

Shelwatch: A Baseline Monitoring Program to Detect Changes in the Benthic Molluscan Communities Adjacent to Sabel Island

PROJECT REPORT

Susan D. Cook

December 1995



Long-term Watch Program
Florida Department of Natural Resources
Florida Marine Research Commission
2205 South Jordan Street
Tallahassee, FL 32309-1550

**Shellwatch: A Baseline Monitoring Program
to Detect Changes in the Unique Molluscan Communities
Adjacent to Sanibel Island**

Susan B. Cook

5310 Deer Run Drive
Fort Pierce, FL 34951

Submitted as project report for
Nongame Wildlife Program project NG88-034

December 1995

This report is the result of a project supported by the Florida Game and Fresh Water Fish Commission's Nongame Wildlife Program. Although the report fulfilled the project's contractual obligations, it has not been reviewed for clarity, style, or typographical errors, and has not received peer review. Any opinions or recommendations in this report are those of the author and do not represent policy of the Commission.

Suggested citation:

Cook, S.B. 1995. Shellwatch: a baseline monitoring program to detect changes in the unique molluscan communities adjacent to Sanibel Island. Fla. Game and Fresh Water Fish Comm. Nongame Wildl. Program Project Rep. 50pp + viii. Tallahassee, Fla.

**Shellwatch: a Baseline Monitoring Program to Detect Changes in the Unique Molluscan
Communities Adjacent to Sanibel Island**

Susan B. Cook

**Florida Game and Fresh Water Fish Commission
Nongame Wildlife Program**

**Submitted as Final Report Number NG88-034
05 December 1990**

ABSTRACT

Project Number: NG88-034

Project Title: Shellwatch: a Baseline Monitoring Program to Detect Changes in the Unique Molluscan Communities Adjacent to Sanibel Island

Date of Final Report: Dec. 5, 1990

Project Director: Dr. Susan B. Cook

The Shellwatch project is a pilot study of populations of 4 species of large, predatory gastropods that live on the grassflats that border the northern shoreline of Sanibel Island, Florida. The purpose of the work has been to provide baseline information on the current status of these ecologically important mollusks so that any future changes in this unique resource can be detected.

A total of 15 rectangular plots (10 x 25 meters) have been censused an average of 6 times per year from the fall of 1988 to the fall of 1990. Data on snail number, behavior, and shell length have been collected for each species, along with information on reproduction and water temperature and specific gravity. In censusing, teams of two to three volunteers walk side by side using feet and eyes to detect snails. An overlapping search pattern is used. Notes on the extent of seagrass cover and the presence or absence of other grassbed organisms have also been made.

Over the 2 year period of the NGWL award, numbers of the two most common species the lightning whelk *Busycon contrarium* and the banded tulip *Fasciolaria hunteria* have been quite variable with abundance peaks tending to occur in the winter. When data from the last two years are combined with earlier census figures from the winter of 1987 and the winter of 1988, there is evidence for a longer term decline in *B. contrarium* numbers.

When the details of snail spatial patterns were examined, *B. contrarium* were found to be more common at sites 1 and 2 than at sites 3 and 4. Within sites 1 and 2, snails were also not uniformly distributed over plots. Instead, specific plots consistently contained more individuals than others. *F. hunteria* abundances varied widely with snails apparently entering and leaving plots and sites in relatively unpredictable waves.

At the two most thoroughly censused sites, the average size of *B. contrarium* individuals appears to follow a yearly cycle of peaks and valleys with dips occurring in the early winter and an increase in the number of larger individuals from summer through early fall in both years. Egg laying by this species had virtually ceased at all of the Shellwatch study plots.

In contrast, both *F. hunteria* and the two relatively rare species studied (the pear whelk *B. spiratum* and the true tulip *Fasciolaria tulipa*) have continued to reproduce in the study areas. The sizes of *F. hunteria* and *B. spiratum* also show some cyclic variation but overall mean size and abundance appears to have remained relatively constant.

Management recommendations include continued monitoring of *B. contrarium* populations, possible restocking of local populations by the transplantation of egg strings onto plots, and possible further restrictions on the collecting of this particular species.

ACKNOWLEDGMENTS: I wish to gratefully acknowledge the cheerful help and hard work of all those in the Sanibel community who were involved in this study whether as hardy field censusers, boat captains, facilitators on shore, or in other capacities.

Three individuals in particular deserve special mention. Without the enthusiasm, encouragement and support of the late Dr. Ken Preston, the project would not have begun. This report is dedicated to his memory.

Alice Anders, the project's 'Head Volunteer', has been the central pivot point of enthusiasm and intelligence around which the project has revolved. Erick Lindblad's support as Director of SCCF, friend and part-time boat captain has been critically importance.

Out of the Shellwatch cast of dozens, a number of hardy individuals have contributed more than their share of rising at 6 am. to work a gray and chilly low tide. Special recognition goes to Mary McHarg, Norman Bowles, Debbie Schloss, Phyllis Harnitt, Melba Ryan and John Veenschotten. Shellwatch participants whose contribution has been less frequent but nonetheless essential include Abbott Byfield, Mary Jane Preston, Bill Whiteside, Len Mead, Kristy Seamanns, Louise Johnson, and Mike Klein.

TABLE OF CONTENTS

I. Introduction	5
II. Project Objectives	7
III. Methods	7
IV. Results	13
V. Discussion and Management Recommendations	18
VI. Conclusions	20
VII. Literature Cited	21
VIII. Appendices	22

INTRODUCTION

Over the past two decades, there has been growing concern about the damage that large scale collecting of live mollusks for their shells may do to the populations of the animals that secrete the shells (Wells, 1981) but relatively little is known about the extent to which subtropical and tropical mollusk populations can be exploited without lasting damage. The greatest potential threat worldwide may be to tropical species in coral reef areas where shells are commercially harvested for the curio trade.

In the Southwest Florida region, abundant local populations of live mollusks (coupled with a broad east-west stretch of Gulf beach) have helped to establish Sanibel Island's reputation as one of the world's most productive shelling areas. Mirroring the worldwide concern about such resources, there has been considerable local debate and at least one suggestion that an apparent decline in the number of shells washed up on the island's beaches may be due to damage done to local mollusk populations by uncontrolled taking of live shells. Human harvesters of this resource locally include tourists, shell collectors, and commercial shellers operating in Pine Island Sound.

The Shellwatch project is a pilot study designed to collect baseline information on several local species often taken by both amateur malacologists and commercial shellers. For the future, it is hoped that this information will be useful as a yardstick against which to determine if shell populations are declining, increasing or holding their own.

In 1987, the project started with seed funding from the Sanibel Captiva Conservation Foundation. High priority was given to obtaining objective scientific data on 4 species of large, conspicuous and ecologically important gastropods so that this resource could be monitored and protected. Later that same year, the state of Florida ratified a local Sanibel ordinance placing a 'bag limit' on the taking of live shells along the island's shoreline. In 1988, the Non Game Wildlife Program provided a small grant to fund a 2 year pilot study to see how difficult or feasible it will be to set up a simple, volunteer based local monitoring effort.

Previous scientific work on the ecological impact of shell collecting has been limited to a series of papers on Kenyan mollusks from shelled and unshelled reefs (McClanahan, 1990) and a study documenting man's impact on shore mollusks in Northeastern Australia (Catterall and Poiner, 1987). Work to date indicates that the extent to which a species will be impacted depends on the balance between the number of adult snails harvested, the number lost for other reasons, and the input of new recruits into the next generation. Species which lay benthic egg cases from which crawling young emerge and in which growth to adulthood is slow are likely to be more heavily impacted. On the other hand, in more prolific species (particularly those with a planktonic or highly mobile juvenile stage), adults lost through human predation may be quickly replaced by a large influx of rapidly growing new recruits from elsewhere. In some situations, where overfishing and shelling go hand in hand, the removal of mollusk eating fishes may give recruits on heavily impacted reefs an improved chance to survive to adulthood and replenish populations (McClanahan, 1990).

The species chosen for this study are the lightning whelk *Busycon contrarium*, the pear whelk *B. spiratum*, the banded tulip *Fasciolaria hunteria* and the true tulip *F. tulipa*. All 4 species lay egg strings or clusters that are either deposited on hard surfaces or anchored in the sand. Because juveniles hatch directly from these masses without a free-swimming planktonic stage, and the pool of recruits to replace harvested individuals may be small, local populations may be especially sensitive to overcollecting. On the other side of the equation, however, both whelks and tulips behave in ways that should make them less susceptible to both human and animal predators. When disturbed, whelks tend to dig down into the substrate, while agile tulips can move quickly, jab predators with their pointed, 'trap door like' opercula and catapult themselves away from danger.

Previous biological work has looked mainly at natural history, (Magalhaes, 1948), diet and the extent to which species compete with one another (Kent, 1983; Paine, 1962; 1963, Wells, 1970). In addition to man, stone crabs and other snails can be important predators. One of the 4 species, the true tulip, frequently preys on its congener, the smaller *F. hunteria*, and can also eat small *Busycon*. In northwest Florida, lightning whelks tend to be relatively uncommon with estimates of 1-2 individuals per 50m by 50m plots from Kent (1983).

SPECIFIC OBJECTIVES

Specific objectives of the study as recorded in the contract with the NGWL program are as follows:

1. To provide a baseline data set on the population densities, size structures and reproduction of predatory snails and their molluscan prey on sandbars and associated grassflats in areas behind Sanibel protected by the state of Florida and the city of Sanibel.
2. To better understand the factors that may underlie spatial and temporal variability within these communities.
3. To estimate the level of harvesting (both legal and illegal) within these reserve areas.
4. To follow existing molluscan communities through time and attempt to determine whether or not significant changes in densities and reproductive activities are occurring.
5. To examine the extent to which areas heavily shelled in the past may be recolonized by hatchling snails from other areas, as well as by the swimming larvae of species such as hard clams, angelwings and the like.

METHODS

Censusing challenges:

The core of any monitoring study is to determine how many of a particular species are present in a specified area. This is not always a simple or straightforward task. Natural environmental factors such as water temperature, the direction and amplitude of the tide and the amount of food available can affect the tendency of animals to move onto or out of study areas. High water and cold temperatures can also affect the ability of census takers to maintain a consistent level of efficiency from one census to the next. In addition, even under the best of conditions, the care with which different people are able to census may vary.

The behavior of the snails themselves is an especially important variable. Animals that have completely buried beneath the surface or hidden among thick grass blades will be missed by visual census techniques. The presence of census takers walking over plots may add to the problem by inducing further burial while the census is being conducted.

On the Sanibel side of Pine Island Sound area, some unique factors also affect the timing of censuses. The volume and shape of the estuary and the position of the island lead to tides that are less frequent and less regular than in other areas. In the fall and winter, the lowest tides occur in the early to mid morning and census conditions are usually good. In contrast, in the spring and summer, conditions can be much more difficult. The best low tides occur at night when it can be impossible to obtain volunteers and to maintain the same level of efficiency as in the daytime. Over the past 2 years, for example, on the few occasions where late afternoon censusing has been possible, conditions have not been optimal. Bars have been under inches of water even at the extreme ebb tide point, and late afternoon thunderstorms have forced us to cancel because it was unsafe to be in a boat or on grassbeds.

Specific protocols:

Shellwatch censusing techniques have been designed to try to minimize as many of these confounding factors as possible. To try to provide optimum census conditions, census periods have been set to coincide with periods of the lowest daytime tides as predicted by the Sanibel-Captiva tide tables. Censuses have been restricted to periods around low tide and confined to occasions when water depths ranged from 0 – 10 inches above plots.

All plots were aligned along the long axis of grassbeds with corners marked with polyvinyl stakes driven into the substrate. A systematic arrangement of plots was chosen with at least 10 meter distance between adjacent plots.

To minimize the skill factor as a source of variability, inexperienced volunteers have typically been paired with more experienced regular team members. Plots are searched by both members of each pair as they walk back and forth across width of each plot. Normally, the less experienced member of the pair retraces the path of the first lead censuser. As teams move

slowly over the plot, both volunteers stroke the surface with dive booty or sneaker clad feet and look carefully for shells projecting above the surface of the sediment or the grasses. In our first Shellwatch censuses during the winters of 1986-87 and 1987-1988, a purely visual non-tactile approach was used.

