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Authors: Mark Gambordella[1], Luke McEachron[1], Carla Beals[2], William S. Arnold[1]

[1]Florida FWCC Fish and Wildlife Research Institute, 100 Eighth Avenue SE, St. Petersburg, Florida 33701

[2]Golder Associates, 5100 W. Lemon Street, Suite 114, Tampa, Florida 33609

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ABSTRACT

The eastern oyster (*Crassostrea virginica*) has been present in Florida since prehistoric times but their abundance and distribution patterns have changed within a particular estuary over time. In more recent times, disease, increased development, pollution and flood control practices have played major roles in the changes occurring to the oyster dynamics along Florida's southeast coast. The goals of this project were to 1) conduct updated mapping of the major oyster reefs in the Sebastian River, Lake Worth Lagoon, and Biscayne Bay to complement mapping efforts conducted during fall 2003 in the St. Lucie and Loxahatchee estuaries, 2) test our ability to map oyster reefs in the vertical dimension using Real-Time Kinematic GPS (RTK GPS), 3) provide a quantitative summary of oyster distribution patterns in the Sebastian River, Lake Worth Lagoon, and Biscayne Bay as a baseline for comparison with future efforts. We utilized RTK GPS to map the surface of each reef in a 1-meter grid pattern collecting latitude, longitude and elevation (height) at each data point. Biological data also were collected by sampling multiple 0.25 m^2 quadrats on each oyster reef, collecting all live and relic oysters from within each quadrat, and measuring the shell height of each individual oyster to the nearest mm. The results of our oyster reef mapping efforts in southeast Florida show that Real-Time Kinematic GPS is a useful tool for mapping oyster reefs. Our approach with RTK GPS produces a high resolution map of the horizontal reef boundaries and a somewhat less accurate but extremely valuable depiction of the oyster reef's vertical surface. Our oyster distribution data reveal that the Sebastian River, St. Lucie Estuary, Loxahatchee River Estuary and Lake Worth Lagoon are significantly different from each other in both the size and the density of their oyster populations. We could find few live oysters and no extant oyster reefs in Biscayne Bay. We also detected a significant difference in the oyster population dynamics within each of the individual estuaries.

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INTRODUCTION

The Eastern Oyster (*Crassostrea virginica*; also called the American Oyster) occupies estuarine and nearshore habitats throughout the eastern and Gulf of Mexico coasts of the United States. This animal supported a subsistence fishery even before European colonization of the United States (MacKenzie, 1997), and throughout recent history has provided an important economic and cultural resource to coastal inhabitants. In addition to its direct economic benefits, the oyster also provides essential habitat for many other estuarine inhabitants (Bahr and Lanier, 1981). The Eastern Oyster is one of the most culturally, economically, and ecologically important inhabitants of U.S. coastal waters.

In Florida, oysters occur along both the Atlantic and Gulf of Mexico coasts in almost all estuarine and nearshore waters. Along the Atlantic coast, oysters are generally confined within bays and lagoons such as Lake Worth Lagoon or the Indian River (Figure 1). Those waters, and other coastal waters on the southeast coast of the State (e.g., the St. Lucie and Loxahatchee estuaries), have experienced altered patterns of water delivery and quality as a result of water management practices related to the St. John's River and Kissimmee River basins, Lake Okeechobee, and the Everglades. In particular, the redirection of freshwater out of those inland basins and into the coastal waters mentioned above has altered both the timing and the range of salinity variation in those coastal waters. Alterations in freshwater flow have reduced or eliminated many oyster reef areas and have impacted both the timing and extent of oyster reproduction (Berrigan et al., 1991). The diverse community associated with the oyster reefs has been impacted to an equivalent or greater degree.

The objectives of this study were to:

1) Conduct a survey of historical and recent oyster distribution information for southeast Florida, including all estuaries from Mosquito Lagoon south to Biscayne Bay;
2) Conduct updated mapping of the major oyster reefs in the Sebastian River, Lake Worth Lagoon, and Biscayne Bay to complement mapping efforts conducted during fall 2003 in the St. Lucie and Loxahatchee estuaries;
3) Test our ability to map oyster reefs in the vertical dimension using Real-Time Kinematic GPS (RTK GPS) technology and local benchmarks;
4) Provide a quantitative summary of oyster distribution patterns in the Sebastian River, Lake Worth Lagoon, and Biscayne Bay as a baseline for comparison with future mapping efforts.

Each of the estuaries listed in (4) above has been impacted by flood control practices in central and south Florida, and those impacts extend to the oyster reef communities inhabiting those estuaries. Oyster reefs in the St. Lucie Estuary, Loxahatchee River Estuary, Lake Worth Lagoon, and Biscayne Bay are included as an essential component of the Comprehensive Everglades Restoration Program (CERP) monitoring scheme. Oyster reefs in the Sebastian River will be included in the Indian River North component of the CERP monitoring program and also will serve as an outlier population (*sensu* Underwood and Chapman, 2003) for effective statistical evaluation of

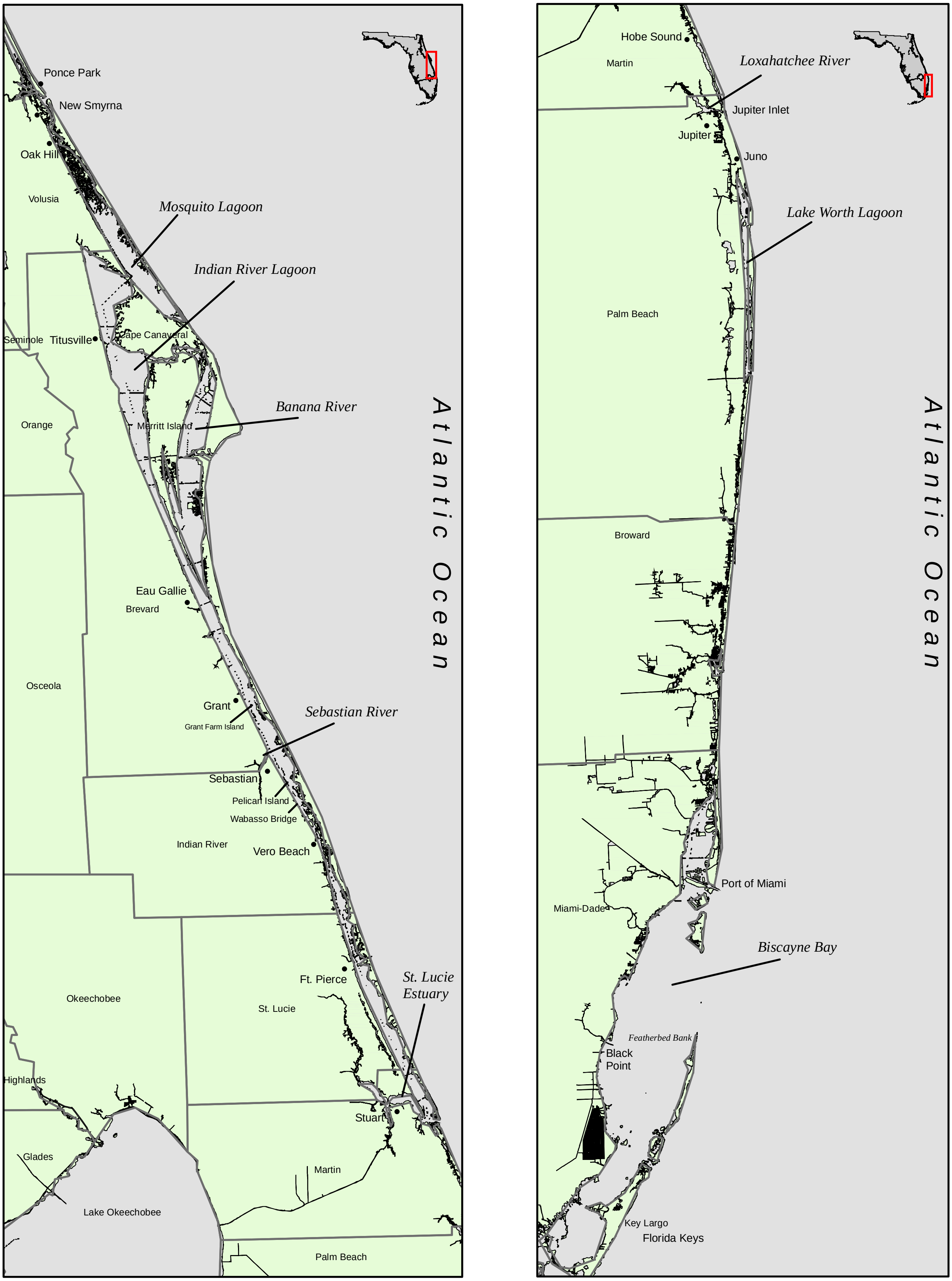

Figure 1. East Coast of Florida.

any changes that may be observed in oyster reefs occupying the other four estuaries in response to CERP activities. Therefore, baseline information on oyster reef distribution patterns is an essential precursor to the effective execution of a long-term monitoring program in southeast Florida. Because flood control modifications incorporated into the CERP plan will be coming online in the near future, filling data gaps in our knowledge of oyster distribution patterns must be effected immediately.

HISTORICAL BACKGROUND

The east coast of Florida is littered with shell middens, testifying to the fact that oysters have been there since prehistoric times (Rouse, 1951; Nance, 1962; Burrell, 1997). It has been said that Florida does not have a great climate for oysters (Ingle, 1982). In spite of this, there was, and still is, an oyster industry (Brice, 1896; Townsend, 1900; Ingle, 1982). Whereas oyster production used to be extensive along both coasts, today it centers mainly in the Gulf coast, specifically in the panhandle (Ingle, 1982). Reasons for the reduction in oyster landings include disease, increased development, and water quality degradation (Ingle, 1982; Burrell, 1997). In the United States, oyster landings have decreased by 70% (Dressel and Whittaker, 1983).

Biscayne Bay

Biscayne Bay is a shallow estuary that began forming about 5000 to 3000 years ago (USGS, 2004). Historically, large quantities of freshwater dispersed into the bay through various interactions with the porous Biscayne aquifer, the Everglades, and numerous freshwater creeks (Smith, 1896; Alleman et al., 1995; Meeder et al., 2001). Permanent settlement of the area around Biscayne Bay can be traced as far back as 2000 B.C., with intermittent human habitation going back as far as 8000 B.C. (Biscayne Bay Aquatic Preserve, 2005). These prehistoric inhabitants left behind middens, some of which contain oyster shells of various sizes. The midden contents suggest both the presence of oysters in the area and, because of the variable size distribution pattern of the shells, the possibility of overharvesting through time (J. Beriault, email communication, June 13, 2005).

Biscayne Bay can be divided into three sections (Figure 1): north (northern boundary to Port of Miami), central (Port of Miami to Featherbed Banks), and south (Black Point to the southern boundary). Historically, northern Biscayne Bay was isolated from the ocean by barrier islands and so was, in effect, a low salinity area (SFWMD, 1995). Information concerning central and southern Biscayne is limited and the information concerning the presence and location of oyster reefs is even more limited. Consequently, in the absence of concrete evidence, the probability of the presence or absence of oysters was inferred by the salinity of the environment at the time.

Examination of the infaunal molluscan assemblage recovered from core samples extracted from Featherbed Bank (at the junction between the central and southern bay) indicated that during the 15th and 16th centuries that area was characterized by a stable marine environment (Stone et al., 2000). During the 17th through 19th centuries, that area appears to have experienced more freshwater input into the area resulting in greater salinity fluctuations. These fluctuations were relatively short-term in nature but did result in salinity decreases to levels as low as 25 ppt. This essentially marine salinity regime makes it unlikely that there were extensive healthy oyster reefs in the central and southern part of Biscayne Bay at least through the 19th century.

The presence of oysters in Biscayne Bay was first documented in the late 1800s but mostly for northern Biscayne Bay. In 1878, Henshall (1884) took a trip down the east coast of Florida and reported that he dined on oysters in Biscayne Bay. In a series of government reports from 1894 to 1897, various authors noted the presence of oysters in Biscayne Bay but stated that there was no commercial fishery (Brice, 1896; Smith, 1896; Townsend, 1900). The lack of commercial exploitation may have been due to inadequate supplies or perhaps because Biscayne Bay was too far from suitable markets to successfully transport perishable items such as oysters (Smith, 1896). Smith (1896) also noted in his report that only the northern part of Biscayne Bay would be suitable for oystering since the salinity south of Florida Key was too high.

By the beginning of the 20th century a small oyster industry was operating in the northern part of Biscayne Bay. This industry disappeared possibly because of increasing salinity due to drainage of the Everglades and concomitant reduction in freshwater inputs to the Bay. The construction of the Intracoastal Waterway and various inlets similarly decreased freshwater input into the Bay (SFWMD, 1995; Meeder et al., 2001). Storm-induced erosion and an increase of sea level by 20 cm in the last 100 years also have contributed to the marine nature of Biscayne Bay. With the construction of protection levees and a canal complex in the mid-1960s, freshwater flow into the bay has been essentially eliminated. Today, freshwater only enters the bay through rainfall and canal discharges (Meeder et al., 2001). Although there is evidence of extensive oyster shell beds in northern Biscayne Bay, no living oyster reefs are presently extant in Biscayne Bay (Harlem, 1979).

Biscayne Bay has changed substantially in the last 100-150 years, and oyster reef restoration could be challenging because of the resultant alteration in water quality. Water quality in northern Biscayne Bay ranges from slightly to heavily degraded in regard to toxins, nutrients, sewage, and reduced water transparency. The central section of the bay has water quality ranging from highly degraded to pristine. Although the southern section experiences less urban and industrial runoff than the northern and central sections, it has problems with leachates from landfills (SFWMD, 1995). In addition, the salinity of central and southern Biscayne Bay has been increasing to marine levels over the last 100 years (Wingard et al., 2003), most of the shoreline is vertical/bulkhead (Harlem, 1979), and residential and commercial development activities are increasing in the southern section of the Bay. At present, live oysters are found only on mangrove roots along the shoreline and on some jetties (Meeder et al., 2001; personal observation).

Lake Worth Lagoon

Lake Worth Lagoon (LWL; Figure 1) was originally a freshwater ecosystem. In the late 1860s, early settlers dug an inlet to connect Lake Worth to the Atlantic Ocean. This inlet was open frequently enough to permit some salt water into the lagoon but it did suffer periodic closures. In 1877, those local residents reconstructed the inlet in a different location. This new location was more stable and allowed a rapid change from freshwater to marine that facilitated an incursion of saltwater fish and some deepwater mollusks which were brought in with the tides. However, by the end of the 1880s the inlet was again migrating to the south and closing frequently; residents had a hard time keeping it open (Hopkins et al., 1970). Dredging of the Florida Atlantic Intracoastal Waterway between 1882 and 1912 finally provided a stable and permanent opening (Roach, 2003).

Oysters did not occur in Lake Worth during the period when it was a freshwater ecosystem. Between the time when the first stable inlet was constructed in 1877 and the Intracoastal Waterway was completed in 1912, oyster distribution and abundance would have been strongly influenced by periodic closures of the inlet. Thus, in 1878 Henshall (1884) reported oysters in the LWL during a trip along the east coast of Florida whereas Brice (1896) claimed that during 1894 and 1895 the lagoon was not known to have any oysters. Smith (1896) basically agreed in his report for the year of 1895, stating that Lake Worth Lagoon was too salty to grow oysters. In 1897, Lake Worth Lagoon was listed as one of the principal fishing centers of the east coast of Florida but it is unknown whether oysters played a major role in that fishery production. Townsend (1900) mentioned the Indian River Lagoon as an important center of commercial oyster production and also reports waters south of the Indian River Lagoon as having oysters although apparently not in commercial quantities. However, Gregg (1902) visited the LWL in 1897 and again in 1898 and said there were no oysters there although he visited primarily to sport fish and mentioned oysters only in passing.

By the early 1900s oysters were a leading industry in the Lake Worth Lagoon region and several businesses had been established to process landed oysters (Linehan, 1980). This fishery apparently crashed no later than 1950 when annual commercial fisheries landings data became available, and essentially no commercial landings have been reported from Palm Beach County (within which the Lake Worth Lagoon is located) since that time. Whether this is because of the lack of oysters at that time or because they were unfit to eat is unknown. One exception to this pattern was noted in 1973 when approximately 5,200 pounds of oyster meats were landed in Palm Beach County (NOAA, 2005). Because the Loxahatchee River also falls within the boundaries of Palm Beach County and also supports oysters, it cannot be stated with certainty that those oysters were harvested from the LWL. Presently, oysters are not harvested in Lake Worth Lagoon, but they are present on reefs around mangrove islands, on jetties, and on spoil islands (personal observation).

Loxahatchee River

Historical information on the occurrence of oysters in the Loxahatchee River (Figure 1) is hard to find. Instead, it is easier to find information on historic oyster presence for Hobe Sound and Jupiter Inlet, both of which are near the Loxahatchee River. Prehistoric middens can be found at both places, some of which can be dated back 3500 years (Rouse, 1951; Nance, 1962). In the late 1700s, areas near Jupiter Inlet/Hobe Sound were full of oysters. However, like Lake Worth Lagoon, the presence of oysters was probably affected by the periodic openings and closings of inlets. Historically, Jupiter Inlet opened and closed naturally. For example, it was closed for some time previous to 1769 after which it stayed open for awhile (Romans, 1775; Forbes, 1964). During periods of closure, the lower Loxahatchee River functioned as a freshwater marsh. After the inlet was permanently opened, the freshwater ecosystem quickly changed to become an estuarine ecosystem (Loxhatchee River – Lake Worth Creek Aquatic Preserve, 2005). During the Seminole War in 1838, General Jessup led an army into Jupiter and the Battle of Loxahatchee River took place. General Jessup noted that the Ft. Pierce and Jupiter areas had a nice abundance of seafood, and that he and his troops really enjoyed the oysters in the area (R. Procyk, personal communication, June 10, 2005). Although oysters were plentiful around Jupiter Inlet, historically the inlet itself closed numerous times over the years due to the forces of nature. For example, another Seminole War participant, U.S. Army surgeon Jacob Motte reported that he visited Jupiter Inlet a couple of times and on one visit it was completely closed (Motte, 1953). Again in 1901, the inlet was closed (Gregg, 1902). Consequently, early settlers went to the Indian River for oysters (Hopkins et al., 1970). While Henshall (1884) mentioned seeing oysters in 1878 in Jupiter Inlet, Brice (1896) and Townsend (1900) do not mention Jupiter with respect to oysters during the years 1894 and 1895. However, on a fishing trip down Florida's coast, Gregg (1902) mentioned seeing oyster bars near the inlet.

There are some accounts that suggest that during the late 19th century and early 20th century there was a significant oyster population close to Jupiter Inlet and within the central embayment (Bachman et al., 2004). However, information between that time and the present is sparse. By the early 1990s, oyster populations had decreased to a minimal presence in the central embayment and north prong of the Loxahatchee River although oysters were found in the northwest and southwest forks of the river (Bachman et al., 2004). In a 2003 oyster mapping study, a total of 72 oyster beds were found in the northwest and southwest forks of the Loxahatchee River, with the greatest concentration in the northwest fork. These beds were small and totaled about 10 acres (Bachman et al., 2004).

Indian River Lagoon

Indian River

The Indian River portion of the Indian River Lagoon (IRL; Figure 1) is not actually a river but rather a narrow, shallow, salt-water lagoon that extends from Titusville south to St. Lucie (Brice et al., 1896). Environmental characteristics such as salinity are shaped by washover events resulting from hurricanes and winter storms, or by the sporadic opening and closing of inlets (Hutchinson, 1975; Johnson et al., 2000). Also included in the Indian River Lagoon system is the Mosquito Lagoon and the Banana River. The southern portion of Mosquito Lagoon falls within the same county (Brevard) as does the northern portion of the Indian River and the entire of the Banana River (Figure 1). Because the Mosquito Lagoon is split between Brevard and Volusia counties, it can be difficult to determine which yields come from Mosquito Lagoon and which yields come from the Indian River when examining landings data. To complicate matters further, allocation of landings differs from year to year (Fernald and Purdum, 1992).

During the Paleoindian period (13500 to 9500 BP), hammocks near freshwater sources and the Atlantic Ocean would have provided a good place for shellfish growth. During the Middle Archaic period (7000 to 5500 BP), shellfish became more abundant.

Some of the earliest middens in the Indian River area date back to this period. In the Late Archaic Period (5000 to 3000 BP), shellfish were found all along the coast as evidenced by numerous middens of estuarine shellfish found from the Florida/Georgia border to Jupiter Inlet (IRAS, 2002). Historically, the northern Indian River switched from fresh to brackish to marine frequently during the Malabar I period (3000 BC to 750 AD) (Rouse, 1951).

Forbes (1964) mentioned the Indian River Lagoon as having oysters in the late 1700s and he emphasized that the salt marshes supported oysters. Henshall (1884) reported oysters as occurring in Indian River Lagoon near Titusville in 1878. In the 1880s, Hutchinson (1975) mentioned that the Indian River Lagoon was more like a freshwater savannah, perhaps implying that the Lagoon was not well-suited for estuarine species such as oysters. However, Ingersoll (1887) described oyster distribution from the upper part of the Indian River Lagoon down to Biscayne Bay in 1880 based upon reports made to him by other people. Commercial exploitation of oysters did not start until 1885 with the building of a railroad to Titusville (Brice, 1896; Brice et al., 1896). During the next couple of years, as the railroad progressed further south, additional fishing stations were established in Sebastian, Stuart (on the St. Lucie Estuary) and at other sites. Brice (1896) commented that Florida oysters did not receive a lot of attention in 1894-1895 despite the fact that Brevard County produced 42,588 pounds of oysters and Volusia County produced 33,950 pounds of oysters at that time. In 1897, Brevard yielded 42,505 pounds while Volusia was zero (Townsend 1900). Townsend (1900) reported that the oyster industry had increased in Brevard County since 1890, attributable to the favorable location and suitable environment of the Lagoon.

By the beginning of the 20th century the Indian River Lagoon was renowned for its oysters. Oysters could be found from Titusville to Jupiter Inlet (Gregg 1902), although most of the crop was harvested in the area between Grant and Oak Hill (C. Sembler, personal communication, August 18, 2005). By 1966, oysters were not as plentiful. From the northern Indian River to Eau Gallie, no oysters were found. In fact, oyster production had dwindled to exist only in the area from Eau Gallie to Sebastian. This area contained oysters totaling 447 acres (Futch 1967).

As mentioned previously, salinity of the Indian River Lagoon was dependent in part on the openings and closings of the inlets. A fisherman commented that in fall 1902 water at Juno (south of Jupiter) was potable. Salinity was highest at Titusville. This same fisherman, Joe Michael, said that he had seen the Indian River change from a low salinity ecosystem to a more marine ecosystem, and that it was this conversion that killed the oysters (J. Michael, personal communication, July 22, 2005).

Mosquito Lagoon

The distribution and production of oysters in Mosquito Lagoon (Figure 1) is not as well documented as in the Indian River portion of the IRL. Historical existence of oyster beds in Mosquito Lagoon is evidenced by middens in areas such as Turtle Mound (Nance, 1962). Mention is provided by Jacob Motte in his journal that the U.S. army camped in New Smyrna where they encountered substantial stocks of oysters (Motte, 1953). Brice (1896) noted that in 1895 oysters were an important fishery component for the northeast coast of Florida (from Volusia north). Although there was no mention of oysters in Townsend's (1900) report for 1897, he did list New Smyrna on Mosquito Lagoon as being one of the principal fishing centers on the east coast of Florida. In the early 1900s, there were lots of oysters in Mosquito Lagoon at Ponce Park, New Smyrna, and Oak Hill (Gregg 1902). Presently, an extensive oyster reef system remains in Mosquito Lagoon (Grizzle, 1990; personal observation).

Sebastian River

Middens containing oyster shell can be found in and around the Sebastian River (Figure 1) particularly near its entry into the IRL (Rouse, 1951, Johnson et al., 2000). Henshall (1884) mentions Ft. Capron (38 miles south of Sebastian River) as having good oysters in 1878. Vero Beach, also south of Sebastian River, was renowned for its oysters in the late 1800s (Nance, 1962) and oysters also were abundant in the Vero Beach area during the early 1900s (Gregg, 1902).

Reflecting the general nature of the IRL, the Sebastian River also has been influenced by the presence and dynamics of ocean inlets. Historically there was no inlet near Sebastian, but attempts to excavate an inlet in that area were initiated in 1886. That attempt, and a second attempt in 1895, failed. A third attempt to link the IRL with the ocean was started in 1919 and successfully completed in 1921 (Nance, 1962; Mehta et al., 1976). Between 1941 and 1942, the inlet was closed in response to World War II enemy submarine activity in that area. The inlet was reopened in 1947 but again closed that same year (Joe Michael, personal communication; Mehta et al., 1976). The inlet was again reopened in 1948 and has remained open since (Mehta et al., 1976). Joe Michael (personal communication) stated that after World War II he was assigned the task of testing salinity at the Wabasso Bridge (8 miles south of Sebastian River), where he recorded a value of 1.2 ppt.

Two early pioneers of the Sebastian area said that there were oysters in Sebastian in the early 1900s but the oysters were not abundant until after World War II when the human population expanded. In the 1950s and 1960s, oysters occurred in the Sebastian River and also at Wabasso Bridge and at Pelican Island between Wabasso Bridge and Sebastian (Woodburn, 1962; C. Sembler, personal communication; J. Michael, personal communication). By the late 1960s the oysters started dying around Wabasso Bridge, possibly in response to increasing salinity in that area (J. Michael, personal communication). At that same time, oysters also appeared to be dying in the Sebastian River, although in this case the mortality was attributed (at least in part) to the construction of the C-54 flood control canal. That canal released high loads of freshwater into the Sebastian River; other contributing discharges originated from a waste water treatment facility and from a dairy farm (J. Michael, personal communication; C. Sembler, personal communication; R. Johns, personal communication). The St. John's River Water Management District subsequently assumed control of the canal and restricted flood water releases through the canal except in extreme events (R. Stanbridge, personal communication). In 1968, four artificial oyster reefs were planted around Grant Farm Island (just north of the Sebastian River) although no substantial increase in economic value was realized from this effort (Whitfield, 1973). Oysters also were reported in the Sebastian River in 1999 (Williams, 1999). However, those oysters began to die again in early 2000, both in the Sebastian River and in nearby areas of the Indian River Lagoon (Glover, 2003). There appeared to be a small resurgence of oysters in the Sebastian River during 2003, but up to the date of initiation of this study there did not appear to be an abundant population of adult oysters in the Sebastian River (Judnich, 2003; personal observation).

METHODS

During the winter of 2005/2006, we mapped as many individual reefs in each of the five estuaries (Figure 2) as we were able to locate, following the reef mapping methods applied to the St. Lucie estuary during both of the 1997 (URS Greiner Woodward Clyde, 1999) and 2003 (Ibis Environmental Inc., 2004) mapping efforts. We used sounding line dragged along the bottom until hard bottom was detected (Anonymous, 1988). Various hard bottom structures such as rocks, clam shells, and oyster shells are detected using this sounding method, but the sound produced by each is distinctive. When an oyster signal was detected, multiple trips were made by walking from the center of the bed to the periphery to provide an outline of the reef. Previous oyster maps of Sebastian River (Williams, 1999), St. Lucie (URS Greiner Woodward Clyde, 1999) and Loxahatchee River Estuary (Bachman et al., 2004) were also used as a basis for locating reefs. Helicopter aerial surveys were also utilized to identify potential oyster reefs. From the helicopter, digital photos were taken of potential reefs and later ground checked for signs of oysters. Once an oyster reef was located and ready to be mapped, we used a Real-Time Kinematic Geographic Positioning System (RTK GPS), capable of sub-meter accuracy in the horizontal dimension, to define the coordinates of the reef outline.

For mapping purposes, parameters were established that defined the outer perimeter of a single reef and the distinction between adjacent versus continuous reef. The outer perimeters of reefs were defined as the areas where oyster shell became very sparse or were void. A reef was said to be adjacent to another reef if there was at least a 3-m void (few if any oysters) between the two reefs. If the gap between oysters was less than 3 meters, it was considered to be a single continuous reef.

Each mapped reef also was characterized as to the proportion of live oysters, and with regard to the shell height (SH) of both the live and relic (boxes = paired valves) assemblages. Previous studies have applied a gross classification scheme for the estimation of density (density classes = 0, 1-5, 6-20, 21-40, 41-70, and 71-100%) and size class (all < 5 cm shell length [SL], mostly < 5 cm SL, mostly 5-10 cm SL, mostly > 10 cm SL, mixed sizes) for the live and relic groups separately (URS Greiner Woodward Clyde, 1999; Ibis Environmental Inc., 2004), but both of those authors recommended a more quantitative approach. Our approach involved sampling multiple 0.25 m^2 quadrats on each oyster reef (e.g., Berrigan, 1988; Grizzle, 1990), collecting all live and relic oysters from within each quadrat, and measuring the shell height of each individual oyster (whether live or relic) to the nearest mm using vernier calipers. The proportion of live oysters was calculated by dividing the number of live by the total number of live and relic within each quadrat.

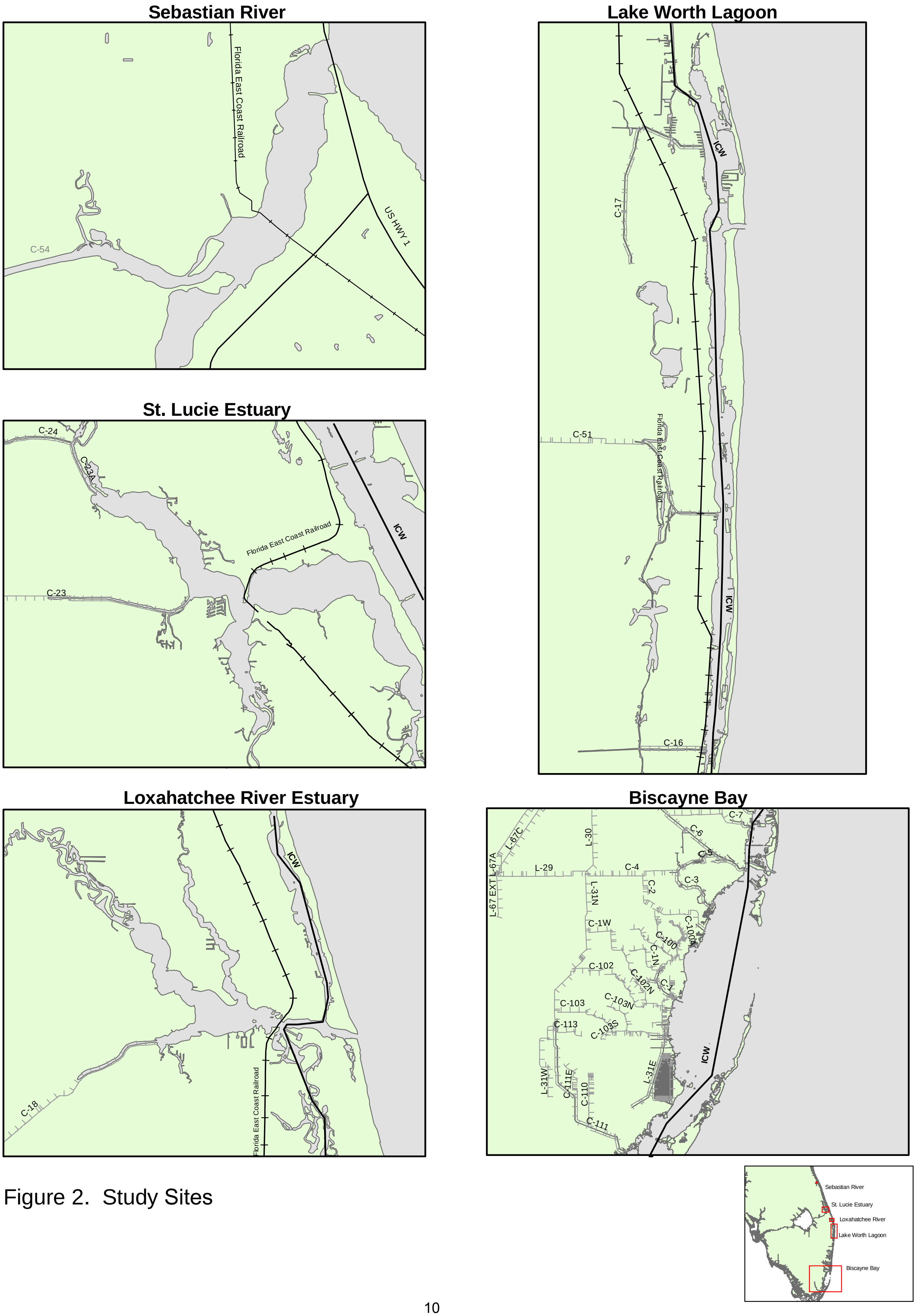

Figure 2. Study Sites

We collected biological samples by anchoring the quadrat to the reef face at a haphazardly chosen location and raking all oyster material from within the quadrat to a depth of 15 cm (Berrigan, 1988). That material was returned to the research vessel where data was collected for the parameters of interest. The oyster reef material was then replaced within the quadrat and the process repeated at the next sampling location. The number of quadrats sampled on each reef varied with reef size and ranged from 0.02% for the largest reef to 12.5% for one of the smaller reefs (Tables A1 and A2 in Appendix I). Quadrat samples were collected by wading, snorkeling, or with the assistance of SCUBA depending upon the characteristics of the individual station. Quadrat sampling was conducted on each reef that was discovered and mapped at the Biscayne Bay, Lake Worth Lagoon, and Sebastian River study sites. Additionally, we conducted similar quadrat sampling at five previously mapped and sampled reefs within St. Lucie site and six reefs at the Loxahatchee site. These data were used to assess the relative value of the quantitative (proposed herein) vs. the semi-quantitative (URS Greiner Woodward Clyde, 1999; Ibis Environmental Inc., 2004) size- and density-classification methods.

Most previous oyster reef mapping efforts have been conducted in two dimensions despite the fact that vertical relief is an essential component of oyster reef structure and community development. We tested RTK GPS technology as a method for defining the vertical structure of selected oyster reefs. The 1-cm accuracy of this methodology in the vertical dimension (Dr. Paul Carlson, personal communication) facilitated the production of three-dimensional maps for the selected reefs. Because oyster reef growth occurs in both the horizontal and vertical dimension, inclusion of a vertical component will be essential for the future assessment of impacts resulting from CERP activities.

Figure 3. Researchers setting up the RTK GPS base station along the shore of the Sebastian River.

The RTK GPS base-station was used as a temporary benchmark for each day's survey (Figure 3). The base station was set to record its position every 10 seconds for a minimum of 2 hours. This temporary benchmark data was later submitted to the National Geodetic Survey's On-line Positioning User Service (OPUS) for post-processing. OPUS uses the three nearest Continuously Operating Reference Stations (CORS) to establish an accurate base position for both its horizontal and vertical dimension. For all applications, the portable RTK GPS rover unit used to acquire geographic coordinates was set with a Position Dilution of Precision (PDOP) value of six or less to maximize the accuracy of our positional data, and the number of satellites used was set at a minimum of six to ensure that PDOP cap. Satellites below 15^{o} above the horizon were not included, and the minimum signal-to-noise ratio was set at 6.0. These settings are consistent with or more rigorous than those employed in the most recent St. Lucie oyster reef surveys (URS Greiner Woodward Clyde, 1999; Ibis Environmental Inc, 2004).

To assist in mapping the reef, the perimeter was marked off using several Styrofoam floats as guides (Figure 4). In areas where the reef was too deep to safely map by walking, a kayak was utilized (Figure 5). Transect surveys were then conducted at 1-m intervals across the face of the reef, perpendicular to the long-axis of the reef and extending from border to border. The latitude, longitude and height (elevation) data for each 1-m interval were collected using the RTK GPS rover unit. No data points were taken outside the perimeter of the reef. These data were stored in the rover unit and later downloaded and corrected using that day's temporary benchmark.

Figure 4. Researcher collecting data points with the RTK GPS rover unit on a reef within the Sebastian River. Note the Florida East Coast Railroad trestle in the background.

Figure 5. Researchers utilizing a kayak to access deeper portions of a reef for data collections.

To account for outliers in elevation data associated with radio signal transmission distortions, we used both linear and spatial filtering models. The linear filter model was used to eliminate data with errors in elevation values due to atmospheric water vapor and multipath signals. Atmospheric water vapor delays the signals arrival at the receiver, thereby effecting the distance calculation. Multipath occurs when the satellite signal reflects off another surface (such as buildings, metal surfaces, etc) and arrives at the receiver simultaneously with non-reflected signals. Both primarily affect the RTK GPS unit vertical (elevation) signal, which can result in discrete sequences of consecutive data points characterized by transformed, amplified, and/or erratic elevation values. These values can be as large as a few meters for the vertical and a few centimeters for horizontal (Iyiade, 2005). The linear model used a series of progressive filters that targeted these sequences of erratically fluctuating data signals. While the linear filter model identified errors in the vertical RTK GPS signal, the spatial filter was used to identify those data points with elevation values that differed significantly from its neighbors in the horizontal plane. The spatial filter used the Moran's Index to identify a data point whose value was more similar than dissimilar to its nearest neighbor (Squires and Lawrimore, 2006). Our spatial model used an inverse distance squared relationship with a euclidean distance method at a threshold distance equivalent to half of the square root of a given reef's area. These identified outliers may either have been errors or actual extreme changes in height.

After the original data were filtered with both models, a final data set was compiled. The final set contained only those data points that were not filtered by either the linear or the spatial model. The data were then plotted in ArcMap 9.1 to generate a predicted surface elevation model, a confidence interval (CI) surface model, and a perimeter polygon for each reef. Predicted surface elevation models were interpolated using an ordinary kriging model. The confidence interval (CI) surface was calculated by clipping the standard error (SE) surface, created from the krigged surface elevation model, using the formula CI=SE*2*1.96 to display the width of a 95% CI. Confidence Interval (CI) surfaces were then represented as CI contour lines. ArcScene was used to display each predicted surface elevation model as a three-dimensional model. Maps were then created for each reef by layering the predicted surface elevation model, CI contour lines and actual data points into a single layer. Also depicted on each map is an illustration of the three dimensional model for each reef.

We were interested in comparing the proportion of live oysters, as well as the sizes and number of both the live and relic assemblages. The hypotheses that we were testing for these components were: 1) did quadrats differ within individual reefs, 2) did reefs differ within an estuary, and 3) did estuaries differ. The proportion of live was tested with logistic regressions. Then a Monte Carlo simulation was used to predict the distribution surrounding the proportion of live oysters. Analyses of variance (ANOVA) were performed to assess differences in shell height and the number of live and relic oysters among quadrats within an individual reef, among reefs within each estuary and among estuaries. For the among estuary analyses, the variable reef was nested within estuary. If significant differences were detected, the Ryan-Einot-Gabriel-Welsch (REGWQ) means comparison test was applied to determine the pattern of statistical variation among locations (Sokal and Rohlf, 1995). Least squares means (LSMeans) were reported instead of means because of unbalanced design and to remove the confounding effects of the other variables on the nominal mean.

Because the fundamental nature of the data differs, direct comparisons between size and density data collected in previous studies (discrete categories) and our data (continuous) were not possible. Instead, we constructed tables of categorical and continuous data. Comparative interpretation of the data within the tables was somewhat qualitative, but did allow for an assessment of the loss of information inherent in the discrete classification scheme.

Sampling oyster reefs in the third (height) dimension has no precedent in southeast Florida, so there is no historic data set with which to compare these data. We mapped the resultant height data and conducted exploratory analyses of 2-D (areal) versus 3-D (volumetric) data collected from our study. From those analyses, we made a determination of the increase in information gained from the extra effort involved in height mapping.

RESULTS

Oyster Reef Mapping

During the winter of 2005/2006, 152 reefs covering 30.51 acres were mapped within the Sebastian River, St Lucie Estuary, Loxahatchee River Estuary and Lake Worth Lagoon. The number of reefs mapped within each estuary and their total areal coverage are listed below:

Site	Number of Reefs	Coverage in Acres
Sebastian River	133	21.70
St. Lucie Estuary	5	1.96
Loxahatchee River Estuary	6	1.76
Lake Worth Lagoon	8	5.09
Biscayne Bay	0	0
Total	**152**	**30.51**

No oyster reefs were found in Biscayne Bay. Consequently, no maps were created nor were any biological parameters surveyed for that estuary. In a few cases within each of the other estuaries, after filtering the geospatial data for vertical error some reefs had all of their vertical data points removed. These reefs still had accurate horizontal data associated with them so perimeter polygon shapefiles were created for these reefs. Similarly, a few reefs are missing confidence interval contour lines because they were not kriged. Kriging these reefs created uninterruptible and/or unrealistic predicted surface elevation grids. This may have been due to a lack of points or to the sampling regime used for the reef. Instead, inverse distance weighting (IDW) was used to illustrate a generalized surface of the reef.

For mapping and analysis purposes, Sebastian River was divided into three regions (north, central, and south) based upon physical features. The north and central regions were separated by a long peninsula that jutted halfway across the river, while the central and south regions were separated by a railroad trestle (Figure 6). The location and number for each reef within the northern region are depicted in Figure 7, and the individual reef's predicted surface elevation, its associated CI widths, the actual data point locations, and a three-dimensional illustration of the reef for the northern reefs are depicted in Figures A1-A18 in Appendix II. The location and number for each reef within the central region are depicted in Figure 8, and the individual reef's predicted surface elevation, its associated CI widths, the actual data point locations, and a three-dimensional illustration of the reef for the central reefs are depicted in Figures A19-A45 in Appendix II. The location and number for each reef within the southern region are depicted in Figure 9, and the individual reef's predicted surface elevation, its associated CI widths, the actual data point locations, and a three-dimensional illustration of the reef for the southern reefs are depicted in Figures A46-A67 in Appendix II. Figures for individual reefs are grouped by region and presented in order from north to south, first for the western shore and then for the eastern shore, within each of the three regions.

The reefs that we mapped in the St. Lucie estuary were chosen based upon results from a previous oyster mapping effort in the estuary that was conducted by URS Greiner Woodward Clyde (1999). We did not remap all of the reefs in the St. Lucie estuary, instead choosing a subset of five reefs with which to compare our results with the results from the previous mapping effort. Depending upon the size of the previously mapped reef, either a portion or the entire reef was remapped and surveyed. Two reefs (SLC3 and SLC4) were chosen from the central estuary and three reefs (SLS16, SLS17, and SLS14) were chosen from the southwest fork (Figure 10). The location and corresponding reef identification numbers, the individual reef's predicted surface elevation, its associated CI widths, the actual data point locations, and a three-dimensional illustration of the reef are

Figure 6. Location of the north, central and south regions mapped within the Sebastian River.

Figure 7. Identification number and location of study oyster reefs within the northern region of the Sebastian River.

