it will make to our knowledge of the biota of South Texas, and our appreciation for the man, Allan H. Chaney.

A special word of thanks goes to Gail Ivie for the pleasant, untiring, and efficient manner in which she carried out the final typing and compiling of the proceedings.

The Caesar Kleberg Wildlife Research Institute of Texas A&I University is greatly acknowledged for publishing the proceedings.

Brian R. Chapman
John W. Tunnell, Jr.
Co-Editors

FOREWARD

The biota of South Texas is rich in both diversity and abundance, perhaps more so for the area's size than anywhere in North America. Elements of the Chihuahuan Desert touch the western edge of South Texas, then give way eastward to the brushlands of the Rio Grande Plains; from the south are numerous and exciting tropical incursions, and from the north and east are temperate species that seemingly complete the colorful biotic mural that is South Texas.

Yet there is more. South Texas meets with the western edge of the Gulf of Mexico. The landscape along the coast is a verdant mix of coastal prairie and saltwater marsh yielding to a complex bay system that is capped by the Laguna Madre. Beyond lie the barrier islands where unique ecological systems entrap forever a biologist's imagination. No one can escape the lure of the shifting foredunes, the fleeting ghost crabs, the unparalleled stoop of a peregrine falcon or the mysteries of the Gulf's tepid waters.

The biota, I repeat, is rich. South Texas is quite literally a biological crossroads for much of North America. Eastern species meet and blend with those of the west, south with north, and we who work with creatures are blessed to be here.

For biology students of nearly two decades' span this setting has been - and remains - further enriched by the perceptive guidance of a dedicated teacher and graduate counselor. He is Allan H. Chaney, Professor of Biology at Texas A&I University. This volume is our tribute to Dr. Chaney and to his accomplishments. His accomplishments are, of course, not merely contributions to the biological sciences, but also to the people who were and are his students and colleagues. Thus, with these papers, we acknowledge the energy he has contributed to our education, to our professionalism, and perhaps of the highest order, to our character.

What follows in this volume is a representation of Dr. Chaney's interests in biology and people. Readers of almost any bent can sample these pages with ample reward. Here are papers on the breeding biology of ground squirrels, the distribution of marine brachiopods, the status of roseate spoonbills, the biology and ecology of crustaceans, and the bioenergetics of whistling ducks. And more - sponges, spoil island ecology, rodent behavior, and morphometric analysis of sirens. This menu is at once delightful and fulfilling. Each paper has two ingredients, the wondrous outdoor laboratory of South Texas and the guiding hand of Allan H. Chaney.

* * * * *

Texas proudly claims our honoree as a native son. Born in the heart of the hill country at Kerrville on December 11, 1923, Allan Harold Chaney - "Case" to his many associates - attended Tivy High School and the Schreiner Institute where he graduated with honors. He joined the Navy V-1 program in 1942, was commissioned in 1945, and served in the Pacific Theatre as a captain of LSM 345.

The years that followed the war were no less active and far more fulfilling. Tulane University was the academic home of Allan Chaney; B.S. (1947), M.S. (1949) and Ph.D (1958) degrees were each granted from that institution. His social life flourished, too, and "Case" took the hand of Mary Jane Koubek in marriage in 1948. This union produced Richard Allan in 1952 and Jane Allane in 1955.

Teaching responsibilities first at Tulane (1950) and later at Arkansas Polytechnic College (1953-58) founded Dr. Chaney's unique rapport with college students. He then joined Del Mar College (1959-63) where he served as professor and Chairman of the Biology Department. Another move followed, and since 1963 Dr. Chaney has continued his productive tenure at Texas A&I University. His teaching abilities and superb interactions with students are the fabric of his career. Twice selected among the Top Ten Teachers, twice nominated for the prestigious Piper Professor award, and revered by all who have attended his classes, Allan H. Chaney is now honored with this symposium in recognition of his singular dedication to the excellence of instruction and personal development. We are indelibly marked by our association with Case Chaney, and remain indebted to him for his unyielding concern.

One final note. It was my pleasure to act as M.C. for the symposium's banquet. One can scarcely report the atmosphere that permeated the audience of students, past and present. How does one ably portray in words the attributes of respect, honor, and affection? I cannot, but I do in these few words acknowledge that these and even more sentiments of our admiration were in the hearts of all there. In Navy terms, I warmly add a hearty "Well done, Case!" from all of us.

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SYMPOSIUM

The symposium in honor of Dr. Allan H. Chaney, Professor of Biology at Texas A&I University in Kingsville, Texas, was held on campus during 21 - 22 December 1977. The banquet and presented papers were a means of expressing sincere appreciation for Dr. Chaney's guidance, encouragement, and friendship from his former students. The following is an outline of the symposium:

21 December 1977

REGISTRATION

Biology Building, Room 101, 2 - 5 PM

BANQUET

Student Union Building, 7:00 PM

Greetings and Introduction - Dr. Eric Bolen

Invocation - Dr. Wes Tunnell

Banquet

The Symposium and its History - Dr. Brian Cain

Chaney's Song - Dr. Joyce Teerling *et al.*

Words of Thanks - Mrs. Scott (Mary) Wright and Dr. Jack Rickner

The Guest of Honor Speaks - Dr. Allan H. Chaney

Closing Thoughts - Dr. Eric Bolen

22 December 1977

SYMPOSIUM

Biology Building, Room 100, 9 - 4:30 PM

Opening of the Symposium - Dr. Brian R. Chapman

Presentation of Papers

- 1) The home range of *Peromyscus leucopus texana* (Woodhouse) at Site 55, Kleberg County, Texas by Josephine Smith.
- 2) Interaction of seven rodent species at Site 55, Kleberg County, Texas by Mary Wright.
- 3) Reproduction of the Mexican ground squirrel (*Spermophilus mexicanus*) in southern Texas by Kenneth G. Matocha.
- 4) Geographic distribution and taxonomic status of rice rats (Genus *Oryzomys*) in Texas by Stanley Parker.
- 5) A morphometric analysis of sirens from southern Texas by V. Rick McDaniel.
- 6) Distribution and habitat of *Discradisca antillarum* (d'Orbigny, 1846) (Brachiopoda: Inarticulata) in the western Gulf of Mexico by John W. Tunnell, Jr.
- 7) The importance of echinoderms in the diet of fishes of a sublittoral rock reef by Thomas C. Shirley.

- 8) Life histories of the snapping shrimps *Synalpheus fritzmuelleri* and *S. apioceros* (Crustacea: Decapoda: Alpheidae) on a sublittoral reef off Texas by Darryl L. Felder.
- 9) Sponges from Seven and One-Half Fathom Reef by Joyce Teerling.
- 10) The ascidians of the Aransas Pass inlet jetties, Port Aransas, Texas by Nancy N. Rabalais.
- 11) Observations on the biology of *Tozeuma carolinense* (Crustacea: Hippolytidae) from Redfish Bay, Texas by Jack A. Rickner.
- 12) Current status of Roseate Spoonbills on the Texas coast by Brian R. Chapman.
- 13) Anatomical and vegetational features of spoil banks and their utilization by birds: upper Laguna Madre of Texas by Carlos H. Mendoza and Rene Ortiz.
- 14) Growth energetics of Black-bellied Whistling Ducks (*Dendrocygna autumnalis*) by Brian W. Cain.

Closing Remarks - Dr. Chapman

SMOKER

Officers Club, Kingsville Naval Air Station, 7:00 PM

**THE REPRODUCTIVE CYCLE OF THE MEXICAN
GROUND SQUIRREL (*Spermophilus mexicanus*)
IN SOUTHERN TEXAS**

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ABSTRACT

The reproductive cycle of the Mexican ground squirrel (*Spermophilus mexicanus*) was investigated in the laboratory and field populations from southern Texas during 1966, 1967 and 1968. The extended period of favorable climatic conditions found in this area was reflected in the reproductive pattern of this species. Laboratory studies revealed an approximation of gestation period, time of breeding and litter sizes. Field studies yielded information on litter size, time of breeding, age of breeding, and number of litters per year. The extended breeding period revealed by the study was probably a result of the onset of sexual maturity of the females and the production of second litters by some of the animals.

GEOGRAPHIC DISTRIBUTION AND TAXONOMIC STATUS OF RICE RATS (Genus *Oryzomys*) IN TEXAS

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ABSTRACT

Rice rats in Texas were separated into two groups that differed in external features, cranial morphology, karyology, mate selection and ecological preferences. Discriminant analysis was used to show that these two groups differ phyletically. Thus, *Oryzomys palustris* and *O. couesi* are identifiable as separate species. They occur sympatrically without recognizable intergradation or hybridization in parts of South Texas.

HOME RANGE ACTIVITY AND HABITAT PREFERENCE OF *Peromyscus leucopus*

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ABSTRACT

A total of 414 (2,108 recaptures) *Peromyscus leucopus* were marked during a 40-month study in South Texas at an annual average of 16.1 mice/ha caught per month, with 19.8 mice/ha in the winter and 11.3 mice/ha in the summer. The average home range for *Peromyscus* on the 2.3 ha plot was .21 ha. The average home range for males and females was 0.22 ha and 0.19 ha, respectively. Both sexes were caught more times and had larger home ranges during breeding than during non-breeding. *Peromyscus leucopus* appeared to be concentrated along an old asphalt road, a ravine and in areas with large mesquites.

In November of 1969, the Texas A&I University Vertebrate Zoology class undertook a rodent study as a class project at Texas A&I Biological Station (Site 55) in Kleberg County, Texas. This project was continued and extended into two master's theses with the preceeding report coming from one of the theses and this one from this author's thesis: "Population Study of *Peromyscus leucopus texanus* (Woodhouse) at Site 55, Kleberg County, Texas." *Peromyscus l. texanus* was the most prevalent rodent throughout the study period. Six subordinate species were *Neotoma micropus micropus* (Baird), *Sigmodon hispidus berlandieri* (Baird), *Baiomys taylori taylori* (Thomas), *Reithrodontomys fulvescens intermedius* (J.A. Allen), *Perognathus hispidus hispidus* (Baird), and *Onychomys leucogaster longipes* (Merriam, Hall and Kelson, 1959). This report deals only with how home range was correlated with the breeding, the density, and habitat of the *Peromyscus* populations.

Home range size may vary widely in response to several factors, including habitat, breeding conditions, population, density and food supply (Dice, 1941). Change in size of home range is one way animals adjust to changes in the environment (Stickel, 1960). Redman and Sealander (1958) reported that the average home range of *P. leucopus* was 0.16 ac (0.06 ha) on 1-acre (.4 ha) grids as compared with an average of 0.18 ac (0.07 ha) for 4-acre (1.6 ha) grids. The average home range for females was 0.18 ac (0.07 ha) and for males 0.15 ac (0.06 ha). Burt (1967) stated that the home range for females was 0.5 ac (0.2 ha) and 1.5 ac (0.6 ha) for males. Davis (1960) gave maximum home range for males as 0.5 ac (0.2 ha) and that of females as 0.33 ac (0.13 ha). A study by Mineau and Madison (1977), consisting of radio tracking the movements of the rodents by the use of radio transmitters, demonstrated larger home ranges for males and females, 1.26 ha and 0.91 ha, respectively. Manville (1956) stated that males must have wandered more during breeding because the number of captures increased. In a study by Harland and Miller (1980), females in semi-natural conditions in enclosures appeared to spend more time away from the nest during breeding than non-breeding. Mineau and Madison (1977) reported the home ranges did shift and overlap, which suggests that activity sites changed during the year.

Wirtz and Pearson (1960) stated that *P. leucopus* is abundant in all major habitats in a given area. Raun and Wilks (1964) reported that white-footed mice prefer grasslands; Getz (1959) suggested that they prefer forested areas and fallen logs or debris, while Metzgar (1973) found that the *P. leucopus* did not orient to features like large trees, fallen logs and debris. A majority of authors (Schnell, et al., 1980, Lackey, 1977, and Sly, 1976) reported that the white-footed mouse preferred forested and dense woody areas. Bowker and Pearson (1976), reported that small dense clumps surrounded by expanse of sparse vegetation was the preferred habitat in their study. In Mexico, they preferred the grainfields (Lackey, 1977).

Information on population density correlated to the home ranges of *P. leucopus* was not found in the literature.

LOCATION

The 2.3 ha study plot was located on the Texas A&I Biological Station (Site 55) southeast of Riviera, Kleberg County, Texas (Fig. 1 - see paper by Wright).

METHODS

The methods used in this study were the same as those in Wright, except for the additional methods used to correlate home range with breeding activity, high and low population density and habitat preference.

Breeding Activity

Breeding condition was recorded for all females with a perforate vagina and/or elongate mammae and for all males with descending testes (Howard, 1950 and Sheppe, 1963). Breeding and non-breeding months were determined for each trapped mouse. The traps that each was caught in during breeding and non-breeding were recorded separately, and those trap locations for captures during the two periods were compared.

High and Low Density Activity

The average number of *P. leucopus* present in the area per month was calculated for each cycle (Fig. 3 - Wright). When more than this average were caught during any month it was considered a high density month, if fewer, a low density month. Locations of traps in which rodents were caught during high density and low density months were then compared.

Habitat Preference

The total number of individual captures in each trap was calculated for each cycle to determine if the *P. leucopus* appeared to prefer any type of habitat in the study plot. If an individual was captured more than once in a trap during one night, it was only counted once for that trap that night. The total number of capture-nights for each trap was plotted on a grid.

Home Range

For the analysis of variation among individual home ranges in the population, data on 22 males and 16 females were used. Each had been trapped at least nine times over a period of 6-months or more. These 38 case histories were used to compare home ranges with breeding activity. In comparing periods of high and low density, only 37 of the 38 were used because one female was caught only during the high density months. Because all traps were always set at fixed and measured points in the grid, it was possible to determine the approximate size and shape of each home range by plotting contours of recapture frequencies, following the method described by Davis (1967) (Fig. 1-12). The individual home range contours represent the number of times an individual was caught in a specific trap during periods of breeding and non-breeding and of high and low density. The contours on the grids showing habitat preference are based on the total number of times all *P. leucopus* were caught in specific traps during a 12-month cycle that included one period each of breeding and of non-breeding and of low and high density.

RESULTS AND DISCUSSION

A total of 414 *Peromyscus l. texanus* (2,108 recaptures) were marked during a 40-month study (Fig. 3 - Wright). There was a cyclic pattern throughout the study with low numbers in the late spring and summer, a gradual increase in individuals to maximum number in November, December and January, then a decline to another low in June. A bloom could have occurred in Cycle II with Cycle I as part of a gradual build-up to the bloom (Fig. 3 - Wright). The average number of mice per hectare during the study was 16.1, with 19.8 mice/ha in the winter and 11.3 mice/ha in the summer.

Home Range

The average home range on the 2.3 ha plot was 0.21 ha. The average home range of both males (0.22 ha) and females (0.19 ha) was larger in this study than that reported by Redman and Sealander (1958) but similar to that reported by Burt (1967). The larger home ranges reported by Mineau and Madison (1977) may have been an artifact of the radio tracking technique, since it

traced maximum movements independent of baited trap sites. The maximum home range for any male *P. leucopus* was 0.38 ha and that for any females was 0.37 ha. These were larger than those reported by Davis (1960). Davis's statement was probably for a state-wide average.

Home Range-Breeding Activity

Both males (15) and females (13) exhibited larger home ranges during breeding activity (Table 1). The location of the home ranges during breeding activity of both males (18) and females (13) appeared to overlap their nonbreeding home ranges (Figs. 1 and 2). This finding agrees with Mineau and Madison (1977). The breeding home ranges appeared to be larger than the nonbreeding ones, suggesting more wandering during times of breeding activities (Figs. 1 and 2). Home ranges of 11 males exhibited complete overlap between breeding and nonbreeding (Fig. 3 - Wright). The epicenters of the home ranges for both sexes (Figs. 4 and 5) shifted between breeding and nonbreeding months (36 of the 38), which suggests more wandering during breeding activity, more competition for nests sites, or both.

More males (9) than females (4) were caught more frequently around one trap site during breeding (Table 1). Both males (8) and females (9) were caught more frequently around one trap site during nonbreeding and 5 males and 3 females were caught as frequently during each period (Table 1). Most of the young adults of both sexes appeared to utilize a first home range until attaining a length of more than 150 mm (old adults), then moved to a new area and established another (Figs. 6 and 7). Males were caught more often than females during breeding, which suggests they wandered more during the periods of breeding activity. However, females also appeared to wander during the breeding months since they were also caught more often then than during nonbreeding periods. This wandering activity of females during breeding coincides with that reported by Harland and Miller (1980).

Home Range-High and Low Density

The average density of *P. leucopus* during Cycle I was 31; Cycle II, 52; Cycle III, 36; and Cycle IV, 22. During high density the home range of some males (10) appeared to be different from that

Table 1. A comparison of home ranges of 38 individuals during times of breeding and nonbreeding.

	Males (22)	Females (16)
More area in breeding	15	13
More area in nonbreeding	7	3
Caught more in breeding	15	10
Caught more in nonbreeding	7	6
Breeding home range isolated from nonbreeding home range	4	3
Breeding home range and nonbreeding home range overlap	18	13
The number of individuals whose breeding and nonbreeding ranges overlapped and coincided	11	5
The number that were most often captured around one trap site during breeding	9	4
The number that were most often captured around one trap site during nonbreeding	8	9
The number that were most often captured around one trap site during both breeding and nonbreeding	5	3
The number of individuals caught as young adults that changed activity areas after being caught as old adults	16	10

during low density (Table 2, Fig. 8), but home ranges during high and low density overlapped more often (12) than they were separated. The results for females were similar. This overlap suggests that this rodent's main activity area is not changed much by changes in density. During high density, both sexes were caught more often (Table 2), which could indicate more wandering due to competition for food and space. Males were localized around specific trap sites in both high (11) and low (10) density periods (Table 2), but females were caught more frequently around one trap site only during high density (Table 2).

Density-Habitat

The rodents in all cycles appeared to be concentrated along the old asphalt road, the ravine and sites around *Prosopis glandulosa* Torr. var. *glandulosa* (Mesquite) (Figs. 9, 10, 11 and 12) (Fig. 2 - Wright). *Rivina humilis* L. (small pokeweed) and *Capsicum annum* L. (chile piquin) were in association with the large mesquite and could have been a source of food when fruiting. Small pokeweed bears a pink fruit and *P. leucopus* were seen with pink chins and pink faces during pokeweed fruiting. The orientation around specific areas of a habitat coincides with the findings of Sly (1976). But Wirtz and Parson (1960) and Metzgar (1973) reported that these rodents appeared in all habitats. Rodents were caught on the study area in areas of dense natural grasses, but the numbers were very low compared to those in areas under the large mesquites. No *P. leucopus* were ever caught in traps 35 and 44, nor in traps 42, 52 and 62 during Cycles II and III. Traps 42, 52 and 62 were at sites devoid of any large trees and at the edge of an area of dense growth of "carpet grass" (St. Augustine Grass). Just south of traps 35 and 44 there was a dense canopy of large mesquites but there were no large mesquites in close association to these traps. Over 60% of the individual home ranges were found in association with wooded areas. They were not found in association with the small mesquites or with open sparsely vegetated areas, as reported by Raun and Wilks (1964) or in small dense clumps surrounded by an expanse of sparse vegetation as reported by Bowker and Pearson (1976).

Because of the great number of *Sigmodon hispidus* in the fourth cycle (Fig. 3 - Wright) a comparison of habitat preference between them and *P. leucopus* was made. In all cycles, the *Peromyscus* population appeared to congregate in different areas than did *S. hispidus* and the "explosion" of the latter made no difference. The *P. leucopus* were not pushed by the *S. hispidus* out of their preferred areas of the asphalt road, the ravine and the areas under large mesquites.

Table 2. A comparison of home ranges of 37 individuals during times of low and high density.

	Males (22)	Females (15)
High density home range is isolated from low density home range	10	6
High density home range and low density home range overlap	12	9
The number of individuals whose home ranges overlapped and coincided.	3	5
Numbers most often caught during high density periods	13	9
Numbers most often caught during low density periods	9	6
The number of individuals whose capture sites were localized during high density	11	9
The number of individuals whose capture sites were localized during low density	10	5
Numbers not localized	1	1

CONCLUSIONS

1. There was an annual average of 16.1 mice/ha, with 19.8 mice/ha in the winter and 11.3 mice/ha in the summer.
2. The average home range for *Peromyscus* on the 2.3 ha plot was 0.21 ha with the average home range size of males and females being 0.22 ha and 0.19 ha, respectively.
3. Both male and female *Peromyscus* were captured over larger areas during breeding and nonbreeding and the location of home ranges overlapped during breeding and nonbreeding periods. Young adults after they attained a length of more than 150 mm change their activity areas.
4. During periods of high density male *Peromyscus* appeared to shift from ranges used during low density but home ranges among all males overlapped more often than during periods of low density.
5. *Peromyscus* during all four cycles were most concentrated along the old asphalt road, the ravine and in sites under large mesquites. The population was not pushed out of its preferred areas by the *S. hispidus* bloom in the fourth cycle.

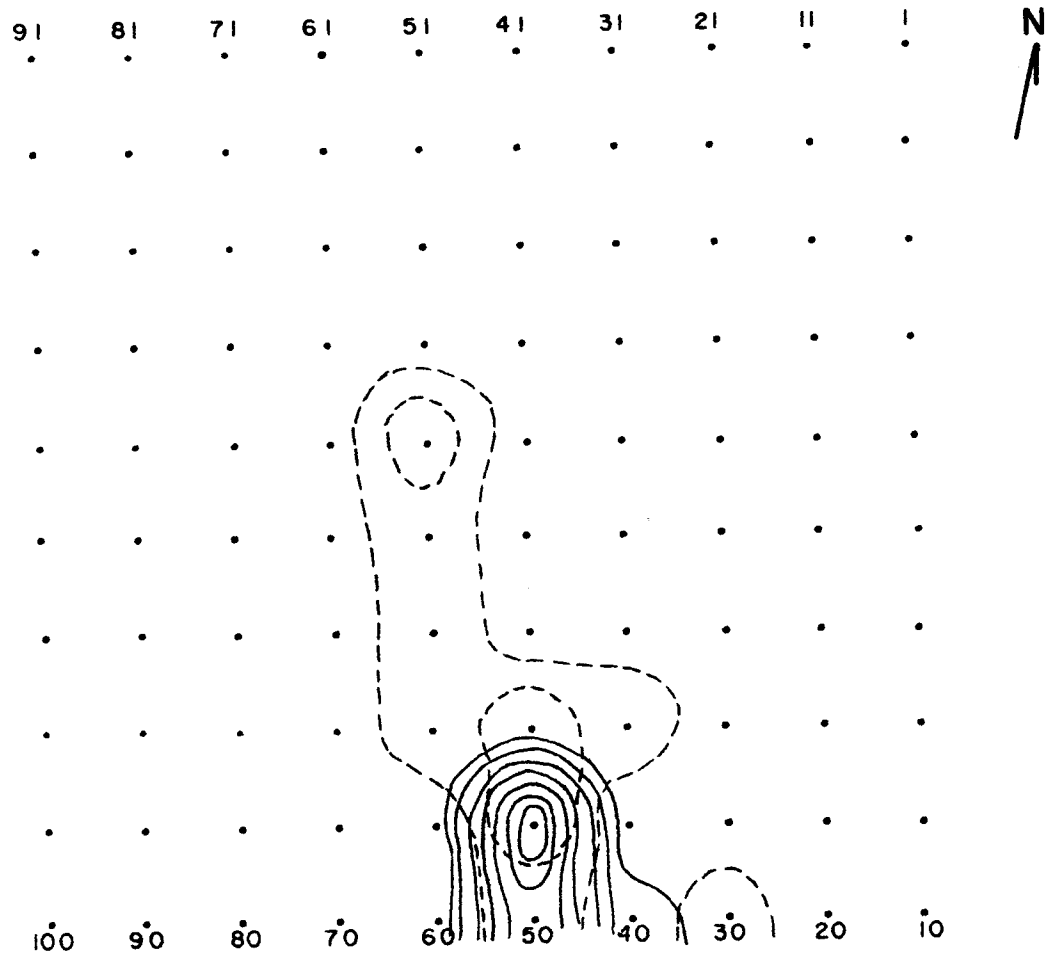


Figure 1. An example of the capture frequency for a female rodent, number 123, to illustrate overlap between breeding (--) and nonbreeding (—) home ranges. Contour interval = 1 capture in the specific included traps

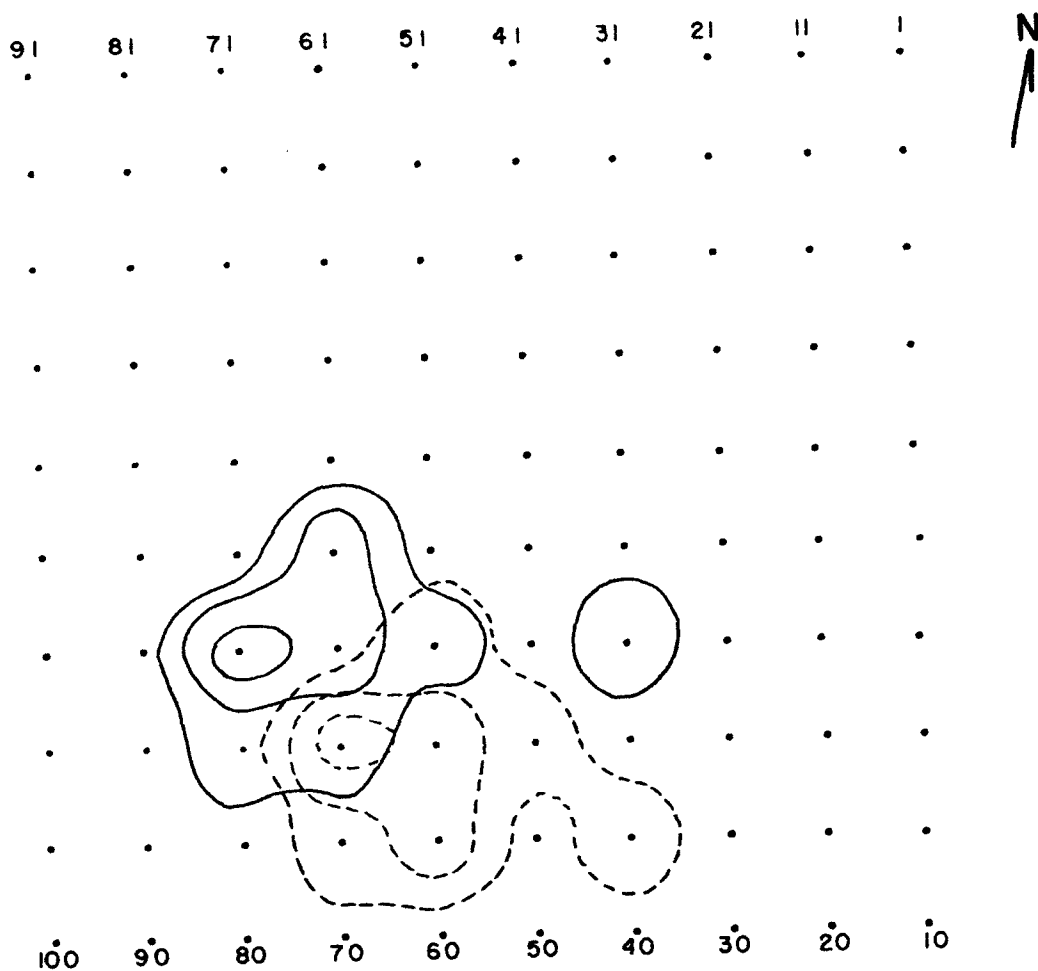


Figure 2. An example of the capture frequency for a male rodent, number 112, to illustrate overlap between breeding (--) and nonbreeding (—) home ranges. Contour interval = 1 capture in the specific included traps

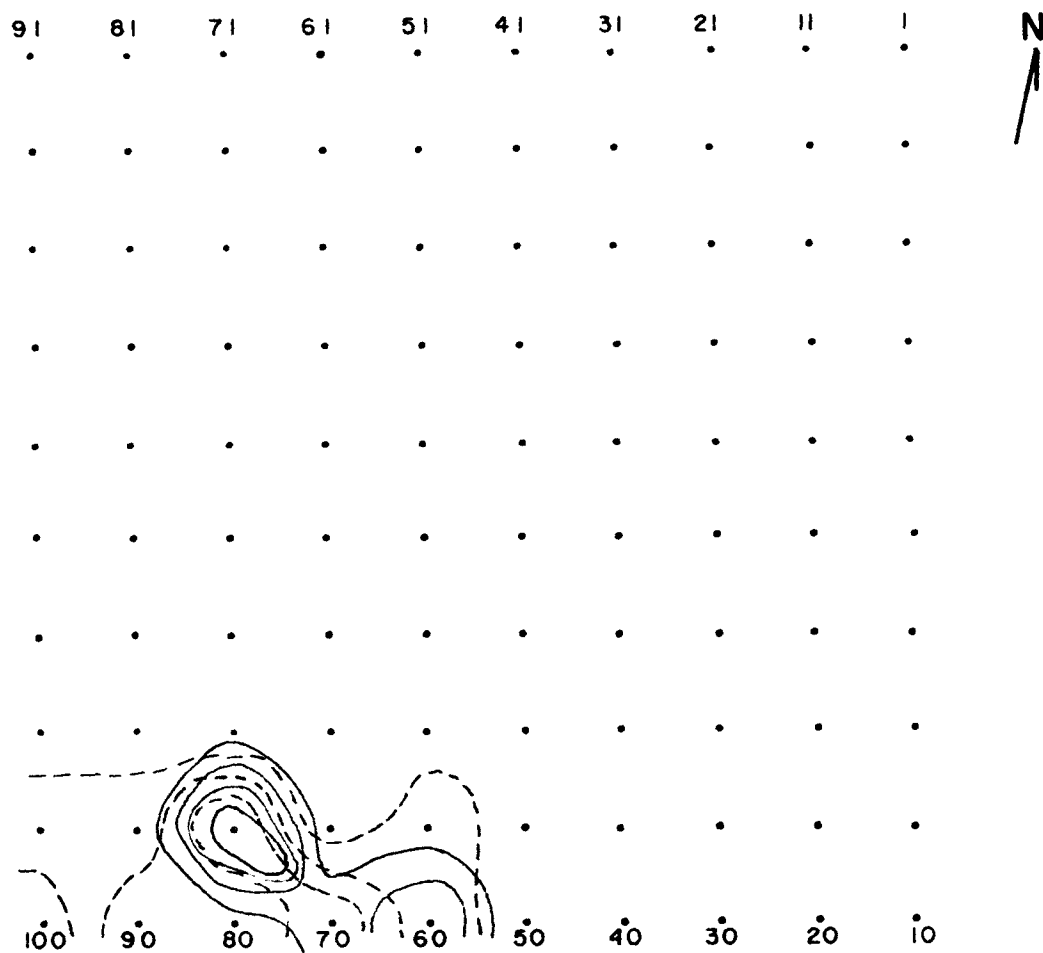


Figure 3. An example of the capture frequency to illustrate that home ranges during breeding (--) are almost identical to those during nonbreeding (—). The rodent used to demonstrate this was rodent 292.
Contour interval = 1 capture in the specific included traps

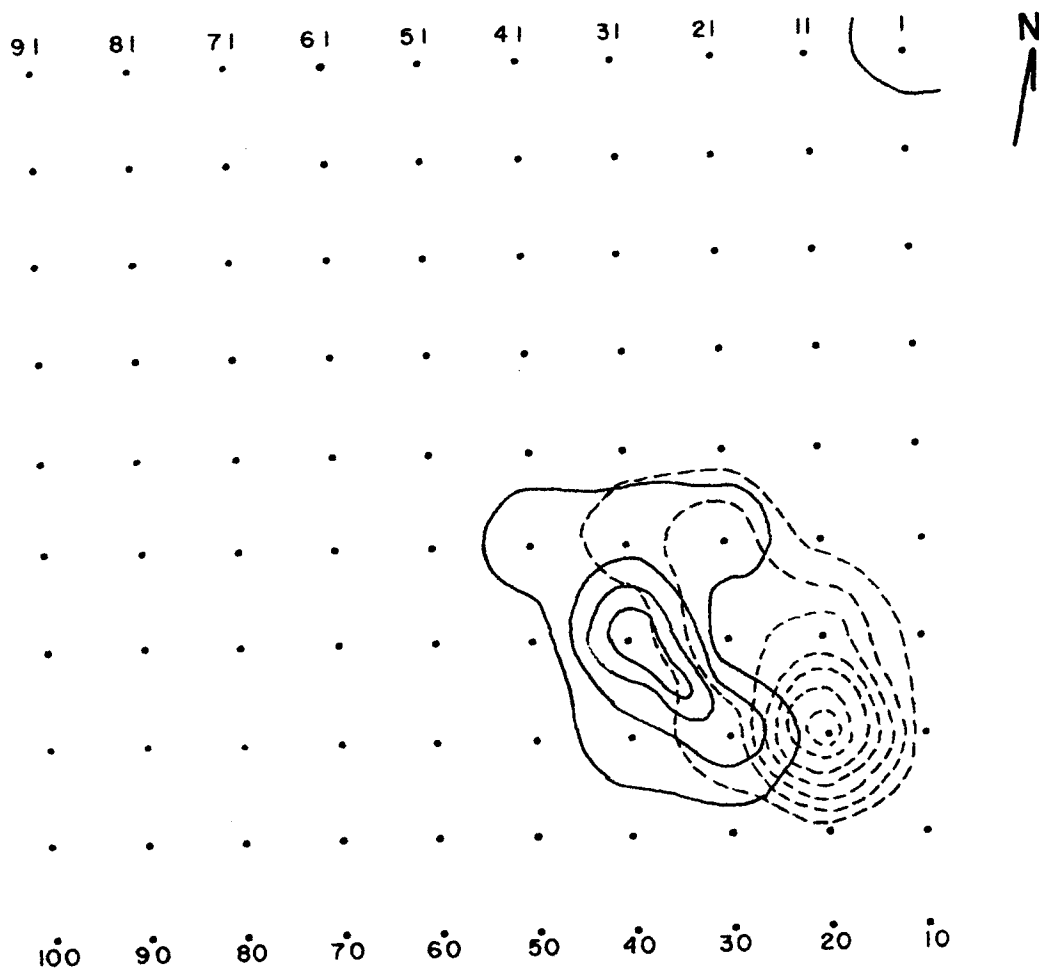


Figure 4. An example of the capture frequency for a male, rodent number 9, to illustrate how epicenters move between breeding (--) and nonbreeding (—) home ranges. Contour interval = 1 capture in the specific included traps