As each shell was found, its length was measured from the shell apex to the tip of the siphon with aluminum calipers. Information on how each animal was found (by visual or tactile means), its microhabitat (shoal grass, turtle grass, sand, mud etc.) and its position relative to the substrate (on the surface or buried) was also checked off on a standard field dataform.

The tactile method that we have developed is similar to 'treading' for clams. In soft sediment particularly, it is relatively easy to learn the distinctive feel of the rounded body whorl of both wheelks and tulips and the sharp, projecting siphon tips of the wheelks.

Several attempts have been made to 'groundtruth' this unconventional method. In one experiment, marked snails were placed in enclosures, left overnight, and then searched for by censusers who were not told how many shells had been added to the area. We also tethered snails to posts, marked others with floats and looked for both groups after they had buried into the bottom and tethers or floats were disconnected so that there was no visible sign of the shell's position.

These trials have unfortunately not yielded an efficiency rating for the method. Instead, we have found that shells which have been handled and tagged tend to bury very deeply and can not be located unless one knows exactly where the snail is located and digs down well below the surface. Of 4 snails placed in a temporary enclosure with minimum handling, the two smallest individuals were relocated with our surface tactile method but the two larger wheelks had vanished. They may have either climbed over the approximately 4 inch tall aluminum strip set up as a barrier or they also buried too deeply to be easily found.

Shell reproduction was quantified by counting the number of coin-like units in the long egg strings laid by wheelks, and the number of 'petals' or individual units deposited in rounded clumps by tulips. The degree of sculpture on individual units is used to identify the species involved. For tulips, true tulip units are more convoluted and 'frillier' than banded tulip petals. Pear wheelk

coins have more spike like projections than the larger and less spinose 'coins' of the lightning whelk (Perry and Schwengel, 1955).

Hard objects such as plot corner stakes, logs and empty shells were routinely examined for juvenile snails as well as for tulip egg masses. On most census days, water temperature was recorded with a pool thermometer and specific gravity was assessed with a hydrometer as an indication of salinity.

From November 1988 to February 1989, 5 bottom samples were collected to provide information on benthos that might serve as snail prey. Samples were positioned between permanent plots with coordinates chosen from a random numbers table.

At each location, a metal box sampler (0.5m by 0.5m) was pushed down into the sediment and the sediment within removed down to a level below the seagrass roots. The sediment was then washed through a hardware cloth screen with an approximate 0.5 cm. mesh size. Specimens picked from the screen were initially preserved in 10% formalin and later transferred to 70% alcohol. At present, these samples have been sorted into component species but detailed quantitative counts of the benthos have not been completed for all samples.

The most common organism in the samples was the rose petal tellin, *Tellina lineata*. Other organisms present in lesser numbers include onuphid polychaetes, brittlestars, and assorted small gastropods and bivalves including lucinid and arciid clams. A subsample of the sediment in one of 5 benthic food samples was picked through before sieving and several tiny *Busycon spiratum* juveniles were found.

Photographs were taken of plots during most censuses but have not been analyzed because water levels were frequently too high and light levels too low to allow parameters such as grass cover to be quantified. As a backup, sketches of plots were made and will allow a rough estimate to be made of the percentage covered by grasses and sand. At the time of this draft, analysis of these sketches had not yet been completed.

On some of the early censuses in 1989, the Principal Investigator conducted timed 10 minute searches of study areas and noted the number of each species seen either resting on the surface of the substrate or partly buried.

To examine snail movement patterns, 3 *Busycon contrarium* were marked with floating tags and released. Floats were clipped onto a cloth covered elastic band wrapped securely around the body whorl. All three individuals dug down into the substrate (as mentioned above) and remained in their initial positions for the entire 48 hour observation period. Early attempts to mark animals with nail polish and plastic tags glued to the shell were relatively unsuccessful. Plastic tags routinely came off within several days and nail polish applied to the apertural lip was found to fade rather quickly, although one animal marked in this way in 1987 was found by a local shell guide on the other side of the channel about a year after its 1987 release at site 1.

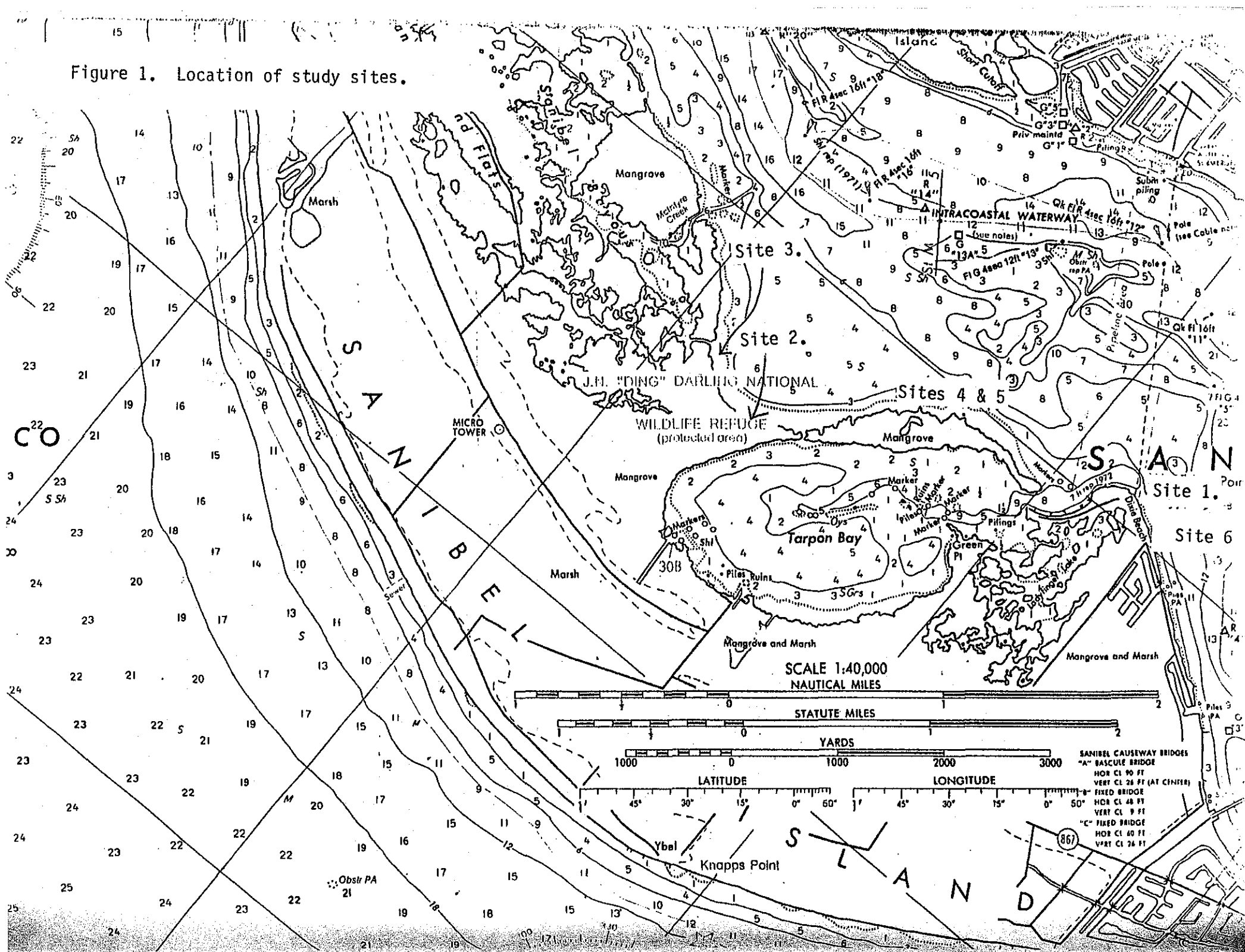
Descriptions of sites and prevailing environmental conditions:

Three of the four Shellwatch study sites are located adjacent to the northern shore of the Ding Darling Wildlife Refuge. The fourth site is located just to the east of the entrance to Tarpon Bay (Figure 1).

At Site 1, the only site accessible by car, the 3 Shellwatch plots parallel the shore. The sand at this site is firmer than at other locations because of an underlying layer of mangrove and seagrass peat. Plot 1A has the highest elevation with reference to mean sea level and contains sand with sparse shoal grass *Halodule wrightii*. 1B is intermediate in elevation with a greater cover of shoal grass, while 1C is the lowest and wettest area and is covered with both shoal grass and turtle grass *Thalassia testudinum*. In the first year of the NGWL study (the only year for which careful records of shellers seen were kept) the greatest frequency of shellers was seen at this site. Since 1987, this area has been posted with a "Do Not Disturb: Research Area" sign.

At site 2, plots 2C and 2D lie along the outermost bar and are primarily sand with a strip of grasses along their seaward edges. Plot 2G, termed the 'mud hole', is the lowest area and is completely covered with a mixture of turtle grass and shoal grass. 2A is a mosaic of sand and shoal grass, while 2F and 2I are mainly covered with shoal grass associated with turtle grass

Figure 1. Location of study sites.



along plot edges and in depressions. 2 of the plots lie within the boundaries of the Ding Darling Wildlife Refuge while the remaining 4 are technically just outside the refuge border. A 'No live shelling' sign is located just seaward of plots 2A and 2C.

At site 3, plots encompass a mosaic of sand, shoal and turtle grass habitats. Shellers and clammers often frequent this area, possibly because it is outside the refuge limits. Just east of plot 3A a shallow channel runs through the mangroves into Tarpon Bay. Sites 1, 2 and 3 were established in 1987. Plots at Site 4 were staked out in September of 1988. Prior to 1987, this area was frequently visited by a commercial shelling group who anchored the party boat the Island Queen off the bars several times a week. In 1987, this practice was discontinued and the area was posted as a "No live shelling site.

Appendix I to this report is a table compiling data on water temperature, specific gravity, the number of shellers in the area, and weather and tide conditions during each census. Natural history notes are also included, because such records can often provide information on the timing of various events important to snail biology (such as the decline and resurgence of seagrasses and the presence or absence of various prey).

Statistical analyses:

The Systat statistical package for microcomputers has been used because of its extensive linear modeling and analysis of variance capabilities. In an attempt to identify some of the causes of variation in the data and to detect significant effects of particular factors such as year, plot and season, two types of analyses have been run (Wilkinson, 1990). The first model, a repeated measures design, corrects for autocorrelation, the fact that censuses of fixed plots over time can be expected to be more similar than censuses from randomly located areas. The second approach, a nested analysis of variance, allows for the fact that the sampling units (i.e. the plots) are subsets of sites, but ignores the problem of autocorrelation.

In some analyses, winter and summer have been treated as separate seasons using water temperature to define winter (temperatures from 57 - 79 degrees Fahrenheit) with 80-100 degrees indicative of summer.

A Friedman non-parametric analysis of variance for ranks has also been used (as described in Wilkinson, 1990) to determine if animals are distributed across plots and sites in a random way or tend to be more abundant at specific sites and specific plots within each site. In this test, sampling units, be they sites or plots, are ranked with respect to the number of snails present, and the pattern of the resulting ranks is tested against a hypothetical situation in which all sampling units contain equal numbers of snails.

RESULTS

The average number of *Busycon contrarium*, *Busycon spiratum*, and *Fasciolaria hunteria* found in plots from September 1988 to September 1990 are presented graphically throughout this section. The raw data from which these statistics are drawn are tabulated in Appendices II – X of this report.

Busycon contrarium abundance:

Clearly the data collected over the past 2 years are quite variable (note the large standard deviations in Figure 2). When snail abundances are examined statistically, results of both repeated measures ANOVA and a nested analysis indicate little systematic change over the two years of this study.