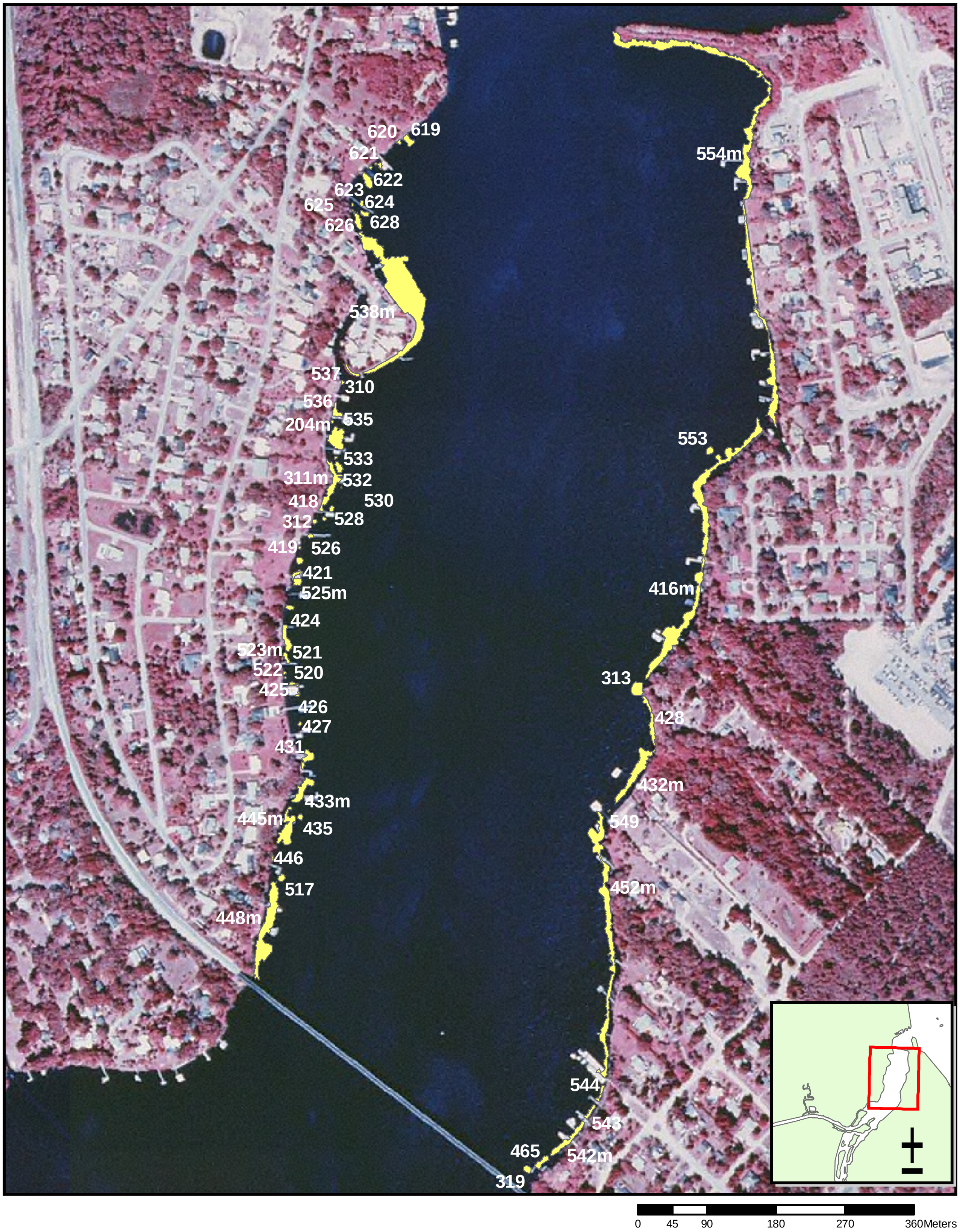

Figure 8. Identification number and location of study oyster reefs within the central region of the Sebastian River.

Figure 9. Identification number and location of study oyster reefs within the southern region of the Sebastian River.

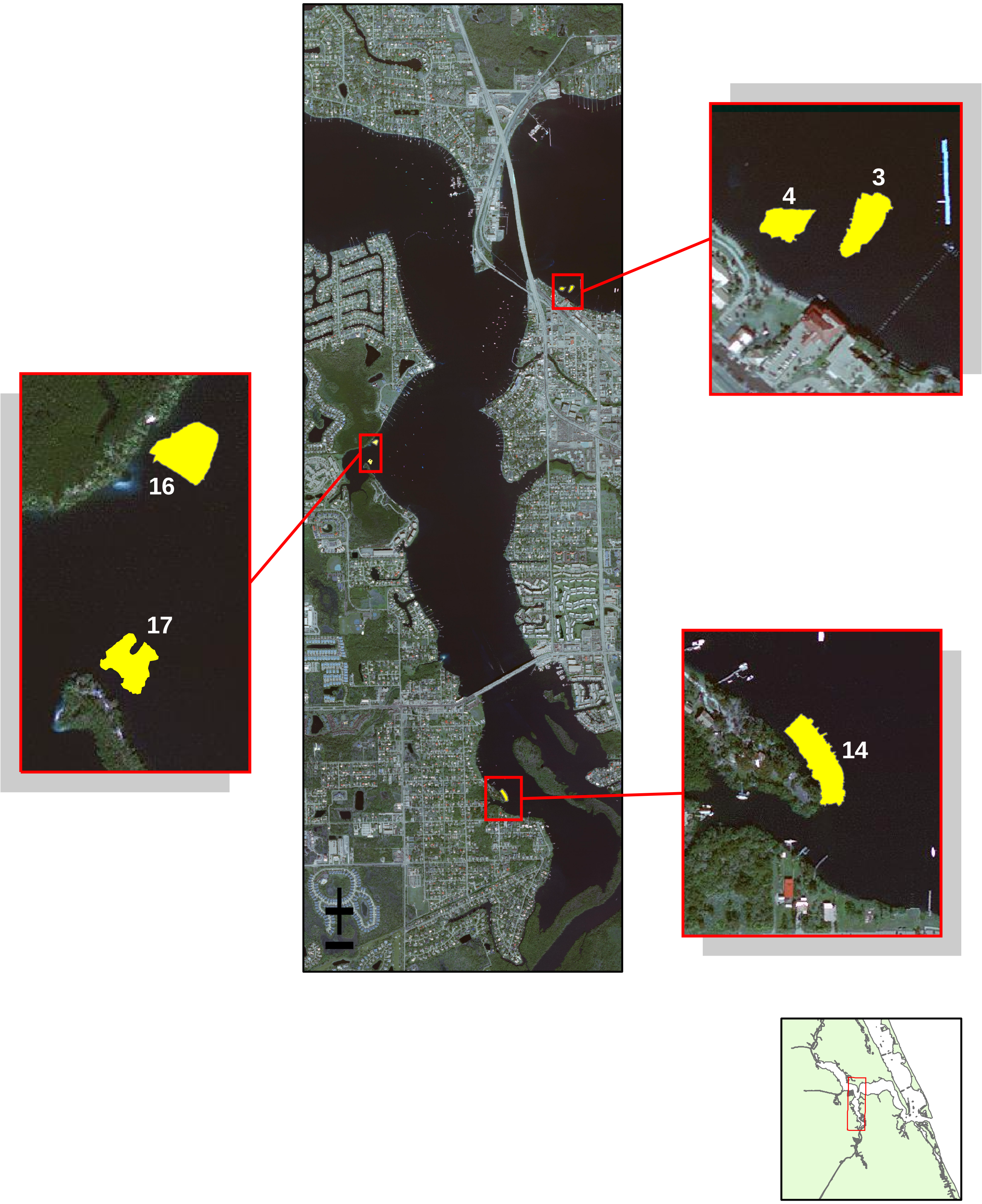

Figure 10. Identification number and location of study oyster reefs within the St. Lucie Estuary.

depicted in Figures A68-A72 in Appendix II. Figures for individual reefs are presented from north to south as they occur in the estuary.

The reefs that we mapped in the Loxahatchee River Estuary were chosen based upon results from a previous oyster mapping effort in the estuary that was conducted by the Loxahatchee River District (Bachman et al., 2004). We did not remap all of the reefs in the Loxahatchee River Estuary, instead choosing a subset of five reefs with which to compare our results with the results from the previous mapping effort. In each case, the entire reef was remapped and surveyed. Three reefs (LXN1, LXN2 and LXN30) were chosen from the northwest fork and three reefs (LXN51, LXN71 and LXN72) were chosen from the southwest fork (Figure 11). The location and corresponding reef identification numbers, the individual reef's predicted surface elevation, its associated CI widths, the actual data point locations, and a three-dimension illustration of the reef are depicted in Figures A73-A77 in Appendix II. Figures for individual reefs are presented from north to south as they occur in the estuary.

We observed several areas within Lake Worth Lagoon that supported oysters, but we identified only eight major reefs that were suitable for mapping (Figure 12). In some areas, the mud was too soft to safely support our mapping activities while other areas only contained sparse clumps of oysters growing on limestone rocks but not in substantial numbers. We focused our efforts on free-standing oyster reefs to the exclusion of sites where individual oysters grew on rock, docks, bulkheads, or other artificial structures. The locations and corresponding reef identification numbers, the individual reef's predicted surface elevation, its associated CI widths, the actual data point locations, and a three-dimension illustration of the reef are depicted in Figures A78-A84 in Appendix II. Figures for individual reefs are presented from north to south as they occur in the lagoon.

Oyster Biological Data

The proportion of live oyster on reefs within the Sebastian River ranged from 0.00 to 1.00 with an overall mean proportion of 0.78 (Figures 13-15). Oyster reefs near the mouth of the river supported the greatest proportion of live oysters, but the proportion of live oysters progressively decreased with distance up the river (Figure 16). The same pattern held for the density of oysters on each reef. Live oysters were relatively abundant on the reefs near the mouth of the river (Figure 17), with peak densities exceeding 150 oysters per 0.25 m^2 quadrat (equivalent to 600 oysters per m^2). The density of live oysters was much less in the central (Figure 18) and south (Figure 19) regions. There, mean density never exceeded 50 oysters per 0.25 m^2 quadrat and most reefs supported densities of live oyster much less than that. Results from the REGWQ means comparison test on the live and relic densities of oysters on each reef can be found in Appendix I Tables A3 and A4, respectively.

Overall for the Sebastian River, the mean shell height of relic oysters generally exceeded the mean shell height of live oysters (Figures 20-22). The mean SH of live oysters ranged from 10.0 to 64.3 mm whereas the mean SH of relic oysters ranged from 28.7 to 110.3 mm. This difference in shell height between the live and relic components of the oyster population became more pronounced with distance up the river (Figures 23 and 24), indicating that those oysters presently occupying the Sebastian River have not

Figure 11. Identification number and location of study oyster reefs within the Loxahatchee River Estuary.

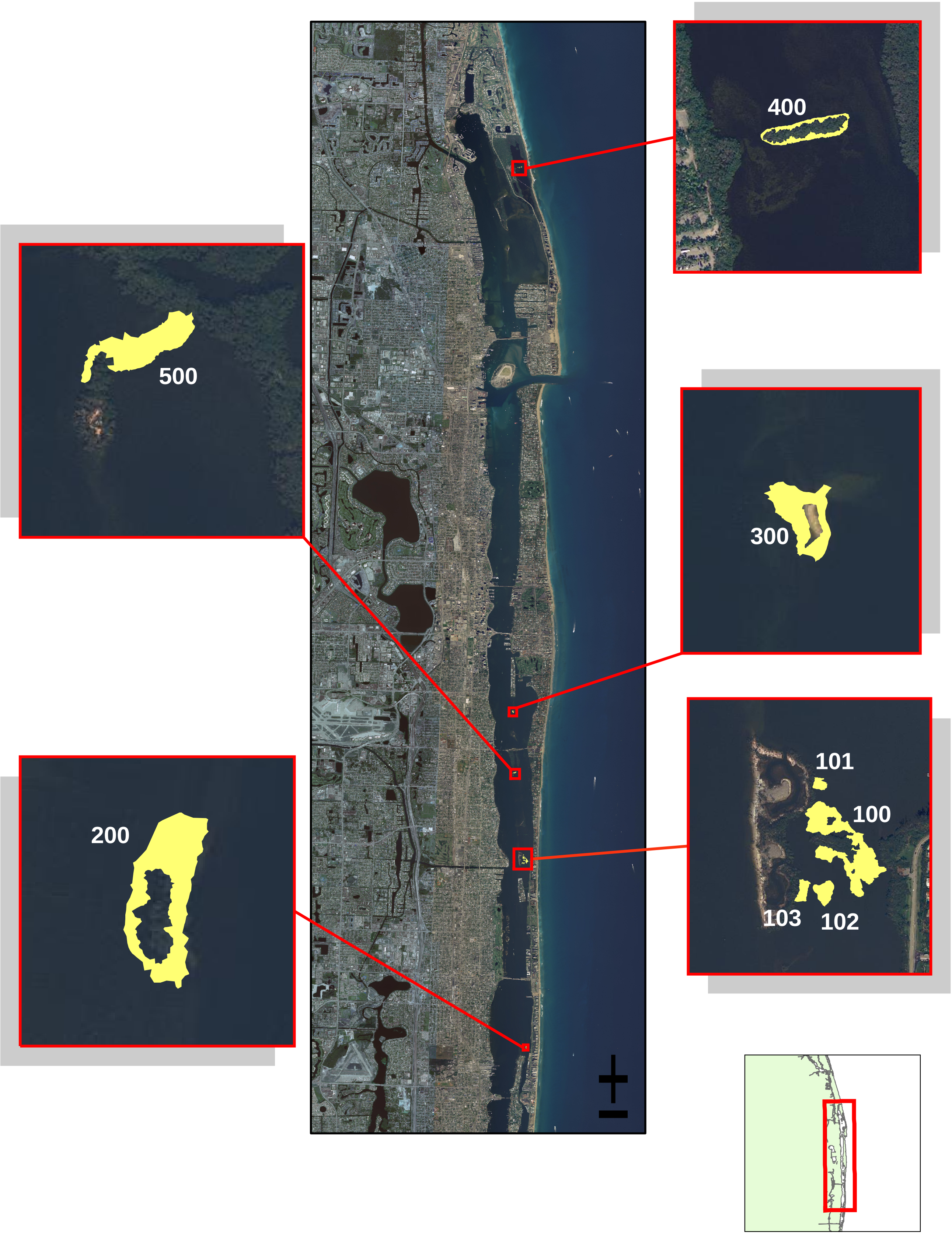

Figure 12. Identification number and location of study oyster reefs within Lake Worth Lagoon

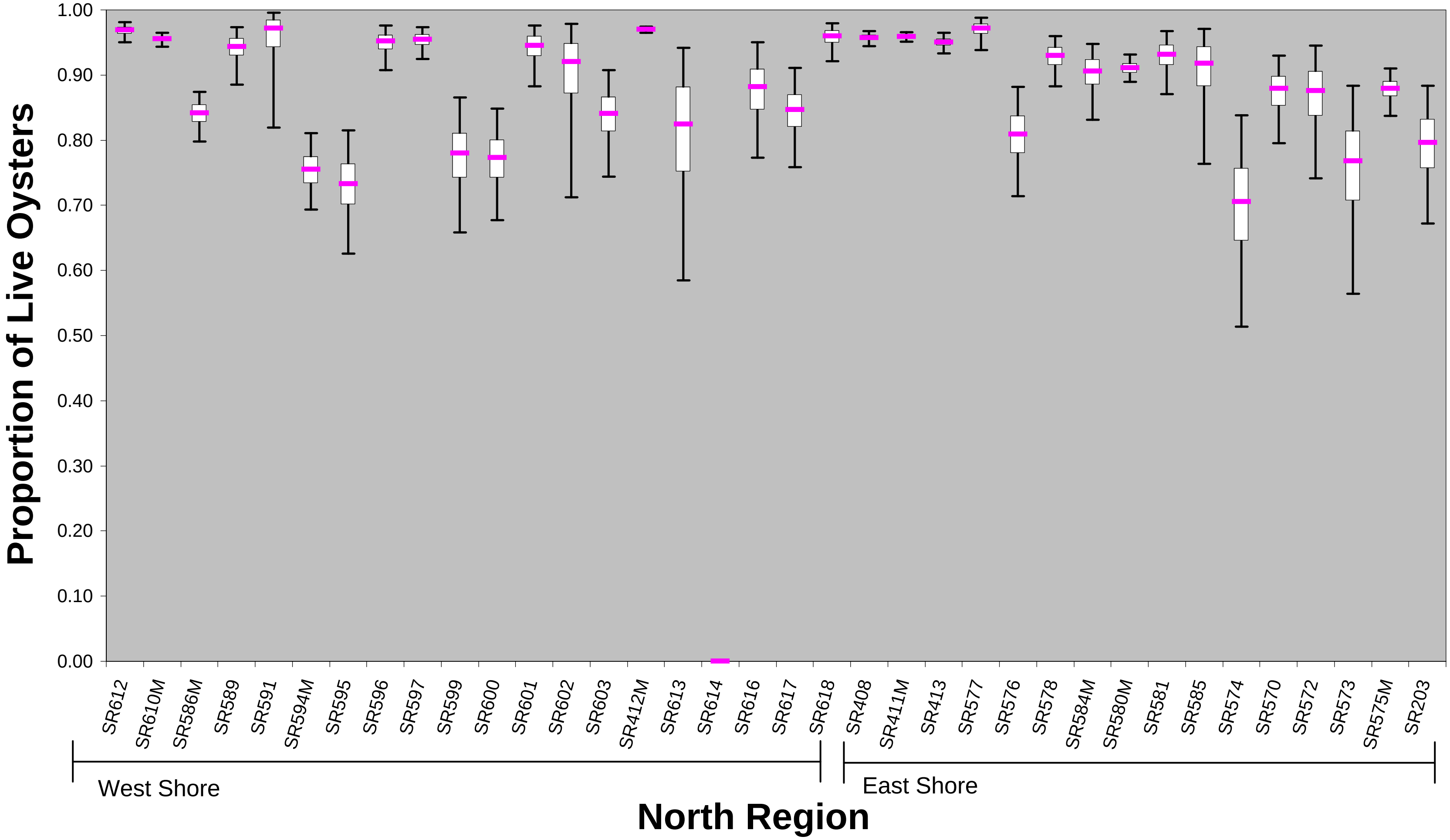

Figure 13. Box and whisker plots of proportion of live oysters by reef from the north region of the Sebastian River. Each box and whisker plot shows the median and the interquartile range (25th–75th percentile; box) and the minimum and maximum concentrations (whiskers). Reefs are listed from north to south by shore.

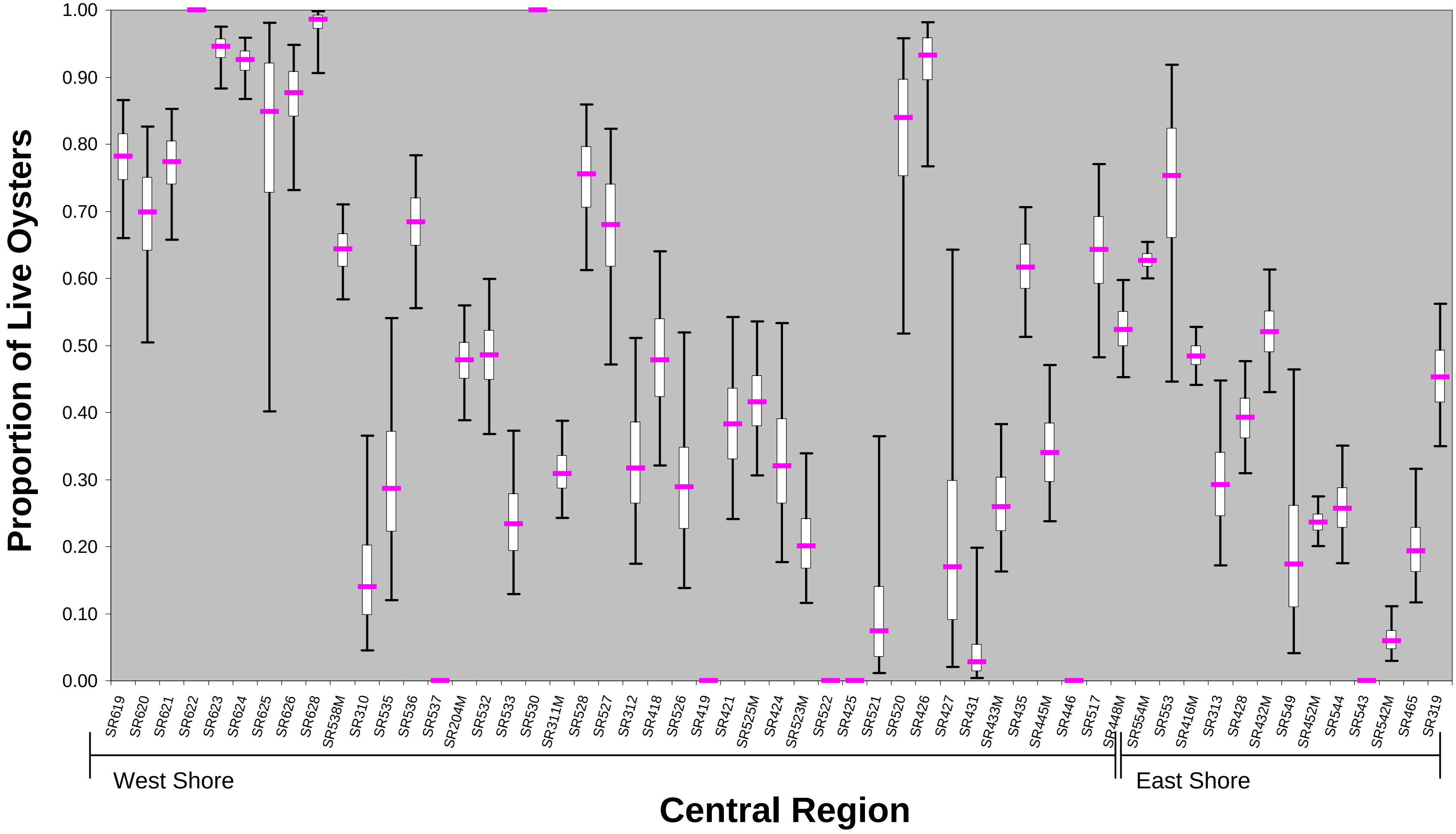

Figure 14. Box and whisker plots of proportion of live oysters by reef from the central region of the Sebastian River. Each box and whisker plot shows the median and the interquartile range (25th–75th percentile; box) and the minimum and maximum concentrations (whiskers). Reefs are listed from north to south by shore.

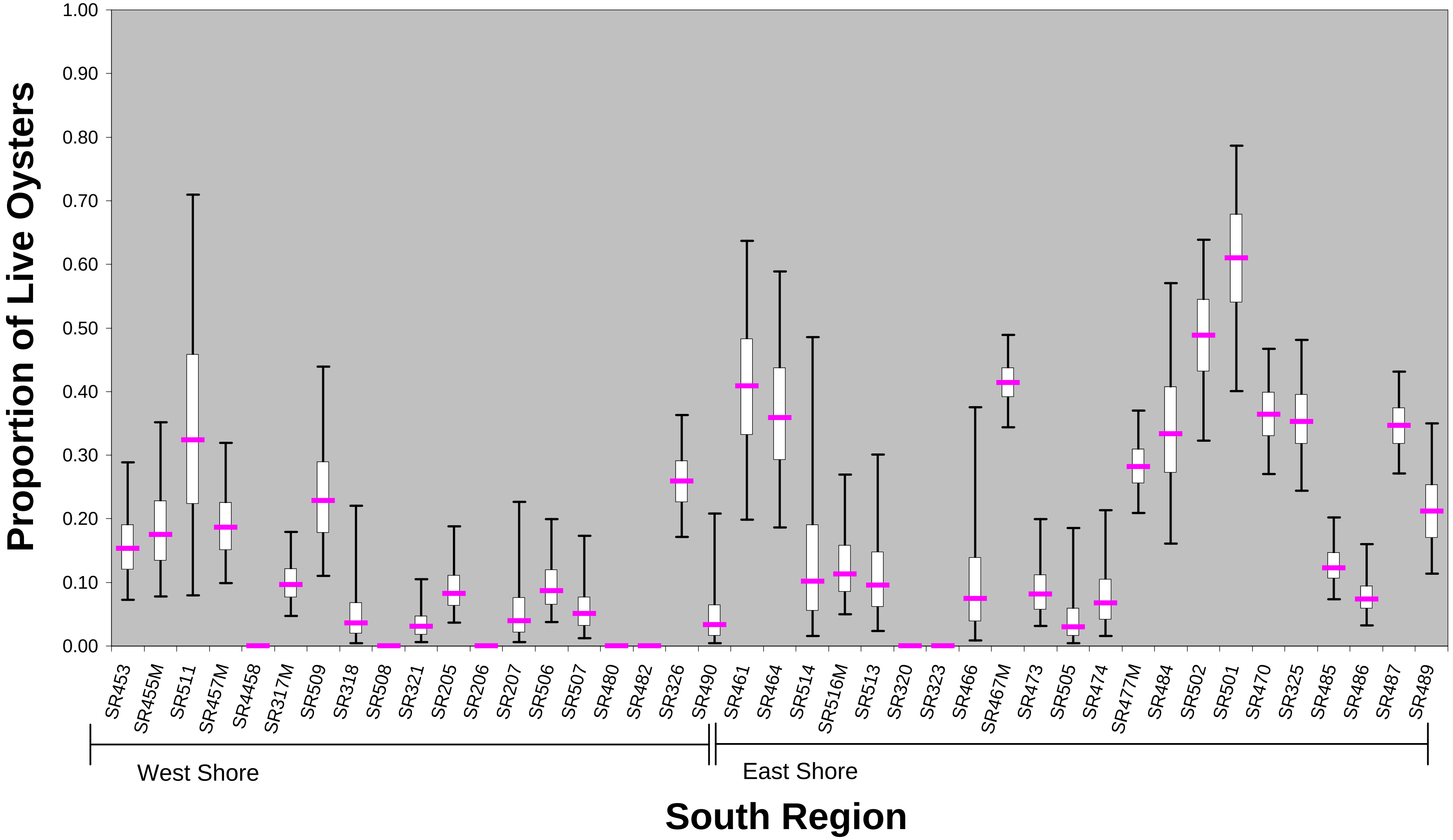

Figure 15. Box and whisker plots of proportion of live oysters by reef from the south region of the Sebastian River. Each box and whisker plot shows the median and the interquartile range (25th–75th percentile; box) and the minimum and maximum concentrations (whiskers). Reefs are listed from north to south by shore.

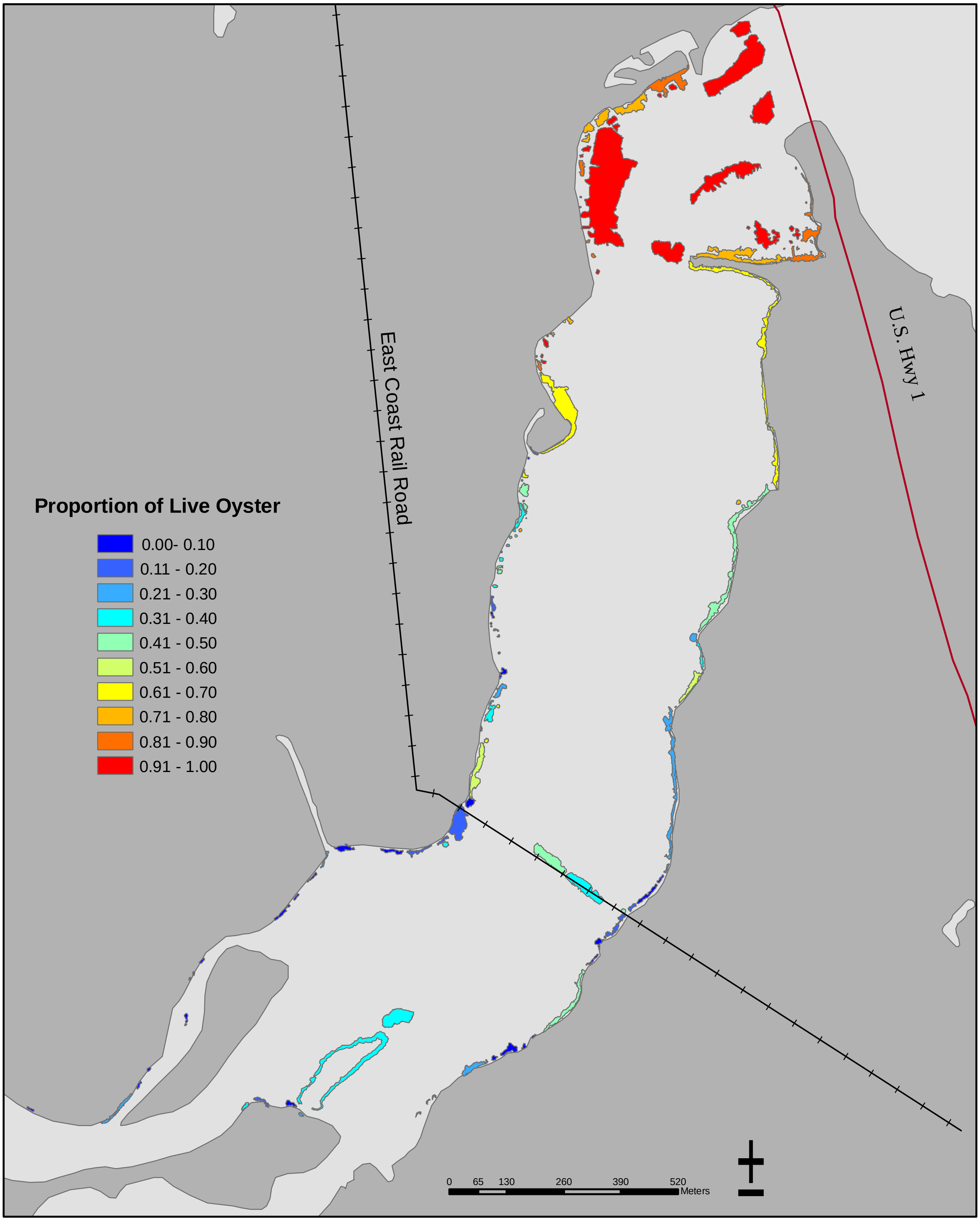

Figure 16. Location of reefs within Sebastian River with associated proportion of live oysters.

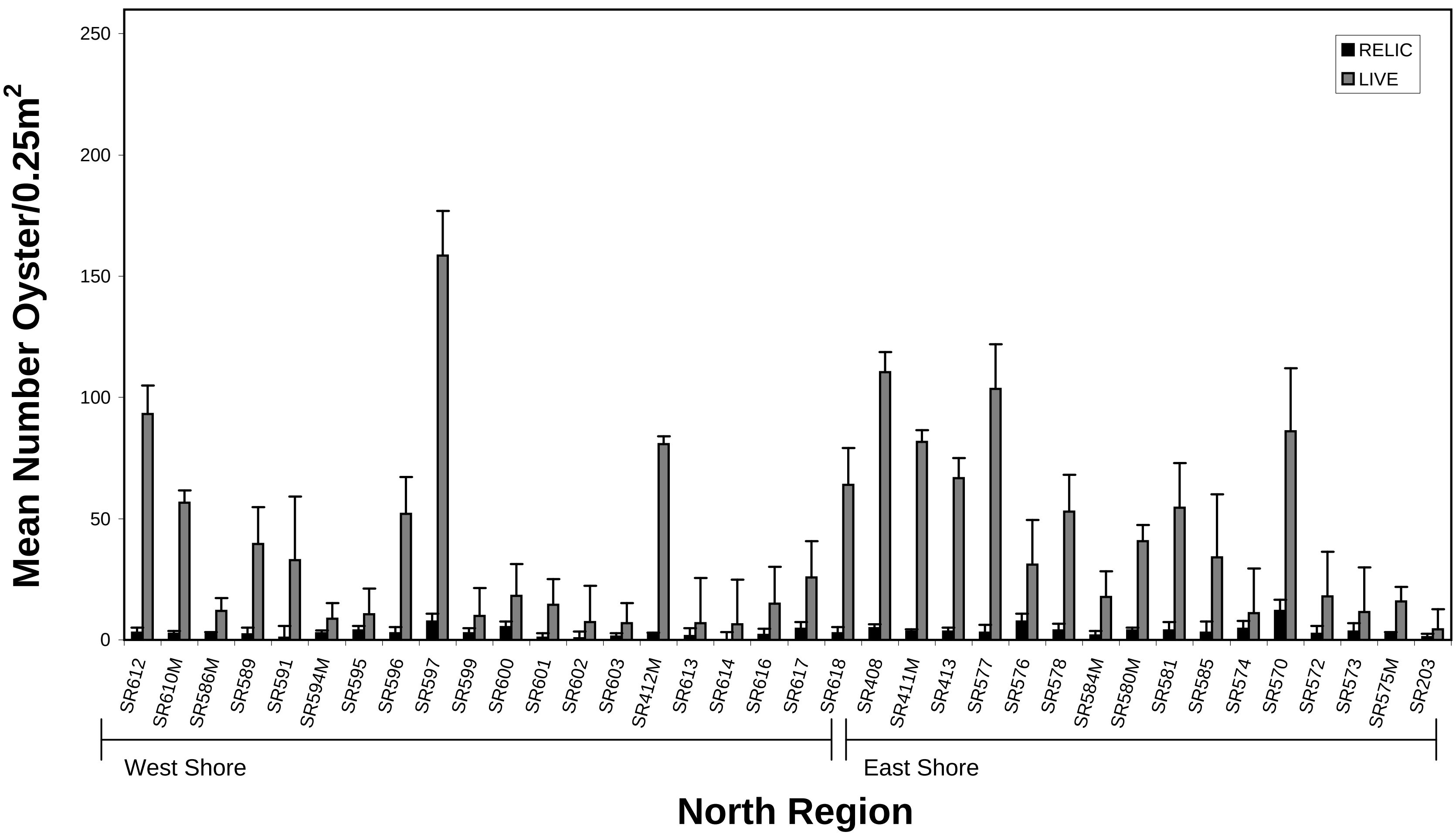

Figure 17. Mean number of both relic and live oysters by reef from the north region of the Sebastian River. Reefs are listed from north to south by shore.

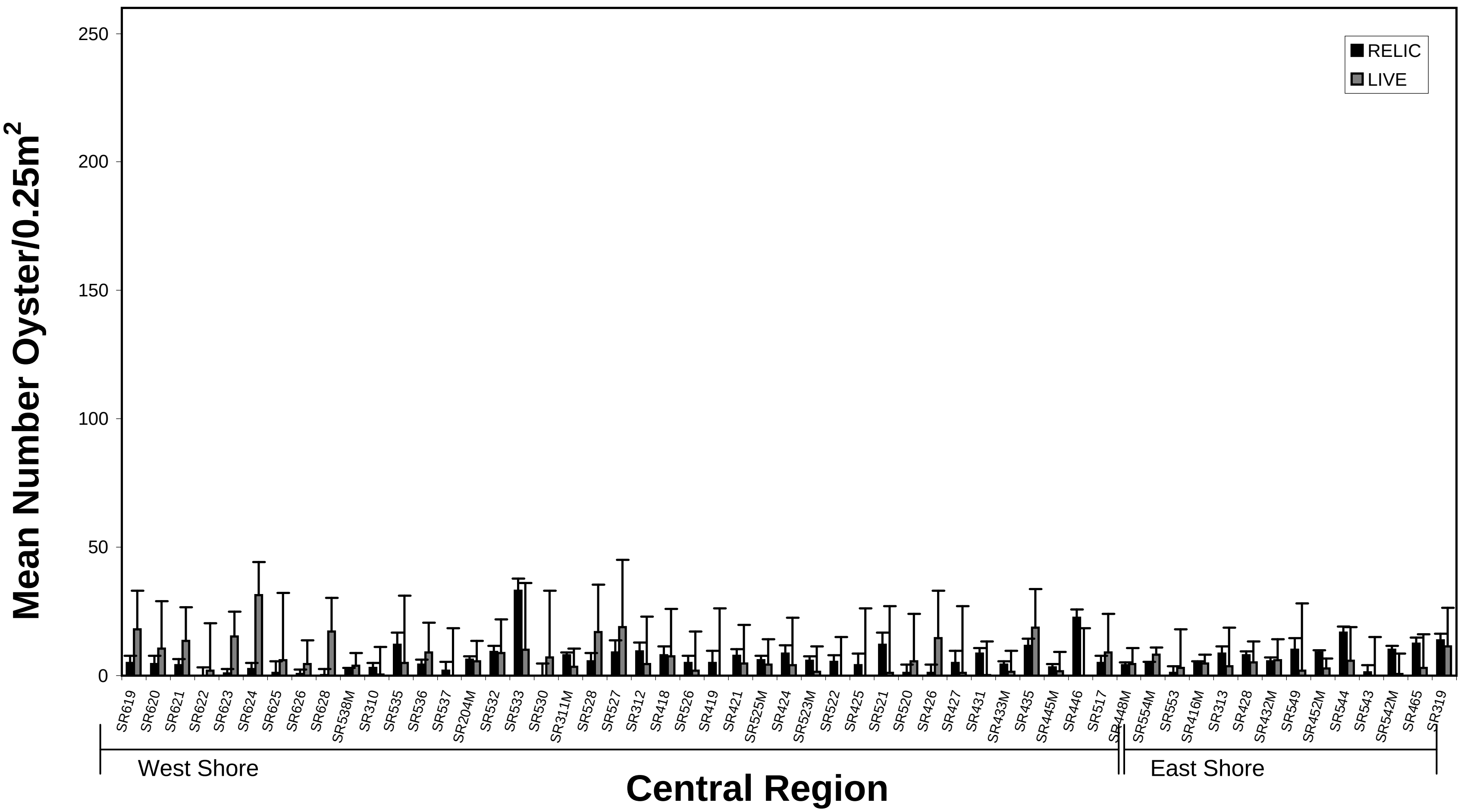

Figure 18. Mean number of both relic and live oysters by reef from the central region of the Sebastian River. Reefs are listed from north to south by shore.

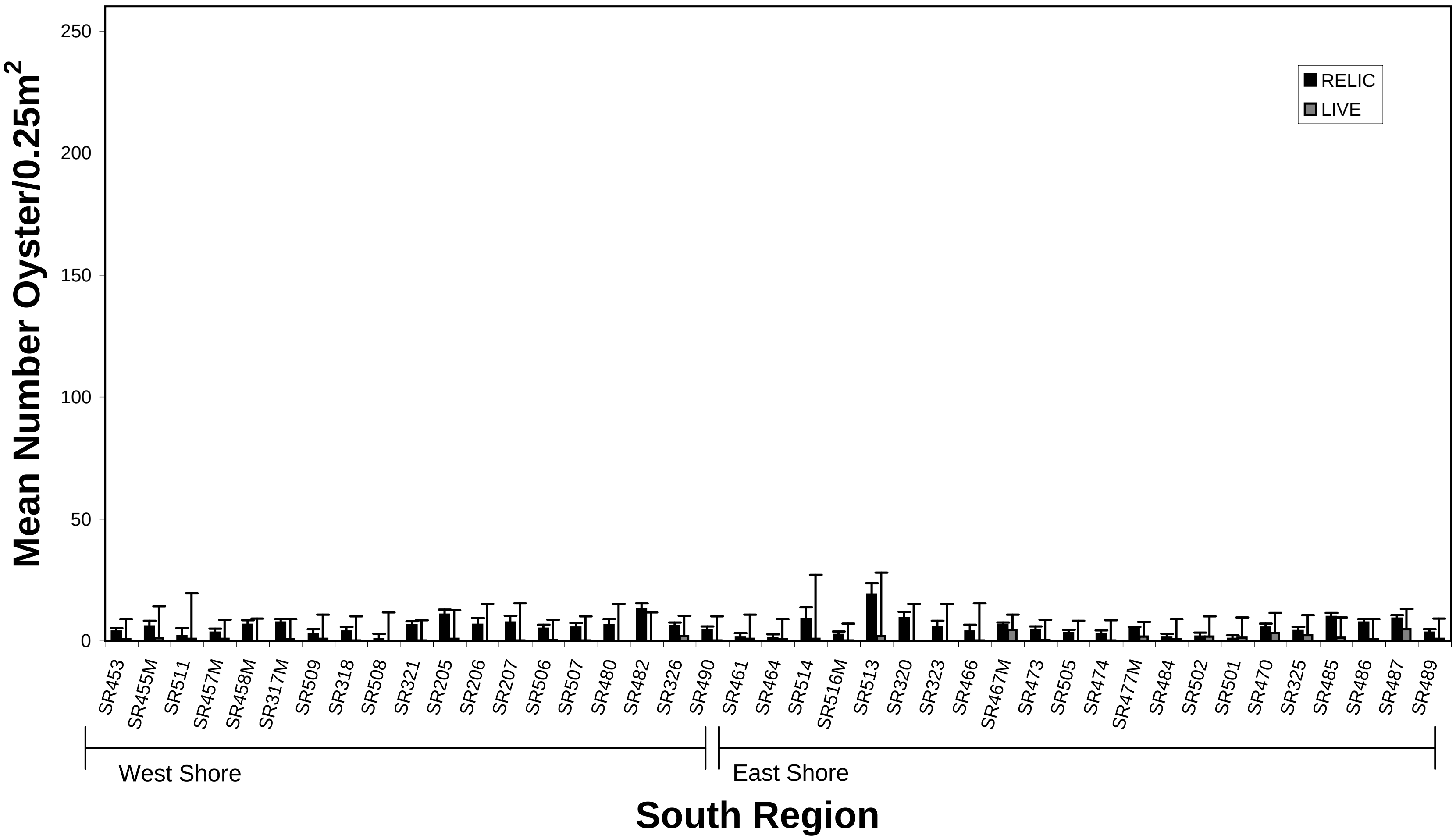

Figure 19. Mean number of both relic and live oysters by reef from the south region of the Sebastian River. Reefs are listed from north to south by shore.

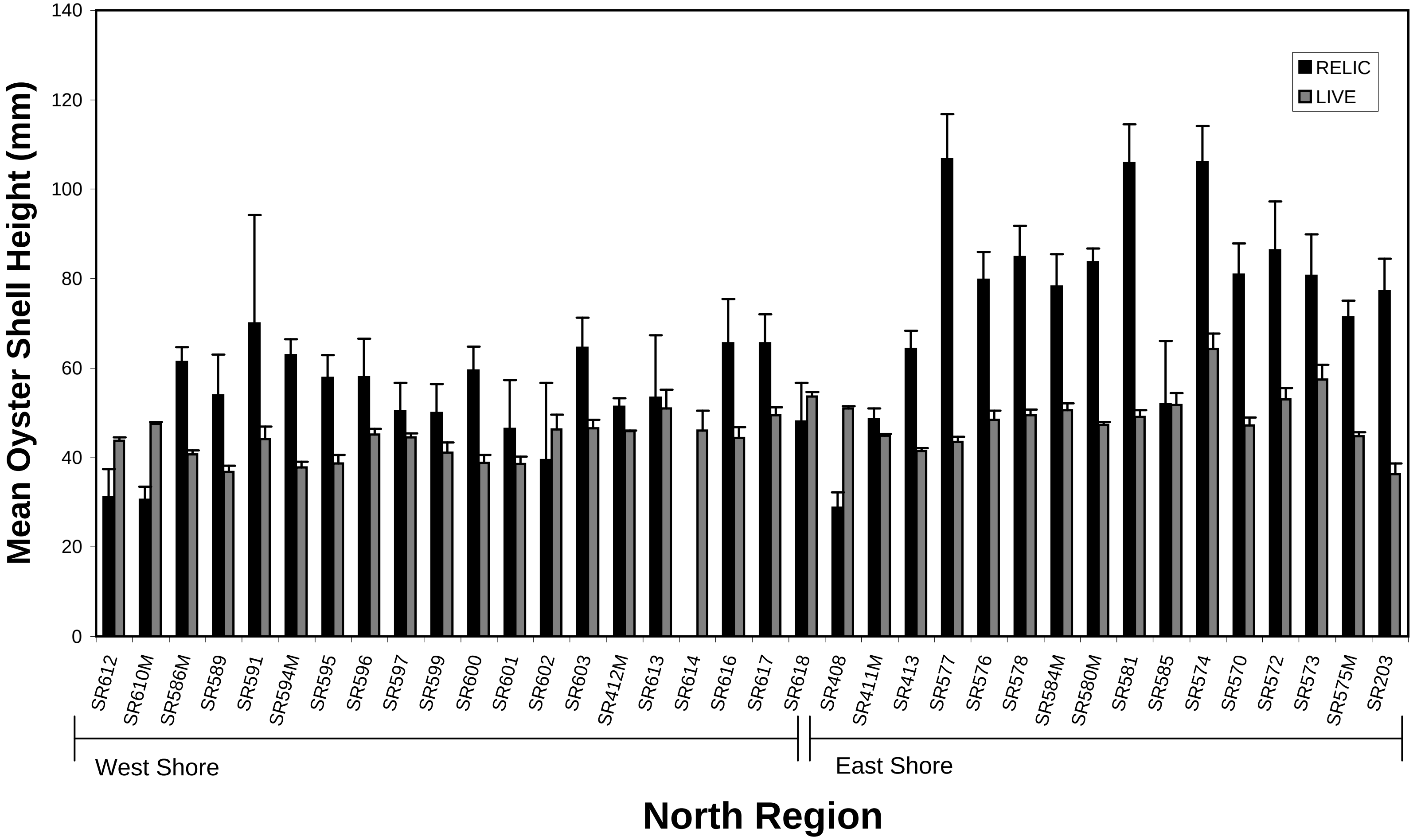

Figure 20. Mean shell height (mm) of both relic and live oysters by reef from the north region of the Sebastian River. Reefs are listed from north to south by shore.