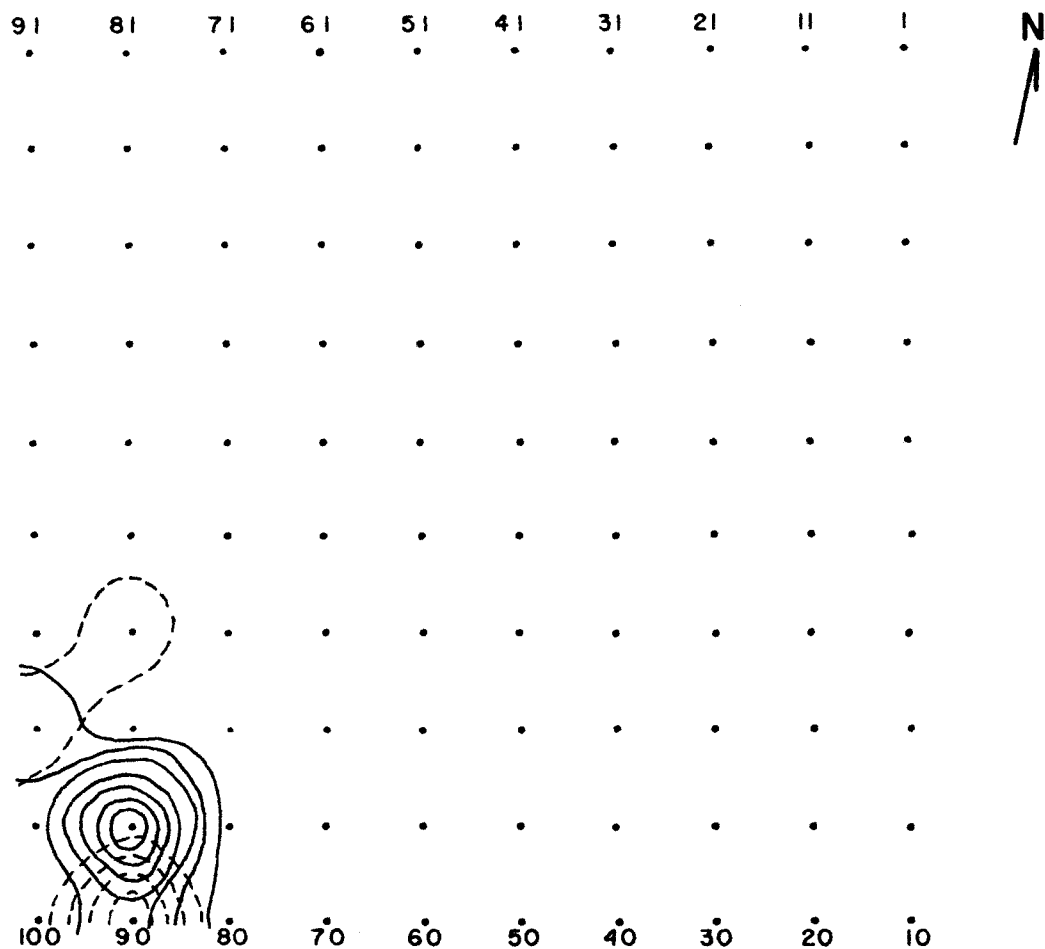


Figure 5. An example of capture frequency for a female rodent, number 158, to illustrate how epicenters move between breeding (--) and nonbreeding (—) home ranges. Contour interval = 1 capture in the specific included traps

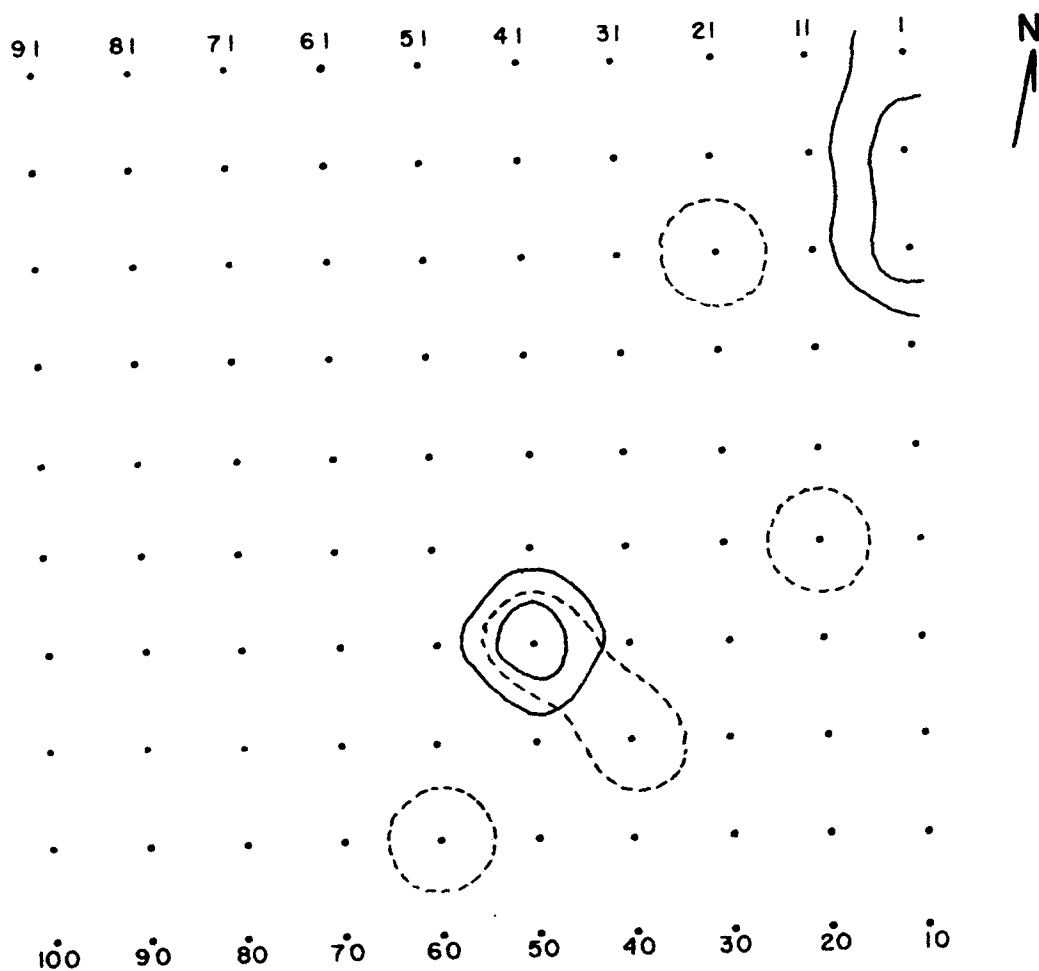


Figure 6. An example of the capture frequency for a male rodent, number 1, to illustrate that young adults (—) establish a home range, then when classifiable as old adults (---), have changed their home range.
Contour interval = 1 capture in the specific included traps

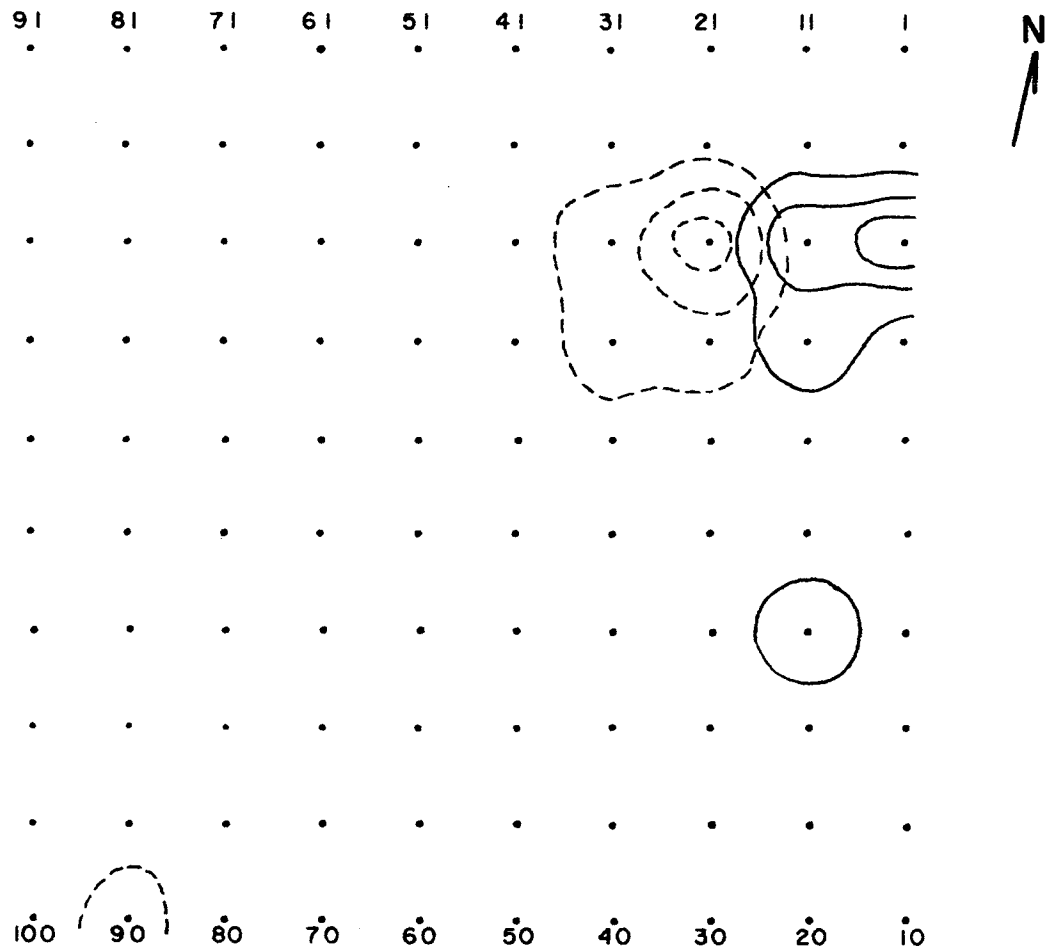


Figure 7. An example of the capture frequency for a female, rodent number 5, to illustrate that young adults (--) establish a home range, then when classifiable as old adults (—), have changed the home range.
Contour interval = 1 capture in the specific included traps

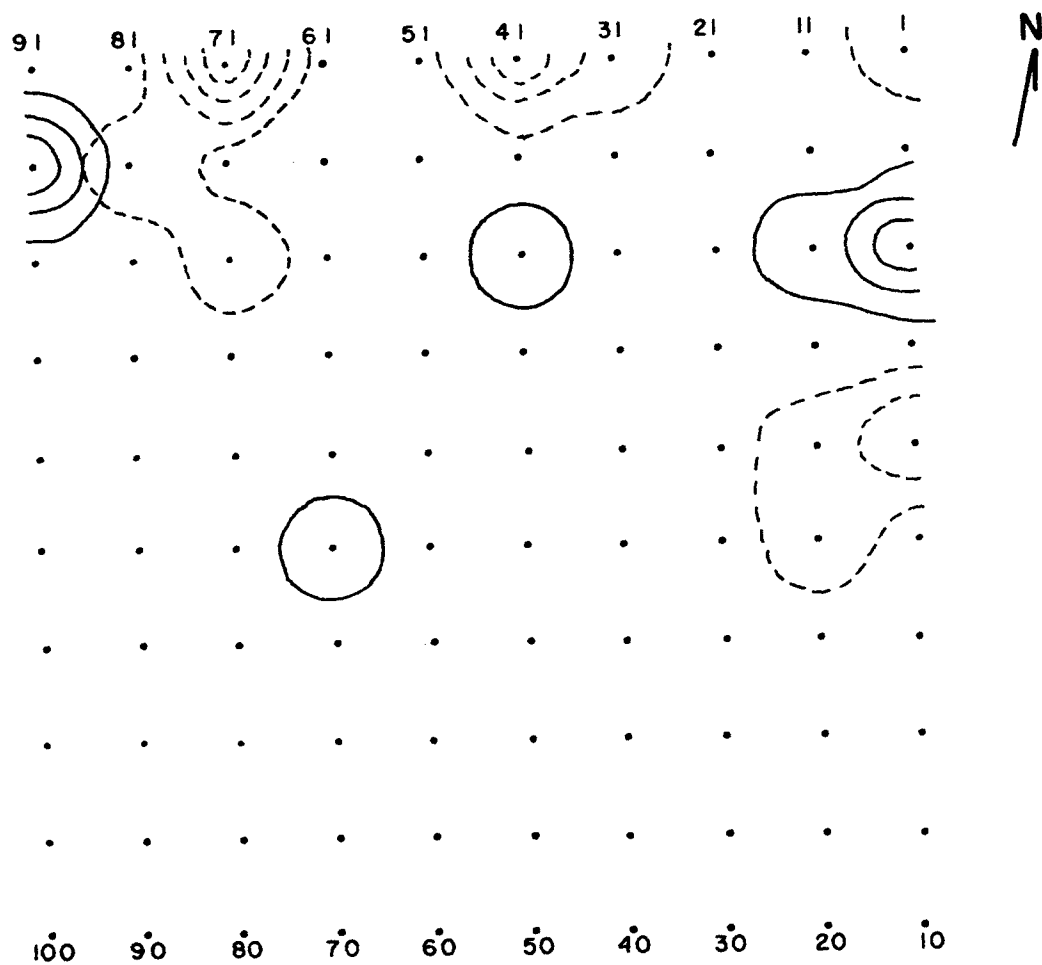


Figure 8. An example of the capture frequency for a male that illustrates that home ranges (—) during high density periods are separate from home ranges (—) during low density periods.

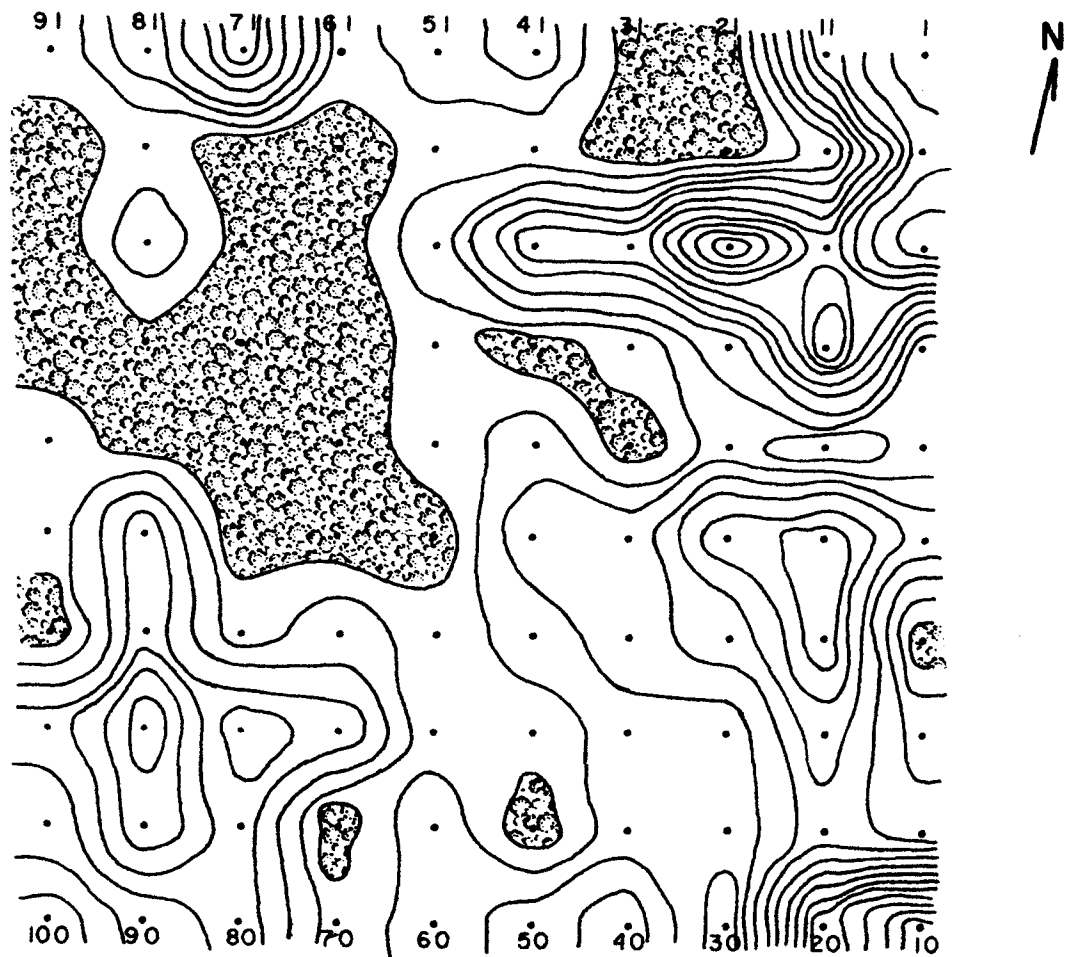


Figure 9. Habitat preference of *P. leucopus* in Cycle I for 67 rodents caught 242 times. Contour interval = 1 capture in the specific included traps



= none caught

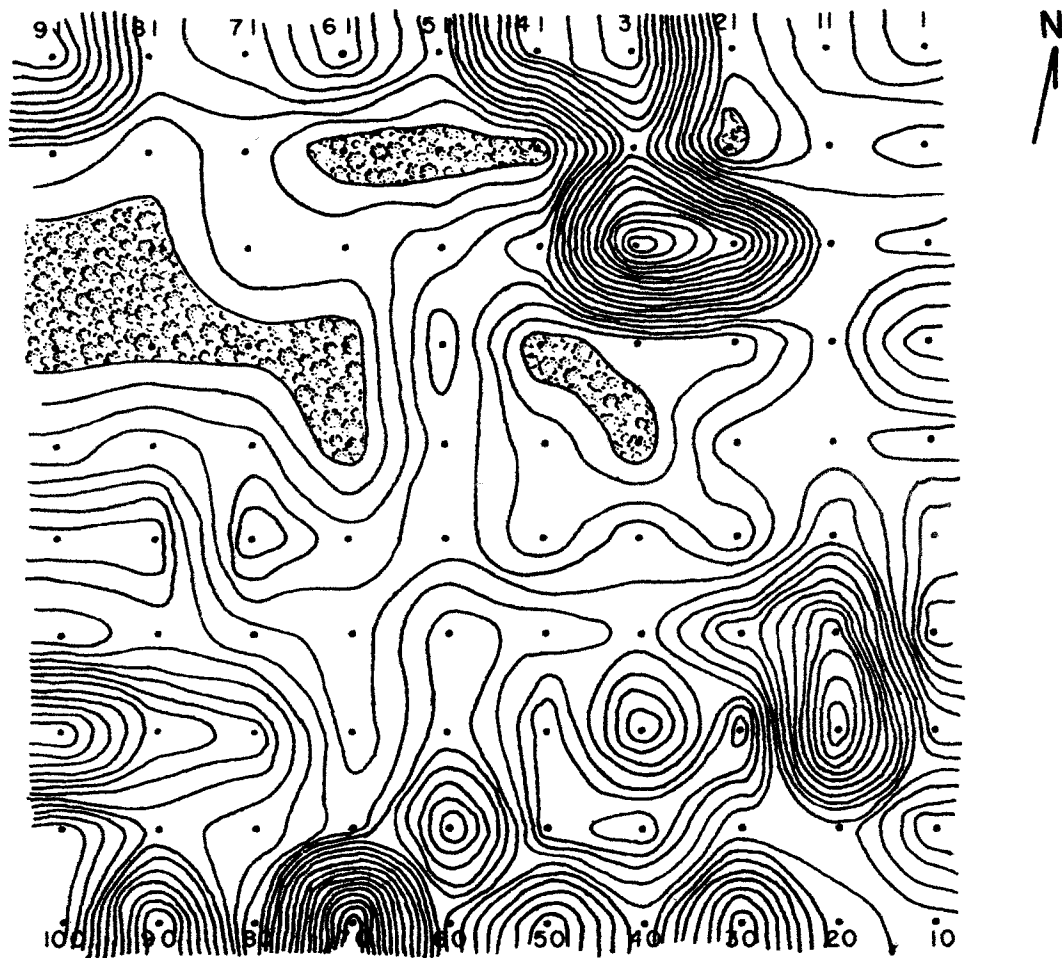


Figure 10. Habitat preference of *P. leucopus* in Cycle II for 155 rodents caught 563 times.
Contour interval = 1 capture in the specific, included traps

 = none caught

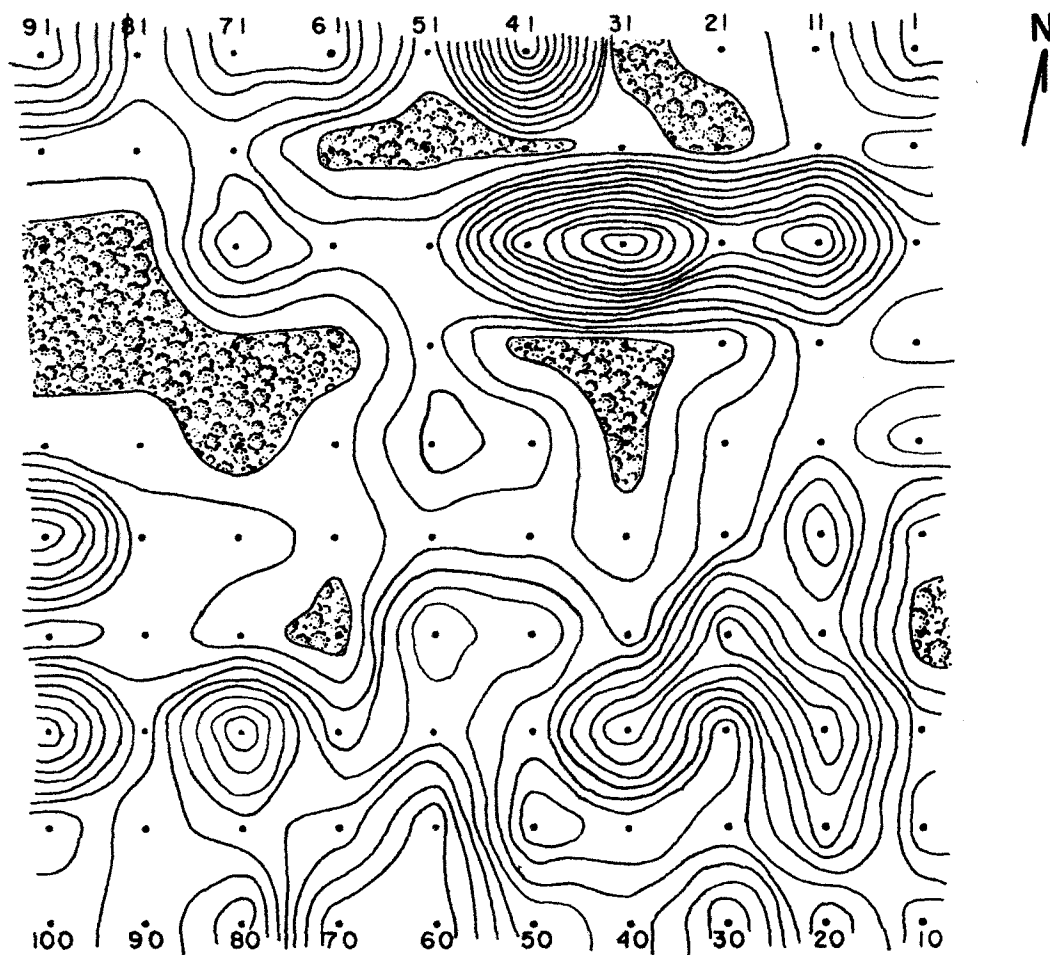


Figure 11. Habitat preference of *P. leucopus* in Cycle III for 123 rodents caught 353 times.
Contour interval = 1 capture in the specific, included traps

 = none caught

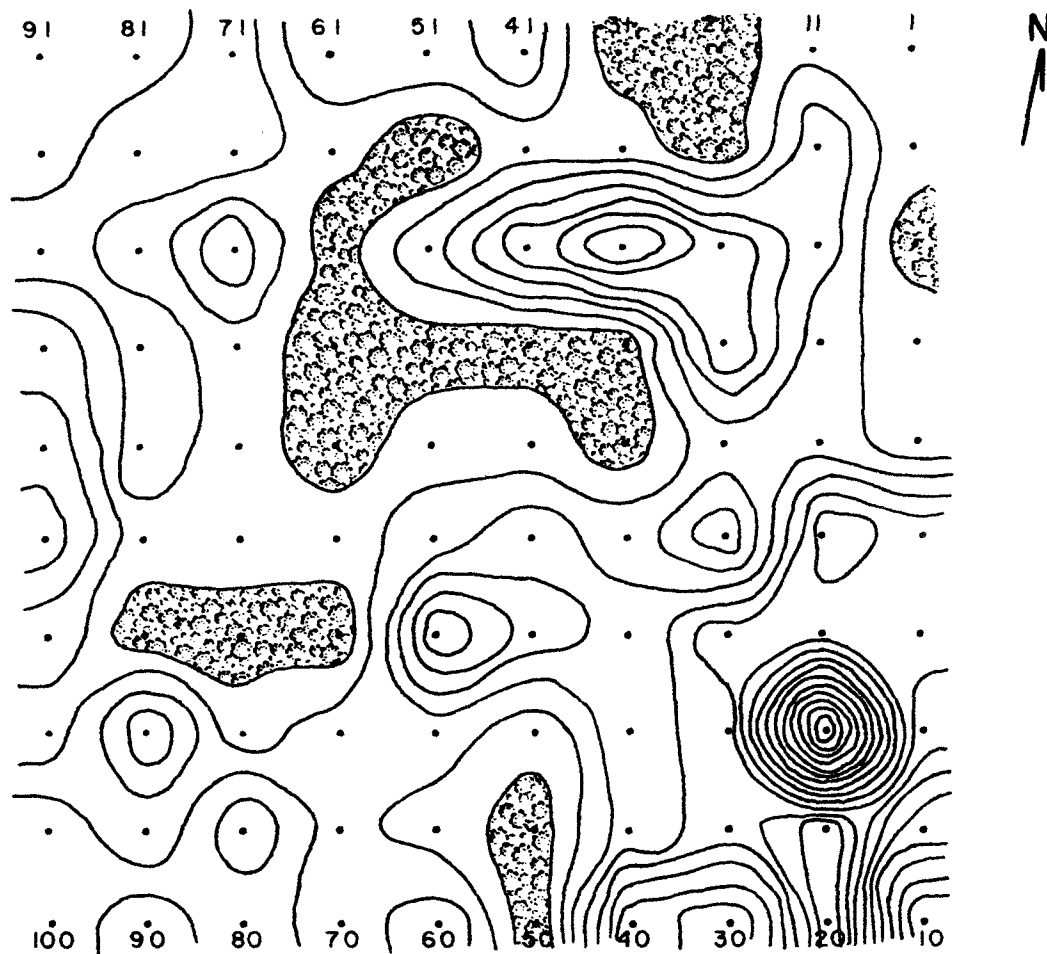


Figure 12. Habitat preference of *P. leucopus* in Cycle IV for 69 rodents caught 250 times.
Contour interval = 1 capture in the specific, included traps

 = none caught

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CYCLES AND DENSITY OF A *Sigmodon hispidus* POPULATION IN SOUTH TEXAS

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ABSTRACT

This study was undertaken in November, 1969 as a continuation of a class project begun three months earlier. This intensive study of rodent population dynamics lasted until February, 1973. The study has been continued to this date.

A total of 1,296 rodents were marked and recaptured 2,870 times. *Peromyscus leucopus texana* (Woodhouse) and *Sigmodon hispidus berlandieri* (Baird) were the most abundant species. The density of the *S. hispidus* population was low (6.81 per ha) at the beginning of the study, rose rapidly (60.48 per ha) toward the end and ultimately "crashed".

INTRODUCTION

As part of a long term examination of rodent population dynamics at the Texas A&I Biological Station, Kleberg County, Texas, two concurrent rodent studies utilizing capture-mark-release techniques were conducted from November, 1969 to February, 1973. One study by my co-worker, Josephine Smith, involved the population dynamics of the most abundant species, *Peromyscus leucopus texana* (Woodhouse). A report of her study follows this paper. Information concerning the study plot and methods in this paper also applies to her report. My study involved six other species occurring in lesser numbers and the interaction among them as well as with *P. leucopus*. These six species were: *Sigmodon hispidus berlandieri* (Baird), *Neotoma micropus micropus* (Baird), *Onychomys leucogaster leucogaster* (Merriam), *Baiomys taylori taylori* (Thomas), *Reithrodontomys fulvescens intermedius* (J. A. Allen), and *Perognathus hispidus hispidus* (Baird). All scientific names of the rodents are from Hall and Kelson (1959).

This report is based on a master's thesis, "Interaction of Seven Rodent Species at Site 55, Kleberg County, Texas" and discusses only the fluctuation in the *S. hispidus* population.

LOCATION AND STUDY PLOT

A 2.3 ha area comprising a small part of Texas A&I Biological Station which borders the northeastern shore of Laguna Salada (Fig. 1) was selected for study. The plot was divided into a grid with ten rows of ten marked trap stations to the row (Fig. 2). On trap nights, a small Sherman box trap was placed at each station. Twenty-five large Sherman box traps were placed at intervals throughout the plot - on trap rows 2, 4, 6, 8 and 10 at trap stations 1, 5 and 10 and on the other rows at trap stations 3 and 8. Major features of the plot included: a deeply eroded ravine that extended north-south through the eastern edge; a one meter bluff bordering the south edge; an abandoned asphalt road, overgrown with vegetation that extended east-west through the middle of the plot; a barbed wire fence, partially fallen, also traversed the plot; an old naval barracks that was occupied occasionally, located at the northeast corner; an asphalt road that traversed the plot on the northern edge; and large mesquites (>32 cm in circumference) that grew along the ravine and over the southern half below the old fence.