Graphs of mean abundance over time contain hints that there may be a seasonal effect with fewer numbers in the summer and peak abundances from November – February, but ANOVA results are mixed (Tables 1 and 2). A difference between winter and summer is suggested by nested ANOVA, but the more conservative repeated measures ANOVA does not show a significant effect. Even if decreased snail counts in the summer are real, there may not be a real population fluctuation. Instead, we could simply be seeing a censusing artifact of the increased difficulty of locating animals hidden at the base of thick, lush grasses.

differences between sites, between plots at each site and from one census time to the next can be seen in the output for both parametric ANOVA models tested. Friedman's nonparametric analysis further indicates that *B. contrarium* are not distributed randomly over plots at site 1 and 2, but are more abundant in some areas than others. At site 1, plot C

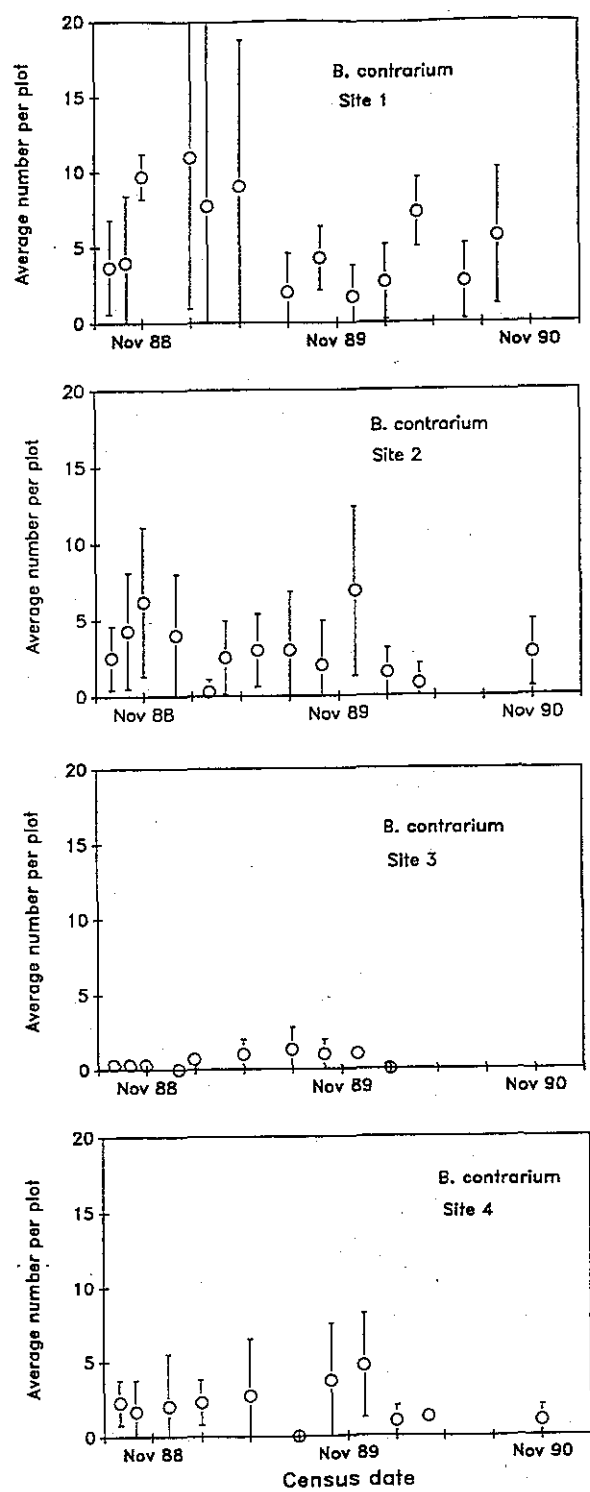


Figure 2. Mean abundances ± 1 S.D. for *B. contrarium* from Sept. 1988 to November 1990.

Table 1.

Analysis of variance. Busycon contrarium abundance
 All plots at sites 1, 2 and 4. Site 3 excluded because of
 sparseness of dataset.

ANOVA tables for repeated measures analysis: separate
 models for effects of site, plot and year.

	SS	DF	MS	F	P
Between Subjects					
Year	77.357	1	77.357	1.61	0.220
Error	912.833	19	48.044		
Within Subjects					
Census	186.071	5	37.214	4.267	0.002
Census*Year	48.357	5	9.671	1.109	0.361
Error	828.5	95	8.721		

	SS	DF	MS	F	
Between Subjects					
Site	129.565	2	64.783	1.355	0.283
Error	860.625	18	47.813		
Within Subjects					
Census	123.462	5	24.692	2.951	0.016
Census*Site	123.899	10	12.39	1.481	0.160
Error	752.958	2			

	SS	DF	MS	F	
Between Subjects					
Plot	472.024	5	94.405	2.733	0.060
Error	518.167	15	34.544		
Within Subjects					
Census	186.352	5	37.27	4.749	0.001
Census*Plot	288.224	25	11.529	1.469	0.104
Error	588.633	75	7.848		

Table 2.

Analysis of variance. *Busycon contrarium* abundance

All plots at sites 1, 2 and 4. Site 3 excluded because of sparseness of dataset.

ANOVA tables for nested design: effects of site, plot nested within site, year, and season nested within year.

	SS	DF	MS	F	P
Source					
Site	148.644	2	74.322	7.584	0.001
Plot(Site)	594.59	9	66.066	6.741	0
Year	20.081	1	20.081	2.049	0.155
Season(Year)	63.3	2	31.65	3.23	0.043
Error	1234.836	126	9.8		

Table 3

Analysis of variance.

Busyon contrarium

abundance

Sites 1 and 2 for 1987-1990.

ANOVA tables for repeated measures analysis: effect
of year; first 2 censuses of each year only.

	SS	DF	MS	F	P
Between Subjects					
Year	576.5	3	192.2	4.8	0.007
Error	1401.6	35	40		
Within Subjects					
Census	17.3	1	17.2	1.02	0.32
Census*Year	36.6	3	12.2	0.72	0.54
Error	590.4	35	16.9		

Nested ANOVA for complete dataset at sites 1 and 2.

Model with season nested within year failed to run.

	SS	DF	MS	F	P
Site	123.7	1	123.7	5.94	0.016
Plot (Site)	812.1	7	116	5.57	0
Year	594.4	3	198.1	9.71	0
Error	2686.8	129	20.8		

consistently contained the largest number of snails, with plot B intermediate and plot A containing the fewest (plot ranks significantly different at $P = 0.015$). At site 2, the western most and wettest plots (2F,2G,2I) clearly harbored more animals than the emergent sand bar plots 2C and 2D, and plot 2A which contains a mixture of sand and shoal grass ($P = 0.0001$). Local spatial trends were not apparent at sites 3 and 4 ($P = 0.889$ at site 3; $P = 0.086$ at site 4).

In 'between-site' comparisons, abundances at site 1 were typically higher than at Site 2, with sites 3 and 4 being the least productive ($P = 0.001$).

The fact that these patterns hold up both between and within sites for censuses by done by different teams is reassuring. Although some snails are undoubtedly missed, and some inter-volunteer variability must certainly exist, the similarity in the rank order of the estimates obtained by the different groups over the 15 plots suggests that a consistent standard of efficiency is being attained.

Comparisons with past years:

In contrast, there is evidence for a decline in *Busycon contrarium* numbers over the full 4 years of the study. Although there is still considerable scatter in the data, an overall drop can be seen in average snail abundances through time when 1987 and 1988 data are added to the NGWL dataset (Figure 3) Repeated measures comparisons between comparable census dates for all four years and nested ANOVA for the entire dataset indicate a significant between year effect; Table 3). Pairwise comparisons within the nested paradigm indicate that a significant difference between 1987 and 1989 ($P=0.000$) and between 1987 and 1990 ($P = 0.000$) but no difference between 1989 and 1990 ($P=0.166$) or 1987 or 1988 ($P = 0.158$).

In reality, the decline must have been greater than that shown in figure 3, because buried snails are were not included in 1987 and 1988 abundance figures. Estimates of burial frequencies (summarized in the next section) indicate that from 20% to 70% of the population may have been buried and therefore would not have been included in these 1987 and 1988 counts.

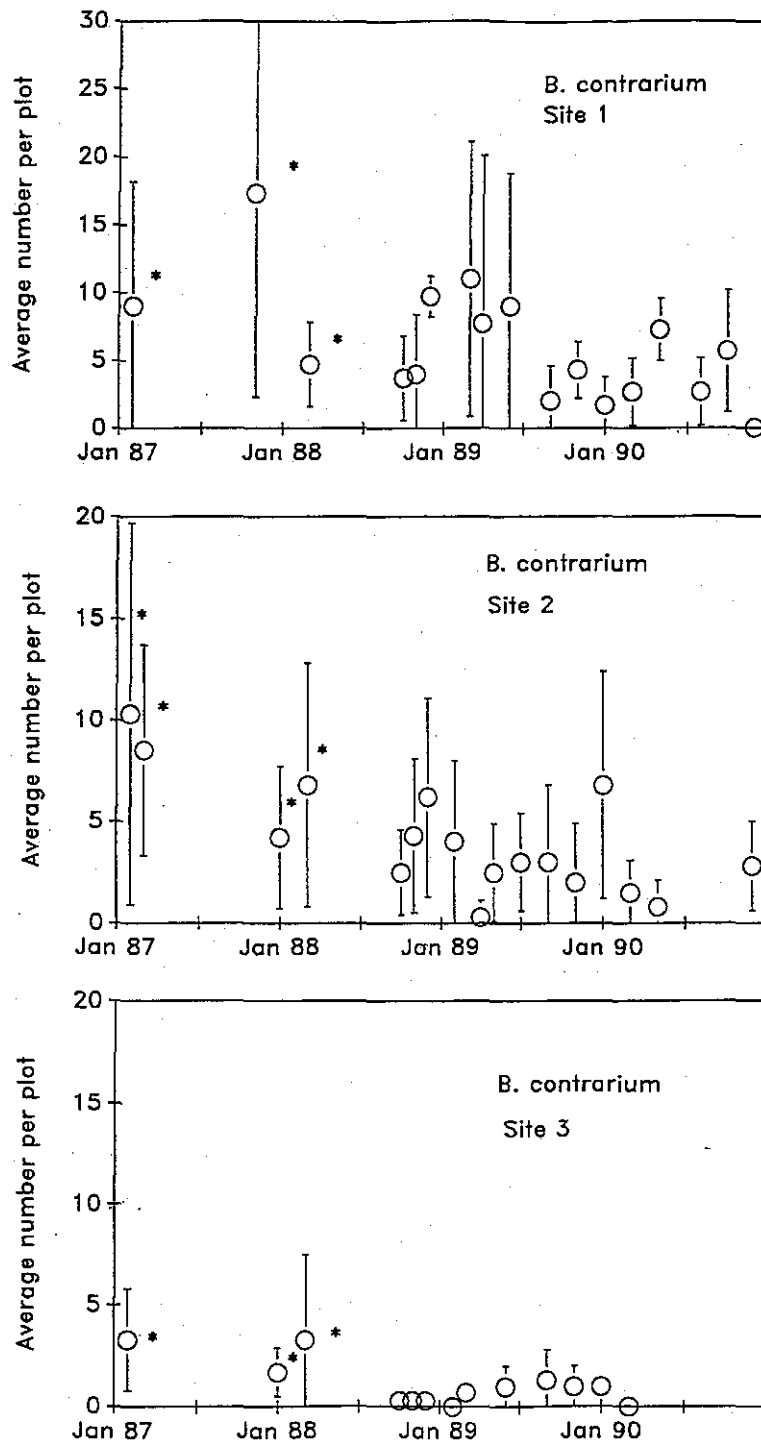


Figure 3. Mean abundances ± 1 S.D. for *B. contrarium* for the 4 year period January 1987 - November 1990. Asterisks indicate censuses done with visual methods only.

B. contrarium behavior and microhabitat:

Many of the *B. contrarium* present in an area were typically buried partially or completely in the sediment, or hidden in grasses. This difference between snails clearly visible on the surface and the number actually present is underscored by figures from a November 1988 timed walk over site 1. In an area that was later found to contain a minimum of 29 lightning whelks, only 1 *B. contrarium* (and one *F. hunteria*) were seen at the surface. Timed walks at other sites yield similarly low figures: 4 *B. contrarium* and 3 *F. hunteria* at site 1; 2 *B. contrarium* and 1 *F. hunteria* in one walk at site 3; 1 *B. contrarium*, 1 *B. spiratum* egg string and 1 *F. hunteria* in a second walk at 3; and 3 *B. contrarium* on a late February walk at site 3.