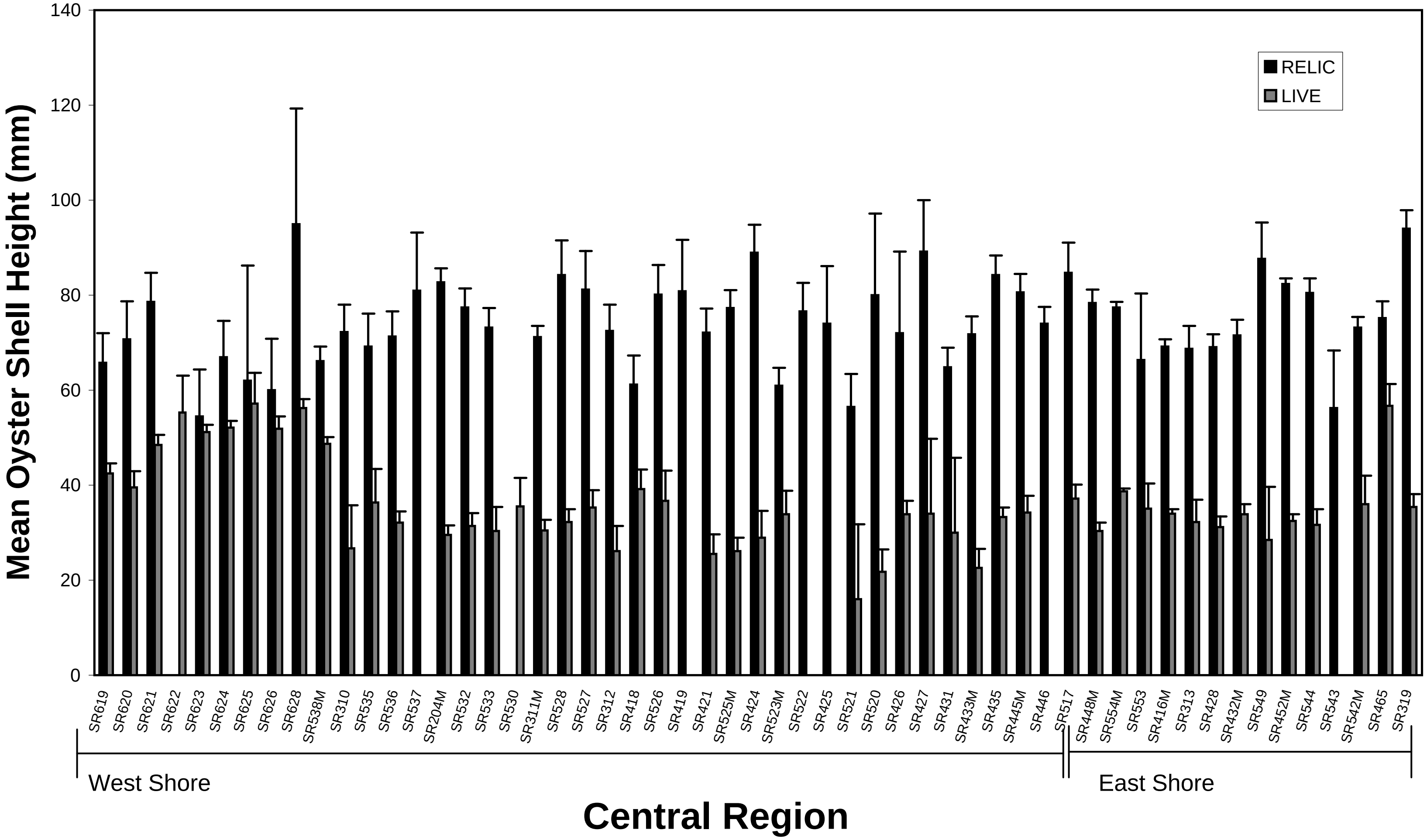

Figure 21. Mean shell height (mm) of both relic and live oysters by reef from the central region of the Sebastian River. Reefs are listed from north to south by shore.

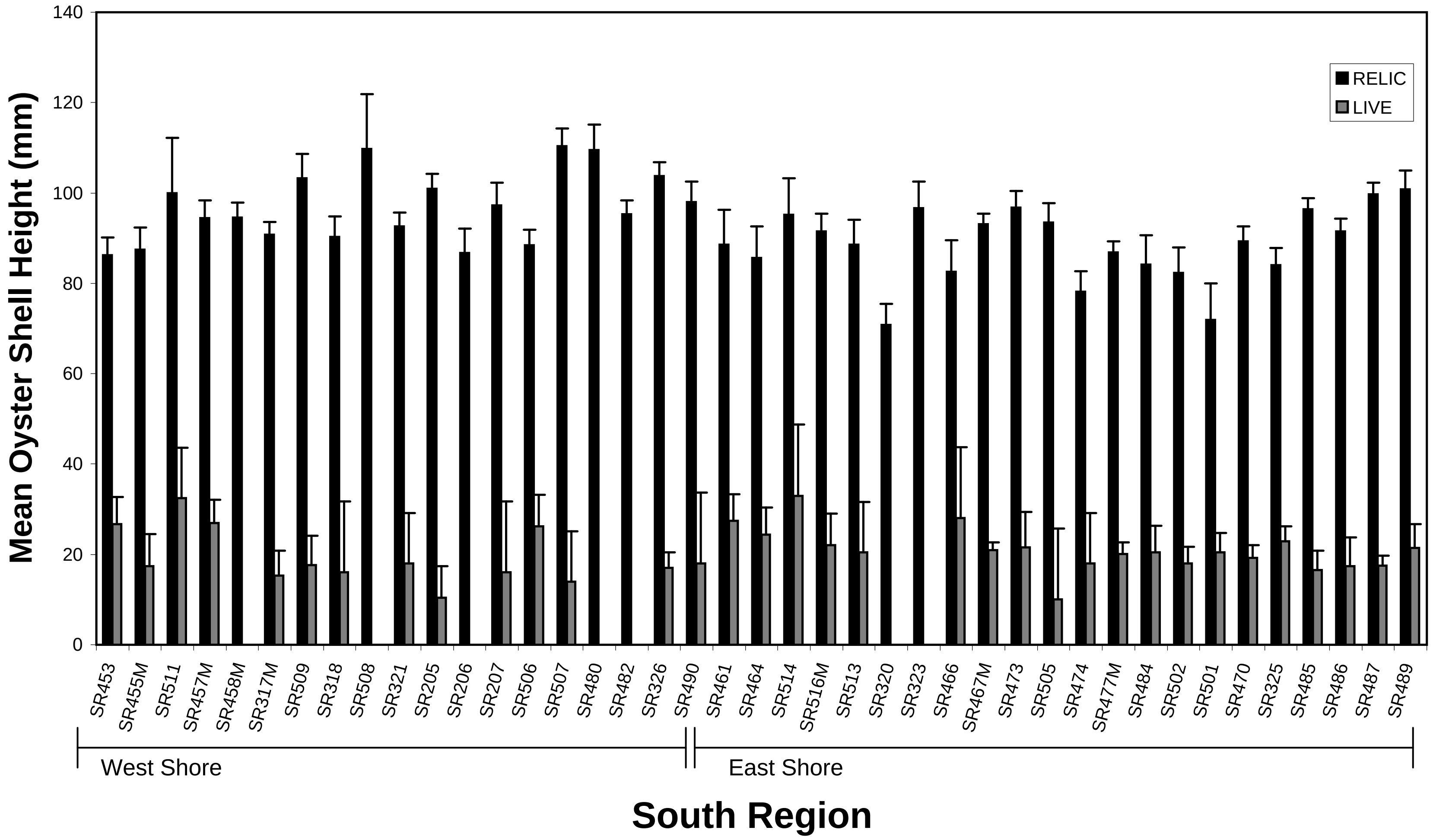

Figure 22. Mean shell height (mm) of both relic and live oysters by reef from the south region of the Sebastian River. Reefs are listed from north to south by shore.

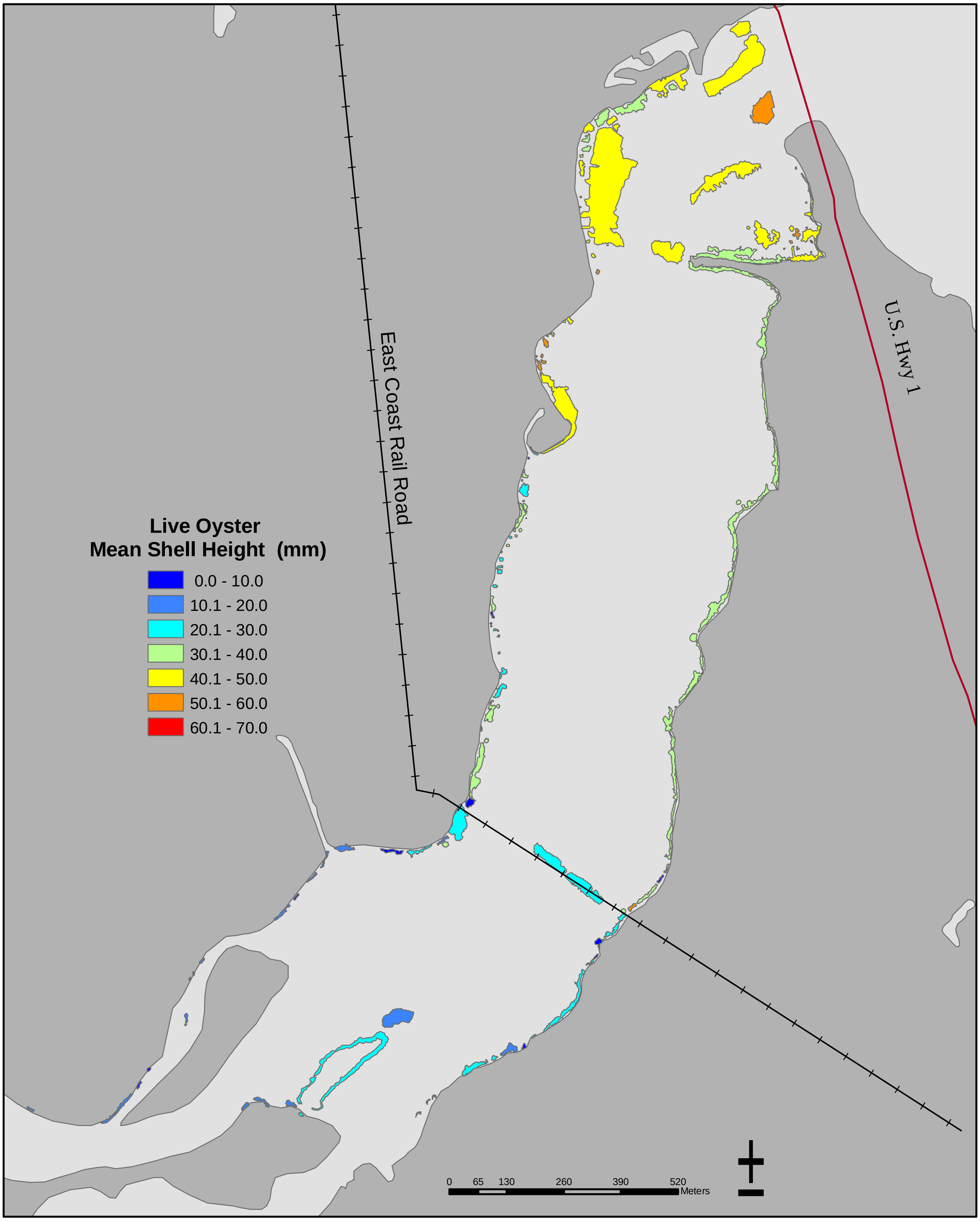

Figure 23. Location of reefs within the Sebastian River with associated live oyster mean shell height (mm).

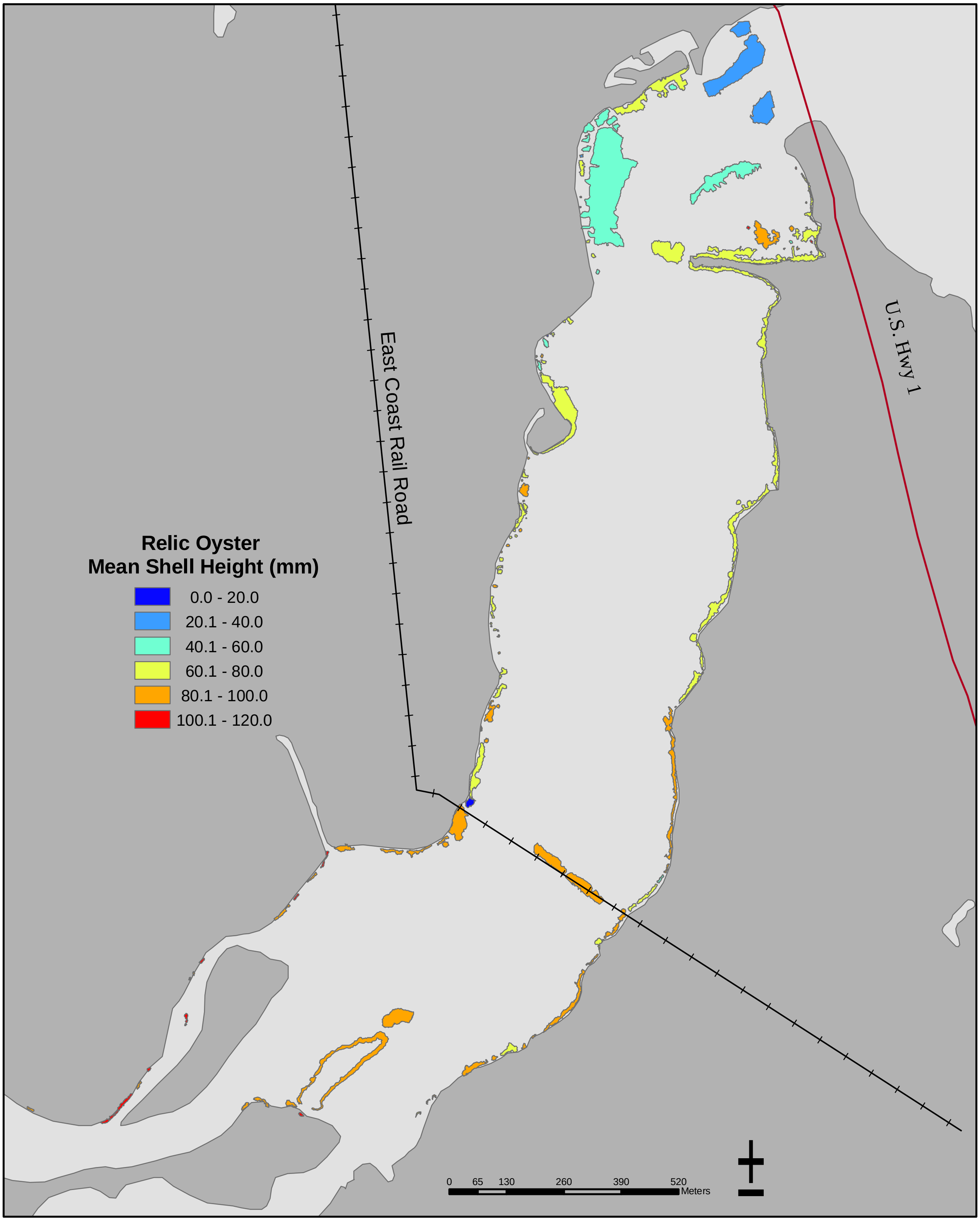

Figure 24. Location of reefs within the Sebastian River with associated relic oyster mean shell height (mm).

yet achieved their full size potential. Within the population of live oysters, a significant difference ($p < 0.001$) was detected in mean SH among reefs (Table A5 in Appendix I). Mean SH of live oysters generally exceeded 40 mm on reefs in the north region whereas mean SH of live oysters never exceeded 40mm on reefs in the south region. The mean SH of oysters on reefs in the central region reflected the pattern observed in the south region with the exception of those reefs in the northwest corner of the central region. Only on those reefs (and on reef SR465 near the Florida East Coast Railroad trestle) did the mean SH of live oysters exceed 40 mm. A significant ($P < 0.001$) and opposite trend was observed for relic oysters (Table A6 in Appendix I). The mean SH of relic oyster shells rarely exceeded 80 mm in the north region, and then only on a few reefs along the eastern shoreline. In contrast, the mean SH of relic oyster shell on reefs in the central region commonly exceeded 80 mm SH and almost all of the reefs in the south region supported a relic oyster assemblage with mean SH > 80 mm. This suggests that the historic center of the oyster population was located farther up the river than its present location near the river mouth.

Of all the sites mapped in this study, St Lucie had the least healthy reefs. The reefs were mainly clumps and bits of oyster shell hash with no live oysters to be found on any of the reefs. The few relic oysters we found had an overall mean SH of 58.83 mm (Figure 25)and an overall mean density of 0.2 relic shells per $0.25m^2$ (Figure 26).

The proportion of live oysters on reefs within the Loxahatchee River ranged from 0.72 to 0.91 with an overall mean proportion of 0.87 (Figure 27). Oyster reefs in the southwest fork supported a greater proportion of live oysters than did the reefs in the northwest fork although this difference was minor (Figure 27). The southwest fork reefs also supported a significantly greater number of live oysters relative to the reefs in the northwest fork ($P < 0.001$). Live oysters were very abundant on southwest fork reefs (Figure 28), with peak densities exceeding 220 oysters per 0.25 m2 quadrat (equivalent to 880 oysters per m^2). The density of live oysters was much less on the northwest fork reefs (Figure 28), where peak densities did not exceed 37 live oysters per 0.25 m^2. The SH of both the live and relic components of the oyster population fell within the 40-60 mm range (Figure 29). Those differences were statistically significant among reefs for both the live ($P < 0.001$) and relic ($P < 0.012$) components, but no clear patterns were apparent and the biological significance appears to be minor.

The proportion of live oyster on reefs within the Lake Worth Lagoon ranged from 0.76 to 0.84 with an overall mean proportion of 0.81 (Figure 30). We detected no clear spatial pattern regarding the proportional representation of live oysters among reefs in the Lagoon. The absolute density of live oysters on the Lake Worth Lagoon reefs ranged from 36-133 oysters per 0.25 m2 quadrat (Figure 31). The SH of both the live and relic components of the oyster population fell within the 22-43 mm range (Figure 32). Those differences were statistically significant among reefs for both the live ($P < 0.001$) and relic ($P < 0.001$) components.

Among the study sites, the greatest proportion of live oysters within each quadrat was recorded from the Loxahatchee study site, with lesser proportions recorded from both the Sebastian and Lake Worth study sites (Figure 33). All three sites were characterized by a mean proportion of live oysters, for all reefs, exceeding 78%. As

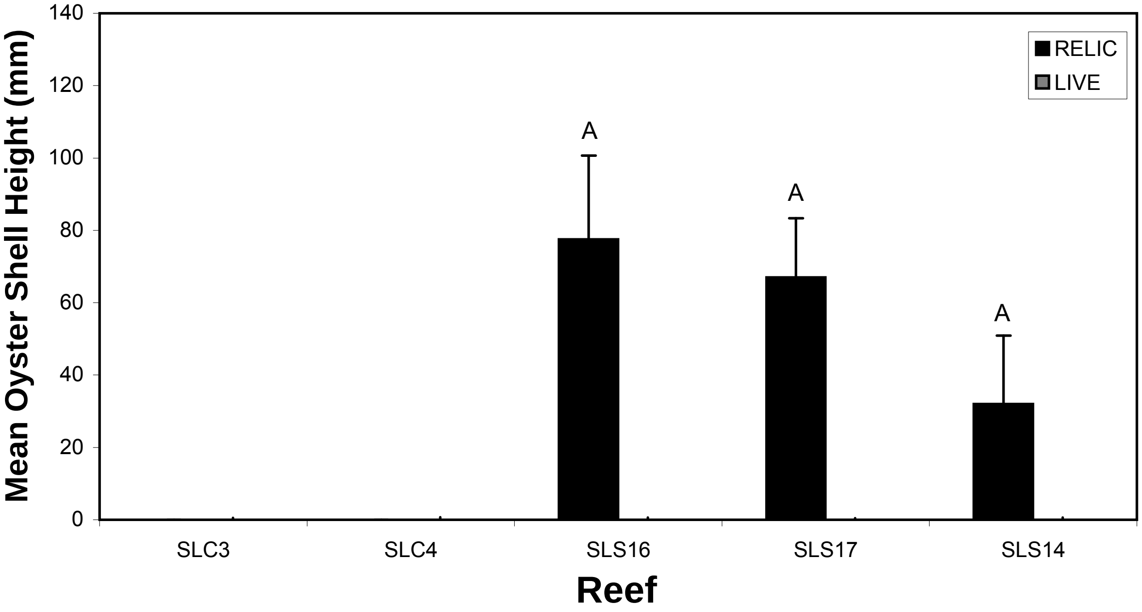

Figure 25. Mean shell height (mm) of both relic and live oysters by reef in St. Lucie Estuary. Reefs are listed from north to south. Within each relic and live assemblage, common letters indicate non-significant differences at α=0.05).

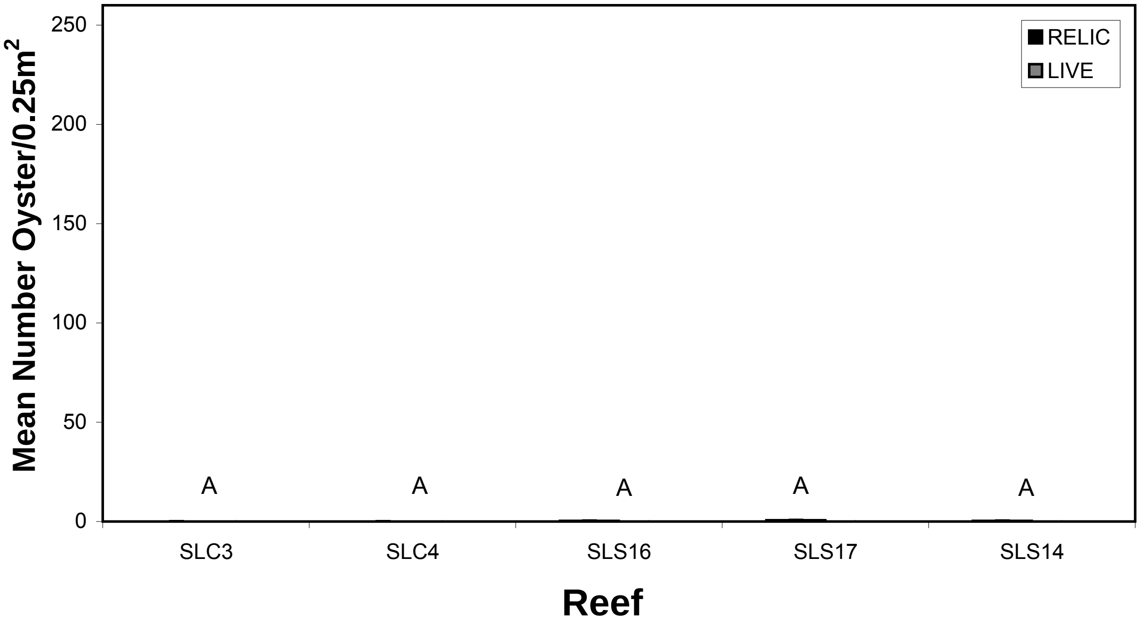

Figure 26. Mean number of both relic and live oysters by reef in St. Lucie Estuary. Reefs are listed from north to south. Within each relic and live assemblage, common letters indicate non-significant differences at α=0.05).

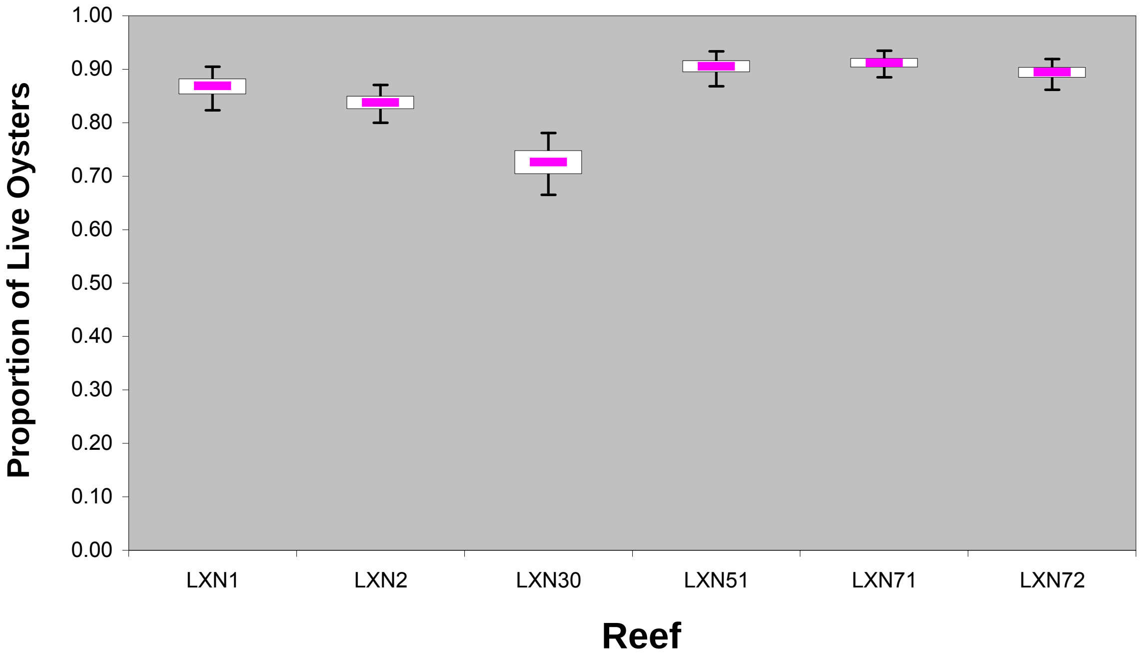

Figure 27. Box and whisker plots of the proportion of live oysters by reef in the Loxahatchee River Estuary. Each box and whisker plot shows the median and the interquartile range (25th–75th percentile; box) and the minimum and maximum concentrations (whiskers). Reefs are listed from north to south.

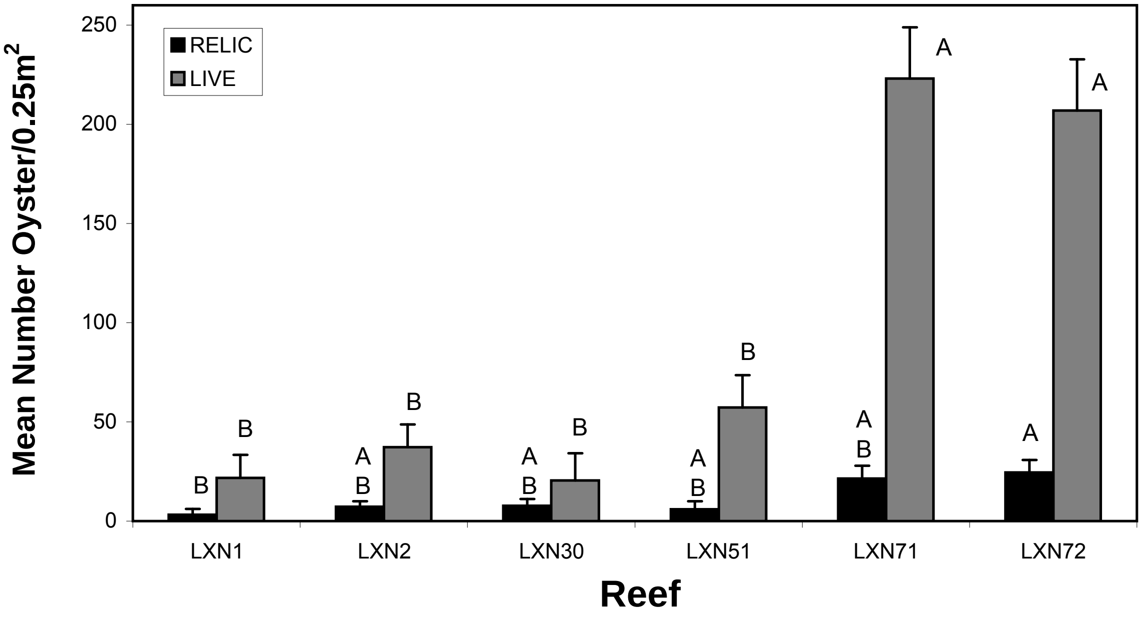

Figure 28. Mean number of both relic and live oysters by reef in the Loxahatchee River Estuary. Reefs are listed from north to south. Within each relic and live assemblage, common letters indicate non-significant differences at α=0.05).

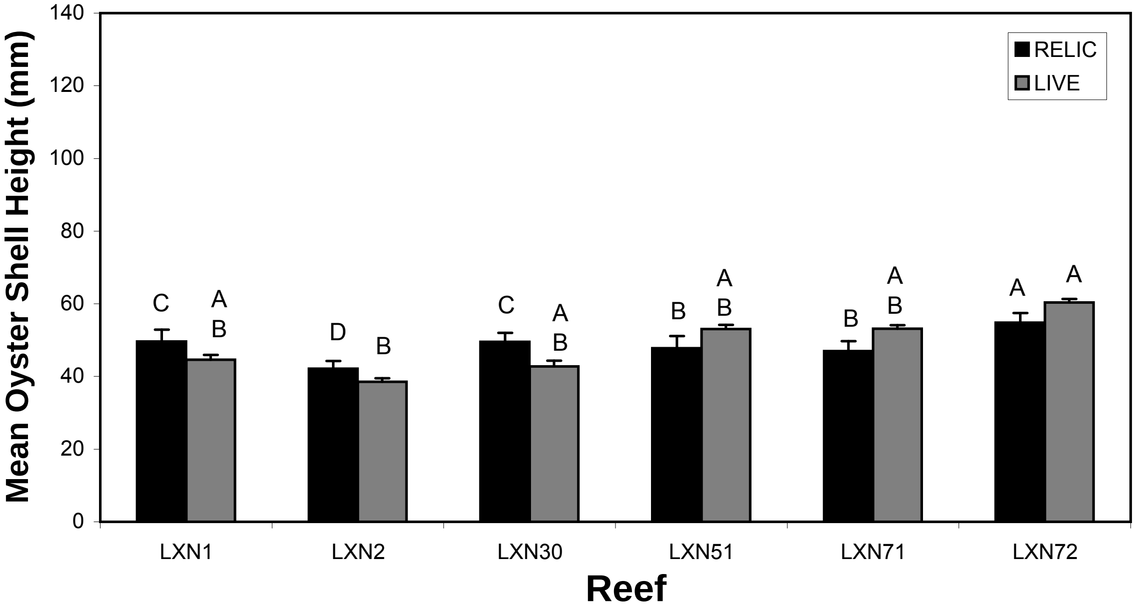

Figure 29. Mean shell height (mm) of both relic and live oysters by reef in the Loxahatchee River Estuary. Reefs are listed from north to south. Within each relic and live assemblage, common letters indicate non-significant differences at α=0.05).

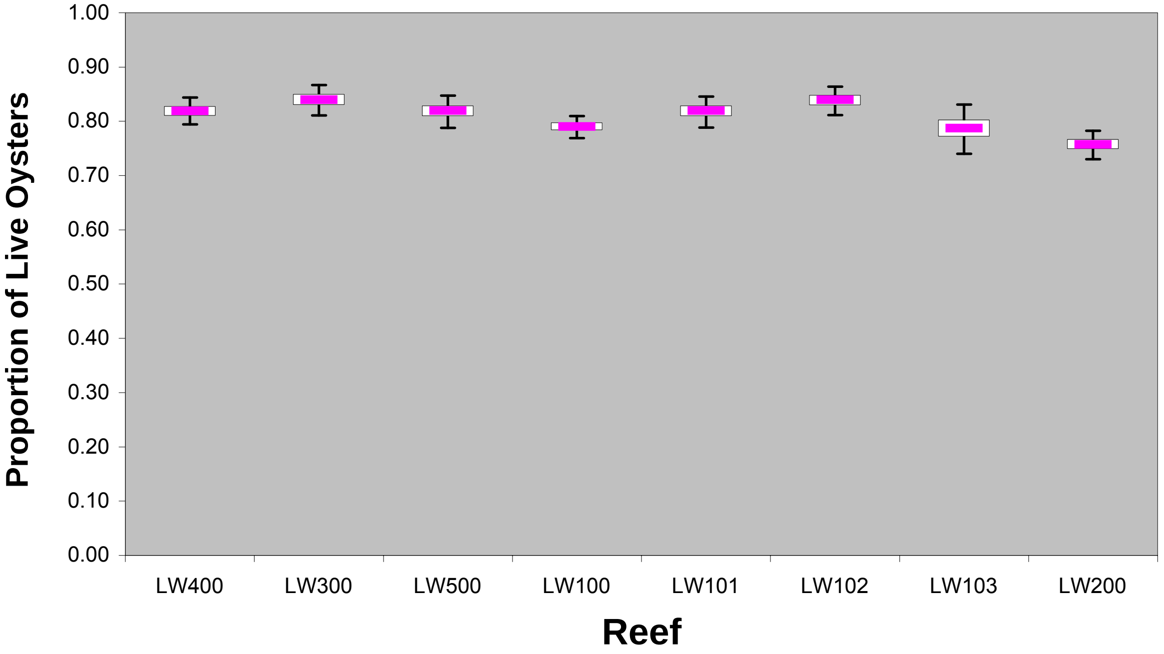

Figure 30. Box and whisker plots of the proportion of live oysters by reef in Lake Worth Lagoon. Each box and whisker plot shows the median and the interquartile range (25th–75th percentile; box) and the minimum and maximum concentrations (whiskers). Reefs are listed from north to south.

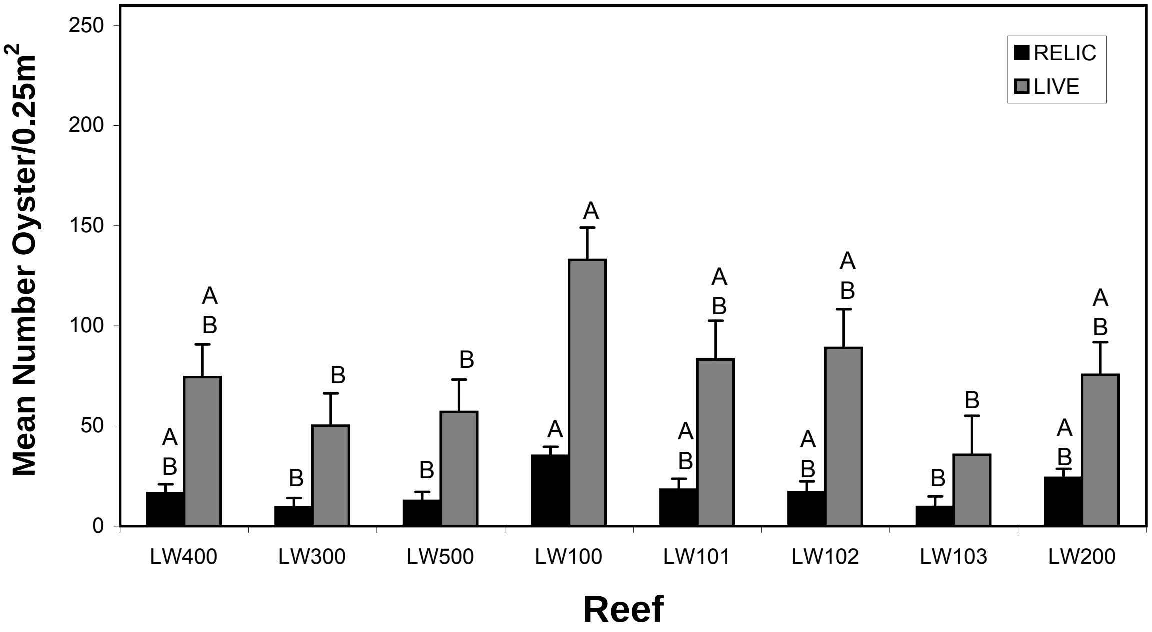

Figure 31. Mean number of both relic and live oysters by reef in Lake Worth Lagoon. Reefs are listed from north to south. Within each relic and live assemblage, common letters indicate non-significant differences at α=0.05).

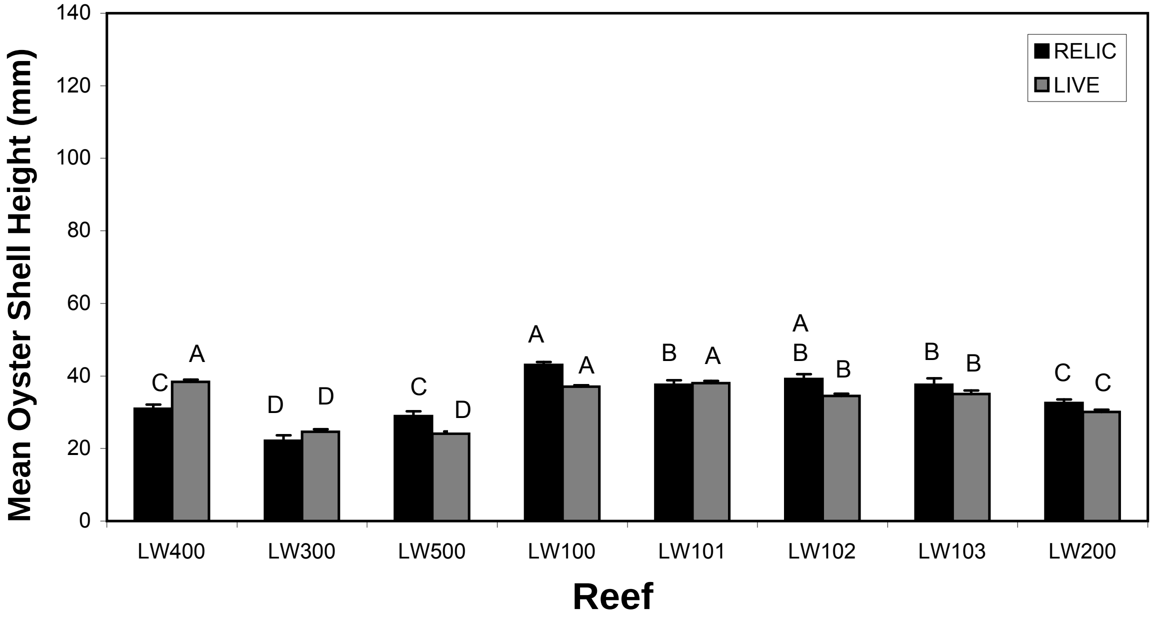

Figure 32. Mean shell height (mm) of both relic and live oysters by reef in Lake Worth Lagoon. Reefs are listed from north to south. Within each relic and live assemblage, common letters indicate non-significant differences at α=0.05).

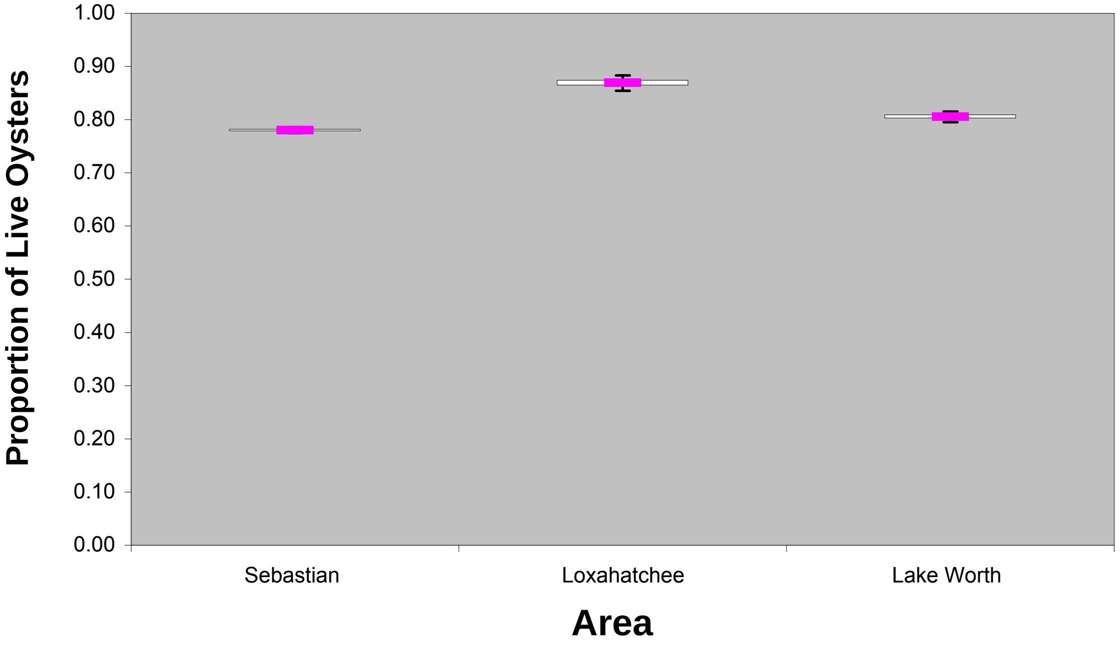

Figure 33. Box and whisker plots of the proportion of live oysters by study site. Each box and whisker plot shows the median and the interquartile range (25th–75th percentile; box) and the minimum and maximum concentrations (whiskers). Sites are listed from north to south.

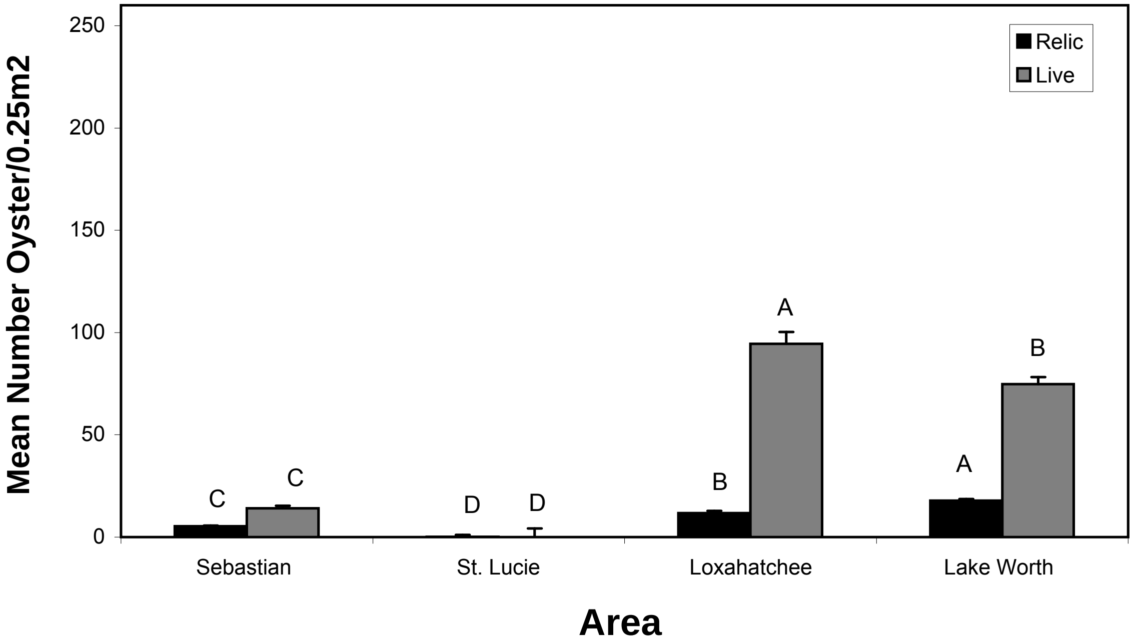

Figure 34. Mean number of both relic and live oysters by study site. Sites are listed from north to south. Within each relic and live assemblage, common letters indicate non-significant differences at α=0.05).

