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I. Is Habitat Availability Limiting Recruitment of Calico Scallops (*Argopecten gibbus*)?

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II. *Abstract*

The fishery for calico scallops, *Argopecten gibbus* (Linnaeus), a commercially valuable species found in the waters of the southeastern United States, sustained harvests of one to greater then ten million pounds per year for three decades, occurred in four states, and involved thousands jobs either directly or indirectly. That fishery has completely collapsed and essentially no landings are being reported. This report describes a dredged-based survey that assessed the current status of the stock. Our findings indicate that calico scallops are still abundant on at least two historic fishing grounds - the Cape Canaveral fishing grounds and a previously poorly-documented fishing ground in the near-shore waters off southwest Florida. The abundance of scallops varied greatly among seasons, from non-existent to extremely dense patches within, periods of months. This characteristic has been understood in the fishery since its inception, and remains true. Both calico scallop shell and shell from other molluscs was abundant, but very heterogeneously distributed. Two disconcerting observations were made. First, very few scallops of a desirable market size were collected; most of the scallops we collected measured less than 40 mm shell height, a size predicted to yield meat counts above 200 per pint. Second, every scallop examined was infected with a protozoan parasite assumed to be of the species *Marteilia*. A high percentage of the scallops had advanced stage infections and were developing pathologies within the digestive diverticula. Ecologically, calico scallops appear to be stable and resilient, they were often the numerically dominant species in our samples, and are clearly producing abundant offspring. As a fishery, the paucity of market size individuals may preclude redevelopment if the current status is permanent, and not a short-term situation coincident with our sample period.

III. *Executive Summary*

The fishery for calico scallops, *Argopecten gibbus* (Linnaeus), a commercially valuable species found in the waters of the southeastern United States, sustained harvests of one to greater then ten million pounds per year for three decades, occurred in four states, and involved thousands jobs either directly or indirectly. That fishery has completely collapsed and essentially no landings are being reported. This report describes a dredged-based survey that assessed the current status of the stock. Our findings indicate that calico scallops are still abundant on at least two historic fishing grounds - the Cape Canaveral fishing grounds and a previously poorly-documented fishing ground in the near-shore waters off southwest Florida. The abundance of scallops varied greatly among seasons, from non-existent to extremely dense patches within, periods of months. This characteristic has been understood in the fishery since its inception, and remains true. Both calico scallop shell and shell from other molluscs was abundant, but very heterogeneously distributed. Two disconcerting observations were made. First, very few scallops of a desirable market size were collected; most of the scallops we collected measured less than 40 mm shell height, a size predicted to yield meat counts above 200 per pint. Second, every scallop examined was infected with a protozoan parasite assumed to be of the species *Marteilia*. A high percentage of the scallops had advanced stage infections and were developing pathologies within the digestive diverticula. Ecologically, calico scallops appear to be stable and resilient, they were often the numerically dominant species in our samples, and are clearly producing abundant offspring. As a fishery, the paucity of market size individuals may preclude redevelopment if the current status is permanent, and not a short-term situation coincident with our sample period.

Dredge surveys were conducted in four seasons on each coast. The Cape Canaveral fishing zone was sampled during November 2004, April-May 2005, October 2005, and July 2006 using the R/V Geoquest (Figure 2). The near shore southwest Florida shelf was sampled during October 2004, September-November 2005, April 2006 (R/V Bonnie E) and August-September 2006 (R/V Veliger, 20' runabout & R/V Calinectes, 26 ' runabout). We tentatively identified a total of 243 taxa.

There was a seasonal variability in adult calico scallop abundance. This pattern was observed on both coasts. Adult scallops were more abundant in east coast samples than samples from the west coast. The catch rate of spat (juvenile scallops) was highest in samples collected during the summer cruises, a result observed on each coast. Spat were more abundant on east coast scallop beds. Spat were more abundant than expected on scallop shell, and less abundant than expected on other mollusc shell and especially on all other substrate. The east coast had much more scallop shell than the west coast but the abundance of other shell did not vary by coast. Comparison with historical data sets suggest that there has been a decline of roughly one order of magnitude in scallop abundance on Florida’s east coast, but no change in the abundance if relic shell. These estimates are subject to possible biases since no comparison between sample gears is possible.

Parasitic infection of a presumed protozoan (*Marteilia* sp.), was detected in every animal inspected, and stage 5 animals, where pathologies are observed, were common.

IV. *Purpose*

A. Problems addressed

The calico scallop, *Argopecten gibbus* (Linnaeus), is a commercially valuable species of the southeastern United States. The calico scallop industry has been reported to have been in existence as an active fishery almost 50 years (Bullis & Ingle, 1959), having first developed in the northeastern Gulf of Mexico (Bullis & Ingle, 1959) before expanding to North Carolina (Cummins, 1971), South Carolina (Anonymous, 1998) and eventually east-central Florida (Taylor, 1967; Cummins, 1971). In fact, some landings occurred in Florida as early as 1927 when 12,800 pounds were recorded (Figure 1). From 1927-1945, roughly 11 seafood harvest surveys were conducted, and of those, only 3 indicated calico scallops had been harvested. At that time, they were recorded as sea scallops, distinctly separate from bay scallops, but had been landed in Florida's southwestern counties, Pinellas and Sarasota. The peak was in 1934 when 120,200 pounds of scallops were landed (Fiedler, 1938). Small numbers are occasionally taken as by-catch by Georgia shrimp boats. Since the fishery became firmly established around 1960, there have been severe fluctuations in both the location and abundance of calico scallop stocks, but the most consistently productive area has remained east-central Florida (the Cape Canaveral beds). The fishery achieved a record level of production in 1984 (43 million pounds of meats) and employed over 2600 people. Landings decreased throughout 1985 and the entire industry collapsed in early 1986 (Rockwood & Pompe, 1988). By 1987 the industry began to rebound. During winter and spring, 1988, production reached 200-300 gallons of shucked meat per boat per day. According to Rockwood and Pompe (1988) the average annual direct spending by the calico scallop fishing industry during the peak (1984-1987) was around $23 million per year, and total indirect economic impact in the region averaged over $86 million per year. These numbers translate into two dollars in direct spending and $8 in indirect impacts for every pound of scallop meat landed.

The future of the industry appeared bright, but in December 1988, the calico scallop population again collapsed. By March 1989, no scallops could be collected from the Cape Canaveral beds, and the industry has since been maintained primarily by sporadic landings in areas such as Cape San Blas, Florida and the west coast of Florida south of Tampa Bay. During the 1990's statewide landings in Florida averaged 1.7 million pounds but have since dropped to essentially no landings since 2002. North Carolina has had no commercial landings in over a decade. Assuming conservatively that the fishery could operate at half the 1980's harvest level of 12 million pounds per year, Florida lost on average 4 million pounds of landings per year during 1990-2000 and 6 million pounds in the each of the last seven years for a total of 86 million pounds of unrealized landings. This would translate into over $160 million in direct expenditures and $690 million in lost regional economic impacts due to the collapse of this fishery. North Carolina could similarly be assumed to have suffered as much as $100-200 million in lost economic earnings.

Many physical and biological factors may influence the interannual success of the Cape Canaveral calico scallop fishery. Hypothesized influences include disease (Moyer et al., 1993), predation (Schwartz & Porter, 1977), senility (Carpenter, 1967; Roe et al., 1971), or unknown factors (Bullis & Cummins, 1961). An additional factor may be inherent in the fishery. Larval scallops settling from the water column are dependent upon a hard and stable substrate for attachment and survival during the first days and weeks post-settlement. To an undefined degree, that firm substrate is composed of the valves of living and dead mollusc shells, the vast majority of which appear to be calico scallop shells. During fishing operations, primarily conducted with modified otter trawls, the bottom is swept of all living and dead shells, thus potentially removing essential habitat for juvenile calico scallops. If true, this suggests that the industry may be self-destructive, in that fishing effort removes the very habitat upon which the fishery depends.

The hypothesis that removal of scallop shell is limiting recruitment of subsequent scallop year classes is controversial within the industry (Anonymous, 1998), and research to test this hypothesis has been requested by the South Atlantic Fishery Management Council (Anonymous, 1998). Presentations at the recent 14th International Pectinid Workshop indicate that removal of scallop shell from the environment is a growing concern worldwide. Since 1976, there have been 160 million pounds of calico scallop meat harvested from Florida waters. Records show (FWRI unpublished data) that this translates into 1.6 billion pounds total weight (shell plus soft tissue), not counting unsorted bycatch. For the present study we proposed to gather information concerning the current distribution and abundance of calico scallop and their shell. Specifically, we planned to study four of the priority research needs listed in the Fishery Management Plan for calico scallops (draft – this plan was never finalized) (Anonymous, 1998). Information was gathered on the on the following:

1) The effect of the removal of shell, which serves as Essential Fisheries Habitat (EFH) for calico spat;
2) Growth and mortality;
3) The size frequency on individual scallop beds;
4) The occurrence of the parasitic protozoan *Marteilia sp.*

The first of these objectives falls directly into the essential fisheries habitat solicitation: what are the effects of gear (trawls and dredges) upon the essential fisheries habitat for this species. We measured the effect of fishing gear on habitat (removal of shell), and, by association, related the distributions of shell, recruits, and adults. We hypothesize that both calico scallop recruits and adults will be most abundant where shell (which is proposed to serve as the EFH for calico scallop recruits, is most abundant. While collecting data to address the question of EFH, we also collected juvenile and adult scallops in order to build a data set suitable for analysis of growth and mortality patterns, for plotting size frequencies of present day scallop beds, and to explore the occurrence of protozoan parasites of the calico scallops.

B. Objectives of the project

The general objectives of the proposed research were to assess the relative abundance patterns of calico scallops on the east Florida shelf and to compare present shell abundance to historical abundance in the same areas. We will:

1) Describe the current distribution and seasonal variation of calico scallops and their shells in areas of historically harvestable populations;

2) Compare the current distribution to historical distributions for this species and its shell, which has been proposed to serve as an essential fisheries habitat for juveniles;
3) Use histological techniques to describe the occurrence of the protozoan, *Marteilia sp.*, and reproductive status of extant calico scallop populations.

V. *Approach*

A. Work performed

Objective 1. Studies of shell, adult, and juvenile distribution.

Dredge surveys were conducted in four seasons on each coast. The Cape Canaveral fishing zone was sampled during November 2004, April-May 2005, October 2005, and July 2006 using the R/V Geoquest (Figure 2). The near shore southwest Florida shelf was sampled during October 2004, September-November 2005, April 2006 (R/V Bonnie E) and August-September 2006 (R/V Veliger, 20' runabout & R/V Calinectes, 26 ' runabout). Thus each coast was sampled twice during fall conditions, once during spring conditions, and once during summer conditions.

During each sample period, we conducted ~15 scallop dredges (Table 1) in each of four latitudinal zones on each coast: East (Sebastian, 27.797 – 28.045 N; Melbourne, 28.045 – 28.305 N; Cocoa, 28.305 – 28.551 N; Titusville, 28.551-28.881 N) (Figure 3) and West (Naples, 26.34 – 26.45 N; Fort Meyers 26.45 – 26.8 N; Englewood, 26.8 – 27.1 N; Sarasota 27.1 –27.5 N). Each zone was divided into a grid of 60 stations (Figure 4). The stations that were sampled were randomly chosen beforehand within the depth ranges of roughly 20 to 80 meters on the east coast and 5-15 m on the west coast. These are the depth zones where historical catches of calico scallops occurred. On each work day we attempted to sample the predetermined random stations although on some occasions one or more stations were reassigned when weather or available daylight prevented the successful acquisition of the target station.

Our goal was to tow for five minutes per sample using dredges with a mouth size of 0.69 m wide x 0.50 m high or 0.42 x 0.25 m (final west coast cruise only) (Figure 5). The larger dredge was utilized on cruises where mechanical winches were available (R/V GeoQuest and R/V Bonnie E). The smaller dredge was deployed from the stern cleat of standard runabouts and retrieved by hand for our final cruise when our own trawler, R/V Bonnie E, suffered mechanical breakdowns of the hydraulic system. Both frames were equipped with 1.25" (3 cm) stretch mesh net and roughly a 1m bridle. We adopted a method of employing numerous short-duration tows at the suggestions of Capt. Bill Burkhardt which allowed us to accomplish more replicate tows per day, which in turn offered a higher spatial resolution. Also, the dredge appears to fish more efficiently and with a higher probability of catching scallops when they are present, especially at low densities. During each tow, we measured initial and final GPS co-ordinates as an estimate of the distance of the tow, from which we calculated area trawled. We also recorded, start and stop times, water column depth, and the length of wire deployed during the tow. Wire angle was determined during preliminary research cruises in which we attached a downward-facing, real-time video system on the upper edge of the mouth of the dredge. Cable length and tow speed were modified until the lower edge of the mouth of the frame consistently remained in contact with the sediment surface, but did not dig deeply into the surface. The optimal wire:depth ratio was about 3.5:1 at 2 knots, and increased with depth and vessel speed. The optimal attachment point for the bridle was at roughly 1/3 of the height from the bottom of the frame. In practice, the wire was deployed until approximately a 3:1 ratio (west coast) to 4:1 ratio (east coast) was reached, and then the boat speed was adjusted downward until tension occurred on the wire, indicating the net was towing on the sediment surface. This was especially true for the deeper east coast stations, where we were limited to about 750 feet of wire, the capacity on the winch.

When processing a dredge sample, we first weighed the entire catch. In most cases, we then sorted the entire catch although for some very large samples (> 20kg) we split the sample into two to four equal subsamples and sorted only one fraction. All scallops, macrofauna and plant matter were removed and weighed. Next, the relic scallop shell and other mollusc shell were separated and each fraction was weighed. We measured the shell height of the first 30 live scallops from each trawl. We preserved the first 15 scallops collected in each zone for histological analyses. We also recorded any observations of spat (juvenile scallops <20 mm SH) either loose or attached to substrate, in an attempt to elucidate preferred settlement substrate. For the latter analysis, we calculated the proportion of total calico shell, other shell, and all other catch, for any tow where spat were observed. From this data set we created an expected frequency distribution (proportion of each substrate multiplied by the number of attached spat observed) to which we compared our observed frequency of attached spat. Unattached spat were not considered in this analysis. We considered loose scallops less than 20 mm as spat, but also considered any byssally attached scallop a juvenile for the purposes of substrate choice.

Once the data had been collected, entered, and proofed, we adjusted the catch data proportionally for time, dredge width, and any sub-sampling that occurred. Graphic representations of the data were created using ARCGIS software. Prediction maps of the data of interest were based on catch rates standardized to tow time and standardized net size were created using the Geostatistical Analyst extension of ArcGIS 9.2. These maps were created by ordinary kriging using the mean for coincidental points within a single time frame. Model error was minimized for each prediction map by optimizing parameters for constant trend removal, anisotropy, lag size, number of lags, and number of nearest neighbors.

The hypothesis that scallops, scallop spat, scallop shells, and other mollusc shells are distributed evenly was tested by ANOVA, with the four latitudinal zones as a fixed factor. Season and Coast also served as fixed factors. Because heterogeneity of variances was a common character of the data, Kruskal-Wallis or Mann-Whitney tests were applied to individual hypotheses when appropriate. The null hypothesis we tested was that all stations have equal density, and that no seasonal variation occurs. The alternative hypothesis anticipated many stations (or seasons) with densities of zero, interspersed with fewer stations (or seasons) supporting relatively high densities.

Objective 2. Historical data on the distribution of calico scallops and calico scallop shell was compiled from any available source - primarily from the NOAA library in Pascagoula, MS, and the FWRI library in St. Petersburg, FL. The data were available largely in the form of unpublished cruise reports (Table 2). We recorded any geographic reference available. Total catch, calico scallop catch, calico scallop size, total shell catch, depth, net size, and tow times were recorded. Catch was adjusted to tow time and net size for comparison to current data. The null hypothesis we tested was that each distinct sampling period would have equal density of scallops and shell. The alternative hypothesis anticipated differences between sampling periods.

Objective 3. During each cruise, we planned to collect up to 60 samples for histological analyses. The soft tissue for each scallop was removed and separated into digestive diverticula (placed in 5% buffered formalin:seawater), and all remaining tissue (preserved in 95% ethanol). Upon return to the laboratory the digestive diverticula were transferred to 70% ethanol. Standard histological procedures were followed including dehydration and embedding in glycol methacrylate. After sectioning the samples were stained with hematoxalin:eosin (H:E), thionin, and periodic acid Shiff's (PAS/MY) haematoxylin-metanil yellow (Grier and Taylor, 1998). Our initial goal was to examine scallops and compare the frequency of infected and healthy scallops between coasts, sites, and seasons. As the study progressed, we found that disease prevalence was much higher than anticipated. Slides were examined at 400x and an infection intensity scale was developed. The infection intensity stage was recorded as follows and compared for seasonal and spatial variation by either Mann-Whitney or Kruskal-Wallis non-parametric comparison, as appropriate:

0: no *Marteilia* detected
1: *Marteilia* detected in single cells of no more than one acini in the field of view
2: *Marteilia* detected in multiple cells, less than half of acini affected
3: *Marteilia* detected in multiple cells, roughly half of acini affected
4: *Marteilia* detected in multiple cells, most acini affected
5: *Marteilia* detected in most acini, pathology or necrosis observed

B. Project management

Dr. Stephen Geiger was principal investigator. He coordinated all contract activities, including scheduling and planning for cruises, oversight of collection and analysis of dredges, and data management. Dr. Geiger participated in all sampling, with the exception of one field day, in which Dr. Arnold served as field PI. Dr. Arnold was co-PI on the project, and oversaw all administrative obligations. Several research staff assisted in phases of the research, including preparation for cruises, participation in cruises, histological analyses, data entry, data analyses, and final report preparation. Dr.'s Geiger and Arnold jointly analyzed results, presented results at the International Pectinid Workshop (May 2007), prepared progress reports and will continue to prepare portions of this final report for publication in peer-reviewed journals.

Financial monitoring was performed by Florida Fish and Wildlife Conservation Commission's Bureau of Accounting Services through Linda Torres (FWRI grants office).

VI. *Accomplishments and findings*

A. Accomplishments

We completed all eight scheduled cruises, four on each coast. We tentatively identified a total of 243 taxa. Although not specified in the proposal, lists of fauna were maintained for each tow. A final list of taxonomic diversity and community association analysis will not be presented here, but will be prepared for publication at a later date. As an additional note, macro- and filamentous algae were much more common in west coast trawls than in east coast trawls. Hard bottom and/or evidence of coral was detected in 46 of the 240 east coast grids (Figure 3), and in 45 of 240 west coast grids (Figure 4). These areas are poorly charted but appear to be exceptionally diverse, and surely harbor many more species than we could detect with our dredge.

East coast cruises were completed during November 2004 (61 tows, 1 aborted), April/May 2005 (65 tows, 4 aborted), October 2005 (61 tows, 2 aborted), and July 2006 (60 tows, 1 aborted) (Figure 3). Calico scallop shell was collected in 92% of valid tows, and other dead shell was collected in 95% of valid tows. Calico scallops were collected in 38% of valid tows.

West coast cruises were completed during October 2004 (59 tows, 5 aborted), September & November 2005 (66 tows, 2 aborted); April 2006 (61 tows, 1 aborted) and August/September 2006 (60 tows, 3 aborted) (Figure 4). Calico scallop shell was collected in 68% of valid tows, and other dead shell was collected in 84% valid tows. Calico scallops were collected in 17% of valid tows.

East Coast - Fall 2004

We completed 59 of 60 planned tows on the east coast. At one station, we had insufficient wire to reach the bottom while towing (depth ~ 350'). In all, 537 scallops were collected from a total of 28 stations, with an average shell height of 37.8 mm. The most calico scallops collected from any single station was 109, from the region east of Sebastian Inlet. Average total catch was 13.8 kg per five-minute tow (~3 pounds per minute per foot of net mouth). Calico scallop shell was collected in 56 of the 59 tows, and other dead shell was collected in 58 of the 59 tows. The average weight of calico scallop shell (in tows that collected scallop shell) was 1.3 kg per five-minute tow and the average weight of other shell (in tows that collected shell) was 3.3 kg per five-minute tow. Numerically, the most widely distributed fauna included the following five taxa: swimming crabs (*Portunus spp.,* 50 of 59 tows); polychaetes or associated tubes (37 of 59 tows); beaded sea star (*Astropecten articulatus*, 33 of 59 tows); venus clams (*Chione* spp., 29 of 59 tows); and calico scallops (*Argopecten gibbus*, 28 of 59 tows). *Oculina* rubble was collected in 10 of the 59 tows, but live coral in only one tow. We tentatively identified 82 taxa.

We collected 60 samples for histological analyses during the fall 2004 east coast cruise, as planned.

East Coast - Spring 2005

We completed 65 tows on the east coast survey, five more than planned. In one case, we lost the sampling gear on the tow, and repeated sampling at that station. In the other cases, a second tow was conducted because the catch was small, and gear malfunction was suspected. In all, 15 scallops were collected, all spat, from nine stations. The mean shell height was only 9.7 mm. No adult scallops were collected. Seven spat were attached to calico scallop shells (mean shell height 7.8 mm), one spat was attached to other shell and one to plastic trash, and six scallop spat were not attached (mean shell height 12.1 mm). The average catch was 4.3 kg per five minute tow. Calico shell was collected in 56 of the 62 samples that collected any catch. The average weight of calico scallop shell (in tows that collected scallop shell) was 0.7 kg per five-minute tow and the average weight of other shell (in tows that collected shell; 54 of 62 tows) was 0.85 kg per five-minute tow. Numerically, the most widely distributed fauna included the following five taxa: swimming crabs (*Portunus spp.*, 32 of 62 tows); imperial venus clams (*Lirophora latilirata*, 21 of 59 tows); polychaetes or associated tubes (20 of 62 tows); royal sea star (*Astropecten articulatus*, 17 of 59 tows); and distorsio snails (13 of 62 tows). Isolated pieces of *Oculina* rubble were less common on this cruise and no live coral was observed. Of note was the frequent occurrence of one or more coral polyps attached to both calico scallop shell and other shell. We tentatively identified 94 taxa.