Snail habitat preference and burial behavior may vary with season, tide state and site specific factors. For example, the number of snails found visually at site 1 in November 1988 (78%) was higher than at site 2 (32%); part of the explanation for this may be that it is physically more difficult for shells to penetrate the underlying peat at site 1. In summer, there is a pattern of more animals being discovered tactilely than in comparable winter censuses (22% in winter versus 78% in the summer at site 1 and 68% versus 78% for site 2).

While buried, some snails may be depositing new shell. Alice Anders has observed this process numerous times for *B. contrarium* in her aquaria. In February, one of the shells buried at site 1 had clearly just finished such a cycle. The rim of its aperture consisted of brownish shell matrix material which had not yet hardened into calcified shell.

B. contrarium sizes:

Peaks and valleys can be seen in some of the size data (Figure 4). Fluctuations in mean shell length at site 1 (and to a lesser extent at site 2) may reflect cycles in growth and recruitment. Younger and smaller individuals make up most of the population at times of relatively low average size, and mean shell length appears to gradually increase as these animals grow. In the fall a broader range of sizes is found. Mean lengths also reach their peak and then drop. This pattern may be caused by small snails recruiting to the area in the early fall followed by a reduction in the number of larger individuals over the winter.

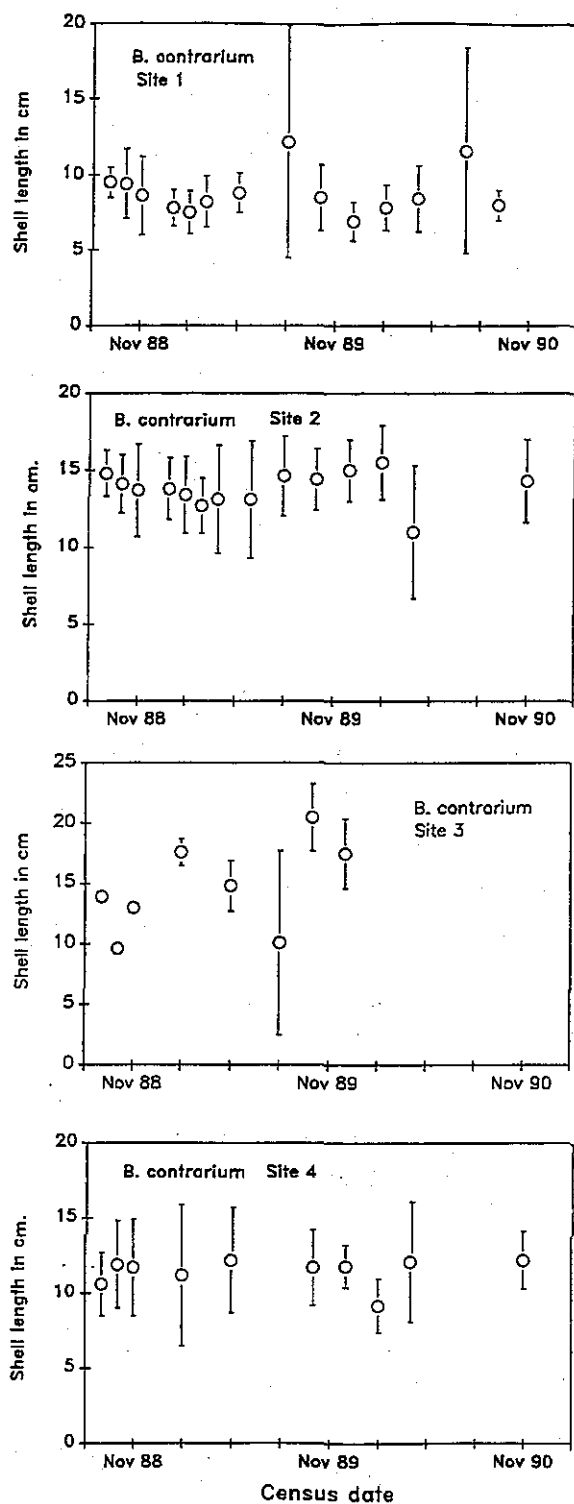


Figure 4. Mean shell lengths ± 1 S.D. for *Busycon contrarium* from September 1988 to November 1990.

Shellwatch natural history notes (see Appendix I) indicate that large numbers of empty shells have been seen for the past two years during the fall at Site 1, the most accessible and thoroughly censused area. The agents responsible could include predation by true tulips and horse conch (predators that remove the flesh but do not damage the shell), or disease. Stone crabs (*Menippe mercenaria*) are probably not involved since *Menippe* crush the shells of their prey. Kent (1983) also discounts rays as *Busycon* predators because of the small size of their mouths relative to the large size of whelks.

Sites can be ranked with regard to the average size of the snails found there. The relatively few shells found at site 3 tend to be quite large, with site 2 a close second. Site 1 is at the opposite end of the spectrum and site 4 was intermediate (Friedman's 2 way ANOVA of ranks; $P = 0.002$).

The only *B. contrarium* egg string seen anywhere during the course of the NGWL funded study was at 3C in October of 1988. The absence of egg strings can be explained by the fact that females must be larger than 15 cm. in shell length to either mate or lay eggs (Kent, 1983), and very few animals of this size were found on Shellwatch plots.

At the other end of the size spectrum, no shells smaller than 4.6 cm. in length were ever seen, so the whereabouts of very young *Busycon contrarium* are still unknown.

Dietary information obtained for *B. contrarium* during this study has been limited to a few observations of large whelks feeding on large hard clams, *Mercenaria campechiensis*.

B. spiratum:

Average abundances of these smaller whelks was highest at site 1, with fewer at site 2 throughout the study (Figure 5). At sites 3 and 4 only scattered individuals of this species have been seen.

At sites 1 and 2, there were no significant between plot differences (Friedman's ANOVA: $P = .099$ at site 1; $P > 0.05$ at site 2). At site 1, numbers may peak in the fall, but not enough snails were present for statistical analysis of seasonal trends.

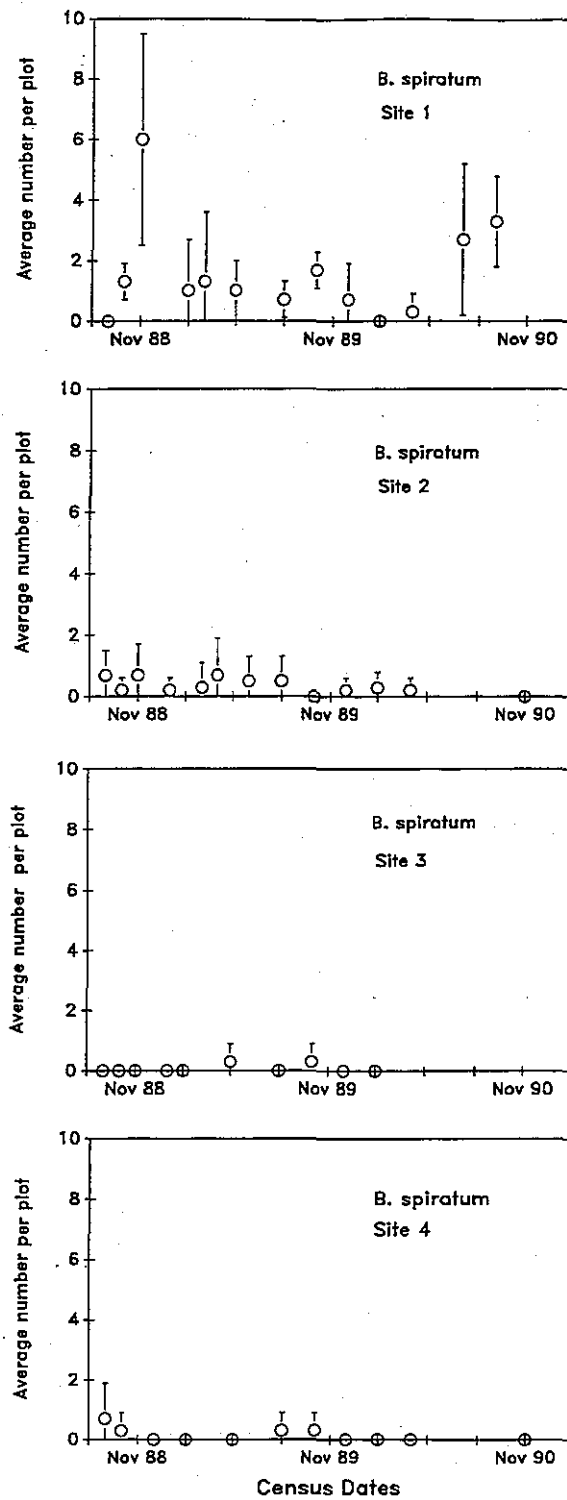


Figure 5. Mean abundances of *B. spiratum* (± 1 S.D.) for September 1988 to November 1990.

Figure 6 presents data on mean sizes of *B. spiratum* at site 1. Most snails were between 6 and 7 cm. long over the two years of the study, with no seasonal patterns evident.

Table 4 presents information on pear whelk reproductive patterns. *B. spiratum* egg strings were found at sites 2, 3 and 4 from Dec 1988 until May 1989 and again from December 89 through the April 1990 census. Mating individuals were seen on several occasions. No egg strings were ever recorded inside site 1 plots, although they have been found outside of plots. A few tiny shells of *B. spiratum* were collected in subsamples of sediment taken from site 1 in November 1988, but no living recruits have been found.

Fasciolaria hunteria:

In both the extensive NGWL dataset and the longer 4 year series, there was considerable variation in *F. hunteria* abundances (Figure 7). These animals seem to undergo large scale movements with dozens in a plot on one occasion and only a few on the next census date.

Analysis of spatial patterns indicates that at sites 1 and 3 there was relatively little tendency for these animals to concentrate in particular localities on a regular basis ($P = 0.103$ at site 1; $P = 0.151$ at site 3). However, at site 2, banded tulips were concentrated in the grassier plots (rank order $G > I > F$ with A having an intermediate rank and C and D containing the fewest snails; $P = 0.0001$). At site 4, the middle plot B tended to contain more banded tulips than plots at either end ($P = 0.019$).

Average banded tulip sizes varied widely with no consistent patterns emerging (Figure 8). As in the pear whelk, reproduction was mainly a wintertime affair with egg capsule clusters appearing from late fall through spring (November 1988 – May 1989), disappearing in August and October of 1989 and being found again from Dec. 89 through April 1990 (Table 5). No masses have yet been seen this fall. Mating individuals were a relatively common sight throughout both winters of this study.

Small juveniles in the 2 – 3 cm. size range were found on several occasions in winter 1990 in 4 specific habitats: crawling on the surfaces of *Thalassia* blades, moving over barnacle clumps on plot corner stakes, hiding inside empty shells and attached to the undersides of sunken logs.

Table 4.

Busycon:

Reproductive activity at Sanibel study sites

		Sept88	Oct88	Nov.88	Dec.88	Jan.89	Feb.89	March 89	April 89
Site 1	<i>B. contrarium</i>	No reproduction during study.							
	<i>B. spiratum</i>	No reproduction during study.							
Site 2	<i>B. contrarium</i>	No reproduction.							
	<i>B. spiratum</i>					2A: 50 coins 2C: 68,54 2D: 48,24,33,20		2A:38,35,40 2D:82 2G:68 2I:38,20	
Site 3	<i>B. contrarium</i>		3C: 80 coins						
	<i>B. spiratum</i>					3A: 24,42,37 3A:44,16,23 3b:62,38,82, 3B:56,62,64 3C:54			
Site 4	<i>B. contrarium</i>								
	<i>B. spiratum</i>				4A: 7 inches long				

Table 4.