METHODS

Traps were baited with cracked corn and set once each month for forty months and checked four times throughout the night. The interval between each trap run was dependent on the total number of night hours, which was divided into quarters. Upon capture, the rodents were toe-clipped for individual identification, sexed, checked for reproductive condition, measured (total length and right hind foot length), and released. Trap number, time of capture, comments about external indications of breeding, and ectoparasites were also recorded. To determine fecundity of adult *S. hispidus*, Goertz (1965) considered males fecund if the testes were in the scrotal position

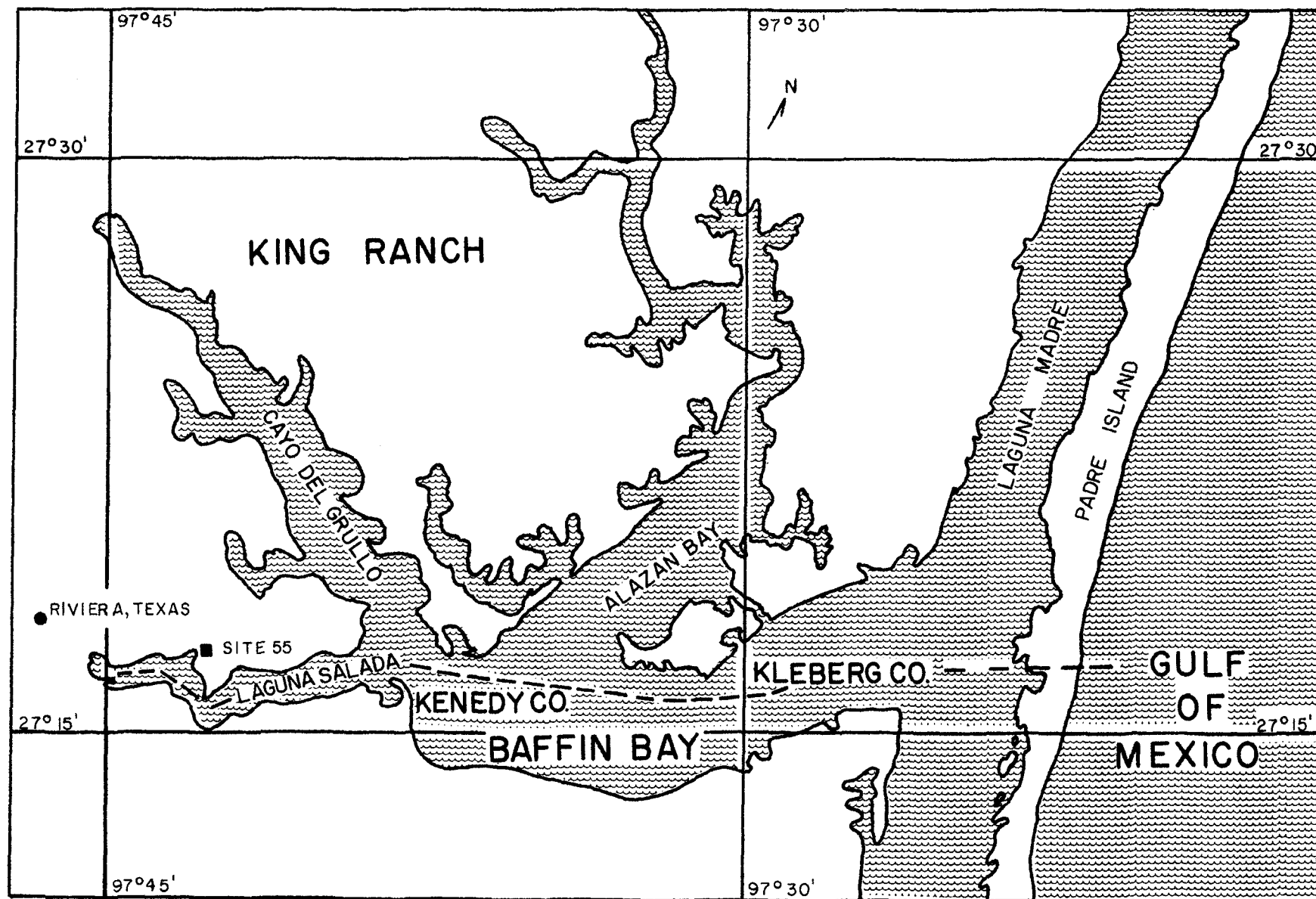


Figure 1. Location of the study plot and the Texas A&I University Biological Station.

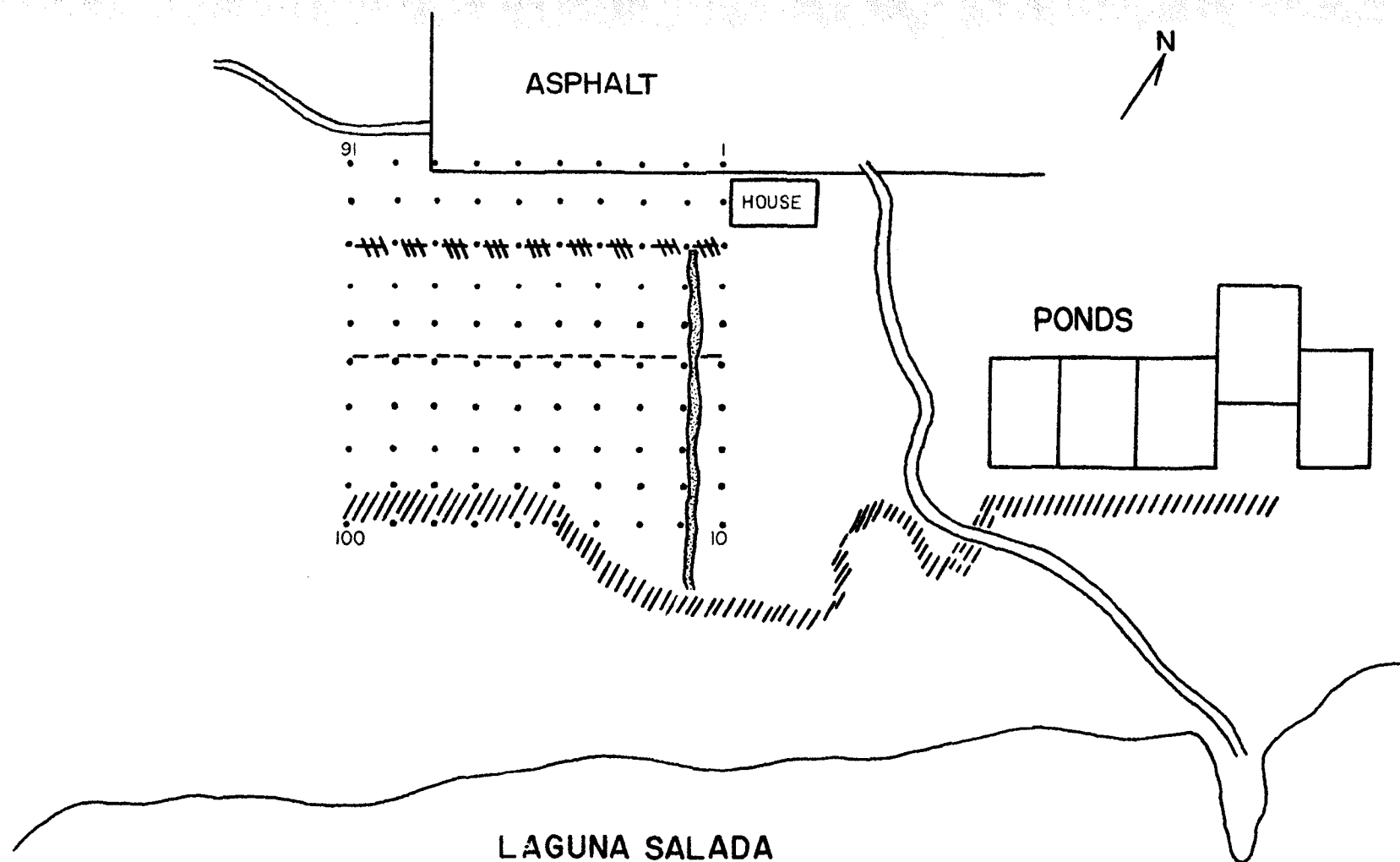


Figure 2. Diagram of the study plot and surrounding area at Site 55, Kleberg County, Texas.

Trap Site
 Asphalt Road
 Fence
 Bluff
 Ravine
 Caliche Road

or could be manipulated to the scrotum. He considered a female to be fecund if her vulva was perforate. Only the presence of scrotal testes, a perforate vagina, and elongate mammae were used in my study as external indicators of breeding.

Estimations of the monthly population size were based on new captures, recaptured marked individuals, and rodents not caught but known to be in the area as a result of later captures.

A rodent was considered to be a resident if it was trapped two or more times. If caught only once, the rodent was considered a transient.

On trap nights, air temperature measured with a centigrade thermometer was recorded before each of the four trap runs. Monthly precipitation amounts were obtained from the records of the Kingsville Naval Air Station.

RESULTS AND DISCUSSION

Total Rodent Population

There were 1,296 rodents toe-clipped and recaptured a total of 2,870 times. The total rodent population density was low in the summer and high in fall and winter (Fig. 3). Four yearly cycles were evident from these repeated high and low densities. Cycle I was low in numbers which might have been due to the possibility of poorly set traps in the early stages of the study, or initiation of a recovery period from a population explosion. Cycles II and III were similar in numbers (a difference of one individual) and might represent the carrying capacity of the area. As evidenced by the increase in numbers, Cycle IV was a population "explosion".

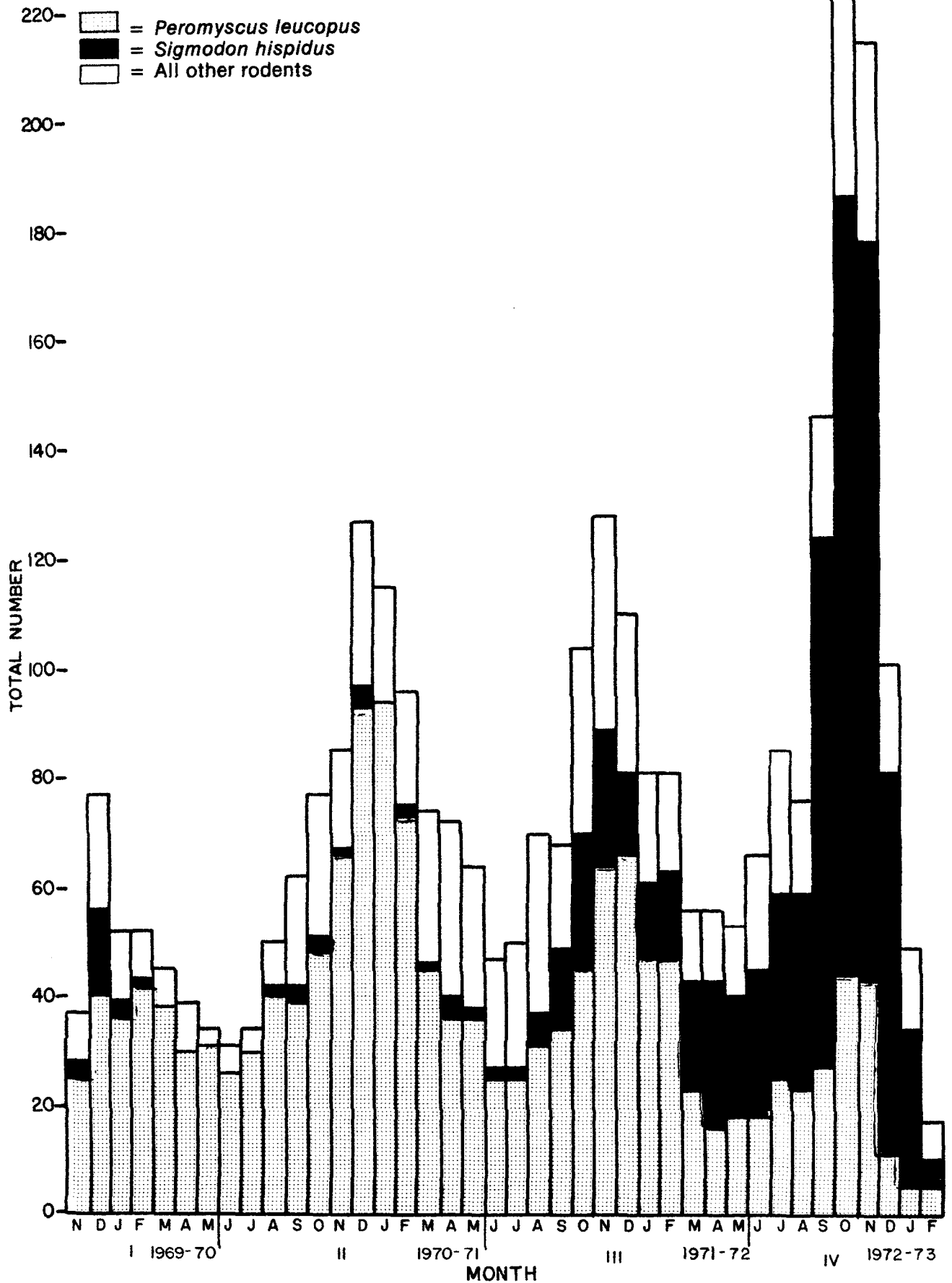
During the four cycles, 414 *P. leucopus* and 479 *S. hispidus* were marked. Fluctuation in the total number of rodents was a result of variation in numbers of these two with the other species being less important.

Sigmodon hispidus

As reflected in the total rodent population, the density of the *S. hispidus* population was low in the summer and high in the fall and winter. Briese and Smith (1974) found population density of *S. hispidus* in Georgia higher in January. However, this is not consistent with findings of Schnell et. al (1980), who found the density of a *S. hispidus* population in Oklahoma higher in March. In Florida, Bigler and Jenkins (1975) found a higher density in summer as did Dunnaway and Kaye (1964) in Tennessee. Density of the *S. hispidus* population was low initially, followed by a slow but steady increase in Cycle III; then the "explosion" and "crash" came in Cycle IV. Only 22½% of the total number of *S. hispidus* were marked in the first twenty-seven months while 77½% were marked in the last twelve months (three times as many). In February, 1973, only four marked and one new individual were present in the area. *S. hispidus* never exceeded 24.04% of the total rodent population in the first three cycles but comprised 63.4% in October of Cycle IV (Table 1). In the months of the highest density in the four cycles, on the average there were 6.81, 1.70, 10.65 and 60.48 *S. hispidus* per hectare (Table 2). In the total rodent population during these same periods, the averages were 31.10, 54.11, 54.53 and 95.42 rodents per hectare (Table 3). Thus *S. hispidus* made up 20%, 3%, 20% and over 50% of the overall numbers per year. This would indicate that stress was put on the whole population of rodents by *S. hispidus* in the last cycle.

Goertz (1964) and Dunnaway and Kaye (1964) found that low temperatures could affect density of *S. hispidus* populations. The low density at the onset of the study could have resulted from low temperatures in January, 1970 (Fig. 4). The low numbers of rodents in the breeding population, plus the observance of only one fecund adult, explain the meager reproduction that occurred in Cycle II when all *S. hispidus* trapped were transients (Fig. 5). At the beginning of Cycle III there was a small increase in numbers of *S. hispidus* with a corresponding decrease in numbers of *P. leucopus*. This trend continued throughout Cycle III until a peak of *S. hispidus* numbers in October and November, 1971. The number of *S. hispidus* that were carried over into the breeding population of Cycle IV was greater than other years and greater than for *P. leucopus*. With this large breeding population in the beginning of Cycle IV, the numbers grew rapidly to extreme levels in October and November, 1972. This carry over of large numbers of adults to the breeding season coincided with the development of lush vegetation aided by rains the preceeding September (Fig. 6). *S. hispidus* also began breeding in March of Cycle IV, instead of May as in the other cycles. With this early beginning, adults could produce three litters (second generation fecundity) one in May, one in July, and one in October. The second generation that appeared in

Figure 3. Monthly population levels for the rodent species at the study site, based on trap results. Cycles are designated as Roman numerals.



May could produce litters in July and October (third generation), and the second generation that appeared in July could produce a litter in October (third generation). The third generation that appeared in July could produce a litter in October (fourth generation). Thus in Cycle IV, four generations could have been added to the population, with three fecund generations, unlike the other cycles.

After November, the "crash" occurred, presumably because the area could not support such a large number of rodents. During the winter of 1972 the temperatures again were very low (almost equal to those of January, 1970) (Fig. 4). Low temperature in conjunction with normal cessation of breeding, stress of high density, poor vegetation (result of cold winter) could account for the deaths or emigration which resulted in the drastic decline of the population (Goertz, 1964), (Dunnaway and Kaye, 1964), and (Briese and Smith, 1974).

Table 1. Monthly percentages of *Sigmodon hispidus* in the rodent population.

Cycle I		Cycle II		Cycle III		Cycle IV			
1969-70		1970-71		1971-72		1972-73		1973	
Mo.	%	Mo.	%	Mo.	%	Mo.	%	Mo.	%
		Feb	1.92	Feb	2.08	Feb	20.99	Feb	29.41
		Mar	0	Mar	1.35	Mar	35.71		
		Apr	0	Apr	5.56	Apr	48.21		
		May	0	May	3.13	May	41.51		
		Jun	0	Jun	4.26	Jun	40.91		
		Jul	0	Jul	4.00	Jul	40.00		
		Aug	4.00	Aug	8.57	Aug	47.37		
		Sep	4.84	Sep	22.06	Sep	66.44		
		Oct	3.90	Oct	24.04	Oct	63.39		
Nov	8.11	Nov	1.18	Nov	19.53	Nov	63.08		
Dec	20.78	Dec	3.15	Dec	13.64	Dec	69.31		
Jan	5.77	Jan	0	Jan	17.28	Jan	69.39		

Table 2. Number of *Sigmodon hispidus* per hectare in the study plot.

Cycle I		Cycle II		Cycle III		Cycle IV			
1969-70		1970-71		1971-72		1972-73		1973	
Mo.	%	Mo.	%	Mo.	%	Mo.	%	Mo.	%
		Feb	0.42	Feb	0.84	Feb	7.21	Feb	2.12
		Mar	0	Mar	0.42	Mar	8.52		
		Apr	0	Apr	1.70	Apr	11.51		
		May	0	May	0.84	May	9.36		
		Jun	0	Jun	0.84	Jun	11.51		
		Jul	0	Jul	0.84	Jul	14.48		
		Aug	0.84	Aug	2.54	Aug	15.34		
		Sep	1.28	Sep	6.39	Sep	41.31		
		Oct	1.28	Oct	10.65	Oct	60.48		
Nov	1.28	Nov	0.42	Nov	10.65	Nov	57.52		
Dec	6.81	Dec	1.70	Dec	6.39	Dec	29.79		
Jan	1.28	Jan	0	Jan	5.95	Jan	14.48		

Table 3. Total number of rodents per hectare in the study plot.

Cycle I		Cycle II		Cycle III		Cycle IV	
1969-70		1970-71		1971-72		1972-73	
Mo.	%	Mo.	%	Mo.	%	Mo.	%
		Jun	13.19	Jun	20.01	Jun	28.11
		Jul	14.48	Jul	21.29	Jul	36.22
		Aug	21.29	Aug	29.82	Aug	32.37
		Sep	26.41	Sep	28.96	Sep	62.19
		Oct	31.10	Oct	44.30	Oct	95.42
Nov	15.76	Nov	36.22	Nov	54.53	Nov	91.18
Dec	31.10	Dec	54.11	Dec	46.82	Dec	43.18
Jan	21.11	Jan	48.99	Jan	34.51	Jan	20.88
Feb	21.11	Feb	40.89	Feb	34.51	Feb	7.21
Mar	19.15	Mar	31.52	Mar	23.87		
Apr	16.60	Apr	30.66	Apr	23.87		
May	14.48	May	27.25	May	22.58		

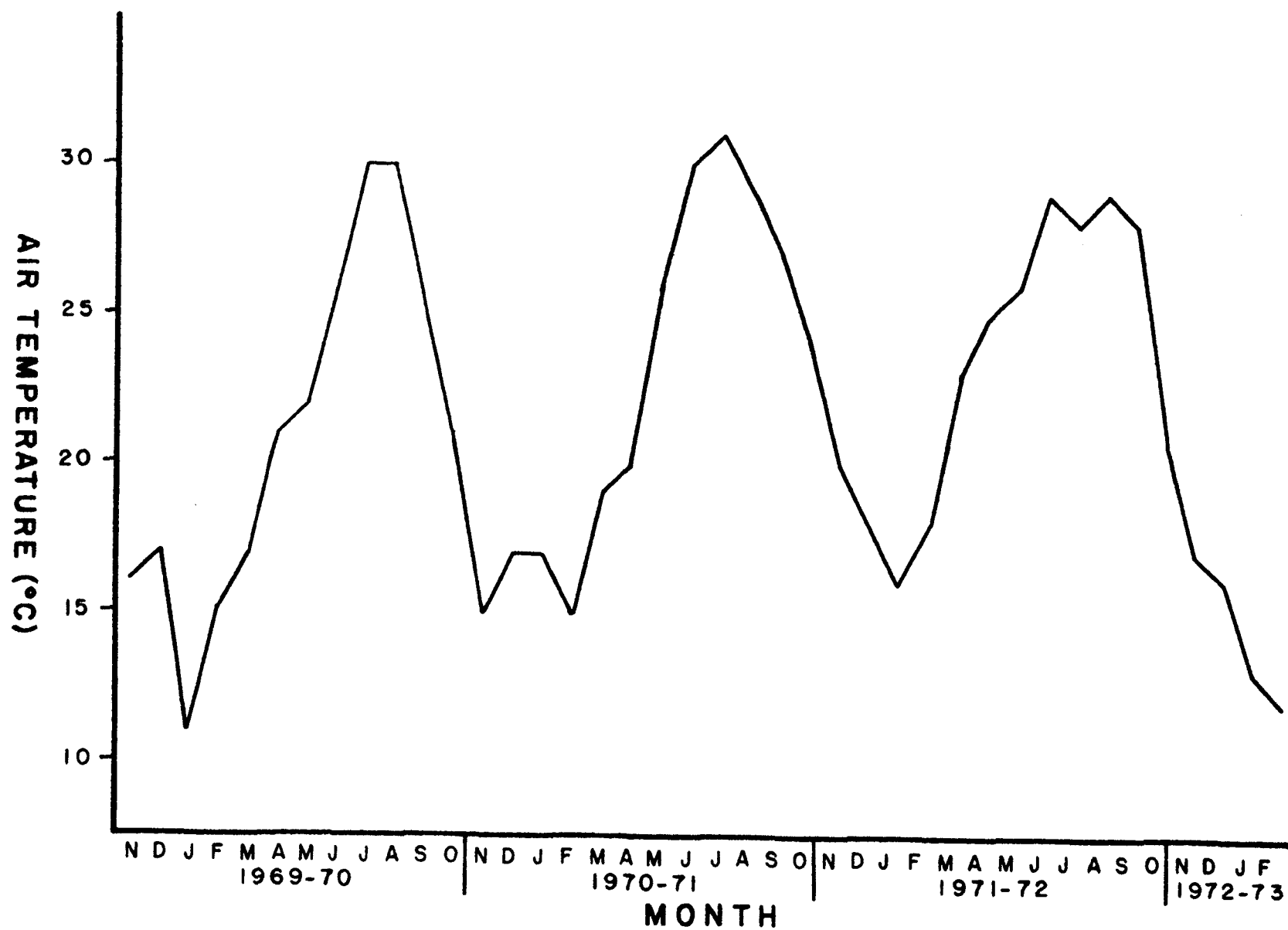


Figure 4. Fluctuation of the average monthly air temperature for the study period.

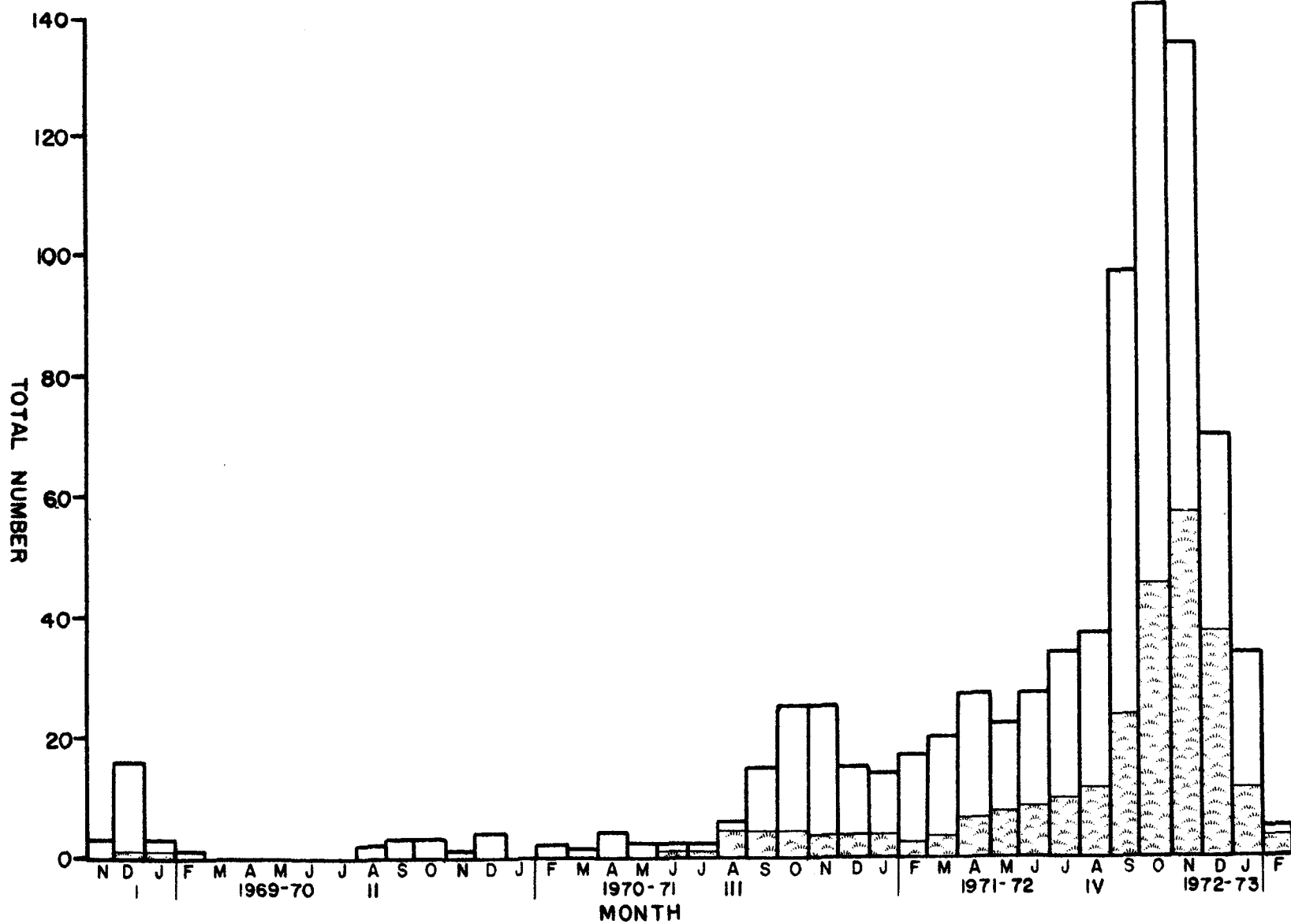


Figure 5. Comparison of numbers of residents with transients during each month for *S. hispidus*. Cycles are designated by Roman numerals.

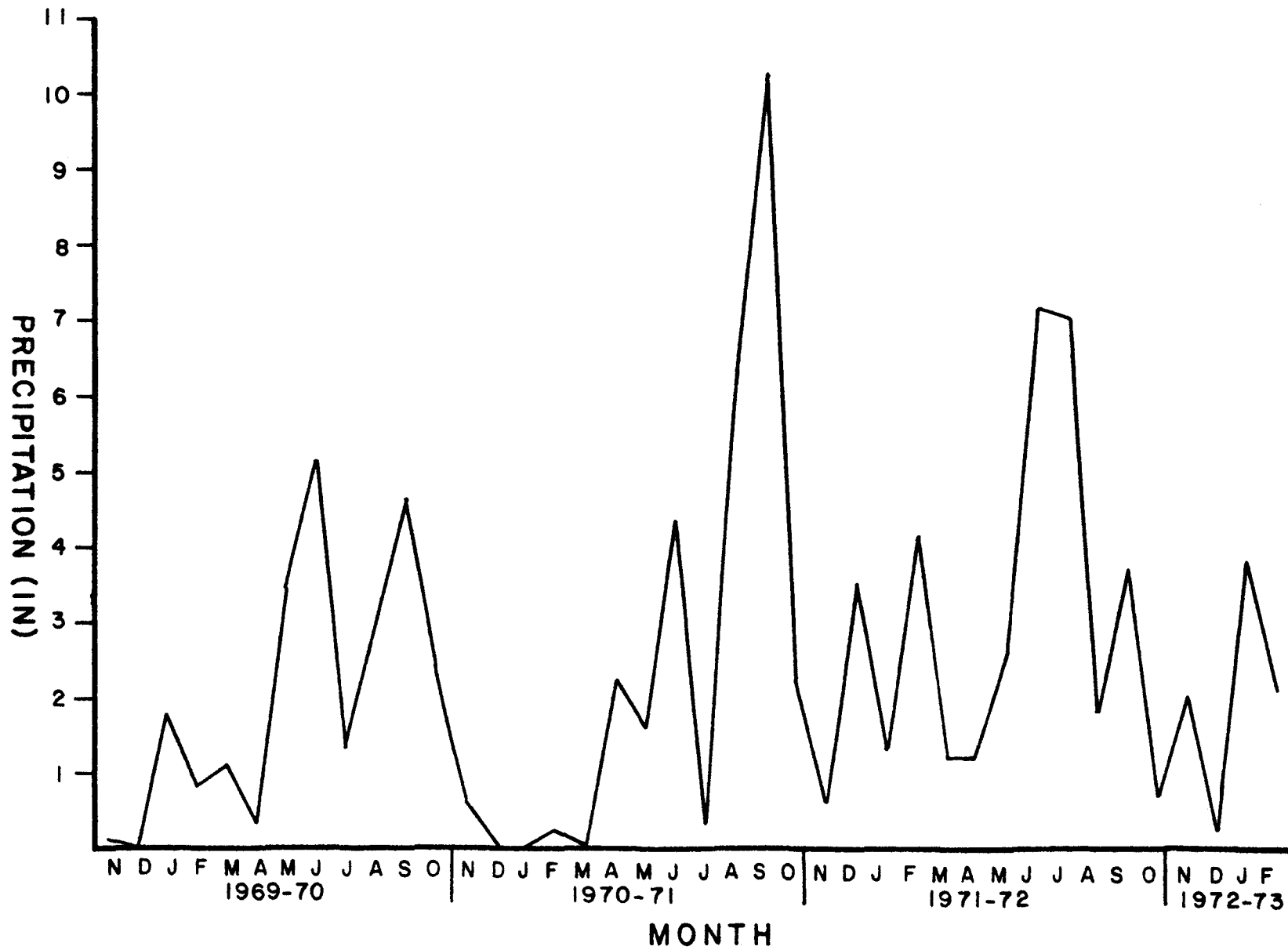


Figure 6. Fluctuation in the amount of monthly precipitation for the study period.

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A MORPHOMETRIC ANALYSIS OF SIRENS FROM SOUTHERN TEXAS

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ABSTRACT

Two subspecies of *Siren intermedia* reportedly intergrade in the vicinity of Kingsville, Texas. However, recent specimens from this area do not indicate intergradation or the presence of two subspecific morphs. In this study, 256 sirens from the Kingsville area were morphometrically compared with 42 specimens known to be *S. i. nettingi* and 14 known to be *S. i. texana*. Only slight sexual dimorphism was detected in the Kingsville sample. Univariate and multivariate analyses revealed no evidence of intergradation and did not demonstrate significant differences between the Kingsville sample and *S. i. texana*. Discriminant function analysis assigned all sirens collected from the vicinity of Kingsville to the reference sample *S. i. texana*. The most likely interpretation of these results concludes that the two subspecies intergrade at some point along the Texas coast east of Kingsville.

INTRODUCTION

Two species of sirens are found in the United States: *Siren lacertina* Linnaeus, inhabiting the Atlantic coastal plain north to Maryland and the Gulf coastal plain west to Alabama, and *Siren intermedia* LeConte, of the southern Atlantic and Gulf coastal plains and the Mississippi and Ohio River valleys. Three subspecies of the latter are recognized (Conant, 1975): *S. i. intermedia* LeConte, *S. i. nettingi* Goin, and *S. i. texana* Goin. There is overlap in the ranges of *S. lacertina* and eastern populations of *S. intermedia*, and intergradation of the three subspecies of *S. intermedia*.

Goin (1942) originally separated *S. intermedia* into two subspecies: *S. i. intermedia*, found east of Louisiana and fitting LeConte's original description; and *S. i. nettingi*, found west of eastern Louisiana and morphologically intermediate between *S. lacertina* and *S. i. intermedia*. Goin reported a maximum length of 17 inches and 34 to 36 costal grooves in *S. i. nettingi*. He also pointed out that certain specimens from near Brownsville, Texas differed from "typical *S. i. nettingi*". After further study of Texas specimens, Goin (1957) described *S. i. texana* from southern Texas, as somewhat larger than *S. i. nettingi*, attaining a maximum length of almost 25 inches and having 36 to 38 costal grooves. He considered three specimens from south of Kingsville as intergrades between *S. i. nettingi* and *S. i. texana*. In the 1960's, however, a large number of sirens was collected in the vicinity of Kingsville, and all appeared referable to the South Texas race. No intergrades and no specimens of pure *S. i. nettingi* were found in the area. It seemed possible at that time, in light of assumed sympatric *S. i. nettingi* morphs, that South Texas sirens were behaving as full species rather than as intergrading subspecies. However, Guttman (1965) reported no significant electrophoretic differences in the blood proteins of the two Texas sirens. In light of this situation a morphometric study was initiated to: 1) collect additional sirens from the vicinity of Kingsville, and request specimens of the two taxa from localities removed from the overlap zone; 2) morphologically compare the three groups; and 3) utilize any patterns of variation in an attempt to elucidate the taxonomic relationship of the two Texas sirens.

METHODS

During the course of this study, 378 sirens were collected from the vicinity of Kingsville, through the use of seines, throw lines, trot lines, or wire box traps, or by hand. Each siren was catalogued, tagged, injected and hardened with 10% formalin, and subsequently stored in 45% isopropyl alcohol.