No adult scallops were available for histological analyses.

East Coast - Fall 2005

We completed 60 tows on the east coast survey, as planned. In all, 311 scallops were collected from 22 stations. Seventeen of those scallops were spat. The mean shell height of adult scallops was 29.3 mm and the mean shell height of spat was 16.5 mm. Eight spat were attached to calico scallop shells (mean shell height 15.9 mm), three spat were attached to other shell (mean shell height 16.7 mm), three spat were loose, two were attached to rock, and one was attached to a barnacle. The average catch was 6.2 kg per five minute tow. Calico shell was collected in 53 of the 57 samples that collected any catch. The average weight of calico scallop shell (in tows that collected scallop shell) was 1.4 kg per five-minute tow and the average weight of other shell (in tows that collected shell; 56 of 57 tows) was 1.6 kg per five-minute tow. Numerically, the most widely distributed fauna included the following five taxa: swimming crabs (*Portunus spp.*, 37 of 60 tows); polychaetes or associated tubes (28 of 60 tows); calico scallops (28 of 60 tows); imperial venus clams (*Lirophora latilirata*, 21 of 60 tows); and distorsio snails (17 of 62 tows). Isolated pieces of coral rubble were observed at nine stations. We tentatively identified 94 taxa.

We collected 60 samples for histological analyses during the fall 2005 east coast cruise, as planned.

East Coast - Summer 2006

We completed 60 tows on the east coast survey during July 2006. In all, 1216 scallops were collected from 40 stations and 562 of those scallops were spat. The mean shell height of adult scallops was 27.8 mm and the mean shell height of spat was 12.1 mm. Spat were attached to calico scallop shells (73%), other shell (15%), loose (8%), rock (4%), and one was attached to a live scallop. The average catch was 7.4 kg per five minute tow. Calico shell was collected in 54 of the 58 samples that collected any catch. The average weight of calico scallop shell (in tows that collected scallop shell) was 2.25 kg per five-minute tow and the average weight of other shell (in tows that collected shell; 57 of 58 tows) was 1.28 kg per five-minute tow. The most widely distributed fauna included the following five taxa: swimming crabs (*Portunus spp.*, 50 of 60 tows); calico scallops (40 of 60 tows); rock shrimp (*Sicyonia brevirostris*, 33 of 60 tows); polychaetes or associated tubes (21 of 60 tows), and imperial venus clams (21 of 60 tows). Miscellaneous crabs and fishes were common. Isolated pieces of coral rubble were observed at 14 stations. We tentatively identified 92 taxa.

We collected 60 samples for histological analyses during the summer 2006 east coast cruise, as planned.

West Coast - Fall 2004

We completed 59 of 60 planned tows on the west coast. One station was eliminated because of navigation hazards. Five tows were aborted before the planned five minutes when the net snagged on hard bottom and four tows were retrieved with essentially no catch. In all, 16 scallops were collected from a total of six stations, with an average shell height of 29.7 mm. Average total catch was 3.3 kg per five-minute tow (~0.7 pounds per minute per foot of net mouth). Calico scallop shell was collected in 38 of the 59 tows, and other dead shell was collected in 45 of the 59 tows. The average weight of calico scallop shell (in tows that collected scallop shell) was 0.1 kg per five-minute tow and the average weight of other shell (in tows that collected shell) was 1.9 kg per five-minute tow. Numerically, the most widely distributed fauna included the following five taxa: *Anadara* spp. (ark shells, 29 of 59 tows); sand dollars (*Clypeasteroidea*, 24 of 59 tows); variegated sea urchins (*Lytechinus variegatus*, 24 of 59 tows); Florida fighting conch (*Strombus alatus*, 22 of 59 tows); and blue crabs (*Callinectes sapidus*, 17 of 59 tows). Coral rubble was collected in only one of the 59 tows. We tentatively identified 46 separate taxa.

We were only able to collect 16 adult scallops for histological analyses during the fall 2004 west coast cruise.

West coast - Fall 2005

We completed 66 of 60 planned tows on the west coast. Forty adult scallops were collected from seven stations, with an average shell height of 29.2 mm. Twenty five spat were collected from ten stations (mean shell height = 6.7 mm). Average total catch was 2 kg per five-minute tow. Calico scallop shell was collected in 49 of the 66 tows, and other dead shell was collected in 53 of the 59 tows. The average weight of calico scallop shell (in tows that collected scallop shell) was 0.06 kg per five-minute tow and the average weight of other shell (in tows that collected shell) was 1.2 kg per five-minute tow. Numerically, the most widely distributed fauna included the following five taxa: *Anadara* spp. (ark shells, 53 of 66 tows); swimming crabs (*Portunus spp.*, 39 of 66 tows); hermit crabs (22 of 66 tows); white shrimp (16 tows) and brittle stars (14 tows). Coral rubble was collected in eight of the 66 tows. We tentatively identified 96 separate taxa.

We were only able to collect 40 adult scallops for histological analyses during the fall 2005 west coast cruise.

West Coast - Spring 2006

We completed 61 of 60 planned tows on the west coast. Twenty eight adult scallops were collected from eight stations, with an average shell height of 27.8 mm. Fifteen spat were collected from nine stations (mean shell height = 8.1 mm). Average total catch was 7.6 kg per five-minute tow. Calico scallop shell was collected in 43 of the 61 tows, and other dead shell was collected in 52 of the 61 tows. The average weight of calico scallop shell (in tows that collected scallop shell) was 0.05 kg per five-minute tow and the average weight of other shell (in tows that collected shell) was 1.5 kg per five-minute tow. Numerically, the most widely distributed fauna included the following six taxa: *Anadara* spp. (ark shells, 42 of 61 tows); swimming crabs (*Portunus spp.*, 22 of 61 tows); polychaetes or associated tubes (21 of 66 tows); brittle stars (17 tows); cross-barred venus clams (*Chione sp*) (14 tows) and calico scallops (14 tows). Coral or coral rubble was collected in six of the 66 tows, live rock in 15 of the 66 tows. We tentatively identified 71 separate taxa.

We were only able to collect 28 adult scallops for histological analyses during the spring west coast cruise.

West Coast - Summer 2006

We completed 60 of 60 planned tows on the west coast. Calico scallops were more abundant than on previous west coast cruises; 387 were collected, of which three were spat. They were collected from 20 stations, and had an average shell height of 31.1 mm. Three spat were collected from two stations (mean shell height = 12.1 mm). Average total catch was 2.5 kg per five-minute tow (but see note below). Calico scallop shell was collected in 37 of the 61 tows, and other dead shell was collected in 55 of the 60 tows. The average weight of calico scallop shell (in tows that collected scallop shell) was 0.042 kg per five-minute tow and the average weight of other shell (in tows that collected shell) was 0.92 kg per five-minute tow. Numerically, the most widely distributed fauna included the following six taxa: *Anadara* spp. (ark shells, 37 of 60 tows); cross-barred venus clams (*Chione sp*) (23 tows); calico scallops (20 tows); polychaetes or associated tubes (15 tows), and *Lytechinus variagatus* (sea urchin, 14 tows). Swimming crabs (*Portunus* spp.) were less abundant than previous seasons (9 tows, but see below). Coral or coral rubble was collected in only one tow, live rock in 6 of the 60 tows. We tentatively identified 59 separate taxa.

We collected 33 samples for histological analyses during the summer 2006 west coast cruise. Although we did collect many more scallops they were concentrated in the Ft. Myers and Naples zones. None were collected in the Englewood zone.

Historical perspective

Data from numerous NOAA survey vessels has been identified and at least partially entered into databases as follows (Table 2):

1) M/V Silver Bay (1957-1964); 1566 samples from 26 cruises.

2) R/V Oregon (1956 - 68); 1100+ samples from 8 cruises. Additional cruise reports may exist.

3) R/V Bowers (1969 - 1976); 18 cruises, mostly descriptive regional assessments. Additional cruise reports and catch data may exist.

4) R/V Oregon II (1975-1981); 4 cruises, mostly descriptive regional assessments. Additional cruise reports and catch data may exist.

5) R/V Delaware II (1982); 19 samples from 1 cruise.

6) R/V Bellows (1989); 41 samples from 1 cruise.

In addition, the FWRI museum has records of 218 calico scallop collections, many of which provide geographic coverage of areas that have not been heavily fished (Figure 20).

B. Findings

Total Catch

The total catch was not different between east and west coast samples (Mann Whitney U test Z = 1.13, p = 0.259) (Table 1). The median east coast samples yielded 0.67 kg min^{-1} m^{-1} with a range of 0-51.7 kg min^{-1} m^{-1}. The median west coast sample yielded 0.64 kg min^{-1} m^{-1} with a range of 0-36.2 kg min^{-1} m^{-1}. Basically, high within-coast variability precluded detection of differences between the coasts. There was a seasonal variability in catch rates (Kruskall-Wallis H (3,465) = 21.93, P < 0.001). The initial cruises, in fall 2004, had roughly twice as much catch as in the fall 2005 cruises. The spring and summer cruises were intermediate.

On the east coast there was no statistical difference between zones. The Sebastian site yielded the highest total catches but was not statistically higher than other sites. There was seasonal variability (H = 23.69, p<0.001), with the fall of 2004 yielding the highest catch rates. Both of these results may be biased by very large catches in the SW corner of the Sebastian zone, where some random sampling stations were located shoreward of the 20m contour, in a region of very abundant marine life and large catches of sediment. The southern end of our sampling grid is also a region where the shelf is relatively narrow, and diverse, hard-bottom communities were frequent, and possibly more productive. These outcroppings were observed throughout the depth range of the Sebastian zone. The high diversity and probable high productivity must be partly due to the increased slope on the narrow shelf, but, may also reflect the proximity of both the Gulf Stream and upwelled bottom waters.

On the west coast there were differences in total catches between zones ($H = 49.03$, $p < 0.001$). Catches were highest in the Naples zone, and were lowest in the Englewood zone. There was also seasonal variability ($H = 13.62$, $p = 0.004$), with the fall 2005 cruise yielding lowest catch rates, and other seasons being similar. There was a very high catch rate in the spring of 2006, in the Naples zone. In other seasons, the difference between west coast zones was reduced. One likely explanation for the increased catch rates south and southwest of Sanibel Island is the ebb tidal flow from San Carlos Bay and the Caloosahatchee River. Similar increases in benthic productivity appear to occur in the waters off the mouth of Tampa Bay, an area not studied in this project. A second possibility is that the west Florida shelf is susceptible to prolonged periods of northeast winds which can drive surface waters offshore and consequently induce upwelling in the near-shore regions. The two processes are not mutually exclusive and most likely act synergistically to create hotspots of both diversity and productivity similar to more thoroughly described east coast habitats.

Calico Scallops

There was a strong seasonal variability in adult calico scallop abundance ($H = 43.71$, $p < 0.001$). Adult scallops were most abundant in the summer cruise, less abundant in the two fall cruises, and essentially absent during spring. This pattern was observed on both coasts. Adult scallops were more abundant in east coast samples than samples from the west coast ($Z = 3.92$, $p < 0.001$). The median east coast samples yielded 0 scallops (half of the tows had no adult scallops) and an average of 2.11 with a range of 0-49.52 scallops $min^{-1}\ m^{-1}$. The median west coast sample yielded 0 scallops. The average yield was 2.35 with a range of 0 - 253.57 scallops $min^{-1}\ m^{-1}$.

Shell heights of 1726 scallops were measured, 1412 of those from the east coast and 314 from the west coast, including both spat and adults. Many of the spat detected were originally measured as adults, but were later classified as loose juveniles because their shell heights were less than 23 mm, the size at which sexual maturity has been previously reported by observing gonadal color changes (Miller et al. 1979). We can confirm through occasional observation of our sections of gonad in our histological slides collected for the *Marteilia* study that scallops as small as 22 mm do occasional have ripe gonads; both male and female gametes have been observed.

Over the course of our eight cruises, we rarely captured commercial size scallops, those over about 40 mm which might be expected to have meat counts approaching 200 meats per pint, a size indicated by Blake and Moyer (1991) to be most profitable (Figure 6). Only 7 % of the scallops we measured were 40 mm or larger. During previous surveys, meat counts of 110-120 per pint or less and shell heights exceeding 50 mm were common.

There was no statistical difference in scallop abundance between east coast zones ($H = 5.87$, $p = 0.118$) despite a trend of the following order: Sebastian, Cocoa, Melbourne and Titusville (Table 3). There was a strong seasonal difference ($H = 44.3$, $p = 0.001$); the yield during the summer cruise exceeded all others, both fall cruises were similar, and the spring cruise had the lowest yield (Figure 7). A composite view of calico scallop abundance on the east coast suggests that in fact the center of abundance occurs at the 20 fathom (40m) depth contour, and that scallops are relatively evenly distributed along the length of our sample grid (Figure 8). However, the four seasonal models suggest that while in summer 2006 that pattern was present, in each of the four seasons unique distribution patterns occurred (Figure 7). In the fall 2004 cruise, there were three distinct centers of distribution, all centered shoreward of the 40 m line. In the spring 2005 cruise, adult scallops were not present on the fishing grounds. By fall 2005, there was a strong south - north gradient in abundance. These results suggest that variations in the abundance of calico scallop have a strong temporal component and large beds can appear and disappear on a time scale of roughly six months, a characteristic trait of this fishery throughout its history.

On the west coast there was a strong difference between zones ($H = 46.34$, $p < 0.001$). A consistent trend was for a peak in scallop abundance southwest of Sanibel Island, near the border of the Naples and Ft. Myers zones (Figure 9). While the intensity of this peak varied seasonally ($H = 15.75$, $p = 0.001$), there were always more scallops in the Naples zone, and few north of Boca Grande pass (Figure 10). It is likely that the increased abundance of scallops occurs where it does for reasons similar to those described for the total catch. During summer 2006, in some individual tows, west coast scallop beds had abundances that met and exceeded those on the east coast, but these patches were smaller in extent and did not cover large portions of any given zone in any cruise.

The catch rate of spat was highest in samples collected during the summer cruises, a result observed on each coast. Spat were more abundant on east coast scallop beds ($Z = 4.39$, $p < 0.001$). The average east coast samples yielded 0.96 with a range of 0-26.45 spat min^{-1} m^{-1}. The average west coast samples yielded 0.15 with a range of 0-8.21 spat min^{-1} m^{-1}. The spat abundance data are highly influenced by a high proportion of samples with no spat observed, leading to very heterogeneous distributions.

On the east coast, spat were more abundant in samples from the summer cruise ($H = 93.73$, $P < 0.001$). There was no significant difference between zones ($H = 4.11$, $p = 0.25$) (Figure 11).

On the west coast, there were more spat in samples from the Naples zone ($H = 16.60$, $p = 0.001$). There were also more spat in samples collected during the spring and summer than during fall cruises ($H = 8.76$, $p = 0.033$). All zones had at least some recruits. The spring 2006 recruits appeared to translate into a very slight increase in adult scallop abundances in fall 2006 in the Englewood and Sarasota zones (Figure 12).

Scallop spat & settlement substrate

Spat were more abundant than expected on scallop shell, and less abundant than expected on other mollusc shell and especially on all other substrate (Table 4). This pattern held for analyses of all spat($X^2 = 35.83$, $p < 0.001$) and total east coast ($X^2 = 35.83$, $p < 0.001$) but not total west coast samples ($X^2 = 3.11$, $p > 0.05$), although the trend was similar on the west coast. Small sample size may have precluded detection of true differences. On each east coast zone during the summer 2006 cruise, the only cruise with sufficient sample size to examine spatial variability within a single season, higher than expected numbers of spat were found on calico scallop spat (Titusville, $X^2 = 8.55$, $p < 0.05$; Cocoa; $X^2 = 6.93$, $p < 0.05$; Melbourne, $X^2 = 13.36$,

$p < 0.01$; Sebastian; $X^2 = 18.48$, $p > 0.001$) and less than expected on other substrates. West coast samples indicated that spat there were more likely to detach by a size of 20mm than on the east coast, where half of the 20 mm scallops were still bysally attached (Table 5). Two possible explanations include the reduced energy of the west coast habitats or the relatively reduced proportion of the preferred settlement substrate, calico scallop shell. We also note that spat will regularly use the most abundant substrate available. Alternative substrates were most commonly shell from other molluscs, but also included live rock, algae, live organisms (including an unidentified drill), and even moderately fouled trash. Another potential explanation of the relative paucity of spat on the west coast could be that spat settle on macroalgae which may be poorly sampled by our dredge; algae was more abundant in west coast samples and has been suggested to be a good primary settlement substrate for scallops. Bremec et al. (2008) showed that the shells themselves may not be the primary substrate for newly settled spat of Patagonian scallops, but may instead provide structure for the fouling community that spat prefer. In samples we collected, fouling organisms on scallop shells were very diverse, as described by Schwartz & Porter (1977) (Figure 13).

Shell

Calico scallop shell tended to be more abundant in summer, each fall cruise was similar, and in spring abundance was lowest, but the seasonal differences were not significant when pooled data from each coast was compared. Despite the observation that the seasonal trends were similar, the east coast had much more scallop shell than the west coast ($Z = 12.36$, $p < 0.001$) (Table 6). Other shell did vary seasonally; it was more abundant in summer, each fall cruise was similar, and in spring abundance was lowest ($H = 10.71$, $p = 0.013$). Other shell did not vary by coast ($Z = -1.93$, $p = 0.055$) though east was slightly higher than west.

One result of this is that the ratio of scallop shell to other shell was much higher on the east coast, and was in fact usually the dominant shell type and more abundant than all other species' shells combined. On the west coast, the majority of the shell present was from other molluscs.

On the east coast, calico scallop shell was abundant in the Cocoa and Sebastian zones than the Melbourne and Titusville zones ($H = 10.68$, $p = 0.014$). Scallop shell was most abundant in the summer, less during the two fall cruises, and least abundant during spring ($H = 15.72$, $p = 0.001$) (Figure 15). It is important to note that scallop shell was almost ubiquitous, present in 92% of the valid tows. Other mollusc shell was even more widely distributed, present in 95% of valid tows, albeit at lower density. Other mollusc shell was abundant in the Cocoa and Sebastian zones than the Melbourne and Titusville zones ($H = 9.56$, $p = 0.023$). One obvious trend in other shell is that there is more shell from non-scallops at shallower depths (Figure 16). This trend is especially true where the 20 m contour line extends seaward into the sampling grid in the southwest corner of the Sebastian zone and northwest corner of the Cocoa Zone. Venerid bivalves were especially abundant in these shoal waters. Other shell also varied seasonally ($H = 15.38$, $p = 0.002$), but no trend was apparent.

On the west coast, calico scallop shell abundance was highest in the south and decreased in the north ($H = 20.01$, $p < 0.001$) (Figure 17). Note that the scale on the figure is roughly

1/10th that of east coast calico scallop shell (Figure 11). The abundance of scallop shell on the wets coast did vary seasonally ($H = 3.99$, $p = 0.262$). There were interactive effects observed. There was a high abundance of shell in the Fort Myers zone during fall 2004, which was not detected in later cruises. There was a wider distribution of scallop shell (68% of valid tows) than either adult (17% of valid tows) or juvenile scallops. This observation suggests that at times calico scallops may be much more abundant and widespread on the very near-shore, west Florida shelf, than we observed. Recent observations of large wracks of dying calico scallops along the gulf beaches after strong west wind events provides further evidence of the dynamic nature of the coastal zone of this supposedly low-energy and relatively low productivity region (Figure 18). Other mollusc shell was most abundant in the Naples Zone, but was widespread ($H = 52.11$, $p < 0.001$) (other shell was collected in 84% valid tows, Figure 19). This result was consistently true, but appeared to be especially pronounced in the spring 2006 cruise, though seasonal differences were not significant ($H = 1.35$, $p = 0.716$). The Naples zone typically had twice as much other shell as any of the other zones. Possibly, the persistent red tide in this region resulted in large abundances of empty shell on the sediment surface. Note that the scale on the figure is roughly equal to that of east coast other mollusc shell (Figure 16).

Temporal Changes on Cape Canaveral fishing bed

Quantitatively, we have reliable data from three sources: our current results, the original Silver Bay cruises (1957-1964), and the Oregon cruises, 1967-68. The Silver Bay cruises averaged 31 scallops per minute per meter of net, with maximum catch rates of up to 406. The Oregon had average catch rates of 38 scallops min^{-1} m^{-1}, with maximum catch rates of up to 187. In our current study, we have averaged only about 2.1 scallops min^{-1} m^{-1} with maximum rates of 49.5. These estimates suggest a decline of roughly one order of magnitude in scallop abundance on Florida's east coast. A Bowers cruise from 1972 averaged 415 scallops min^{-1} m^{-1} on the primary fishing areas (various concentrations observed with video were sampled with dredges) but reached peak abundances approaching 5000 scallops min^{-1} m^{-1}, suggesting densities of up to $150/m^2$. All of these cruises relied on some type of dredge to gather data. Two cruises during the 1980's were largely focused on gathering samples for research purposes. A limited amount of trawl samples suggest average catch rates of 4.8 scallops min^{-1} m^{-1} with a peak of 92. Unfortunately, we have no data to compare efficiencies between vessels and gears throughout the years.

The M/V Silver Bay sampled throughout the southeast U.S. waters for at least seven years (Figure 20). For comparative purposes, the only other database we have found that capture the extent of calico scallop distribution throughout the waters surrounding the southeastern United States comes from the museum collection at FWRI (Figure 20). The potential certainly exists that other museum collections have relevant spatial data. Relevant to the calico scallop fishery, there were numerous cruises to the Cape Canaveral fishing grounds in the period 1957-1964. In Figures 21 – 26 the variability of the yield is depicted from a three year period, June 1960 through November 1963. Clearly, scallops were generally abundant, but the actual distribution could change from widespread, to highly spatially heterogeneous over very short periods, and recover quickly. From June 1960 to May 1961, abundance declined greatly in the northernmost and central region of the study area. By July, abundance continued to stay low north of Cape Canaveral, but began to increase south of the Cape, and remained high off

Sebastian. By September 1961, abundance appeared to increase shoreward of the 20 fathom line. By August-September 1962, abundance was again high over most of the region, but had notably declined off Sebastian and increased along the 20 fathom line north of Cape Canaveral. Finally, in the fall of 1963, abundance was concentrated seaward of the 20 fathom line north of the cape, and moderate to low throughout the southern half of the study area.