Busycon:

		May 89/June 89	Aug. 89	Oct 89	Dec 89	Feb, 11 1990	Apr 24/90	No repro. at any site July or Nov. 90
Site 1	<i>B. contrarium</i>							
	<i>B. spiratum</i>							
Site 2	<i>B. contrarium</i>							
	<i>B. spiratum</i>	2A:21,14 2C:26 2D:34,32,38			2A:45,18 2c:53 2D:25	2A: BS laying 20-30 coins + 29 coin string 2C:46,17	2F:50	
Site 3	<i>B. contrarium</i>							
	<i>B. spiratum</i>	3A:26,66 3B:52,45,40			3B: 48	3A:70,54 3B:48,43 no length for third mass		
Site 4	<i>B. contrarium</i>						4B: 23 coins	
	<i>B. spiratum</i>	4A:39 4C:56					4B: 32,60	

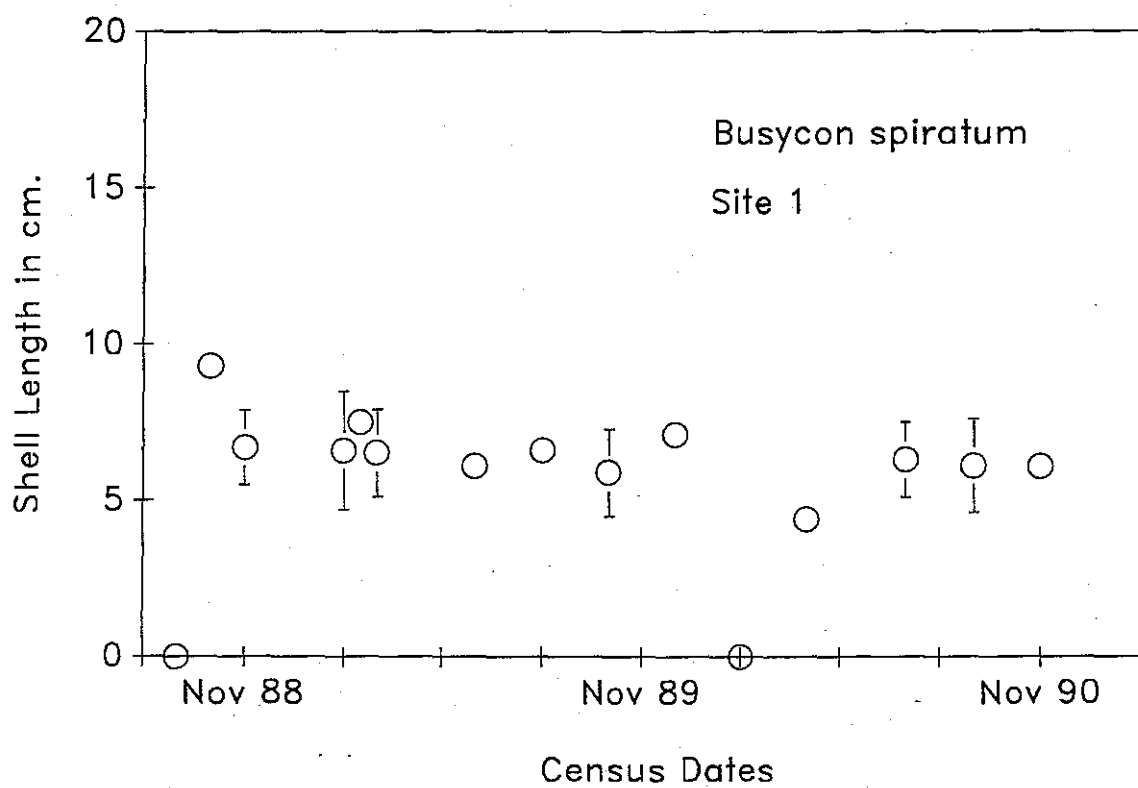


Figure 6. Mean shell lengths ± 1 S.D. for *B. spiratum* at site 1 for September 1988 to November 1990. Data for other sites too sparse to plot.

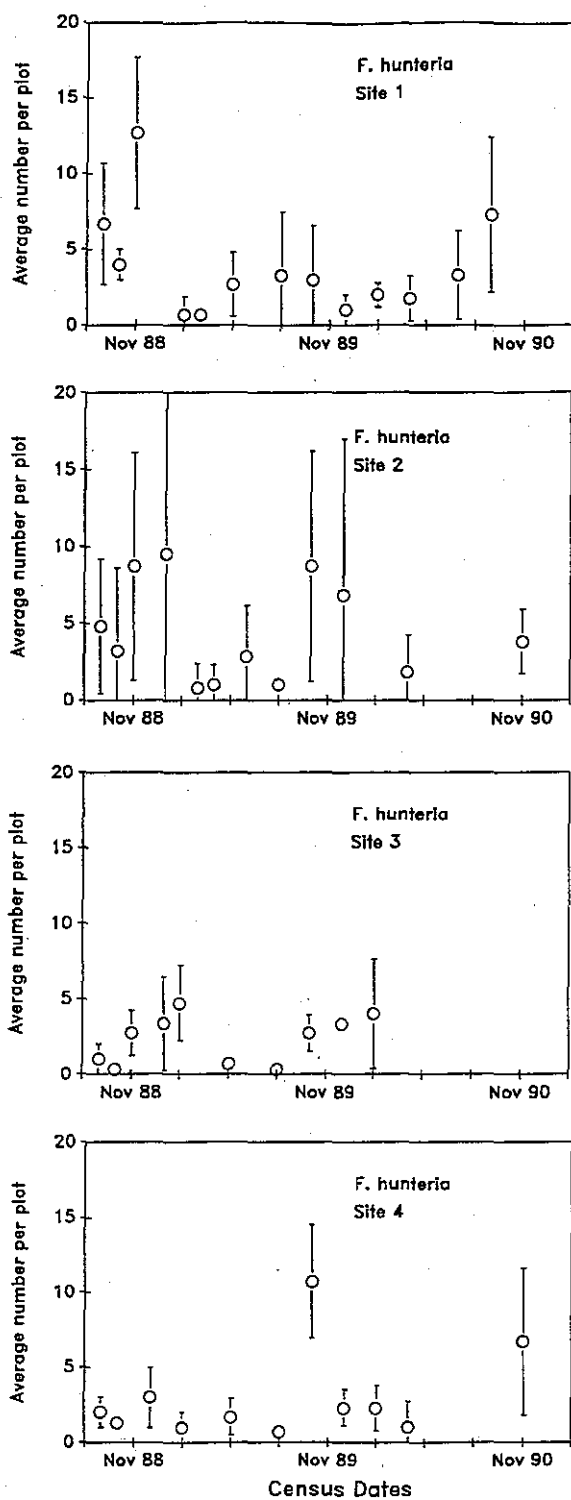


Figure 7. Mean abundances for *F. hunteria* ± 1 S.D, for September 1988 - November 1990.

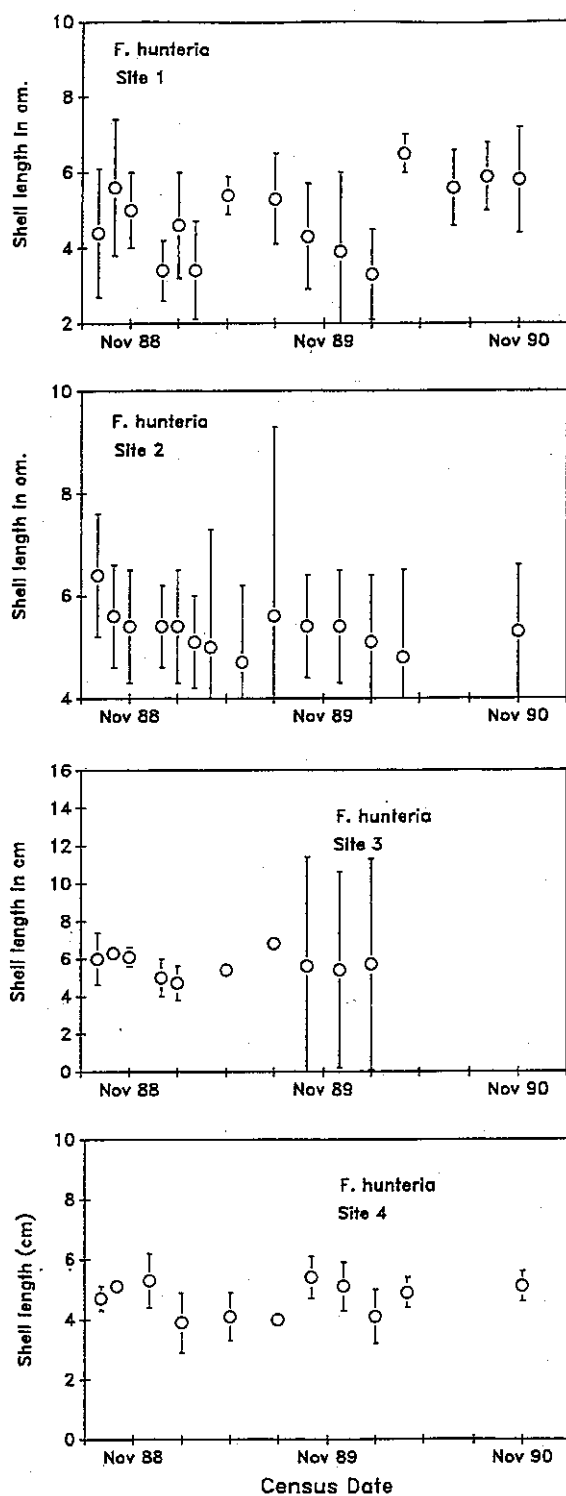


Figure 8. Mean shell length for *F. hunteria* (± 1 S.D.) for September 1988 to November 1990.

Table 5.

Fasciolariid reproduction.

		Sept88	Oct88	Nov.88	Dec.88	Jan.89	Feb.89	March 89	April 89
Site 1	<i>F. hunteria</i>								
Site 2	<i>F. hunteria</i>			4 FH masses: no size data 2I:36,17		2F:36,12,18 2G:20,40,25,1,93	2G:3,16,21,37 8,9,10,3,13,12 On outside of 2G posts: 14,28,13,20	2F: 30	2G:21,12,11 2I:5
	<i>F. tulipa</i>					2G: 50 4 FT adults in area			2I: 60 One FT adult in area
Site 3	<i>F. hunteria</i>			3B:238,32,39 3C:723			3B:24		
Site 4	<i>F. hunteria</i>				4B:3,20				

Table 5.

Fasciolariid reproduction.

		May 89/June 89	Aug.89	Oct 89	Dec 89	Feb, 11 1990	Apr 24/90
Site 1	<i>F.hunteria</i>					2 FH masses: 20 and 19 petals larvae hatched prior to census One floating FT mass with 37 petals	One FH mass: 13 petals No reprod. July or Nov.
Site 2	<i>F. hunteria</i>	2F: sp. not recorded, 31,57 2I:8			2G:1,11,25,16 2I: 11,24,27 ck. date could be Feb.	2A: 10 petals on post 2F: 38 2G: 14,8,17,12 2g on BC shell:10,3,22 2G: 7,12,45,34,7,24 9,10,7,15,9	
	<i>F. tulipa</i>	2I: 33,36,40,30 5 FT adults				2G: 38,10,20	
		in 2I and 2G					
Site 3	<i>F. hunteria</i>					3A: 2,6,6,12,7 3B: 15,62,9	
Site 4	<i>F. hunteria</i>				4B:14,20 4C:18	4B: 2	

F. hunteria have been frequently observed feeding on small gastropods including *Cerithium* and *Terebra*. From the other side of the food chain, these small tulips are occasionally seen being eaten by *F. tulipa*.

F. tulipa:

These large, brightly colored tulips have been found at sites 2, 3 and 4 but have not been seen in site 1 (Table 6).

At site 2, all true tulips were found in plots heavily covered with grass (namely 2G and 2I). In addition, the only true tulip egg cases recorded during this study were attached to hard objects within these same two plots.

Both this species and the banded tulip are quite aggressive when handled. Compared to the relatively placid whelks, both tulips thrash about and try to jab the collector with their opercula.