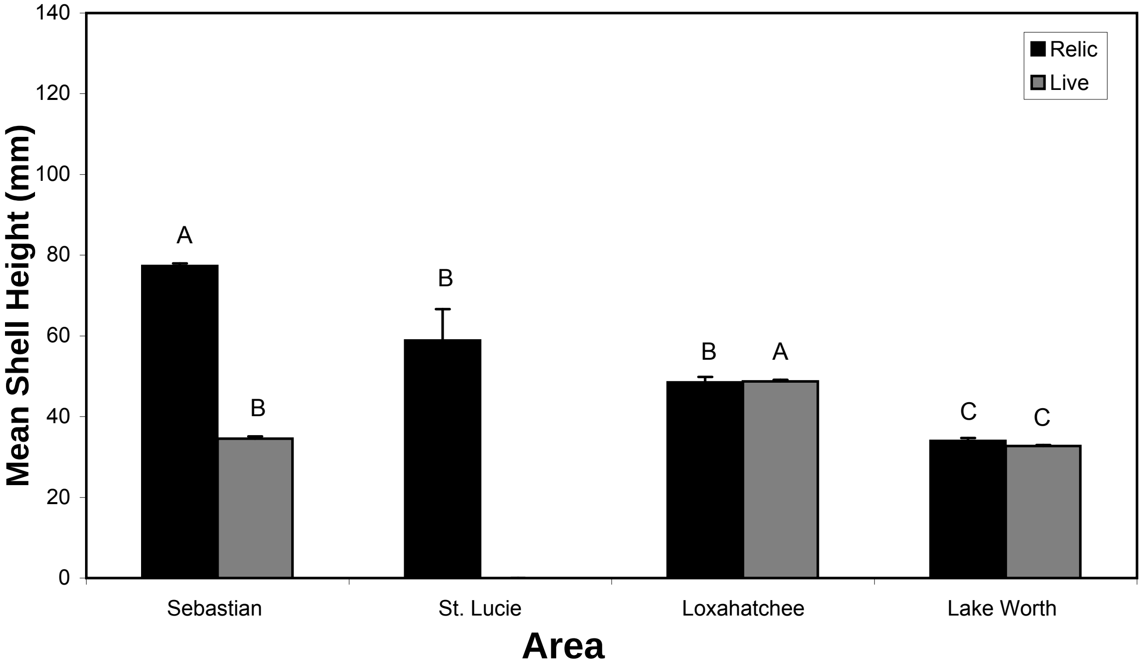

Figure 35. Mean shell height (mm) of both relic and live oysters by study site. Sites are listed from north to south. Within each relic and live assemblage, common letters indicate non-significant differences at α=0.05).

noted earlier, we found no live oysters at our St. Lucie study site. However, although the mean proportions of live oysters were similar among the Sebastian, Loxahatchee, and Lake Worth study sites, the standing stock of oysters differed significantly ($P < 0.001$) among sites for both the live and relic components of the population and each mean differed significantly from its neighboring means (Figure 34). Although significantly different from one another, the two southernmost populations (Loxahatchee and Lake Worth Lagoon) supported substantially more live oysters than either of the two northernmost populations (Sebastian and St. Lucie). Loxahatchee also supported a larger mean size of live oysters relative to either the Lake Worth or Sebastian populations, and live oysters in Lake Worth were significantly larger than their Sebastian River counterparts. In contrast, a distinct and significant north to south trend in the size of relic oysters was detected, with the relic population in Sebastian being largest and the relic population in Lake Worth Lagoon being smallest (Figure 35). Interestingly, the mean SH of the death assemblage greatly exceeded the mean SH of the live animals in both the Sebastian River and the St. Lucie River (where no live oysters were found). In contrast, the mean SH of the relic shells and the mean SH of the live oysters was essentially identical in both Loxahatchee and Lake Worth Lagoon. Based upon those shell height comparisons, it appears that oyster populations in Loxahatchee and Lake Worth Lagoon are in equilibrium (the size distribution of the live assemblage reflects that of the death assemblage) whereas populations in Sebastian and St. Lucie are biased towards smaller, younger oysters.

We compared the categorical density and shell height results from previous studies with the continuous data collected from select reefs within the St. Lucie Estuary and Loxahatchee River Estuary during our study to assess the relative value of each approach. Relative to the categorical approach, our continuous data approach provided a more representative and reliable estimate of the actual size and densities of the live and relic oyster assemblages on each reef (Table 1). Moreover, our sampling method allows for statistical modeling of the data where previous studies only allow for a subjective interpretation of the data. The location of our current study oyster reefs within St. Lucie Estuary in relation to the reefs surveyed in 1997 by URS Greiner Woodward Clyde and in 2003 by Ibis Environmental Inc. is illustrated in Figure 36. The location of our current study oyster reefs within the Loxahatchee River Estuary in relation to the 2003 study reefs surveyed by the Loxahatchee River District (Bachman et al., 2004) is illustrated in Figure 37.

We used reef SR470, from the south region of the Sebastian River, to assess the increase in information gained from collecting 3-D (volumetric) data relative to 2-D (aereal) data. Figure 38 shows the 3-D surface model of reef SR470 as it appears in this 2006 study along with a simulated surface model of the reef five years later (2011). For this model, we kept the reef perimeter constant but modified the reef elevation by randomly adjusting each vertical data point by 3-10 cm. Utilizing spatial and 3-D analyst programs in ArcMap 9.1, we are able to overlay the two surface models and subtract the difference in elevation between the two, generating a third surface model. This third surface model illustrates areas of the reef where volume was gained, unchanged or lost in relation to the 2006 surface model. From this information we calculated the overall volumetric change of the reef over time. Our analysis of this simulation reveals that between 2006 and 2011 reef SR470 had an estimated growth in volume of 62.55 m^3 and a

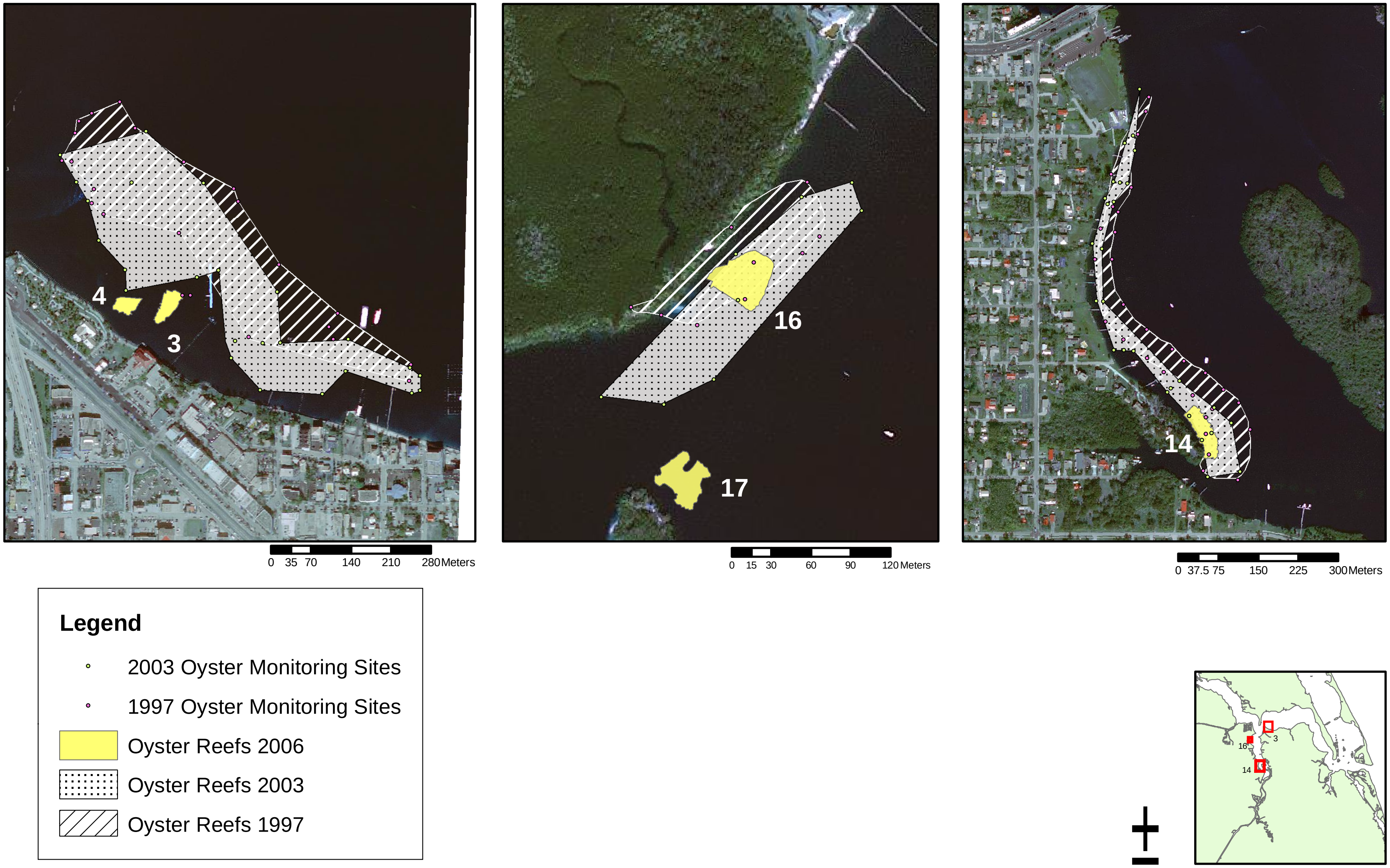

Figure 36. Location of our current study oyster reefs, within St. Lucie Estuary, in relation to the reefs surveyed in 1997 by URS Greiner Woodward Clyde and in 2003 by Ibis Environmental Inc. Reef ID corresponds to reef identified in 2006.

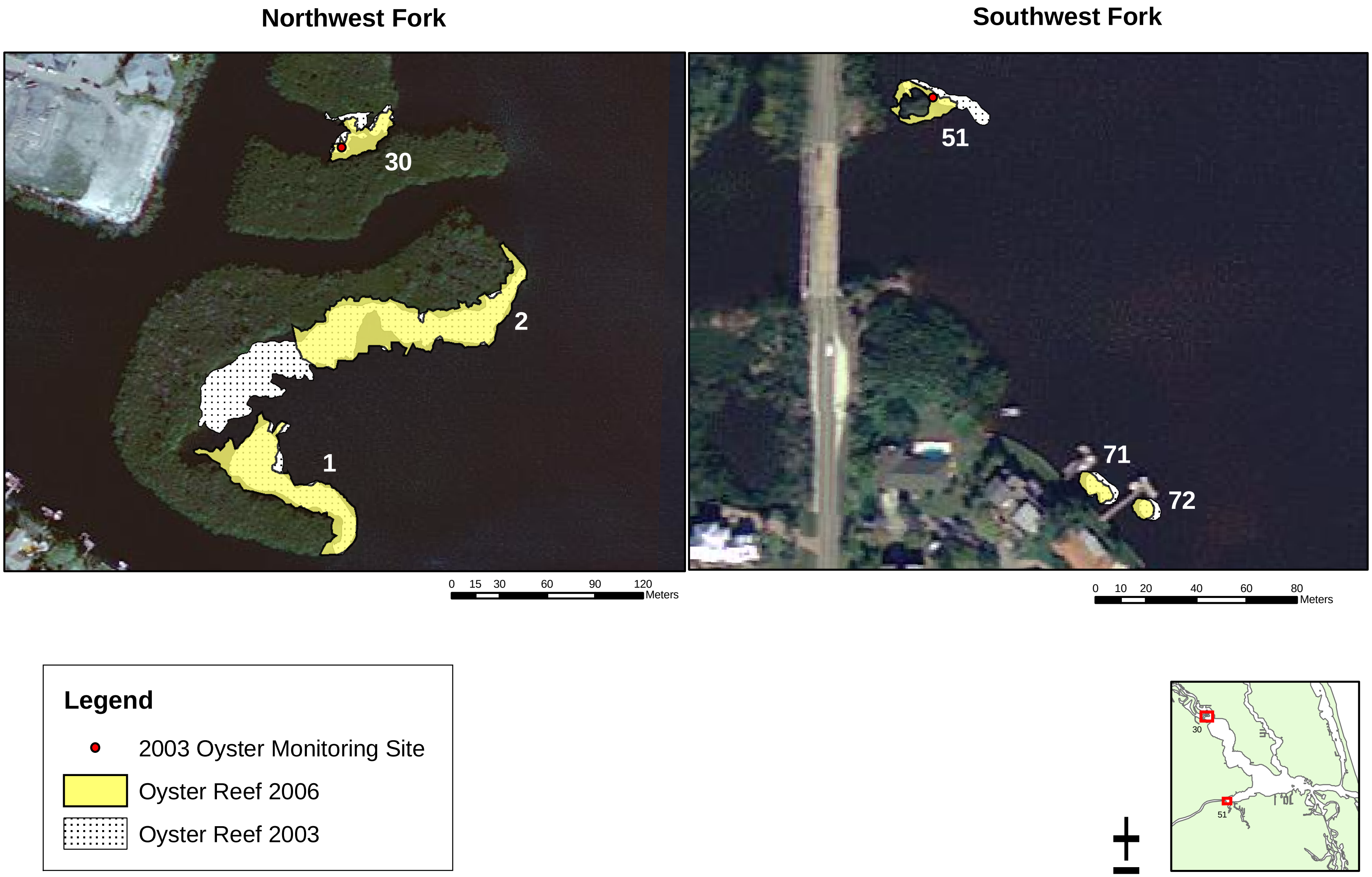

Figure 37. Location of current study oyster reefs, within the Loxahatchee River Estuary, in relation to the 2003 study reefs surveyed by the Loxahatchee River District. Reef ID corresponds to reef identified in 2006.

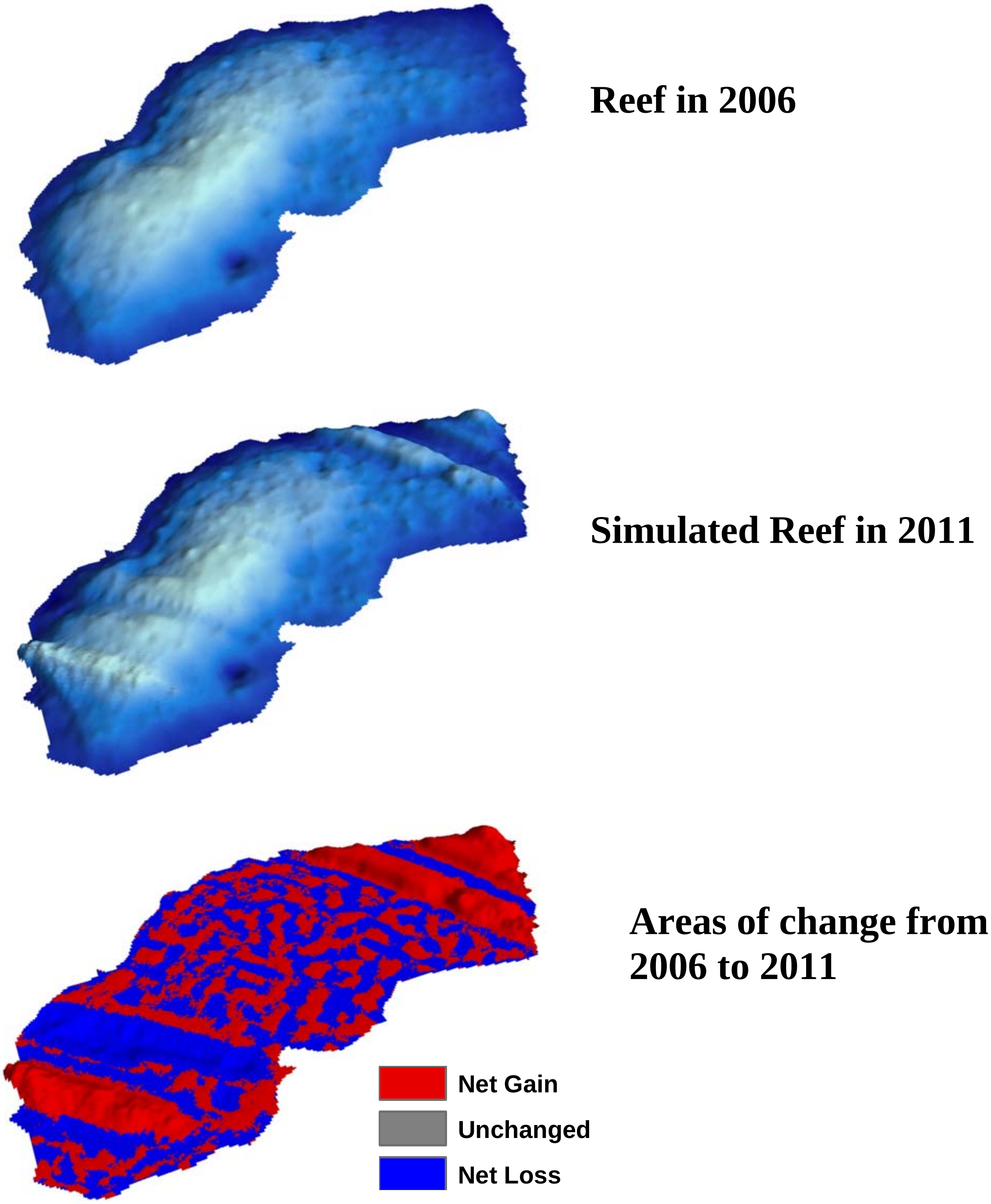

Figure 38. Simulated change in oyster reef surface between 2006 and 2011.

Table 1. A.) Size classification of live and relic oyster assemblage on select oyster reefs within the St. Lucie Estuary from surveys conducted in 1997 by URS Greiner Woodward Clyde, 2003 by Ibis Environmental Inc. and in 2006 by our current study. B.) Size and density classification of live and relic oyster assemblage on select reefs within the Loxahatchee River Estuary from the 2003 survey by the Loxahatchee River District and the current 2006 surveys.

A.)

	1997	**2003**	**2006**
	SLC3 & 4	**SLC3 & 4**	**SLC3 & 4**
Live Oyster Mean Shell Height	Mixed all sizes	0	0
Relic Oyster Mean Shell Height	Mixed all sizes	Mostly 5 - 10 cm	0
	SLS14	**SLS14**	**SLS14**
Live Oyster Mean Shell Height	All < 5 cm	0	0
Relic Oyster Mean Shell Height	Mostly 5 - 10 cm	Mostly 5-10cm	3.20 cm
	SLS16	**SLS16**	**SLS16**
Live Oyster Mean Shell Height	Mostly 5 - 10 cm	0	0
Relic Oyster Mean Shell Height	Mostly 5 - 10 cm	Mixed all sizes	7.80 cm

B.)

	2003	**2006**
	LXN30	**LXN30**
Live Oyster Mean Shell Height	Most < 5 cm	4.27 cm
Relic Oyster Mean Shell Height	Most < 5 cm	4.85 cm
Mean Number of live Oysters	167 /1m^2	20 /0.25m^2 (80/m^2)
Mean Number of Relic Oysters	105 /1m^2	7 /0.25m^2 (28/m^2)
Proportion of Live	0.61	0.72
	LXN51	**LXN51**
Live Oyster Mean Shell Height	Most < 5 cm	5.30 cm
Relic Oyster Mean Shell Height	Most < 5 cm	4.77 cm
Mean Number of live Oysters	247 /1m^2	57 /0.25m^2 (228/m^2)
Mean Number of Relic Oysters	178 /1m^2	6 /0.25m^2 (24/m^2)
Proportion of Live	0.58	0.90

loss in volume of 9.41 m^3 giving it an overall total net gain of 53.14 m^3 despite no change in lateral dimensions. By combining the volumteric data gained from 3-D modeling along with the reefs biological data, a more enhanced interpretation of the overall reef dynamics can be determined. This analysis emphasizes the need to collect oyster reef data in three rather than just two dimensions.

DISCUSSION

The coastal estuaries of southeast Florida are and historically have been strongly influenced by freshwater inputs from inland areas, particularly the Everglades. As Florida has been developed during the last 50-100 years, the magnitude of those freshwater inputs has increased and their seasonal timing has been substantially altered in areas such as the Sebastian, St. Lucie, and Loxahatchee Rivers, Lake Worth Lagoon, and Biscayne Bay. Although *Crassostrea virginica* displays a considerable tolerance to salinity fluctuations, the timing and extent of freshwater flows that largely control salinity in those coastal areas is critical to oyster survival. Anthropogenic changes to the coastal zone of southeast Florida have benefited oysters in some areas (e.g., Lake Worth Lagoon) but appear to have been detrimental in other areas (e.g., Biscayne Bay, St. Lucie River). Even in Lake Worth Lagoon, an historically freshwater body but now fully estuarine in nature, recent freshwater inflows from flood control canals appear to be negatively affecting oyster populations that have relatively recently occupied that lagoon.

The Comprehensive Everglades Restoration Program (CERP) will attempt to modify freshwater flows to the estuaries of south Florida and thereby enhance the distribution and health of oyster and other resources. To verify the success of the CERP, various salinity-sensitive species including oysters will be monitored to determine their response to CERP activities. One goal of CERP is to increase the acreage of live oyster reefs in south Florida estuaries, but to determine if that goal is achieved requires baseline maps of oyster distribution with which future conditions can be compared. As previously noted in this report, baseline 2-D maps have been prepared for both the St. Lucie and Loxahatchee systems. The present study was designed to 1) provide an overview of the history of oyster reefs in southeast Florida, 2) test the efficacy of using RTK GPS technology for mapping oyster reefs in both the horizontal and vertical planes, 3) use RTK GPS technology to map the present status of oyster reefs in each of the Sebastian River, Lake Worth Lagoon, and Biscayne Bay estuarine systems, 4) further validate that technology by comparing map outputs from RTK GPS data with map outputs from more standard 2-dimensional approaches in the Loxahatchee and St. Lucie estuaries, and 5) quantify the abundance of live oysters and relic shell (boxes = paired valves) on each mapped reef. These data would then be available to provide a baseline and guidance for future oyster mapping efforts. Implicit in these goals is the need for future mapping against which our maps and data can be compared.

Within the Sebastian River, oyster reefs ranged in size from very small patches less than 10 m^2 in area to very extensive reefs that exceeded 5,000 m^2 including one reef with an area exceeding 18,000 m^2. Most of the larger reefs were located near the mouth of the river although fringing reefs of considerable length (although not much width) were located throughout the Sebastian River study area. We found reefs essentially touching the shoreline, especially in the south and central regions, under docks and within cattail stands, along the Florida East Coast railroad bridge, and standing alone in or near the center of the river. Reef shape varied substantially and reefs were oriented parallel, perpendicular, and at oblique angles to the long axis of the river. Most reefs were located in shallow water but few were truly intertidal, probably because of the very small tidal range within the Sebastian River. We found no reefs at water depths of 2 m or beyond. Despite the shallow water depths characteristic of oyster reefs in the Sebastian River, there were areas where gaps between reefs were so narrow as to confine river navigation, particularly between the peninsula and the western shore in our north study region.

We found few reefs in Lake Worth Lagoon, but those that we did find appeared to be very healthy and the oyster population occupying those reefs to be well-developed. Most of the Lake Worth Lagoon reefs that we mapped occurred along the central axis of the lagoon, apparently sitting atop dredge spoil material extracted during excavation of the Atlantic Intracoastal Waterway. Most of these reefs were intertidal although a small portion of reef LW100 did extend to a water depth of 1.7 m. The most healthy of the Lake Worth Lagoon oyster reefs was LW100 (and associated reefs LW101, LW102, and LW103). That group of reefs was located to the east of a spoil island and therefore may benefit by being protected from vigorous wave and wake action. We did observe oysters growing on rocks and bulkheads in various areas, the most obvious being along the shore near a golf course on the western shore of the lagoon between the Lake Avenue bridge and the C-51 canal. We did not map those oysters because, from the perspective of habitat provision, they do not appear to function in a manner similar to 'natural' reefs. However, from the perspective of water filtration, those oysters and all oysters within an estuary do contribute to that function. One exception to the general location of the Lake Worth Lagoon reefs along the ICW was a reef that we mapped in Lake Worth Cove within MacArthur Park. Because of complications with the vertical signal from the RTK system, we were only able to map that reef in the horizontal dimension. We also noticed an abundant oyster population growing on the mangroves that surround Lake Worth Cove; again, the value of those oysters should not be discounted despite our poor understanding of their contribution to the ecology of Lake Worth Lagoon.

We did not map all of the reefs in the Loxahatchee River Estuary and the St. Lucie Estuary, so we cannot make general statements regarding their distribution and coverage. Our purpose in those estuaries was not to remap but to compare methods. However, it does appear from our limited data that reef area continues to contract in the St. Lucie estuary compared with the 2003 Ibis Environmental Inc. survey and especially compared with the 1997 URS Greiner Woodward Clyde survey. For example, reefs SLC 3 and SLC4 represent a fraction of the reef area mapped during either previous survey. Moreover, that reef system appears to be migrating towards shore as it shrinks. The causative factors for these changes are unclear, and some component of spatial change may be due to differences in geographic reference points. Such differences, if they exist, must be eliminated from future mapping efforts. In contrast, we detected little change in the size or position of the oyster reefs we mapped in the Loxahatchee River relative to the 2003 Loxahatchee River District study. Although the areal extent of oyster reefs in the Loxahatchee River is limited, those reefs appear to be healthy and stable. Again, we found no oyster reefs in Biscayne Bay.

Our oyster distribution data reveal that the Sebastian River, St. Lucie Estuary, Loxahatchee River Estuary and Lake Worth Lagoon are significantly different from each other in both the size and the density of their oyster populations. We could find few live oysters and no extant oyster reefs in Biscayne Bay. We also detected a significant difference in the oyster population dynamics within each of the individual estuaries. Differences between sites and among reefs within each site could be attributed to decreased water quality and fluctuating salinity levels. Oysters have a range of water conditions they can tolerate and if those conditions exceed optimum levels for a sufficient amount of time the oyster population could be negativity impacted resulting in a die off or collapse in the population. Within the Sebastian River, we noticed that the oyster population seems to be rebounding from what appears to have been a collapse. This assumption is based on the relatively large size of relic oyster shell compared to the small size of live oysters. This difference between the size structure of the relic and live cohorts indicates that the live oysters occupying Sebastian River reefs during 2005-2006 have not yet achieved their full size potential. Definitive information is not available, but the lack of large oysters in Sebastian River could be due to the 2004-2005 hurricane season. During those hurricane seasons, the central east coast of Florida was impacted by seven tropical systems that introduced large amounts of freshwater into those estuarine systems and substantially reduced salinity for an extended period of time. Salinity responded not just to direct inputs from rainfall and the historic watershed, but also to floodwaters pumped out of central Florida into the Sebastian River via the C-54 canal system. As a result, the overall impact of those rainfall events to the oysters of Sebastian River probably was exacerbated by floodwater releases, creating an artificial salinity regime to which the oysters were not adapted. This would explain the apparent die-off that is evidenced by the dearth of large live oysters relative to the abundance of empty but paired valves.

A similar explanation may apply in the St. Lucie estuary, a system that also is strongly influenced by floodwaters emanating from the many canals that empty into St. Lucie from central Florida. During 2005, health warnings were issued for the St. Lucie estuary due to high levels of *Enterococcus* and fecal coliform bacteria (Florida Healthy Beaches Program). Suboptimal water quality conditions caused by bacteria and other pollutants may contribute to oyster mortality in this estuarine system although we have no direct data on the relative importance of salinity and water quality to oyster survival. From the results of a separate oyster monitoring study, we do know that live oysters were essentially non-existent in the St. Lucie estuary (and Sebastian River) during 2005. That observation corroborates to some degree our hypothesis that the large size of the oyster death assemblage in these estuaries reflects a recent mortality event. It is then a reasonable expectation that, barring additional events of a similar magnitude, the assemblage of live oysters in each of these estuarine systems will achieve a size composition consistent with the death assemblage within a year or two.

In both the Loxahatchee River Estuary and Lake Worth Lagoon, the size spectrum of live oysters is essentially identical to that of the death assemblage. This suggests either that those oyster populations have not recently suffered mortality events similar to those experienced by oysters in Sebastian and St. Lucie or that they have had sufficient time to recover. We argue that oysters in Lake Worth Lagoon did not experience a similar mortality event. Although some flood control waters do enter Lake Worth Lagoon, the magnitude of those introductions is small relative to the size of the lagoon. Additionally, the impact of freshwater intrusions is ameliorated by oceanic inputs from the two inlets that serve Lake Worth Lagoon. The explanation is less clear for oysters in the Loxahatchee River because those oysters are exposed to freshwater inputs and are somewhat isolated from the nearest oceanic inlet. Nevertheless, at least the recent history of oysters in Loxahatchee suggests a relatively stable population.

The results of our oyster reef mapping efforts in southeast Florida show that Real-Time Kinematic GPS is a useful tool for mapping oyster reefs. Our approach with RTK GPS produces a high resolution map of the horizontal reef boundaries and a somewhat less accurate but extremely valuable depiction of the oyster reef's vertical surface. Our mapping efforts confirm that the denser and more uniform the data points are over the surface of the reef, the tighter the confidence interval becomes resulting in a more accurately predicted surface elevation model (Figure 39). Thus, depending upon the

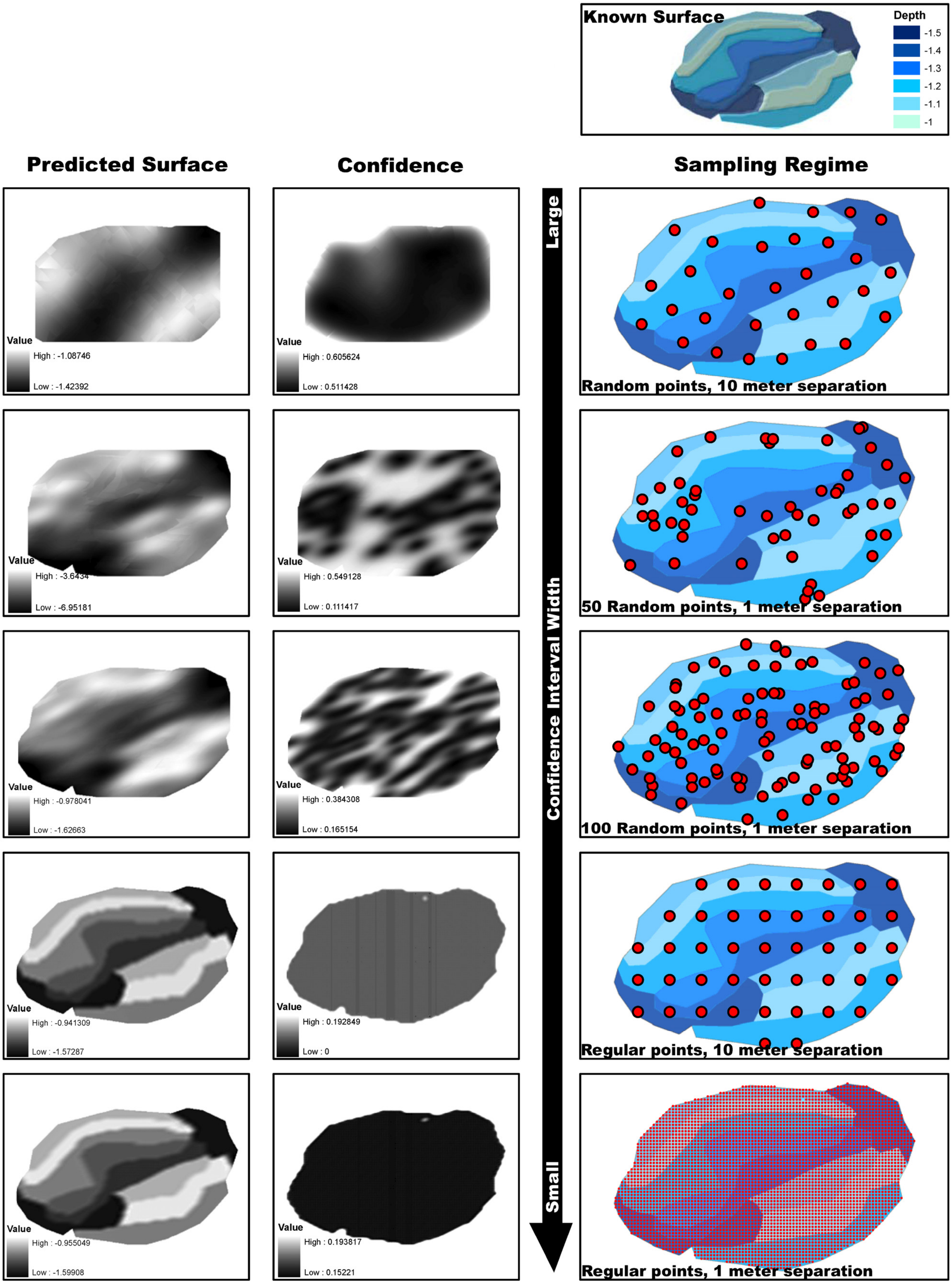

Figure 39. Sampling regime impacts on interpolation.

vertical confidence interval desired, a more or less intense data collection effort can be made. Because intensive mapping of every reef in an estuary may not be realistic or cost-effective, our advice would be to select representative reefs within the estuary and concentrate monitoring efforts on those reefs. This is particularly applicable when mapping in the vertical dimension.

We did encounter some problems while collecting data using the RTK GPS system. Particularly in the Sebastian River, we experienced distortion of the radio signal transmission (multipath error) resulting in amplified vertical data. Because of the environment we were working in and around, (i.e. numerous metal and wooden boathouses, thickly covered mangrove shorelines, and a large metal railroad trestle) placement of the base station to achieve system security while maintaining an open line-of-sight between the base and the portable unit was key to minimizing multipath error. Weather conditions during field sampling efforts also could be problematic. Although efforts were made to sample under ideal weather conditions (clear sunny skies), that was not always possible. There were days in which cloud cover (increased water vapor) may have created inaccuracies in the vertical data. It also was difficult to maintain a perfect 1-meter spacing of grid nodes over the entire surface of the reef. We did use floats to aid in maintaining a straight line transect, but turbidity, reef terrain, and depth forced us to deviate from that perfect grid. A kayak, pushed by one researcher while a second sat on top and recorded data points, proved useful in addressing depth issues but was ineffective under adverse conditions (strong wind and waves). All of these issues resulted in either having the data point eliminated or increasing the distance between data points, both of which contributed to decreasing the confidence interval widths of our predicted surface elevation models.

The oyster reef GIS data base generated from this project has already proven itself in two separate occasions to be a very valuable management tool. First, the St. John's River Water Management District and Taylor Engineering, Inc. have utilized the oyster reef shapefiles and associated biological data to revise their current proposed dredging plans of the Sebastian River. Our study revealed previously unknown live oyster reefs that lay within the proposed dredging path. Without the data generated from this study, acres of live oyster reef could have been destroyed. Second, the Palm Beach County Department of Environmental Resources Management has utilized the oyster reef shapefiles to assist with their oyster restoration efforts in Lake Worth Lagoon. The fundamental value of oyster reef mapping will be compounded as we expand these efforts throughout Florida.

In compliance with the requirements of the grant, Appendix I contains the listings of file names and data types for all associated oyster reef GIS data base files (Table A7 – A11). A copy of all GIS raster, shapefies and metadata associated with this study are provided on CD. Also on CD is a PDF copy of this report and an Excel spreadsheet containing geographic coordinates for all data points used to create the oyster reef GIS data base files.

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Appendix I

Data Appendix

Table A1. List of the percentage of each oyster reef sampled within the Sebastian River.

Study Site	Reef ID	Number of Quadrats Sampled	Reef Area (m^2)	Percentage of Reef Sampled
Sebastian River	SR203	10	3078.62	0.08
Sebastian River	SR204M	11	439.28	0.63
Sebastian River	SR205	5	58.28	2.14
Sebastian River	SR206	3	21.13	3.55
Sebastian River	SR207	3	12.91	5.81
Sebastian River	SR310	6	68.28	2.20
Sebastian River	SR311M	14	455.81	0.77
Sebastian River	SR312	2	30.11	1.66
Sebastian River	SR313	3	232.97	0.32
Sebastian River	SR317M	10	383.59	0.65
Sebastian River	SR318	7	86.20	2.03
Sebastian River	SR319	3	73.36	1.02
Sebastian River	SR320	3	192.33	0.39
Sebastian River	SR321	10	216.09	1.16
Sebastian River	SR323	3	46.43	1.62
Sebastian River	SR325	10	3899.89	0.06
Sebastian River	SR326	10	466.49	0.54
Sebastian River	SR408	10	2583.35	0.10
Sebastian River	SR411M	30	3809.00	0.20
Sebastian River	SR412M	63	18616.07	0.08
Sebastian River	SR413	10	2587.44	0.10
Sebastian River	SR416M	53	3197.71	0.41
Sebastian River	SR418	2	22.11	2.26
Sebastian River	SR419	1	12.33	2.03
Sebastian River	SR421	3	65.10	1.15
Sebastian River	SR424	2	53.29	0.94
Sebastian River	SR425	1	13.89	1.80
Sebastian River	SR426	2	18.66	2.68
Sebastian River	SR427	1	18.04	1.39
Sebastian River	SR428	10	285.95	0.87
Sebastian River	SR431	4	187.93	0.53
Sebastian River	SR432M	10	729.97	0.34
Sebastian River	SR433M	10	333.64	0.75
Sebastian River	SR435	3	42.07	1.78
Sebastian River	SR445M	12	538.47	0.56
Sebastian River	SR446	2	18.88	2.65
Sebastian River	SR448M	18	1398.67	0.32
Sebastian River	SR452M	46	2257.16	0.51
Sebastian River	SR453	10	1972.00	0.13
Sebastian River	SR455M	4	132.68	0.75
Sebastian River	SR457M	11	320.83	0.86
Sebastian River	SR458M	8	296.40	0.67
Sebastian River	SR461	7	1715.49	0.10
Sebastian River	SR464	10	1971.26	0.13
Sebastian River	SR465	4	130.77	0.76
Sebastian River	SR466	3	65.33	1.15
Sebastian River	SR467M	17	1196.60	0.36

Table A1. (continued)

Study Site	Reef ID	Number of Quadrats Sampled	Reef Area (m^2)	Percentage of Reef Sampled
Sebastian River	SR470	10	1961.93	0.13
Sebastian River	SR473	10	37.17	6.73
Sebastian River	SR474	10	437.32	0.57
Sebastian River	SR477M	20	630.48	0.79
Sebastian River	SR480	3	52.34	1.43
Sebastian River	SR482	5	72.09	1.73
Sebastian River	SR484	10	34.01	7.35
Sebastian River	SR485	10	207.77	1.20
Sebastian River	SR486	10	197.76	1.26
Sebastian River	SR487	10	127.20	1.97
Sebastian River	SR489	10	58.86	4.25
Sebastian River	SR490	7	69.83	2.51
Sebastian River	SR501	10	34.81	7.18
Sebastian River	SR502	10	26.16	9.56
Sebastian River	SR505	10	78.16	3.20
Sebastian River	SR506	10	89.86	2.78
Sebastian River	SR507	7	92.59	1.89
Sebastian River	SR508	5	55.97	2.23
Sebastian River	SR509	7	126.58	1.38
Sebastian River	SR511	2	123.37	0.41
Sebastian River	SR513	1	9.05	2.76
Sebastian River	SR514	1	13.92	1.80
Sebastian River	SR516M	15	453.06	0.83
Sebastian River	SR517	3	67.59	1.11
Sebastian River	SR520	2	36.17	1.38
Sebastian River	SR521	1	7.35	3.40
Sebastian River	SR522	3	67.28	1.11
Sebastian River	SR523M	7	221.45	0.79
Sebastian River	SR525M	7	141.84	1.23
Sebastian River	SR526	3	33.54	2.24
Sebastian River	SR527	1	2.00	12.50
Sebastian River	SR528	2	38.34	1.30
Sebastian River	SR530	1	2.05	12.20
Sebastian River	SR532	4	98.68	1.01
Sebastian River	SR533	1	12.16	2.06
Sebastian River	SR535	1	11.76	2.13
Sebastian River	SR536	5	117.55	1.06
Sebastian River	SR537	2	15.75	3.17
Sebastian River	SR538M	28	4087.26	0.17
Sebastian River	SR542M	11	351.86	0.78
Sebastian River	SR543	3	86.73	0.86
Sebastian River	SR544	4	68.89	1.45
Sebastian River	SR549	1	6.01	4.16
Sebastian River	SR553	3	76.15	0.98
Sebastian River	SR554M	85	4141.60	0.51
Sebastian River	SR570	1	10.03	2.49
Sebastian River	SR572	2	23.39	2.14

Table A1. (continued)

Study Site	**Reef ID**	**Number of Quadrats Sampled**	**Reef Area (m^2)**	**Percentage of Reef Sampled**
Sebastian River	SR573	2	7.49	6.68
Sebastian River	SR574	2	23.59	2.12
Sebastian River	SR575M	20	2155.56	0.23
Sebastian River	SR576	2	9.52	5.25
Sebastian River	SR577	2	11.56	4.33
Sebastian River	SR578	3	90.85	0.83
Sebastian River	SR580M	16	1669.18	0.24
Sebastian River	SR581	2	35.66	1.40
Sebastian River	SR584M	6	173.99	0.86
Sebastian River	SR585	1	35.23	0.71
Sebastian River	SR586M	24	2065.64	0.29
Sebastian River	SR589	3	170.85	0.44
Sebastian River	SR591	1	58.60	0.43
Sebastian River	SR594M	16	1436.79	0.28
Sebastian River	SR595	6	684.26	0.22
Sebastian River	SR596	3	270.54	0.28
Sebastian River	SR597	2	145.94	0.34
Sebastian River	SR599	5	352.57	0.35
Sebastian River	SR600	4	171.94	0.58
Sebastian River	SR601	6	172.89	0.87
Sebastian River	SR602	3	33.50	2.24
Sebastian River	SR603	10	309.49	0.81
Sebastian River	SR610M	25	6459.76	0.10
Sebastian River	SR612	5	1107.66	0.11
Sebastian River	SR613	2	10.99	4.55
Sebastian River	SR614	2	11.62	4.30
Sebastian River	SR616	3	47.05	1.59
Sebastian River	SR617	3	60.18	1.25
Sebastian River	SR618	3	58.75	1.28
Sebastian River	SR619	3	119.64	0.63
Sebastian River	SR620	2	26.15	1.91
Sebastian River	SR621	4	40.87	2.45
Sebastian River	SR622	2	15.64	3.20
Sebastian River	SR623	7	164.04	1.07
Sebastian River	SR624	4	61.42	1.63
Sebastian River	SR625	1	9.87	2.53
Sebastian River	SR626	8	140.24	1.43
Sebastian River	SR628	4	32.57	3.07

Table A2. List of the percentage of each oyster reef sampled within the St. Lucie Estuary, Loxahatchee River, and Lake Worth Lagoon.