Collections of preserved sirens were examined from selected localities within the range of *S. intermedia*. A series of 32 *S. i. nettingi* was borrowed from Tulane University and two from Lamar University. Visits were made to the Strecker Museum at Baylor University (28 sirens), Texas Southmost College (3), and the Texas Memorial Museum at the University of Texas at Austin (21).

On each specimen, the following characters were noted and/or measured: 1) presence or absence of dark dorsal spots or blotches, 2) dark pigmentation on the ventral surface of the limbs, 3) presence or absence of a well-defined lateral line system, 4) costal groove count (including all complete grooves between axilla and vent), 5) sex (determined by dissection), 6) sexual maturity (determined by dissection), 7) number of major filament-containing branches on outside of third gill, 8) costal groove count to origin of dorsal fin, 9) total length, 10) snout-vent length, 11) body length (distance from axilla to anterior end of vent), 12) mid-body diameter, 13) head width (widest measurement across head anterior to gills), 14) head length (tip of snout to anterior base of first gill), 15) internarial distance measured from medial edges of nares, 16) distance across exposure of lower lip, 17) distance between angles of jaws, and 18) origin of ventral fin (from anterior end of ventral fin to posterior end of vent).

Both univariate and multivariate statistical procedures were utilized in the study. Indeterminate growth complicated examination of linear characters. As a consequence, sexually mature South Texas specimens taken on a single collection date were found to range from about 220 mm to 630 mm in total length (Fig. 1). To eliminate the effects of age on morphometric variation, all possible ratios (45) were computed from the original array of linear measurements. Ratioed values were plotted as scattergrams in a check for linear correlations. All ratios revealed linear relationships.

Frequency distributions were plotted for specimens collected from the vicinity of Kingsville in a check for sexual dimorphism. Z-tests were performed in a test for statistically significant differences between sexes. The Z-statistic was selected to accommodate unequal and sometimes small sample size and possible asymmetry or skewedness (Sokal and Rohlf, 1969). In similar tests specimens from the vicinity of Kingsville (sexes lumped since dissection was not allowed on some borrowed specimens) were compared with samples of *S. i. nettingi* and *S. i. texana*.

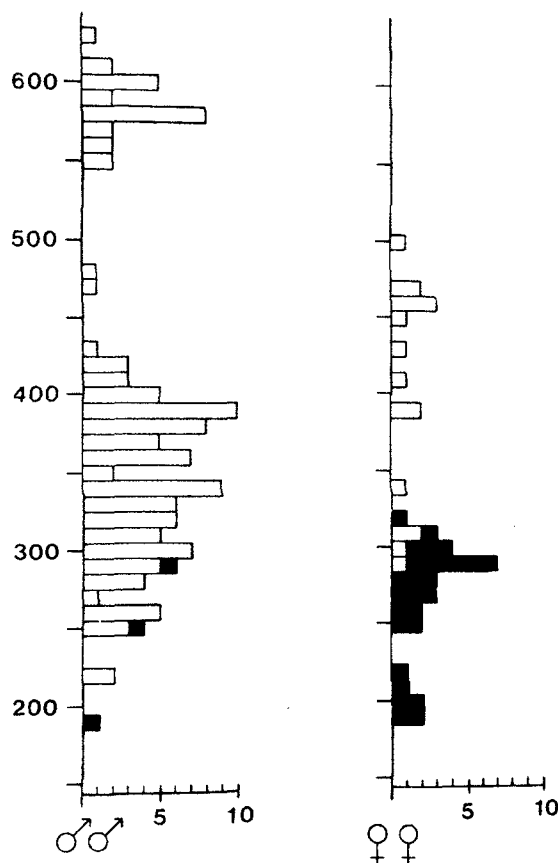


Figure 1. Bar-histogram of total length in mm for 171 sirens collected 17 March, 1967. Shaded areas denote sexually immature specimens.

Multivariate analyses included discriminate function analysis for computer assisted assignment of AIM (Vicinity of Kingsville) specimens to one of the known taxa, multivariate analysis of variance, factor analysis, and Duncan's multiple range on factor scores of populations. Multivariate testing was performed on ratios previously found with the Z-statistic to vary significantly at the 0.01 level.

Univariate testing was performed on an IBM-360 utilizing programming supplied by Mr. Don McCarty, and multivariate testing was performed on an IBM-370 at the University of Arkansas at Fayetteville utilizing SAS 79.

RESULTS AND DISCUSSION

Univariate testing revealed statistically significant differences between male and female sirens for 13 of 45 ratios (Table 1) and one unratioed parameter. Males were found to have a slightly higher costal groove count than females ($Z = 7.48$). Females were found to have a significantly more narrow head with respect to measurements of length (total length and snout-vent length). Females were also found to have less exposure of the lower lip with respect to head or body width. Both trends were expressed in other ratios as well. Although significant differences between means were shown to exist, ranges of each ratio overlapped to such an extent that no ratio provided a reliable method for externally sexing sirens.

Multivariate analysis of variance supported univariate results showing slight sexual dimorphism with greatly overlapping ranges. A bar graph of MANOVA-generated canonical variable scores (Fig. 2) supported the creditability of subsequent testing on groups of combined sexes. Step-down analysis revealed that, again, variables associated with head width contributed most to separation of the sexes.

Inspection of frequency distributions of ratios for AIM specimens revealed a unimodal population from the vicinity of Kingsville. Absence of a bimodal population discounted the concept of two distinct populations with limited intergradation, and suggested that a population of primarily intergrades existed, or that AIM specimens were a morphological extension of one of the two known taxa.

Z-testing repeatedly indicated significant differences between AIM specimens and the *S. i. nettingi* population (Table 1). No significant differences were found between AIM specimens and the *S. i. texana* population. On the basis of univariate testing of the variables included in this study, sirens from the vicinity of Kingsville were assigned to *S. i. texana*, and no evidence of intergradation was found.

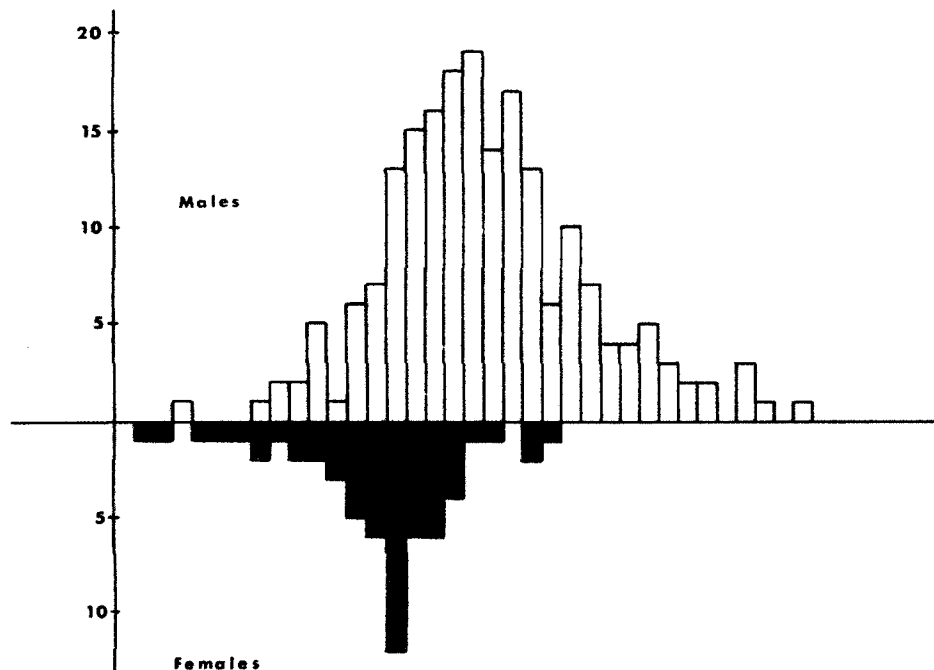


Figure 2. Bar-histogram of canonical variable scores of sirens from the vicinity of Kingsville, Texas.

Table 1. Results of Z-tests on ratios found to vary between three populations of sirens.

	nettingi/ AIM		nettingi/ texana		AIM/ texana	
	Z	Sign. level	Z	Sign. level	Z	Sign. level
total length/body width	7.48	.01	4.16	.01	1.33	-
total length/head width	13.42	.01	0.71	-	0.32	-
snout-vent length/head length	1.57	.05 +	1.83	.05 +	0.75	-
snout-vent length/internasal dist.	4.29	.01	3.22	.01	1.03	-
axilla-vent length/internasal dist.	5.23	.01	4.09	.01	1.29	-
body width/head width	4.68	.01	2.16	.05	0.39	-
body width/internasal distance	10.00	.01	3.24	.01	1.35	-
costal groove count	24.15	.01	8.16	.01	1.04	-

Multivariate testing of ratios showing significant Z-test differences substantiated the results of univariate analysis. A plot of factor scores along the first two factor axes revealed greatly overlapping scores (Fig. 3). The mean of values for the Kingsville population fell almost on top of the mean for *S. i. texana* and Duncan's Multiple Range test revealed no significant difference (0.05 level) along either axis between the two populations. The mean for *S. i. nettingi* was significantly different from the other populations along the first factor axis, but not along the second factor axis. The first factor axis apparently represented a size axis of general stockiness as ratios having width characters as denominators contributed most to variation along this axis.

MANOVA-testing substantiated the results of Z-testing and revealed high F values indicating significant (>0.01 level) differences in the ratios for *S. i. nettingi* when compared with *S. i. texana* and/or specimens from the vicinity of Kingsville.

On the basis of discriminant function analysis, all 256 specimens collected from the vicinity of Kingsville were assignable to *S. i. texana*. Although character intergradation had been predicted, and in fact, reported by Goin (1957) in sirens collected from the vicinity of Kingsville, no evidence of intergradation was demonstrated in this study. There are three possible explanations for these results: 1) intergradation between the two subspecies occurs somewhere east of Kingsville and is not expressed in the Kingsville population, 2) there is no intergradation and *S. i. texana* behaves as a full species, and 3) intergradation occurs, but its demonstration here was hampered by the geographic remoteness of the *S. i. nettingi* sample. Of the three, the first explanation seems most plausible. All of the observed results would be consistent with the presence of an east-west morphometric cline in which character intergradation was gradual or even steep at some point east of Kingsville, Texas. Behavior of *S. i. texana* as a full species is discounted by the near completion overlap of factor scores on Figure 3, and the third possibility, intergradation present but not demonstrated due to geographic remoteness, is discounted by the extreme similarity of factor score averages for *S. i. texana* and the Kingsville population and their significant difference from average scores for *S. i. nettingi*. In addition, very high posterior probability of membership values were generated during discriminant function classification of specimens from Kingsville. Classification, then, was definite and indicated no evidence of intergradation with *S. i. nettingi*.

On the basis of these analyses, *S. i. spp.* collected from the vicinity of Kingsville, Texas, are assignable to *S. i. texana*. No evidence of intergradation occurs in the Kingsville population and character intergradation would apparently occur east of Kingsville along the Texas coast. If this zone of intergradation is found to be narrow and associated with an isolating factor (e.g., a major arid zone, etc.), *S. i. texana* could eventually undergo speciation and become elevated to full specific status.

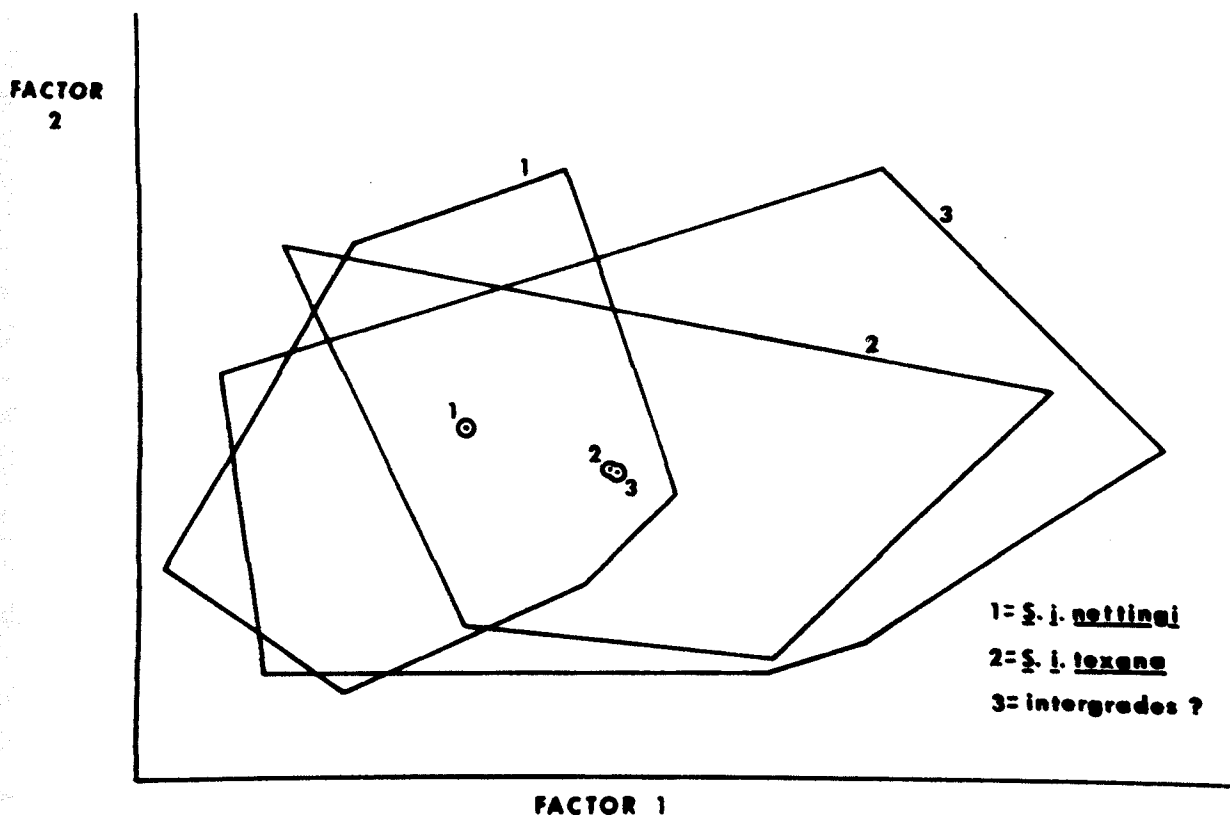


Figure 3. Factor scores for the three populations of sirens under study. Population perimeters and means are indicated. Intergrades refers to sirens collected from the vicinity of Kingsville, Texas.

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Drs. A. H. Chaney and R. B. Davis provided advice and encouragement throughout this study. Dr. A. Posey provided invaluable assistance in multivariate techniques, and J. E. Gardner spent many hours punching cards. K. G. Matocha and R. Leal provided assistance in collecting, and D. M. McCarty spent many hours programming for univariate analysis.

I am grateful to the following curators and institutions for permission to examine specimens: Dr. B. C. Brown, Strecker Museum, Baylor University; Dr. H. Dundee, Tulane University; Dr. C. Douglass, Texas Memorial Museum, University of Texas; Dr. E. C. Tanzer, Lamar University; Mrs. B. Warburton, Texas Southmost College; Dr. A. H. Chaney, Texas A&I University.

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DISTRIBUTION AND HABITAT OF *Discradisca antillarum*
(d'ORBIGNY, 1846)
(BRACHIOPODA: INARTICULATA) IN THE WESTERN
GULF OF MEXICO

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ABSTRACT

The small inconspicuous, inarticulate brachiopod *Discradisca antillarum* (d'Orbigny) was collected in three wide-ranging geographic areas in the western Gulf of Mexico: a submarine bank off Freeport, Texas; a submarine bank off Padre Island, Texas; and, a coral reef southsoutheast of Tampico, Mexico. Shell morphology, habitat, and distribution of this previously little known eurythermic tropical species are discussed. Close-up photographs and a map are included.

INTRODUCTION

Discradisca antillarum d'Orbigny is a small inconspicuous, inarticulate brachiopod of which there have been few reported collections since its original description from Cuba. Recent investigations, however, of submerged hard banks and coral reefs in the western Gulf of Mexico have revealed quite a broad distribution of this previously rarely collected species (Tunnell and Chaney, 1970; Tunnell, 1978).

Davidson (1888) regarded *D. antillarum* as an "uncertain species", noting that it might simply be the "young stage of some other" species. Dall (1871, 1873, 1889, 1920), on the other hand, apparently regarded the species as a valid one in his reviews of western Atlantic brachiopods. Only recently, however, have a description and good illustrations been published (Cooper, 1977) of *D. antillarum*, but bathymetric data is totally lacking and its geographical distribution is only partially known. The purpose of this paper is to contribute information on the bathymetry, habitat, and distribution of *D. antillarum* in the Western Gulf of Mexico, and also, to contribute close-up photographs and further descriptions of this hitherto "rarely" known species.

SYSTEMATICS

Class inarticulata Huxley, 1869
Order Acrotretida Kuhn, 1949
Suborder Acrotretidina Kuhn, 1949
Superfamily Discinacea Gray, 1840
Family Discinidae Gray, 1940
Subfamily Disciniscinae Schuchert and LeVene, 1929

Discradisca Stenzel, 1964: p. 627.

Stenzel (1964) proposed this name as a subgenus of *Discinisca* because of the radial costellae on the exterior, thus relegating the subgenus *Discinisca* to those species with a smooth dorsal valve. Cooper (1977) subsequently elevated *Discradisca* to the generic rank noting . . . "the genus is rare in the Caribbean but several specimens were taken by early collectors and found their way into the national collection. Unfortunately, the geographic and bathymetric data with the specimens are meager."

Stenzel (1964) designated *Discinisca (Discradisca) antillarum* (d'Orbigny) as a type-species of the subgenus *Discradisca*.

Orbicula antillarum (d'Orbigny), 1846,
Figures 1-6

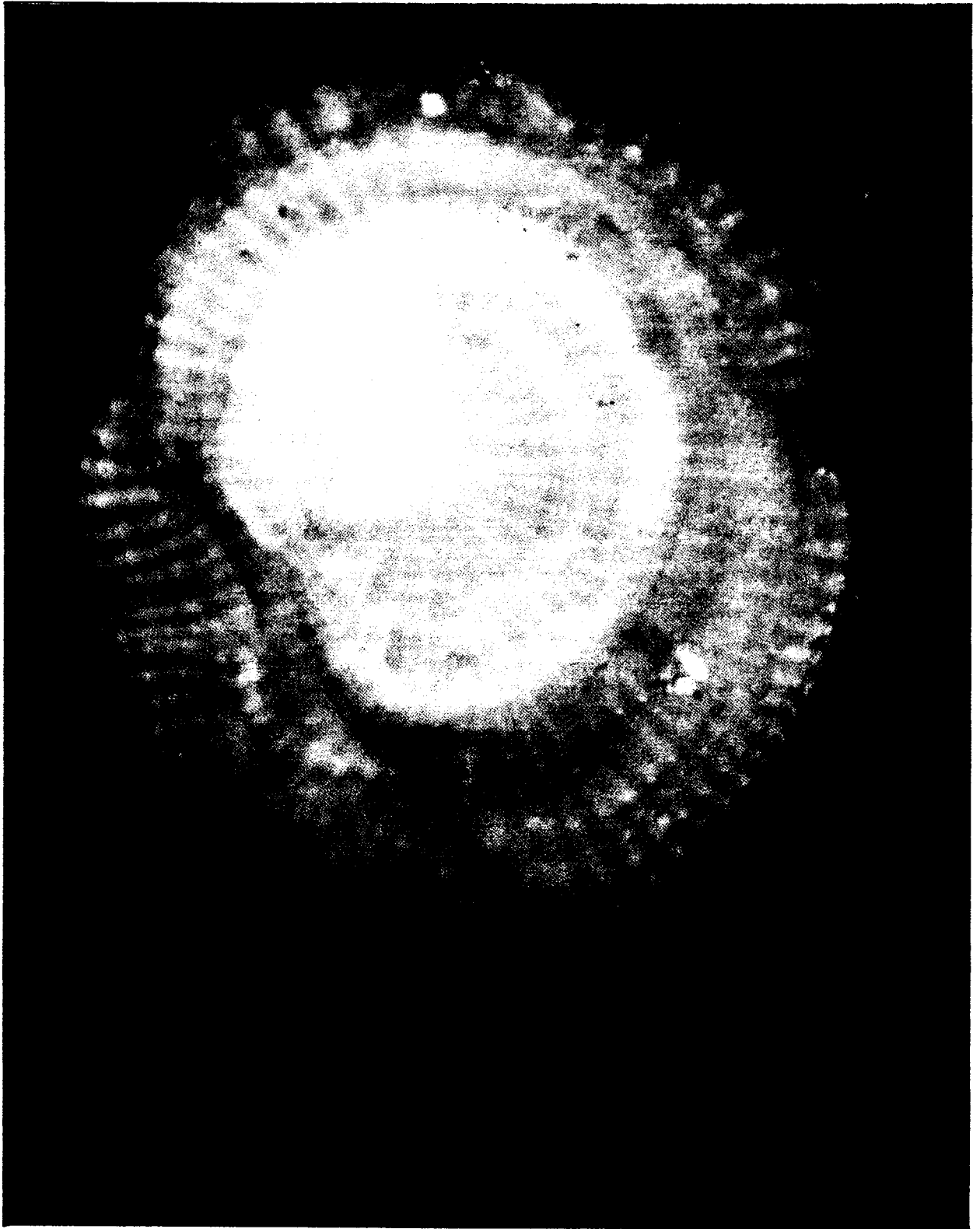


Figure 1. *Discradisca antillarum* (d'Orbigny): dorsal view, x 8, of entire dorsal valve showing smooth apex, radial sculpturing, and marginal setae. Locality: West Bank, off Freeport, Texas, northwestern Gulf of Mexico.



Figure 2. *Discradisca antillarum* (d'Orbigny): ventral view, x 8, of dorsal valve animal and setae embedded in shell margin. Locality: West Bank, off Freeport, Texas, northwestern Gulf of Mexico.

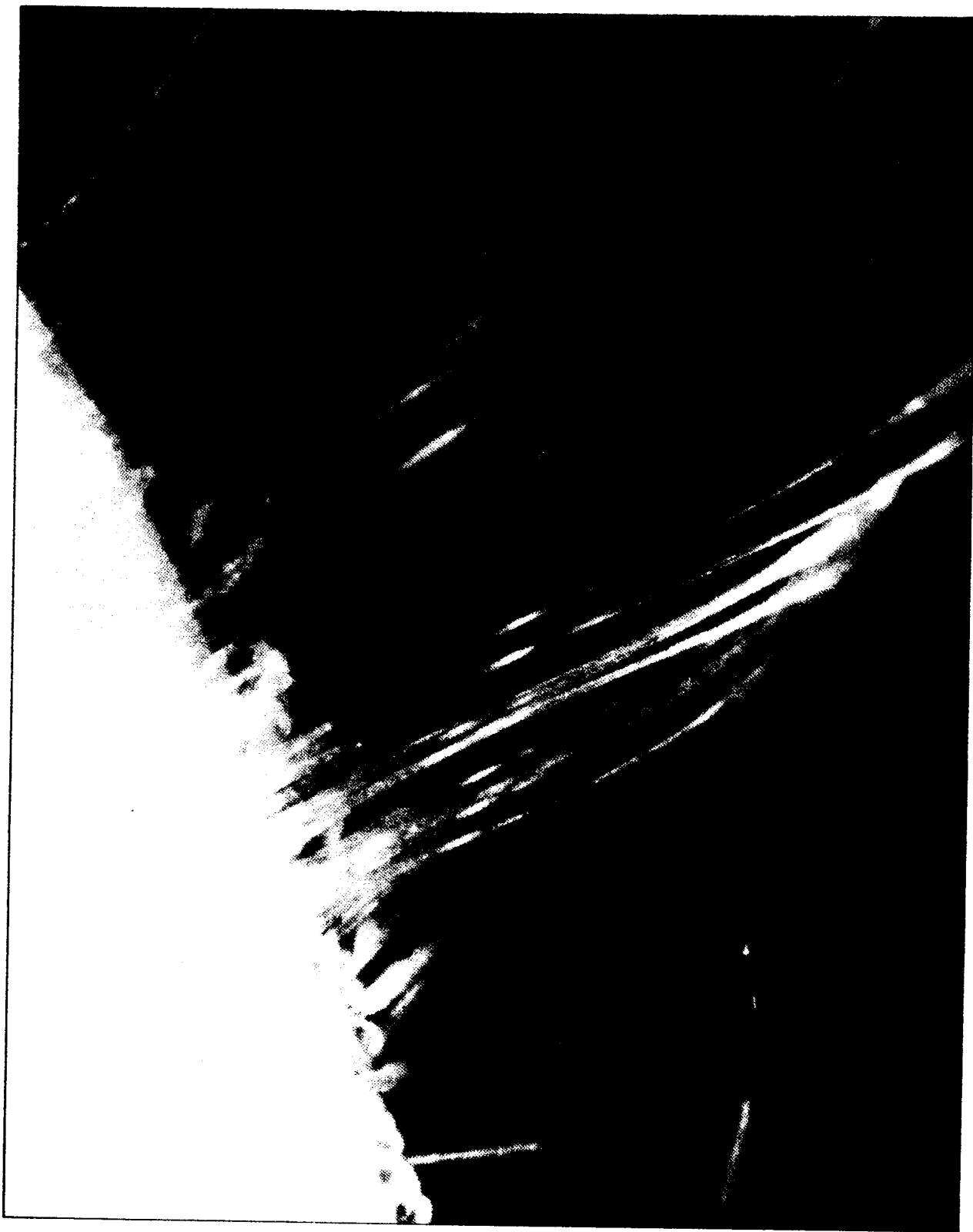


Figure 3. *Discradisca antillarum* (d'Orbigny): ventral view, x 32, of margin of dorsal valve showing barbs projecting laterally from marginal setae. Locality: West Bank, off Freeport, Texas, northwestern Gulf of Mexico.



Figure 4. *Discradisca antillarum* (d'Orbigny): ventral view, x 8, of partially broken ventral valve showing radiating sculpture and pedicle area. Locality: West Bank, off Freeport, Texas, northwestern Gulf of Mexico.



Figure 5. *Discradisca antillarum* (d'Orbigny): ventral view, x 20, of margin of ventral valve showing dense short and sparse long marginal setae. Locality: West Bank, off Freeport, Texas, northwestern Gulf of Mexico.



Figure 6. *Discradisca antillarum* (d'Orbigny): dorsal view, x 8, of dorsal valve. Valve almost completely encrusted with coralline red algae (light areas) and *Homotrema rubra* Lamark, and encrusting foraminiferan (dark pitted area). Locality: Lobos Reef, south-southeast of Tampico, Mexico southwestern Gulf of Mexico.

Orbicula antillarum d'Orbigny, 1846 [1845-1853]:368,
pl. 28, figs. 34-36; 1853:371, pl. 1, fig. 2.
(see note in Lit. Cit.)

Discina antillarum (d'Orbigny) Suess, 1859:228;
Dall, 1889:30.

Discinisca antillarum (d'Orbigny) Dall, 1871:42; 1873:201;
1920:278. - Davidson, 1888:204, pl. 26, fig. 31, 31a.

Discradisca antillarum (d'Orbigny) Cooper, 1977:51-52,
pl. 2, figs. 13-24.

Type Locality

Presumably Cuba. I have not been able to obtain the rare text of d'Orbigny's (1845, 1853) work.

Type

The location of d'Orbigny's originally described specimen is unknown. Cooper (1977) figured four hypotypes from the U.S. National Museum (USNM 64335 a-c, Jamaica; 364180a, Sao Francisco do Sul, Santa Catharina, Brazil).

Material

West Bank, off Freeport, Texas 28° 46'N, 95° 38'W, 15m:1, 5/24/74; Seven and One-half Fathom Reef, off Padre Island, Texas 21° 28'N, 97° 19'W, 12m:1, 7/20/68; Lobos Reef off Cabo Rojo, Veracruz, Mexico, 21° 28'N, 97° 13'W, 7m:1, 6/9/73.

Description

Dorsal (brachial) valve unevenly subcircular in outline and lowly conical in profile, apex located slightly posterior of center; shell thin to moderately thick; anterior and posterior slope gentle and slightly convex; apex narrowly to broadly smooth; sides and posterior marked with irregularly spaced, thread-like radii, 3-5 per millimeter at margin; anterior slope uniformly to indistinctly marked by radii, more at base than near apex, extra ribs added 1/4 to 1/3 down slope in interspaces; shell margin very irregular, conforming generally to the surface from which it was removed; irregular concentric growth lines evident on some; color pale yellow-brown, except for radii which are lighter and apex which is white; numerous short broad setae at shell margin, overlaid ventrally by much longer, slender setae (up to 4-5 mm) which bear fine, radiating barbs or thorns; inner edge of margin with the numerous radiating bases of the setae appearing as glass fibers embedded in the shell; dorsal valve slightly overlaps ventral valve. Ventral (pedicle) valve subcircular, concave medially by gently convex marginally; pedicle region subcircular and occupying about 1/4 to 1/3 of the valve; pedicle opening a narrow slit; surface with numerous, thread-like radii extending from pedicle opening to shell margin; some radii bifurcate 1/4 to 1/2 way out; external ribs easily seen through transparent valve; shell margin with numerous short setae overlaid dorsally by longer, slender barbed setae; longer setae not as numerous as short ones, somewhat local in distribution; short setae on ventral valve denser and more numerous than on dorsal valve.

Measurements in mm	length	width	height
West Bank	7.8	6.7	2.8
Seven and One-half Fathom Reef*	12.0	8.0	4.0
Lobos Reef	8.9	7.2	2.8

Remarks

The northwestern Gulf specimens closely resemble a specimen from Brazil illustrated by Cooper (1977). These specimens differ from the southwestern Gulf and Caribbean specimens in having a slightly thinner shell and radii distinctly extending over the anterior slope of the dorsal valve. Further, more extensive collections may prove otherwise, but I believe all of these specimens (Gulf, Caribbean, and Brazilian) are of the same species, and that the slight morphological differences represent ecomorphs at the periphery of the range of this eurythermic tropical species.

*This specimen was inadvertently reported (Tunnell, 1972) as *Crania* sp. The specimen did not have a pedicle valve revealing the characteristic pedicle opening and was therefore misidentified. Although the brachial valves of *Crania* and *Discradisca* may closely resemble each other, the pedicle valve in *Crania* is partly or wholly cemented to the substrate and *Discradisca* attaches by its pedicle through an opening in the pedicle valve (Rowell 1965).

Habitat and Distribution

Since its original description by d'Orbigny (1845, 1853), *Discradisca antillarum* had only received mention in several older works (e.g., Suess, 1859; Dall, 1871, 1873, 1889, 1920; Davidson, 1888), until Cooper (1977) listed it in his survey of Gulf of Mexico and Caribbean Sea brachiopods. Cooper noted its apparent wide distribution throughout the Caribbean as indicated by the older literature and the few specimens that were in the national collection. However, he also pointed out the lack of geographic and bathymetric data noting that the 64 species known from the Gulf and Caribbean, only 2 totally lacked known depth ranges, and *D. antillarum* was one of these.

Discradisca antillarum has not been previously reported from the Gulf of Mexico. It is now known, however, to be wide ranging in the western Gulf from warm temperate waters in the north to tropical waters in the south. In the northwestern Gulf *D. antillarum* was collected from two shallow-water, submarine banks: West Bank and Seven and One-half Fathom Reef (Figure 7). West Bank, located off Freeport, Texas in 14-16 m of water is one of a series of small (approximately 30 x 100 m) beachrock, topographic highs within 10-12 km of shore and with 2-5 m of relief. The surface of the rocks are covered with an encrusting matt of hydroids, serpulid polychaetes, bryozoans, and tunicates. Most of the organisms on West Bank are Carolinean Province, warm temperate species, although a few eurythermic tropical species are present.

Seven and One-half Fathom Reef is a moderate sized (approximately 50 x 350 m) submarine bank located in approximately 14 m of water and about 3 km offshore from Padre Island, Texas. This bank's rocky substrate is composed of a "well indurated calichified lake marl" of late Pleistocene origin (Thayer, et al., 1974). With 4-7 m of relief, the topography is quite irregular consisting of precipitous slopes, shallow to deep crevices, and small to large rocks and boulders. A dense fouling mat covers the shallower parts of the reef and is predominately made of polychaete tubes (*Phyllochaetopterus*) overlain by hydroids and tunicates (Tunnell and Chaney, 1970; Felder and Chaney, 1979). Sponges are scattered within the matt of tubes, on top of it, and on exposed areas of rock surface. Seven and One-half Fathom Reef organisms have a considerably larger tropical component than West Bank, but still have a large number of Carolinean species (Tunnell, 1973; Felder and Chaney, 1979).