Discussion and Recommendations:

Of the 4 species that we have studied, *Busycon contrarium* and *Fasciolaria tulipa* are the most likely to be at risk from overcollecting. Both species attain relatively large sizes, grow slowly to sexual maturity (for *B. contrarium* see Kent, 1983) and construct shells that are attractive to collectors and the shell curio industry. *Busycon spiratum* and *Fasciolaria hunteria* are smaller and bear shells that are either less sturdy (*B. spiratum*) or less colorful (*F. hunteria*).

Although we have found evidence for significant declines in Sanibel Island *B. contrarium* populations over the past 4 years, the project has not been able to address or identify the underlying causes of this pattern. In particular, it is not known to what extent this situation is a local one or more widespread.

More information is clearly needed on sources of mortality at all stages in whelk life histories. Although collecting is probably the primary cause of death for large adult whelks (they are too large to be preyed upon by other natural predators), the presence of small to medium sized

Table 6. Abundance of *Fasciolaria tulipa*:

	Sept88	Oct88	Nov.88	Dec.88	Jan.89	Feb & Mar '89	April 89	May/June 8	Aug.89	Oct 89	Dec 89	Feb, 11 1990	Nov 90
Site 1	No FH seen at this site.												
Site 2	2 FT no sizes				2G: 4 FT 13.9,11.2, 8.4,12.2		2I: 1FT 9.1	2G: 3FT 6.1,5.4 12.5	2G: 1FT 13.4 2I: 2 FT 6.6,14	2G: 3FT 7.2,9, 13.5	2G: 1FT 13.9 2I: 1FT 8.1		2I: 1 FT 10.3
	2I: 2FT	2I: 2FT	2I: 1 FT		2I: 1 FT 9.1			2I: 2 FT 7,11.1					
Site 3					3A: 1FT 13.8					3A: 1FT 13.5		3B: 1 FT 5.2	
Site 4	4B: 1 FT under sand no length 4C: 1 FT no length	4b: 3FT 8.1,7,7.7		4B: 1 FT						4B: 2 FT 9.3,8.8 4C: 1 FT 10	4b: 1FT 13		4B: 2 FT 9.4,4.6 4C: 1 FT 12

empty shells on plots and on beaches clearly indicates that an unknown proportion of the population dies before the large adult stage is reached.

The absence of large whelks coupled with local reproductive failure is of immediate concern if Sanibel island wishes to retain the presence of a self sustaining population of these distinctive snails.

The city of Sanibel may wish to consider a three pronged approach: further restrictions on collecting for this particular species, continued monitoring and/or the transplantation of egg masses from elsewhere in the Pine Island Sound estuarine complex to see if this will help resupply lightning whelk populations.

If collecting is not banned, the setting of a minimum size limit may be helpful. Although the lack of reproductive activity in the Sanibel area has precluded any direct examination of fecundity in these snails, I would recommend that any such threshold be set well above the 15 cm. minimum size for mature females reported by Kent (1983). The cutoff should be set well in excess of this length because growth in these mollusks is indeterminate (does not stabilize at sexual maturity), and fecundity increases with adult size. Unlike vertebrates where reproduction stops in older animals, large snails continue to grow slowly and lay increasing numbers of eggs. If such individuals are harvested (with the rationalization that they are probably too old to reproduce), this may significantly lower the total egg production of the area and reduce the size of the pool of recruits available to replenish the population.

One recommended research priority would be to locate areas within the estuary where *B. contrarium* are continuing to reproduce and use some of these egg strings for possible transplantation efforts. Although strings that wash up on the Gulf beach at Sanibel could also be used, these capsules have been scoured out of their original deposition sites by storms and may not contain healthy young snails.

Another recommendation would be to continue to monitor lightning whelk populations. The best strategy would be to focus on conducting 2 or 3 thorough censuses in the fall when snail abundances are high and census conditions are good. The Center for Field Research and the Earthwatch organization have expressed interest in supplying funding and manpower for several

2 week field periods. Local volunteers could help train these individuals and this would allow the program to continue in spite of the tendency of busy residents to eventually 'burn out' and drop out of Shellwatch monitoring.

Overall Conclusions:

1. Local populations of the lightning whelk appear to have declined on grassbeds just north of the Ding Darling Wildlife Refuge and management policies need to take this fact into account.

2. Populations of the other 3 species under study either appear to be holding there own (*F. hunteria*) or the species are not abundant enough for an assessment to be made at this stage (the pear whelk *B. spiratum* and the true tulip *F. tulipa*).

Literature cited:

- Catterall, C. P., and I. R. Poiner, 1987. The potential impact of human gathering on shellfish populations, with reference to some NE Australian intertidal flats. *Oikos* 50: 114-122.
- Kent, B., 1983. Patterns of coexistence in busyconine whelks *J. Exp. Mar. Biol. Ecol.* 66: 206-283.
- Magalhaes, H., 1948. An ecological study of snails of the genus *Busycon* at Beaufort, North Carolina. *Ecol. Monogr.* 18: 377-409.
- McClanahan, T. R., 1990. Kenyan coral reef-associated gastropod assemblages: distribution and diversity patterns. *Coral Reefs* 9: 63-74.
- Paine, R. T., 1962. Ecological diversification in sympatric gastropods of the genus *Busycon*. *Evolution* 16: 515-523.
- Paine, R. T., 1963. Trophic relationships of eight sympatric predatory gastropods. *Ecology* 44: 63-73.
- Perry, L. M. and J. S. Schwengel, 1955. Marine shells of the western coast of Florida. Paleontological Research Institution, Ithaca, N.Y., 318 pp.
- Wells, F. E., 1970. An ecological study of two sympatric species of *Fasciolaria* in Alligator Harbor, Florida. *Veliger* 13: 95-108.
- Wells, S. M., 1981. International trade in ornamental corals and shells. *Proc. 4th Int. Coral Reef Symp.* 1: 323-330.
- Wilkinson, L., 1990. SYSTAT: The System for Statistics. Evanston, IL: SYSTAT, Inc.

Appendix I Shellwatch Site Descriptions and Environmental Parameters

Weather calm unless otherwise noted.

Date	Site	Water temperature in degrees Fahrenheit	Specific gravity	Weather & tide notes	Sheller count	Misc. natural history notes
1988:						
Sept 28	2	n.d.	n.d.	Calm, no waves at site, slight chop in sound; am. low tide.		
Sept 29	3	n.d.	n.d.	Am. low	5	
Sept 30	4	87-90: 4 noon reps.	1.021	Am low followed by rising tide		King's crowns (<i>Melongena corona</i>) near mangroves
	2	85	1.0205			
	3	84	1.0205			
Oct 26	1	70	1.0215	Am low + rising		Bubble shells, mud snails (<i>N. vibex</i>), dove shells (<i>Anachis</i>) & misc. bivalves common
Oct 27	2	Thermometer lost				
Oct 28	3&4			Am low + rising	2 - S4	Fewer small shells & worms at site 3 than at site 4
Nov 22	1			Water choppy after Hurricane Keith brush on 11; am low + rising	1	Many onuphiid worms in 1C. Less in 1b; sparse in 1A.
Nov 25	2	75	1.022	Choppy at first but calmed. Am low + rising	5 - S3	Spider crabs common, moon shell (<i>Polinices</i>) egg collars, horseshoe crabs (<i>Limulus</i>) and ragged sea hares (<i>Bursatella</i>) common; <i>Modulus</i> very common 1C.
Nov. 26	1	71 at 8.05; 75 at 10.40.	1.022	Very light chop; air 60 degrees. Am low.	6	Oyster drills (<i>Urosalpinx</i>); large <i>Limulus</i> , red urchins and pen shells.
Nov. 29	2	Thermometer broken	1.0225	Moderate 15-18k. wind; moderate chop but sunny. Air temp. rising from 60s to 70s. Am low + rising.		Lots of <i>Nassarius</i> , small polychaete egg bags, two large horse conch. Grass may have died back.
Dec. 12	4			Strong NE wind. Water rough. Cold & wet. Low not as low as predicted.		Many <i>Melongena</i> ; some mating. Shoal grass thin and brown.
1989:						
Jan 7	3	69	1.022	Very low am tide.		More grass dieback: no shoal grass; turtle grass frost bitten. Many P. egg collars.
Jan 20	2	70	1.024	Light easy wind 5-7k. Beautiful weather. Very low.		P. collars. Some new grass growth.
Feb 6	3	70	1.022	Am low.	3 - S3	Lots of P. collars.
Feb 7	1C	78	n.d.	Too rough to use hydrometer.	2	
Feb 8	2	80	1.023	Am low		Many <i>Melongena</i> ; red algae

Feb. 10	1	70	n.d.	Too choppy for hydrometer; Rising tide.	(Graciliaria) on grasses. More shoal grass?
Feb. 20	1C	71	1.0225	NE wind; strong & foggy.	
Mar 6	1	72	1.021	Cloudy & overcast but warm; am low	Many bivalve siphons, 1 P. collar, pen shells, horse conchs & 3 apple murex. Grass thinner than in Feb.?
Mar 8	2A &	57	1.0215	Strong NE wind; terrible weather; late am low.	P. collars; many buried Melongena in 2F; spider crabs; grass dieback
Apr 18	2			Late day census; water deep, inexperienced crew.	Many Melongena; 6-10 bay scallops; no P. collars.
May 17	3 &			5 pm. but calm and bright sunset. Very good conditions.	Grasses heavy; flowers on turtle grass; many small Melongena
May 31	1	92	1.025	Late day low.	Bottom very muddy; red + filamentous on grasses.
June 1	2	90	1.025	Afternoon low.	Many Melongena in health green shoal grass.
June 3	2				Small Limulus common; one P. egg collar.
Aug. 22	1	88 - 11am 4 reps: 98, 97 98, 98, 102 mud 94 air 95	1.021	Afternoon low.	Pen shells, P. collars & Nassarius vibex common. Bursatella in shoal grass. Red algae and filamentous species have disappeared.
Aug 23	4	1 pm.: 96, 94 96, 102	1.0215	Afternoon low.	Juvenile FH in oyster clumps. Buried Melongena & polychaete egg bubbles common.
Oct. 16	2	84	1.021	Very low morning tide.	Worm egg bubbles common stone crabs, Modulus & Limulus common. Bulla. 3 chipped tulips (stone crab damage?)
Oct. 18	4	85	1.021	Morning low.	Ark shells abundant; true tulip eating a banded tulip.
Oct. 20	1	70	1.021	Very stiff north wind; whitecaps; water much lower than expected.	Many solitary ascidians in grasses.
Dec. 12	2	64	1.021	Relatively calm; little wind.	Abundant P. sand collars; mating tulips.
Dec. 13	1 A &	64	1.021	Cold front has come in. Windy. Air temp. still mild. Am. low.	Plentiful tulip food: Cerithium & Nassarius. FH eating a Cerithium. A few polychaete bubbles. Many Busycon shells: 3 BS; 9 BC. Grasses sparse.
Dec. 14	1B			Temperature has dropped. Very cold. Wind from NE.	Many worm bubbles; dozens of onuphiids. One P. sand collar; 9 pen shells

Dec. 17	3	66	1.022	Air temp. in the 50s and cloudy.	and one cockle.
	4	62	1.0215	Temp. at 4 at 9.40; Site 3 temp. at noon higher due to sun coming out by afternoon.	
Feb. 9	2	71 @ 9.30	1.025	Wind abated, sunny. Temp rising from 60s to low 80s.	T. grass sparse but some green growth. Huge #s of FH at 2G. Juvenile FH on posts, under pen shells, & on turtle grass. Many Cerithium & Modulus. P. egg colors 2C.
Feb.10	3 &	71	1.023	Very low water. At end of census wind rippling water quite a bit. Hard to see.	Melongena, polychaete bubble cases + few lugworm sacs. Spyridaea on t.grass. Nassarius & Cerithium on grasses. Mating pear whelks. Shoal grasses with fuzzy algal film. T.g.die back. Baby FH on turtle grass.
Feb. 12	1			Windy with white caps from northeast.	One deeply buried BC with new partly calcified shell. Dead BC:10, BS:4. 4 apple murex.
Apr 23	4	82	1.024	Warm but light chop with west wind. Back to afternoon low tides. Water deep at first; bars out at end.	Small Limulus & spider common. New green grass shoots.
Apr 24	1	77	1.024	Rain; afternoon tide.	Nassarius and Cerith., juvenile Strombus alatus; 1 horse conch; new grasses.
Apr 25	2			Water dropped from 8 inches to 0 on afternoon low.	Water very clear; spider crabs common; grasses healthy & green.
July 19	1	86 @9 am	1.0235	Moderate chop with onshore breeze; aft. low.	Large BC eating huge Mercenaria. Grasses in good condition. A few polychaete egg bubbles, 1 Pinna and one red urchin. Mod. # Nassarius.
Sept 1	1			Morning low.	
Nov. 4	1	78	1.023	Weather good; tide not as low as expected. Census on rising am tide.	Many empty shells: BC:15,10BS Stone crabs in area. Grass brown from cool snap.
Nov.5	2	80	1.023	Low to rising water.	Large Modulus on grass. Grass in good shape. Many Lucina floridana clams.
Nov 6	4	80	1.022	Calm and sunny; rising tide.	Small Limulus, small Modulus & polychaete eggs 2 big Horse conch.
	3				

Appendix II.