The R/V Oregon sampled the southeast U.S waters for calico scallops intensively during 1967 and 1968. The sampling conducted in this period was extremely focused on the commercially viable fishing grounds, and thus was directed at the 20 fathom (40m) line (Figure 27). While developing the graphic representation of the data, those areas near the onshore and offshore edges of our sample region would only give poor estimates of the actual scallop abundance.

The R/V Bowers sampled with a new type of design, a towed video system, beginning around 1969 and continuing through at least 1976. Unfortunately, in most of the cruise reports, the only available data are summaries and hand-drawn maps, indicating regions of commercial abundance. The data were presented as in Table 7. While difficult to interpret on a quantitative basis, these reports were highly focused to providing usable data to the fishing community. Chart points (or lines) were provided using a combination of current technology for the time, Loran A and later Loran C, and depth. Regions sampled were described, and importantly both regions of low and high abundance outlined. Further, detailed descriptions of condition and size of the meats were frequently provided, along with general descriptions of the bycatch. All would have important implications on deciding when and where the fishery would prove profitable. Records indicate these data were provided to the fishing community within about two weeks of return to the dock. In most cases, the reports suggest scallops ranging 50-60 mm SH were desirable, having meat counts around 100 per pint. Scallops with shell heights over 60 mm often had larger meats but of poorer quality.

Our findings suggest that there are fewer scallops on the Canaveral fishing grounds when compared to the 1960's. Results also suggest this difference is reflected in the weights observed in catches. Results also suggest that more shell is currently available as settlement substrate than in the Silver Bay cruises. Our results suggest the apparent abundance of shell, in particular calico scallop shell, can change dramatically on a time scale of months. On a qualitative basis, we can see that the scallop bed essentially covers a similar geographic extent as was observed during historic surveys.

Potential biases are numerous, including different gear and the exclusion of zero data from historic reports (reports often indicate that catches less than 1 bushel were not reported although in many cases they are). Also, the Oregon and Bowers cruises were less random and more focused on commercially fishable areas. It is likely that differences in gear efficiency and data recording methodology contribute to the quantitative differences we observed. The general pattern is that calico scallops are highly heterogeneous both spatially and temporally, that within the selected region calico scallops are the dominant fauna, and that scallop shell is the dominant substrate in a majority of the samples. Clearly, there is resource available for harvest and at quantities similar to historic levels although patch size may have declined.

Current research in particular focused on abundance of shell, whereas historic databases only indicated shell when commercial species were not abundant.

Marteilia infection intensity

Parasitic infection of a presumed protozoan (*Marteilia* sp.), was detected in every animal inspected, and stage 5 animals, where pathologies are observed, were common (Table 8). Intensity was higher in west coast samples ($Z = -5.60$, $p < 0.001$) but did not vary seasonally. On the east coast, intensity was slightly higher during the fall 2004 and summer 2006 cruises than during fall 2005 ($H = 13.54$, $p = 0.001$). No samples were collected during the spring cruise. There was no difference in average infection intensity between sampling zones. On the west coast, sample size was insufficient for a full factorial design. Parasite intensity was highest in the Fort Myers and Naples zones, and less in the Englewood and Sarasota zones. Infection intensity varied seasonally, fall 2005 and summer 2006 had higher infection intensity than fall 2004 ($H = 24.27$, $p < 0.001$).

No samples with either stage 0 or only stage 1 infection of the digestive diverticula were observed. In Figure 28, we show a relatively clean section of a stage 3 infected scallop, which indicates what healthy digestive tubules (acini) would look like. But, note the nearby infected tubules (arrows). This photo thus would be classified as stage 2, if it were the only portion available. In fact, only a very small percentage of the scallops were classified as stage 2. Further photographs are representative of stage 3 (Figure 29), stage 4 (Figure 30) and stage 5 (Figure 31). In stage 3, roughly half of the acini are infected. There is often more than one cell per acini infected. In stage 4, note that most of the acini are infected and most of the cells in each acini are infected. Importantly, no significant degradation of the tissues, or pathology or necrosis, is observed. In stage 5, essentially all acini are infected and all cells are infected. Necrosis or pathology in the form of gross degradation of the general structure of the acini is observed.

C. Problems encountered

The principal problem that we encountered occurred when the last remaining calico scallop fisherman, Capt. William Burkhardt, retired from scallop fishing concurrent with the onset of the study. With the fishery collapsed and no commercial participants, we were forced to utilize vessels of opportunity. We were fortunate to contract the services of the Florida Geological Society's R/V GeoQuest for east coast sampling. We utilized our own modified Maine lobster boat, the Bonnie E, for three of the four gulf cruises, and utilized size reduced sampling gear as well as much smaller vessels when our own vessel became inoperable, and we had insufficient funds for a second set of major repairs. FWRI did provide institutional funds for a major rebuild of the engine prior to the first west coast cruise. Undoubtedly, the knowledge we could have gained by working with an experienced member of the industry would have yielded priceless insight, and we were unfortunate to have lost that opportunity.

D. Need for additional work

During analysis of the data collected for this project we have identified numerous questions that could aid in the understanding of calico scallops and their habitat, and could aid in development of a fishery management plan for the species.

There appears to be a lack of fishery size scallops, those > 40mm and particularly the most valuable scallops, those 50-60mm SH. Are there size-specific causes of mortality and what influences those rates?

There is an extremely poor understanding of the distribution of scallops in the Gulf of Mexico, and virtually any life history characteristics, despite historic harvests exceeding 1,000,000 pounds per year from three separate beds within this region.

We have no knowledge whatsoever about current stocks north of Cape Canaveral, from Daytona north to Cape Hatteras, despite historic harvests exceeding 1,000,000 pounds per year from this region.

There appears to be a strong relationship between scallop abundance and environmental factors, especially upwelling, but possibly also regions of increased productivity related to coastal nutrient input, but the complexity of the actual process is unknown.

Oceanic currents and upwelling processes appear to play a role in the life history of calico scallops and likely the entire community of benthic invertebrates associated with this habitat. Hydrographic processes may play a role not just in increased productivity but in dispersal and recruitment processes. These processes may be vital to regional connectivity of all shelf edge biota.

Although we have shown that scallop spat prefer scallop shell as their juvenile habitat, the primary settlement substrate remains to be described.

In both Atlantic and Gulf near-shore waters, there appears to be much more hard-bottom habitat than has been charted, and there may be much more biodiversity associated with the fouling community of shell hash beds than previously described. These habitats may not only be important for benthic invertebrate communities, but, based on their extensive geographic extent, may be important to the fish stocks in and around shell beds, especially early life stages.

VII. *Evaluation*

A. Describe the extent to which the project goals and objectives were attained. This description should address the following:

1. Were the goals and objectives attained? How? If not, why?

The goals of this project were met. Two potentially important discoveries were made. The first is that calico scallops can exist in nearshore beds at densities that would be commercially harvestable. That these beds can exist on the gulf coast may not indicate that there are similar habitats on the Atlantic coast. Certainly the wave energy would be very different. But, some of the historic data suggest there are stocks shoreward of the traditional fishing grounds on the east coast. Secondly, it is likely that the extent of calico scallops in Gulf waters is much greater than previously recognized. Historic data suggests that fishing grounds occurred near Port St. Joe (SW of Cape San Blas) and near the Tortugas fishing grounds. Large uncharted regions of low-relief habitat, essentially the entire shelf edge from Cape San Blas to the Tortugas, occur in the Gulf at depths appropriate for calico scallops. Based on molluscan shell fragments, these communities may provide settlement substrate for a wide range of fauna, to the point where the abundance of fouling organisms easily exceed that of the original shell (Figure 13). These diverse assemblages may in turn be important to almost any benthic or epibenthic species found in the Gulf, simply based on the large extent of this type of habitat.

2. Were modifications made to the goals and objectives? If so, explain.

Modifications to the actual sample sites were made on the Cape Canaveral fishing ground to facilitate completion of the sample design with sufficient sample size. In particular, we sampled closer to Cape Canaveral, and were unable to sample the waters east of Daytona and points north.

We planned to analyze histological samples but did not anticipate high infection intensity, and thus expected to compare the frequency of infected and healthy scallops. Instead, every scallop examined was infected. To analyze the spatial and temporal variability we develop a 6 stage classification scheme, amenable to more detailed analyses.

B. Dissemination of Project results:

To date our project results have been presented at the 2006 International Pectinind Workshop held in Halifax, Nova Scotia, and portions of our project were presented at National Shellfisheries Association meetings (see below). Extensive portions of the calico scallop section of the draft SAFMC FEP were based on our field work or as background work associated with the present study. Additionally, we will make our Final Report available to any fishermen or other interested parties who may have an interest in the fishery. We also plan to publish the results of this study in peer-reviewed scientific journals.

Presented at the National Shellfisheries Association Annual Meeting, Monterey CA, 2006

Is Habitat Availability Limiting Recruitment of Calico Scallops (*Argopecten gibbus*)?

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The Florida calico scallop fishery has declined from a peak of 42.7 million pounds of adductor muscle meats landed in 1984 to none landed in 2005. Removal of scallop and other shell as bycatch may have depleted the essential fisheries habitat for settling veligers. The goal of this study was to describe current abundance and distribution of scallops, shell, and associations between spat and its preferred substrate on two of the historic scallop fishing grounds.

Scallops were collected at 31% of the Atlantic stations, spat at 9%, and both calico scallop shell and other shell at 89%. Spat were most commonly found on scallop shells (46%), but were also found loose, on other shells, rocks and trash. Shell from other molluscs was 1.75 times as abundant as scallop shell. Potential predators that were abundant included *Astropecten articulatus*, *Portunus gibbesii* (also common in the Gulf) and *Distorsio clathrata.*

Scallops were collected at 10% of the Gulf of Mexico stations, spat at 8%, scallop shell at 63%, and other mollusc shell at 71%. Rocks and hard bottom were common. Spat preferred other mollusc shells (64%) but were also found loose, on rocks, and on calico scallop shells. Shell from other molluscs was 20 times as abundant as scallop shell.

Our findings suggest that the Cape Canaveral calico scallop bed currently has a similar spatial extent to historic records, and that calico scallops are seasonally abundant and are associated with shell deposits. The southwest Florida scallop bed is limited in extent and abundance.
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Presented at the International Pectinid Workshop (Halifax, N.S.), 2007.

Abundance and distribution of calico scallops (*Argopecten gibbus*) on two historic fishing grounds.

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Calico scallops supported a commercial fishery in the southeastern United States for over four decades. In Florida's waters, calico scallop landings declined from a peak of 42.7 million pounds of adductor muscle meats landed in 1984 to none landed in 2004 or 2005. One historic fishing ground, near Cape Canaveral, Florida, produced the majority of all calico scallops landed. It was well studied before the peak of the fishery through a series of NOAA surveys that lasted from 1954-1976, was the focus of some renewed interest during the expansion of the fishery in the mid-1980's and has been poorly studied since complete collapse of the fishery in the late 1990's. A second fishing ground off southwest Florida has received almost no prior scientific study and is known primarily through verbal accounts of the fishing community. Removal of large quantities of scallop shell and other shell as bycatch has been hypothesized to have depleted the essential fisheries habitat for settling veligers.

The goal of this study was to describe current abundance and distribution of calico scallops, shell, and associations between spat and its preferred substrate on these two historic scallop fishing grounds. We conducted a series of eight surveys to describe current abundance and distribution in two regions. On each survey, we conducted 15, randomly placed, 5-minute scallop dredges in each of four zones for a total of 60 samples per survey, and a total of 480 overall. We recorded start and stop time and location, depth, and wire length. Catch data included total weight, number and weight of scallops, scallop shells and other shell, and number and weight of live macrofauna, identified to the lowest taxon practicable at sea. Photographs and voucher specimens were preserved for many but not all unknown specimens. We also recorded observations of any calico scallop spat and their settlement substrate if possible. Scallops were considered to be spat only if they were less than 20mm if loose, but always as spat if bysally attached to a substrate.

On the Cape Canaveral fishing grounds, scallops were collected at 40% of the stations, spat at 23% of the stations, and both calico scallop shell and other shell at greater than 90 % of the stations. Spat were most commonly found on scallop shells (70%), but were also found on other shells, loose, on rocks, live calico scallops and trash. Overall, shell from other molluscs was slightly more abundant than scallop shell. We collected from 55 to 105 separate taxa per survey. Potential predators included *Portunus gibbesii* (also common in the Gulf), *Astropecten articulatus*, and *Distorsio clathrata.*

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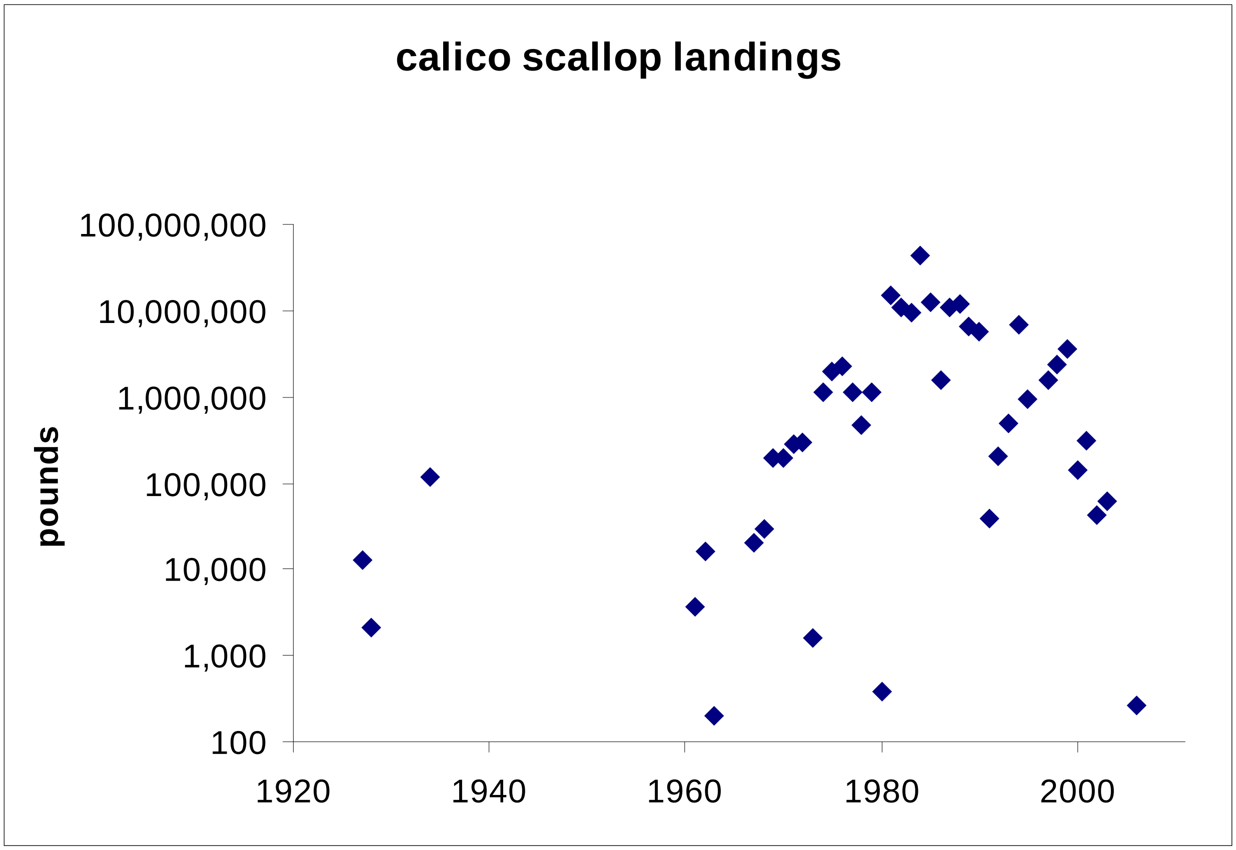

Figure 1. Florida's calico scallop landings, in pounds of meat, 1926-2007.

Figure 2. The 50' survey vessel R/V Geoquest (top) and R/V Bonnie E (bottom), a 36' modified Maine lobster boat.

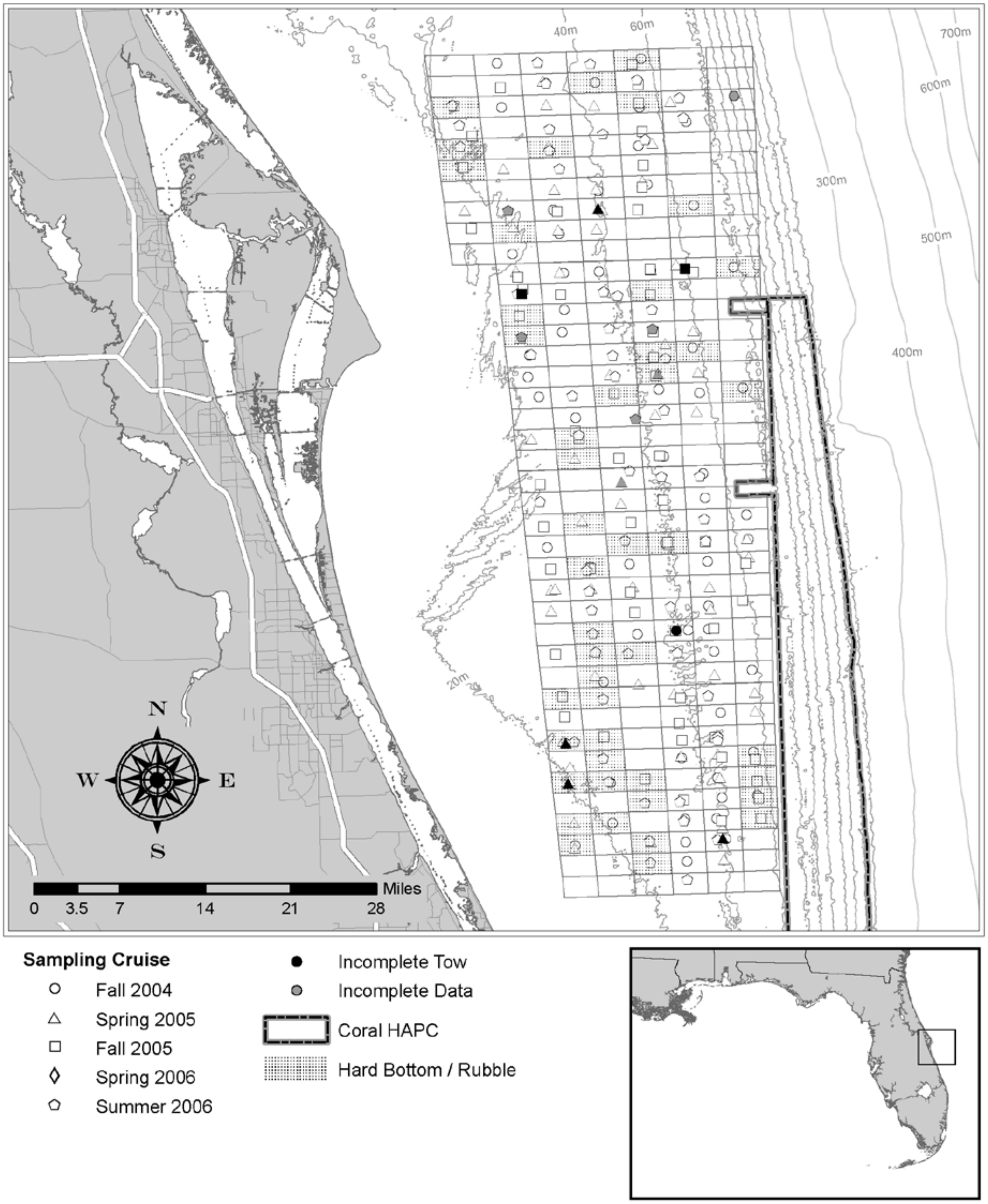

Figure 3. East coast calico scallop sampling stations, 2004-2006. The four sampling zones, from north to south, were named Titusville, Cocoa, Melbourne and Sebastian. Complete tows are indicated by open symbols, and incomplete tows are indicated by solid symbols. Sample grids in which hard bottom or coral were detected are indicted by shaded boxes.