Study Site	Reef ID	Number of Quadrats Sampled	Reef Area (m^2)	Percentage of Reef Sampled
St. Lucie Estuary	SLC3	10	1516.8	0.16
St. Lucie Estuary	SLC4	10	1067.2	0.23
St. Lucie Estuary	SLS14	10	3003.3	0.08
St. Lucie Estuary	SLS16	7	1388.4	0.13
St. Lucie Estuary	SLS17	7	956.3	0.18
Loxahatchee River	LXN1	10	2459.7	0.10
Loxahatchee River	LXN2	10	3973.5	0.06
Loxahatchee River	LXN30	7	597.8	0.29
Loxahatchee River	LXN51	5	180.3	0.69
Loxahatchee River	LXN71	2	94.5	0.53
Loxahatchee River	LXN72	2	56.4	0.89
Lake Worth Lagoon	LW100	10	10559.4	0.02
Lake Worth Lagoon	LW101	7	562.6	0.31
Lake Worth Lagoon	LW102	7	1406.0	0.12
Lake Worth Lagoon	LW103	7	870.0	0.20
Lake Worth Lagoon	LW200	10	1653.8	0.15
Lake Worth Lagoon	LW300	10	1816.2	0.14
Lake Worth Lagoon	LW400	10	1398.3	0.18
Lake Worth Lagoon	LW500	10	2322.4	0.11

Table A3. Ryan-Einot-Gabriel-Welsch (REGWQ) means comparison of number of live oysters/0.25m^2 for reefs within the Sebastian River. Common letters indicate non-significant differences at α=0.05.

Region	Reef ID	Mean Number of Live Oyster/0.25m^2	REGWQ Grouping				
North	SR597	158.50	A				
North	SR408	110.40	A	B			
North	SR577	103.50	A	B	C		
North	SR612	93.20	A	B	C	D	
North	SR570	86.00	A	B	C	D	E
North	SR411M	81.73	A	B	C	D	E
North	SR412M	80.71	A	B	C	D	E
North	SR413	66.80		B	C	D	E
North	SR618	64.00		B	C	D	E
North	SR610M	56.52		B	C	D	E
North	SR581	54.50		B	C	D	E
North	SR578	53.00		B	C	D	E
North	SR596	52.00		B	C	D	E
North	SR580M	40.81		B	C	D	E
North	SR589	39.67		B	C	D	E
North	SR585	34.00		B	C	D	E
North	SR591	33.00		B	C	D	E
Central	SR624	31.25		B	C	D	E
North	SR576	31.00		B	C	D	E
North	SR617	25.67			C	D	E
Central	SR527	19.00				D	E
Central	SR435	18.67				D	E
North	SR600	18.25				D	E
North	SR619	18.00				D	E
Central	SR572	18.00				D	E
North	SR584M	17.67				D	E
Central	SR628	17.25				D	E
Central	SR528	17.00				D	E
North	SR575M	15.95				D	E
Central	SR623	15.14				D	E
North	SR616	15.00				D	E
North	SR426	14.50				D	E
Central	SR601	14.50				D	E
Central	SR621	13.50				D	E
North	SR586M	11.96				D	E
North	SR573	11.50				D	E
Central	SR319	11.33				D	E
North	SR574	11.00				D	E
North	SR595	10.50				D	E
Central	SR620	10.50				D	E
Central	SR533	10.00				D	E
North	SR599	9.80				D	E
Central	SR536	9.00				D	E
Central	SR517	9.00				D	E
Central	SR532	8.75				D	E
North	SR594M	8.69				D	E

Table A3. (continued)

Region	**Reef ID**	**Mean Number of Live Oyster/0.25m^2**	**REGWQ Grouping**	
Central	SR554M	8.20	D	E
Central	SR418	7.50	D	E
North	SR602	7.33	D	E
Central	SR530	7.00	D	E
North	SR613	7.00	D	E
North	SR603	6.90	D	E
North	SR614	6.50	D	E
Central	SR432M	6.00	D	E
Central	SR625	6.00	D	E
Central	SR544	5.75	D	E
Central	SR204M	5.64	D	E
Central	SR520	5.50	D	E
Central	SR428	5.10	D	E
Central	SR535	5.00	D	E
South	SR487	4.80	D	E
Central	SR421	4.67	D	E
Central	SR416M	4.62	D	E
South	SR467M	4.53	D	E
Central	SR312	4.50	D	E
Central	SR448M	4.50	D	E
Central	SR626	4.50	D	E
North	SR203	4.40	D	E
Central	SR525M	4.29	D	E
Central	SR424	4.00	D	E
Central	SR538M	3.93	D	E
Central	SR313	3.67	D	E
Central	SR311M	3.50	D	E
South	SR470	3.20		E
Central	SR465	3.00		E
Central	SR553	3.00		E
Central	SR452M	2.80		E
South	SR325	2.30		E
South	SR326	2.10		E
South	SR513	2.00		E
Central	SR526	2.00		E
Central	SR549	2.00		E
Central	SR622	2.00		E
South	SR477M	1.90		E
South	SR502	1.80		E
Central	SR445M	1.67		E
Central	SR433M	1.50		E
Central	SR523M	1.43		E
South	SR485	1.40		E
South	SR501	1.40		E
South	SR455M	1.25		E
South	SR205	1.00		E

Table A3. (continued)

Region	Reef ID	Mean Number of Live Oyster/0.25m^2	REGWQ Grouping
Central	SR427	1.00	E
South	SR461	1.00	E
South	SR511	1.00	E
South	SR514	1.00	E
Central	SR521	1.00	E
South	SR489	0.90	E
South	SR509	0.86	E
South	SR457M	0.82	E
South	SR317M	0.80	E
South	SR453	0.70	E
South	SR464	0.70	E
South	SR484	0.70	E
Central	SR542M	0.64	E
South	SR486	0.60	E
Central	SR310	0.50	E
South	SR506	0.50	E
South	SR473	0.40	E
South	SR207	0.33	E
South	SR466	0.33	E
South	SR516M	0.33	E
South	SR507	0.29	E
Central	SR431	0.25	E
South	SR321	0.20	E
South	SR474	0.20	E
South	SR318	0.14	E
South	SR490	0.14	E
South	SR505	0.10	E
South	SR206	0.00	E
South	SR320	0.00	E
South	SR323	0.00	E
Central	SR419	0.00	E
Central	SR425	0.00	E
Central	SR446	0.00	E
South	SR458M	0.00	E
South	SR480	0.00	E
South	SR482	0.00	E
South	SR508	0.00	E
Central	SR522	0.00	E
Central	SR537	0.00	E
Central	SR543	0.00	E

Table A4. Ryan-Einot-Gabriel-Welsch (REGWQ) means comparison of number of relic oysters/0.25m^2 for reefs within the Sebastian River. Common letters indicate non-significant differences at α=0.05.

Region	Reef ID	Mean Number of Relic Oyster/0.25m^2	REGWQ Grouping				
Central	SR533	33.00	A				
Central	SR446	22.50	A	B			
South	SR513	19.00		B	C		
Central	SR544	16.75		B	C	D	
Central	SR319	13.67		B	C	D	E
South	SR482	13.20		B	C	D	E
Central	SR465	12.50		B	C	D	E
North	SR570	12.00		B	C	D	E
Central	SR535	12.00		B	C	D	E
Central	SR521	12.00		B	C	D	E
Central	SR435	11.67		B	C	D	E
South	SR205	10.80		B	C	D	E
Central	SR542M	10.18		B	C	D	E
Central	SR549	10.00		B	C	D	E
South	SR485	9.90		B	C	D	E
Central	SR312	9.50		B	C	D	E
South	SR320	9.33		B	C	D	E
Central	SR532	9.25		B	C	D	E
South	SR487	9.10		B	C	D	E
Central	SR452M	9.09		B	C	D	E
South	SR527	9.00		B	C	D	E
Central	SR514	9.00		B	C	D	E
Central	SR313	8.67		B	C	D	E
Central	SR431	8.50		B	C	D	E
Central	SR424	8.50		B	C	D	E
Central	SR418	8.00		B	C	D	E
Central	SR428	7.90		B	C	D	E
Central	SR311M	7.86		B	C	D	E
South	SR421	7.67		B	C	D	E
Central	SR207	7.67		B	C	D	E
South	SR597	7.50		B	C	D	E
South	SR486	7.50		B	C	D	E
North	SR576	7.50		B	C	D	E
North	SR317M	7.50		B	C	D	E
South	SR458M	6.75			C	D	E
South	SR206	6.67			C	D	E
South	SR321	6.50			C	D	E
South	SR467M	6.47			C	D	E
South	SR480	6.33			C	D	E
Central	SR204M	6.18			C	D	E
South	SR326	6.10			C	D	E
South	SR525M	6.00			C	D	E
Central	SR455M	6.00			C	D	E
Central	SR523M	5.71			C	D	E
South	SR323	5.67			C	D	E
South	SR470	5.60			C	D	E

Table A4. (continued)

Region	Reef ID	Mean Number of Relic Oyster/0.25m^2	REGWQ Grouping		
South	SR507	5.57	C	D	E
Central	SR432M	5.50	C	D	E
Central	SR528	5.50	C	D	E
Central	SR522	5.33	C	D	E
North	SR600	5.25	C	D	E
South	SR506	5.10	C	D	E
Central	SR419	5.00	C	D	E
Central	SR427	5.00	C	D	E
Central	SR517	5.00	C	D	E
Central	SR526	5.00	C	D	E
Central	SR619	5.00	C	D	E
Central	SR416M	4.91	C	D	E
North	SR408	4.90	C	D	E
Central	SR554M	4.88	C	D	E
South	SR477M	4.80	C	D	E
North	SR617	4.67	C	D	E
South	SR473	4.60	C	D	E
North	SR574	4.50	C	D	E
Central	SR620	4.50	C	D	E
South	SR490	4.29	C	D	E
South	SR325	4.20	C	D	E
Central	SR433M	4.20	C	D	E
Central	SR536	4.20	C	D	E
Central	SR448M	4.06	C	D	E
South	SR318	4.00	C	D	E
South	SR466	4.00	C	D	E
North	SR578	4.00	C	D	E
North	SR580M	4.00	C	D	E
North	SR581	4.00	C	D	E
Central	SR425	4.00	C	D	E
Central	SR621	4.00	C	D	E
South	SR453	3.90	C	D	E
North	SR595	3.83	C	D	E
South	SR457M	3.55	C	D	E
North	SR413	3.50	C	D	E
North	SR573	3.50	C	D	E
North	SR411M	3.47	C	D	E
South	SR489	3.40	C	D	E
Central	SR445M	3.25	C	D	E
South	SR505	3.20	C	D	E
South	SR509	3.00	C	D	E
North	SR577	3.00	C	D	E
North	SR585	3.00	C	D	E
North	SR612	3.00	C	D	E
Central	SR310	3.00	C	D	E
North	SR594M	2.81	C	D	E

Table A4. (continued)

Region	Reef ID	Mean Number of Relic Oyster/0.25m^2	REGWQ Grouping		
South	SR474	2.80	C	D	E
North	SR599	2.80	C	D	E
North	SR596	2.67		D	E
North	SR618	2.67		D	E
North	SR610M	2.64		D	E
South	SR516M	2.60		D	E
North	SR412M	2.51		D	E
North	SR572	2.50		D	E
Central	SR624	2.50		D	E
North	SR589	2.33		D	E
North	SR586M	2.25		D	E
North	SR575M	2.20		D	E
Central	SR538M	2.18		D	E
South	SR511	2.00		D	E
North	SR616	2.00		D	E
Central	SR537	2.00		D	E
South	SR502	1.90		D	E
North	SR584M	1.83		D	E
North	SR613	1.50		D	E
South	SR461	1.43		D	E
South	SR484	1.40		D	E
Central	SR543	1.33		D	E
North	SR603	1.30		D	E
South	SR464	1.20		D	E
North	SR203	1.10		D	E
North	SR591	1.00		D	E
Central	SR426	1.00		D	E
Central	SR520	1.00		D	E
Central	SR553	1.00		D	E
Central	SR625	1.00		D	E
South	SR501	0.90		D	E
Central	SR623	0.86		D	E
North	SR601	0.83		D	E
South	SR508	0.80		D	E
North	SR602	0.67		D	E
Central	SR626	0.63		D	E
Central	SR628	0.25			E
North	SR614	0.00			E
Central	SR530	0.00			E
Central	SR622	0.00			E

Table A5. Ryan-Einot-Gabriel-Welsch (REGWQ) means comparison of live oyster shell height for reefs within the Sebastian River. Common letters indicate non-significant differences at α=0.05.

Region	**Reef ID**	**Mean Live Oyster Shell Height (mm)**	**REGWQ Grouping**							
North	SR574	64.32	A							
North	SR573	57.44	A	B						
Central	SR625	57.17	A	B	C					
Central	SR465	56.75	A	B	C					
Central	SR628	56.22	A	B	C					
Central	SR622	55.25	A	B	C	D				
North	SR618	53.58	A	B	C	D	E			
North	SR572	52.97	A	B	C	D	E	F		
Central	SR624	52.18	A	B	C	D	E	F		
Central	SR626	51.89	A	B	C	D	E	F	G	
North	SR585	51.71	A	B	C	D	E	F	G	
Central	SR623	51.18	A	B	C	D	E	F	G	
North	SR408	50.98	A	B	C	D	E	F	G	
North	SR613	50.93	A	B	C	D	E	F	G	
North	SR584M	50.65	A	B	C	D	E	F	G	
North	SR578	49.49	A	B	C	D	E	F	G	
North	SR617	49.43	A	B	C	D	E	F	G	
North	SR581	49.07	A	B	C	D	E	F	G	
Central	SR538M	48.66	A	B	C	D	E	F	G	
Central	SR621	48.46	A	B	C	D	E	F	G	
North	SR576	48.42	A	B	C	D	E	F	G	
North	SR610M	47.54	A	B	C	D	E	F	G	H
North	SR580M	47.36	A	B	C	D	E	F	G	H
North	SR570	47.20	A	B	C	D	E	F	G	H
North	SR603	46.51	A	B	C	D	E	F	G	H
North	SR602	46.23	A	B	C	D	E	F	G	H
North	SR614	46.08	A	B	C	D	E	F	G	H
North	SR412M	45.87	A	B	C	D	E	F	G	H
North	SR596	45.13	A	B	C	D	E	F	G	H
North	SR411M	44.94	A	B	C	D	E	F	G	H
North	SR575M	44.80	A	B	C	D	E	F	G	H
North	SR597	44.56	A	B	C	D	E	F	G	H
North	SR616	44.42	A	B	C	D	E	F	G	H
North	SR591	44.12	A	B	C	D	E	F	G	H
North	SR612	43.80	A	B	C	D	E	F	G	H
North	SR577	43.49	A	B	C	D	E	F	G	H
Central	SR619	42.44	A	B	C	D	E	F	G	H
North	SR413	41.49	A	B	C	D	E	F	G	H
North	SR599	41.08	A	B	C	D	E	F	G	H
North	SR586M	40.66	A	B	C	D	E	F	G	H
Central	SR620	39.52	A	B	C	D	E	F	G	H
Central	SR418	39.20	A	B	C	D	E	F	G	H
North	SR600	38.77	A	B	C	D	E	F	G	H
Central	SR554M	38.66	A	B	C	D	E	F	G	H
North	SR595	38.65	A	B	C	D	E	F	G	H
North	SR601	38.52	A	B	C	D	E	F	G	H

Table A5. (continued)

Region	Reef ID	Mean Live Oyster Shell Height (mm)	REGWQ Grouping							
North	SR594M	37.75	A	B	C	D	E	F	G	H
Central	SR517	37.15	A	B	C	D	E	F	G	H
North	SR589	36.77	A	B	C	D	E	F	G	H
Central	SR526	36.67	A	B	C	D	E	F	G	H
Central	SR535	36.40	A	B	C	D	E	F	G	H
North	SR203	36.27	A	B	C	D	E	F	G	H
Central	SR542M	36.00	A	B	C	D	E	F	G	H
Central	SR530	35.57	A	B	C	D	E	F	G	H
Central	SR319	35.41	A	B	C	D	E	F	G	H
Central	SR527	35.32	A	B	C	D	E	F	G	H
Central	SR553	35.11	A	B	C	D	E	F	G	H
Central	SR445M	34.20	A	B	C	D	E	F	G	H
Central	SR427	34.00	A	B	C	D	E	F	G	H
Central	SR416M	33.97	A	B	C	D	E	F	G	H
Central	SR432M	33.92	A	B	C	D	E	F	G	H
Central	SR523M	33.90	A	B	C	D	E	F	G	H
Central	SR426	33.83	A	B	C	D	E	F	G	H
Central	SR435	33.25	A	B	C	D	E	F	G	H
South	SR514	33.00	A	B	C	D	E	F	G	H
South	SR511	32.50	A	B	C	D	E	F	G	H
Central	SR452M	32.50	A	B	C	D	E	F	G	H
Central	SR528	32.29	A	B	C	D	E	F	G	H
Central	SR313	32.18	A	B	C	D	E	F	G	H
Central	SR536	32.07	A	B	C	D	E	F	G	H
Central	SR544	31.70	A	B	C	D	E	F	G	H
Central	SR532	31.40	A	B	C	D	E	F	G	H
Central	SR428	31.24	A	B	C	D	E	F	G	H
Central	SR311M	30.47	A	B	C	D	E	F	G	H
Central	SR533	30.40	A	B	C	D	E	F	G	H
Central	SR448M	30.38	A	B	C	D	E	F	G	H
Central	SR431	30.00	A	B	C	D	E	F	G	H
Central	SR204M	29.50	A	B	C	D	E	F	G	H
Central	SR424	29.00	A	B	C	D	E	F	G	H
Central	SR549	28.50	A	B	C	D	E	F	G	H
South	SR466	28.00	A	B	C	D	E	F	G	H
South	SR461	27.43	A	B	C	D	E	F	G	H
South	SR457M	26.89	A	B	C	D	E	F	G	H
South	SR453	26.71	A	B	C	D	E	F	G	H
Central	SR310	26.67	A	B	C	D	E	F	G	H
South	SR506	26.20		B	C	D	E	F	G	H
Central	SR312	26.11		B	C	D	E	F	G	H
Central	SR525M	26.07		B	C	D	E	F	G	H
Central	SR421	25.50		B	C	D	E	F	G	H
South	SR464	24.43		B	C	D	E	F	G	H
South	SR325	22.91		B	C	D	E	F	G	H
Central	SR433M	22.53		B	C	D	E	F	G	H

Table A5. (continued)

Region	**Reef ID**	**Mean Live Oyster Shell Height (mm)**	**REGWQ Grouping**						
South	SR516M	22.00	B	C	D	E	F	G	H
Central	SR520	21.73	B	C	D	E	F	G	H
South	SR473	21.50	B	C	D	E	F	G	H
South	SR489	21.44	B	C	D	E	F	G	H
South	SR467M	20.92	B	C	D	E	F	G	H
South	SR501	20.50	B	C	D	E	F	G	H
South	SR513	20.50	B	C	D	E	F	G	H
South	SR484	20.43	B	C	D	E	F	G	H
South	SR477M	20.08	B	C	D	E	F	G	H
South	SR470	19.25		C	D	E	F	G	H
South	SR321	18.00			D	E	F	G	H
South	SR474	18.00			D	E	F	G	H
South	SR490	18.00			D	E	F	G	H
South	SR502	18.00			D	E	F	G	H
South	SR509	17.67			D	E	F	G	H
South	SR487	17.46			D	E	F	G	H
South	SR455M	17.40			D	E	F	G	H
South	SR486	17.33			D	E	F	G	H
South	SR326	17.05				E	F	G	H
South	SR485	16.57				E	F	G	H
South	SR207	16.00				E	F	G	H
South	SR318	16.00				E	F	G	H
Central	SR521	16.00				E	F	G	H
South	SR317M	15.25					F	G	H
South	SR507	14.00						G	H
South	SR205	10.40							H
South	SR505	10.00							H

Table A6. Ryan-Einot-Gabriel-Welsch (REGWQ) means comparison of relic oyster shell height for reefs within the Sebastian River. Common letters indicate non-significant differences at α=0.05.

Region	**Reef ID**	**Mean Relic Oyster Shell Height (mm)**	**REGWQ Grouping**													
South	SR507	110.33	A													
South	SR508	109.75	A	B												
South	SR480	109.53	A	B	C											
North	SR577	106.83	A	B	C	D										
North	SR574	106.00	A	B	C	D	E									
North	SR581	105.88	A	B	C	D	E									
South	SR326	103.72	A	B	C	D	E	F								
South	SR509	103.29	A	B	C	D	E	F								
South	SR205	100.94	A	B	C	D	E	F	G							
South	SR489	100.79	A	B	C	D	E	F	G							
South	SR511	100.00	A	B	C	D	E	F	G	H						
South	SR487	99.67	A	B	C	D	E	F	G	H	I					
South	SR490	98.03	A	B	C	D	E	F	G	H	I	J				
South	SR207	97.22	A	B	C	D	E	F	G	H	I	J				
South	SR473	96.80	A	B	C	D	E	F	G	H	I	J	K			
South	SR323	96.59	A	B	C	D	E	F	G	H	I	J	K			
South	SR485	96.37	A	B	C	D	E	F	G	H	I	J	K	L		
South	SR482	95.33	A	B	C	D	E	F	G	H	I	J	K	L		
South	SR514	95.11	A	B	C	D	E	F	G	H	I	J	K	L		
Central	SR628	95.00	A	B	C	D	E	F	G	H	I	J	K	L		
South	SR458M	94.54	A	B	C	D	E	F	G	H	I	J	K	L	M	
South	SR457M	94.46	A	B	C	D	E	F	G	H	I	J	K	L	M	
Central	SR319	94.05	A	B	C	D	E	F	G	H	I	J	K	L	M	
South	SR505	93.44	A	B	C	D	E	F	G	H	I	J	K	L	M	
South	SR467M	93.11	A	B	C	D	E	F	G	H	I	J	K	L	M	
South	SR321	92.60	A	B	C	D	E	F	G	H	I	J	K	L	M	
South	SR516M	91.51	A	B	C	D	E	F	G	H	I	J	K	L	M	
South	SR486	91.49	A	B	C	D	E	F	G	H	I	J	K	L	M	
South	SR317M	90.76	A	B	C	D	E	F	G	H	I	J	K	L	M	
South	SR318	90.25	A	B	C	D	E	F	G	H	I	J	K	L	M	
South	SR470	89.32	A	B	C	D	E	F	G	H	I	J	K	L	M	
Central	SR427	89.20	A	B	C	D	E	F	G	H	I	J	K	L	M	
Central	SR424	88.94	A	B	C	D	E	F	G	H	I	J	K	L	M	
South	SR461	88.60	A	B	C	D	E	F	G	H	I	J	K	L	M	
South	SR513	88.53	A	B	C	D	E	F	G	H	I	J	K	L	M	
South	SR506	88.47	A	B	C	D	E	F	G	H	I	J	K	L	M	
Central	SR549	87.60	A	B	C	D	E	F	G	H	I	J	K	L	M	
South	SR455M	87.46	A	B	C	D	E	F	G	H	I	J	K	L	M	
South	SR477M	86.86	A	B	C	D	E	F	G	H	I	J	K	L	M	N
South	SR206	86.70	A	B	C	D	E	F	G	H	I	J	K	L	M	N
North	SR572	86.40	A	B	C	D	E	F	G	H	I	J	K	L	M	N
South	SR453	86.28	A	B	C	D	E	F	G	H	I	J	K	L	M	N
South	SR464	85.58	A	B	C	D	E	F	G	H	I	J	K	L	M	N
North	SR578	84.83	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Central	SR517	84.73	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Central	SR435	84.29	A	B	C	D	E	F	G	H	I	J	K	L	M	N

Table A6. (continued)

Region	**Reef ID**	**Mean Relic Oyster Shell Height (mm)**	**REGWQ Grouping**																
Central	SR528	84.18	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
South	SR484	84.14	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
South	SR325	84.05	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
North	SR580M	83.75	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
Central	SR204M	82.66	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
South	SR466	82.50	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
Central	SR452M	82.37	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
South	SR502	82.37	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
Central	SR527	81.22	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
Central	SR537	81.00	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
North	SR570	80.92	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
Central	SR419	80.80	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
North	SR573	80.71	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
Central	SR445M	80.59	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
Central	SR544	80.51	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
Central	SR526	80.13	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
Central	SR520	80.00	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
North	SR576	79.73	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
Central	SR621	78.63	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
Central	SR448M	78.38	A	B	C	D	E	F	G	H	I	J	K	L	M	N			
North	SR584M	78.18	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O		
South	SR474	78.11	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O		
Central	SR532	77.38	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	
Central	SR554M	77.35	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	
Central	SR525M	77.26	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	
North	SR203	77.18	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	
Central	SR522	76.56	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	
Central	SR465	75.22	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR425	74.00	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR446	73.96	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR542M	73.13	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR533	73.12	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR312	72.42	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR310	72.28	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR421	72.09	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR426	72.00	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
South	SR501	71.89	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR433M	71.79	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR432M	71.55	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
North	SR575M	71.43	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR536	71.29	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR311M	71.16	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
South	SR320	70.82	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR620	70.67	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
North	SR591	70.00	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR416M	69.22	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q

Table A6. (continued)

Region	Reef ID	Mean Relic Oyster Shell Height (mm)	REGWQ Grouping																
Central	SR535	69.17	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR428	69.08	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR313	68.73	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR624	66.90	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR553	66.33	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR538M	66.11	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR619	65.73	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
North	SR617	65.57	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
North	SR616	65.50	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR431	64.79	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
North	SR603	64.54	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
North	SR413	64.29	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
North	SR594M	62.87	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR625	62.00		B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
North	SR586M	61.37			C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR418	61.19				D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR523M	60.93				D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR626	60.00				D	E	F	G	H	I	J	K	L	M	N	O	P	Q
North	SR600	59.52				D	E	F	G	H	I	J	K	L	M	N	O	P	Q
North	SR596	58.00					E	F	G	H	I	J	K	L	M	N	O	P	Q
North	SR595	57.78					E	F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR521	56.42						F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR543	56.25						F	G	H	I	J	K	L	M	N	O	P	Q
Central	SR623	54.50							G	H	I	J	K	L	M	N	O	P	Q
North	SR589	53.86							G	H	I	J	K	L	M	N	O	P	Q
North	SR613	53.33							G	H	I	J	K	L	M	N	O	P	Q
North	SR585	52.00								H	I	J	K	L	M	N	O	P	Q
North	SR412M	51.36									I	J	K	L	M	N	O	P	Q
North	SR597	50.40										J	K	L	M	N	O	P	Q
North	SR599	50.00										J	K	L	M	N	O	P	Q
North	SR411M	48.56											K	L	M	N	O	P	Q
North	SR618	48.13												L	M	N	O	P	Q
North	SR601	46.40													M	N	O	P	Q
North	SR602	39.50														N	O	P	Q
North	SR612	31.13															O	P	Q
North	SR610M	30.52																P	Q
North	SR408	28.73																	Q

Table A7. Oyster polygon map details for the north region of the Sebastian River. (SRpoly_north_2-9-07.shp)

Date	Reef_ID	Perc_Live	HT_Live	HT_Dead	Perimeter_m	Area_sqm	Acres	Hectares	Num_Live	Num_Dead
01/25/06	203	80.0	36	77	818.2	3078.6	0.76074	0.30786	4.4	1.1
03/24/06	408	95.8	51	29	239.3	2583.3	0.63836	0.25833	110.4	4.9
03/21/06	411m	95.9	45	49	613.4	3809.0	0.94122	0.38090	81.7	3.5
03/28/06	412m	97.0	46	51	969.9	18616.1	4.60013	1.86161	80.7	2.5
03/21/06	413	95.0	41	64	258.7	2587.4	0.63937	0.25874	66.8	3.5
02/06/06	570	87.8	47	81	12.0	10.0	0.00248	0.00100	86.0	12.0
02/06/06	572	87.8	53	86	28.2	23.4	0.00578	0.00234	18.0	2.5
02/06/06	573	76.7	57	81	11.2	7.5	0.00185	0.00075	11.5	3.5
02/06/06	574	71.0	64	106	20.5	23.6	0.00583	0.00236	11.0	4.5
02/07/06	575m	88.0	45	71	894.3	2155.6	0.53265	0.21556	16.0	2.2
02/07/06	576	80.5	48	80	11.9	9.5	0.00235	0.00095	31.0	7.5
02/07/06	577	97.2	43	107	13.6	11.6	0.00286	0.00116	103.5	3.0
02/07/06	578	93.0	49	85	37.7	90.9	0.02245	0.00909	53.0	4.0
02/07/06	580m	91.1	47	84	340.2	1669.2	0.41246	0.16692	40.8	4.0
02/07/06	581	93.2	49	106	22.6	35.7	0.00881	0.00357	54.5	4.0
02/07/06	584m	90.6	51	78	88.3	174.0	0.04299	0.01740	17.7	1.8
02/07/06	585	91.9	52	52	23.3	35.2	0.00871	0.00352	34.0	3.0
02/08/06	586m	84.2	41	61	405.2	2065.6	0.51043	0.20656	12.0	2.3
02/08/06	589	94.4	37	54	50.6	170.8	0.04222	0.01708	39.7	2.3
02/08/06	591	97.1	44	70	30.1	58.6	0.01448	0.00586	33.0	1.0
03/20/06	594m	75.5	38	63	281.2	1436.8	0.35504	0.14368	8.7	2.8
03/20/06	595	73.3	39	58	123.3	684.3	0.16908	0.06843	10.5	3.8
03/20/06	596	95.1	45	58	78.0	270.5	0.06685	0.02705	52.0	2.7
03/20/06	597	95.5	45	50	59.9	145.9	0.03606	0.01459	158.5	7.5
03/28/06	599	77.8	41	50	83.3	352.6	0.08712	0.03526	9.8	2.8

Table A7. (continued)

Date	Reef_ID	Perc_Live	HT_Live	HT_Dead	Perimeter_m	Area_sqm	Acres	Hectares	Num_Live	Num_Dead
03/28/06	600	77.7	39	60	80.1	171.9	0.04249	0.01719	18.3	5.3
03/28/06	601	94.6	39	46	61.9	172.9	0.04272	0.01729	14.5	0.8
03/28/06	602	91.7	46	40	26.3	33.5	0.00828	0.00335	7.3	0.7
03/28/06	603	84.2	47	65	113.3	309.5	0.07648	0.03095	6.9	1.3
03/28/06	610m	95.5	48	30	473.7	6459.8	1.59624	0.64598	56.5	2.6
03/28/06	612	96.9	44	31	142.1	1107.7	0.27371	0.11077	93.2	3.0
03/28/06	613	82.4	51	53	12.6	11.0	0.00272	0.00110	7.0	1.5
03/28/06	614	100.0	46	na	13.0	11.6	0.00287	0.00116	6.5	0.0
03/28/06	616	88.2	44	66	30.5	47.1	0.01163	0.00471	15.0	2.0
03/29/06	617	84.6	49	66	31.7	60.2	0.01487	0.00602	25.7	4.7
03/29/06	618	96.0	54	48	30.1	58.8	0.01452	0.00588	64.0	2.7

Table A8. Oyster polygon map details for the central region of the Sebastian River. (SRpoly_central_2-9-07.shp)

Date	Reef_ID	Perc_Live	HT_Live	HT_Dead	Perimeter_m	Area_sqm	Acres	Hectares	Num_Live	Num_Dead
01/25/06	204m	47.7	30	83	103.6	439.3	0.10855	0.04393	5.6	6.2
01/20/06	310	14.3	27	72	58.4	68.3	0.01687	0.00683	0.5	3.0
01/06/06	311m	30.8	30	71	202.4	455.8	0.11263	0.04558	3.5	7.9
01/05/06	312	32.1	26	72	21.7	30.1	0.00744	0.00301	4.5	9.5
01/19/06	313	29.7	32	69	61.3	233.0	0.05757	0.02330	3.7	8.7
01/17/06	319	45.3	35	94	32.4	73.4	0.01813	0.00734	11.3	13.7
01/23/06	416m	48.5	34	69	973.0	3197.7	0.79017	0.31977	4.6	4.9
01/05/06	418	48.4	39	61	17.9	22.1	0.00546	0.00221	7.5	8.0
01/05/06	419	0.0	na	81	13.1	12.3	0.00305	0.00123	0.0	5.0
01/05/06	421	37.8	26	72	29.9	65.1	0.01609	0.00651	4.7	7.7
01/05/06	424	32.0	29	89	29.9	53.3	0.01317	0.00533	4.0	8.5
01/05/06	425	0.0	na	74	14.5	13.9	0.00343	0.00139	0.0	4.0
01/05/06	426	93.6	34	72	22.2	18.7	0.00461	0.00187	14.5	1.0
01/05/06	427	16.7	34	89	17.6	18.0	0.00446	0.00180	1.0	5.0
01/19/06	428	39.2	31	69	157.2	285.9	0.07066	0.02859	5.1	7.9
01/05/06	431	2.9	30	65	87.4	187.9	0.04644	0.01879	0.3	8.5
01/18/06	432m	52.2	34	72	227.9	730.0	0.18038	0.07300	6.0	5.5
01/05/06	433m	26.3	23	72	114.2	333.6	0.08244	0.03336	1.5	4.2
01/05/06	435	61.5	33	84	24.7	42.1	0.01040	0.00421	18.7	11.7
01/05/06	445m	33.9	34	81	177.7	538.5	0.13306	0.05385	1.7	3.3
01/04/06	446	0.0	na	74	28.7	18.9	0.00467	0.00189	0.0	22.5
01/04/06	448m	52.6	30	78	341.2	1398.7	0.34562	0.13987	4.5	4.1
01/18/06	452m	23.6	32	83	859.6	2257.2	0.55776	0.22572	2.8	9.1
01/17/06	465	19.4	57	75	63.2	130.8	0.03231	0.01308	3.0	12.5
01/04/06	517	64.3	37	85	35.9	67.6	0.01670	0.00676	9.0	5.0
01/05/06	520	84.6	22	80	33.1	36.2	0.00894	0.00362	5.5	1.0
01/05/06	521	7.7	16	56	11.4	7.3	0.00182	0.00073	1.0	12.0

Table A8. (continued)

Date	Reef_ID	Perc_Live	HT_Live	HT_Dead	Perimeter_m	Area_sqm	Acres	Hectares	Num_Live	Num_Dead
01/23/06	522	0.0	na	77	42.9	67.3	0.01662	0.00673	0.0	5.3
01/23/06	523m	20.0	34	61	87.3	221.4	0.05472	0.02214	1.4	5.7
01/05/06	525m	41.7	26	77	87.1	141.8	0.03505	0.01418	4.3	6.0
01/05/06	526	28.6	37	80	21.7	33.5	0.00829	0.00335	2.0	5.0
01/06/06	528	75.6	32	84	24.1	38.3	0.00947	0.00383	17.0	5.5
01/06/06	530	100.0	36	na	6.3	2.0	0.00051	0.00020	7.0	0.0
01/06/06	532	48.6	31	77	48.0	98.7	0.02438	0.00987	8.8	9.3
01/06/06	533	23.3	30	73	14.1	12.2	0.00300	0.00122	10.0	33.0
01/06/06	535	29.4	36	69	13.4	11.8	0.00291	0.00118	5.0	12.0
01/06/06	536	68.2	32	71	63.3	117.6	0.02905	0.01176	9.0	4.2
01/06/06	537	0.0	na	81	17.1	15.8	0.00389	0.00158	0.0	2.0
03/29/06	538m	64.3	48	66	637.9	4087.3	1.00998	0.40873	3.9	2.2
01/17/06	542m	5.9	36	73	145.1	351.9	0.08695	0.03519	0.6	10.2
01/17/06	543	0.0	na	56	58.1	86.7	0.02143	0.00867	0.0	1.3
01/17/06	544	25.6	32	81	55.4	68.9	0.01702	0.00689	5.8	16.8
01/19/06	549	16.7	29	88	9.9	6.0	0.00149	0.00060	2.0	10.0
01/23/06	553	75.0	35	66	35.2	76.1	0.01882	0.00761	3.0	1.0
01/25/06	554m	62.7	39	77	1685.9	4141.6	1.02341	0.41416	8.2	4.9
03/29/06	619	78.3	42	66	50.6	119.6	0.02956	0.01196	18.0	5.0
03/29/06	620	70.0	40	71	22.2	26.1	0.00646	0.00261	10.5	4.5
03/29/06	621	77.1	48	79	39.7	40.9	0.01010	0.00409	13.5	4.0
03/29/06	622	100.0	55	na	16.4	15.6	0.00386	0.00156	2.0	0.0
03/29/06	623	94.6	51	55	61.5	164.0	0.04054	0.01640	15.1	0.9
03/29/06	624	92.6	52	67	39.8	61.4	0.01518	0.00614	31.3	2.5
03/29/06	625	85.7	57	62	12.2	9.9	0.00244	0.00099	6.0	1.0
03/29/06	626	87.8	52	60	78.6	140.2	0.03465	0.01402	4.5	0.6
03/29/06	628	98.6	56	95	23.3	32.6	0.00805	0.00326	17.3	0.3

Table A9. Oyster polygon map details for the south region of the Sebastian River. (SRpoly_south_2-9-07.shp)

Date	Reef_ID	Perc_Live	HT_Live	HT_Dead	Perimeter_m	Area_sqm	Acres	Hectares	Num_Live	Num_Dead
11/30/05	205	8.5	10	101	39.2	58.3	0.01440	0.00583	1.0	10.8
11/30/05	206	0.0	na	87	26.7	21.1	0.00522	0.00211	0.0	6.7
11/30/05	207	4.1	16	97	18.3	12.9	0.00319	0.00129	0.3	7.7
12/20/05	317m	9.6	15	91	128.6	383.6	0.09479	0.03836	0.8	7.5
11/30/05	318	3.5	16	90	68.0	86.2	0.02130	0.00862	0.1	4.0
12/21/05	320	0.0	na	71	78.3	192.3	0.04753	0.01923	0.0	9.3
11/30/05	321m	3.0	18	93	113.2	216.1	0.05340	0.02161	0.2	6.5
12/21/05	323	0.0	na	97	34.2	46.4	0.01147	0.00464	0.0	5.7
11/15/05	325	35.4	23	84	1141.3	3899.9	0.96368	0.38999	2.3	4.2
11/29/05	326	25.6	17	104	231.1	466.5	0.11527	0.04665	2.1	6.1
12/21/05	453	15.2	27	86	234.8	1972.0	0.48729	0.19720	0.7	3.9
12/20/05	455m	17.2	17	87	78.6	132.7	0.03279	0.01327	1.3	6.0
12/20/05	457m	18.8	27	94	151.3	320.8	0.07928	0.03208	0.8	3.6
12/20/05	458m	0.0	na	95	127.8	296.4	0.07324	0.02964	0.0	6.8
12/23/05	461	41.2	27	89	244.3	1715.5	0.42391	0.17155	1.0	1.4
12/23/05	464	36.8	24	86	274.4	1971.3	0.48711	0.19713	0.7	1.2
12/21/05	466	7.7	26	83	54.1	65.3	0.01614	0.00653	0.3	4.0
01/25/06	467m	41.2	21	93	423.5	1196.6	0.29569	0.11966	4.5	6.5
11/16/05	470	36.4	19	89	211.0	1961.9	0.48480	0.19619	3.2	5.6
11/17/05	473	8.0	22	97	31.1	37.2	0.00918	0.00372	0.4	4.6
11/17/05	474	6.7	18	78	125.5	437.3	0.10806	0.04373	0.2	2.8
11/16/05	477m	28.4	20	87	176.1	630.5	0.15579	0.06305	1.9	4.8
11/29/05	480	0.0	na	110	30.8	52.3	0.01293	0.00523	0.0	6.3
11/29/05	482	0.0	na	95	53.5	72.1	0.01781	0.00721	0.0	13.2
11/15/05	484	33.3	20	84	41.6	34.0	0.00840	0.00340	0.7	1.4
11/16/05	485	12.4	17	96	108.9	207.8	0.05134	0.02078	1.4	9.9
11/16/05	486	7.4	17	91	89.2	197.8	0.04887	0.01978	6.0	7.5
11/16/05	487	34.5	17	100	70.9	127.2	0.03143	0.01272	4.8	9.1
11/16/05	489	20.9	21	101	34.1	58.9	0.01454	0.00589	0.9	3.4
11/29/05	490	3.2	18	98	44.8	69.8	0.01726	0.00698	0.1	4.3

Table A9. (continued)

Date	Reef_ID	Perc_Live	HT_Live	HT_Dead	Perimeter_m	Area_sqm	Acres	Hectares	Num_Live	Num_Dead
11/15/05	501	60.9	21	72	46.7	34.8	0.00860	0.00348	1.4	0.9
11/15/05	502	48.7	18	82	39.3	26.2	0.00646	0.00262	1.8	1.9
11/17/05	505	3.0	10	93	41.7	78.2	0.01931	0.00782	0.1	3.2
11/30/05	506	8.9	26	85	42.8	89.9	0.02221	0.00899	0.5	5.1
11/30/05	506b	0.0	na	0	17.2	11.0	0.00272	0.00110	0.0	0.0
11/30/05	507	4.9	14	110	51.8	92.6	0.02288	0.00926	0.3	5.6
11/30/05	508	0.0	na	110	41.5	56.0	0.01383	0.00560	0.0	0.8
11/30/05	509	22.2	18	103	94.7	126.6	0.03128	0.01266	0.9	3.0
12/20/05	511	33.3	33	100	46.5	123.4	0.03048	0.01234	1.0	2.0
12/21/05	512	na	na	na	80.9	287.1	0.07094	0.02871	na	na
12/21/05	513	9.5	21	89	12.0	9.0	0.00224	0.00090	2.0	19.0
12/21/05	514	10.0	33	95	14.8	13.9	0.00344	0.00139	1.0	9.0
12/21/05	516m	11.4	22	92	183.4	453.1	0.11195	0.04531	0.3	2.6

Table A10. Oyster polygon map details for St. Lucie Estuary, Loxahatchee River Estuary and Lake Worth Lagoon.

St. Lucie Estuary (SLpoly_2-9-07.shp)

Date	Reef_ID	Perc_Live	HT_Live	HT_Dead	Perimeter_m	Area_sqm	Acres	Hectares	Num_Live	Num_Dead
03/16/06	3	0.0	na	0	190.2	1516.8	0.37480	0.15168	0.0	0.0
03/16/06	4	0.0	na	0	148.1	1067.2	0.26371	0.10672	0.0	0.0
03/14/06	14	0.0	na	32	320.4	3003.3	0.74213	0.30033	0.0	0.3
03/16/06	16	0.0	na	78	154.9	1388.4	0.34309	0.13884	0.0	0.3
03/15/06	17	0.0	na	67	170.1	956.3	0.23631	0.09563	0.0	0.6

Loxahatchee River Estuary (LXpoly_2-9-07.shp)

Date	Reef_ID	Perc_Live	HT_Live	HT_Dead	Perimeter_m	Area_sqm	Acres	Hectares	Num_Live	Num_Dead
01/10/06	1	86.9	45	50	385.8	2459.7	0.60780	0.24597	21.8	3.3
01/11/06	2	83.8	39	42	506.2	3973.5	0.98187	0.39735	37.2	7.2
03/08/06	30	72.6	43	49	163.1	597.8	0.14773	0.05978	20.4	7.7
03/07/06	51	90.5	53	48	119.7	180.3	0.04456	0.01803	57.2	6.0
03/07/06	71	91.2	53	47	42.5	94.5	0.02335	0.00945	223.0	21.5
03/07/06	72	89.4	60	55	27.8	56.4	0.01394	0.00564	207.0	24.5

Lake Worth Lagoon (LWpoly_2-9-07.shp)

Date	Reef_ID	Perc_Live	HT_Live	HT_Dead	Perimeter_m	Area_sqm	Acres	Hectares	Num_Live	Num_Dead
02/28/06	100	79.1	37	43	1124.8	10559.4	2.60929	1.05594	132.9	35.2
02/28/06	101	82.0	38	38	107.2	562.6	0.13903	0.05626	83.3	18.3
02/28/06	102	84.0	35	39	157.7	1406.0	0.34744	0.14060	17.0	17.0
02/28/06	103	78.9	35	38	151.2	870.0	0.21499	0.08700	35.7	9.6
03/01/06	200	75.8	30	33	382.7	1653.8	0.40866	0.16538	75.6	24.2
03/01/05	300	84.1	25	22	335.3	1816.2	0.44880	0.18162	50.1	9.5
03/02/06	400	82.0	38	31	655.3	1398.3	0.34552	0.13983	74.5	16.4
03/03/06	500	81.9	24	29	335.3	2322.4	0.57387	0.23224	57.0	12.6

Table A11. Oyster reef raster data details.