Abundance and mean size data Site 1 Sept 88 - Nov 1990

Census date	<u>Busycon contrarium</u>			<u>Busycon spiratum</u>			<u>Fasciolaria hunteria</u>		
	Abundance	Mean size	S.D.	Abundance	Mean size	S.D.	Abundance	Mean size	S.D.
Plot 1A									
1988									
Sept	3	8.8	0.7	0			9	4.3	1.8
Oct	2	13.3	2.5	1	9.5		3	3.1	0.1
Nov	10	8.7	1.5	4	6.2	0.7	8	5.3	0.7
1989									
Feb	13	7.4	1.1	0			0		
Mar	1	6.9	0.0	0			1	4.3	
May	6	9.2	1.2	1	6.2	0.7	1	5.4	
Aug	0			0			0		
Oct	2	11.5	1.3	1	5.9		0		
Dec	0			0			1	2.4	0.0
1990									
Feb	0			0			3	3.1	0.3
Apr	6	8.7	2.5	0			0		
July	0			0			0		
Sept	6	8.2	1.2	3	5.1	1.2	3	6.7	0.2
Plot 1B									
1988									
Sept	1	7.7		0			2	1.5	1.5
Oct	1	7.0		2	9.0	0.5	5	7.0	0.6
Nov	8	9.3	4.2	4	5.5	1.1	12	5.0	1.2
1989									
Feb	No data for any species								
Mar	0			0			0		
May	1	8.4		0			2	5.1	1.0
Aug	1	28.0		1	6.2		2	4.1	1.6
Oct	5	6.6	1.6	2	5.4	1.6	7	4.3	1.4
Dec	4	6.6	1.4	2	7.1	0.1	2	2.7	3.8
1990									
Feb	5	6.1	3.7	0			2	3.6	2.3
Apr	6	7.3	0.8	0			3	6.2	0.1
July	3	7.2	0.3	5	6.6	1.0	5	4.8	0.5
Sept	10	7.7	0.7	2	5.5	0.6	13	5.5	0.9
Plot 1C									
1988									
Sept	7	10.1	0.6	0			9	4.7	1.6
Oct	9	8.8	0.9	1	9.5		4	6.1	1.1
Nov	11	7.5	3.1	10	6.6	2.5	18	4.5	1.5
1989									
Feb	20	8.1	1.2	3	6.6	2.3	2	3.9	1.1
Mar	22	8.2	1.7	4	6.5	1.7	1	2.5	
May	20	8.9	1.4	2	6.3	0.0	5	5.3	0.6
Aug	5	9.1	0.4	1	7.0		8	4.5	2.2
Oct	6	9.1	1.2	2	6.4	1.9	2	5.0	1.9
Dec	1	7.9		0			0		
1990									
Feb	3	8.0	1.8	0			1	5.2	
Apr	10	9.4	2.7	1	4.4		2	6.7	0.7
July	5	14.2	7.6	3	5.7	1.6	5	6.2	1.0
Sept	1	8.7		5	7.0	1.3	6	6.5	0.7
Nov-1C only	0			1	6.1		11	5.8	1.4

Appendix III. A.

Raw shell length data for
Busycon contrarium at Site 1. n.d.=no data; m.d.=length not recorded

	1988			1989			1990								
	Sep.28	Oct.27	Nov.26	Feb.1	Feb.19	Mar.6	May.30	Aug.21	Oct.19	Dec.13	Feb.11	Apr.24	July19	Sept20	Nov.4
Plot1A	8.1 8.5 9.7	10.8 15.9	11.5 9.5 9.8 9.5 6.6 8 7.4 6.9 7.5	6.1 8.7 8.1 9 8.2 6.1 6.6 5.9 8.1 6.7 7	n.d.	6.9	8.9 9.4 8.8 8.4 8	No Bc	12.7 10.2	No Bc	No Bc	10 6.9 7 7.6 6.7	n.d.	9.9 8.2 9.4 7.4 6.4	n.d.
Plot1B	7.7	7.0	9.7 7.9 6.6 7.7 9.7 6.8 19.1 6.6	n.d. n.d. Ic not done; 1B censused twice.	n.d.	no B	8.4	28	6 6.8 6.2 9.2 4.8	7.7 7.4 4.6 6.8	6.7 7.7 m.d. 9.9 6.4	8.2 6 7.4 8.1 6.8 7.5	7.5 7.2 6.9	6.9 8.4 7.6 8.3 7.7 7.5 6.8 7.8 7.1 9.1	n.d.
Plot1C	10.6 9.3 10.4 9.7 9.7 11.1 9.7	9.3 8.5 7.7 9.3 8.5 7.7 8.5 9.7 10.4	8.7 6.4 6.9 7.8 9.1 11.1 5 10 10.5 7	7.6 6.4 6.6 10.1 8.6 8.4 7.7 8.6 6.9 8.5 5.3 6.8 7.4 6 8.3 10 7.2 7.5 7.4 9 7	6.5 8.5 10.3 7.1 7.3 8.4 8.4 6.9 8.4 6.9 5.3 6.8 7.4 5.7 5.6 7.8 7.1 10.4 8.6 9 7	10.4 7.4 8.9 10.9 6.8 7 11.3 8.3 8.4 8.7 6.8 7.5 8.9 9.5 8.5 11.4 6.7 8.1 7 7.1 8.8 7	10.2 9 9.3 9.3 8.4 8.4 10.7 9.1 8.7 6.8 7.5 8.4 8.9 9.5 8.5 6.6 6.7 8.1 7 7.1 8.8 7	9.5 9 9.3 9.2 8.4 7.3	9 8.4 9.5 11 9.4 7.3	7.9	6 8.6 9.5	6.8 9.9 8.4 7.1 8.3 11.2 6.8 14.7 11.4 12.7 7.7	8.4 27.5 8.4 11.4 12.4 11.2	8.7	No BC

Appendix IIIB.

Raw shell length data for
Busycon spiratum at site 1. n.d.= no data

	1988			1989				1990							
	Sept28	Oct.27	Nov.26	Feb.10	Feb.20	Mar6	May30	Aug21	Oct 19	Dec 13	Feb.11	Apr 24	July 1	Sept 2	Nov 4
Plot1A	No BS	9.5	5.1 6.2 6.4 7.2	no BS	n.d.	no BS	5.7	No BS	5.9	No BS	No BS	No BS	No BS	4.8 3.9	n.d.
Plot1B	No BS	9.5 8.5	6.5 6.2 5.2 4.1	n.d.	n.d.	no BS	no BS	6.2	6.5 4.2	7.1 7	No BS	No BS	6.5 6.1 5.7 8.4 6.4	5.9 5	n.d.
Plot1C	No BS	9.5	6.1 8.7 8.5 7.2 7 7 6.2 6.7 9	5 5.6 9.2	7.4 7.5	6.9 7.3 7.8 4.1	6.3 6.3	7	7.7 5	no BS	No BS	4.4	7.5 4.5 5.1	7 8.6 8.1 6.1 5.4	6.1

Appendix IV.

Abundances and mean sizes Site 2 Sept. 88 - Nov. 1990

<u>Busycon contrarium</u>				<u>Busycon spiratum</u>			<u>Fasciolaria hunteria</u>		
Abundance Mean size S.D.size data				Abundance Mean siz S.D.size data			Abundance Mean size S.D. size data		
Plot 2A									
1988	Sept	1	14.7	2	7.8	1.1	2	6.9	0.9
	Oct	5	13.3	0			0		
	Nov	6	11.6	2	6.6	0.2	1	3.8	
1989	Jan	0		0			2	5.3	0.6
	March	0		0			1	5.1	
	April	1	13.7	1	6.0		0		
	May/June	5	7.9	2	7.2	0.1	7		
	Aug	0		0			2	8.4	5.5
	Oct	0		0			13	5.1	1.6
	Dec	4	13.8	0			2	5.9	0.8
1990	Feb	0		1	7.6		7	4.6	1.4
	April	3	9.9	1	6.7		2	3.2	4.5
	Nov	4	14.2	0			6	5.3	0.9
Plot 2c									
1988	Sept	1	15.5	0			1	7.0	
	Oct	0		0			1	3.9	
	Nov	2	8.6	0			4	5.7	0.6
1989	Jan	0		0			0		
	Mar	No data for any species							
	April	0		0			0		
	May/June	0		0			0		
	Aug	0		0			1	7.0	
	Oct	0		0			0		
	Dec	1	14.6	0			1	2.1	
1990	Feb	0		0			2	5.9	0.7
	April	0		0			0		
	Nov	1	18.7	0			2	5.7	1.1
Plot2d									
1988	Sept	0		0			3	6.5	0.5
	Oct	0		0			0		
	Nov	0		0			1	5.5	
1989	Jan	1	8.0	1	6.5		1	5.1	
	Mar	No data for any species							
	April	2	7.0	0			0		
	May/June	0		0			0		
	Aug	0		0			0		
	Oct	0		0			0		
	Dec	3	16.2	0			0		
1990	Feb	0		0			0		
	April	0		0			0		
	Nov	0		0			1	6.5	

Plot2f and 2i data
on next page.

B.contrarium

B. spiratum

F. hunteria

	Abundance	Mean siz	S.D.size	Abundance	Mean siz	S.D.size	Abundance	Mean siz	S.D.size
Plot2f									
1988 Sept	5	15.0	1.6	1	10.0		10	6.8	1.2
Oct	10	14.1	0.9	1	7.4		14	5.8	0.9
Nov	8	15.3	3.1	2	8.4	0.2	14	5.0	0.8
1989 Jan	8	14.7	1.4	0			7	5.5	0.8
March	2	12.7	1.8	2	6.3	0.5	4	5.2	1.0
April	6	15.7	0.7	0			1	5.1	
May/June	4	13.8	3.6	0			7	5.4	0.7
Aug	3	12.7	5.2	1	8.2		1	5.1	
Oct	1	14.5		0			15	5.6	0.4
Dec	11	15.5	0.9	0			0		
1990 Feb	3	15.4	0.4	0			14	5.1	1.1
April	2	12.6	5.4	0			3	4.9	0.8
Nov	4	14.7	3.5	0			5	5.3	0.4
Plot2g									
1988 Sept	4	15.1	0.8	1	6.0		11	6.1	1.2
Oct	5	13.5	1.5	0			1	5.3	
Nov	7	14.6	0.6	0			17	5.3	1.2
1989 Jan	7	13.2	1.9	0			32	5.5	0.9
Mar	No data for any species								
April	5	12.0	3.3	3	7.6	0.9	3	5.7	0.7
May/June	5	15.4	0.9	1	8.2		2	5.9	0.2
Aug	6	14.4	1.6	2	6.6	0.6	1	5.2	
Oct	7	13.7	2.1	0			17	5.4	0.9
Dec	6	13.0	1.4	0			13	5.8	0.5
1990 Feb	3	14.7	3.6	1	5.1		144	4.6	1.2
Apr	0			0			0		
Nov	6	13.7	2.6	0			6	5.8	0.2
Plot 2i									
1988 Sept	4	14.0	2.3	0			2	5.8	1.8
Oct	6	15.3	2.6	0			3	5.6	1.2
Nov	14	14.5	2.9	0			15	5.9	1.4
1989 Jan	8	14.1	8.0	0			15	5.0	0.4
Mar	No data for any species								
April	1	15.3		0			2	6.4	0.5
May/June	4	16.0	4.0	0			1	5.7	
Aug	9	15.3	2.1	0			1	5.2	
Oct	4	15.4	2.0	0			7	5.6	0.6
Dec	16	15.2	1.3	1	4.2		25	5.5	0.4
1990 Feb	3	16.2	2.8	0			25	5.4	1.1
Apr	0			0			6	4.5	2.2
Nov	2	13.6	3.9	0			3	5.7	0.7

Appendix V-A.