In the southwestern Gulf *Discradisca antillarum* was collected from the windward (east) forereef slope of Lobos Reef (Figure 7) in 7 m of water. Lobos Reef is an emergent, platform type coral reef located on the inner continental shelf approximately 10 km southeast of Cabo Rojo, Veracruz, Mexico in 24 m of water (Rigby and McIntire, 1966; Chavez, et al. 1970). Lobos Reef is one of three northernmost emergent reefs in the western Gulf. These reefs are predominately of Caribbean Province (tropical) biotic composition. *D. antillarum* was taken from the groove and buttress, *Acropora palmata* zone.

All three discoveries of *D. antillarum* involved SCUBA-collected rock samples being closely examined in the laboratory for epifaunal and infaunal molluscs.

Range

Off Fernandina, Florida (Dall, 1889) southward to Cuba (d'Orbigny, 1845, 1853) and westward into the western Gulf of Mexico; Jamaica (Cooper 1977) southward to Martinique (Dall, 1871), Wounta Haulover, Nicaragua (Stenzel, 1964), and Sao Francisco do Sul, Santa Catharina, Brazil (Cooper, 1977).

DISCUSSION

Even though *Discradisca antillarum* has a wide-ranging distribution in the Gulf of Mexico and Caribbean Sea areas, it has probably not been collected or has been overlooked for several reasons: 1) its camouflaging coloration, much like the rocks to which it attaches; 2) its conformity to the rocks on which it attaches; 3) its rocky habitat, namely submarine banks and coral reefs, which have not been examined closely until recent years, concordant with advances in underwater sampling techniques, such as SCUBA.

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I would like to sincerely thank Dr. A. H. Chaney for not only leading me into the projects from which some of this work arose, but also for inspiring me to become a biologist in the first place with his zeal, love and enthusiasm for nature. I also gratefully acknowledge Mr. Javier Fonseca for his darkroom and printing assistance.

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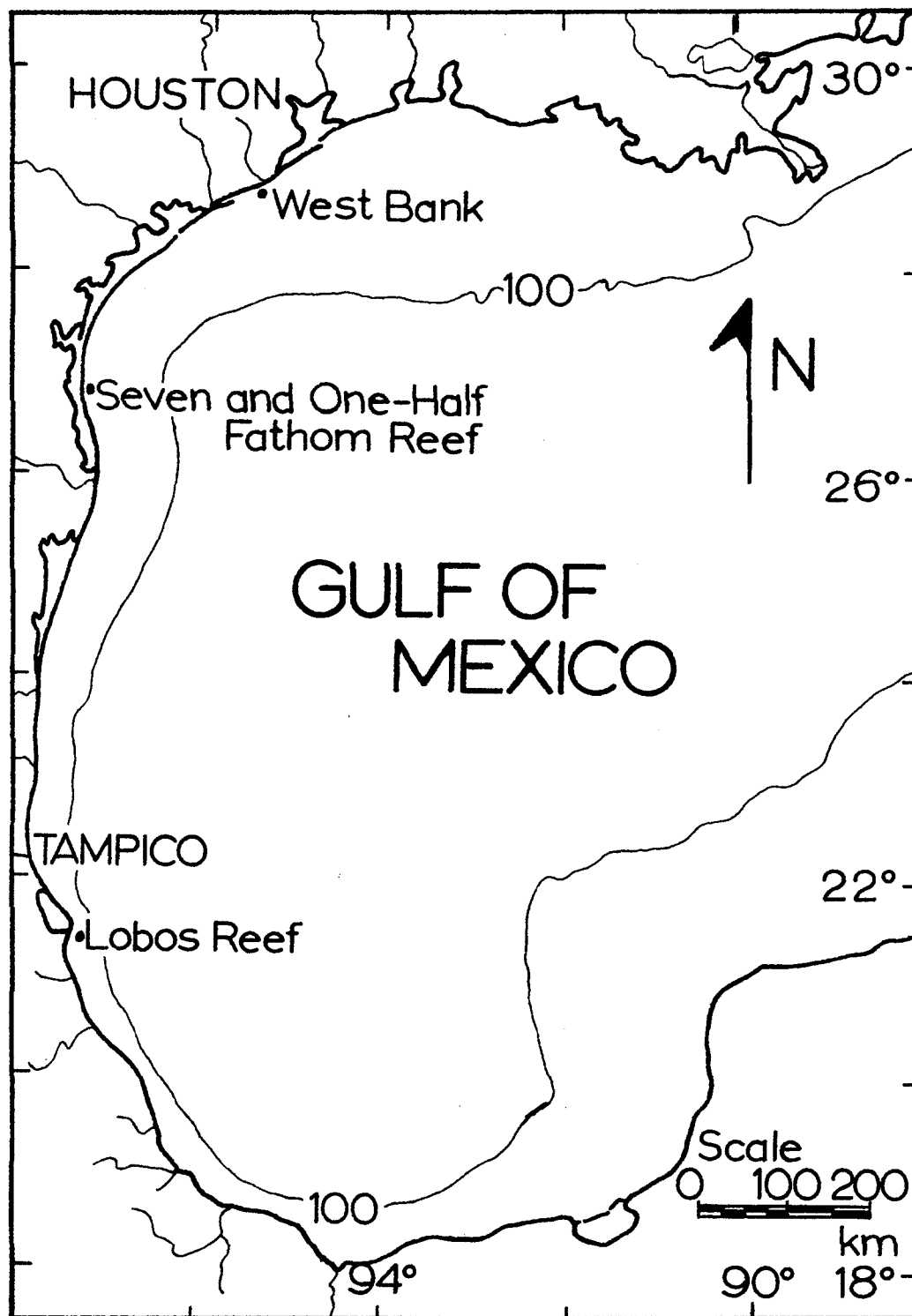


Figure 7. Regional map of the western Gulf of Mexico showing the locations of the three collecting sites. Bathymetry contoured in fathoms.

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*Cooper (1977) notes that both the 1845 and 1853 volumes have a description of *Discinisca antillarum* by d'Orbigny which is dated 1846, but that no reference is given to a volume with a date 1846. Dall (1885) on the other hand, explains that this publication appeared in two volumes and forms one of the Sagra series (in Spanish language), but was independently issued in French and appeared irregularly as follows: Vol. 1, signatures 1-14 in 1841, signatures 15-17 and atlas in 1842; Vol. 2, signatures 1-7 in 1842, signatures 8-24 in 1847-1853. In addition, Dall notes that both volumes were issued as a whole in 1853, with the latter date on the title page.

THE IMPORTANCE OF ECHINODERMS IN THE DIET OF FISHES OF A SUBLITTORAL ROCK REEF

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ABSTRACT

As part of an investigation of the echinoderms of Seven and One-half Fathom Reef, a rock reef 3 km offshore Padre Island, Texas, the stomach contents of 702 reef fish belonging to 31 species were examined to determine the importance of echinoderms in their diet. All species of resident nektonic fish and 15 of 22 species of resident benthic fish reported from the reef, as well as 10 species of occasional fish, were examined. Echinoderms were found in the stomachs of 60 specimens belonging to 8 species of fish, all but one of which were benthic. Echinoderms appeared to comprise a substantial part of the diet of 2 of the fish species, *Opsanus pardus* and *Serranus subligarius*. The two most abundant echinoderms, the ophiuroids *Ophiactis* sp. and *Ophiothrix angulata*, were the most common prey items. The latter was a more common prey item even though much less abundant.

INTRODUCTION

Echinoderms are often abundant enough in the marine environment that they are used to characterize marine benthic communities (Peterson, 1918; Vevers, 1952; Thorson, 1957; Barnard and Ziesenhenné, 1961; Singletary and Moore, 1974). The effect of grazing or predation pressure of echinoderms on the species composition, both plant and animal, of bottom communities, has been the topic of numerous investigations (Thorson, 1957; Barnard and Ziesenhenné, 1961; Mann, 1973; Paine and Vadas, 1969; Ogden, et al., 1973; Singletary and Moore, 1974). A paucity of information, however, exists concerning the importance of echinoderms as prey items.

The abundance and distribution of echinoderms of Seven and One-half Fathom Reef, a sublittoral rock reef off the Texas coast, were investigated during the period October, 1971, to August, 1973 (Shirley, 1974). The species richness of the echinoderm fauna of the reef and the densities of echinoderms, as great as 2500/m², when considered in conjunction with data available from prior studies about the reef's ichthyofauna (Causey, 1969; Davis, 1975) afforded a unique opportunity for the investigation of the importance of echinoderms in the diet of reef fishes. In order to ascertain the possible importance of echinoderms in the diet of the reef's ichthyofauna, the stomach contents of 702 fish, collectively belonging to 31 species, were examined for echinoderms. The predation frequency of the echinoderms is reported, with consideration given to the relative abundance and life history patterns of both the echinoderms and the fish. Other possible predators of echinoderms on the reef are also discussed.

DESCRIPTION OF STUDY AREA

Seven and One-half Fathom Reef is located 3.2 km off North Padre Island, Texas (Figure 1). It is in approximately 14 m of water with depths to 20 m in areas scoured by currents and wave action. The reef is a depositional remnant of terrestrial origin and is composed of sandy caliche (Thayer, et al., 1974). The surface of the reef is highly irregular, varying from crevices and abrupt sides to gentle slopes. Rock surfaces have been extensively riddled by the attacks of boring mollusks, polychaetes, sponges and sipunculoid worms. The surface of the reef was scarcely visible in many areas due to an encrusting mat of compound ascidians, sponges, coelenterates, bryozoans, algae and polychaete tubes. The mat, which harbored dense concentrations of a wide spectrum of invertebrates, was composed primarily of compound ascidians overlying a dense network of long, flexible polychaete tubes with various sponges dispersed throughout. The polychaete tubes, which belong to *Phyllochaetopterus socialis*, exceeded 20,000 tubes per m² in some areas of the reef (McCarty, 1974).

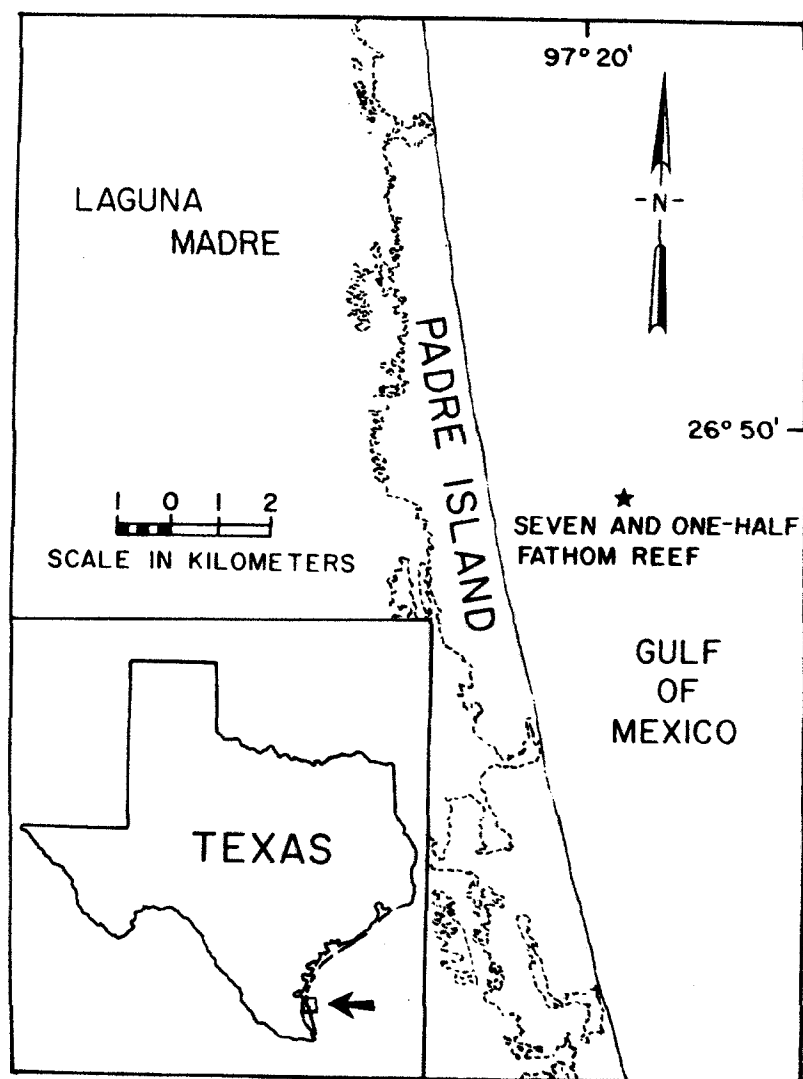


Figure 1. Map of a portion of the Texas coast showing the location of Seven and One-half Fathom Reef.

MATERIAL AND METHODS

Fish were collected from the vicinity of Seven and One-half Fathom Reef by means of hook and line, speargun, fish traps and by poisoning with rotenone by the author and by other researchers between April, 1968, and July, 1973. All of the fish except for *Lutjanus campechanus* Poey, the red snapper, were deposited in the Texas A&I University Museum, Kingsville, Texas. The fish were initially preserved in 10% buffered formalin and later transferred to 60% isopropyl alcohol. The fish were identified and then classified according to the following criteria established by Causey (1969): resident benthic (RB), resident nektonic (RN), occasional benthic (OB) and occasional nektonic (ON). Abundance, distribution and life history data on the fish on Seven and One-half Fathom Reef were taken from Causey (1969). The stomach of each fish was removed and its contents examined. All echinoderms were identified as completely as their state of digestion permitted. The absence of food in fish stomachs was noted to preclude biasing data by those fish which may have regurgitated their stomach contents while being captured.

The abundance and distribution of echinoderms on the reef were determined by several methods. Visual counts of the more conspicuous epifaunal species were made *in situ* with the aid of SCUBA gear in fifteen 1.0 m² quadrats arranged in three transects traversing the reef approximately perpendicular to its long axis. Smaller and more cryptic species were counted in the lab from subsamples composed of all material collected from a 0.25 m² area located within the previously mentioned 1.0 m² quadrats. Additional 1.0 m² counts and 0.25 m² samples were taken from areas away from the transects. Rock samples and sediment samples were also collected from various areas of the reef and examined for echinoderms. The sediment areas peripheral to the reef were sampled for echinoderms by means of a biological dredge.

RESULTS

Of the 87 fish species reported from Seven and One-half Fathom Reef (Causey, 1969), 31 were examined in the present study to see if they preyed upon echinoderms. A list of fish examined, their ecological classification and data concerning predation frequency are given in Table 1. All resident nektonic fish species and 15 of the 22 species of resident benthic fish reported by Causey (1969) were examined. The more abundant occasional fish were examined.

Echinoderms were found in the stomachs of 60 individuals of eight species of fish. Six of the 15 species of resident benthic fish and one species of occasional benthic fish contained echinoderms. The only nektonic fish found to contain an echinoderm was *Lutjanus campechanus*, the red snapper, the most abundant fish on Seven and One-half Fathom Reef. Of 391 specimens of *L. campechanus* examined, only a single specimen contained a part of an echinoderm, that being a primary spine of *Arbacia punctulata* (Lamarck), the purple urchin.

The two most abundant echinoderms on the reef, the ophiuroids *Ophiactis* sp. and *Ophiothrix angulata* (Say), were the most common prey items. The latter was the more common prey, being found in the stomachs of seven species of fish, even though much less abundant, while the former was found in the stomachs of a single fish species. *Ophiactis* sp. commonly comprised 85 - 90% of the total echinoderms in quadrat samples, while *O. angulata* never comprised more than 8%. The only other ophiuroid which could be identified from fish stomachs was the amphiurid brittlestar *Amphiodia pulchella* (Lyman), found in *Serranus subligarius*.

Ophiuroids comprised a substantial part of the diet of *S. subligarius*, the belted sandfish, as they were found in 52 of 179 stomachs which contained food. Three species of ophiuroids could be identified in *S. subligarius*: *Ophiothrix angulata*, *Ophiactis* sp. and *Amphiodia pulchella*. The seasonal importance of echinoderms in the fish's diet may not be accurately represented, as on certain days a large percentage of the *S. subligarius* would contain brittlestars. On one day, 9 of 10 specimens contained ophiuroids as the major portion of their stomach contents.

The purple urchin, *Arbacia punctulata*, was the only common urchin on the reef, and had an average abundance of 2.9 individuals per m². As previously mentioned, it was found in *L. campechanus* and additionally in the leopard toadfish, *Opsanus pardus*. One leopard toadfish contained a nearly complete and undamaged urchin. Another leopard toadfish also contained representatives of two other classes of echinoderms, parts of the ophiuroid *O. angulata* and what appeared to be the end plates of the tube feet of a holothurian.

All other fish species which contained echinoderms were resident benthic fish and contained only the brittlestar *O. angulata*.

Table 1. Frequency of occurrence of echinoderms in fish stomachs. Number in parenthesis is total number of specimens found in stomachs of the predator; * indicates the number could not be determined; % is frequency of occurrence in the predator. Fish classification follows Causey (1969).

FISH EXAMINED	CLASS	NO.	NO. WITH FOOD	ECHINODERMS, IF PRESENT	%
<i>Archosargus probatocephalus</i> (Walbaum)	RN	2	2		
<i>Arius felis</i> (Linnaeus)	OB	1	0		
<i>Balistes capriscus</i> (Gmelin)	RN	1	1		
<i>Blennius marmoreus</i> (Poey)	RB	5	5	<i>O. angulata</i> (*)	20
<i>Brotula barbata</i> (Bloch & Schneider)	OB	1	1		
<i>Chaetodipterus faber</i> (Broussonet)	RN	3	3		
<i>Chaetodon sedentarius</i> (Poey)	RB	2	2		
<i>Diplodus holbrooki</i> (Bean)	RN	1	1		
<i>Epinephelus adscensionis</i> (Osbeck)	RB	8	5	<i>O. angulata</i> (*)	20
<i>Haemulon aurolineatum</i> (Cuvier)	RN	8	8		
<i>Halichoeres bivittatus</i> (Bloch)	RB	3	3	<i>O. angulata</i> (*)	33
<i>Halichoeres caudalis</i> (Poey)	RB	7	6	<i>O. angulata</i> (*)	17
<i>Hypleurochilus geminatus</i> (Wood)	RB	5	5		
<i>Kyphosus secatrix</i> (Linnaeus)	ON	2	1		
<i>Labrisomus nuchipinnis</i> (Quoy & Gaimard)	RB	1	1		
<i>Lagodon rhomboides</i> (Linnaeus)	OB	1	1		
<i>Lutjanus campechanus</i> (Poey)	RN	391	292	<i>A. punctulata</i> (1)	0.3
<i>Lutjanus griseus</i> (Linnaeus)	ON	1	1		
<i>Monacanthus hispidus</i> (Linnaeus)	OB	3	3	<i>O. angulata</i> (*)	33
<i>Mycteroperca bonaci</i> (Poey)	RB	1	0		
<i>Mycteroperca rubra</i> (Bloch)	RB	4	3		
<i>Odontoscion dentex</i>	RB	1	1		
<i>Opsanus pardus</i> (Goode & Bean)	RB	13	11	<i>holothurian</i> (1)	9
				<i>O. angulata</i> (*)	9
				<i>A. punctulata</i> (1)	9
<i>Pareques acuminatus</i> (Bloch & Schneider)	RB	8	8		
<i>Peprilus paru</i> (Linnaeus)	ON	1	0		
<i>Pomacentrus variabilis</i> (Castelnau)	RB	7	4		
<i>Porichthys porosissimus</i> (Valenciennes)	OB	3	0		
<i>Rypticus saponaceus</i> (Bloch & Schneider)	RB	25	19		
<i>Scorpaena plumieri</i> (Bloch)	OB	4	2		
<i>Serranus subligarius</i> (Cope)	RB	195	179	<i>Ophiactis</i> sp. (28)	13
				<i>O. angulata</i> (13)	8
				<i>A. pulchella</i> (6)	1
				unidentified (21)	11
<i>Sphoeroides spengleri</i> (Bloch)	OB	2	2		

DISCUSSION

Reports on predation on echinoderms by marine fishes are sparse, particularly when the abundance and biomass of echinoderms in some marine habitats are considered. One of the few investigations that considered the importance of echinoderms in the diet of reef fishes was that of Randall (1967). In this exhaustive work, he reported 46 species of fish which contained echinoderms in their diet, but in only 8 of these fish species were echinoderms the principal food. The ichthyofauna of the coral reef areas examined by Randall was substantially different than the rock reef ichthyofauna of Seven and One-half Fathom Reef. Only 11 of the 46 species reported by Randall (1967) to contain echinoderms in their diet were also sighted on Seven and One-half Fathom Reef. Six of these species were examined and two contained echinoderms. Only two of the eight species which had echinoderms as a principal food were sighted during the present investigation and neither was abundant enough to examine.

Arbacia punctulata were expected to be a common food of fishes on the reef, as recently broken urchin tests were observed on many dives. The predation on *A. punctulata* by *O. pardus* may partially explain the circumstantial evidence of predation. Fish predation on echinoids has been reported by numerous investigators. The toadfish, *Opsanus beta* (Goode and Bean), the queen triggerfish, *Balistes vetulata* Linnaeus, and various grunts, *Haemulon* spp., have been reported to feed on echinoids (Moore, 1966). Likewise, the goby *Ginsburgellus novemlineatus* (Fowler) has been reported to feed primarily on the tube feet and pedicellariae of the echinoid *Echinometra lucunter* (Linnaeus) (Teytaud, 1971). Randall (1967) found 34 species of reef fishes with echinoid remains in their stomachs and echinoids were the principal food for six of these species. A number of fishes feed on the pencil urchin *Eucidaris tribuloides* (Lamarck), which is present but uncommon on Seven and One-half Fathom Reef, but it is not considered a major dietary item in any of these fishes (McPherson, 1968). No evidence of predation on the pencil urchin was found during the present study.

Fish, particularly haddock, plaice, dab and cod, have been listed as being important predators of ophiuroids, particularly the large forms (Fell, 1966). Randall (1967) reported that brittlestars occurred in the stomachs of 33 species of fishes and were the main food of two species. He reported *Ophiothrix* to be the most common genus identified from the stomach contents. In the present study the distinctive arm spines of *Ophiothrix angulata* permitted positive identification even in well-digested specimens. Seven species of fish were found to contain *O. angulata*. The selection of the less abundant and more spinous *O. angulata* by fishes may be due to its larger size. Although fish tend to ignore ophiuroids with long or sharp spines, they feed more commonly on the larger and more conspicuous species (Fell, 1966). The North Atlantic species *O. fragilis* (Abildgaard) has been reported to be a common but rarely important part of the diet of *Callionymus lyra* (Linnaeus) and *Pleuronectes platessa* (Cuvier) (Warner, 1971).

The large and conspicuous ophiuroids *Ophionereis reticulata* (Say) and *Ophioderma appressum* (Say) were expected to be prey items, as many specimens from the reef demonstrated evidence of predation by having regenerated arm tips. No corroborating evidence was found in fish stomachs.

The high frequency of occurrence of brittlestars in stomachs of *Serranus subligarius* is noteworthy, especially since *S. subligarius* was the most abundant resident benthic fish on the reef (Causey, 1969). Although no published dietary report of *S. subligarius* was found, other species of *Serranus* are reported to feed primarily on crustaceans (Robins and Starck, 1961). The fish is a functional hermaphrodite and is strongly territorial (Clark, 1959). The strong territorial nature may explain the disparity in the diets of different specimens. The fouling mat of the reef, and therefore the distribution of the organisms found within it, is highly heterogeneous. Different territories may limit food availabilities to the fish and explain why some specimens contained almost exclusively caprellid amphipods while others contained brittlestars, or some other group of organisms. The diet of the species in general suggests that it is an opportunistic predator, feeding on virtually any organism within its territory.

Holothurians are rarely noted to have predators other than man (Hyman, 1955). Pawson (1966) cited unpublished data of the snapper *Chrysophrys auratus* (Bloch & Schneider) feeding on two species of holothurians to support his belief that holothurians may comprise a significant part of the diet of demersal fish. Randall (1967) found that eight fish species utilized holothurians as food, but that only trunkfish *Lactophrys bicaudalis* (Linnaeus) consumed more than four percent by volume. Many species of holothurians are toxic and the percentage which are toxic approaches 100 percent in many tropical areas (Bakus and Green, 1974). Holothurians were a

conspicuous part of the fauna on Seven and One-half Fathom Reef (Shirley, 1974; Pawson and Shirley, 1977), however evidence for only a single instance of predation was found in the present study.

Only two species of asteroids were found on the reef; however, several species were found on the level bottom sediment areas adjacent to the reef. Randall (1967) found starfishes in the stomachs of only five fishes in a coral reef area, with the largest amount ingested being only six percent by volume of the total stomach contents. The extremely low densities of asteroids on Seven and One-half Fathom Reef, only three specimens having been collected over a six year period, may be due to extremely high predation pressure.

Among the few non-fish predators that have been reported to feed selectively on echinoderms are the asteroids, *Luidia ciliaris* (Philippi) and *L. sarsi* Duben and Koren (Brun, 1972; Fenchel, 1965). Neither of the two asteroids found on the reef, *Luidia clathrata* (Say) and *Linkia bouvieri* Perrier contained echinoderms, nor are their diets reported to include echinoderms (Hulings and Hemlay, 1963).

Although suspected as echinoderm predators (Warner, 1971; Aldrich, 1976), crabs were not examined due to the small number of specimens available for examination. Stomach content analysis is often destructive to crustacean specimens. The efficiency of the crustacean jaw apparatus and gastric mill at mastication and trituration would probably preclude identification of most echinoderm species that might have been consumed. Likewise, food contents of molluscs were not examined, even though several *Cymatium* species are found on Seven and One-half Fathom Reef (Tunnell and Chaney, 1970) and members of the genus are reported to feed on echinoderms (Andrews, 1977). Other species of mollusks that have been reported to feed on echinoderms (Moore, 1956) were not found on Seven and One-half Fathom Reef. No evidence of predation by any non-fish predators was observed during the present investigation.

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LIFE HISTORIES OF THE SNAPPING SHRIMPS
Synalpheus fritzmuelleri* AND *S. apioceros
(CRUSTACEA: DECAPODA: ALPHEIDAE)
ON A SUBLITTORAL REEF OFF TEXAS

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ABSTRACT

During winter months on Seven and One-half Fathom Reef, reproduction is attenuated in populations of *Synalpheus fritzmuelleri* and *S. apioceros*. Some ovigerous specimens occur throughout the year, but much lower percentages of both populations carry normal eggs in winter months and broods of these eggs appear to be smaller. The seemingly wasteful production of nonviable, minute, chalky eggs by *S. apioceros* during winter months and the absence of such eggs in *S. fritzmuelleri* under the same ambient conditions could relate to the more tropical restriction of the former species. On Seven and One-half Fathom Reef, *S. apioceros* is probably near the northernmost extreme at which it can successfully reproduce.

INTRODUCTION

Snapping shrimps of the genus *Synalpheus* typically inhabit eroded rocks, coral rubble, abandoned mollusc shells, tide pools, dense grass beds, sponge cavities, crinoids, or porous encrusting materials (Hazlett 1962, Chace 1972, Banner and Banner 1975). Year-round collections of such cryptic species are often difficult to obtain, and life histories of most American snapping shrimps are poorly understood. In the course of systematic studies, ovigerous specimens of some species are reported from specific months and localities (Williams 1965, Chace 1972), but annual reproductive cycles remain undocumented. In some cases, variations in egg sizes (Coutière 1909, Chace 1972) and maturational changes in secondary sex characters (Banner and Banner 1975) are noted within snapping shrimp populations, but seasonal variations in these qualities are likewise unknown.

Two snapping shrimps, *Synalpheus fritzmuelleri* Coutière 1909 and *S. apioceros* Coutière 1909, are major components of the crustacean epifauna on shallow sublittoral reefs off Texas (Felder and Chaney 1979). The present study of reproductive cycles is based upon series of these species collected from one such reef during quantitative ecological studies conducted in 1970 and 1971.

MATERIALS AND METHODS

Shrimp were collected at depths ranging from 10 to 12 m on the highest rise of Seven and One-half Fathom Reef near 26° 49.0'N, 97° 19.3'W. The reef, which is composed of a "well indurated calichified marl" of late Pleistocene origin, is extensively eroded by boring molluscs, sipunculans, and other organisms (Thayer, LaRocque, and Tunnell 1974). The top and upper slopes of the reef are heavily encrusted by a mat of fouling organisms hereafter referred to as "fouling mat." This encrusting mat, which *Synalpheus* inhabits, is predominantly tubes of the polychaete genus *Phyllochaetopterus* overlain and intermixed with hydroids, compound ascidians, and sponges. A more detailed description of the reef and its encrusting assemblage is given by Felder and Chaney (1979).

Snapping shrimps were collected on eight occasions between August, 1970 and July, 1971. SCUBA was used to collect 0.25-m² samples of fouling mat from the top, inshore slope, and offshore slope of the reef on each collecting date. Samples were placed into plastic bags underwater and later preserved in 10% formalin. Each sample was analyzed by shredding the fouling mat, picking shrimp from the shredded materials, washing the materials over a 1.19-mm sieve, and carefully picking shrimps from the sieve residues. A final inspection was made under

magnification to remove any remaining specimens.

Ovigerous and non-ovigerous shrimp were identified, counted, and measured in total length (tip of rostrum to tip of telson) to the nearest 0.2 mm. All specimens were closely examined for the presence of normal, yellow eggs (>0.6 mm in maximum diameter) and minute, whitish objects (usually <0.4 mm in maximum diameter); as the latter objects resembled the small chalky "eggs" which Coutiere (1909) described from *S. brooksi*, they were hereafter termed "minute, chalky eggs."

Because of the difficulty in interpreting secondary sex characters, sexing of entire collections was not attempted; however, the first abdominal pleura of ovigerous individuals were inspected and classified as male-form (with acutely-angular, produced, posterior margin) or female-form (with rounded or bluntly-cornered posterior margin). No specimens of *S. apioceros* under 9 mm and no specimens of *S. fritzmuelleri* under 10 mm carried normal, yellow eggs; these sizes were therefore chosen to represent the total lengths at which maturity is reached in the respective species.

RESULTS

A total of 830 *Synalpheus fritzmuelleri* and 617 *S. apioceros* were examined from collections made in August, October, and December of 1970 and January, March, May, June, and July of 1971. Normal, yellow eggs were found on at least some specimens of both species during all sampling periods; however, minute chalky eggs were found only on *S. apioceros* and predominantly during October, December, and January (Fig. 1). When present, minute eggs were usually few in number (6-20) and aggregated into masses on either side of the abdomen just beneath the first and second abdominal pleura (Fig. 2). As many as 36 minute eggs occurred on a few specimens, and in those cases egg masses often extended to the third abdominal pleura.

Breeding activity in *S. fritzmuelleri* began to increase in March and was greatest during summer months (Figs. 1 and 3). Reproduction peaked sharply in June when the percentage of ovigerous specimens (among mature) rose to 48.8% (Fig. 3). The percentage of ovigerous specimens decreased to 27.3% in July, slightly increased to 34.2% in August, and then fell to the low percentages of October, December, and January.

Length-frequency distributions suggested that marked recruitment of *S. fritzmuelleri* juveniles began in June and continued through October (Fig. 1). Occurrence of a few 4.0-5.8 mm juveniles during winter months probably reflected a low-level of recruitment which persisted through January; no recruitment of 4.0 - 5.8 mm juveniles was evident in March and May. Growth of the young-of-the-year age class after August was manifest in both increased modal length of this class and increased mean length of the entire sample from October through May.

Breeding activity in *S. apioceros*, as reflected by occurrence of normal eggs, also peaked in June (Fig. 3). The spring increase in breeding activity began in March when the percentage of ovigerous specimens rose sharply to 36.2%. Percentages of ovigerous *S. apioceros* remained well above those for *S. fritzmuelleri* from March through July and then showed a linear decrease from 34.0% in August to a low of 7.3% in January.

Recruitment of *S. apioceros* juveniles began in June, the only month in which the 4.0 - 5.8 mm size class was represented (Fig. 1). The persistence of significant percentages in the 6.0 - 7.8 mm size class suggested that moderate rates of recruitment probably continued through October. However, the percentage in the 6.0 - 7.8 mm size class was greatly diminished by December, low through March, and zero in the May sample. These data suggested little if any recruitment of juveniles during the winter and spring months. Growth of the young-of-the-year age class was reflected in increasing mean lengths of samples from June to August; however, mortalities in the 14.0 - 15.8 mm size class appeared to offset growth in mean lengths for October and December samples.