Location	Reef_ID	Reef Surface Files	Conf_Interval Files
Sebastian River	203	sr203_surface	sr203_ci
Sebastian River	204m	sr204m_surf	sr204m_ci
Sebastian River	205	sr205_surface	sr205_ci
Sebastian River	206	sr206_surface	sr206_ci
Sebastian River	207	sr207_surface	sr207_ci
Sebastian River	310	sr310_surface	sr310_ci
Sebastian River	311m	sr311m_surf	sr311m_ci
Sebastian River	312	sr312_surface	sr312_ci
Sebastian River	313	sr313_surface	sr313_ci
Sebastian River	317m	sr317m_surf	sr317m_ci
Sebastian River	318	sr318_surface	sr318_ci
Sebastian River	319	sr319idw_surf	
Sebastian River	320	sr320_surface	sr320_ci
Sebastian River	321m	sr321m_surf	sr321m_ci
Sebastian River	323	sr323_surface	sr323_ci
Sebastian River	325	sr325_surface	sr325_ci
Sebastian River	408	sr408idw_sur	
Sebastian River	411m	sr411msurface	sr411m_ci
Sebastian River	412m	sr412msurface	sr412m_ci
Sebastian River	413	sr413_surface	sr413_ci
Sebastian River	416m	sr416m_surf	sr416m_ci
Sebastian River	418	sr418_surface	sr418_ci
Sebastian River	419	sr419_surface	sr419_ci
Sebastian River	421	sr421_surface	sr421_ci
Sebastian River	425	sr425_surface	sr425_ci
Sebastian River	426	sr426_surface	sr426_ci
Sebastian River	427	sr427_surface	sr427_ci
Sebastian River	428	sr428_surface	sr428_ci
Sebastian River	431	sr431_surface	sr431_ci
Sebastian River	432m	sr432_surf	sr432m_ci
Sebastian River	433m	sr433_surf	sr433m_ci
Sebastian River	435	sr435_surface	sr435_ci
Sebastian River	445m	sr445m_surf	sr445m_ci
Sebastian River	448m	sr448m_surf	sr448m_ci
Sebastian River	452m	sr452m_surf	sr452m_ci
Sebastian River	453	sr453_surface	sr453_ci
Sebastian River	455m	sr455m_surf	sr455m_ci
Sebastian River	457m	sr457m_surf	sr457m_ci
Sebastian River	458m	sr458m_surf	sr458m_ci
Sebastian River	465	sr465_surface	sr465_ci
Sebastian River	466	sr466_surface	sr466_ci
Sebastian River	467m	sr467m_surf	sr467_ci
Sebastian River	470	sr470_surface	sr470_ci
Sebastian River	473	sr473_surface	sr473_ci
Sebastian River	474	sr474_surface	sr474_ci
Sebastian River	477m	sr477m_surf	sr477m_ci
Sebastian River	484	sr484_surface	sr484_ci
Sebastian River	501	sr501_surface	sr501_ci
Sebastian River	502	sr502_surface	sr502_ci

Table A11. (continued)

Location	Reef_ID	Reef Surface Files	Conf_Interval Files
Sebastian River	505	sr505idw_surf	
Sebastian River	506	sr506_surface	sr506_ci
Sebastian River	506b	sr506b_surf	sr506b
Sebastian River	507	sr507_surface	sr507_ci
Sebastian River	508	sr508_surface	sr508_ci
Sebastian River	509	sr509_surface	sr509_ci
Sebastian River	511	sr511_surface	sr511_ci
Sebastian River	512	sr512_surface	sr512ci
Sebastian River	513	sr513idw_surf	
Sebastian River	514	sr514idw_surf	
Sebastian River	516m	sr516m_surf	sr516m_ci
Sebastian River	517	sr517_surface	sr517_ci
Sebastian River	520	sr520_surface	sr520_ci
Sebastian River	522	sr522idw_surf	
Sebastian River	523m	sr433_surf	sr523m_ci
Sebastian River	525m	sr433_surf	sr525m_ci
Sebastian River	526	sr526_surface	sr526_ci
Sebastian River	528	sr528_surface	sr528_ci
Sebastian River	532	sr532idw_surf	
Sebastian River	533	sr533_surface	sr533_ci
Sebastian River	535	sr535_surface	sr535_ci
Sebastian River	536	sr536_surface	sr536_ci
Sebastian River	537	sr537_surface	sr537_ci
Sebastian River	538m	sr433_surf	sr538m_ci
Sebastian River	542m	sr433_surf	sr542m_ci
Sebastian River	543	sr543_surface	sr543_ci
Sebastian River	544	sr544idw_surf	
Sebastian River	553	sr553_surface	sr553_ci
Sebastian River	554m	sr433_surf	sr554m_ci
Sebastian River	570	sr570idw_surf	
Sebastian River	572	sr572idw_surf	
Sebastian River	574	sr574idw_surf	
Sebastian River	575m	sr575m_comb	
Sebastian River	576	sr576idw_surf	
Sebastian River	577	sr577idw_surf	
Sebastian River	578	sr578_surface	sr578_ci
Sebastian River	580m	sr580msurface	sr580m_ci
Sebastian River	581	sr581_surface	sr581_ci
Sebastian River	584m	sr584m_idw	
Sebastian River	585	sr585_surface	sr585_ci
Sebastian River	586m	sr586msurface	sr586m_ci
Sebastian River	589	sr589surface	sr589_ci
Sebastian River	591	sr591surface	sr591_ci
Sebastian River	594m	sr594msurface	sr594m_ci
Sebastian River	595	sr595surface	sr595_ci
Sebastian River	596	sr596surface	sr596_ci
Sebastian River	597	sr597surface	sr597_ci
Sebastian River	599	sr599surface	sr599_ci
Sebastian River	600	sr600_surface	sr600ci

Table A11. (continued)

Location	Reef_ID	Reef Surface Files	Conf_Interval Files
Sebastian River	601	sr601_surface	sr601_ci
Sebastian River	602	sr602_surface	sr602_ci
Sebastian River	603	sr603_surface	sr603_ci
Sebastian River	610m	sr610msurface	sr610ci
Sebastian River	612	sr612surface	sr612ci
Sebastian River	613	sr613_surface	sr613_ci
Sebastian River	614	sr614_surface	sr614_ci
Sebastian River	616	sr616_surface	sr616_ci
Sebastian River	617	sr617_surface	sr617ci
Sebastian River	618	sr618_surface	sr618_ci
Sebastian River	619	sr619_surface	sr619_ci
Sebastian River	620	sr620_surface	sr620_ci
Sebastian River	621	sr621_surface	sr621_ci
Sebastian River	622	sr622_surface	sr622_ci
Sebastian River	623	sr623_surface	sr623_ci
Sebastian River	624	sr624idw_surf	
Sebastian River	625	sr625_surface	sr625_ci
Sebastian River	626	sr626_surface	sr626_ci
Sebastian River	628	sr628idw_surf	
St. Lucie Estuary	3	sl3	sl3ci_clip
St. Lucie Estuary	4	sl4	sl4ci_clip
St. Lucie Estuary	14	sl14	sl14ci_clip
St. Lucie Estuary	16	sl16	sl16ci_clip
St. Lucie Estuary	17	sl17	sl17ci_clip
Loxahatchee River	2	lxn2_surface	lxn2ci
Loxahatchee River	30	lxn30_surface	lxn30ci
Loxahatchee River	51	lxn51_surface	lxn51ci
Loxahatchee River	71	lxn71_surface	lxn71ci
Loxahatchee River	72	lxn72_surface	lxn72ci
Lake Worth Lagoon	100	lw100_surface	lw100ci_clip
Lake Worth Lagoon	101	lw101_surface	lw101ci_clip
Lake Worth Lagoon	102	lw102_surface	lw102ci_clip
Lake Worth Lagoon	103	lw103_surface	lw103ci_clip
Lake Worth Lagoon	200	lw200_surface	lw200ci_clip
Lake Worth Lagoon	300	lw300_surface	lw300ci_clip
Lake Worth Lagoon	500	lw500_surface	lw500ci_clip

Appendix II

Map Appendix

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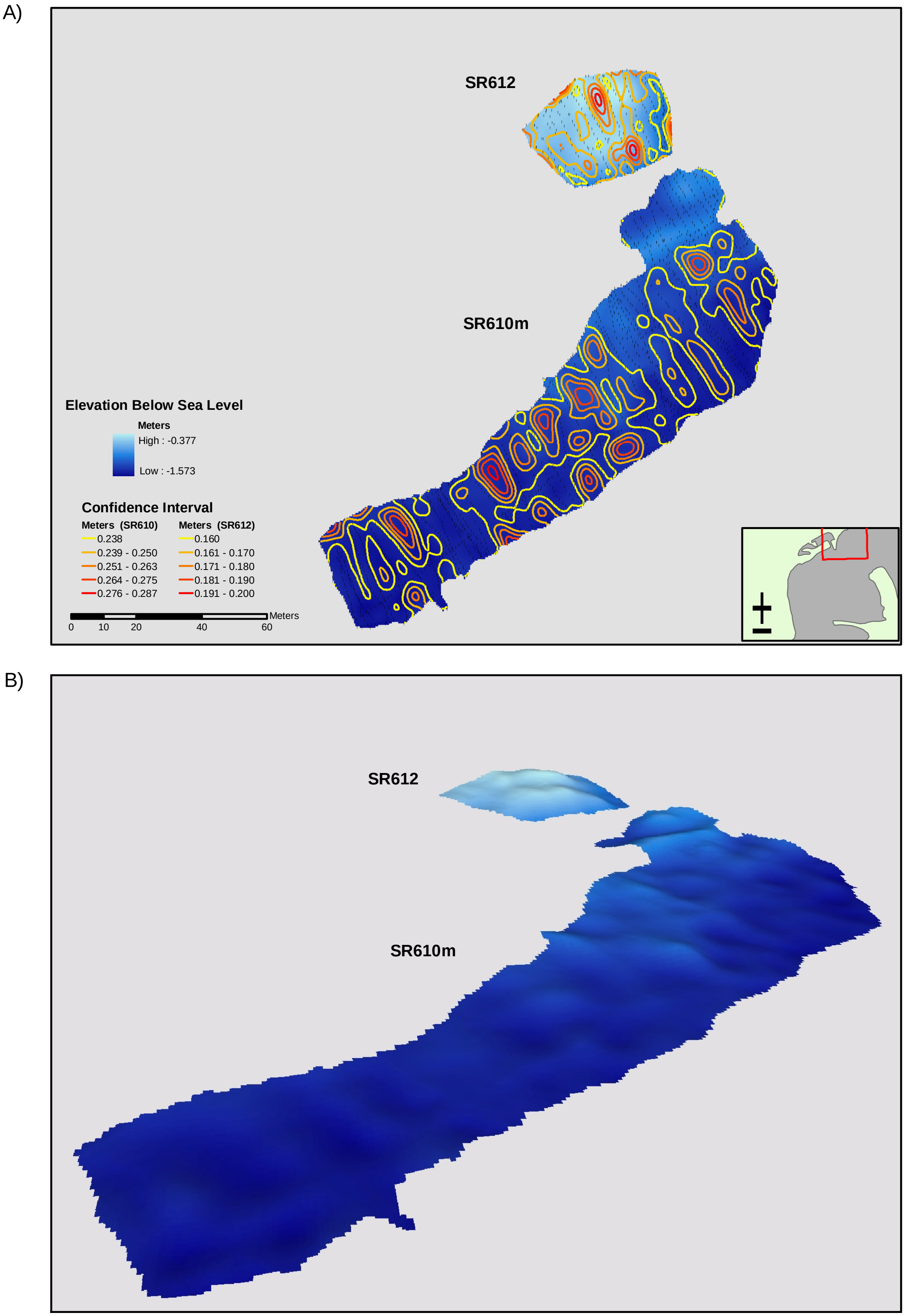
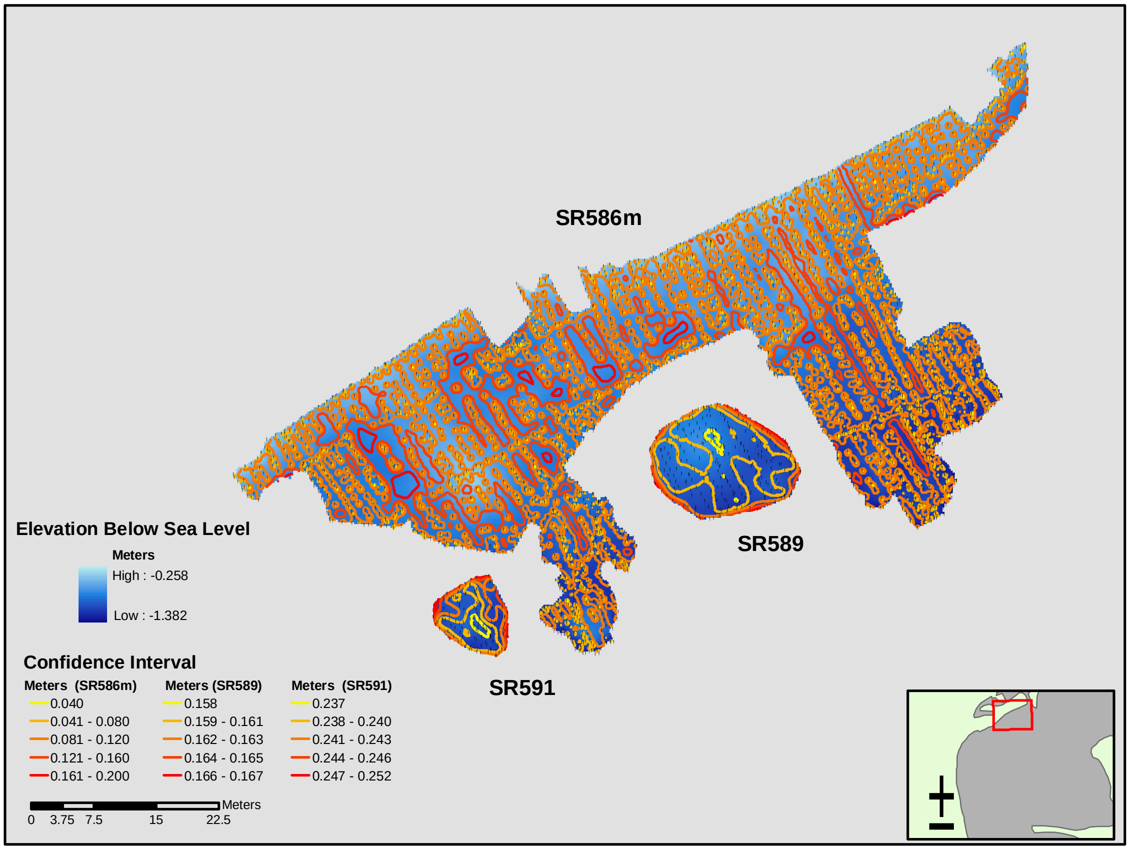


Figure A1. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR610m a nd SR612. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR610m and SR612 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

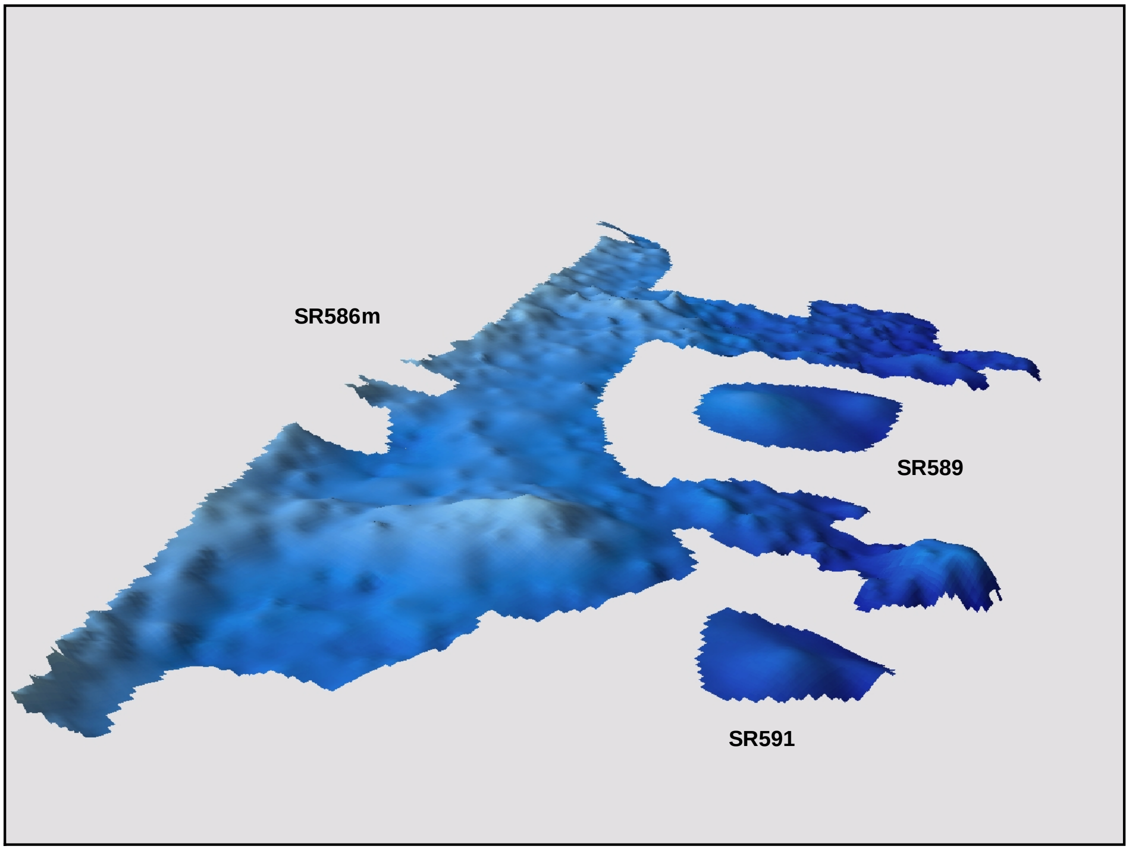


Figure A2. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR586m, SR589, and SR591. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR586m, SR589, and SR591 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

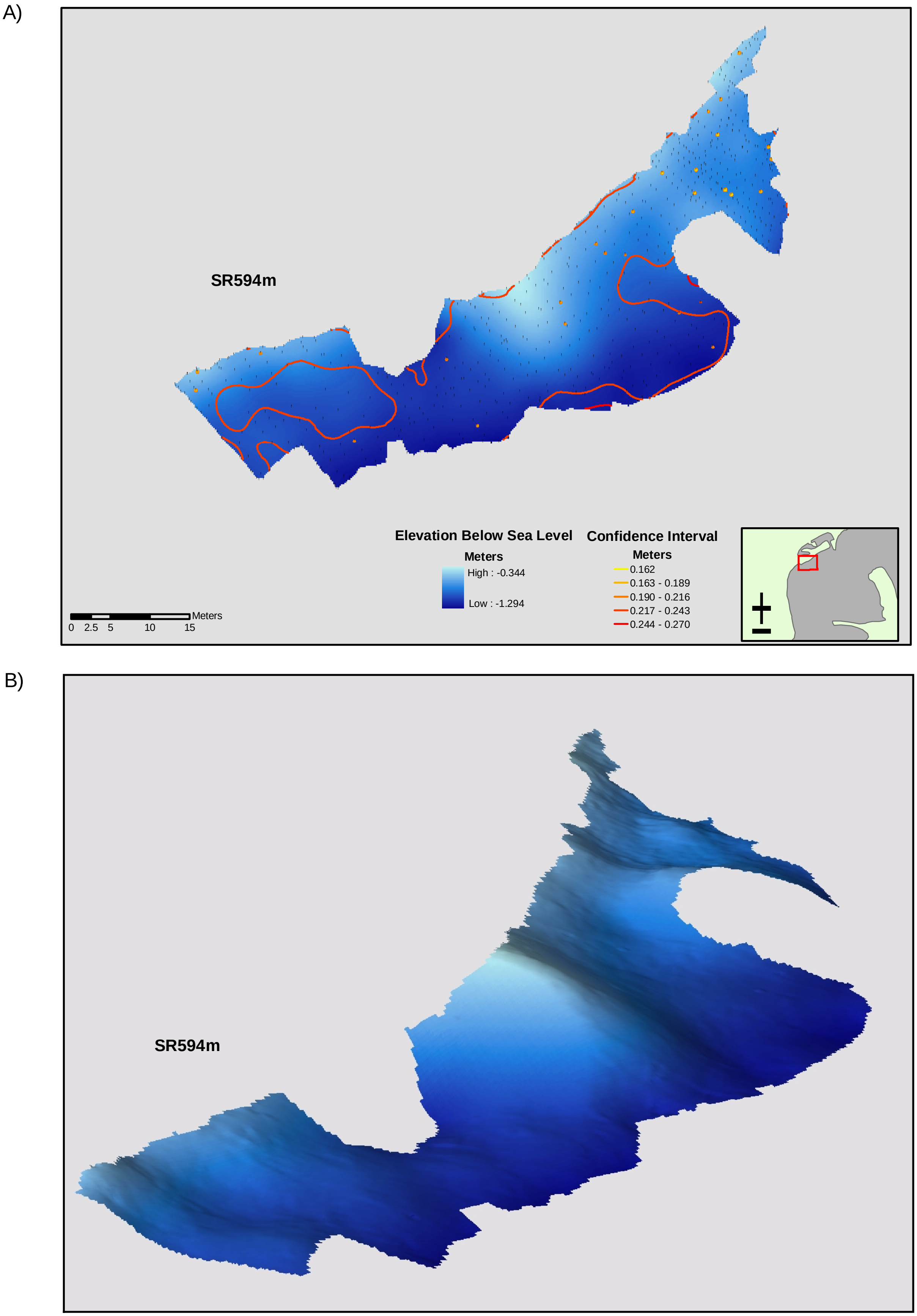


Figure A3. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR594m. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR594m based on the predicted surface elevations. The vertical relief has been exaggerated 10x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

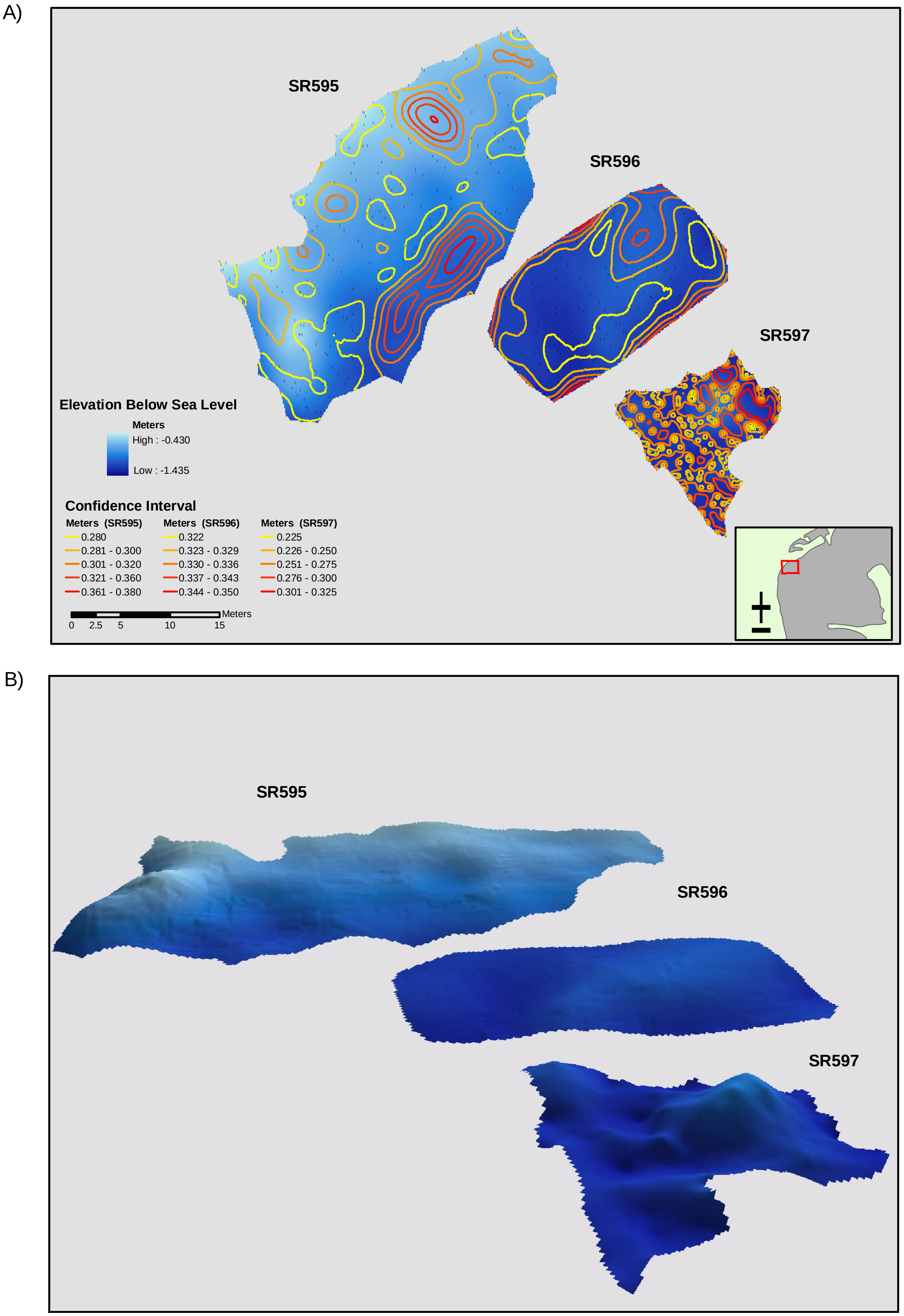


Figure A4. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR595, SR596, and SR597. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR595, SR596, and SR597 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

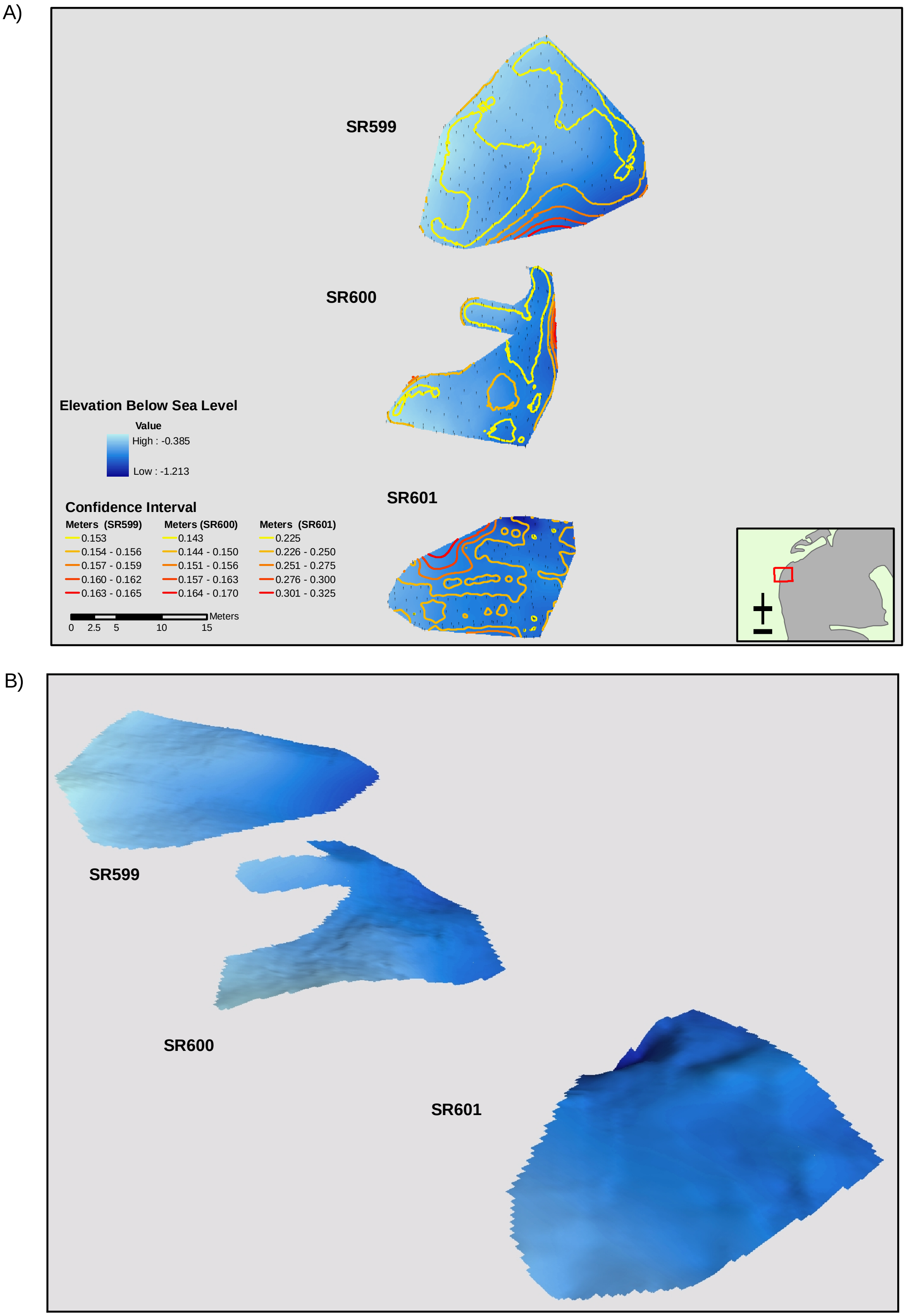


Figure A5. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR599, SR600, and SR601. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR599, SR600, and SR601 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

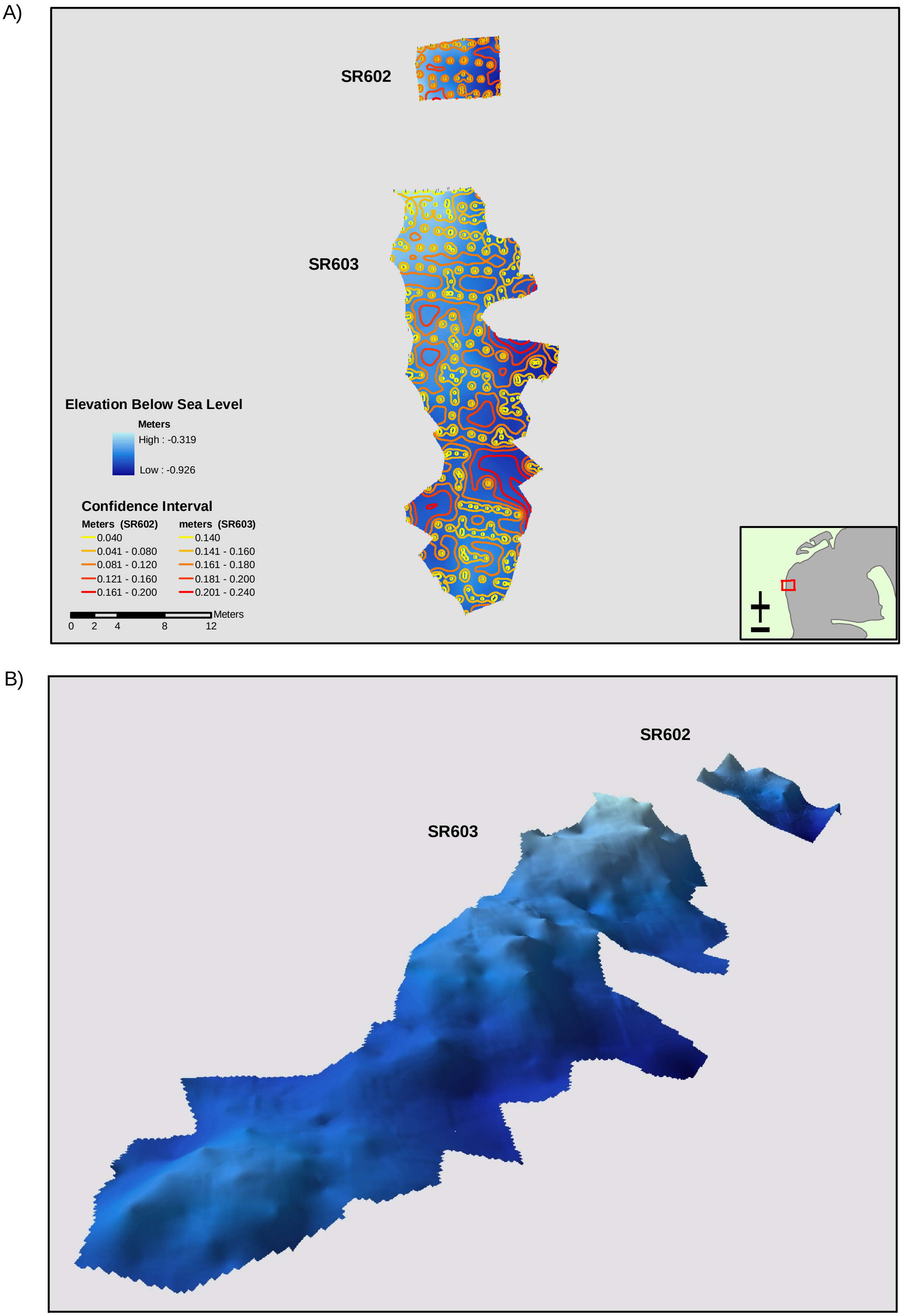
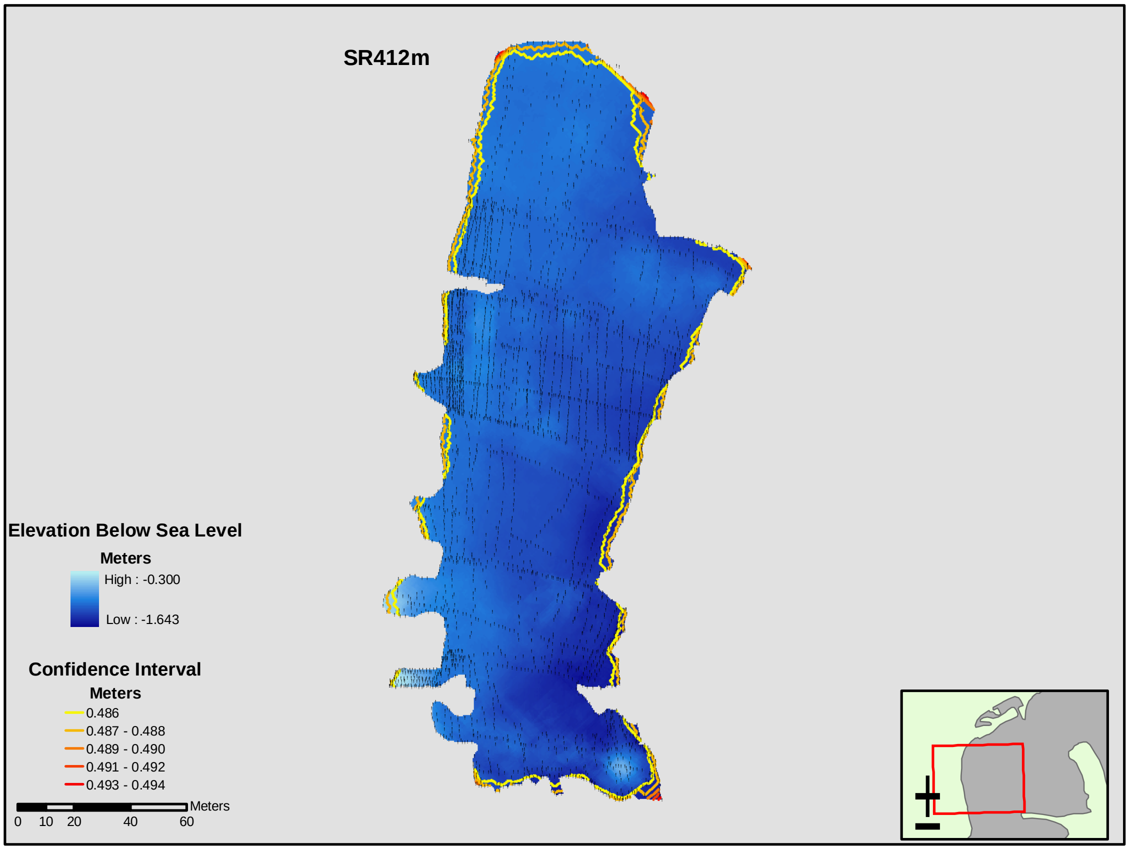


Figure A6. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR602 and SR603. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR602 and SR603 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

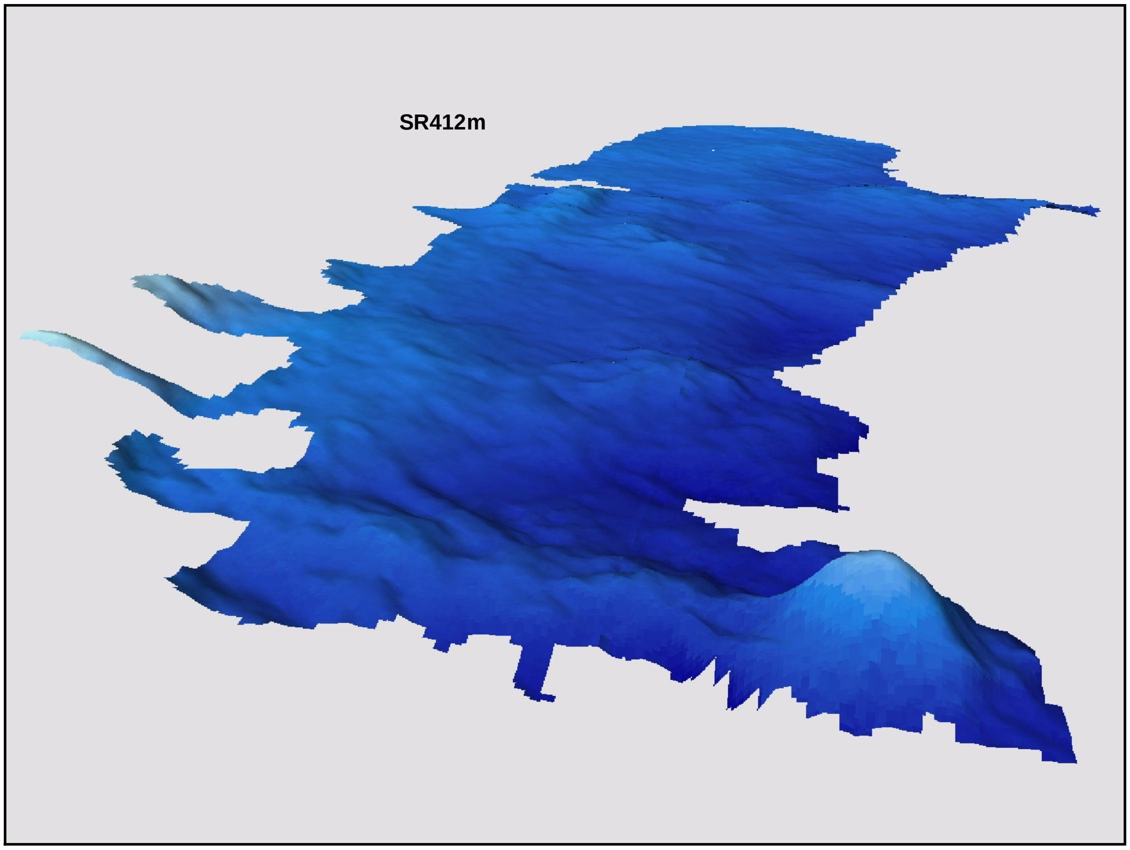
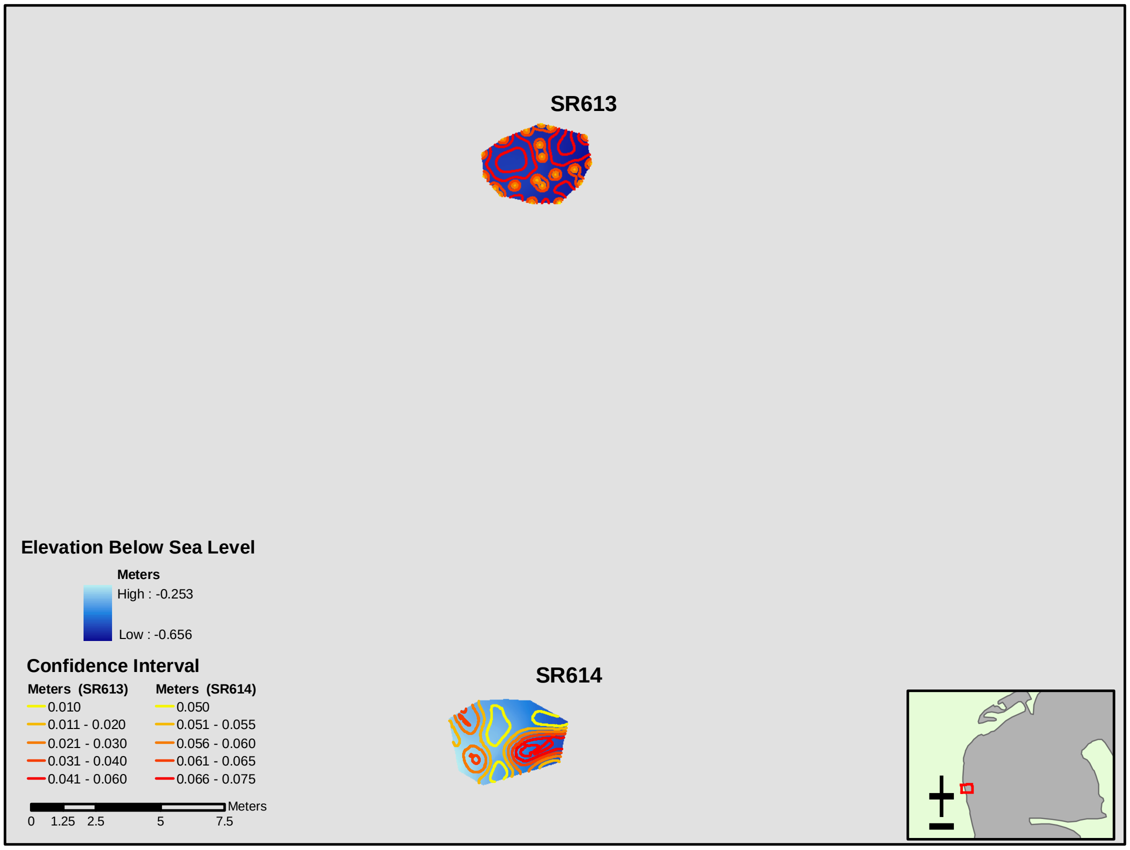


Figure A7. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR412m. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR412m based on the predicted surface elevations. The vertical relief has been exaggerated 10x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