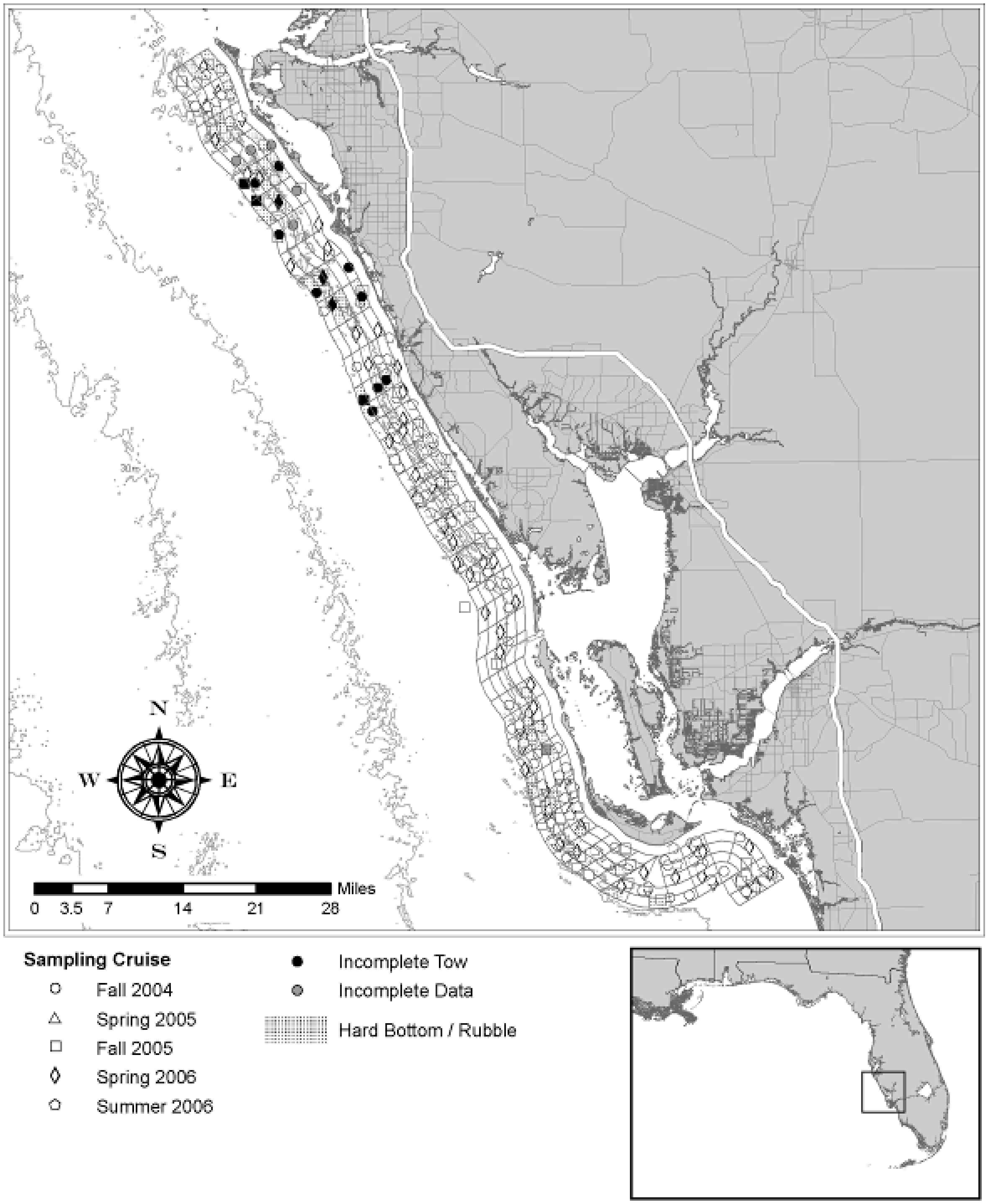

Figure 4. West coast calico scallop sampling stations, 2004-2006. The four sampling zones, from north to south, were named Sarasota, Englewood, Fort Myers and Naples. Complete tows are indicated by open symbols, and incomplete tows are indicated by solid symbols. Sample grids in which hard bottom or coral were detected are indicted by shaded boxes.

Figure 5. Dredges used in this study: 0.69 x 0.50 m (left) or 0.42 x 0.25 m (right).

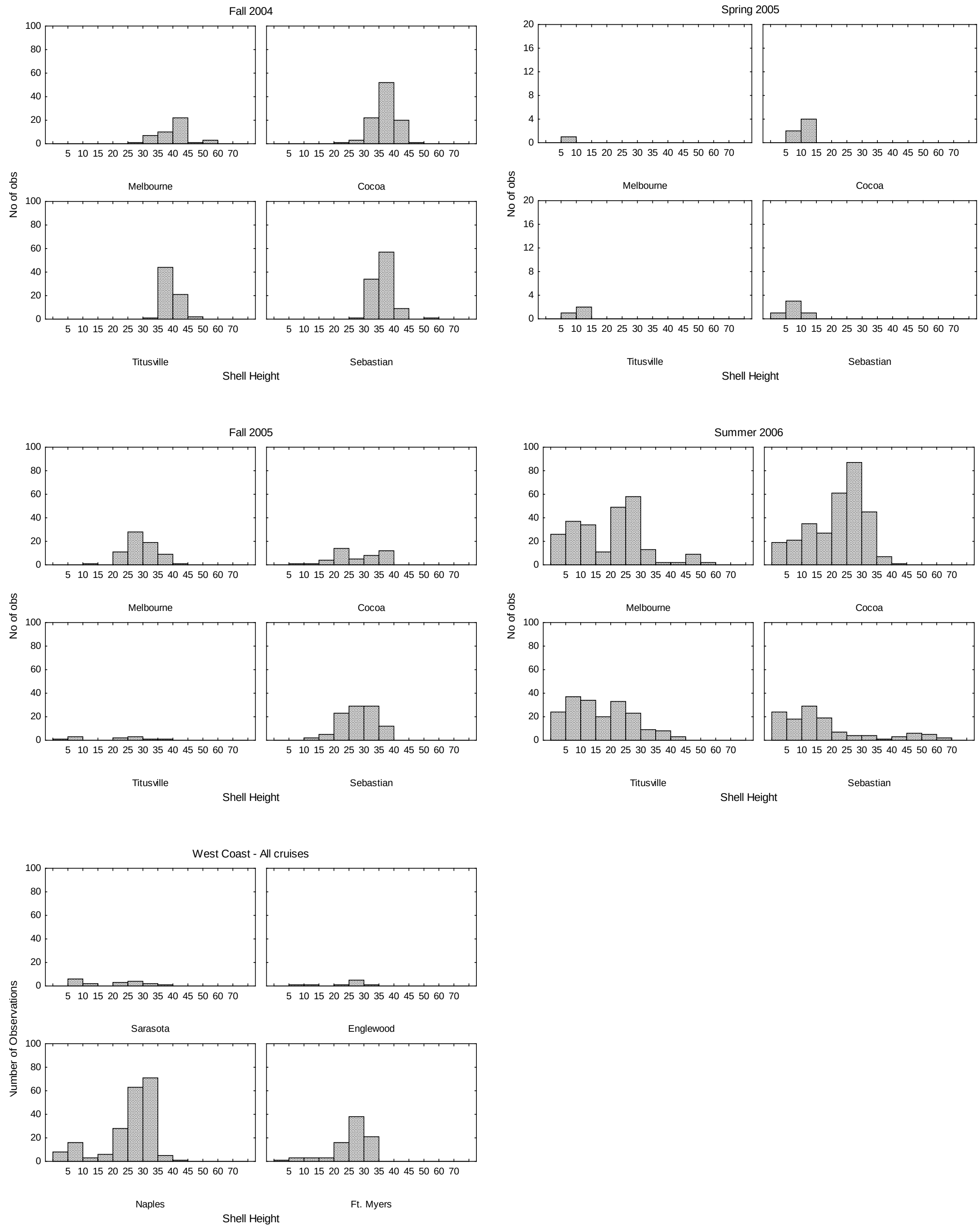

Figure 6. Histograms of shell heights for calico scallops collected in dredge surveys to east coast (each of the zones presented separately for each of the four cruises) and west coast (all four cruises combined) Florida calico scallop grounds.

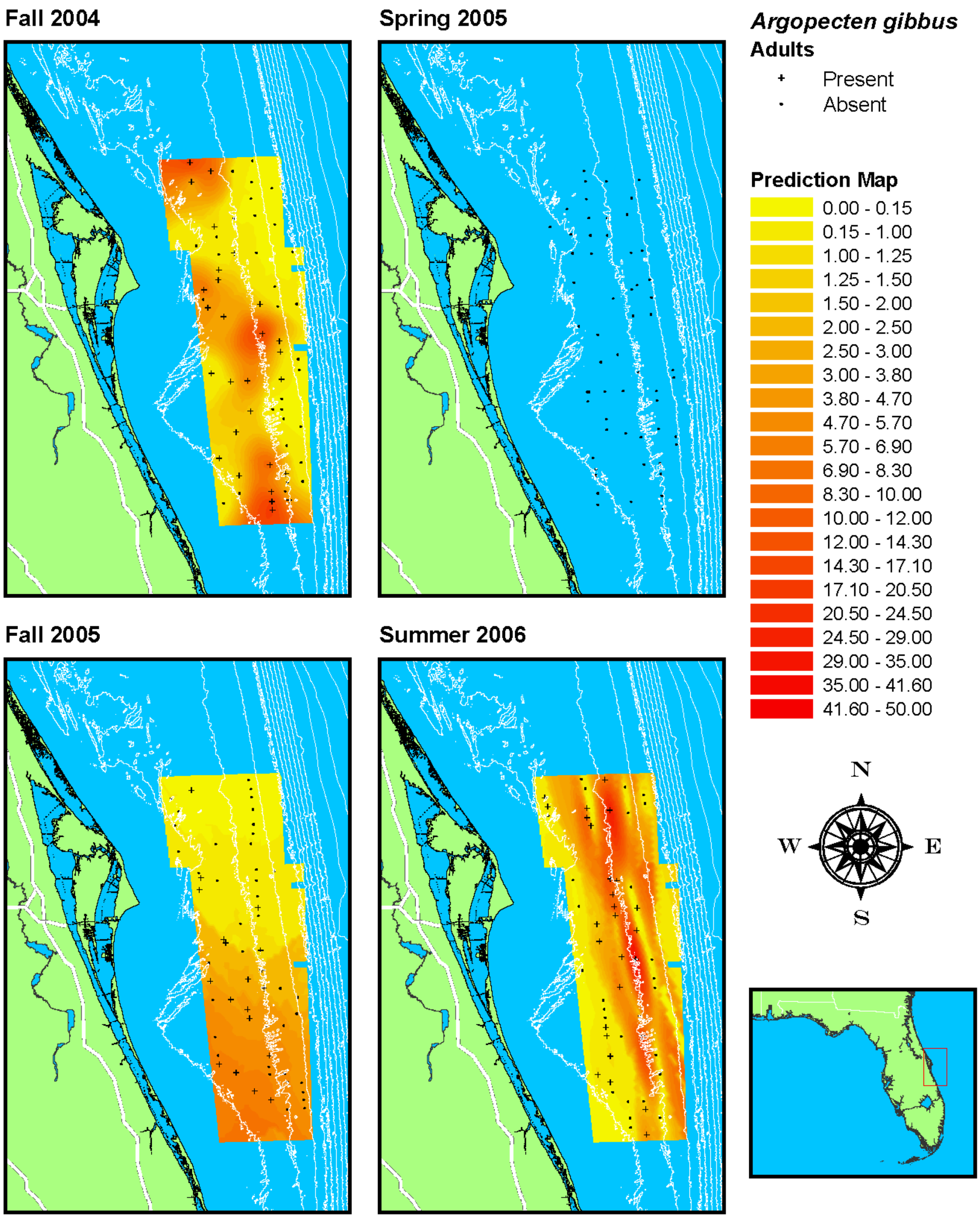

Figure 7. Adult calico scallop yield during four east coast cruises. The surfaces of the sample grid were generated by ordinary kriging as described in the text after all appropriate expansion factors and effort standardizations were applied to single cruises. Data expressed in terms of number of scallops expected min-1 m-1 where m is the mouth width of the net.

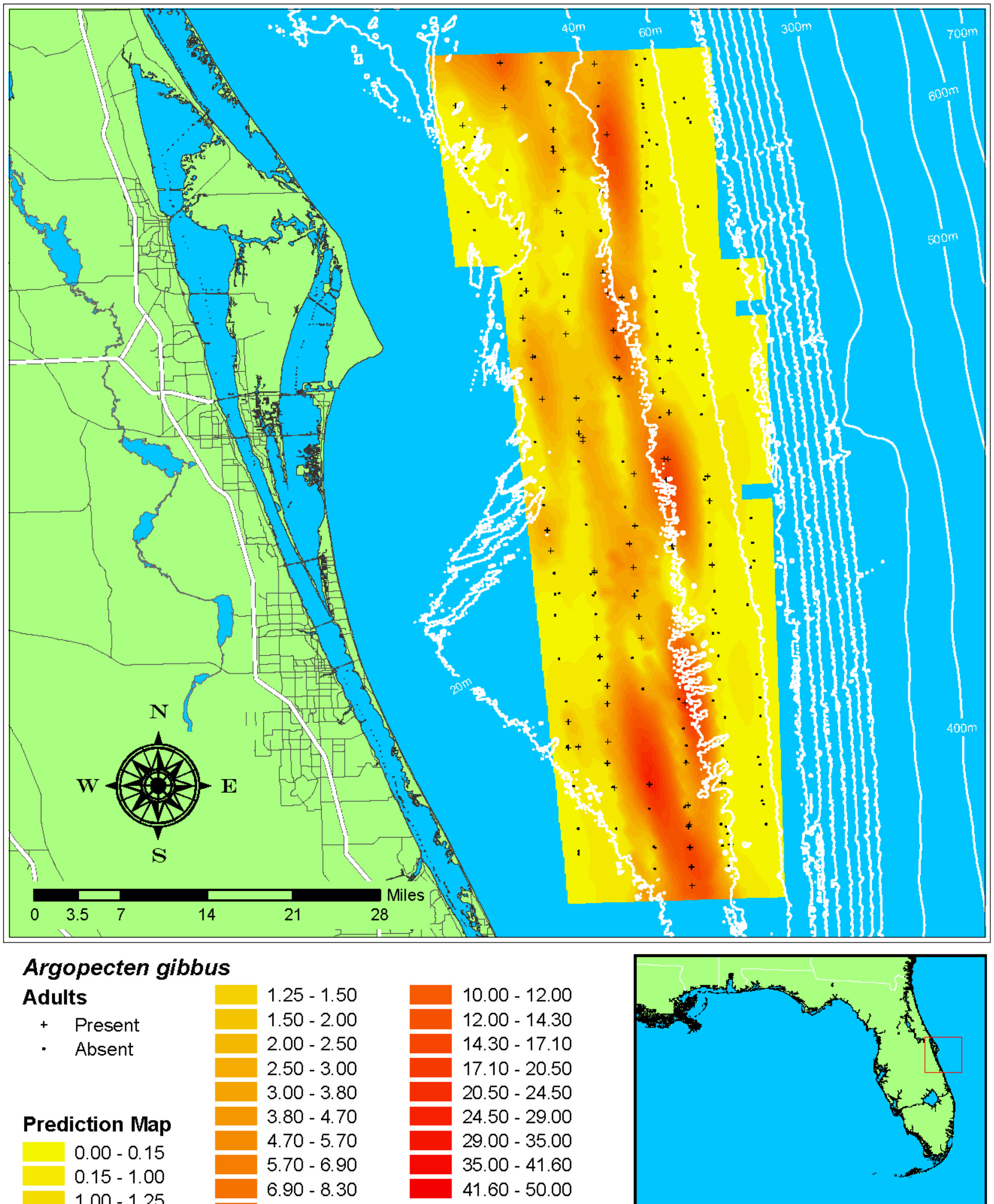

Figure 8. Composite image adult calico scallop yield during four east coast cruises. The surfaces of the sample grid were generated by ordinary kriging as described in the text after all appropriate expansion factors and effort standardizations were applied and the data from all four cruises were combined. Data expressed in terms of number of scallops expected m-1 min-1.

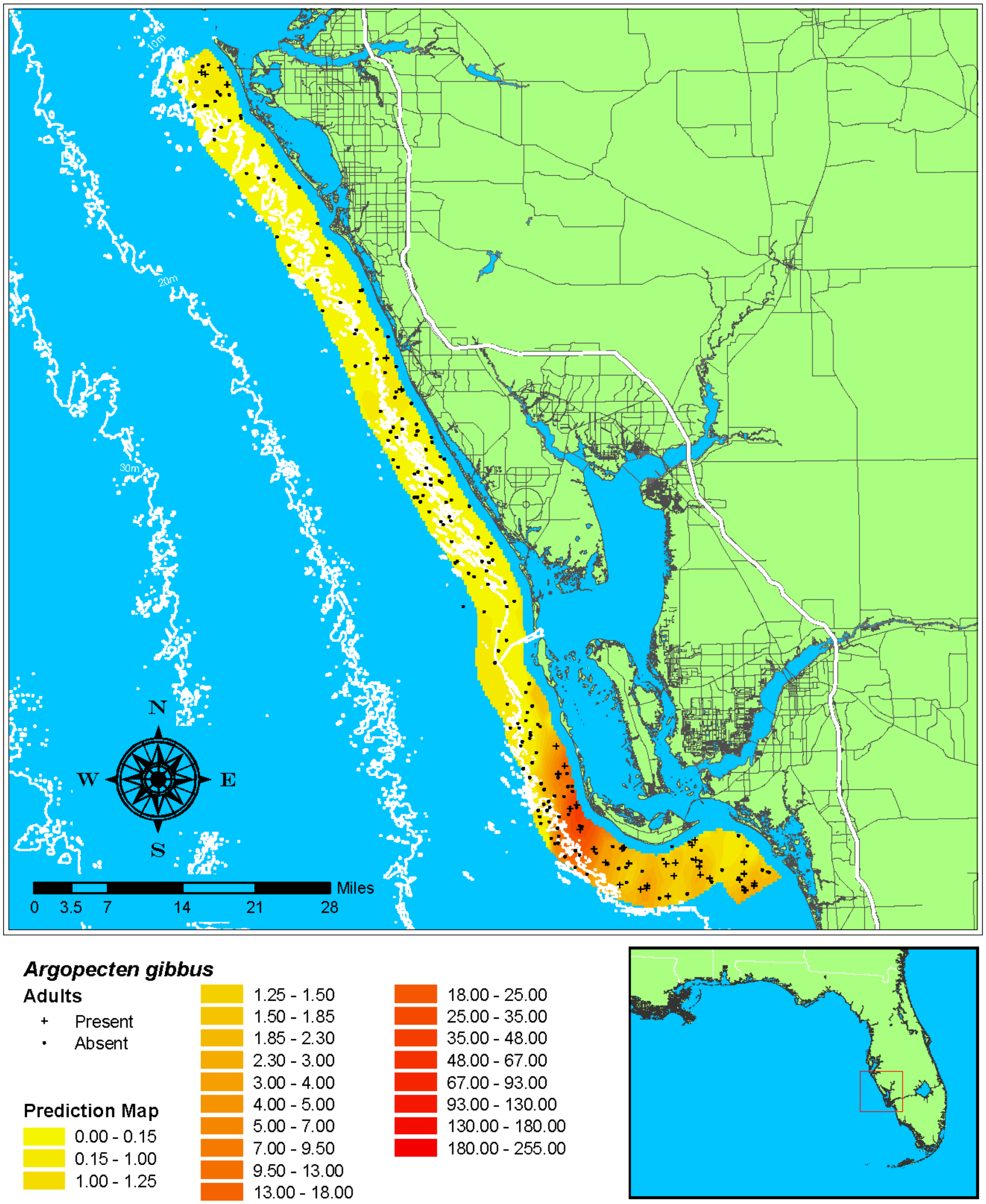

Figure 9. Composite image adult calico scallop yield during four west coast cruises. The surfaces of the sample grid were generated by ordinary kriging as described in the text after all appropriate expansion factors and effort standardizations were applied and the data from all four cruises were combined. Data expressed in terms of number of scallops expected m-1 min-1.

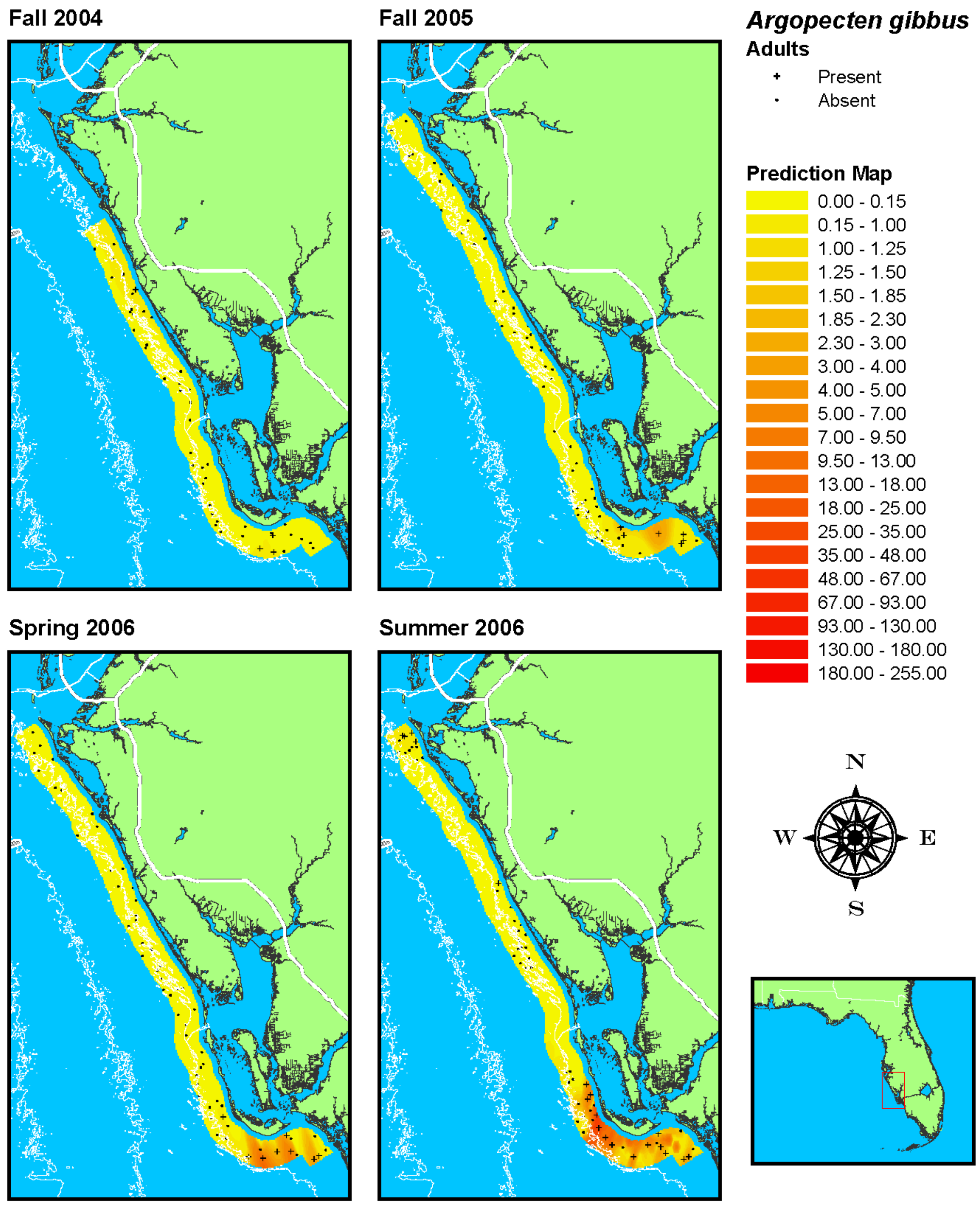

Figure 10. Adult calico scallop yield during four west coast cruises. The surfaces of the sample grid were generated by ordinary kriging as described in the text after all appropriate expansion factors and effort standardizations were applied to single cruises. Data expressed in terms of number of scallops expected m-1 min-1.