The abundant production of "minute, chalky eggs" by *S. apioceros* during fall and winter months was not followed by proportional recruitment of juveniles (Fig. 1). Because minute eggs also did not show measurable increase in size or other evidence of maturation, it seems unlikely that they were destined to develop. During October, December, and January, most ovigerous specimens of *S. apioceros* carried either minute eggs only (eggs minute, chalky) or minute and normal eggs simultaneously (eggs mixed). Specimens with normal eggs only (eggs normal), which predominated from March through August, were not found until January (when they occurred as a very low percentage among ovigerous specimens). Of the specimens with minute eggs only, most ranged from 9.0 - 11.8 mm in length and 67 - 87% had male-form abdominal pleura. However, most

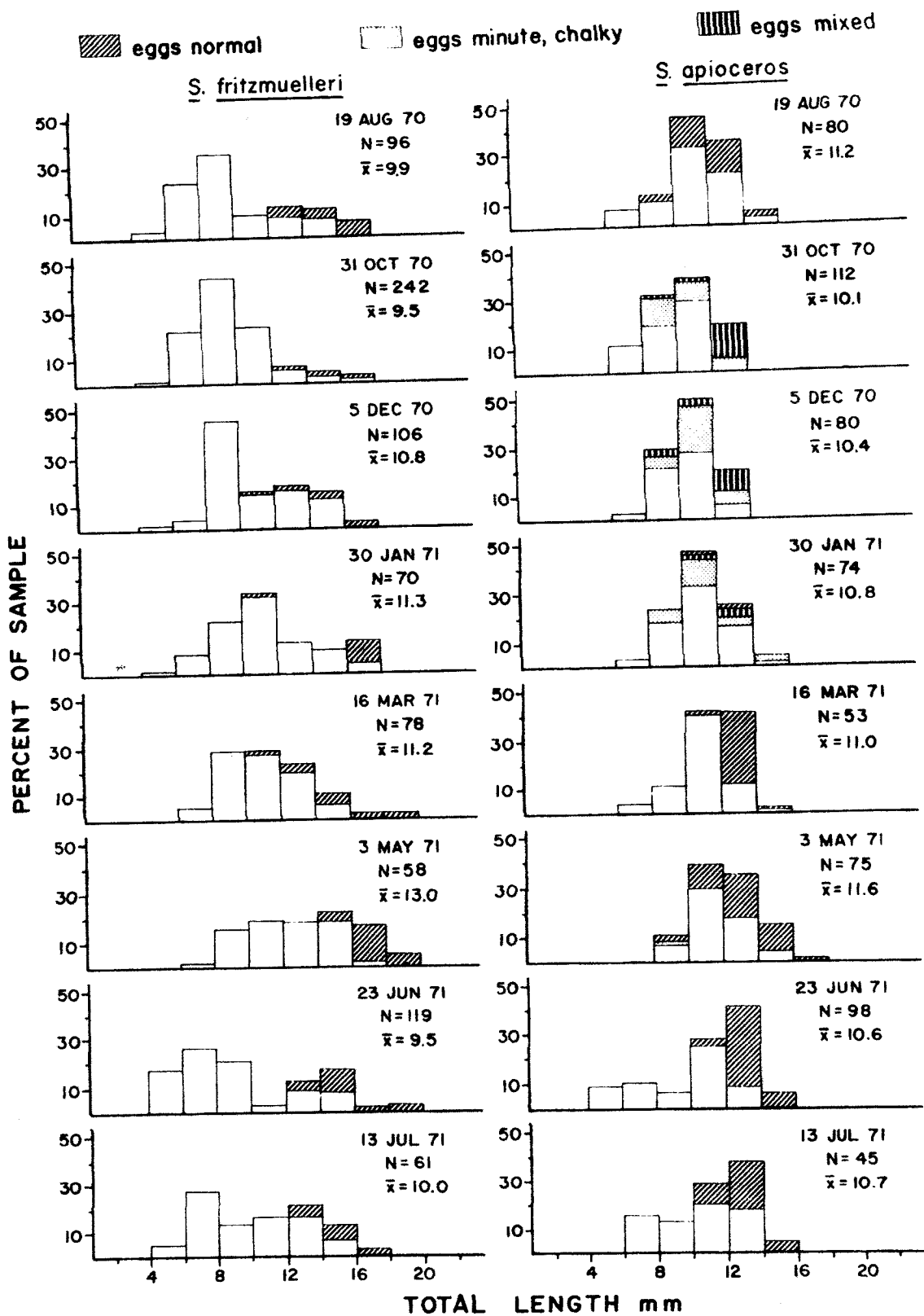


Figure 1. Length-frequency histograms of *S. fritzmuelleri* and *S. apioceros* collected from Seven and One-half Fathom Reef in 1970 and 1971. "Eggs normal" indicates percentages comprised of specimens with normal eggs only; "eggs minute, chalky" indicates percentages with minute, chalky eggs only; "eggs mixed" indicates percentages which carried normal and minute eggs simultaneously.

specimens with "eggs mixed" were ≥ 12 mm in length and fewer (31 - 40%) had male-form pleura. In contrast, male-form pleura occurred on $< 3.0\%$ of the *S. apioceros* and *S. fritzmueelleri* specimens that carried normal eggs only.

Although normal eggs were not enumerated during these studies, fall and winter specimens of *S. apioceros* with normal eggs appeared to have a much smaller mass of normal eggs than did the spring and summer specimens. Similar but less obvious variation in egg masses was noted for *S. fritzmueelleri*. The reproductive cycle represented in Figure 3 does not therefore accurately reflect fecundity, and reproductive activity is actually lower in fall and winter months than suggested by the percent of specimens with normal eggs. During spring and summer months, some specimens of both species were observed to have ripe ovaries while carrying large broods of normal eggs; this suggests that the deposition of at least two broods per year is possible in at least some individuals.

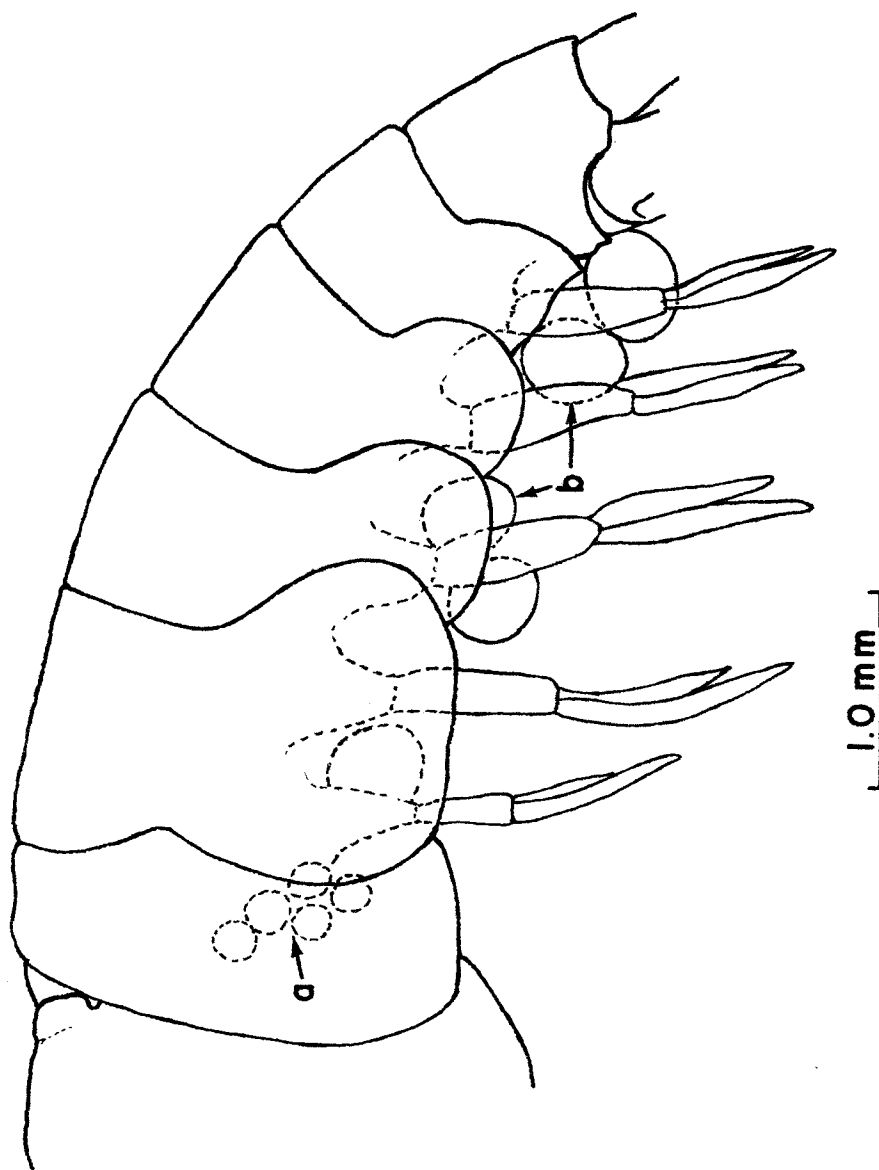


Figure 2. Abdomen of ovigerous *S. apioceros* from Seven and One-half Fathom Reef with both minute, chalky eggs (a) and normal, yellow eggs (b). Specimen figured is from sample taken October 31, 1970.

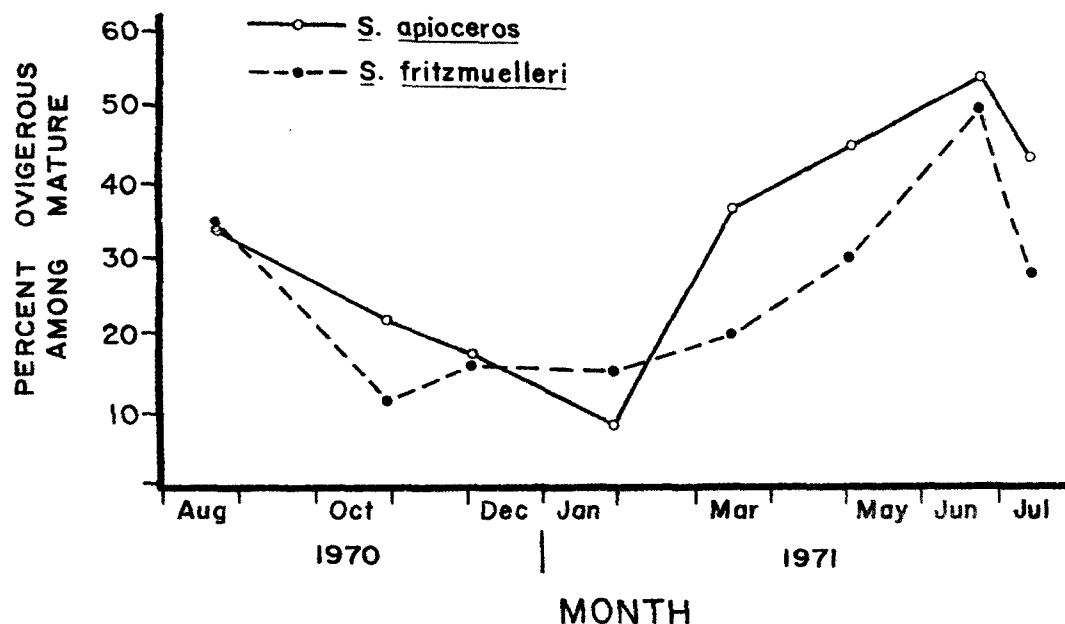


Figure 3. Percent normal ovigerous specimens (those with normal, yellow eggs) among mature-size *S. fritzmueelleri* and *S. apioceros* collected from Seven and One-half Fathom Reef, August 1970 to July 1971. Mature size is ≥ 10 mm for *S. fritzmueelleri* and ≥ 9 mm for *S. apioceros*. Counts of *S. apioceros* include those specimens which carried minute and normal eggs simultaneously.

DISCUSSION

The reproductive cycles here reported are for two species which differ somewhat in geographic distribution. The western Atlantic range of *Synalpheus fritzmueelleri* extends from North Carolina to Estado de Santa Catarina, Brazil (Williams 1965, Chace 1972), and encompasses warm-temperate as well as subtropical and tropical waters. The known latitudinal range of *S. apioceros* is restricted to more tropical waters from Southern Florida to Surinam (Chace 1972). On Seven and One-half Fathom Reef, these species are exposed to transitional water conditions; coastal waters bathing the reef originate from the northern Gulf in winter months and from the more tropical southwestern Gulf in summer months (Watson and Behrens 1970). Consequently, water temperatures on the reef vary between winter lows of 13 - 15°C and summer highs of 26 - 30°C (Tunnell and Chaney 1970, Felder and Chaney 1979). The temperature regime on the reef could therefore be regarded as marginally adequate for establishment of tropical species, such as *S. apioceros*, but well within the extremes of variation normally found within the range of *S. fritzmueelleri*.

In accommodating local conditions, mechanisms such as winter dormancy and attenuation of the breeding period are often exhibited by decapods adapted to warmer temperature regimes (Christensen and McDermott 1958, Williams 1965, Abele 1970). During winter months on Seven and One-half Fathom Reef, reproduction is attenuated in populations of both *S. fritzmueelleri* and *S. apioceros*; although some ovigerous specimens occur throughout the year, much lower percentages of both populations carry normal eggs in winter months and broods of these eggs appear to be smaller.

Ovigerous specimens of *S. fritzmueelleri* are known from February and June through October in the Carolinas, and a long breeding season has consequently been suggested for this species in that area (Williams 1965). Reported patterns of water circulation off the Carolinas (Cerrame-Vivas and Gray 1966) produce temperature regimes which are in many respects similar to those off Texas, so the occurrence of ovigerous specimens could be expected during most, if not all, months of the year in both areas. It is also likely, however, that the percentage of ovigerous specimens cycles in response to temperature in both area, and that reproduction of *S.*

fritzmuellerei in all such warm-temperate regions of the western Atlantic is attenuated during winter months. The reproductive strategy of *S. fritzmuellerei* in tropical areas is not known well enough to permit detailed comparisons with present findings; however, ovigerous specimens are apparently common from at least January through April on St. Helena Island at latitude 15° 58'S (Chace 1966).

Several hypotheses have been previously advanced to account for various forms of anomalous small eggs which occasionally occur on snapping shrimps, but it seems doubtful that any single hypothesis can account for all forms in the several species concerned. In the present case, it is assumed that the "minute, chalky eggs" found on *S. apioceros* are indeed eggs, and that, from the evidence available, these eggs are not viable. The seemingly wasteful production of non-viable, minute eggs by *S. apioceros* during winter months and the absence of these eggs in *S. fritzmuellerei* under the same ambient conditions could relate to the more tropical restriction of the former species. On Seven and One-half Fathom Reef, *S. apioceros* is probably near the northernmost extreme at which it can successfully reproduce, and one may expect that its adjustment of breeding activities to winter temperatures would not be as refined as that of *S. fritzmuellerei*. However, whether *S. apioceros* also produces these minute eggs during reproductive cycles in the tropics remains to be determined; ovigerous specimens of *S. apioceros* occur during April in tropical waters of the Lesser Antilles and eastern Yucatan (Chace 1972), but annual reproductive cycles in these areas have not been studied.

The minute, chalky eggs of *S. apioceros* appear to be much like small, chalky eggs which Coutière (1909) described from *S. brooksi*. Coutière noted that the females bearing these eggs "have in their abdominal pleura the characters of males, as if they had been castrated by some internal parasite." Chace (1972) also reported the occurrence of "spherical objects, possibly infertile eggs" on the pleopods of *S. brooksi* specimens with male abdominal pleura. A high percentage of *S. apioceros* specimens with minute eggs have male-form pleura, but close inspection reveals no overt evidence of parasitism, except for the occasional occurrence of bopyrid isopods. It furthermore seems unlikely that the effects of parasitic castration would be exhibited on Seven and One-half Fathom Reef almost exclusively in fall and winter months.

In the genus *Synalpheus*, immature specimens of either sex may have pleura similar to those of the adult males (Coutière 1909). Specimens with male-form abdominal pleura may thus include immature females, and their minute, chalky eggs may be the first ones produced before fertile ones appear. The application of this hypothesis to the present length-frequency data for *S. apioceros* (Fig. 1) suggests that it is the young-of-the-year age class that produces minute, chalky eggs during the fall and winter months. It then appears that the larger females (12.0 - 13.8 mm) of this age class are more likely to simultaneously carry both minute and normal eggs during these months, and that, with the approach of spring, these larger females of *S. apioceros* are the first to show elevated reproductive activity. As the production of minute eggs is primarily a fall and winter activity, exclusive in this case to *S. apioceros*, the phenomenon may still represent the temperature response of a tropical species near the limits of its latitudinal range. In other words, the coincidence of decreasing winter temperatures with maturation of young-of-the-year females may physiologically limit reproductive activity to the production of minute, chalky eggs in this species.

Eventual studies of reproduction by *S. apioceros* under the more stable temperature regimes of the tropics should be undertaken to test the credibility of this hypothesis. The mechanism of sex determination in this species should likewise be investigated, as present data could reflect some environmentally influenced sexual lability in *S. apioceros*. Suzuki (1970) reported protandrous, consecutive, hermaphroditism in four species of *Athanas*, one of the lower genera of the Alpheidae. However, Banner and Banner (1973) have noted that "To date, there is no evidence of sexual ambiguity in the higher genera."

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THE ASCIDIANS OF THE ARANSAS PASS INLET JETTIES, PORT ARANSAS, TEXAS¹

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ABSTRACT

The ascidians of the Aransas Pass inlet jetties at Port Aransas, Texas were surveyed and their relative abundance determined. Seven species previously unreported from the northwestern Gulf of Mexico were identified. The ascidian component of samples taken from the base of the jetties averaged 54.1% of the total biota, with a mean abundance of 1406.5 ml/m². In quantitative samples, *Eudistoma carolinense* was the most abundant, by volume, and *Didemnum candidum* was the most frequently occurring species. An annotated checklist of species is given.

INTRODUCTION

Ascidians are one of three classes of Tunicata (Urochordata), a group of exclusively marine invertebrates. Ascidians are usually sessile as adults and may be simple or compound. The soft, sac-like body or zooid is enclosed in an outer tunic called the test, which is gelatinous or tough and leathery.

Van Name (1954) stated that of the 81 [Millar (1971) cited 83] species of ascidians reported from the West Indian region, 71 have been found in the Gulf of Mexico. Most Gulf ascidians have been collected in the shallow waters of southwestern Florida. In comparison, the northern Gulf of Mexico ascidian fauna is less diverse but abundant in individuals. A preliminary survey of western Gulf species reported in Plough (1978) and based upon collections by Rabalais (1975) indicated affinities to the West Indian faunal group. A large portion of the Gulf coast, including Texas and Mexico, awaits further investigation.

Although Hildebrand (1954) rarely found ascidians in trawl catches in the northwestern Gulf of Mexico, he did report *Styela partita* (Stimpson) and *S. plicata* (Lesueur) attached to shell debris. Whitten et al. (1950) also reported *S. partita* and *S. plicata* from old shells in shallow water offshore at Port Aransas and Port Isabel. Behre (1950) stated that *Molgula manhattensis* (DeKay) ranged along the Gulf coast as far as southern Texas. Holland et al. (1973) tentatively listed *M. manhattensis* as a member of the benthic community of Galveston Bay. Plough (1978) has listed *Trididemnum savignii*, *Ascidia curvata*, *Molgula complanata*, *Eugyra arenosa padrensis*, and *Bostrichobranchus pilularis* from the south Texas coast and *Eudistoma capsulatum* and *E. hepaticum* from the western Gulf south of Texas.

Studies in the distribution and abundance of ascidians are few. Millar (1971) stated that the local distribution of ascidian fauna presents many ecological problems and that striking differences in ascidian fauna of apparently similar habitats await explanation. The significance of ascidian fauna on solid substrates has scarcely been investigated, and Millar (1971) feels the group may be an important component in the economy of coastal waters.

Since the Texas coast is naturally devoid of rocky shores, solid substrates are usually represented by jetties, seawalls, piers and other artificial structures. Whitten et al. (1950) described the general characteristics and biota of the Texas coast jetties. A brief description of the organisms of the Port Aransas jetties and their zonation was given by Hedgpeth (1953), while Fotheringham and Brunenmeister (1975) also discussed common marine invertebrates of jetties in the northwestern Gulf. Hedgpeth (Whitten et al., 1950), in an annotated checklist of marine invertebrates on Texas jetties, stated that while no ascidians had been collected from the jetties,

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it was probable that one species, *Molgula manhattensis*, occurred but had been overlooked.

While no single abiotic factor controls the composition of any jetty ecosystem, a combination of factors including wave action, scour, shifting sand, turbidity, sudden variations in salinity, tidal fluctuations, and climatic conditions, all influence the habitat (Collard and D'Asaro, 1973). Ascidians are sensitive to reduced salinity, the amount of suspended organic matter, and changes in water temperature and turbidity (Van Name, 1945; Wells, 1961; Millar, 1971). Consequently, by their presence and abundance, or absence, they represent possible sources of water quality indicators.

The ascidians of the Aransas Pass Inlet Jetties, Port Aransas, Texas were studied as part of an ecological survey of hard substrate areas on the south Texas coast (Rabalais, 1975). The purpose of the study was to survey and identify the ascidians present, determine their relative abundance, and supplement knowledge of the ecology of these insufficiently studied organisms.

DESCRIPTION OF STUDY AREA

Aransas Pass Inlet is located at approximately 27°50' N, 97°02.5'W (Fig. 1) and connects the Corpus Christi-Redfish-Aransas Bay system with the Gulf of Mexico. A jetty complex maintained by the United States Army Corps of Engineers stabilizes this navigable channel. The jetties were constructed between 1907 and 1916, and concrete caps were added between 1935 and 1955. They have been repeatedly repaired, most recently in 1972. The north jetty is 2.8 km long, and the south is 2.2 km. The distance between them is approximately 0.5 km (Fig. 1).

The jetties are roughly triangular in cross-section and constructed of large granite rocks over a fill of rubble and small stones (Fig. 2). Water depth is approximately 3.5 m on the Gulf side, 6 m on the aprons at the ends of the jetties, and 15 m in the channel.

METHODS

Most quantitative collections were made on the south side of the south jetty, 1.2 km from the origin, near the Corps of Engineers survey marker 38 + 00 (Station SS in Fig. 1 and Table 1). This station was sampled seasonally from June, 1973 to August, 1974. Additional quantitative samples were taken from the south side of the south jetty near the beach (Station SSB in Fig. 1 and Table 1) and the end of the south jetty (Station SE in Fig. 1 and Table 1). Random collections were made at these stations and at other points on both jetties.

Meteorological (air temperature, wind speed and direction, cloud cover) and hydrological (water temperature and salinity, depth, visibility, wave height, current) data were recorded during the study period so that any observable influences of abiotic factors on the distribution of ascidians could be noted.

Collections were made in 2 to 6 m deep water by snorkeling and scuba diving. For quantitative samples, a randomly selected area of 0.25 m² was delimited on the bottom by a circular galvanized cable. The epifauna inside the cable was removed by various methods depending on the type of substrate. On a solid, continuous, fairly level substrate, the epifauna was scraped from the rocks. When the bottom consisted of small stone rubble, all rocks from the surface of the area were collected.

Studies in the distribution and abundance of ascidians have dealt primarily with solitary species that are easily quantified by number of individuals or size. These measurements are not applicable to colonial ascidians which vary inter- and intra-specifically in number of zooids per colony and colony size and growth form. In this study, therefore, relative abundance was determined by volumetric displacement in water and expressed in ml/m².

For each 0.25 m² sample, the total volume of all biota was determined. In samples which contained rocks, all organisms were separated from the substrate prior to volumetric determinations. The ascidians were separated from other organisms and identified to species. The total volume for each ascidian species was determined. Some approximations were made because of the difficulty involved in separating ascidians from the substrate, each other, or other organism. The remainder of the sample was examined to identify and count the associated biota.

The identification of ascidians is often problematic. The zooids are small (1 to 3 mm), anatomical parts are soft and contractile, and variations may result from the method of preservation or physiological condition. Morphological studies were facilitated by dissections and microscopic techniques as outlined by H. H. Plough (personal communication, Amherst College, Amherst, Mass.), Van Name (1930, 1945), Gosner (1971), Berrill (1950), Millar (1970), Smith

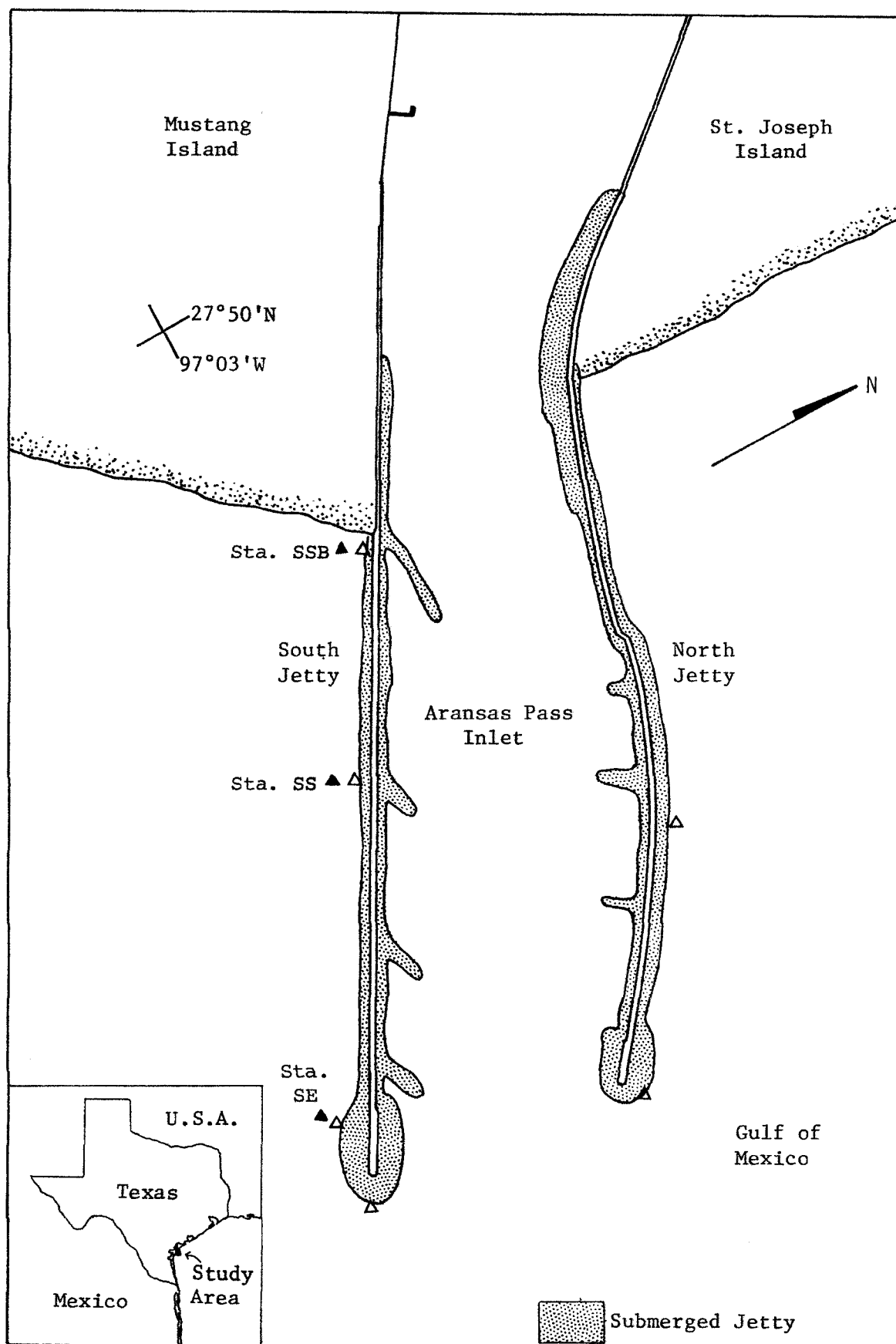


Figure 1. Location of study area at Aransas Pass Inlet jetties, Port Aransas, Texas with points of collection (▲ quantitative samples, △ random samples).

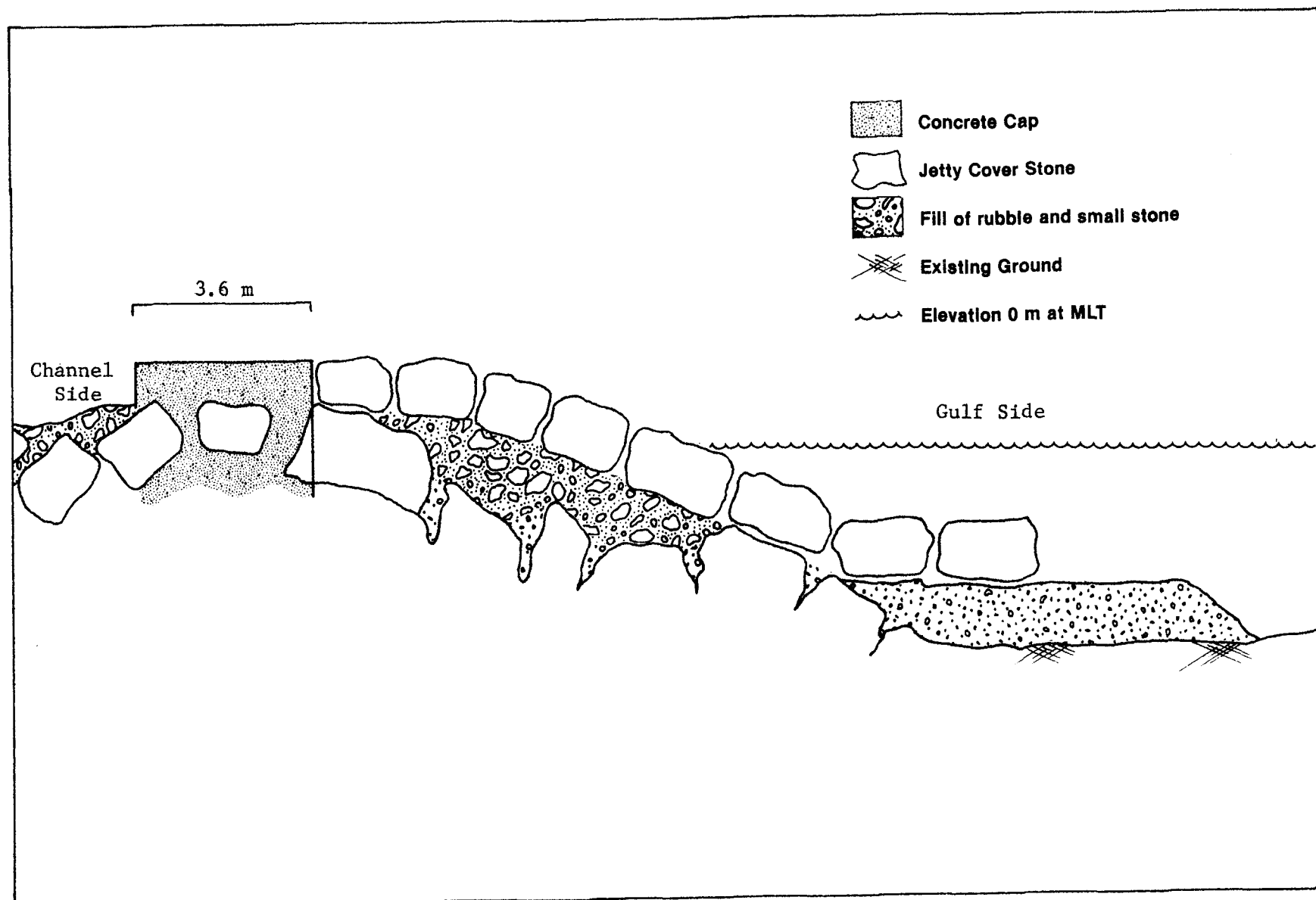


Figure 2. Typical cross-section of Aransas Pass Inlet jetty, Port Aransas, Texas at U.S. Army Corps of Engineers station 27 + 00 to 59 + 31.

Table 1. Relative abundance, by volume, and diversity of ascidians. Abbreviations for stations (SS = south side of south jetty, SE = end of south jetty, SSB = south side of south jetty near beach).

Item	Sample Dates							
	30 Sep 1973	2 Dec 1973	6 Jan 1974 A	6 Jan 1974 B	8 May 1974	8 May 1974	25 Jun 1974	15 Jul 1974
Location of sample	SS	SS	SS	SS	SS	SE	SSB	SS
Total biota (ml/m ²)	3280	720	1080	600	220	1280	6084	2200
Total volume of ascidians (ml/m ²)	2000	280	540	140	100	648	6080	1460
Percentage composition of ascidians (%)	61.0	36.1	50.0	23.3	45.4	50.6	99.9	66.4
Volume (ml/m ²) of ascidians by species								
<i>Didemnum candidum</i>	1740	200	486	36	4	80	-	580
<i>Diplosoma macdonaldi</i>	-	-	-	-	-	-	<1	-
<i>Trididemnum savignii</i>	-	-	-	-	-	280	-	-
<i>Eudistoma carolinense</i>	-	40	27	-	8	100	6080	860
<i>Distaplia bermudensis</i>	256	40	27	104	-	8	-	20
<i>Perophora viridis</i>	-	-	-	-	-	-	<1	-
<i>Symplegma viride</i>	4	-	-	-	88	180	-	-

(1964), C. Monnoit (1972a, 1972b), F. Monnoit (1972), and Plough (1978). Problematic specimens were sent to H. H. Plough for verification and/or identification.

Non-ascidian organisms were identified to major descriptive taxa. All specimens of ascidians and representative samples of quantitative collections were catalogued and placed in the Texas A&I University Invertebrate Collection, Kingsville, Texas.