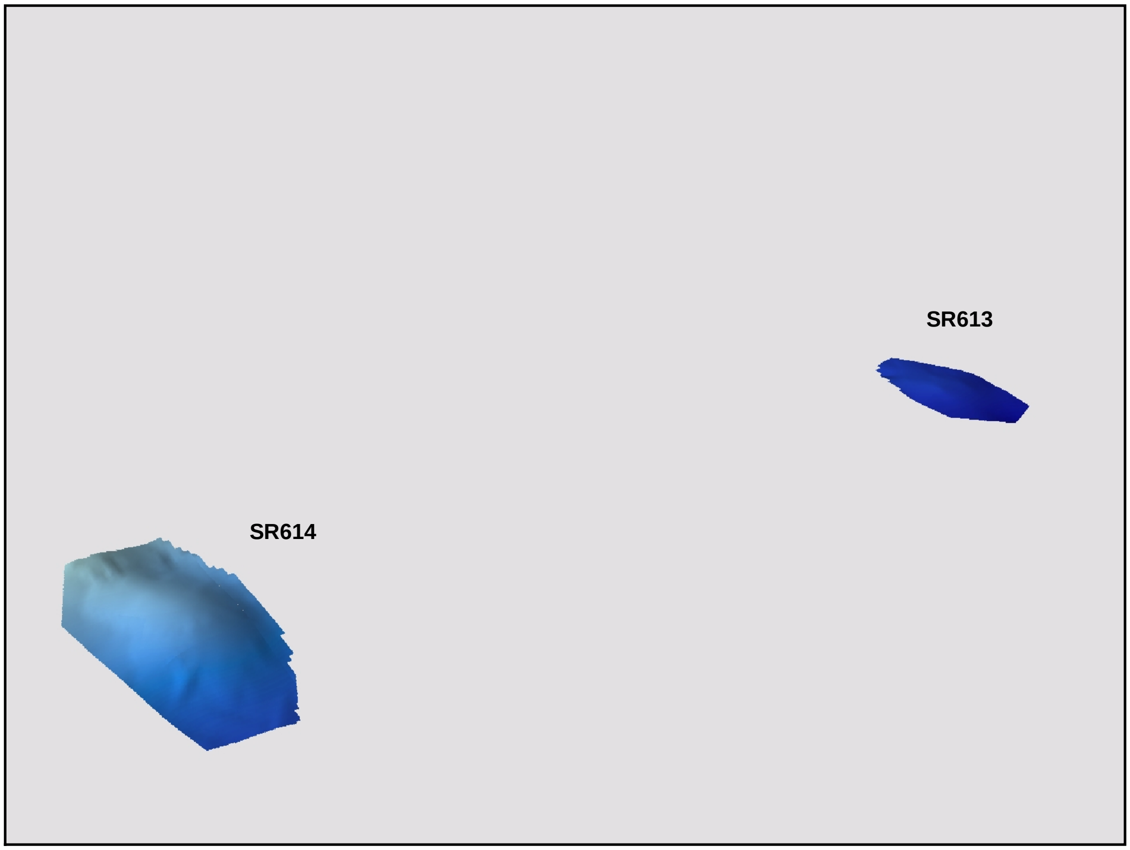


Figure A8. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR613 and SR614. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR613 and SR614 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

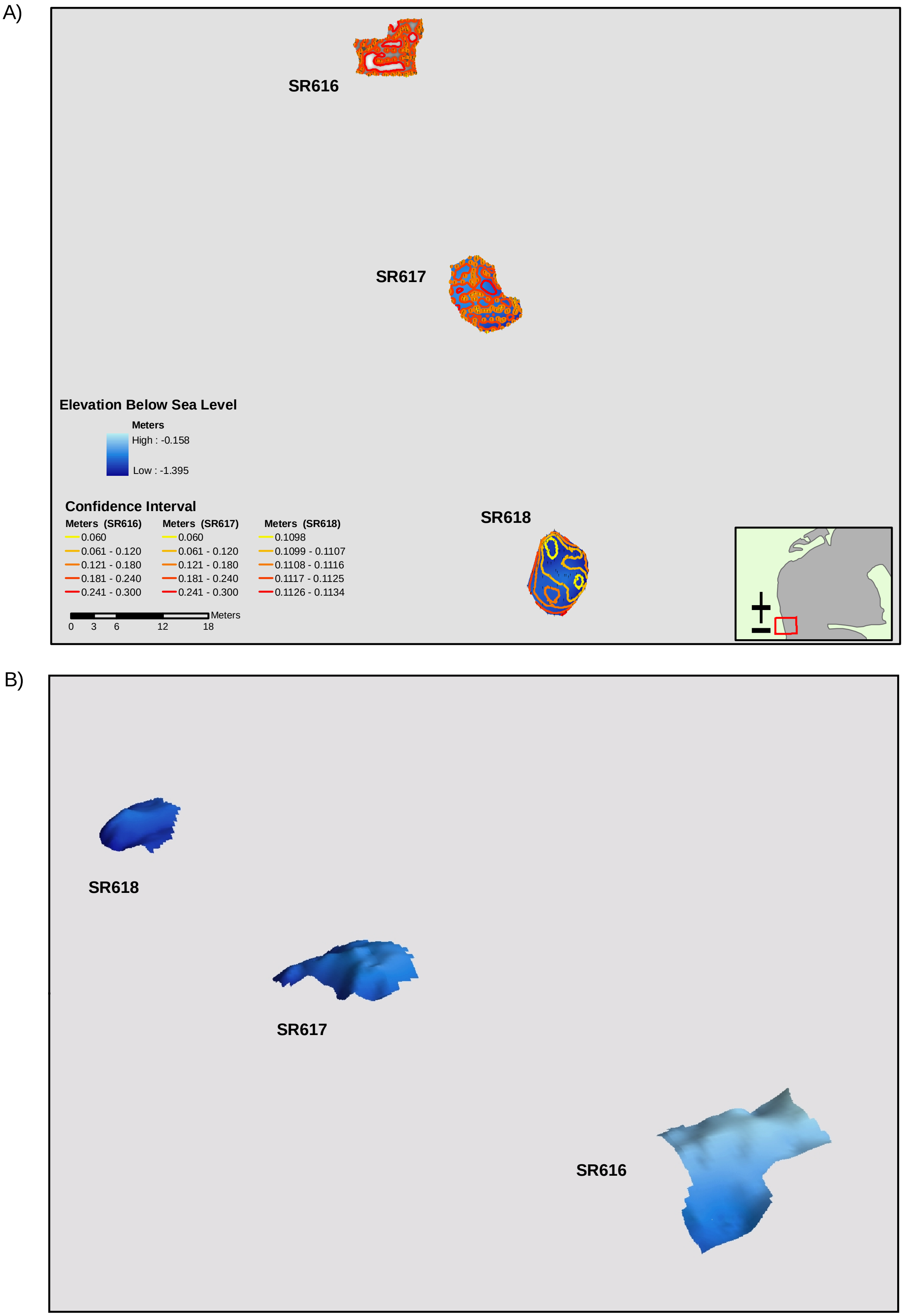


Figure A9. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR616, SR617, and SR618. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR616, SR617, and SR618 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

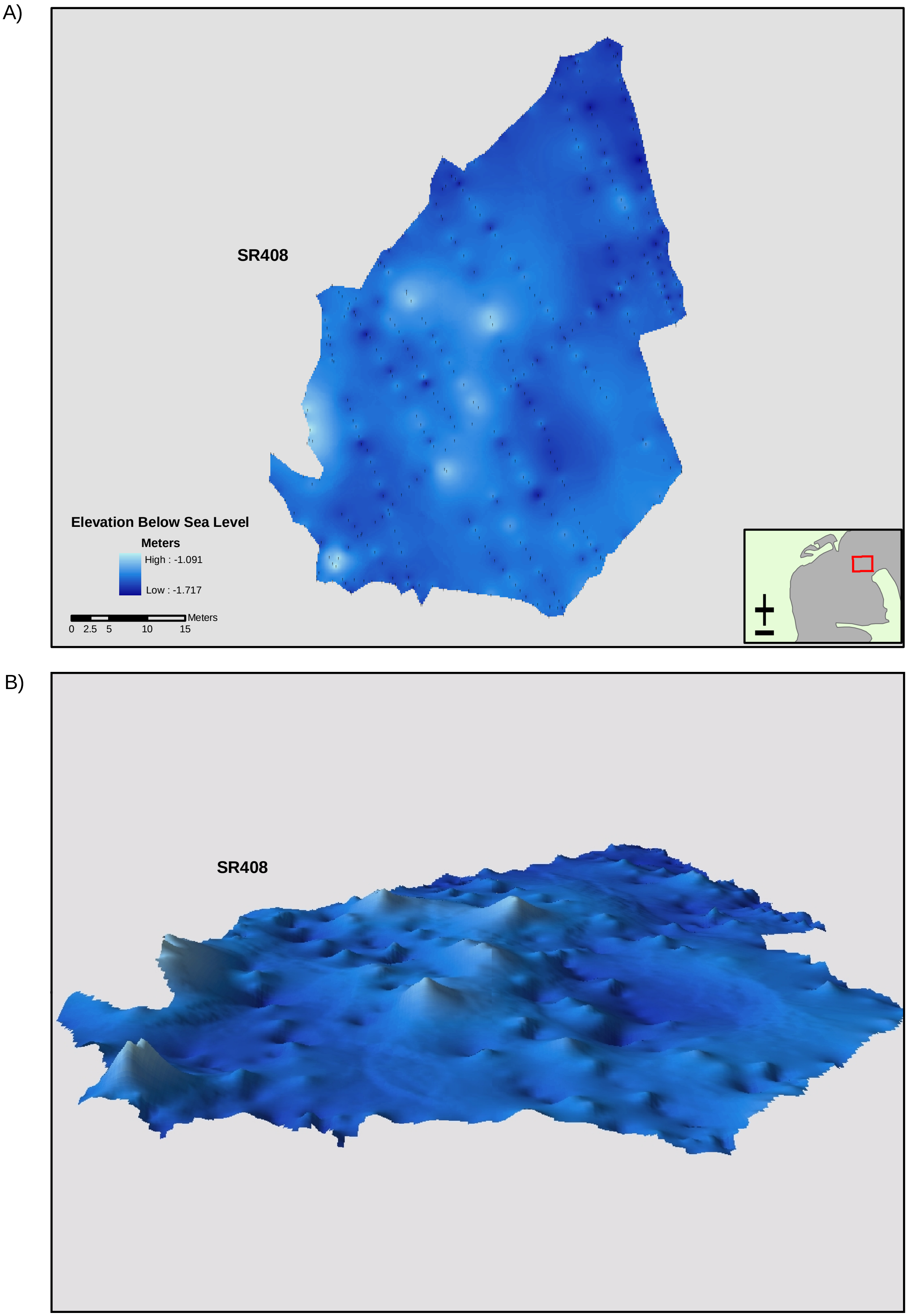


Figure A10. A) Predicted surface elevation and location of data points for reef SR408. Elevation is shown as meters below sea level. Location of data points are shown as single points. B) The three-dimensional model of reef SR408 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

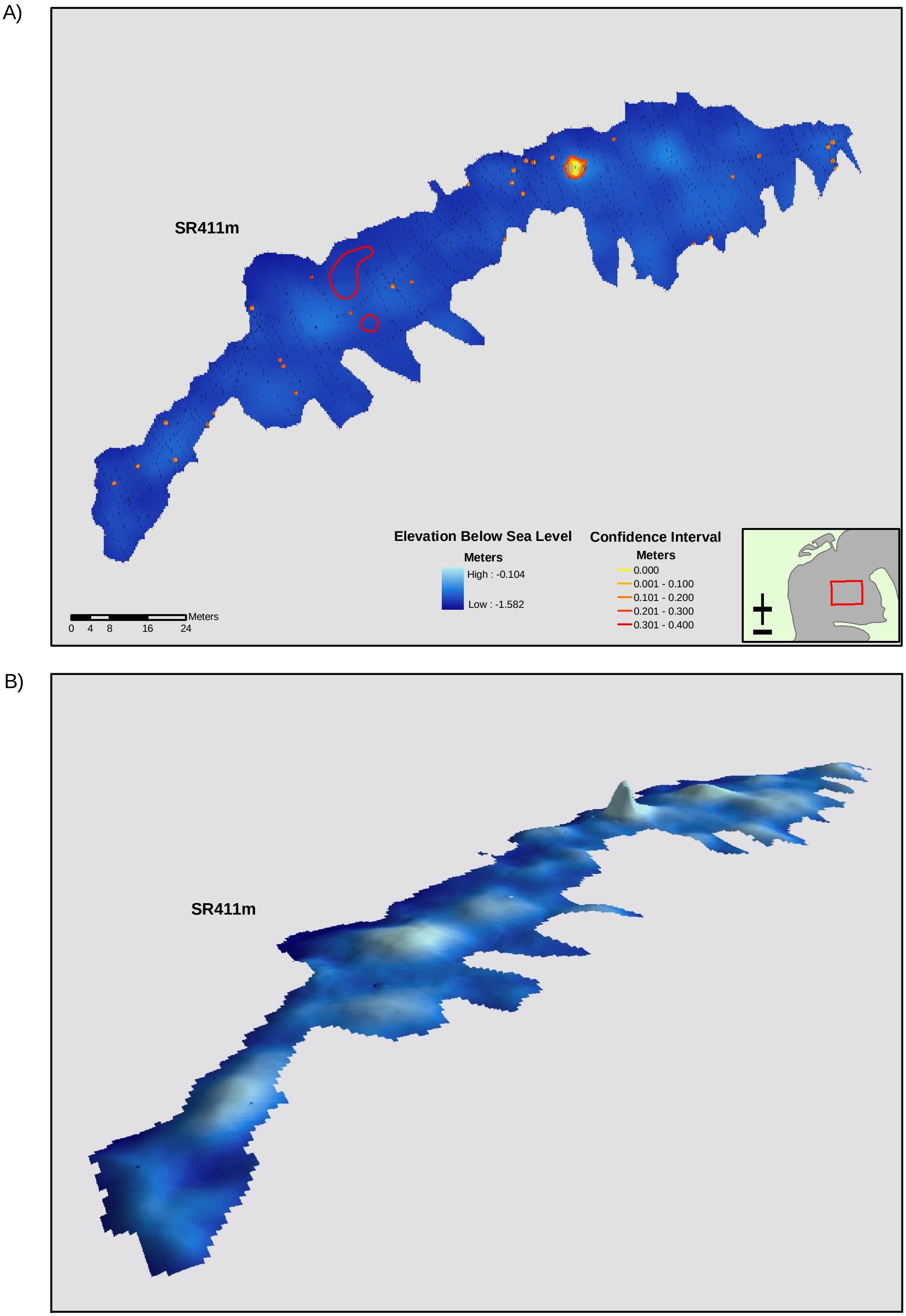
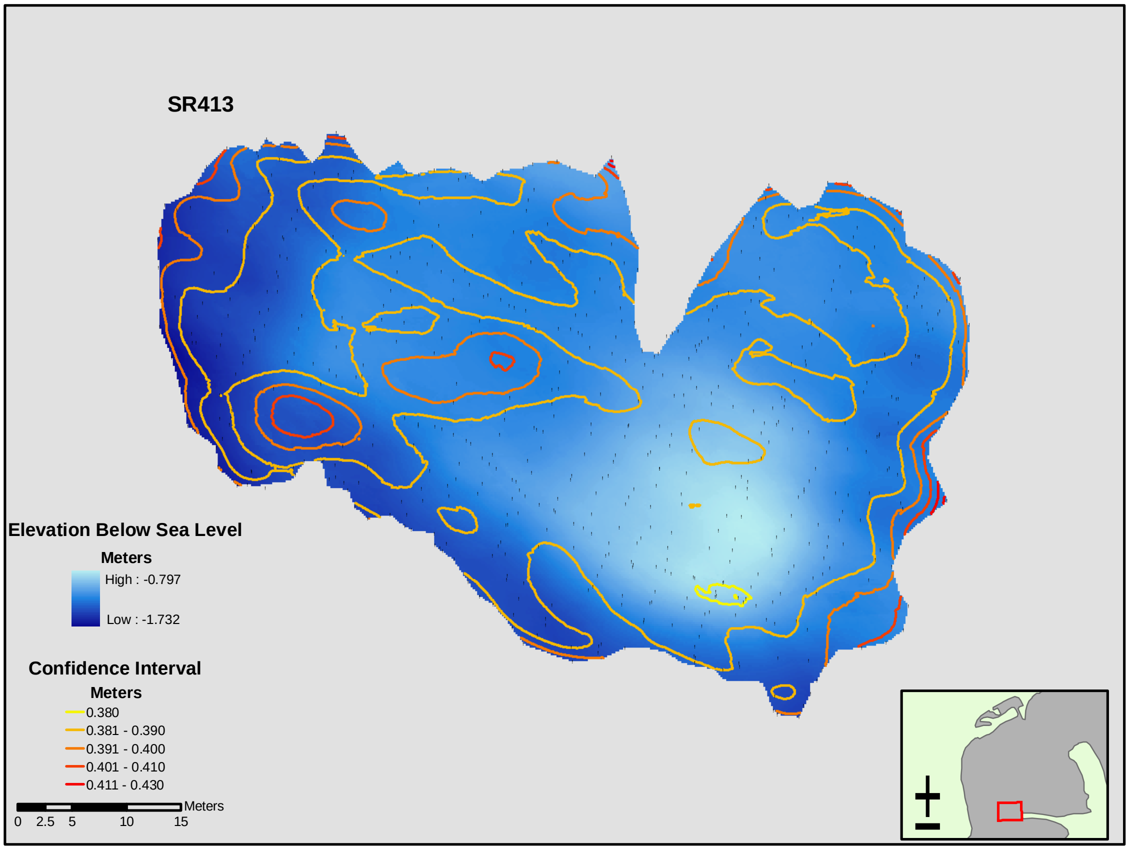


Figure A11. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR411m. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR411m based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

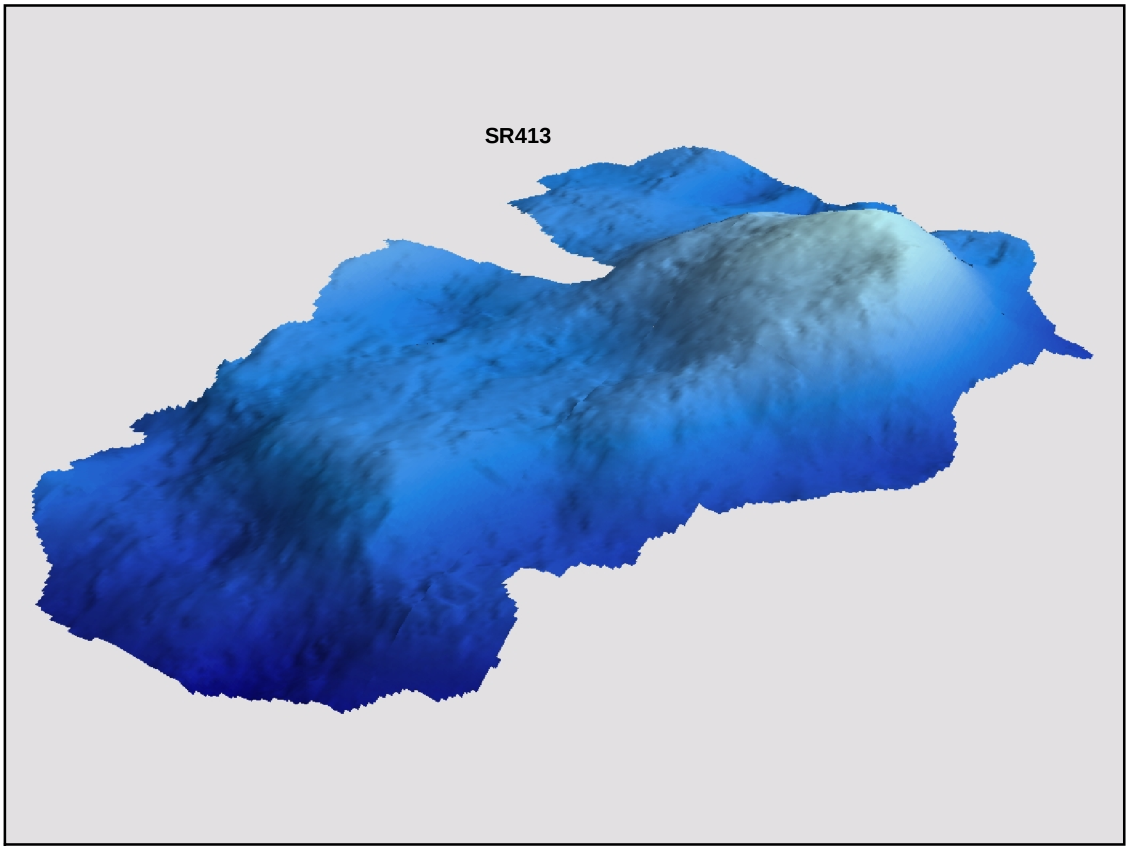
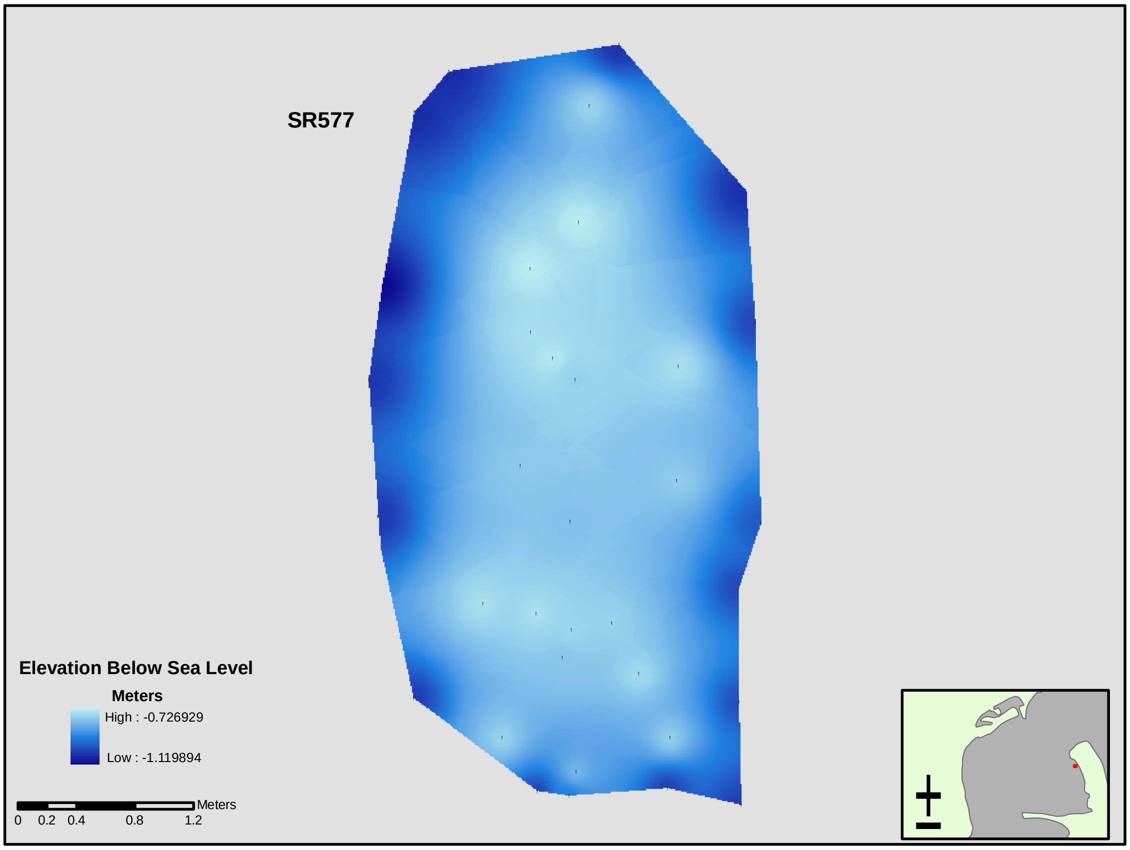


Figure A12. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR413. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR413 based on the predicted surface elevations. The vertical relief has been exaggerated 10x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

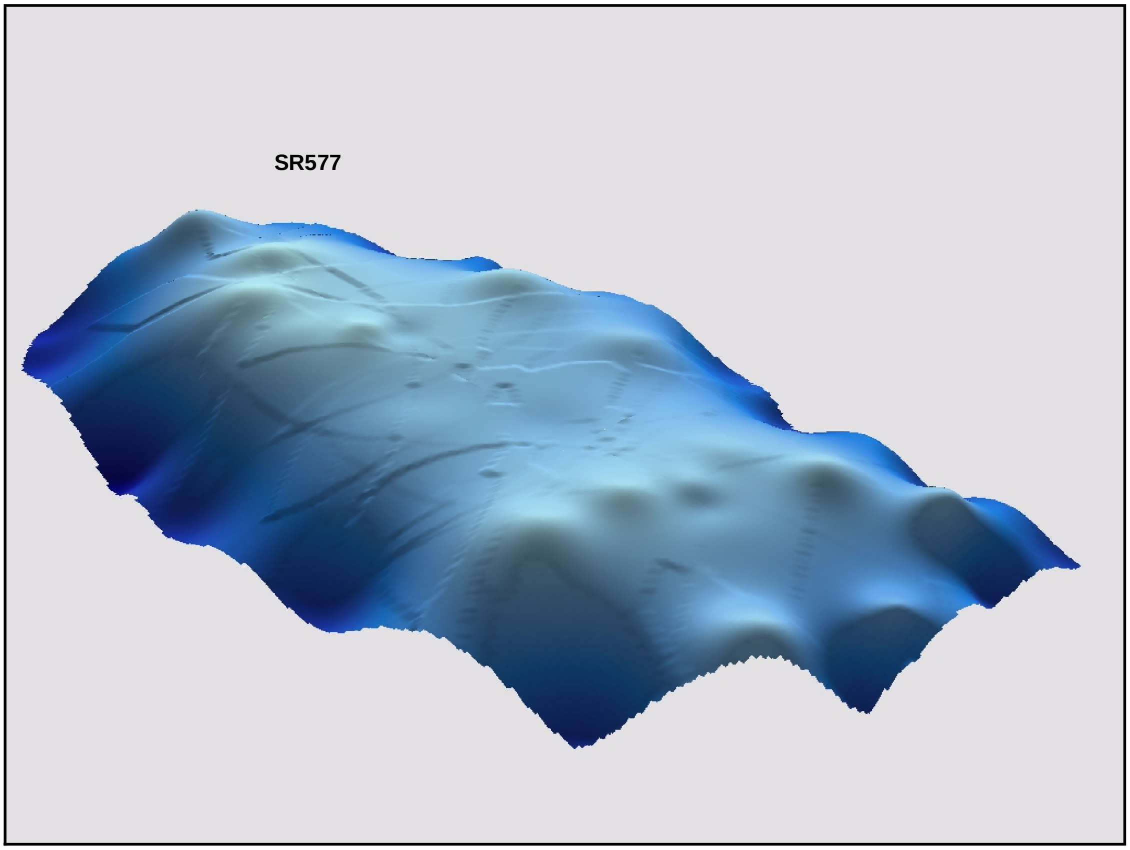


Figure A13. A) Predicted surface elevation and location of data points for reef SR577. Elevation is shown as meters below sea level. Location of data points are shown as single points. B) The three-dimensional model of reef SR577 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

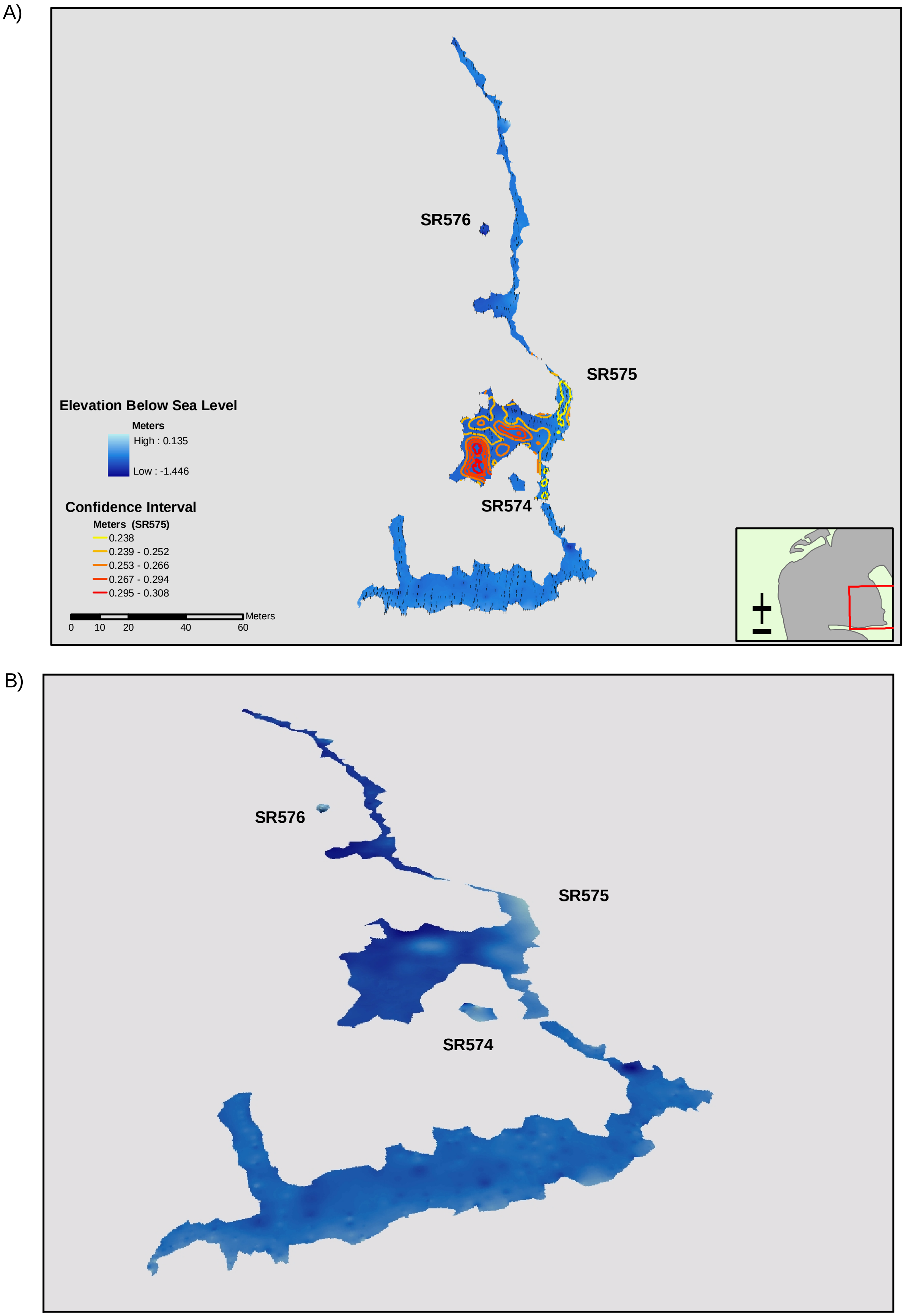


Figure A14. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR574, SR575, and SR576. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR574, SR575, and SR576 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

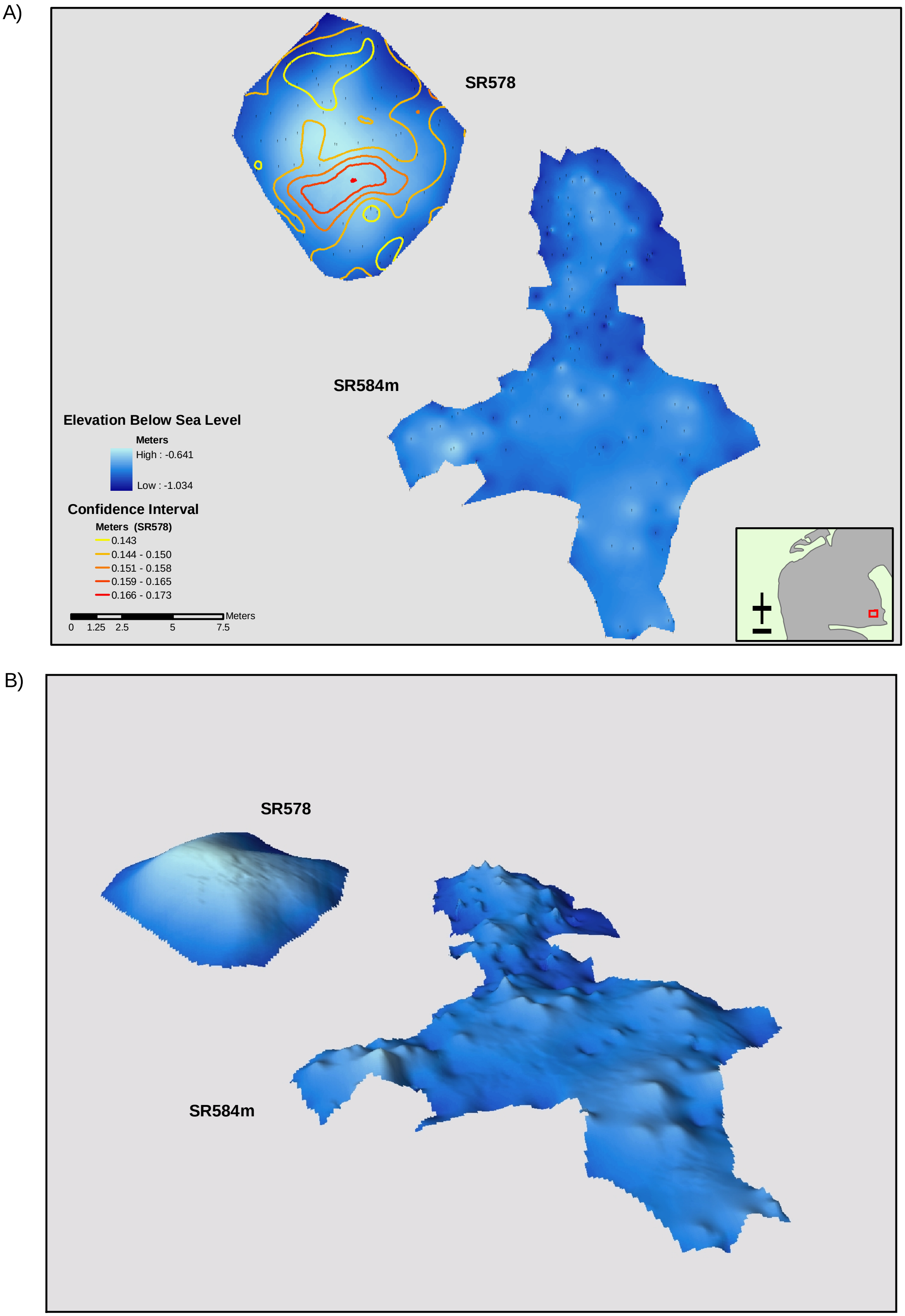


Figure A15. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR578 and SR584m. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR578 and SR584m based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

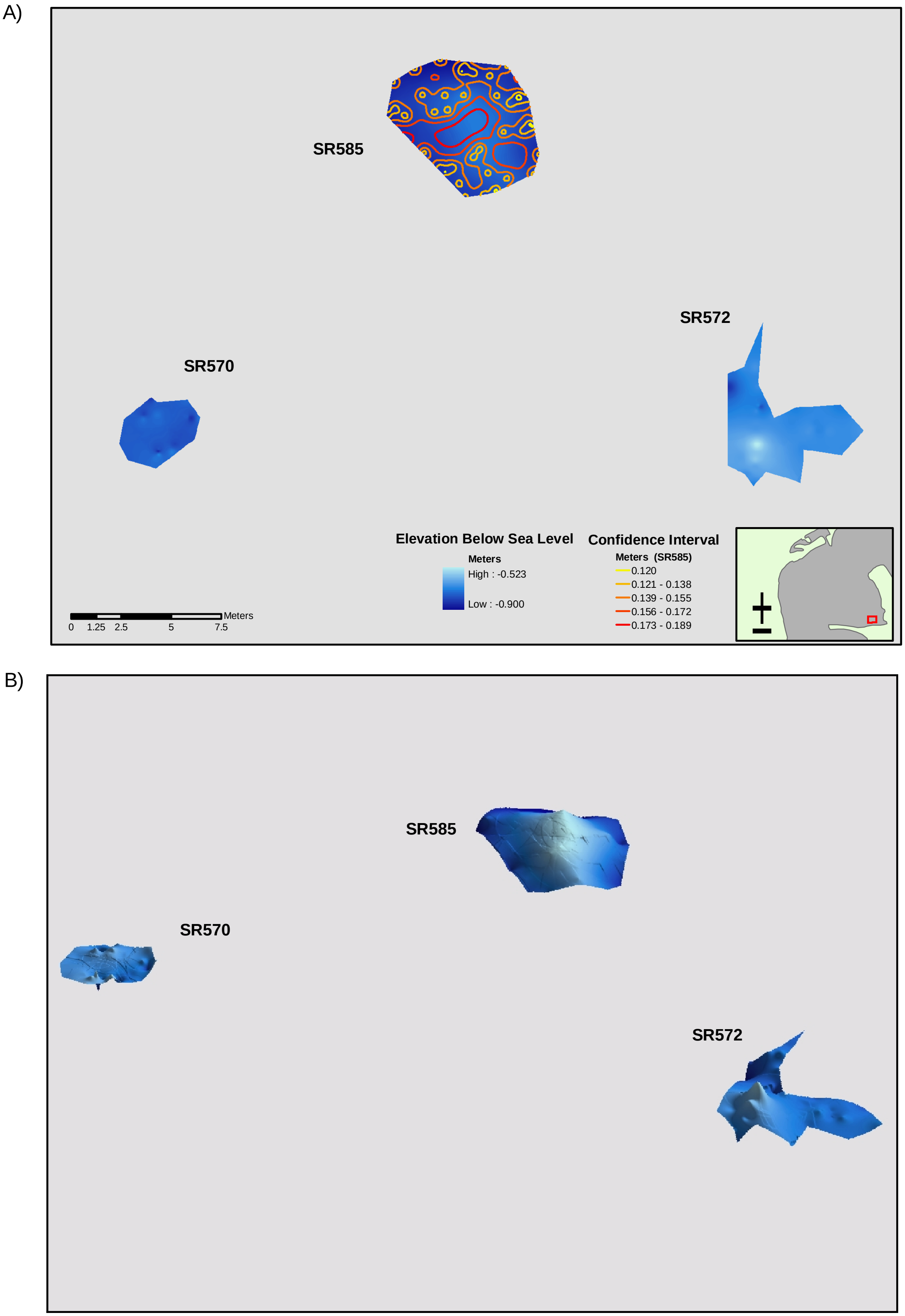


Figure A16. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR570, SR572, and SR585. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR570, SR572, and SR585 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

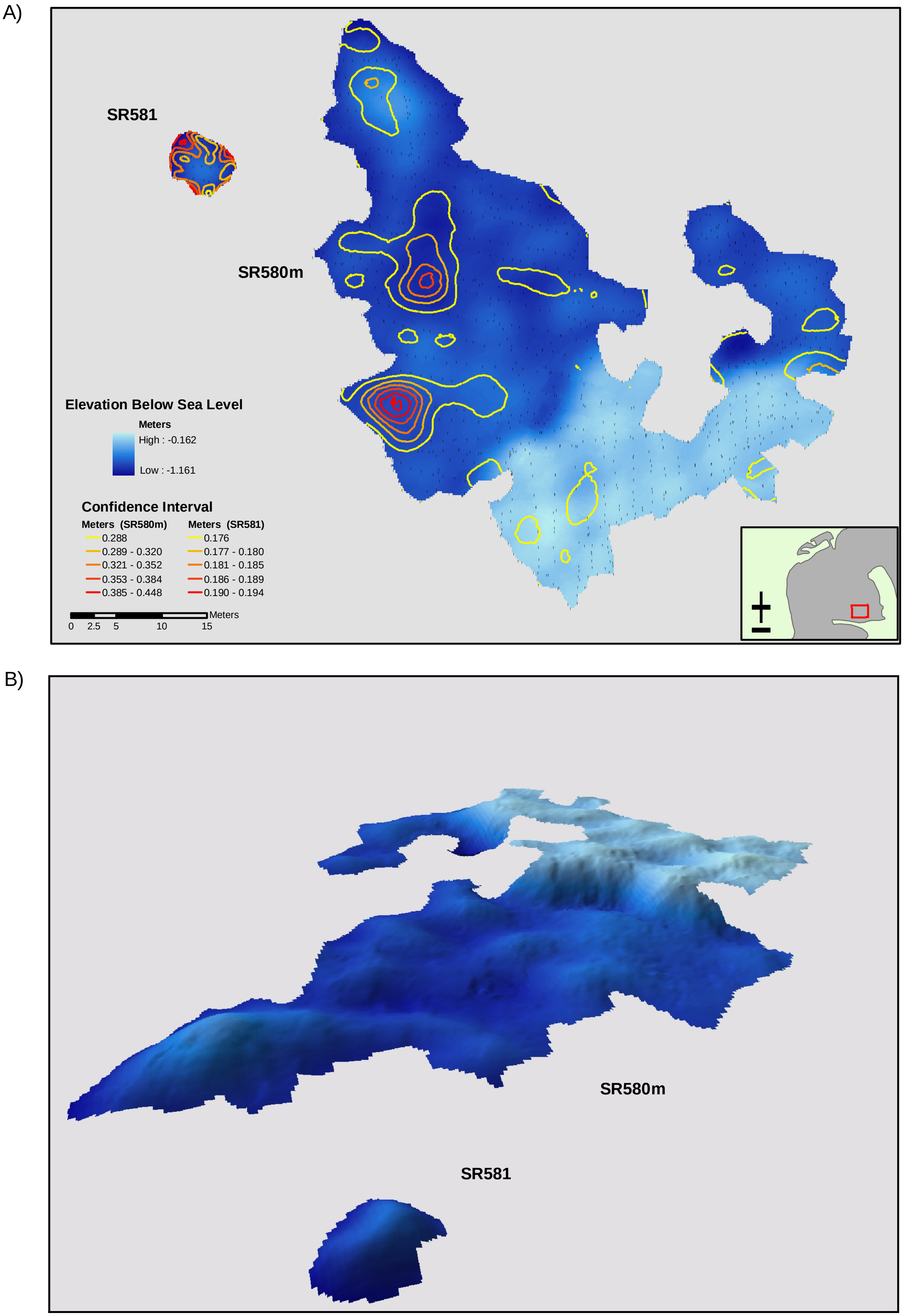
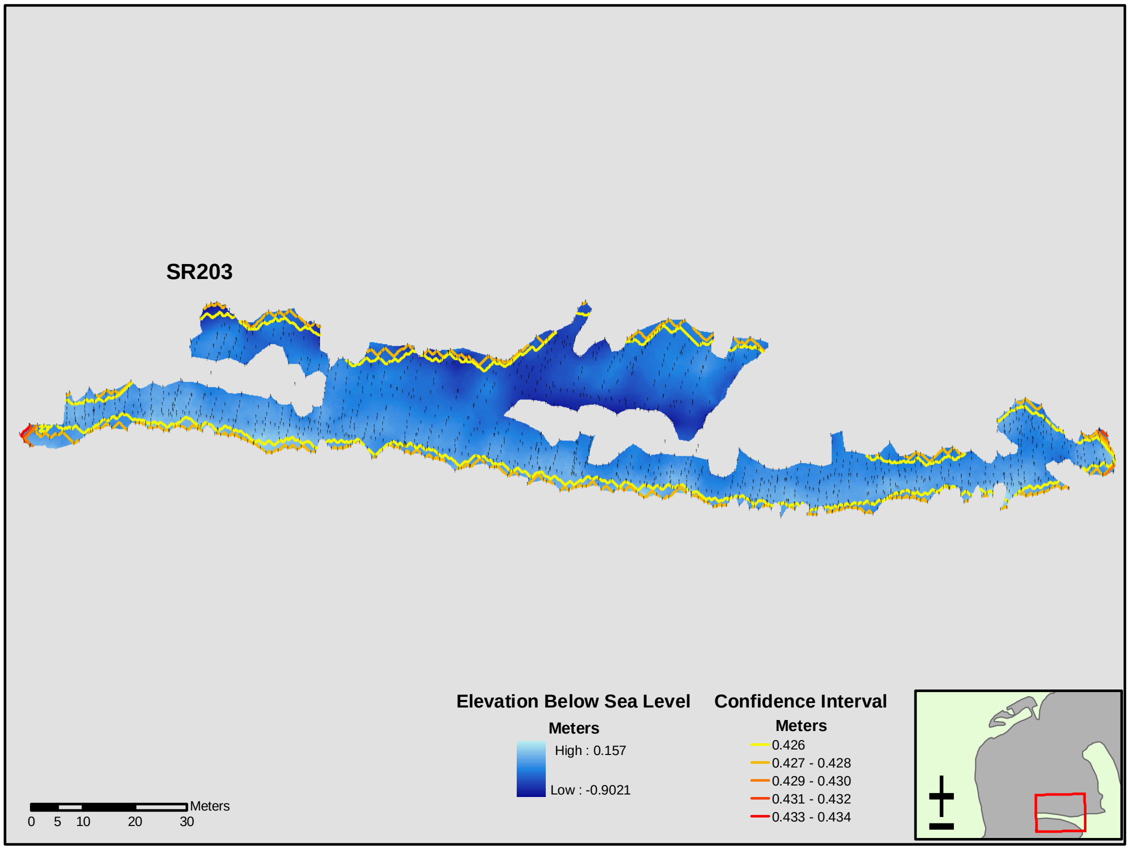