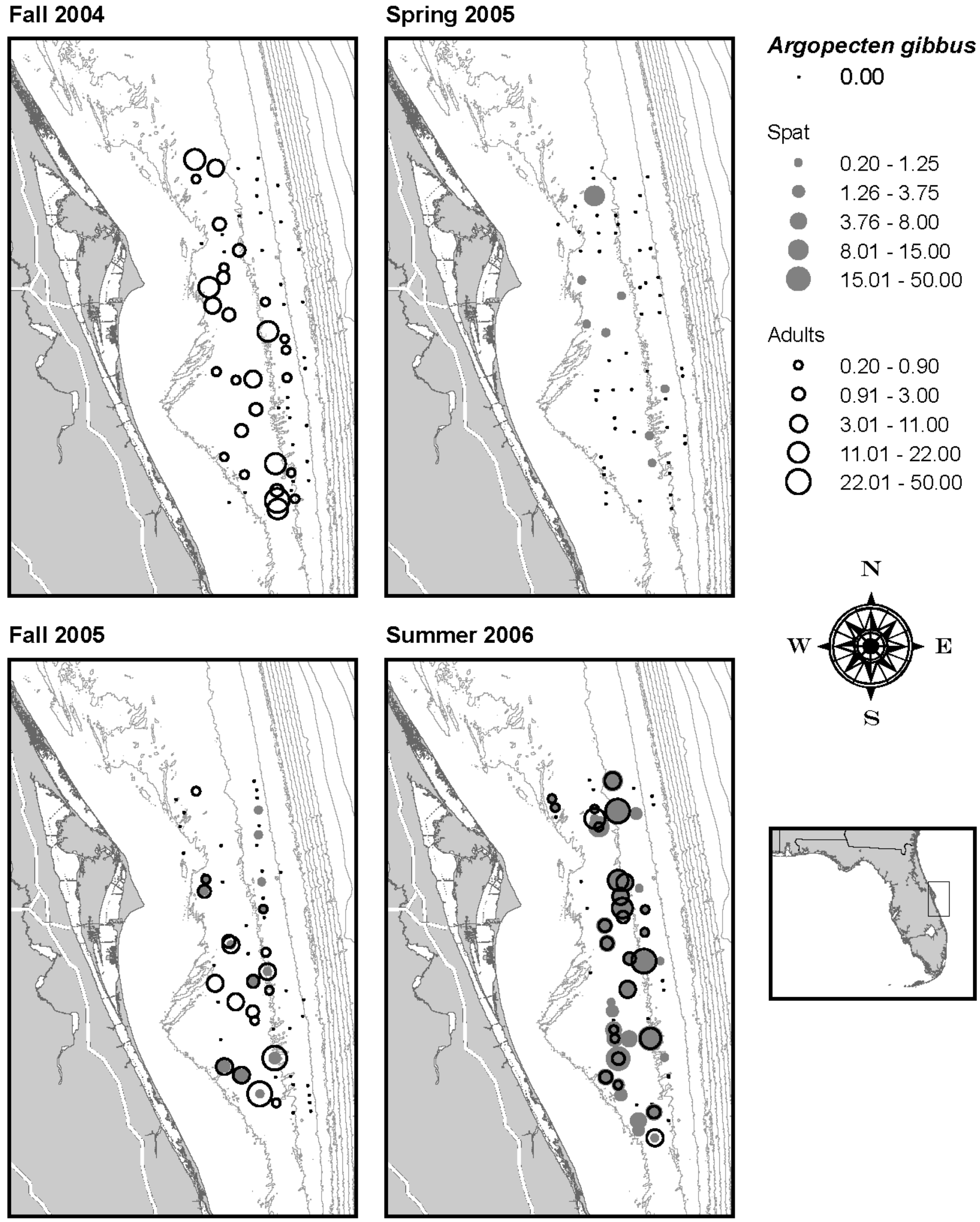

Figure 11. Calico scallop spat yield during four east coast cruises. Spat and adult catch rates expressed in terms of number of scallops expected m-1 min-1. Symbols are scaled to increase with increased catch rate.

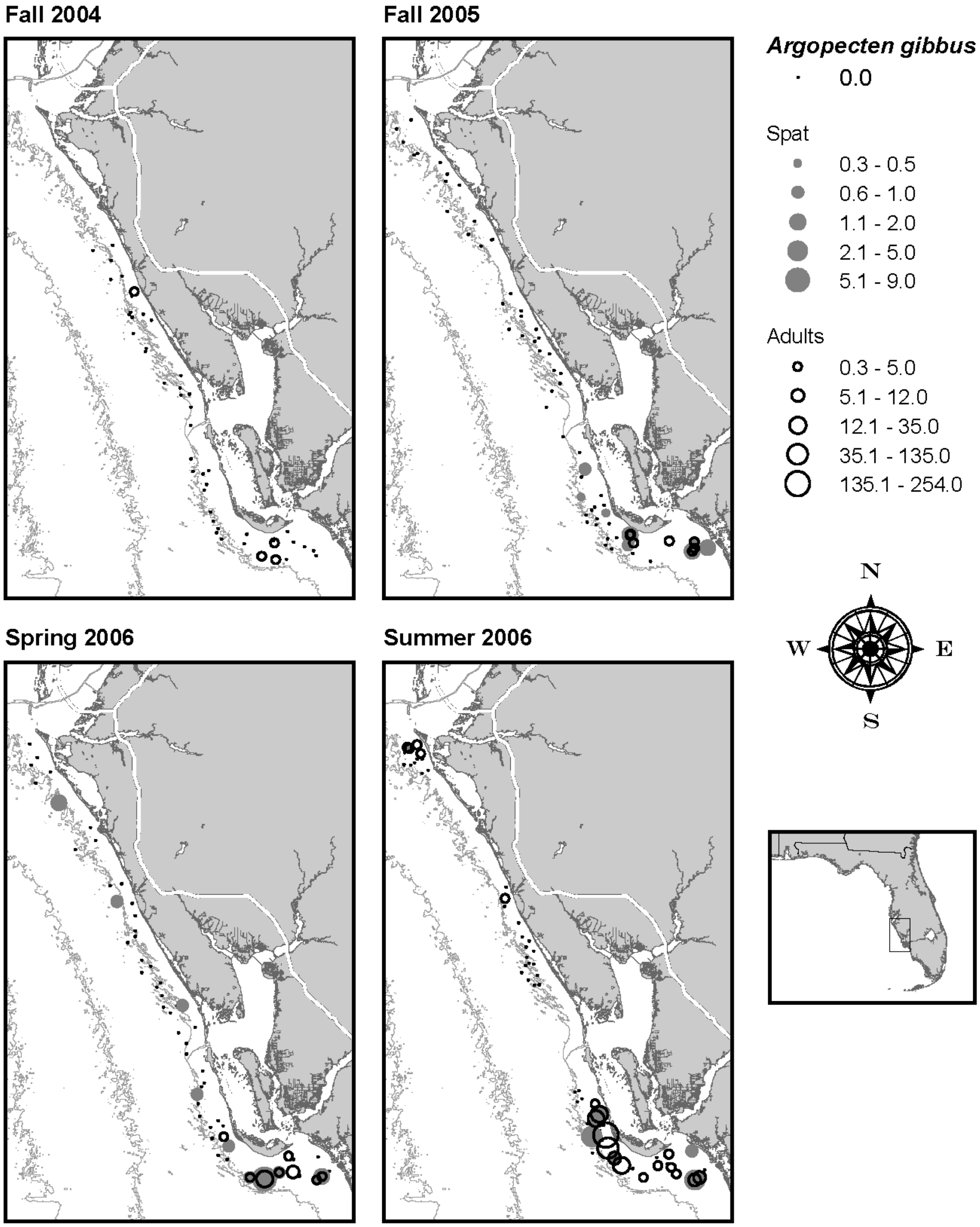

Figure 12. Calico scallop spat yield during four west coast cruises. Spat and adult catch rates expressed in terms of number of scallops expected m-1 min-1. Symbols are scaled to increase with increased catch rate.

Figure 13. Examples of four highly fouled calico scallop shells, exhibiting dead tubeworms, barnacles, and coral polyps.

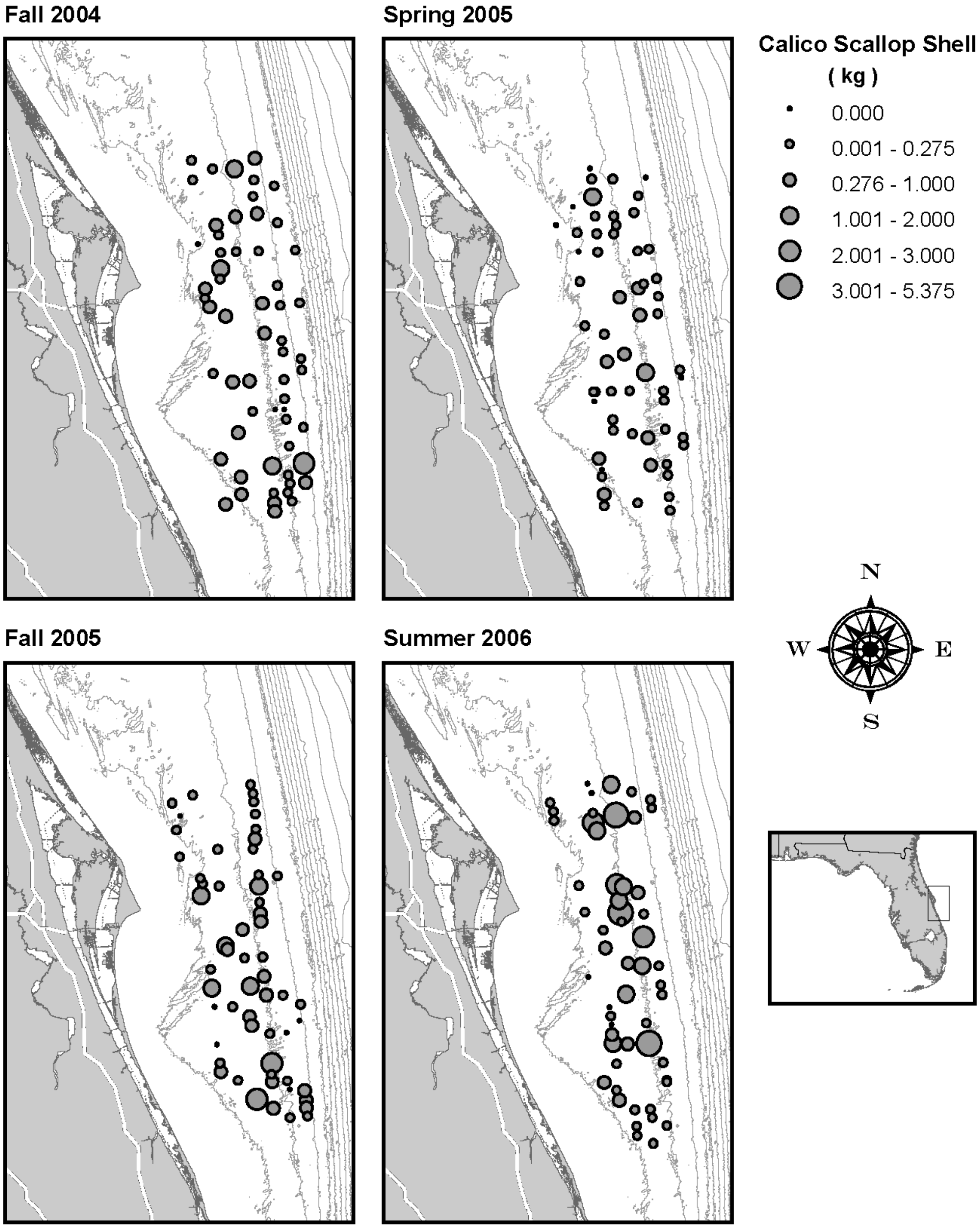

Figure 15. Calico scallop shell yield during four east coast cruises. Catch rates expressed in terms of kilograms of scallop shell expected m-1 min-1. Symbols are scaled to increase with increased catch rate.

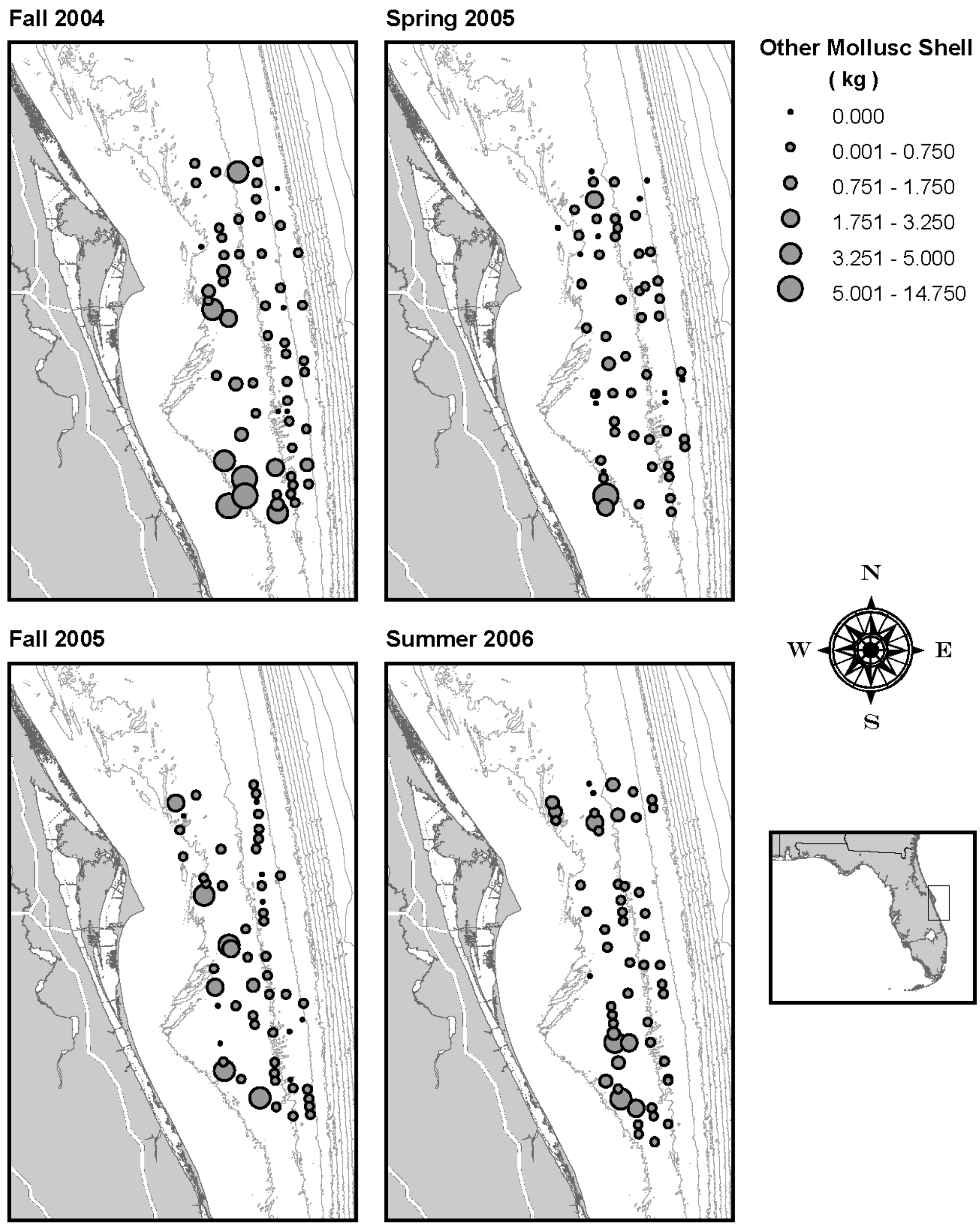

Figure 16. Other shell yield during four east coast cruises. Catch rates expressed in terms of kilograms of shell expected m-1 min-1. Symbols are scaled to increase with increased catch rate.

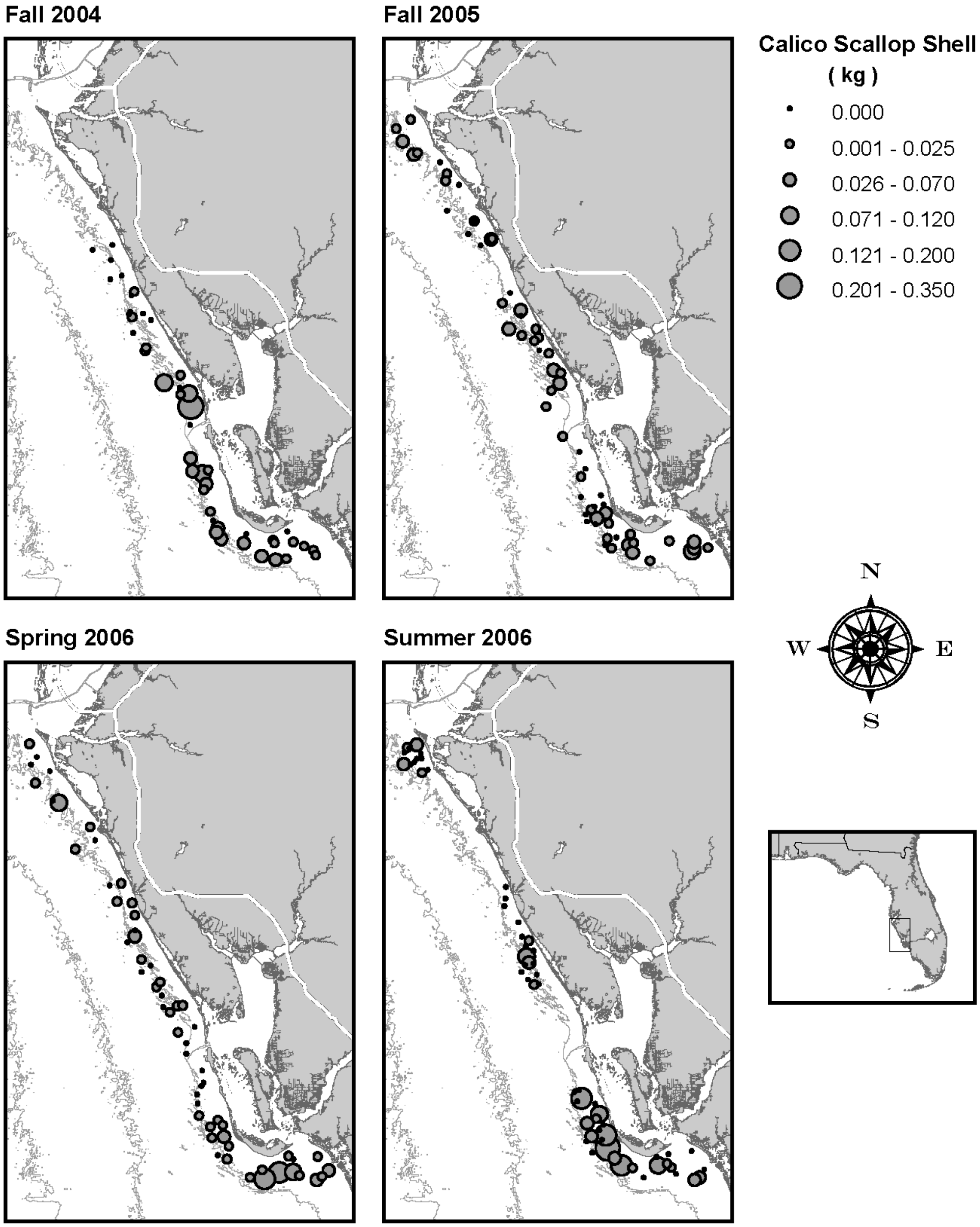

Figure 17. Calico scallop shell from four west coast cruises. Catch rates expressed in terms of kilograms of shell expected m-1 min-1. Symbols are scaled to increase with increased catch rate.

Figure 18. Live calico scallops (*Argopecten gibbus*) have been observed to wash ashore in abundance from Sanibel (Top) through Pinellas County (Bottom) on at least four occasions between fall 2006 and spring 2008.