RESULTS

During the study period, water temperature ranged from 13.5 to 30.8 °C; air temperature, from 19 to 32 °C; salinity, from 24 to 32‰; and water visibility, from 0.2 to 6.0 m.

A total of 11 species were identified, representing five families within two orders (see Annotated Checklist). All species were listed by Van Name (1945) from the West Indian region.

Only five species, *Didemnum candidum* Savigny, *Trididemnum savignii* (Herdman), *Eudistoma carolinense* Van Name, *Distaplia bermudensis* Van Name, and *Symplegma viride* Herdman, were found often enough in quantitative samples to warrant further discussion of their relative abundance. Two species, *Diplosoma macdonaldi* Herdman and *Perophora viridis* Verrill, were found in negligible amounts in only one quantitative sample. The remaining four species, *Aplidium* sp. (cf. *exile*), *Didemnum* sp. (cf. *vanderhorsti*), *Didemnum albidum* (Verrill), and

Trididemnum sp. (cf. *orbiculatum*), were collected only in random samples.

The size of the samples varied considerably (Table 1). The mean volume of total biota was 1933 ml/m² and ranged from 220 to 6084 ml/m². The volume of ascidians ranged from 100 to 6080 ml/m², with a mean of 1406.5 ml/m². The ascidian portion of the samples averaged 54.1% and ranged from 23.3 to 99.9%.

In the quantitative samples, *Eudistoma carolinense* was the most abundant, by volume, with a mean of 889.7 ml/m², and *Didemnum candidum* followed at 390.7 ml/m² (Fig. 3). The high mean volumetric displacement of the former was attributable to the dense, thick mats collected on the south side of the south jetty near the beach.

The species with the greatest frequency of occurrence in all quantitative samples was *Didemnum candidum* (87.5%) (Fig. 3). *Eudistoma carolinense* and *Distaplia bermudensis* followed at 75% each.

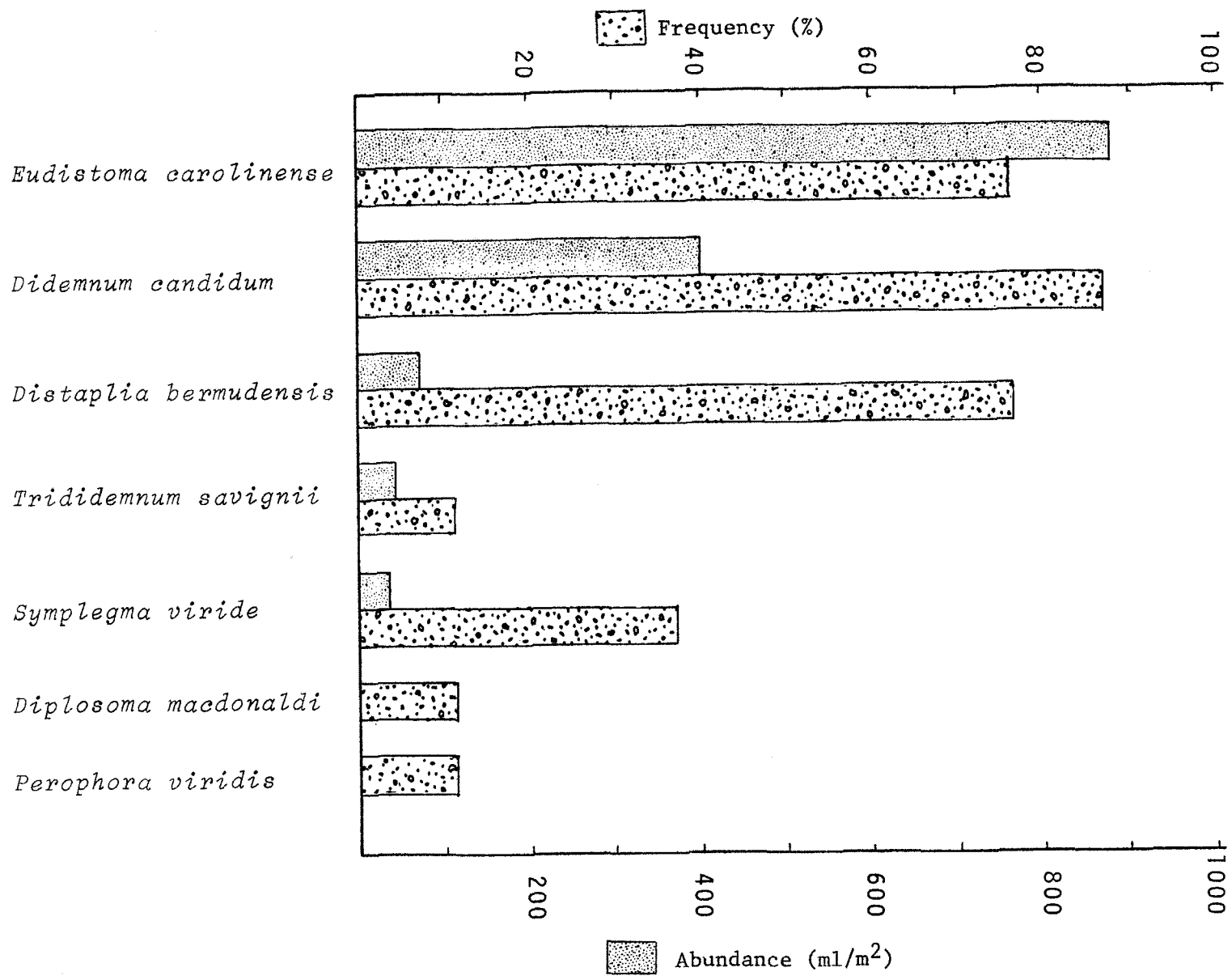
The diversity of ascidians varied with location on the jetty. The greatest number of species was found at the end of the south jetty (Station SE) where all but three of the eleven species were collected. The least number of species was found in the *Eudistoma carolinense* mats on the south side of the south jetty near the shoreline (Station SSB). These samples were composed almost entirely of *E. carolinense* with two other ascidians being epizoic. Intermediate number of species occurred at the collection point midway on the south side of the south jetty (Station SS).

Turbulence, wave action, scour and shifting sand may have been influential in the distribution of the ascidians on the jetties. With increased water depth, these factors seemed to be less influential on the type of colonies that were established.

Although the volume of ascidians fluctuated with water temperature and salinity, the correlation coefficients (0.85 and 0.60, respectively) were not significant at the 95% level.

That portion of the quantitative samples not composed of ascidians was made up of a wide variety of biota including red and brown algae, yellow boring sponges, sea anemones, acorn barnacles, polychaete worm tubes, oysters, and colonial hydroids. In addition to these encrusting organisms, there were varying quantities of invertebrates, including polychaetes, amphipods, decapod crustaceans, pelecypods, gastropods, and ophiuroids.

Figure 3. Frequency and abundance of ascidians.



ANNOTATED CHECKLIST

Classification follows that of Plough (1978). Species descriptions are in agreement with Van Name (1945) and Plough (1978) unless otherwise noted.

Phylum Chordata
Subphylum Urochordata
Class Ascidiacea
Order Enterogona
Suborder Aplousobranchia
Family Clavelinidae
Subfamily Polycitorinae

***Eudistoma carolinense* Van Name, 1945**

This was one of the more common ascidians found in the study area. The colonies formed compact, thick mats against the flat surfaces of rocks. The colonies were composed of groups of long, narrow, and irregularly tapering clavate heads supported by an expanded encrusting base. The heads were widened on the end and narrower and flattened towards the base. The rigid test, embedded with coarse sand grains, formed the bulk of the colony. The zooids were located near the surface of the clavate heads. Developed larvae were found in the atrial chambers of zooids collected in June and August.

The colonies provided an additional substrate and habitat for numerous organisms. They were often covered by anemones, hydroids, sponges, barnacles, and other ascidians, such as *Perophora viridis*, *Diplosoma macdonaldi*, *Didemnum albidum* and *Trididemnum savignii*. The spaces between the clavate heads were occupied by dense concentrations of molluscs, ophiuroids, decapod crustaceans, amphipods, and polychaetes.

Subfamily Holozoinae

***Distaplia bermudensis* Van Name, 1902**

This ascidian was found on both jetties. The living colonies were more varied in color than any other. They were brilliant green, blue-green, pale blue, whitish, mud brown, and sometimes mottled and marbled with areas of red and pink. The forms of the colonies were equally variable sometimes capitate, consisting of one or more heads tapering to a short stalk. Others were flat, smooth, encrusting sheets, 7 to 10 mm thick. A few colonies were found growing on *Eudistoma carolinense*. Brood pouches with developing larvae were found in zooids collected in August.

Distaplia bermudensis is commonly and widely distributed in the West Indian region and on both coasts of Florida (Van Name, 1945) and is among the more common and conspicuous ascidians of the Gulf of Mexico (Van Name, 1954), as well as the commonest species on the Atlantic continental shelf (Plough, 1978).

Family Polyclinidae

***Aplidium* sp. (cf. *exile* Van Name, 1902)**

The only specimen of this gold-colored, encrusting colonial ascidian was collected in approximately 6 m of water at the end of the south jetty. Irregularly distributed, white zooids were visible through the semitransparent test. The surface was smooth with rounded, projecting lobes. The colony was 85 by 35 mm and 8 to 9 mm thick.

Family Didemnidae

***Didemnum candidum* Savigny, 1816**

This was one of the more common species found during the study. The encrusting colonies were translucent to opaque white with the zooids arranged in patterns around common cloacal apertures. The opaqueness of the test was due to an abundance of spicules. Color variations of pale orange, pinkish orange, yellow or drab brown were found. The colonies were extensive (80 to 90 mm in diameter) and usually 2 to 3 mm thick.

Didemnum candidum has been found on both coasts of Florida (Van Name, 1945) and is listed by Van Name (1954) as one of the more common and conspicuous ascidians in the Gulf of Mexico.

***Didemnum* sp. (cf. *vanderhorsti* Van Name, 1924)**

The only colony was found in 5 m of water off the end of the south jetty. The colony was bright orange in life, fading in preservatives. The colony was encrusting, massive and smooth with rounded lobes. The test was fairly translucent with the white zooids and common cloacal apertures visible in the matrix. The zooids were irregularly distributed, and spicules were absent.

***Trididemnum savignii* (Herdman, 1886)**

A few specimens were found on the south jetty in 3.5 and 6 m of water. Colonies were encrusting, irregularly shaped and often massive. The matrix, which contained brown pigment cells, resembled soft mud. White spots in the test were congregates of stellate spicules. The matrix of the colony nearest the substrate was more translucent with heavy concentrations of spicules. The colonies were flattened against the substrate or around objects such as hydroid stalks, polychaete tubes, and lobes of the ascidian *Eudistoma carolinense*.

Trididemnum savignii is reported from the west coast of Florida (Van Name, 1945) and off the south Texas coast (Plough, 1978).

***Didemnum albidum* (Verrill, 1871)**

Only one colony was found. The thin, encrusting colony was fairly translucent but appeared chalky white because of the many stellate spicules embedded in the upper layers of the test. The surface, in life, was smooth, but in preserved materials was uneven and raised at the zooids. The area of the test above the zooids was usually clear and circular with the intervening areas whiter and more opaque.

***Trididemnum* sp. (cf. *orbiculatum* (Van Name, 1902))**

A single specimen was collected from the end of the south jetty in 6 m of water. The colony was encrusting with low, rounded lobes and colored mud brown from pigment cells in the test. The whitish zooids were visible through the test. No spicules were present. The zooids were characteristic of the didemnids with three rows of stigmata.

***Diplosoma macdonaldi* Herdman, 1886**

A single colony was found growing on *Eudistoma carolinense*. Because of the structure of this species, others may have been overlooked. The encrusting colony was thin and delicate, with a transparent test, usually colorless but sometimes suffused with milk white. The irregularly distributed zooids were clearly visible through the test. According to Van Name (1945), this ascidian grows on pilings, corals, gorgonians, sponges, and especially on other ascidians, often close to the low-water mark.

The species is reported from both coasts of Florida (Van Name, 1945).

**Suborder Phlebobranchiata
Family Perophoridae**

***Perophora viridis* Verrill, 1871**

This ascidian was always found attached to colonies of *Eudistoma carolinense*. The small size (1 to 2 mm diameter) of the zooids may have been a reason why more were not found in samples. The compound species was composed of sac-like ovoid zooids united by slender stolons which grew like vines over objects. The test was thin and semitransparent covering a yellowish-green mantle.

This ascidian is one of the more common and conspicuous species found in the Gulf of Mexico (Van Name, 1954).

**Order Pleurogona
Suborder Stolidobranchia
Subfamily Polyzoinae
Family Styelidae**

***Symplegma viride* Herdman, 1886**

Specimens were found on both the north and south jetties. The colonies were normally thin and encrusting and occasionally thicker and more irregularly shaped when growing on branching objects. The colonies were extensive, measuring 60 to 90 mm across. The dark purple, sac-like

zooids were visible through the transparent gelatinous test. The zooids were irregularly distributed in the test.

Symplegma viride is reported from both coasts of Florida (Van Name, 1945).

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OBSERVATIONS ON THE BIOLOGY OF *Tozeuma carolinense* (CRUSTACEA: HIPPOLYTIDAE) FROM REDFISH BAY, TEXAS

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ABSTRACT

The caridean shrimp, *Tozeuma carolinense*, occurring in seagrass meadows of Redfish Bay, Texas, was sampled for 12 consecutive months. Samples were taken from discrete beds of *Thalassia testudinum* and *Halodule beaudettei* as well as a shallow water unvegetated area. Populations of *T. carolinense* were present in these grass beds throughout the year with major concentrations occurring October to January. Population densities were greatest in *Thalassia* (73.5% of total), followed by *Halodule* (26.3% of total). No significant difference in the day/night abundance was found. The number of eggs carried by females was positively correlated with increasing carapace length.

INTRODUCTION

Redfish Bay, Texas, supports vigorous stands of turtlegrass (*Thalassia testudinum*, Koenig) and shoalgrass (*Halodule beaudettei*, den Hartog). Such seagrass meadows provide habitat for many organisms (Parker 1959, Phillips 1960, and Moore 1963) including crustaceans such as the small caridean stick shrimp, *Tozeuma carolinense* (Kingsley 1878). Although earlier studies of Redfish Bay (Ladd 1951, Parker 1955, and Hoese and Jones 1963) did not mention *T. carolinense*, Zimmerman (1969) in his seasonal investigation of the biota of turtlegrass in Redfish Bay provided some information concerning its abundance. This study considers the seasonal abundance, distribution among habitat types, sex ratios, and some other ecological aspects of the life history to *T. carolinense*.

METHODS

Seagrass meadows surrounding Stedman Island, Redfish Bay, were visited monthly between February 1974 and January 1975. These meadows were composed of turtlegrass and shoalgrass growing in discrete beds with little intermixing. Turtlegrass grew farthest offshore in water depths between 45 cm and 130 cm. No seagrasses were found at depths greater than 1.3 m, probably as a result of poor light penetration in this turbid bay. Shoalgrass grew in depths between 20 cm and 45 cm. Inshore to the shoalgrass was an unvegetated area.

A push-net modified from that described by Allen and Ingles (1958) was used to sample for small natantian crustaceans. Twice daily, once in the afternoon and once in the early evening, two 10-m transects were sampled from each of the three areas. At completion of each transect, contents of the seine were placed in plastic bags, labeled, and formalin added. A total of 144 seine samples were taken during the one year period, 12 samples per trip per month. The samples were returned to Texas A&I University for sorting and counting of individuals.

Biology of *Tozeuma carolinense*

Members of the genus *Tozeuma* are easily separated from other carideans by their extremely long rostrum, nearly twice the length of the carapace proper, and their long narrow body. Although three species of *Tozeuma* occur in the Western Hemisphere, only *Tozeuma carolinense* was taken. This species ranges from Massachusetts to Florida, through the West Indies to the northern coast of South America, and along the Gulf coast of the U.S. to Yucatan, and Panama (Bryce 1961 and Williams 1965). It occurs in shallow water to depths of 75 m (Holthuis 1947). Commonly found inhabiting seagrass beds of *Thalassia*, *Zostera*, *Halodule*, and *Cymodocea* (Ewald 1969), it has also been reported to occur among colonies of alcyonarians of the genera *Antillogorgia* and *Pterogorgia* (Voss 1956). These carideans display a variety of colors typically ranging in shades of green from light yellowish green to a rich deep green; however brownish and

red individuals occur frequently (Bryce 1961). Purple individuals were collected by Voss (1956) from alcyonarians in Florida. Nearly colorless individuals were reported by Verrill (1922). Individuals collected during this study were commonly yellowish green to dark green or light to dark brown.

Tozeuma carolinense was collected during all months of the year, although relatively few individuals were taken in February and April through July (Fig. 1). Recorded water temperatures ranged from 17°C in December to 33°C in August. Salinities ranged between 13 ppt and 36 ppt. Of the 3194 individuals collected during this study, only 27 were taken in February, but more than 250 individuals (11% of total) in March. After a decline in population densities for April and sustained low densities through July, a slight increase in population density was noted for August. This increase continued through September with maximum densities occurring between September and January (84% of total). This major peak density period corresponded to a marked decline in the water temperature and salinity. Densities as high as 200 individuals per square meter from grass beds of Florida have been reported by Ewald (1969); however, the maximum density recorded during this study was 75 individuals per square meter with an average near 40 individuals per square meter for the peak months of September to January.

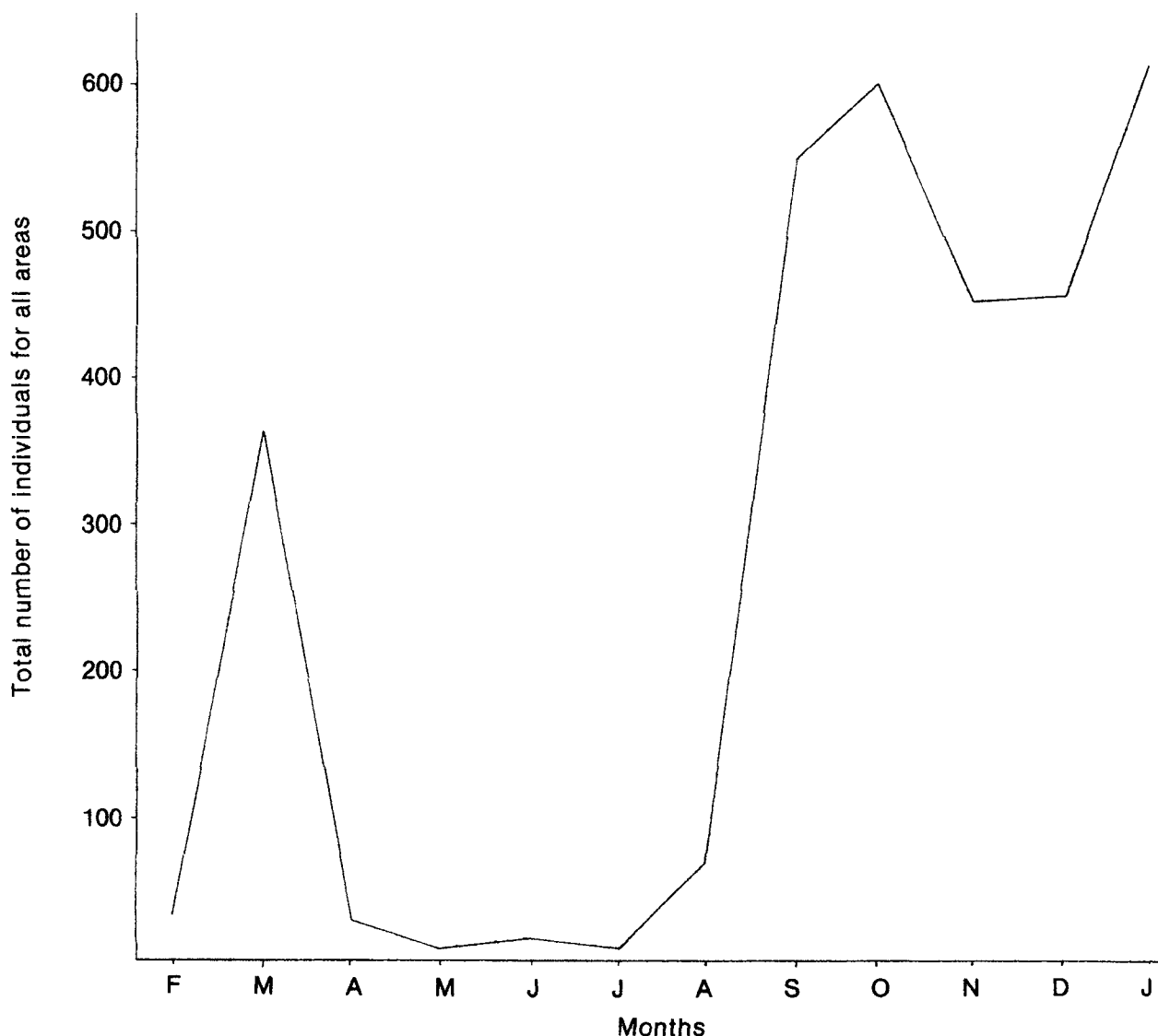


Figure 1. Total monthly catch of *Tozeuma carolinense*, Stedman Island, Redfish Bay, Texas, 1974-1975.

Population densities differed significantly between areas. The catch from the *Thalassia* area comprised 73.5% of the total, while only 26.3% was taken from the *Halodule* area and less than 1% from shallow waters of the unvegetated area near shore. In contrast, Ewald (1969) found the stick shrimp in greatest abundance in beds composed chiefly of *Cymodocea* and to a lesser extent in beds composed of both *Thalassia* and *Cymodocea*. He stated that *T. carolinense* was only occasionally encountered in beds composed purely of *Thalassia*.

There was no significant difference in the day/night abundance. Only slightly more stick shrimp were collected during the day with a day/night ratio of 1692/1502. Zimmerman (1969) found a day/night ratio of 1/1.2. This might be expected for animals which are dependent upon the blades of seagrasses for both food and protection. These shrimp apparently do not migrate out of the area on a daily cycle nor burrow into the sediment during the day as do some other shrimp. Bryce (1961) and Ewald (1969) reported the species to graze on the small epiphytic algae associated with the grass blades.

Sex ratios between adult *T. carolinense* was 10:1.6 ♀. Ovigerous females were found to be slightly larger than adult males. The mean carapace length of ovigerous females was 6.6 mm while the mean carapace length of males was 4.6 mm. No females were found to have a total length greater than 45 mm, although Zimmerman (1969) reported individuals as long as 50 mm. Williams (1965) gives the total length of ovigerous females as being between 28 mm and 50 mm.

Of 1966 females collected, only 149 (7.6%) were gravid. Ewald (1969) reported egg-carrying females as occurring year-round in Florida; however, during this study ovigerous females were taken between March and October, with 77 gravid females (52%) taken in the 3 months of August, September, and October. While approximately 200 eggs per ovigerous female were reported by Ewald (1969) from Florida, a mean of 129 eggs per female was determined for this study. The number of eggs carried by females was positively correlated ($r = 0.57$) with increasing carapace length, although many exceptions were found.

SUMMARY

Tozeuma carolinense occurs throughout the year in the grass beds of Redfish Bay, Texas. The population appears to have two peaks of abundance, one in March and another from October to January. These shrimp were found in greater abundance in *Thalassia* beds than in *Halodule* stands or unvegetated areas. No difference was determined in the day/night occurrence. Females were larger than males, and larger females tended to carry more eggs than smaller females. Samples contained slightly more females than males.

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CURRENT STATUS OF ROSEATE SPOONBILLS ON THE TEXAS COAST

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ABSTRACT

After nearly going extinct in Texas, Roseate Spoonbill populations have recovered and expanded. At present, over 2200 nesting pairs of spoonbills occupy 27 nesting colonies. There has been an apparent population shift from the upper to the central Texas coast. Approximately half of the colonies are now situated on dredged material islands. Although the spoonbill population is currently regarded as stable, human population expansions threaten that stability.

INTRODUCTION

During the period from 1850 to 1890, populations of Roseate Spoonbills, *Ajaia ajaja*, declined throughout their breeding range in the United States. By 1900 the species was almost completely extirpated from the Gulf Coast. In his monograph on the species, Allen (1942) attributed the decline to the cumulative effects of several factors: (1) spoonbills were killed to provide meat for commercial fisherman and Indians, (2) their breeding habitats were destroyed by the increasing human populations along the Gulf Coast following the Civil War, and (3) they were killed to provide commercial traffic in their feathers.

The decline in Roseate Spoonbill populations became so severe that in 1902 the National Audubon Society (then the National Committee of Audubon Societies) employed its first warden to protect Florida spoonbill colonies as well as the other wading birds that nested in the same area (Allen 1942). However, no breeding colonies of Roseate Spoonbills were known to remain in Texas by this time.

Roseate Spoonbills apparently did not breed in Texas during the period from approximately 1890 to 1923. Many ornithologists (Smith 1910, Pearson 1920, 1921, Friedmann 1925, Carroll 1927, Eifrig 1930) visited the Texas coast during this period and could not find evidence of spoonbill nesting activities even though many of them visited sites where spoonbills nest today. Pearson (1921) toured the entire Texas Coast and concluded that Roseate Spoonbills must breed in Mexico and later migrate to Texas. Griscom and Crosby (1925) listed the species as a "Summer Resident" of the lower Texas coast and speculated that a nesting colony was likely to be soon discovered.

The first known Texas nesting colony of Roseate Spoonbills in the Twentieth Century was discovered in 1923 by G. F. Simmons on the Second Chain of Islands in San Antonio Bay (in Bent 1926). In that same year A. C. Bent found a second colony nesting in swampy, forested bottomland along the Guadalupe River (in Allen 1942). Thereafter, the nesting population of spoonbills in Texas showed steady gains; by 1942 seven breeding colonies were established and the mid-summer (breeding and nonbreeding) population exceeded 5000 individuals (Allen 1942).

In the 25 years since the report by Allen, great changes have occurred along the Texas coast. Industrial and urban development have encroached upon natural habitats, the potential for colony disturbance has escalated with recreational usage of bays and lagoons by increasing human populations, and water quality and circulation patterns have been altered by dredging and damming activities. Because Roseate Spoonbills have been more closely surveyed on the ground in coastal Texas since the late 1930's than have most other waders (Ogden 1978), I thought it might be useful to examine recent population trends of this species. Information gained from a recent survey of dredged material island wading bird colonies (Chaney et al. 1978) will be included in a description of current nesting preferences.

POPULATION ESTIMATES, 1942-1968

Estimates of Roseate Spoonbill populations in Texas made during the period from 1942 to 1968 are unreliable. Observers counted all birds sighted; no attempt was made to distinguish

breeding birds from migrants and, furthermore, some observers included nestlings in their counts. Additionally, the published counts were made at various seasons and included different areas of the coast (Table 1). However, the population seemed to expand during this period. The number of known colonies increased from two (Sprunt 1935), possibly three (Allen 1942), to at least six (Oberholser 1974).

Table 1. Historical summary of Roseate Spoonbill census efforts, 1934-1974.

COUNT DATE		NUMBER COLONIES	NUMBER SPOONBILLS	METHOD NOTATION	REFERENCE
MONTH	YEAR				
April	1934	2	879	1	Allen 1935
June	1935	2	1865	1	Sprunt 1935
(Spring)	1939	-	844	2	Allen 1952
(Summer)	1941	3(?)	5035	2	Allen 1942
(Summer)	1950	-	526	2	Allen 1952
May	1968	± 6	4470	2	Oberholser 1974

METHOD NOTATION:

1. Total count of all birds observed from Galveston Bay south to lower Laguna Madre.
2. Total count of all birds observed from Sabine Pass to the Rio Gande River.

PRESENT STATUS

Beginning in 1968 a group was organized by Henry H. Hildebrand and Gene W. Blacklock to census colonial waterbird colonies along the central Texas coast. The census grew in scope to include all of Texas so that beginning in 1973 a coordinated effort was made to census all colonial waterbird colonies in Texas using standardized techniques during a limited period. Although this census, called the Texas Colonial Waterbird Census (Blacklock, et al. 1978), is not without sources of error and variability, it began to provide a much more reliable estimate of Roseate Spoonbill population trends.

The Texas population of Roseate Spoonbills seems to have stabilized at 2200 to 2400 nesting pairs (Table 2). There is some cause for concern that the population might be declining slightly. However, it is difficult to draw definite conclusions from census data alone; mortality rates, survivorship, and the effects of annual variations in climate upon nesting are unknown for this species.

One indicator of population stability is the number of colonies presently occupied by nesting spoonbills. In 1977 there were 27 colonies along the Texas coast. Most of the colonies and approximately half of the nesting pair are along the central coast. There appears to be a population shift occurring from the upper coast to the central coast, but this trend may be more imagined than real because not all colonies have been censused annually.

Approximately half of the colonies and half of the nesting pairs were situated on dredged material islands (Table 3). Most of the dredged material islands in Texas have been created since 1946 (Chaney et al. 1978). These islands have become significant nesting areas for colonial waterbirds and have undoubtedly contributed to the increase in Roseate Spoonbill populations since 1942.

Part of the recent expansion of Roseate Spoonbill populations is due to their ability to nest in a variety of habitats. Primitive colonies (before large human populations displaced them) of Roseate Spoonbills were situated in riparian forests or on islands. All records indicate that

Table 2. Total nesting pairs of Roseate Spoonbills and their distribution in the coastal regions of Texas, 1973-1977.

YEAR	COASTAL REGION			TOTAL PAIRS
	UPPER	CENTRAL	LOWER	
1973	1901	596	105	2606
1974	1427	919	120	2466
1975	1420	1271	30	2721
1976	1762	542	66	2370
1977	1037	1013	165	2215

Table 3. Distribution of nesting pairs and colonies of Roseate Spoonbills on dredged material islands and natural sites in 1977.

	COLONIES		PAIRS	
	NATURAL	DREDGED	NATURAL	DREDGED
TOTAL COUNT	14	13	1085	1130
PERCENT OF TOTAL	52	48	49	51

spoonbills nested exclusively in trees or shrubs. However, there are at least six colonies in Texas where Roseate Spoonbills nest on the ground.

Allen (1942) mentions that Roseate Spoonbill colonies must be free from human and predatory disturbance if nest success is to be achieved. Freedom from disturbance is a common factor in all 27 colonies of the spoonbill in Texas. Only one colony site (Shamrock Island, Corpus Christi Bay) is located closer than 1 km to regular human habitation. Four colonies are located along the Houston Ship Channel, but human encroachment on the colony islands is minimal.

In 1941 Allen (1942) counted 5035 Roseate Spoonbills in Texas. Of these approximately 33 percent were breeding birds. Therefore, there were about 830 nesting pairs. While the 2215 nesting pairs recorded in 1977 represents a substantial increase over the 36-year period, the population faces an uncertain future. Continued human population expansion, industrial and urban developments in coastal regions, and invasion of nesting areas by recreation-oriented activities do not bode well for the species.

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ANATOMICAL AND VEGETATIONAL FEATURES OF DREDGED MATERIAL ISLANDS AND THEIR UTILIZATION BY BIRDS: UPPER LAGUNA MADRE OF TEXAS

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ABSTRACT

Eleven dredged material islands in the Upper Laguna Madre of Texas were studied for 20 months from January, 1973 to August, 1974. The purpose of this study was to determine what physical and floristic factors on a dredged material island were most closely associated with the greatest diversity and density of nesting bird species. Topographic maps of each island were made using aerial photographs and land survey techniques. Soil samples were collected in the field and tested in the laboratory for texture, pH, alkalinity, and salinity. Plant community distribution and cover were established using area reconnaissance and the line intercept method. To minimize nest disturbance, visual counts of birds were made during the early morning and late evening hours.

The average maximum elevation of the island was 1.52m and the average area was 2.96ha. The major textural component was sand; clay and silt were found in smaller quantities. Seventy plant species representing 26 families were collected and identified. The distribution of these species was found to be a consequence of topographic variances. Members of the families Gramineae and Asteraceae were among the most numerous and were found throughout most of each island. Members of the families Chenopodiaceae and Fabaceae were limited to distinct areas of the spoil banks. Fourteen fish-eating bird species nested on the study islands. The distribution of nesting bird colonies was found to be a consequence of: (1) the presence of preferred plant species at a vegetative cover of less than 90 percent; (2) the availability of expanses of barren dredged material and (3) areas in which vegetative cover was less than 30 percent, but not barren.

Island size, elevation, soil composition, vegetative composition and distribution, and human activity influenced the use of dredged material island as nesting sites by fish-eating birds.

INTRODUCTION

The Laguna Madre is a shallow, hypersaline lagoon located along the Texas Gulf Coast between Corpus Christi, Texas and Brownsville, Texas. Between 1947 and 1949 a series of dredged material islands were created by the U.S. Army Corps of Engineers while dredging the Gulf Intracoastal Waterway (GIWW). These islands provide nesting sanctuaries that are somewhat isolated from mammalian and reptilian predators that might reduce avian reproductive success. Previous studies of the Laguna Madre have not emphasized the islands. Simmons (1957) was concerned with decreased water exchange and possible adverse salinity changes caused by the dredged material island chain. Information concerning dredged material islands as ecological entities has only recently become available. Recent Texas studies are by Barnes (1971), McMurray (1971), Simersky (1971), DePue (1974), and Mrazek (1974). Soots and Parnell (1975a, 1975b) have conducted studies on plant succession and avian nesting on similar dredged material islands in North Carolina.