Raw size data for site 2.

Busyon n.d.= no data
contrarium

	1988				1989				1990					
	Sept.2	Oct.27	Nov.26	Jan20	Feb.8	Mar 8	Apr 18	June 1	Aug 23	Oct 16	Dec 11	Feb 9	Apr 24	Nov 5
Plot2A	14.7	12.9	14.8	No BC	n.d.	no BC	13.7	9	No BC	No BC	14.6	No BC	8	14.7
		15.4	8.4					7.5			16.2		14.9	15.9
		14.6	8.1					9.4			6.6		6.9	12.2
		9.4	9.4					7.3			17.6			14.1
		14.2	15.7					6.5						
			13.3											
Plot2C	15.5	No B	10	No BC	n.d.	n.d.	No BC	No BC	No BC	n.d.	14.6	No BC	n.d.	18.7
			7.2											
Plot2D	No B	No B	No B	8	n.d.	n.d.	7.2	No BC	No B	n.d.	14.4	n.d.	n.d.	No BC
							6.7	20% area			19			
							censused				15.3			
Plot2F	12.4	12.7	13.2	16.4	n.d.	14	15.5	9.4	6.7	14.5	15	15.2	16.4	13.7
	15.5	13	19	14.1		11.4	16.2	12.7	16.1		16.5	15.2	8.7	19.8
	15.1	13	18	14.1			14.5	17.8	15.3		15.6	15.9		12.2
	15.5	14.3	12.9	16.9			16.3	15.2			15.9			12.9
	16.6	14.4	19.4	14.5			16				16.6			
		15.2	12.1	12.9			15.4				16.8			
		13.8	12.2	13.3							14.5			
		15.2	15.6	15.1							15.1			
		14.4									14.5			
		15									15.8			
											14.5			
Plot2G	15.9	13.8	14.1	9.5	14.1	n.d.	15.2	14.9	14.9	14	14.7	18.9	n.d	11.2
	15.5	12.9	14.6	13.7	13.8		10.4	15.4	13.9	12.7	13.1	12.6		14.2
	15.1	12.4	15.6	13.7	6.9		15.8	16.7	11.6	17.3	12.7	12.6		12.4
	13.9	12.3	15	15.1	15.6		8.6	15.7	16.3	13.4	11.2			18.6
		15.9	13.7	12.2	13		9.8	14.2	15.2	15.6	11.8			12.9
			14.2	13.3	13.6				14.6	11.4	14.5			12.9
			14.9	15	15.6					11.8				
					13.7									
					15.3									
					12.3									

Plot2I Data on next page

B. contrarium
raw data

	1988				1989				1990					
	Sept.2	Oct.27	Nov.26	Jan20	Feb.8	Mar 8	Apr 18	June 1	Aug 23	Oct 16	Dec 11	Feb 9	Apr 24	Nov 5
Plot #	15.1	19.8	14.2	12.9	n.d.	n.d.	15.3	14.1	16.8	14.7	17	18.9	No BC	10.8
	12.8	13.2	11.2	14				15.7	13.3	16	12.8	16.4	65% of	16.3
	11.6	15.5	12.5	15.5				17.1	16.9	13	15	13.4	plot	
	16.6	15.2	14	13.2				17	19.4	17.8	16.4			
		15.9	13	14.2					12.6		15.8			
		12.4	14.2	12.5					15.2		15.8			
			10.7	16.3					14.1		13.5			
			19.1	14					14.8		14.8			
			19						14.5		16.1			
			10.8								12.8			
			15.1								16.4			
			14.4								15			
			15.2								16.5			
											14.3			

Appendix V - B

Raw size data for plot 2.

Busycon spiratum No data = n.d.

	1988		1989					1990						
	Sept 2	Oct.27	Nov.26	Jan 20	Feb.8	March	Apr 18	June 1	Aug 2	Oct 16	Dec 11	Feb.9	Apr 24	Nov90
Plot2A	8.5 7	No BS	6.4 6.7	No BS	n.d.	No BS	6	7.1 7.2	No BS	No BS	No BS	7.6	6.7	No BS
Plot2C	No BS	No BS	No BS	No BS	n.d.	n.d.	No BS	No BS	No BS	n.d.	No BS	No BS	n.d.	No BS
Plot2D	No BS	No BS	No BS	6.5	n.d.	n.d.	No BS	No BS	No BS	n.d.	no bs	n.d.	N.d.	No BS
Plot2F	10	7.4	8.5 8.2	No BS	n.d.	6.6 5.9	No BS	No BS	8.2	No BS	No BS	No BS	No BS	No BS
Plot2G	6	No BS	No BS	No BS	No BS	n.d.	7.3 8.6 6.9	8.2	6.2 7	No BS	No BS	5.1	n.d.	No BS
Plot2I	No BS	No BS	No BS	No BS	n.d.	n.d.	No BS	No BS	No BS	No BS	4.2	No BS	No BS 65% of plot	No BS

Appendix V - C

Raw size data for site 2.

Fasciolaria hunteria n.d.= no data

	1988		1989				1990								
	Sept.2	Oct.27	Nov.26	Jan20	Feb.8	Mar 8	Apr 18	June 1	Aug 23	Oct. 16	Dec 11	Feb 9	Apr 24	Nov 5	
Plot2A	6.2 7.5	No FH	3.8	4.9 5.7	n.d.	5.1	No FH	3.4 4.1 6.4 4 5.1 4.6 3.8	4.5 12.3	5.5 5.5 5.1 4.7 5.4 5.3 6.5 5.9 5.4 5.6 6.6 5.2	5.3 6.5	5.3 4 7 3.8 4.4 4.9 2.7	6.4	5.7 6.3 4.2 4.3 6.3 5	
Plot2C	7	3.9	5.3 5.1 6 6.3	No FH	n.d.	n.d.	No FH	No FH	7	n.d.	2.1	6.4 5.4	n.d.	4.9 6.4	
Plot2D	6.5 7 6	No FH	5.5	5.1	n.d.	n.d.	No FH	No FH in 20%	No FH	n.d.	6 6.5	n.d.	n.d.	6.5	
Plot2F	8 7.5 6.5 3.75 7.5 7 6 7 7 8 5.2 5.1 5.1 6.4	7 5.2 5.5 6.1 6.7 6.4 6.8 6.5 4.3 4.6 5.2 5.1 5.1 6.4	5.4 5.1 5 5.4 5 2.4 5.6 5.6 5.3 4.6 4.8 5.1 5.4 5.2	5.6 5.3 5.2 5.8 4.5 4.9 6.9	n.d.	3.9 5.4 5 6.3	5.1	4.2 5.1 5.9 5.8 5.8 4.8 5.9	5.1	5.6 5.3 5.4 5.9 5.4 5.7 5.5 6.3 5.4 5.2 4.8 6 6.2 6 5.3	No FH	5.3 5.6 6.6 5 6.2 5.7 4.8 5.2 3.2 5.1 3.2 3.8 5.9 6.8 4.9	4.9 4.2 5.7 4.9 5 5.3	4.9 5.3 6 5 5 5.3	
Plot2G	6 7 9 6 5 7 5 5 6 5 6	5.3	6.7 5.5 5.7 4.6 5.7 6.4 5.7 3 5 6.2 4.6	6.2 4.8 6.2 4.4 6.3 4.7 6.5 3.4 6.3 4.7 5.1	5.4 n.d. 6.1 4.8 5.7 6.3 9.3 5 5.3 5.7 5.1	6.2 6.3 4.9	4.8 6	5.1	5.3 6 6.2 5.4 5.4 6 5.6 6 5.5 5.5 3.7 6	6.1 6.4 6.2 5.8 5.5 6 6 6.8 5.1 5.4	144FH Av.size 4.6cm	n.d.	5.4 5.7 6.1 5.8 5.7 5.9		

6.3	5.5	5.8
2.2	6	5.4
5.6	5.9	4.9
4.7	7.3	3.5
5.8	5.3	5.3
5.7	6.2	3.5
	5.9	6
	5.3	6
	6.2	4.6
	4.9	4.8
	6.4	6.8
	4.9	5.4
	4.3	4.8
	5.3	4.7
	5.3	5.7
	4.6	5.6
	7.1	
	5.3	
	4.5	
	5.9	
	6.4	

4.9	5.4
5.9	5.3
6.2	
5.9	
2.9	
5.1	

Plot2I	4.5	4.4	9.6	4.8	n.d.	n.d.	6	5.7	5.2	5.2	5.7	7	5.3	5.1
	7	5.6	6.2	5.4			6.7			6.4	5.2	6.5	5.8	6.5
		6.8	5.5	5.7						5.2	5.6	6.7	5.4	5.5
			6.4	4.2						6	5.7	6.9	5.1	
			3.6	4.9						6.2	5.5	4	5.4	
			6	5.2						5.7	5.7	5.2	Data from 65% of plot	
			5	4.6						4.6	5.2	4.7		
			5.2	5							6	5.1		
			6.2	4.9							5.4	7		
			7	5.6							4.8	4.8		
			6.4	5.3							5.6	5.5		
			4.2	4.8							4.9	5.5		
			5.3	4.4							6.2	3.5		
			6.3	5							5.7	5.2		
			5.2	4.6							6.2	6		
											5	6.4		
											5.8	6		
											5.8	5.4		
											5.1	5.1		
											6.1	3.5		
											5.8	5.2		
											5.9	6		
											5	5.1		
											5.5	4.2		
											5.4	3.4		
											6			
											5.3			
											5.2			
											6.5			
											5.7			
											5.1			
											5.7			
											3.7			
											5.8			
											6.6			
											5.8			
											5.7			
											2.8			

Appendix VI.

Abundance and average size data Sites 3 and 4

[illegible]

Abundance and average size data Sites 3 and 4

[illegible]

Appendix VI.

Abundance and average size data Sites 3 and 4

		<u>Busycon contrarium</u>			<u>Busycon spiratum</u>			<u>Fasciolaria hunteria</u>		
		Abundance	Mean size	Std.Dev.	Abundance	Mean size	Std.Dev.	Abundance	Mean size	Std.Dev.
Plot 4B										
1988	Sept	4	9.7	1.4	2	7.6	0.849	3	4.7	0.4
	Oct	4	12.9	2.4	0			1	5.2	
	Dec	6	11.7	3.2	0			5	5.0	0.7
1989	Feb	2	16.7	5.0	0			0		
	Mar n.d.									
	Apr n.d.									
	May	1	8.4		0			1		
	Aug	0			1	6.7		1		
	Oct	8	11.9	2.4	0			15	5.4	0.8
	Dec	8	12.1	1.1	0			3	5.1	0.8
1990	Feb	2	8.4		0			1	5.1	
	Apr	2	9.6		0			0		
	Nov	0			0			10	5.2	0.3
Plot 4C										
1988	Sept	1	9.9		0			1	4.3	
	Oct	1	8.3		1	7.6		1	0.0	
	Dec	0			0			3	5.6	1.1
1989	Feb	4	9.5	2.6	0			1	3.8	
	Mar n.d.									
	Apr n.d.									
	May	0			0			1	4.8	
	Aug	0			0			1	4.0	
	Oct	1	11.9		1	7.8		8	5.4	0.7
	Dec	1	12.9		0			3	5.4	0.7
1990	Feb	1	10.9		0			4	3.9	0.9
	Apr	1	17.6		0			3	4.9	0.5
	Nov	2	11.2	0.7	0			9	4.6	0.8