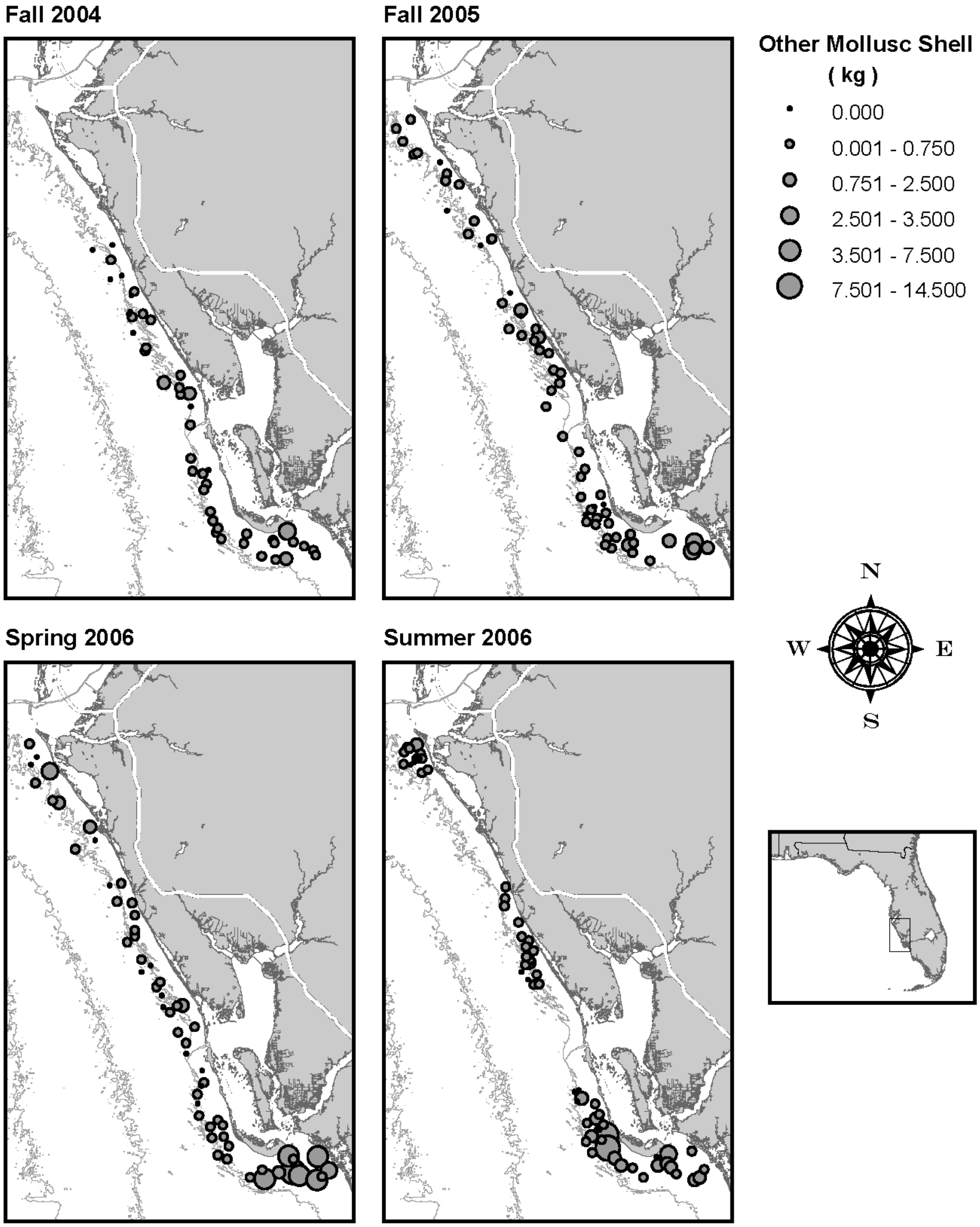

Figure 19. Other shell from four west coast cruises. Catch rates expressed in terms of kilograms of shell expected m-1 min-1. Symbols are scaled to increase with increased catch rate.

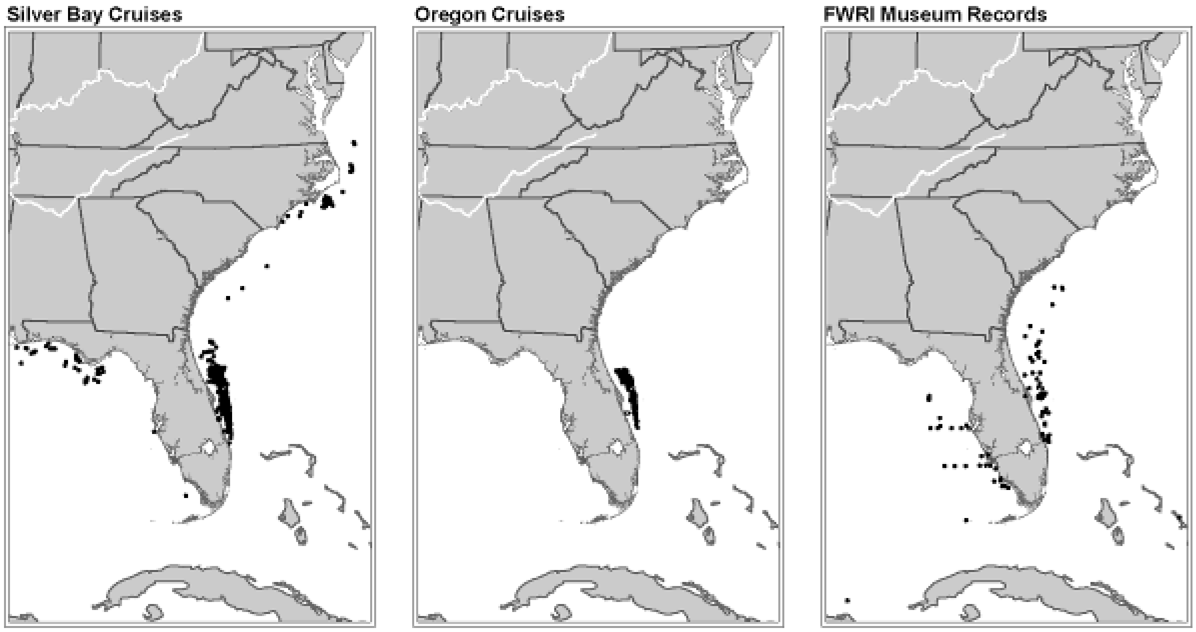

Figure 20. Calico scallop collections by M/V Silver Bay, R/V Oregon and from the FWRI museum. The points on these figures indicate locations where at least one live calico scallop or calico scallop shell was collected.

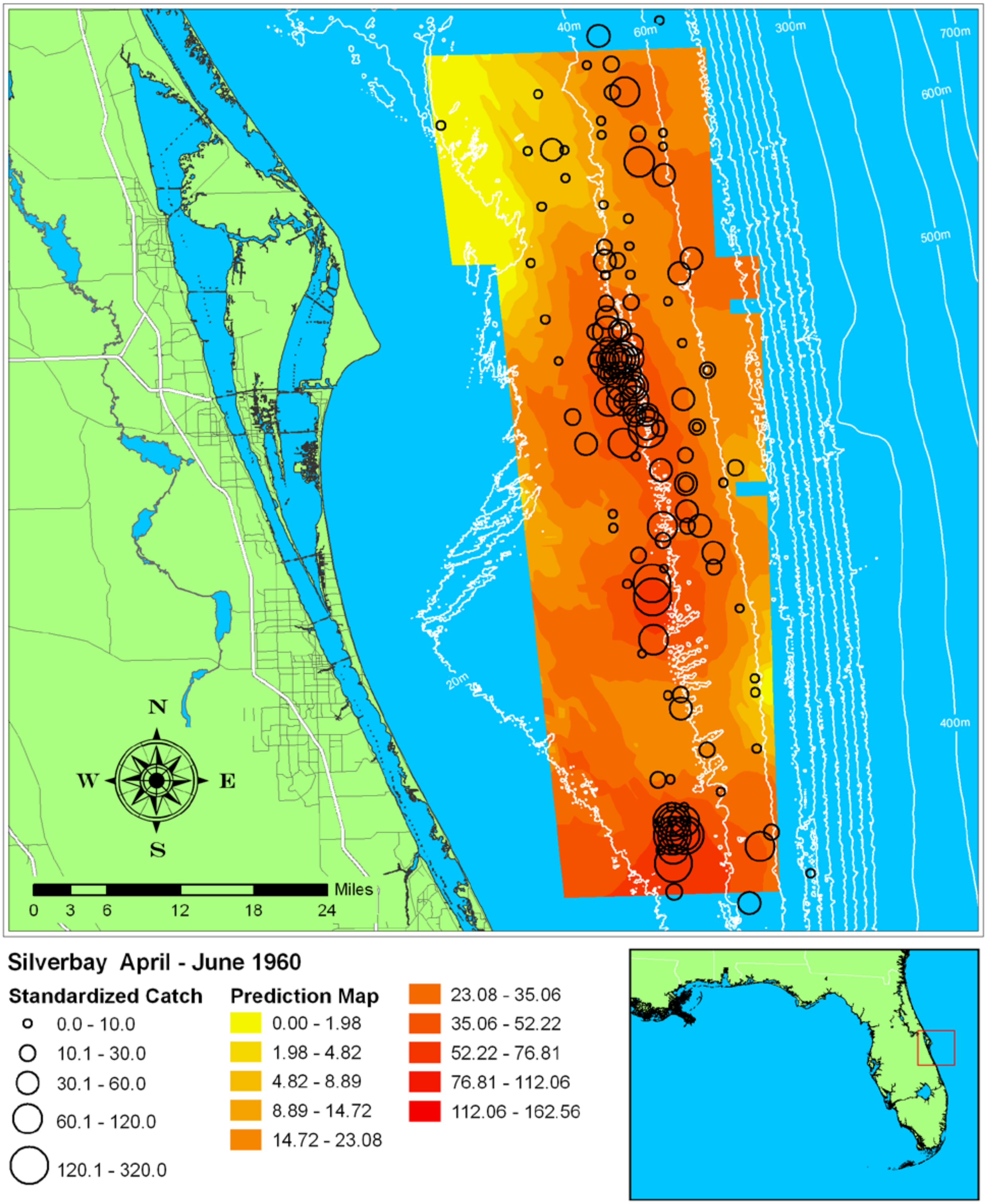

Figure 21. M/V Silverbay April - June 1960. A prediction surface for calico scallop catch rates within our sample grid was created by ordinary kriging, as explained in the text. In some cases, contours were drawn using nearest neighbors outside the grid.

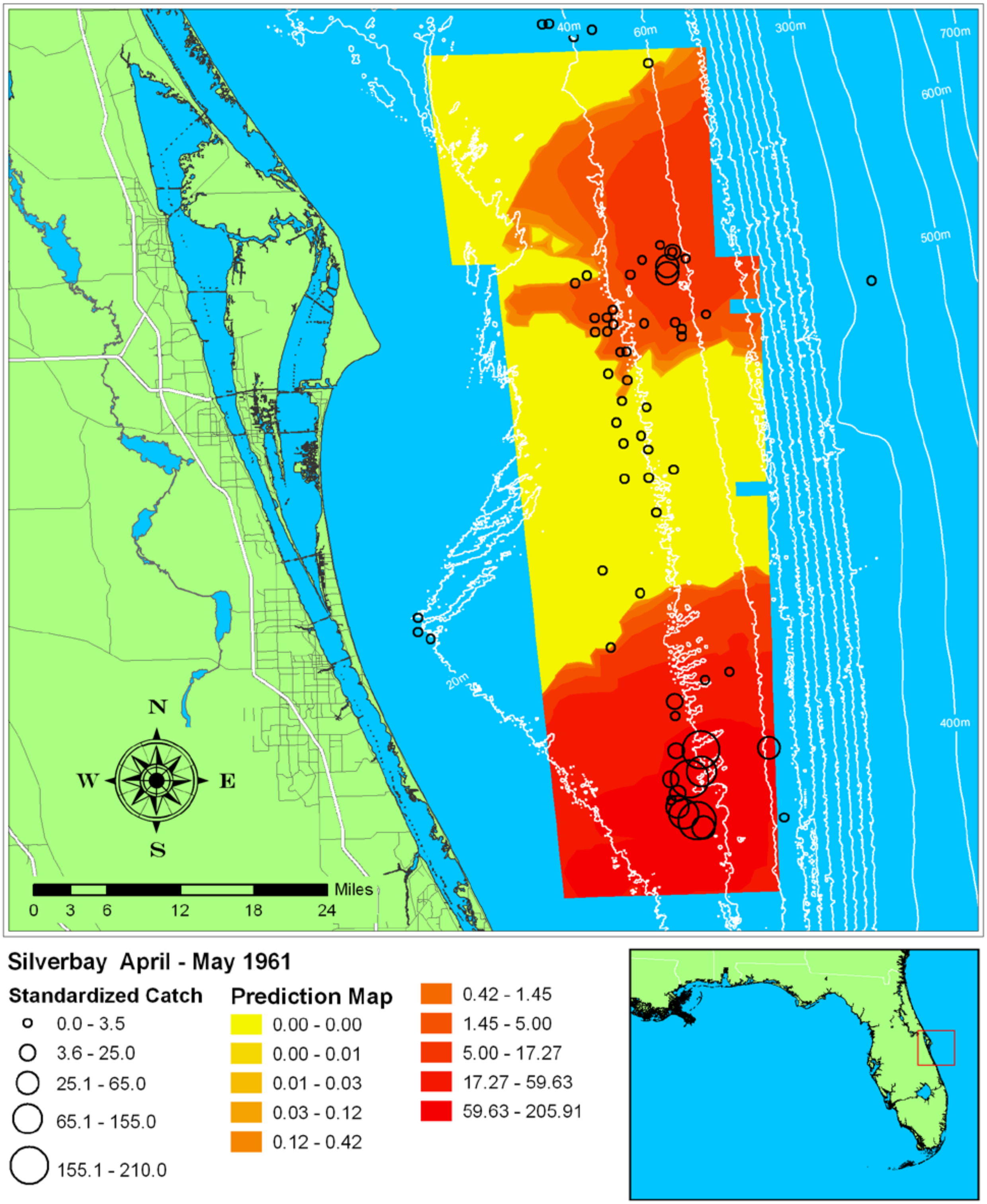

Figure 22. M/V Silverbay April - May 1961. A prediction surface for calico scallop catch rates within our sample grid was created by ordinary kriging, as explained in the text.

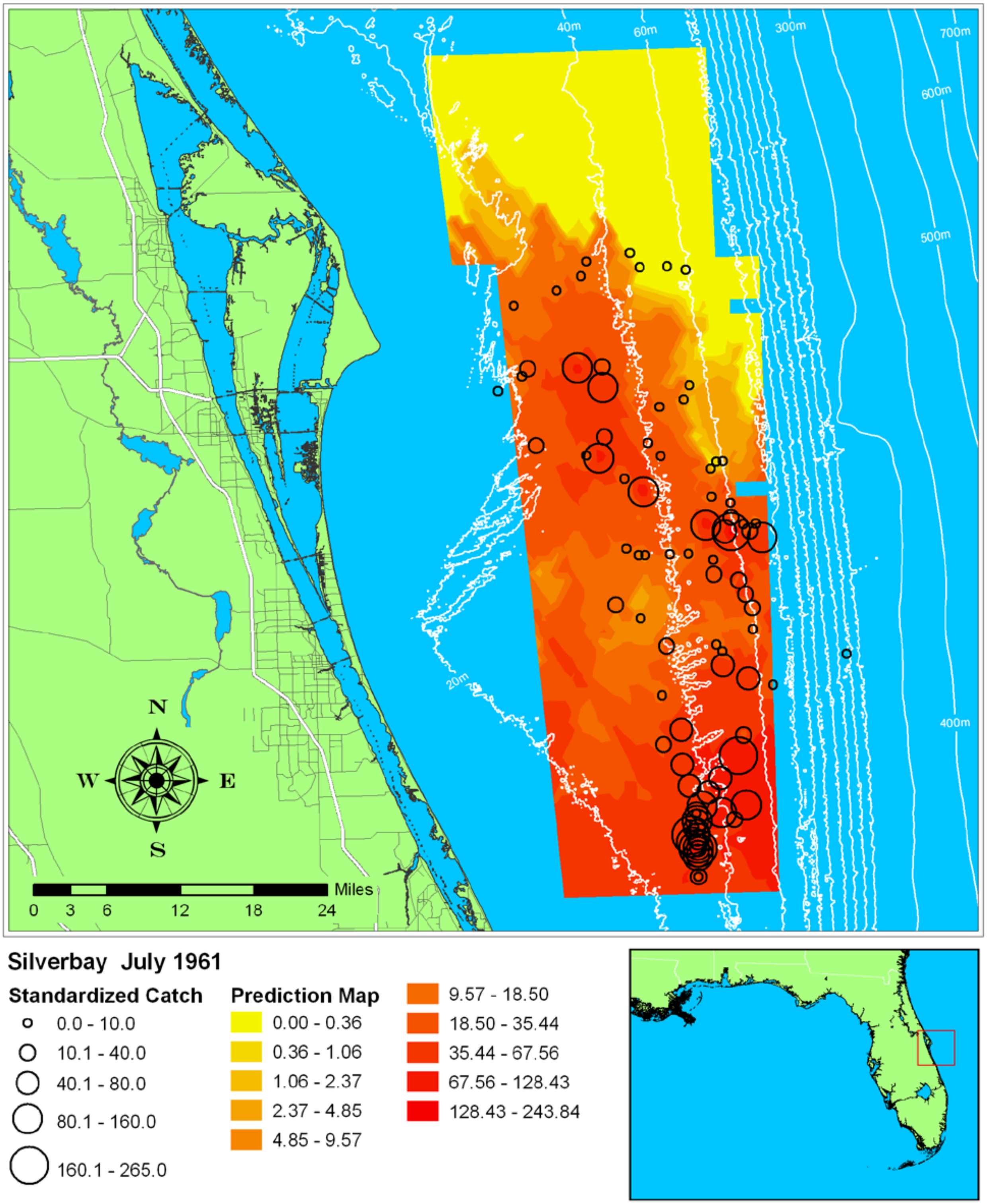

Figure 23. M/V Silverbay July 1961. A prediction surface for calico scallop catch rates within our sample grid was created by ordinary kriging, as explained in the text. In this sample period, no points were present in the north of the sample grid, so high error in the northern portion of the prediction surface was noted during creation of this figure.

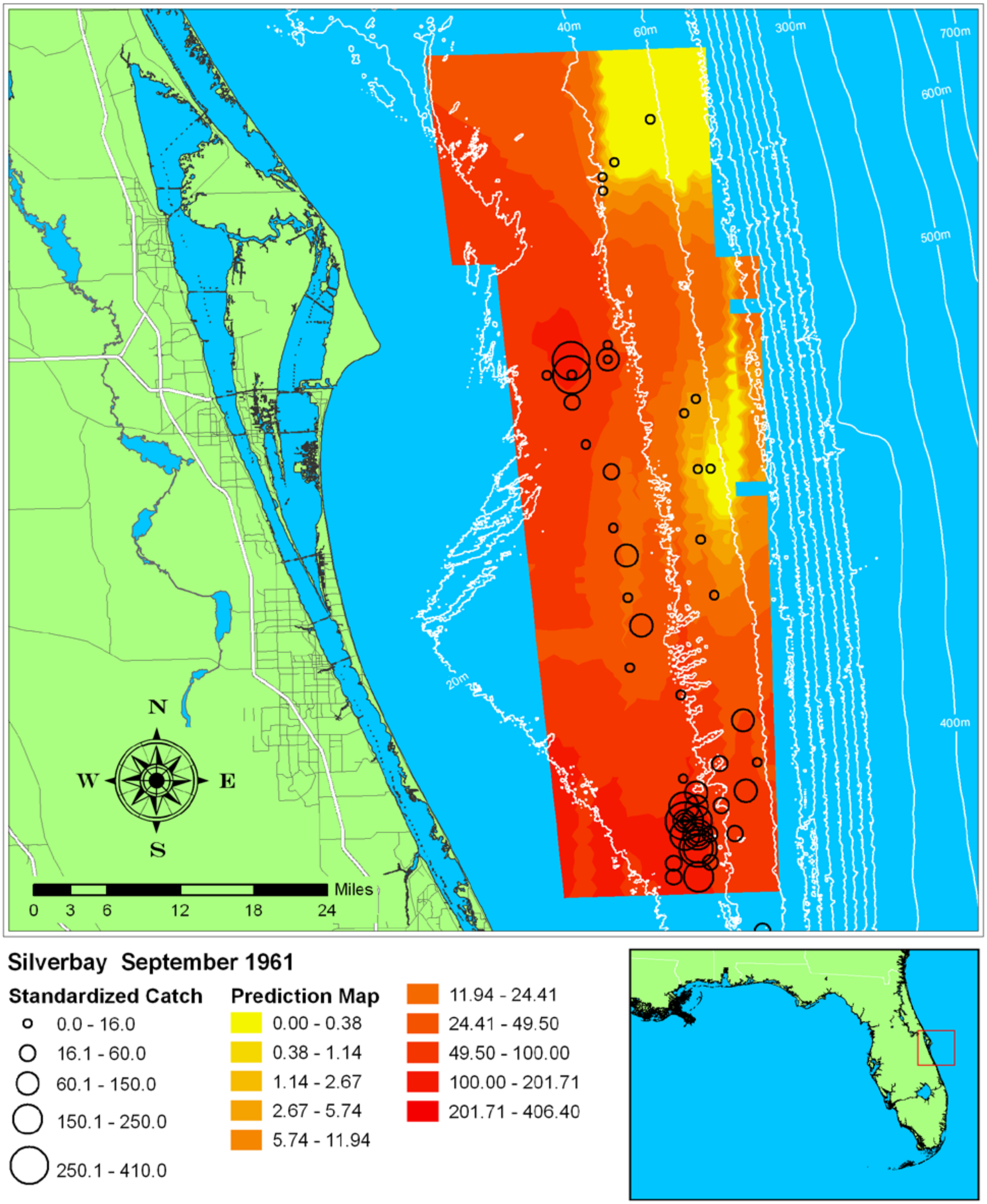

Figure 24. M/V Silverbay September 1961. A prediction surface for calico scallop catch rates within our sample grid was created by ordinary kriging, as explained in the text.