Dredged material islands are subject to processes of ecological succession comparable to those on natural islands. Barnes (1971) stated that the topography of a dredged material island, its soil composition, and the distribution of its vegetation were important factors that affected the kinds, numbers, and stability of its bird fauna. She found a correlation between soil type and plant community.

The purpose of this study was to determine which physical and floristic features of a dredged material island were associated most closely with the greatest diversity of nesting bird species and the greatest number of birds nesting per species.

The study area consisted of five sets of dredged material islands (11 islands) from marker 29 to marker 57A (Fig. 1). The islands were numbered to correspond with the nearest GIWW marker buoy or to a position along the Humble Channel (HC), a tributary channel to the GIWW. The islands were chosen because of the presence or absence of vegetative cover and bird use. The islands chosen were (north to south) HC3, HC3N, Tern Island, 41, 41.5, 47.5, 47A, 49A, 51, 57, and 57A (Fig. 1). All but the first 5 islands were within the boundaries of the Padre Island National Seashore.

METHODS

The study was conducted over a 20-month period (January 1973-August 1974) to include seasonal variations in vegetation and bird nesting. Trips to the study area were made bimonthly using a boat.

Topography

A private company was hired to take aerial photographs of each island. The photographs were printed at a scale of 2.5cm to 61m and were used in conjunction with elevation contours to construct topographic maps. Elevation contours were determined by surveying each island with an engineer's transit and stadia rod. A point of maximum elevation was visually selected and used as the instrument station. Using magnetic-north (Zero degrees) as the initial survey line, a total of 12 survey lines were made at 30° intervals. Rod readings were taken along each line at intervals and smaller units of 7.6m, 3.7m, and 1.5m were used between the instrument station and the first 15.2m.

Plant Survey

Two transect lines (0° and 150°) were randomly selected from among the twelve, and were thereafter used on all the islands studied. A third transect was established along the longest possible axis of an island in the event the first two transects did not traverse all plant communities. The line-intercept method (Brown, 1954) was chosen because the investigator could randomly place the transects, obtain linear measurements of floral canopy, and adapt the transects to the contour stratifications found on the spoil banks. Line intercept estimates for each plant species were taken from 1m sections (contour interval sub-plots), and plants in contact with either side of the tape or intersecting a vertical projection of its path were included.

Since intercept measurements were taken for each species at each contour interval on all transect lines, the total intercept length (area) per species per contour interval was then used to compute Percent Cover. Because the presence or absence of vegetation seemed to most affect nesting bird populations, percent cover was deemed the most indicative parameter of favorable or unfavorable nesting conditions.

Outlines of the plant communities were estimated by reconnaissance of each island and were plotted on scaled maps. Aerial photographs of each island were used to correct the reconnaissance maps. Descriptions of plant species within the communities and of community compositions were based on the plant transect data. Plant nomenclature followed Correll and Johnston (1970).

Bird Census

Bird counts were made on 24 of the trips to the study area over a 14 month period (May 1973 to June 1974). Although Simersky (1971) and McMurry (1971) both agreed that counting the number of active nests and multiplying by two produced a more accurate count, we used total counts of

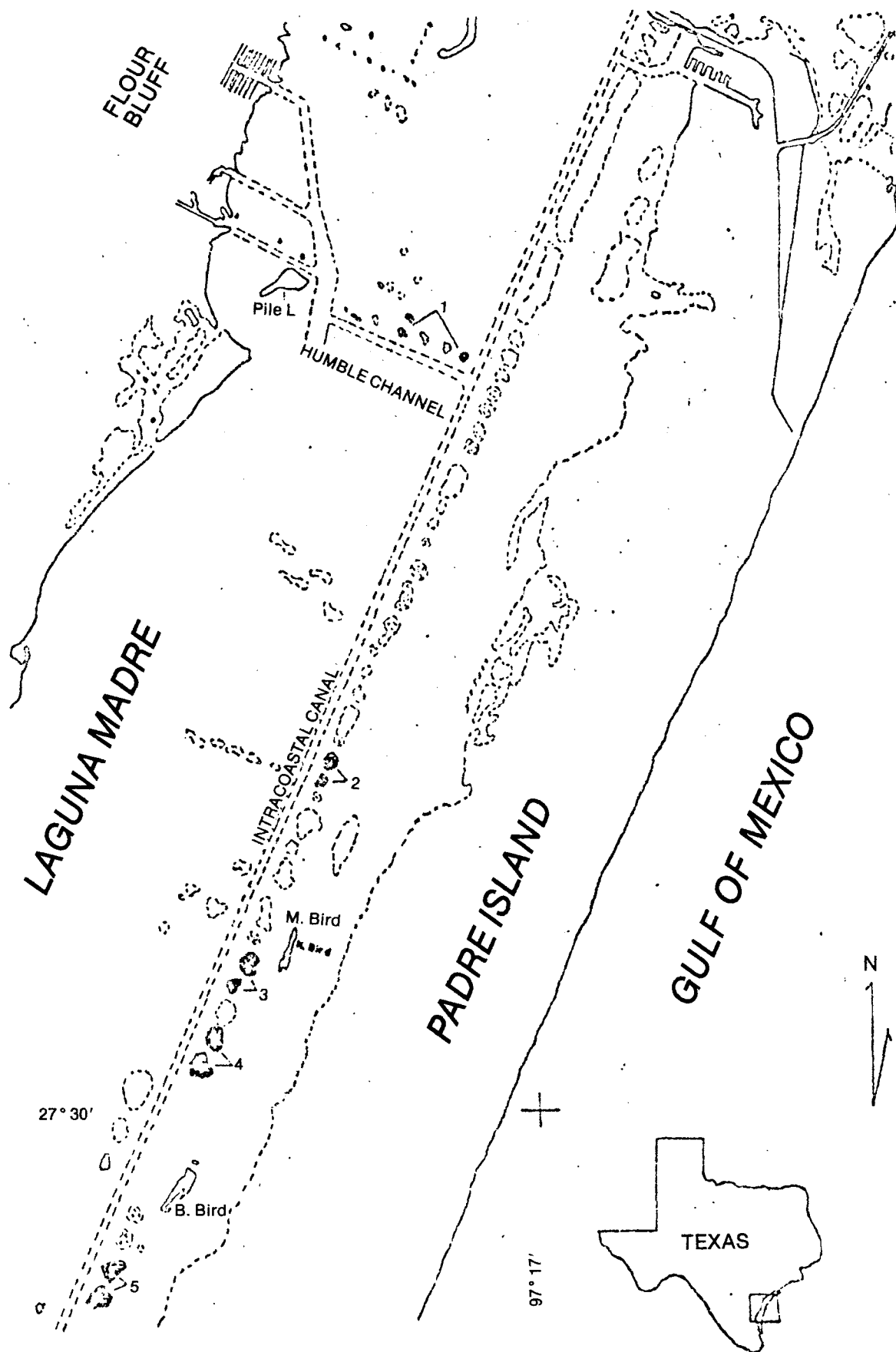


Figure 1. Location of study area. Source of map was (1) the Texas Intracoastal Waterway: Redfish Bay to Middle Ground including Baffin Bay; Nautical Chart no. 893-SC, U.S. Department of Commerce, and (2) U.S. - Gulf Coast, Texas, Aransas Pass to Baffin Bay; Chart No. 1286, U.S. Department of Commerce.

all birds seen. Visual counts of large fish-eating birds nesting on, in flight above, or at the water's edge on each island were made during the early morning and late evening hours to minimize nest disturbance. The distribution of the 1973 and 1974 nesting colonies was recorded in a field notebook and later drawn on the topographic maps to illustrate colony distribution according to location and elevation. Bird nomenclature followed the A.O.U. Checklist (1957).

RESULTS AND DISCUSSION

Topography

The topographic data were used to calculate island area (Table 1). The average maximum elevation for the islands was 1.52m and the average area was 2.96ha. Island shape varied from circular to elliptical with elevation contours following similar patterns.

Table 1. Topographic data for islands included in the study.

Island No.	Island Area (hectares)	Max. Island Elev. (meters)
HC3	0.3	0.3
HC3N	0.6	0.3
Tern	1.6	1.2
41	2.8	1.2
41.5	2.3	1.2
47.5	4.3	2.1
47A	2.6	1.5
49A	4.6	3.1
51	5.7	4.0
57	5.3	1.5
57A	6.9	1.2

Exceptions to these patterns could have resulted from subsequent spoil deposition. Portions of the GIWW in that area had been periodically maintenance dredged and spoil had been occasionally deposited on established islands. The variation in island shapes could have been caused by the predominantly southeastern winds. Carlson (unpubl. M.S.) stated that erosion by wind-generated waves produced "crescent-shaped" islands. Islands having the long axis parallel to the wind direction would be less affected by erosion.

The major textural components of the soils were sand and shell fragments in all elevation intervals on all of the islands. Such coarse-textured soils typically have low water retention, high permeability, and low cation exchange capabilities (U.S. Salinity Laboratory Staff, 1954).

Topography and Vegetation

Six plant communities were defined (Table 2). Dominance, relative succulence or woodiness, plant height, and relation to elevation were the criteria used to distinguish community types. A few plant communities of almost monotypic composition were treated separately.

Table 2. Description of common plant communities.

Plant Community Type	Dominant Plant Species Represented	Plant Community Character and Its Location Relative to Elevation
I	<i>Salicornia</i> , <i>Sesuvium</i> , <i>Suaeda</i> , <i>Hydrocotyle</i> , and <i>Heliotropium</i>	Shore plants; Herbaceous annuals and perennials, usually below 0.3m level.
II	<i>Borrichia</i> and <i>Machaeranthera</i>	Annual herbs found at elevations of 0.3m to 1m; usually not restricted either to shore or inland positions.
III	<i>Sporobolus</i> , <i>Eragrostis</i> , <i>Erigeron</i> , and <i>Hedyotis</i>	Mainly grasses, some associated herbs, found at elevations of 0.3m to not more than 1.3m; usually found away from shore.
IV	<i>Ipomoea</i> , <i>Cuscuta</i> , <i>Indigofera</i> , <i>Limonium</i> , and <i>Euphorbia</i>	Herbaceous perennials found above 1m, in sparsely vegetated areas.
V	<i>Gaillardia</i> , <i>Heterotheca</i> , <i>Ambrosia</i> and <i>Aphanostephus</i>	Low woody annuals and perennials found above the 1m elevation interval.
VI	<i>Tamarix</i> and <i>Baccharis</i>	Shrub species found within the 0.6m and 1m elevation intervals

Seventy plant species representing 26 families were collected and identified. The distribution of these species on the spoil banks was usually consistent with changes in topography. This is not to say, however, that topography alone was the mechanism responsible. Significant salinity changes, however, coupled with negligible pH changes, indicated that island topography was a factor controlling soil condition which in turn influenced vegetational distribution. Plant species consistently found at elevation intervals higher than 0.6m were *Heterotheca subaxillaris*, *Chloris petraea*, *Bothriochloa saccharoides*, *Eragrostis oxylepis*, *Ambrosia artemisifolia*, *Hedyotis nigricans*, *Cuscuta pentagona*, *Gaillardia pulchella*, and *Aphanostephus skirrhobasis*. Those consistently found at the 0.3m and 0.6m elevation intervals were *Paspalum monostachyum*, *Borrichia frutescens*, *Typha domingensis*, and *Sporobolus virginicus*. Those found at the water's edge were *Salicornia virginica*, *S. bigelovii*, *Suaeda linearis*, *Monanthochloe littoralis*, and *Sesuvium portulacastrum*.

Percent vegetative cover was also affected by island topography, i.e., plant cover decreased at elevation intervals higher than 1m. The low water retention and high permeability properties of the soil may have affected the amount of water available to plants.

Dikes on dredged material islands also influenced vegetational distribution. The barrier-like effect may have prevented plant propagules from reaching all areas of an island and, thus, slowed plant colonization. Loose sands on the dikes created unsuitable conditions for many plants. Loose sand eroded from broken dikes and covered existing vegetation and leaving bare ground.

The location and extent of plant communities varied with the size and structure of an island. Whitehead and Jones (1968) stated that the ecology of islands with an area of less than 1.5 ha would be favorable only to salt-tolerant species, and the ecology of islands with a larger area would be favorable to both salt-tolerant and nonsalt-tolerant species. Larger islands also present a bigger "target" and thus increase the probability that plant propagules would land on the island.

Birds and Vegetation

Variations in the visual counts of fish-eating birds made during 24 trips to the study area were similar to those of Simersky (1971). Peak numbers usually occurred during the early spring and summer months, and were lowest in the winter months. Nineteen fish-eating birds species associated with the study islands were recorded, and 14 of these nested on the study islands (Table 3). White Pelicans, Double-crested Cormorants, Common Egrets, Herring Gulls, and Ring-billed Gulls were sighted on some of the islands but did not establish any nesting colonies. The total number of species of large fish-eating birds ranged from 14 on island 57A to 3 on Tern Island in 1973, and from 11 on island 57A to 4 on island HC3N in 1974.

Table 3. List of bird species that nested on the study islands during 1973 and 1974.

SPECIES	
Great Blue Heron	(<i>Ardea herodias</i>)
Cattle Egret	(<i>Bubulcus ibis</i>)
Reddish Egret	(<i>Dichromanassa rufescens</i>)
Snowy Egret	(<i>Egretta thula</i>)
Louisiana Heron	(<i>Hydranassa tricolor</i>)
White-faced Ibis	(<i>Plegadis chihi</i>)
Laughing Gull	(<i>Larus atricilla</i>)
Royal Tern	(<i>Sterna maximus</i>)
Sandwich Tern	(<i>Sterna sandvicensis</i>)
Caspian Tern	(<i>Sterna caspia</i>)
Least Tern	(<i>Sterna albifrons</i>)
Gull-billed Tern	(<i>Gelochelidon niltoica</i>)
Black Skimmer	(<i>Rynchops niger</i>)

The herons, egrets, and ibises nested in areas where *Borrchia frutescens*, *Machaeranthera phyllocephala*, *Tamarix chinensis*, and other woody plant species were available for nests. Laughing Gulls nested in areas where *Sporobolus virginicus*, *Eragrostis oxylepis*, *Erigeron myrionactis*, *Hedyotis nigricans* and other similar herbs and grasses were a part of the plant community and provided at least 20% cover. Black Skimmers and terns nested either on unvegetated areas of dredged material (usually coarse-textured soils or in areas where plants such as *Heterotheca subaxillaris* and *Gaillardia pulchella* provided only sparse (30%) vegetative cover. DePue (1974) noted the Black Skimmers and terns nested primarily in areas with 25% or less vegetative cover.

Two of the study islands 41, 41.5, and 47A were not used by wading birds as nest sites. Large areas on islands 41 and 41.5 were covered with dense (85-95%) stands of *Bothriochloa saccharoides*. The central peaks of these islands included small areas sparsely (27.9%) covered by *Heterotheca subaxillaris*. Very little exposed shell was found on the shore areas which were not covered by soft, succulent, salt-tolerant plant species such as *Salicornia* sp., *Sesuvium portulacastrum* and *Suaeda linearis*. These conditions were not favorable for nesting by the herons and egrets because woody plant species such as *Borrchia frutescens* were not present, nor were these conditions favorable for nesting by Black Skimmers and terns, which nested on areas with little or no vegetative cover.

A large, sparsely (15.6%) vegetated peak was found on island 47A, however, neither terns nor Black Skimmers nested on this island. One of two shacks on 47A was frequently used by fishermen and their presence may have discouraged nesting attempts.

Spoil Bank Evaluation

Dredged material islands having colonial bird nesting sites were characterized by one or more of the following attributes: (1) Concentrations of shrubs at a vegetative cover greater than 90%; (2) expanses of barren dredged material; and (3) areas in which the vegetative cover was less than 30%, but not barren. With the exception of island 57A, none of the islands on which large fish-eating birds nested had more than one of these attributes. To enhance the use of spoil islands as nest sites for fish-eating birds, these island attributes should be reproduced:

(1) Islands should be larger than 2ha. This increases the chance of plant propagation and colonization. Larger areas also tend to include a wide variety of habitats for both plants and birds.

(2) Islands should be at least 1m in elevation. Islands with elevations above 1m are more stable and tend to develop suitable plant communities for nest sites (see also Simersky 1971, McMurry 1971, DePue 1974).

(3) Islands should be no higher than 3m. Areas with elevation levels higher than 3m were generally not used by birds.

(4) Islands should have mounds of fresh dredged material periodically placed on them. Depositions should be placed close to the island periphery and should not be more than 3m high or larger than 3800m² in area.

(5) Deposits should not be left with a volcanotype center or with gently sloping, concentric contours.

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GROWTH ENERGETICS OF BLACK-BELLIED WHISTLING DUCKS (*Dendrocygna autumnalis*)

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ABSTRACT

The Black-bellied Whistling Duck (*Dendrocygna autumnalis*) is a neotropical species whose northernmost range extends into southern Texas (Delacour, 1954:29). This species began nesting in southern Texas recently (Henze 1962) and has nested in the central Brazos Valley in Texas (Cain and Arnold 1974). Cain (1973) predicted the northern limit to nesting for this species is 33° N. Lat. and is determined by temperature and its regulating effect on the energetic requirements for reproduction.

Bolen (1967) studied the ecology of the Black-bellied Whistling Duck and presented data on its food habits (Bolen and Forsyth 1967), sex ratio (Bolen 1970), and mortality rates (Bolen and McCamant 1971). Incubation behavior and renesting were studied by Delnicki (1973) and Delnicki and Bolen (1976), and data were presented on the growth and plumage development of this species by Cain (1970).

Ricklefs (1969) postulated that the rate at which food can be processed and utilized is a physiological constraint that limits the growth rate of birds. The precocial young of the Black-bellied Whistling Duck acquire their own food but they lack complete thermoregulatory ability until the 12th day of age (Cain 1972). Their growth rate is maximum between the age of 4 to 33 days (Cain 1970) and may be limited by the rate food can be utilized. Growth energetics have been well studied in domestic animals (Scott et al. 1959) but have received little attention in wild waterfowl (Sugden 1969). The objectives of this study were to calculate the food assimilation rate of growing Black-bellied Whistling Ducks, the energetic cost of growth, and the ecological growth efficiency (Brisbin 1965) for this species.

MATERIALS AND METHODS

Eggs were collected from nest boxes in South Texas and incubated at 39°C and 85 percent relative humidity. Hatched ducklings were brooded in these incubators for 48 hours and then placed at 32-38°C in a 10m x 10m room with a 15-hour photoperiod. Ducklings were fed a mixture of chick startena, milo (*Sorghum vulgare*), and cracked corn. Duckweed (*Lemna* sp.), aquatic invertebrates, and fish (*Gambusia affinis*) were placed in the water pans daily to insure a balanced diet for the ducklings.

Specimens were selected from this stock and placed in metabolism cages, described by Owen (1970) but enlarged to 54 x 43 x 48cm, and fed chick startena until 21 days old, and milo thereafter. Each duckling served for three consecutive 3-day periods in the metabolism cages and then were returned to the holding arena.

The food was oven dried at 65°C to a constant weight. A weighed sample was presented in a food pan, and then collected after each 3-day period. The unused food and excreta for these periods were oven dried to a constant weight, homogenized with a Waring blender, and the caloric values were determined with a Parr oxygen bomb calorimeter.

Temperature was kept at 32°C and the photoperiod was 15 hours during the metabolic measurements. Each duckling was weighed to the nearest gram at the beginning and end of each 3-day interval.

The relationship between metabolism and growth was determined using the method developed by Kendeigh (1949). This procedure involves subtracting the caloric value of the excreta (excretory energy = EE) from the caloric value of the food eaten (gross energy intake = GEI). This resulting value is the amount utilized (metabolized energy = ME) and during a period of constant weight (i.e., change within plus or minus 1.5 percent) is called the existence metabolism (EM). Productive metabolism (PM) is the amount metabolized above that needed for existence at a particular temperature and is available for weight increase, feather production, or storage.

To calculate the existence metabolism required for a growing duck, the metabolized energy

for the 3-day period was plotted against the duckling's weight increase. The existence metabolism was the metabolized energy determined from the regression equations when $X = 0$ (i.e., no weight increase) for same-aged ducklings during weekly age classes (Cain 1972). The metabolized energy required per gram of wet weight increase (the slope of the regression equation) multiplied by the percentage of wet weight that is dry weight yields the energy cost per gram of dry weight increase. This value divided by the caloric content of the dry weight and multiplied by 100 equals the productive efficiency.

Regression analysis and tests for significance followed Zar (1967) and required the 0.05 level for significance. Mean values and regression equations are reported with plus or minus two times the standard error.

RESULTS AND DISCUSSION

Body weight

Fifty-six ducklings averaged 28.3g (SD 2.3g) four hours after hatching and at three days of age averaged 25.7g (SD 1.74g). This reduction is due to the metabolism of the yolk that is absorbed at hatching (Kear 1965). Body weight increased rapidly after the third day (Fig. 1) and approached the adult body weight (827g) as measured by Bolen (1964) around 90 days. The dry weight of 1-day-old ducklings averaged 32 percent of the wet weight and increased to 43 percent at six weeks of age and remained constant thereafter.

The caloric value per gram of dry weight decreased from 6.0 kcals at hatching to 4.8 kcals at three weeks of age, then again increased to 5.4 kcals by the fourth week and remained constant thereafter. This reflects the lipid content of the body as it drops from the early stage with a large yolk deposit to the rapid growth stage, and then increases as fat is deposited in the body, which helps to insulate the body.

Energy consumption

The gross energy intake increased with age during the first nine weeks of age (Table 1) and is still twice that needed for adults at the same photoperiod and temperature. This difference reflects the productive and existence metabolism demands of the growing ducklings as opposed to only existence metabolism for the adults.

Excretory energy loss through the excreta increased through the fourth week and declined thereafter (Table 1). The assimilation of the gross energy intake parallels the development of the contour feathers which is completed in the ninth week (Cain 1970) and adds an excellent layer of insulation.

Table 1. Gross energy intake, excretory and metabolized energy, and the utilization coefficients of ducklings at weekly intervals with ± 2 standard errors.

Age in weeks	N	Weight in grams	Gross energy intake (kcals /bird/day)		Excretory energy (kcals /bird/day)		Metabolized energy (kcals /bird/day)		Coefficient of utilization	
2	6	54.0	49.8	7.2	15.4	2.5	34.5	4.6	69.3	4.0
3	14	109.0	93.1	12.0	31.1	4.9	62.0	7.6	66.7	2.0
4	8	148.7	115.3	25.4	40.2	8.0	75.1	17.7	64.7	2.0
5	13	198.9	150.4	22.0	32.2	7.7	118.3	19.7	78.2	5.2
6	15	275.0	195.6	25.7	35.1	5.5	160.5	19.9	82.9	2.0
7	12	379.8	172.3	29.6	30.2	2.4	142.0	17.0	85.8	0.6
9	8	576.5	242.2	47.2	26.3	5.1	215.9	41.8	88.8	1.0
adult	8	684.7	125.5	15.5	16.8	2.8	108.7	17.3	86.5	1.0

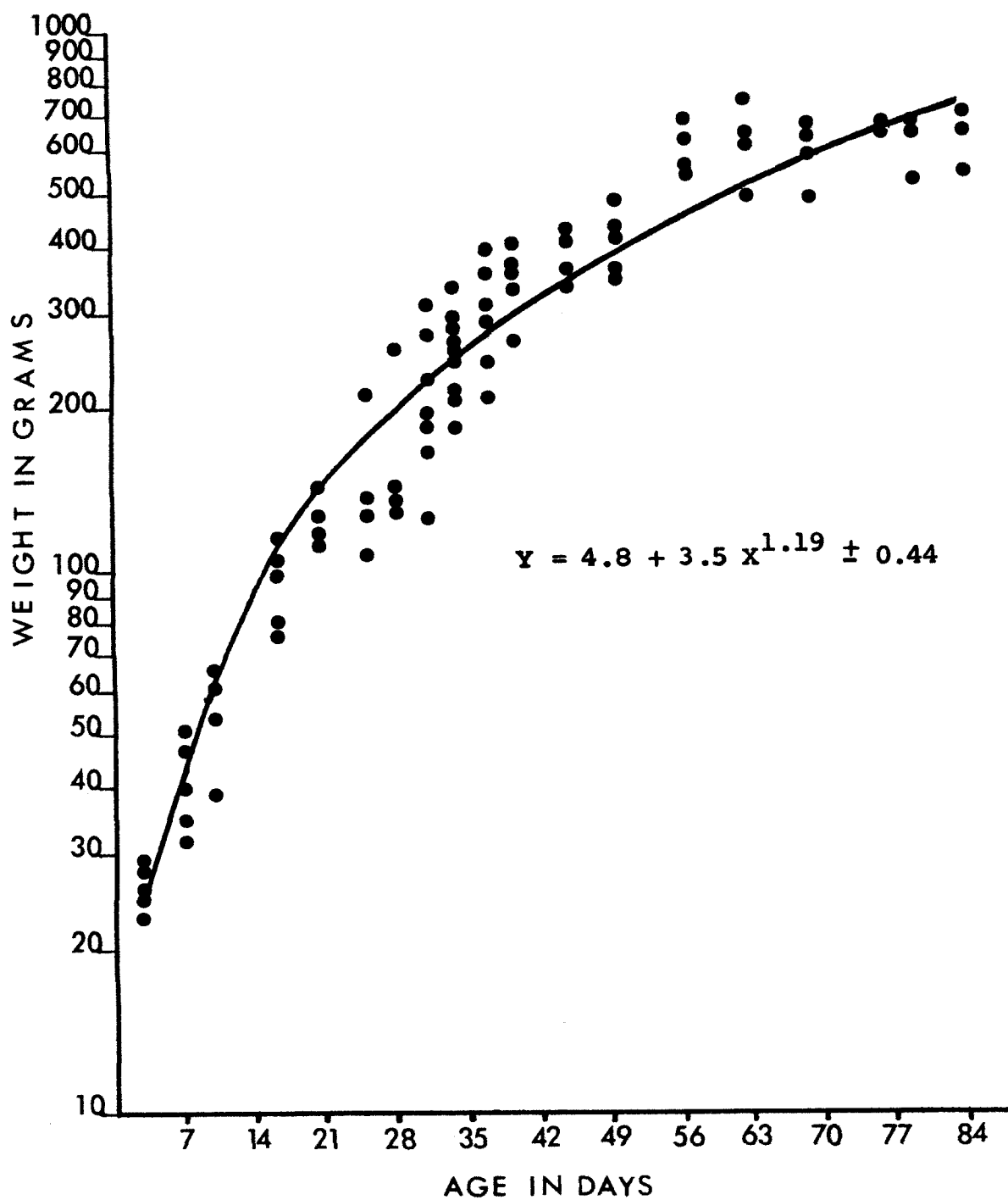


Figure 1. Growth as wet weight for the ducklings at daily intervals for the first 84 days. Least squares non-linear regression provided the line.

Existence metabolism

Regression analysis of metabolized energy to weight gain were performed to determine the metabolism when the value of X (weight change) equalled zero (i.e., existence metabolism) at weekly intervals (Table 2). The calculated values very similar to those observed from a small sample of birds that did not change weight during a 3-day period. As the body weight increased with age the existence metabolism also increased. Larger birds required more total existence metabolism than smaller birds but the existence metabolism decreased on a per gram basis (Table 2), as normally seen in larger birds (Kendeigh 1970). The existence metabolism in kcal/bird/day fits the slope presented by Kendeigh et al. (1977) for the body weights presented in Table 2.

Productive metabolism

The amount of energy metabolized by the growing ducklings beyond that required for existence increased both as an absolute value and as a percentage of the metabolized energy during the first six weeks (Table 3). During the next three weeks the amount of productive metabolism appears to drop as the existence metabolism increased. This may be related to the wing exercise that Black-bellied Whistling Ducks perform at this growth stage (Cain 1970) and perhaps increased their daily energy expenditure.

A complex relationship exists between existence metabolism, productive metabolism, weight increase, and food assimilation during the growth period. In the first four weeks of growth much of the metabolized energy is required for existence since the bird is small bodied and lacks good feather insulation. This results in a low ratio of productive metabolism to metabolized energy (Table 3), and a low co-efficient of utilization for the gross energy intake (Table 1). As the duckling becomes larger it ingests more total energy, requires more energy for existence, is more efficient at metabolizing the ingested energy, and, because of better insulation, is capable of producing body mass, flight feathers, and expend energy for flying.

The slower body growth rate after three weeks of age (Fig. 1) with the concurrent production of feathers is reflected in the increased cost of weight production and the decrease in productive metabolism efficiency (Table 3). The metabolic efficiency is at its highest before the fourth week of age and is perhaps the limiting factor for a faster growth rate. Penny and Bailing (1970) showed a similar trend in the growth of young Black Ducks (*Anas rubripes*) and the American Coot (*Fulica americana*). Brisbin (1965) reported a similar decrease in the growth efficiency for Herring Gull (*Larus argentatus*) chicks and attributed it to an increasing cost of maintaining respiration associated with increasing biomass and muscular activity.

Ecological growth efficiency

Brisbin (1965) defined this as an organism's biomass increment divided by the energy value of the food removed from the environment by that organism per unit of time. To calculate the ecological growth efficiency for Black-bellied Whistling Ducks the biomass increment was divided by metabolized energy for that period. The metabolized energy represents the energy removed from the environment more so than does the gross energy intake (i.e., "food" of Brisbin 1965).

The ecological growth efficiency increased through the first seven weeks of growth (Table 4) and declined thereafter. This increase in efficiency from only 9 percent to 23 percent is related to the increased metabolic efficiency (Table 3) and the reduction in heat loss by the developing feathers. In terms of energy removed from the environment, a brood of 13 ducklings would remove 1639 kcals per week during the first two weeks of growth and increase this to 12, 922 kcals per week during the seventh week. Thirteen adults in a non-reproductive stage would remove 9893 kcals per week at the same photoperiod and temperature.

Kendeigh et al. (1977) stated that the total energy that a bird can mobilize sets a limit to its activities. It appears that contour feather production, which aids in body insulation, is a large energetic requirement to growing Black-bellied Whistling ducks and may be responsible for the reduced growth rate after the third week of growth (Fig. 1). It may be that the total energy mobilized is the physiological constraint that limits avian growth rate because during this period the metabolic efficiency increased to a maximum (Table 1) and biomass production efficiency decreased (Table 3).

Table 2. Existence metabolism at weekly intervals for Black-bellied Whistling Ducks.

Age in weeks	Weight	Existence metabolism (EM)			kcal/g/day
		Calculated	kcal/bird/day N	Observed	
2	54.0	26.9 ¹	1 ²	27.4 ³	0.50
3	109.0	47.7	2	43.2	0.44
4	119.7	55.8	3	59.1	0.46
5	166.9	84.5	2	88.9	0.50
6	277.0	96.8	2	92.2	0.35
7	340.8	101.1	3	123.0	0.30
9	586.5	187.7	1	177.6	0.32
adult	684.7	—	8	108.7	0.16

1. From the regression equations where $X = 0$ (Cain 1972).
2. Sample size of observed ducklings and adults.
3. From ducklings not changing body weight during a metabolic trial.

Table 3. Productive metabolism (PM) and the cost to produce one gram of dry weight.

Age in weeks	N	Productive metabolism kcal/bird/day	PM/ME	Factor to convert dry to wet wt.	Kcals/g cost of dry wt. increase (factor X b)	Productive efficiency
2	6	7.5	21.8	4.01 ¹	6.0 ²	91.6
3	14	14.3	23.1	3.03	6.4	74.8
4	8	19.3	25.7	2.89	10.0	54.1
5	13	33.7	28.5	2.66	14.3	54.7
6	15	63.7	39.7	2.32	14.3	39.6
7	12	40.9	28.8	2.42	15.3	37.0
9	8	27.2	13.0	2.38	27.2	19.6

1. Determine by dividing the percent of dry weight into unity (1).
2. b = the slope of the regression equations used to calculate the metabolic cost to gain weight (see methods).

Table 4. Ecological growth efficiency calculated by dividing the kcals of biomass increase per week by the metabolized energy required for that week's growth.

Age in weeks	N	Dry weight increase	Metabolized energy kcals/bird/week	Kcals in biomass increment	Ecological growth efficiency
0 - 2	6	7.68 ¹	483	43.0	9.0
2 - 3	14	8.50	434	47.6	11.0
3 - 4	8	12.60	525	70.5	13.0
4 - 5	13	18.90	828	105.8	13.0
5 - 6	15	32.70	1123	183.1	16.0
6 - 7	12	43.20	994	241.9	23.0
7 - 9	8	82.00 ¹	1510	459.2	15.0
adults	8	-	761	-	-

1. This is a two week period.

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