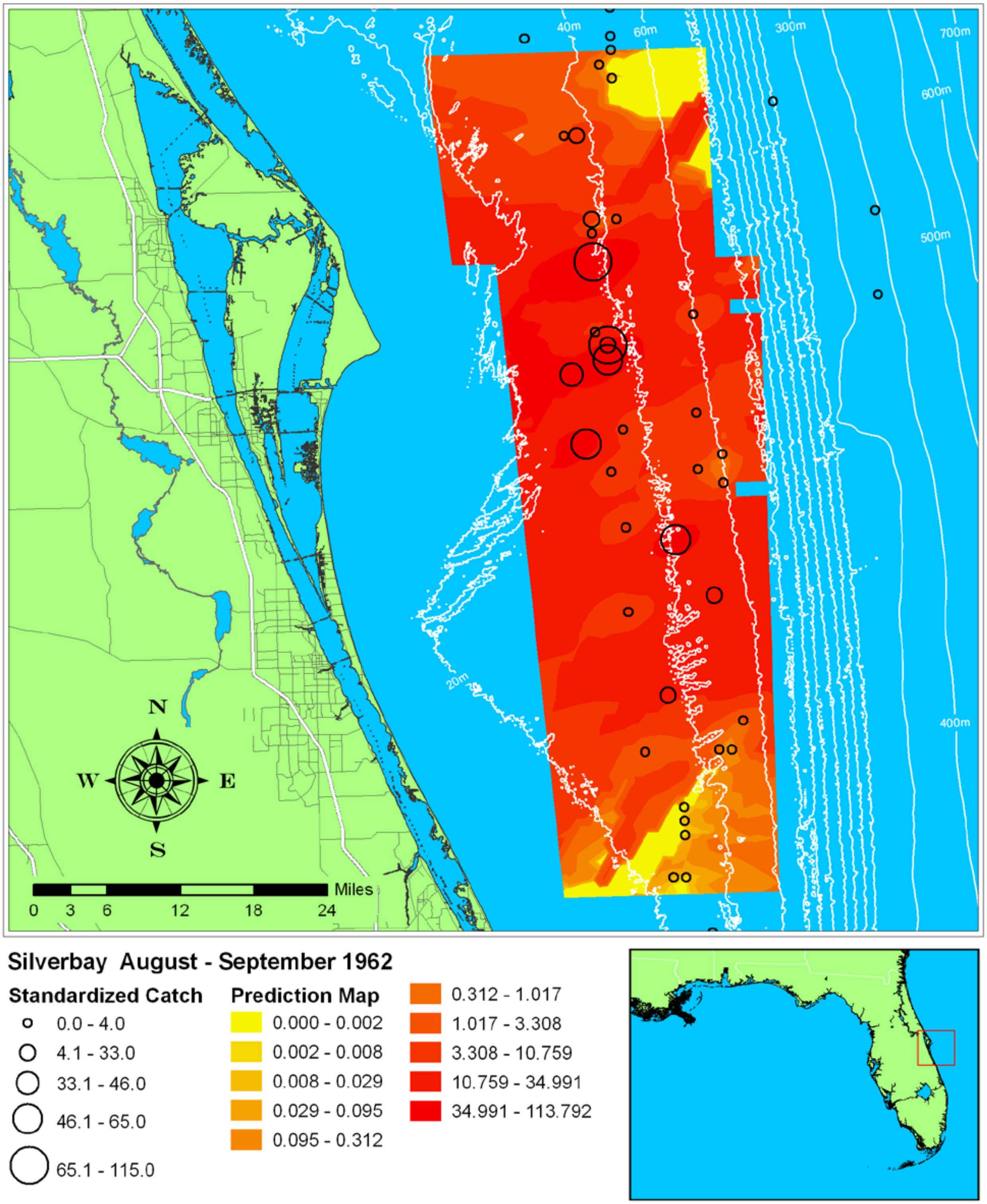

Figure 25. M/V Silverbay August - September 1962. A prediction surface for calico scallop catch rates within our sample grid was created by ordinary kriging, as explained in the text.

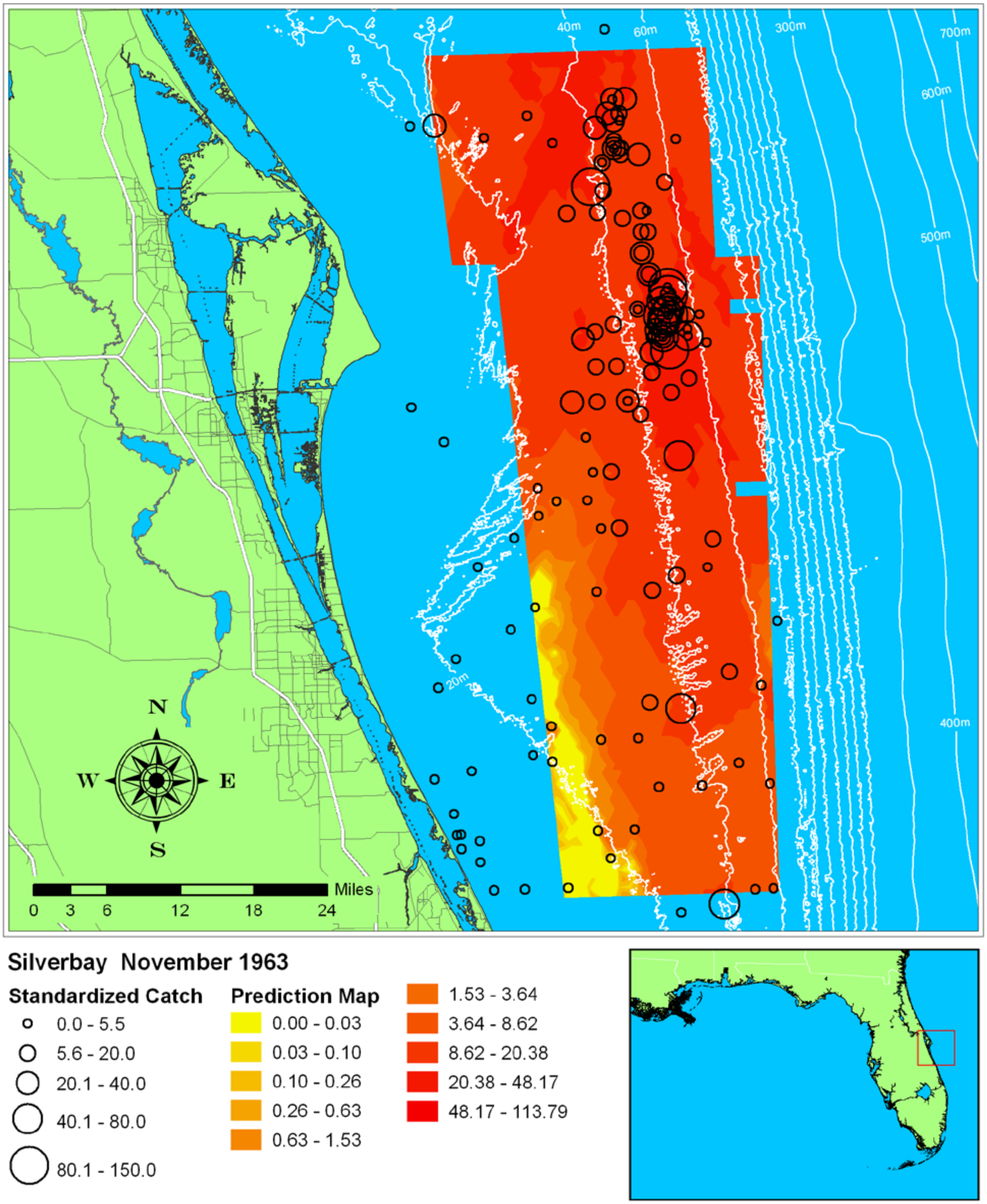

Figure 26. M/V Silverbay November 1963. A prediction surface for calico scallop catch rates within our sample grid was created by ordinary kriging, as explained in the text.

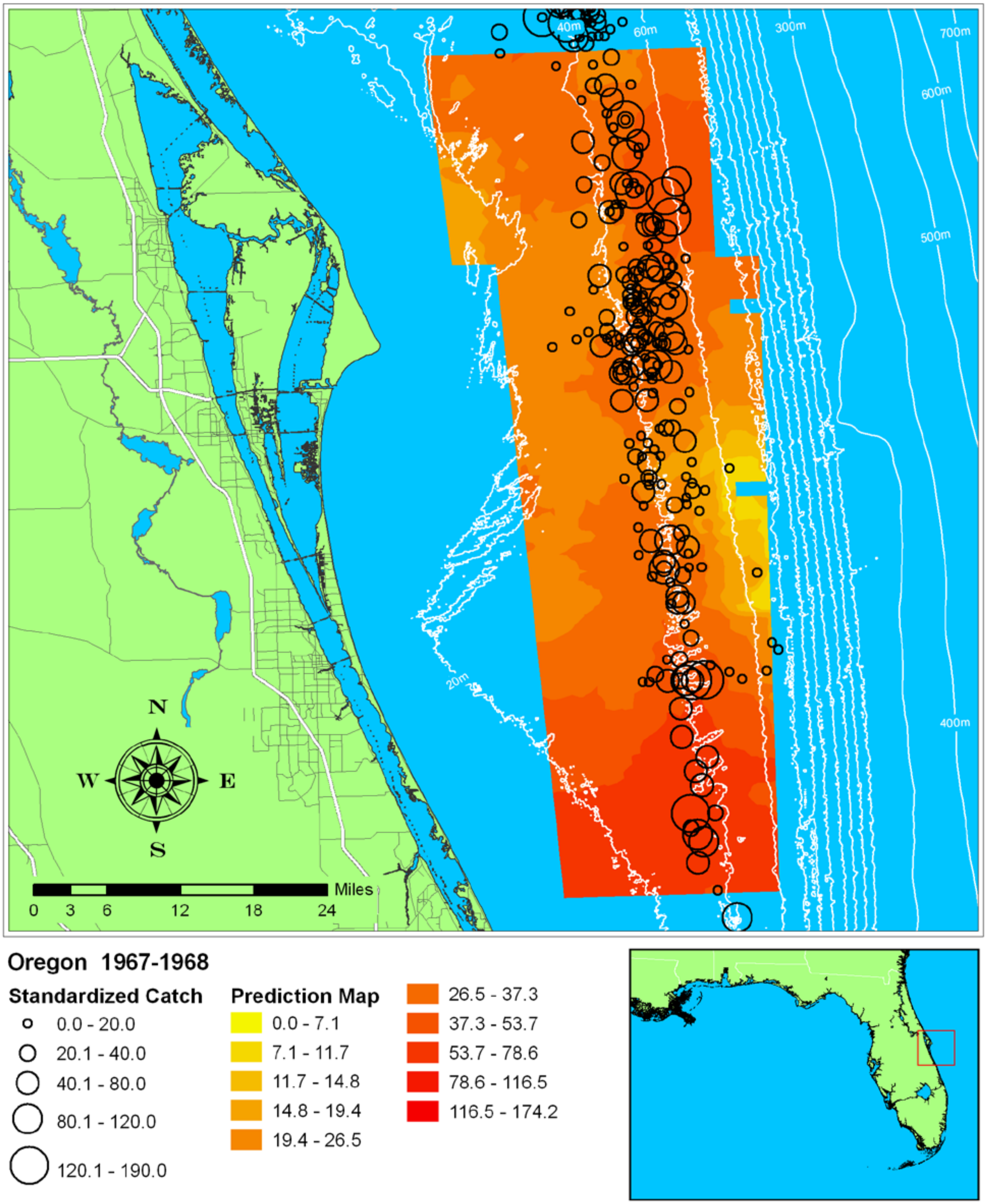

Figure 27. R/V Oregon November 1967 - December 1968. A prediction surface for calico scallop catch rates within our sample grid was created by ordinary kriging, as explained in the text. Note that virtually no samples were collected shoreward of about 35m, so high error in the western portion of the prediction surface was noted during the creation of this figure.

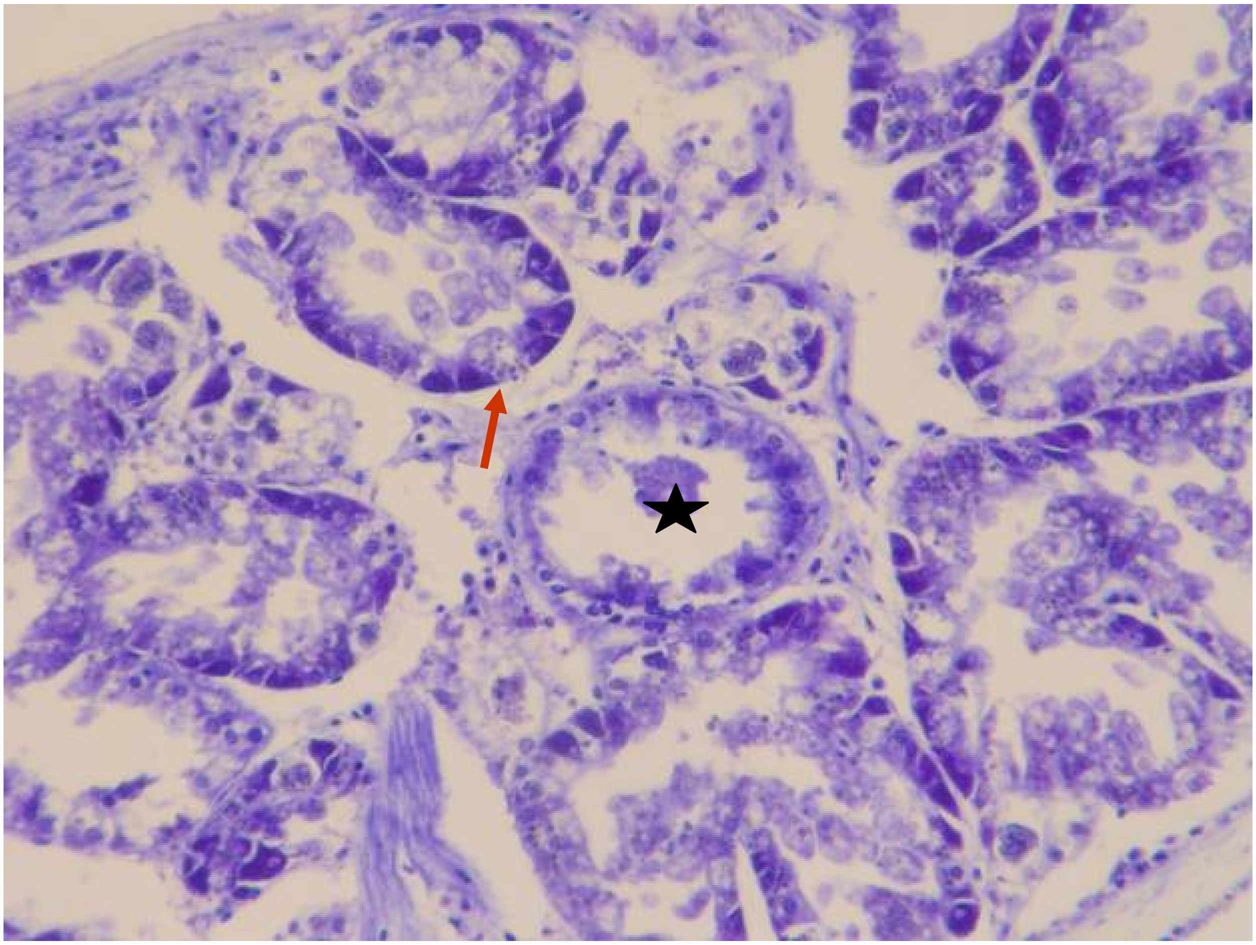

Figure 28. Stage 2 Protozoan infection. Note that more than one and less than half of the acini are infected. There is rarely more than one cell per acini infected. This slide stained with thionin. Magnification 200x. The arrow points to an infected cell. The star is centered on a typical healthy acini.

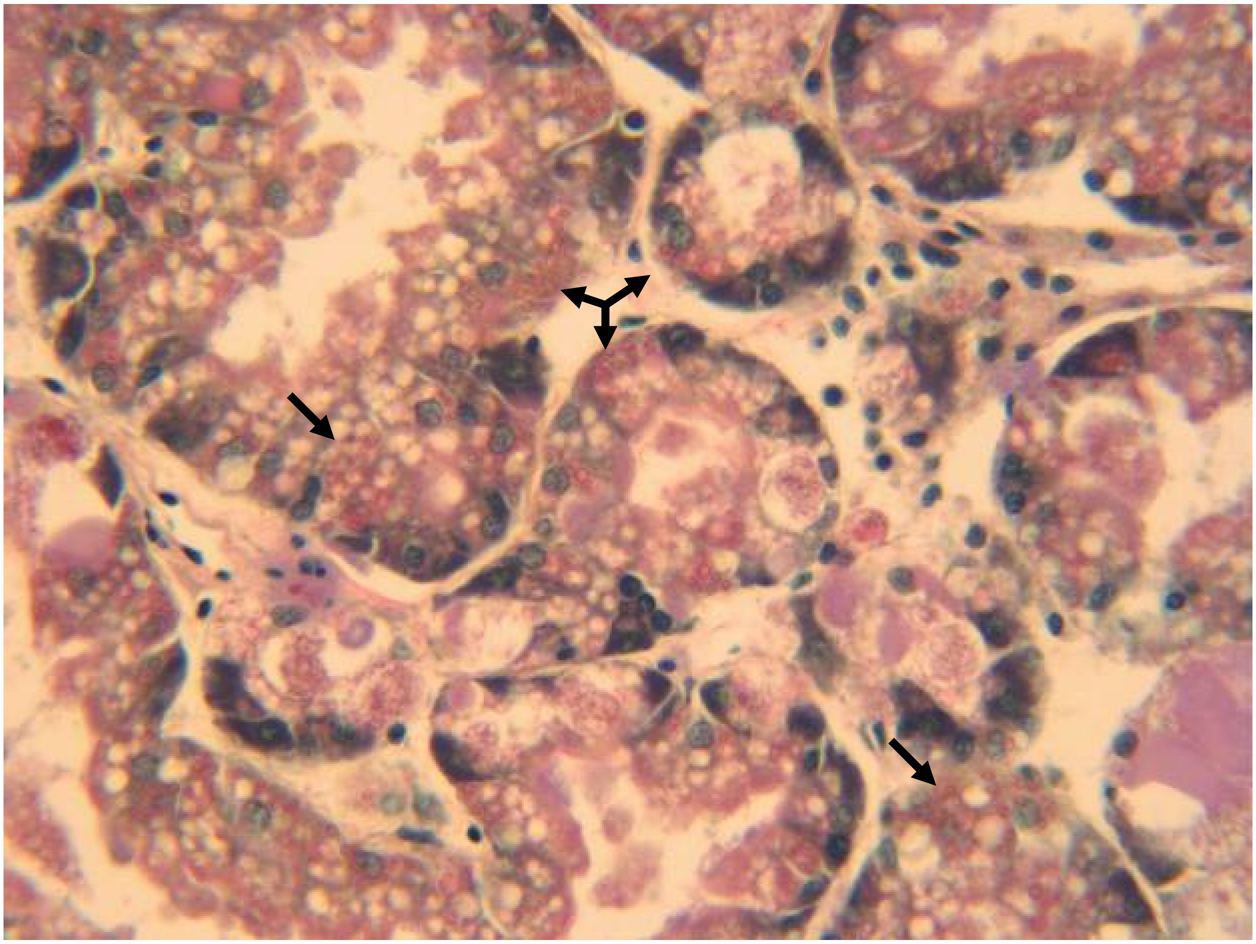
Figure 29. Stage 3 protozoan infection. This slide stained with PAS/MY. Magnification 200x. The arrow point to infected cells.

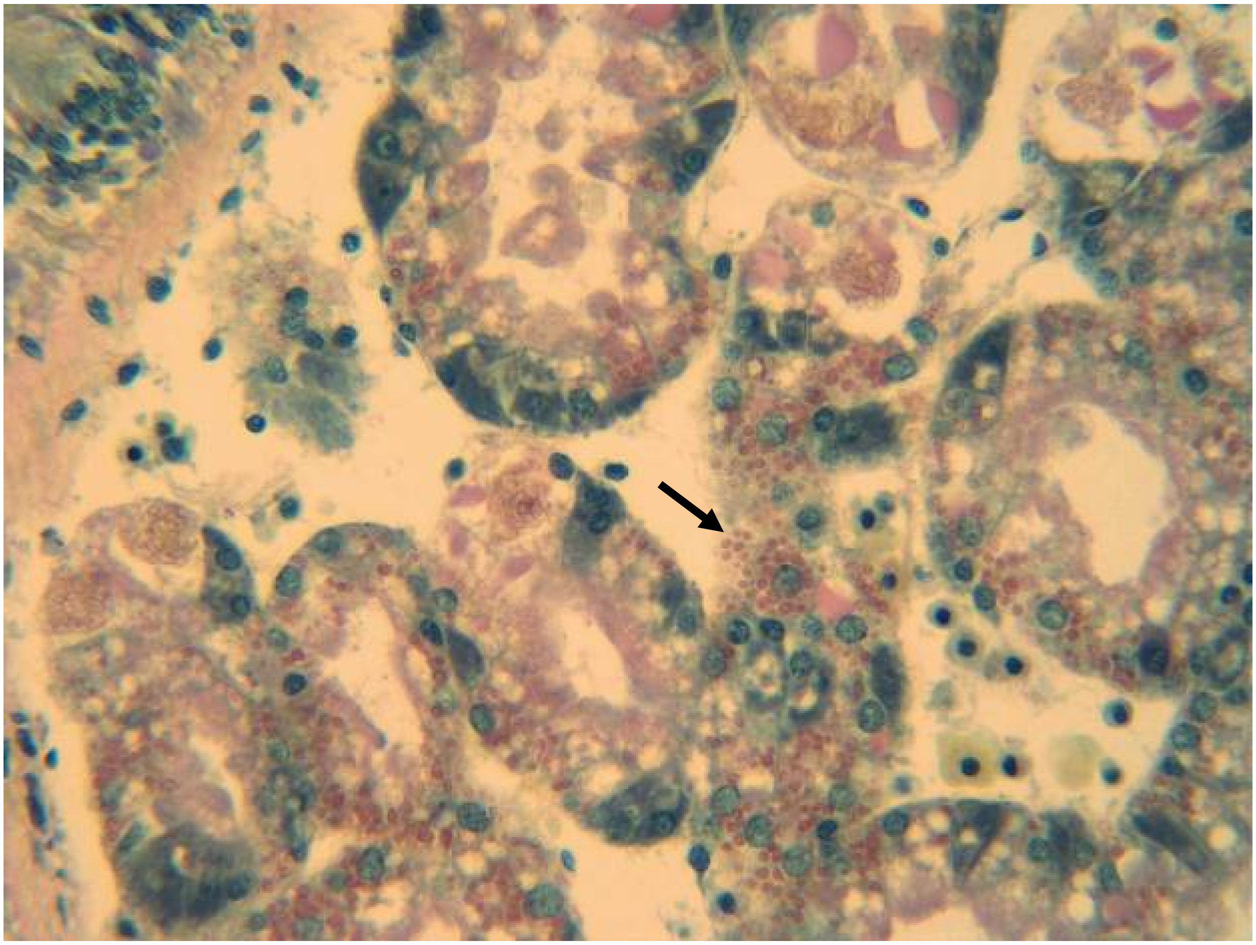

Figure 30. Stage 4 Protozoan infection. This slide stained with PAS/MY. Magnification 200x. The arrow points to small red circular bodies which are individuals of the protozoan parasite infecting most of the cells in this tissue.

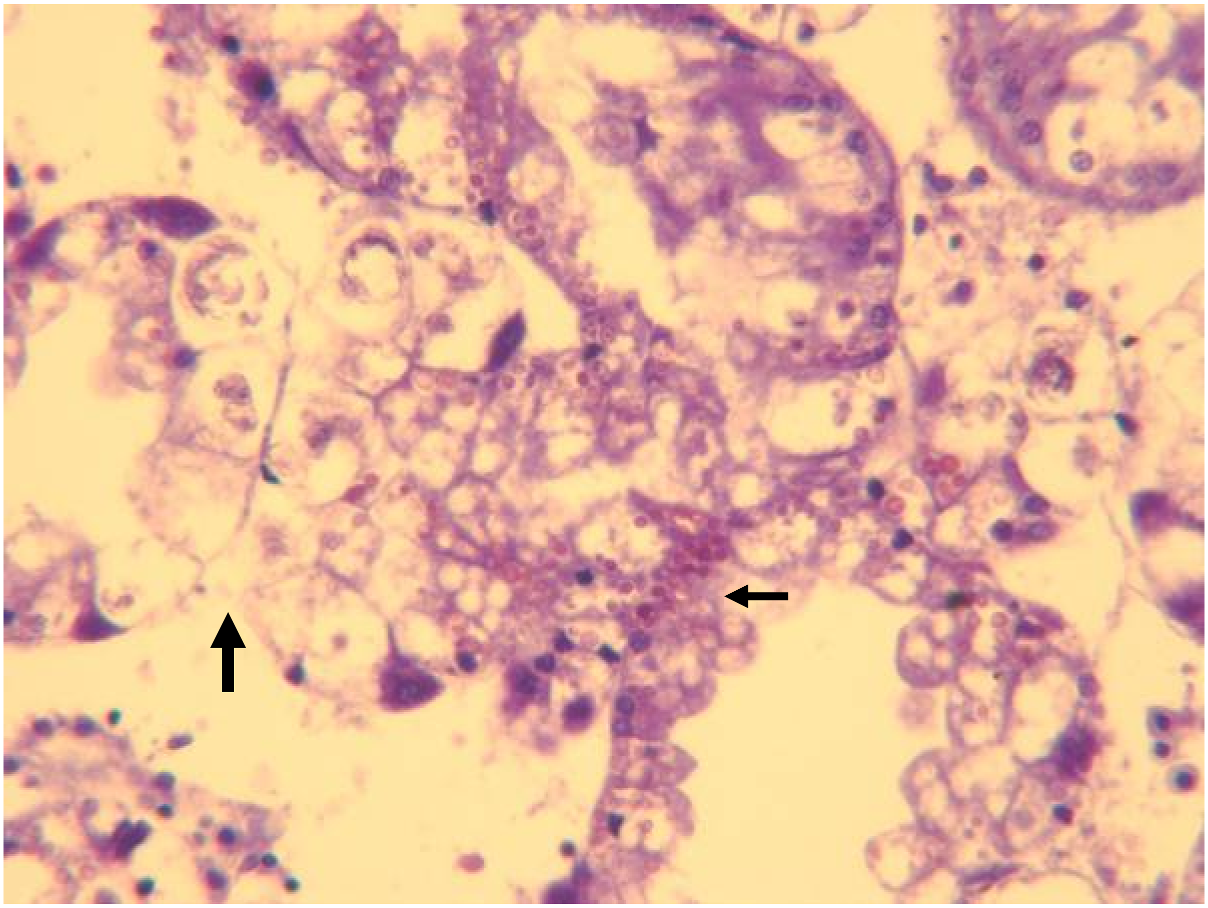

Figure 31. Stage 5 Protozoan infection. This slide stained with thionin. Magnification 200x. Small horizontal arrow indicates a region of individual spores. Larger vertical arrow indicates a region of the tissue where cells of two neighboring acini are beginning to decompose.

Table 1. Average total catch rates during four sampling seasons. In some cases, catch rates have been extrapolated from subsamples of the total catch. Catch rates are also adjusted for tow time and the width of the net, and are thus listed as kg min^{-1} m^{-1}. Each cell represents the average (and standard deviation, sd) of catch of all tows from within a site sampling grid during a single season, as listed.

CRUISE	Data	Titusville	Cocoa	Melbourne	Sebastian	Sarasota	Englewood	Ft. Myers	Naples
Fall 2004	Tows	15	15	16	15	16	16	12	15
	Total kg	2.98	3.01	1.40	8.54	0.02	0.72	1.20	1.49
	sd	*3.93*	*3.43*	*2.37*	*13.03*	*0.02*	*0.95*	*0.93*	*1.01*
Fall 2005	Tows	13	17	15	15	18	16	16	16
	Total kg	1.06	2.03	1.49	2.09	0.39	0.29	0.44	3.44
	sd	*1.86*	*3.21*	*2.91*	*3.06*	*0.26*	*0.36*	*0.63*	*8.54*
Spring 2005	Tows	16	15	16	18	16	15	15	15
(East Coast)	Total kg	0.89	0.62	0.67	2.77	1.42	0.74	0.89	9.06
Spring 2006	*sd*	*1.09*	*0.60*	*0.95*	*6.07*	*1.97*	*0.92*	*0.89*	*8.04*
(West Coast)									
Summer	Tows	15	15	15	14	15	15	15	15
2006	Total kg	2.44	1.79	2.32	2.43	1.51	0.24	4.13	3.15
	sd	*2.81*	*1.33*	*2.35*	*4.45*	*1.67*	*0.40*	*6.23*	*3.89*
Overall	Tows	59	62	62	62	65	62	58	61
	Total kg	1.88	1.86	1.46	3.94	0.97	0.49	1.62	4.27
	sd	*2.83*	*2.60*	*2.33*	*8.11*	*1.50*	*0.74*	*3.49*	*6.86*

Table 2. The historical data listed from NOAA survey cruises (vessels) by years: Silver Bay, 1957-1964; Oregon, 1967-1968; Bowers, 1969-1973; Oregon II, 1975-1981; Delaware II, 1982; and Bellows, 1989. For most cruises, a general description and hand drawn map is provided in the cruise report. In the Data description column, "lat-long" indicates the cruise log provides station location and catch rates (of calico scallops). "Common commercial species" indicates that calico scallops were not necessarily the primary focus of the sampling, but scallops were recorded. For Bowers cruises, spatial data is generally provided in terms of LORAN lines accompanied with indications of what depth along the loran line a catch of scallops was made. When the data description indicates "text, map" only, we have been unable to locate the detailed cruise logs with station and catch data.

Vessel	Cruise	Dates	Location	Data description
Silver Bay	2	7/12-29/57	GoM - FL	text, map
	10	7/17-8/4/58	GoM - FL	text, map
	18	9/2-9/29/59	Atl - NC	text, map, lat-long, common commercial species
	20	11/21-12/13/59	Atl - NC	text, map, lat-long, common commercial species.
	21	1/13-1/29/60	Atl - GA-FL	text, map, lat-long, common commercial species.
	22	2/16-3/18/60	Atl - NC-SC	text, map, lat-long, common commercial species.
	23	4/13-5/6/1960	Atl - FL	text, map, lat-long, ca. scal.
	24	5/26-6/14/60	Atl - FL	text, map, lat-long, cal. scal.
	25	7/13-30/60	Atl - SC-NC	text, map, lat-long, common commercial species
	26	10/11-11/15/60	Atl - FL	text, map
	27	12/1-16/60	Atl - SC	text, map
	28	1/18-2/10/61	Atl - FL	text, map
	29	2/27-3/11/61	Atl - NC	text, map, lat-long, common commercial species
	30	4/17-5/11/61	Atl - FL	text, map, lat-long, common commercial species
	31	7/5-7/21/61	Atl - FL	text, map, lat-long, common commercial species
	32	8/18-23/61	Atl - NC	text, map, lat-long, com. comm. sp., incomplete
	33	9/23-10/6/61	Atl - FL	text, map, lat-long, common commercial species
	35	11/28-12/15/61	Atl - FL	text, map
	36	1/15-2/6/61	Atl - FL	text, map, lat-long, cal. scal. & royal red shrimp
	39	5/24-6/12/62	Atl - NC	text, map, lat-long, common commercial species
	41	8/21-9/7/62	Atl - FL	text, map, lat-long, cal. scal. & roy. red shr.
	42	9/24-10/2/62	Atl - FL	text, map
	47	3/25-4/1/63	Atl - FL	text, map
	51	11/6-19/63	Atl - FL	text, lat-long, cal. scal.
	54	2/4-16/64	Atl - FL	text, map
	55	2/25-3/4/64	Atl - FL	text, map, lat-long, common commercial species
Oregon	123	11/6-20/67	Atl - FL -GA	text, map, lat-long, common commercial species
	124	12/4-19/67	Atl - FL	text, map
	126	2/12-29/68	Atl - FL	text, map, lat-long, common commercial species
	128	4/12-27/68	Atl - FL	text, map, lat-long, common commercial species
	130	6/10-26/68	Atl - FL	text, map, lat-long, common commercial species
	134	10/8-25/68	Atl - FL	text, map
	136	12/9-20/68	Atl - FL	text, map, lat-long, common commercial species
Bowers	85	7/21-8/5/69	Atl - FL	text, map (LORAN)
	93	6/17-25/70	Atl - FL	text, map (LORAN)
	98	10/21-11/2/70	GoM - Fl	text, map (LORAN)
	99	1/21-27/71	Atl -FL	cal. scal. - no data
	100	3/10-17/71	Atl -FL	cal. scal. - no data
	101	4/15-21/71	Atl -FL	cal. scal. - no data
	102	4/28-5/8/71	Atl - GA - SC	text, map
	104	6/3-23/71	Atl - FL	text, maps, LORAN lines
	106	7/17-8/17/71	GoM - FL	text, maps
	109	5/1-6/2/72	Atl - FL	text, maps, LORAN lines
	110	7/12-17/72	Atl - FL	text, maps, LORAN lines
	112	9/13 - 10/10/72	Atl - NC	text, maps (LORAN)
	114	1/9 - 1/26/73	Atl - FL	text, maps
	120	10/25-11/18/73	Atl - FL	text, maps, LORAN
	122	4/22 - 5/16/74	Atl - NC	text, maps
	124	8/13-10/23/74	Atl, FL	text, maps
	128	4/26-5/13/75	GoM	Text
	138	3/9-26/76	Atl, FL	Text
Oregon II	59	6/10-27/75	Atl - FL	text, map (LORAN)

	65	3/19-4/8/76	Atl - GoM	Text
	76	3/27-4/11/77	Atl - FL	Text
	122	10/14-11/20/81	GoM - AL	some text
Delaware II		6/82	Atl - FL	text, lat-long
Bellows		8/2-8/89	Atl - FL	text, map, lat-long

Table 3. Average calico scallop (*Argopecten gibbus*) catch rates during four sampling seasons. In some cases, catch rates have been extrapolated from subsamples of the total catch. Catch rates are also adjusted for tow time and the width of the net, and are thus listed as number of scallops min^{-1} m^{-1}(juvenile and adult) or total kg of scallops min^{-1} m^{-1}. Each cell represents the average (and standard deviation, sd) of catch of all tows from within a site sampling grid during a single season, as listed.

CRUISE	Data	Titusville	Cocoa	Melbourne	Sebastian	Sarasota	Englewood	Ft. Myers	Naples
Fall 2004	Juvenile	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	sd	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
	Adult	2.029	3.072	0.815	4.560	0.072	0.195	0.000	0.116
	sd	*5.056*	*5.989*	*1.812*	*9.153*	*0.240*	*0.676*	*0.000*	*0.296*
	Total kg	0.045	0.060	0.020	0.082	0.000	0.001	0.000	0.000
	sd	*0.109*	*0.109*	*0.043*	*0.165*	*0.000*	*0.005*	*0.000*	*0.001*
Fall 2005	Juvenile	0.081	0.155	0.155	0.486	0.000	0.000	0.100	0.362
	sd	*0.205*	*0.307*	*0.506*	*0.950*	*0.000*	*0.000*	*0.197*	*0.566*
	Adult	0.048	0.757	1.527	7.031	0.000	0.000	0.000	0.688
	sd	*0.160*	*1.608*	*2.365*	*16.085*	*0.000*	*0.000*	*0.000*	*1.233*
	Total kg	0.000	0.007	0.013	0.072	0.000	0.000	0.000	2.179
	sd	*0.000*	*0.007*	*0.013*	*0.072*	*0.000*	*0.000*	*0.000*	*2.179*
Spring 2005	Juvenile	0.618	0.116	0.018	0.085	0.178	0.058	0.039	0.797
(East Coast)	*sd*	*2.314*	*0.177*	*0.070*	*0.277*	*0.476*	*0.217*	*0.145*	*2.025*
Spring 2006	Adult	0.000	0.000	0.000	0.000	0.000	0.000	0.064	2.385
(West Coast)	sd	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.241*	*4.604*
	Total kg	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.027
	sd	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.003*	*0.066*
Summer	Juvenile	3.500	3.224	4.032	2.966	0.019	0.000	0.510	0.317
2006	sd	*6.806*	*4.206*	*5.535*	*4.703*	*0.072*	*0.000*	*1.250*	*0.809*
	Adult	3.423	4.986	4.747	0.704	0.282	0.000	21.684	12.487
	sd	*8.336*	*6.531*	*10.954*	*1.336*	*0.507*	*0.000*	*64.933*	*32.845*
	Total kg	0.018	0.029	0.045	0.019	0.002	0.000	0.234	0.114
	sd	*0.037*	*0.040*	*0.109*	*0.052*	*0.006*	*0.000*	*0.748*	*0.314*

Table 4. Total catch of calico scallop (*Argopecten gibbus*) spat during four sampling seasons. The first line of each season lists the total number of spat collected, by zone. Attachment substrate includes: calico scallop shell (and rarely live calico scallops), other mollusc shell (including shell from other scallop species, primarily *Euvola raveneli*), loose, and other (including live molluscs other than calico scallops, live rock, rocks, algae, and a single case each of a barnacle and trash). When no scallops were collected in a zone in that particular season it is indicated by "-".

CRUISE	Data	Titusville	Cocoa	Melbourne	Sebastian	Sarasota	Englewood	Ft. Myers	Naples
Fall 2004	Scallop spat (n)	-	-	-	-	-	-	-	-
	scallop shell								
	other shell								
	loose								
	other								
Fall 2005	Scallop spat (n)	4	7	2	13	-	-	5	20
	scallop shell	3	1	0	4			0	2
	other shell	1	0	0	0			1	15
	loose	0	6	2	6			1	3
	other	0	0	0	3			3	0
Spring 2005	Scallop spat (n)	3	6	1	5	7	2	1	9
(East Coast)	scallop shell	1	2	1	3	0	1	0	0
	other shell	0	0	0	1	3	1	1	4
Spring 2006	loose	2	4	0	0	1	0	0	1
(West Coast)	other	0	0	0	1	3	0	0	4
Summer	Scallop spat (n)	122	111	111	91	1	-	6	6
2006	scallop shell	68	75	60	33	0		0	0
	other shell	6	9	25	18	1		1	0
	loose	48	27	18	30	0		5	6
	other	0	0	8	10	0		0	0

Table 5a. Summary of calico scallop spat settlement substrate for 6 size classes collected on the west Florida shelf.

size class		loose	calico shell	other shell	live substrate	other
>20mm	n	3	0	1	0	0
	%	75.0	0.0	25.0	0.0	0.0
15-20mm	n	10	0	0	0	0
	%	100.0	0.0	0.0	0.0	0.0
10-15mm	n	4	0	3	2	0
	%	44.4	0.0	33.3	22.2	0.0
5-10mm	n	3	2	14	6	0
	%	12.0	8.0	56.0	24.0	0.0
3-5mm	n	1	1	5	2	0
	%	11.1	11.1	55.6	22.2	0.0
<3mm	n	na	na	na	na	na
	%					

Table 5b. Summary of calico scallop spat settlement substrate for 6 size classes collected on the east Florida shelf.

size class		loose	calico shell	other shell	live substrate	other
>20mm	m	17	12	1	0	1
	%	54.8	38.7	3.2	0.0	3.2
15-20mm	n	55	22	7	2	2
	%	62.5	25.0	8.0	2.3	2.3
10-15mm	n	54	65	16	1	7
	%	37.8	45.5	11.2	0.7	4.9
5-10mm	n	19	86	11	2	4
	%	15.6	70.5	9.0	1.6	3.3
3-5mm	n	3	23	9	5	4
	%	6.8	52.3	20.5	11.4	9.1
<3mm	n	2	29	9	5	2
	%	4.3	61.7	19.1	10.6	4.3

Table 6. Average catch rates of calico scallop (*Argopecten gibbus*) shell and other mollusc shell during four sampling seasons. Each cell represents the average (and standard deviation, sd) of catch of all tows from within a site sampling grid during a single season, as listed. In some cases, catch rates have been extrapolated from subsamples of the total catch. Catch rates are also adjusted for tow time and the width of the net, and are thus listed as kilograms of shell min^{-1} m^{-1}.

CRUISE	Data	Titusville	Cocoa	Melbourne	Sebastian	Sarasota	Englewood	Ft. Myers	Naples
Fall 2004	Scallop shell	0.290	0.374	0.146	0.662	0.000	0.009	0.044	0.022
	sd	*0.457*	*0.408*	*0.216*	*0.641*	*0.000*	*0.020*	*0.056*	*0.022*
	Other shell	0.334	0.601	0.241	2.827	0.001	0.190	0.377	0.712
	sd	*0.804*	*0.967*	*0.457*	*4.037*	*0.001*	*0.276*	*0.416*	*0.763*
Fall 2005	Scallop shell	0.098	0.529	0.366	0.556	0.009	0.015	0.008	0.024
	sd	*0.101*	*0.551*	*0.512*	*0.704*	*0.013*	*0.016*	*0.012*	*0.027*
	Other shell	0.272	0.793	0.325	0.677	0.204	0.228	0.110	0.882
	sd	*0.682*	*1.432*	*0.759*	*1.430*	*0.200*	*0.320*	*0.162*	*1.004*
Spring 2005	Scallop shell	0.149	0.215	0.216	0.161	0.015	0.010	0.007	0.039
(East Coast)	*sd*	*0.339*	*0.297*	*0.396*	*0.234*	*0.030*	*0.014*	*0.009*	*0.054*
Spring 2006 (West	Other shell	0.147	0.068	0.199	0.777	0.629	0.217	0.048	3.168
Coast)	*sd*	*0.482*	*0.070*	*0.320*	*2.192*	*0.983*	*0.371*	*0.057*	*3.777*
Summer	Scallop shell	0.884	1.160	0.657	0.141	0.007	0.009	0.035	0.048
2006	*sd*	*1.443*	*1.001*	*0.961*	*0.196*	*0.013*	*0.020*	*0.055*	*0.092*
	Other shell	0.537	0.275	0.553	0.716	0.280	0.113	1.344	1.704
	sd	*0.588*	*0.486*	*1.021*	*1.370*	*0.405*	*0.291*	*3.623*	*2.377*

Table 7. Typical data format from R/V Bowers cruise reports. * Latitude estimated is given here for comparative purposes only, it was not provided in the 1970's data.

Cruise	Date	Loran Lines	Approximate Latitude*	Depth (fathoms)	Meats per pint	SH (mm)
85	July, 1969	3H7-3000	29.1 – 29.6	15-25	112	50-55
		3H7-1800				
93	June, 1970	3H7-2100	29.1-29.4	15-25	112	50-55, + seed
		3H7-2400				
104	June 1971	3H7-3000	27.5-29.7	10-25	96-136	34-60, + seed
		3H7-1500				
109	June 1972	3H7-1500	27.5-28.0	18-28		44-64.5
		3H7-1700				
110	July 1972	3H7-1500	27.5-28.5	18-30	80-140	40-75
		3H7-1750				
120	November 1973	3L1-2000 to 3L5-1180	28.4-29.3	12-28	160-240	38-55, seed
		3L1-1725 to 3L5-1111				
124	August-October, 1974	3L1-1500	27-29	15-32	120	21-65
		3L1-2200				

Table 8. Mean infection stage by the protist *Marteilia* in Calico scallop (*Argopecten gibbus*) digestive diverticuli collected during four sampling seasons. The first line of each season indicates the total number of scallops collected for histology. The second line indicates the number of scallops in which *Marteilia* was detected. Infection intensity by the following levels: 0, no *Marteilia* detected; 1, at least some protists detected in the digestive tubules (acini), but limited to single cells within any acini and also limited number of acini affected; 2, less than half of the acini with protists, some with multiple cells affected; 3, more than half of the acini infected, many with more than one cell infected; 4, almost all of the acini infected, some with nearly all cells infected; 5, tissue necrosis or pathology observed.

CRUISE	Data	Titusvill e	Coco a	Melbourn e	Sebastia n	Sarasot a	Englewoo d	Ft. Myers	Naple s
Fall 2004	Sample (n)	15	15	15	15	4	6	-	6
	Marteilia avg stage	4.1	4.4	3.9	4.4	3.2	3.7		3.5
Fall 2005	Sample (n)	7	20	12	20	-	-	-	40
	Marteilia avg stage	3.5	3.6	3.8	3.4				4.6
Spring 2005	Sample (n)	-	-	-	-	-	-	-	-
(East Coast) Spring 2006 (West Coast)	Marteilia avg stage								
Summer 2006	Sample (n)	14	15	15	15	5	-	14	13
	Marteilia avg stage	3.4	4.0	3.3	3.8	4.5		5.0	4.4