Figure A17. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR580m and SR581. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR580m and SR581 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

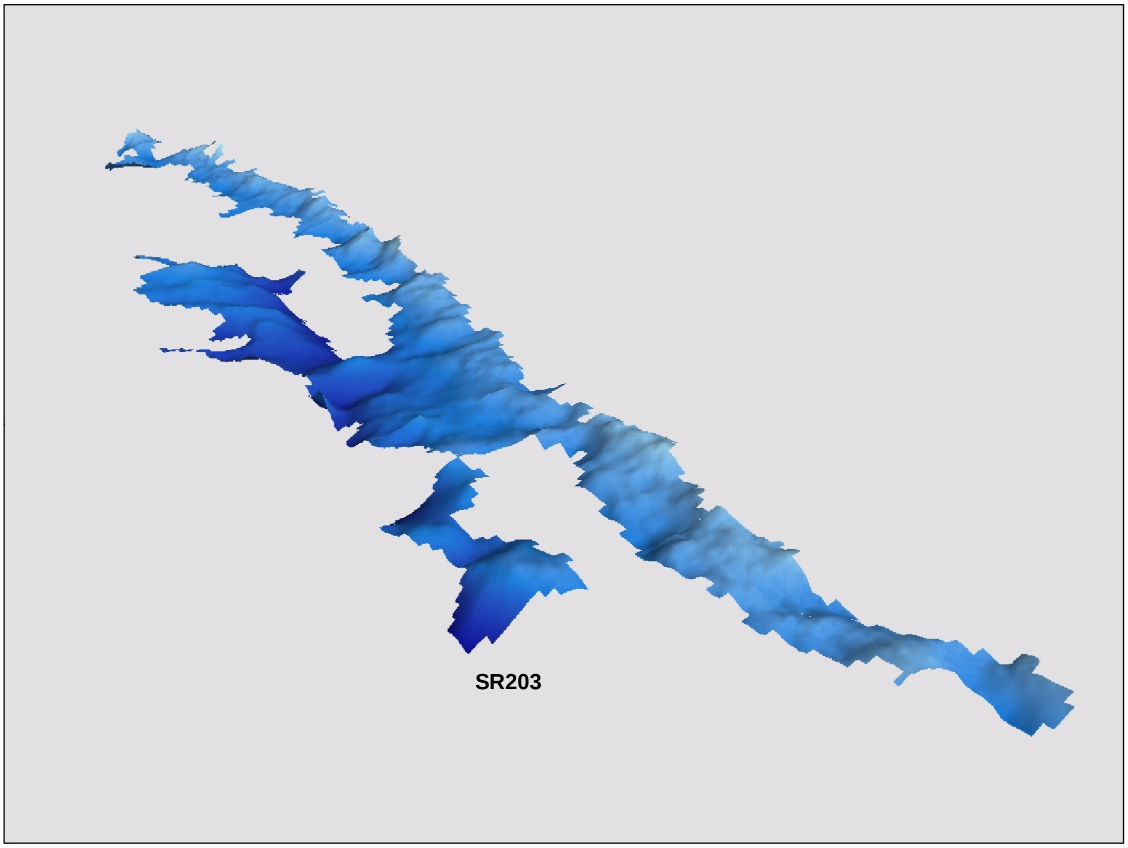


Figure A18. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR203. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR203 based on the predicted surface elevations. The vertical relief has been exaggerated 10x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

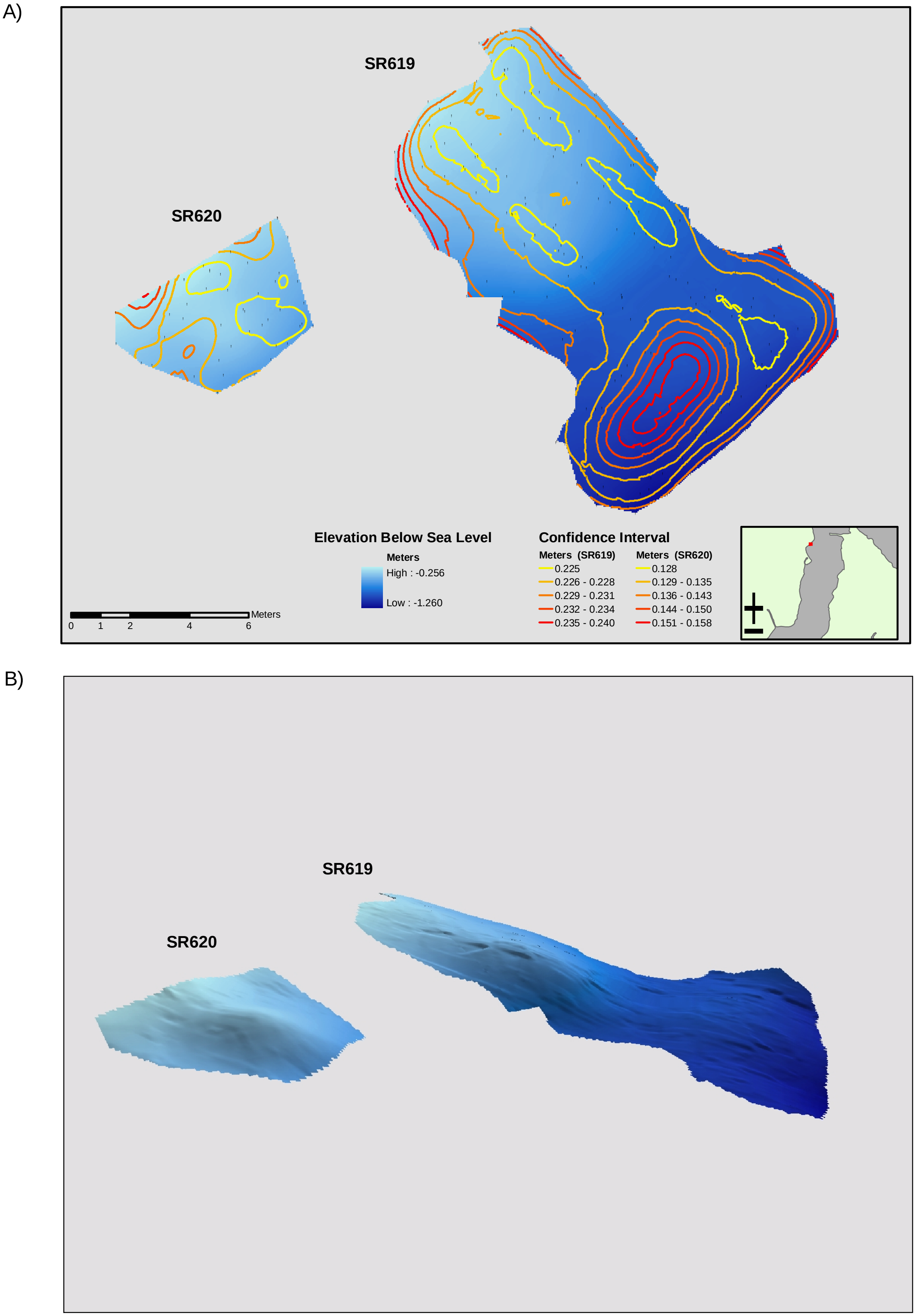


Figure A19. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR619 and SR620. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR619 and SR620 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

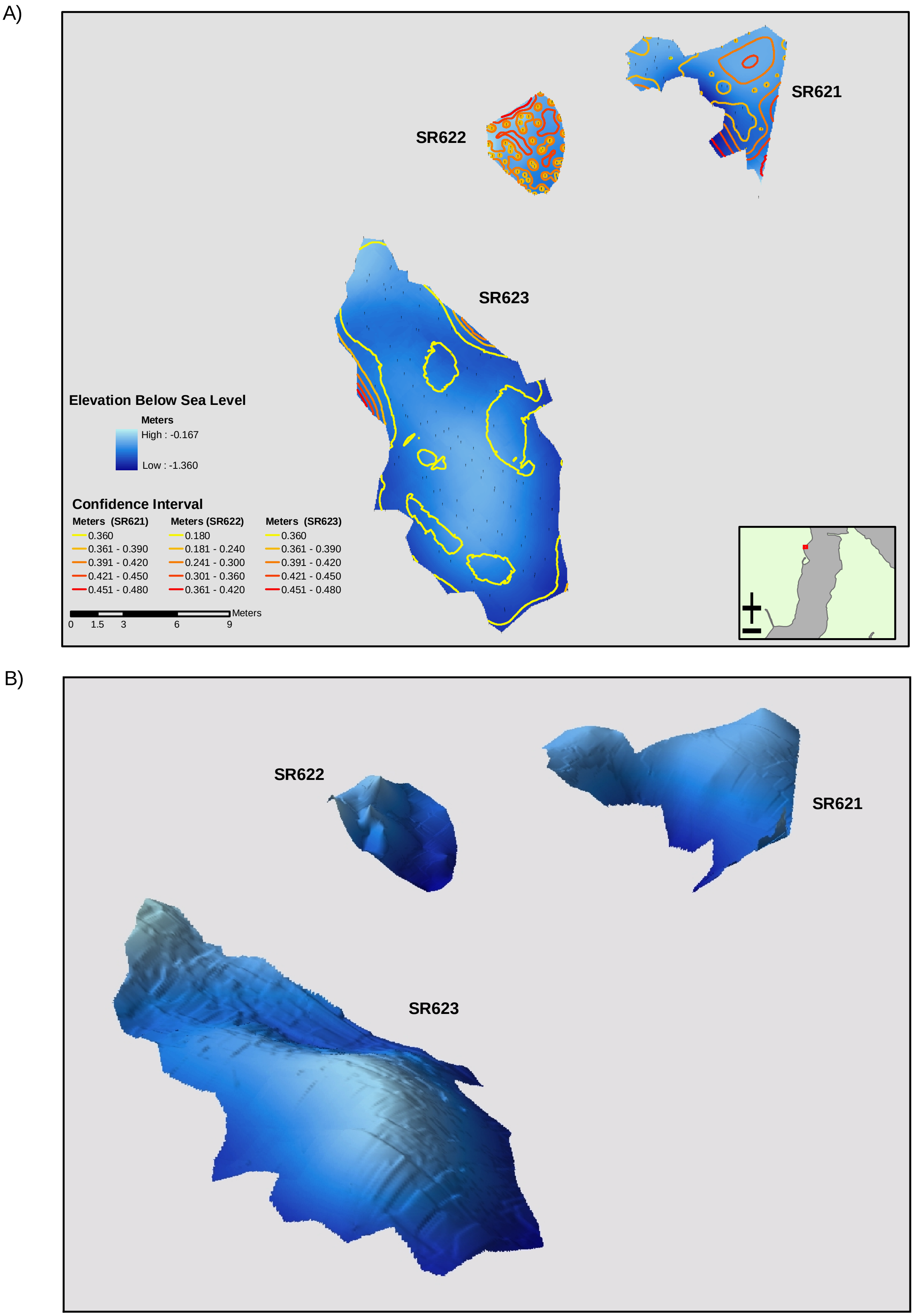


Figure A20. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR621, SR622, and SR623. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR621, SR622, and SR623 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

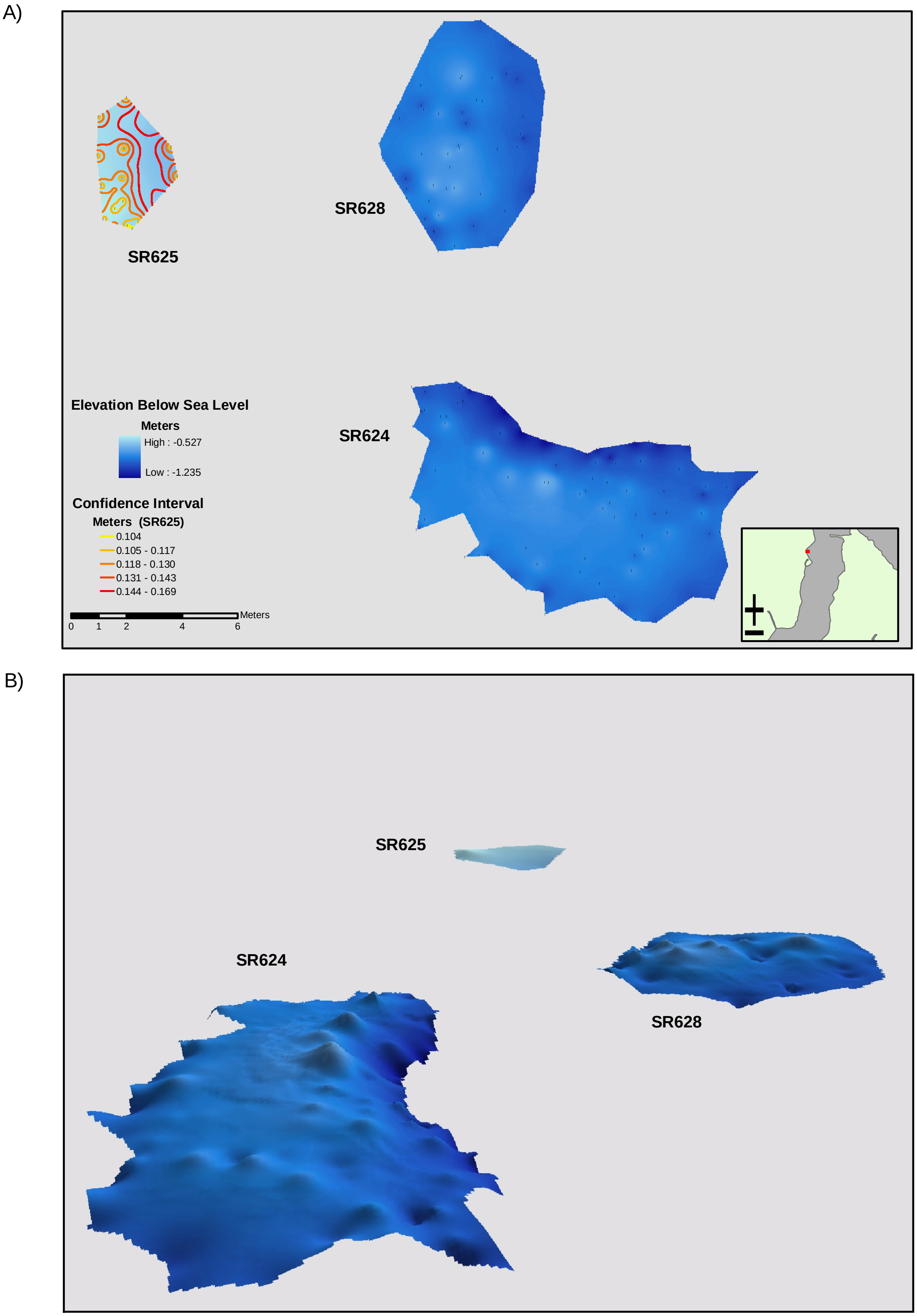
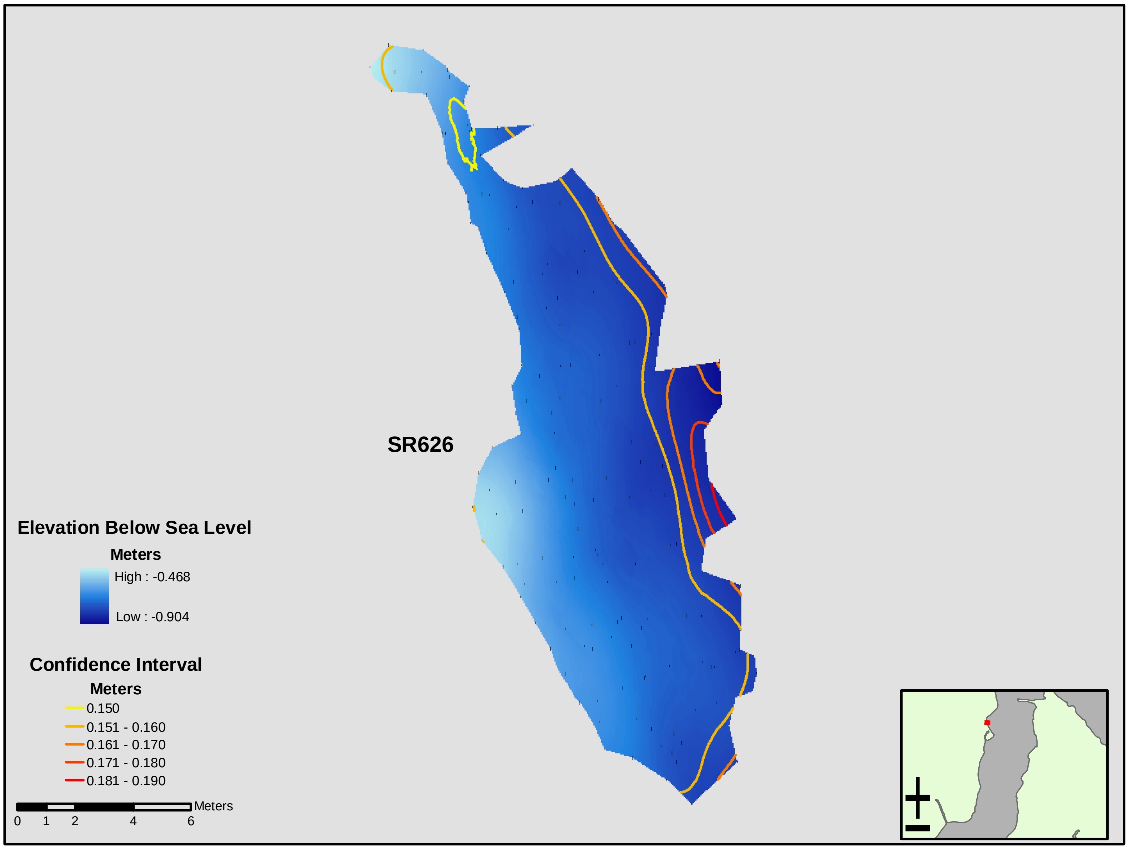


Figure A21. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR624, SR625, and SR628. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR624, SR625, and SR628 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

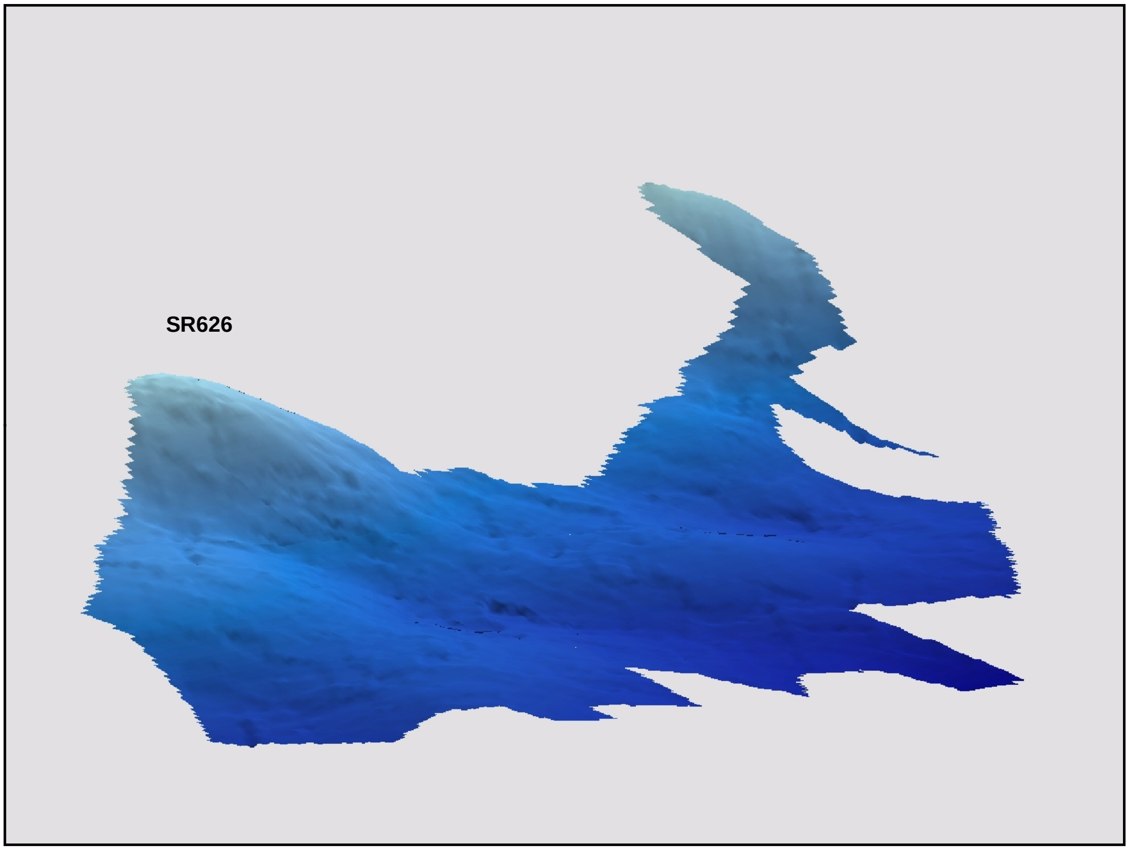
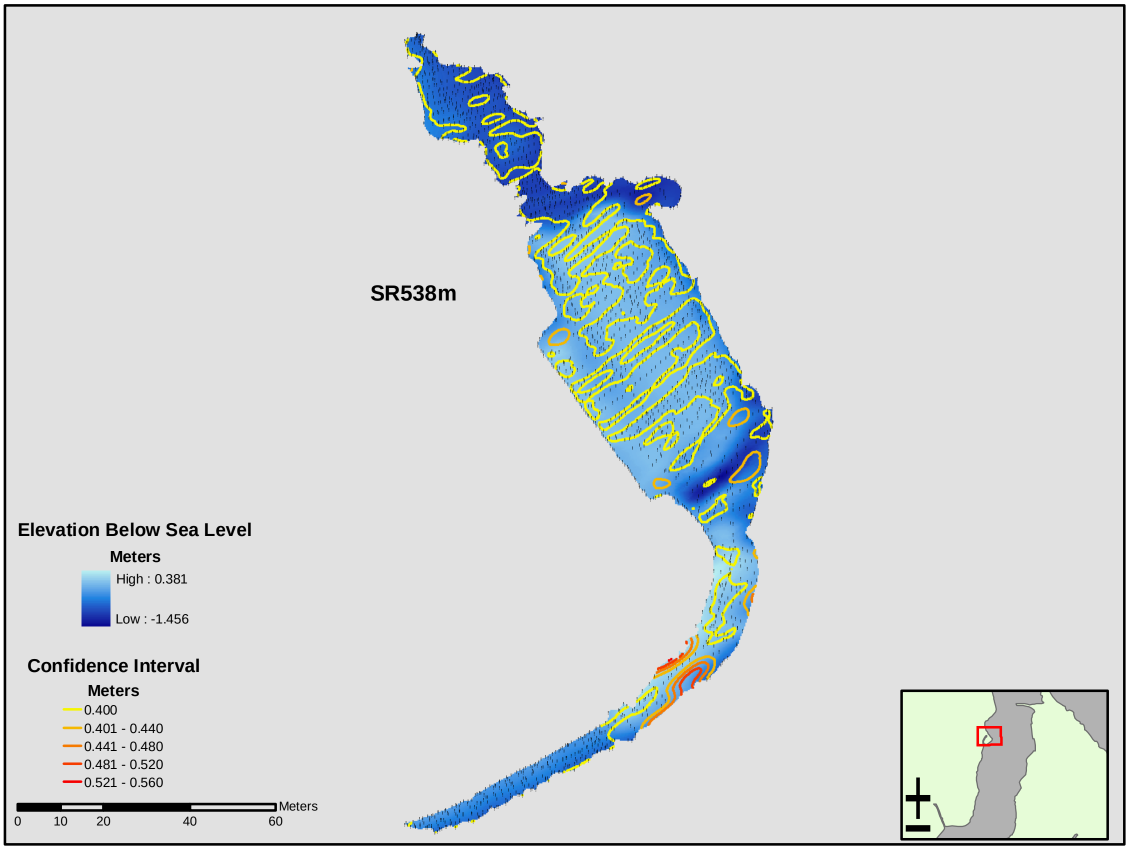


Figure A22. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR626. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR626 based on the predicted surface elevations. The vertical relief has been exaggerated 2x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

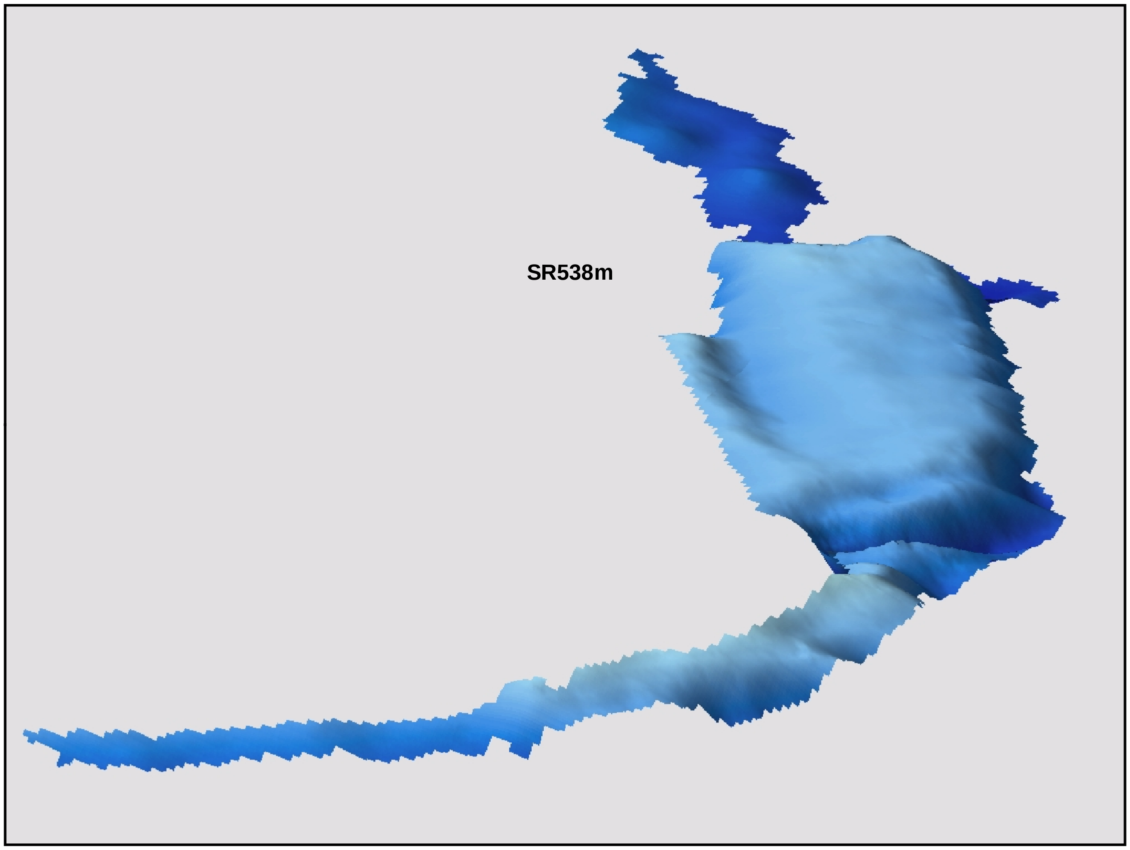


Figure A23. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR538m. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR538m based on the predicted surface elevations. The vertical relief has been exaggerated 7x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

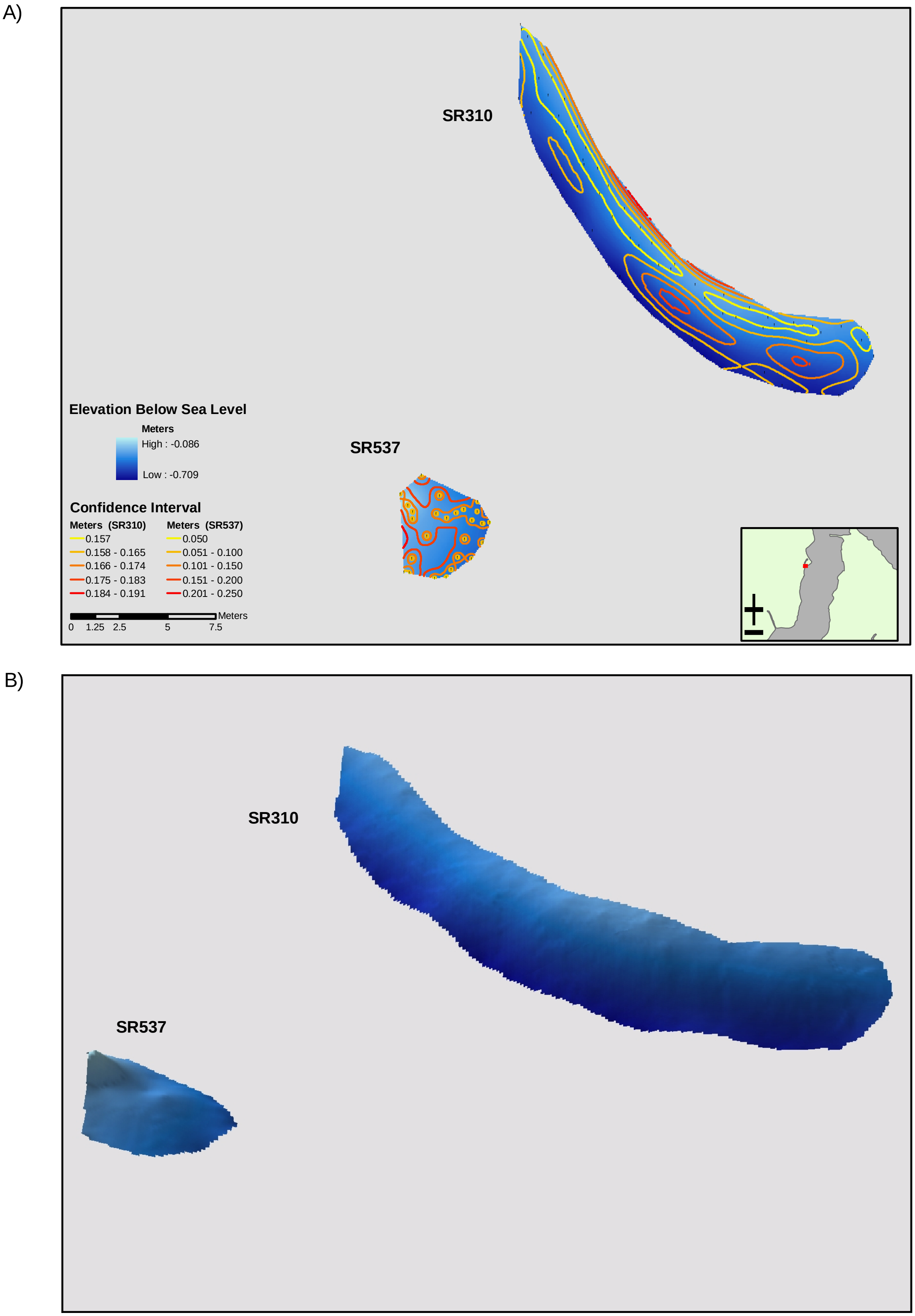


Figure A24. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR310 and SR537. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR310 and SR537 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

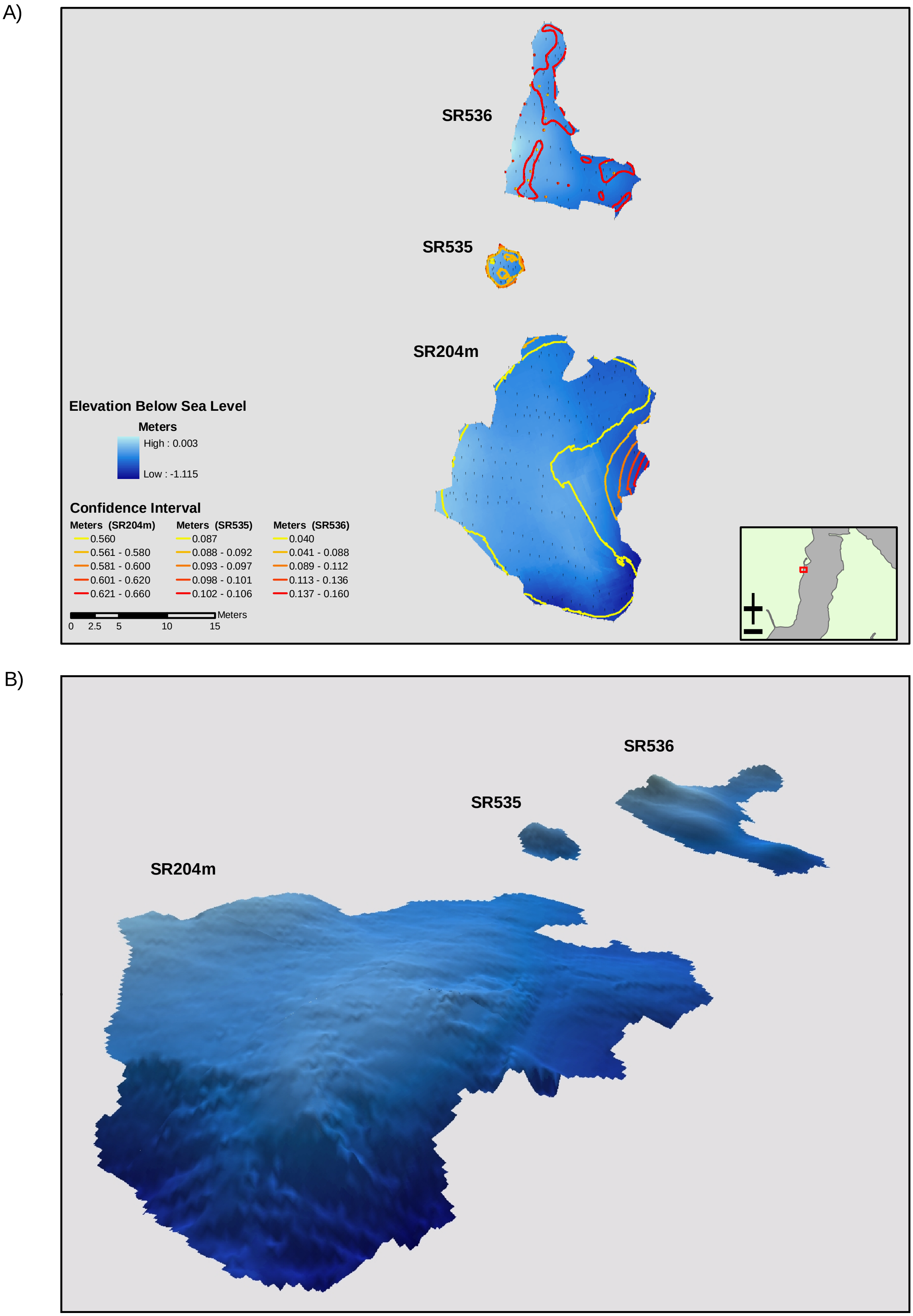


Figure A25. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR204m, SR535, and SR536. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR204m, SR535, and SR536 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

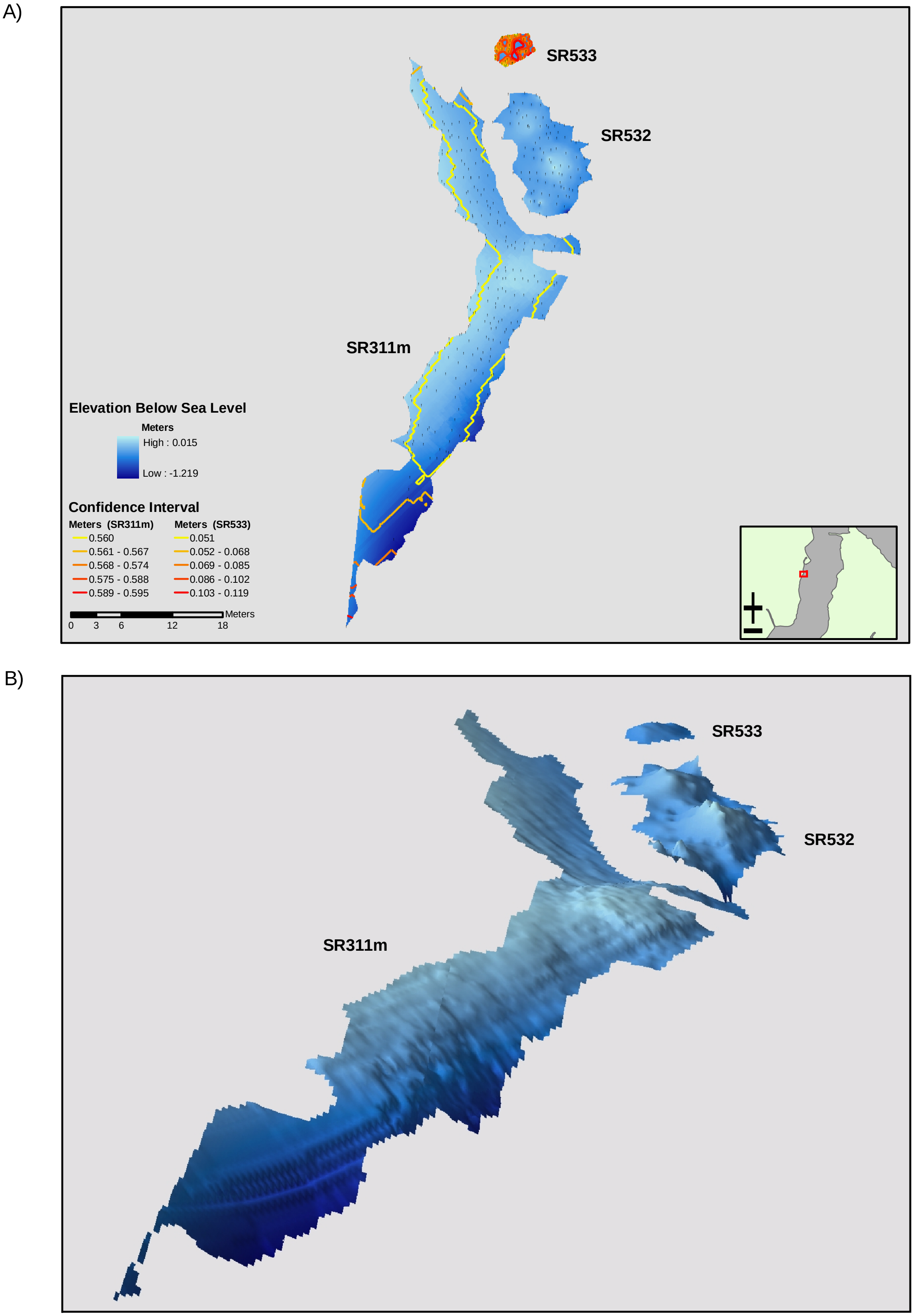


Figure A26. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR311m, SR532, and SR533. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR311m, SR532, and SR533 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

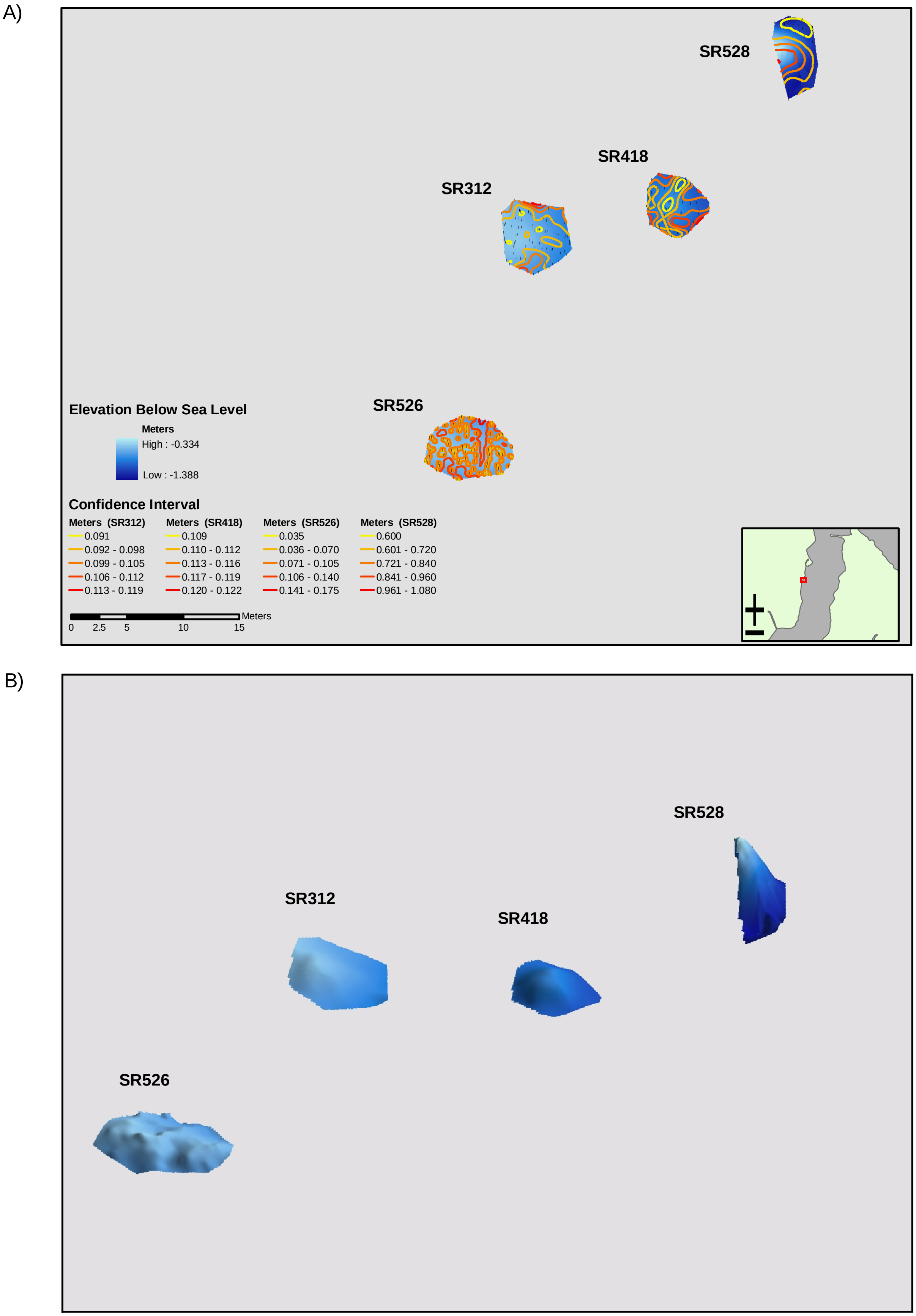


Figure A27. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR312, SR418, SR526, and SR528. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR312, SR418, SR526, and SR528 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

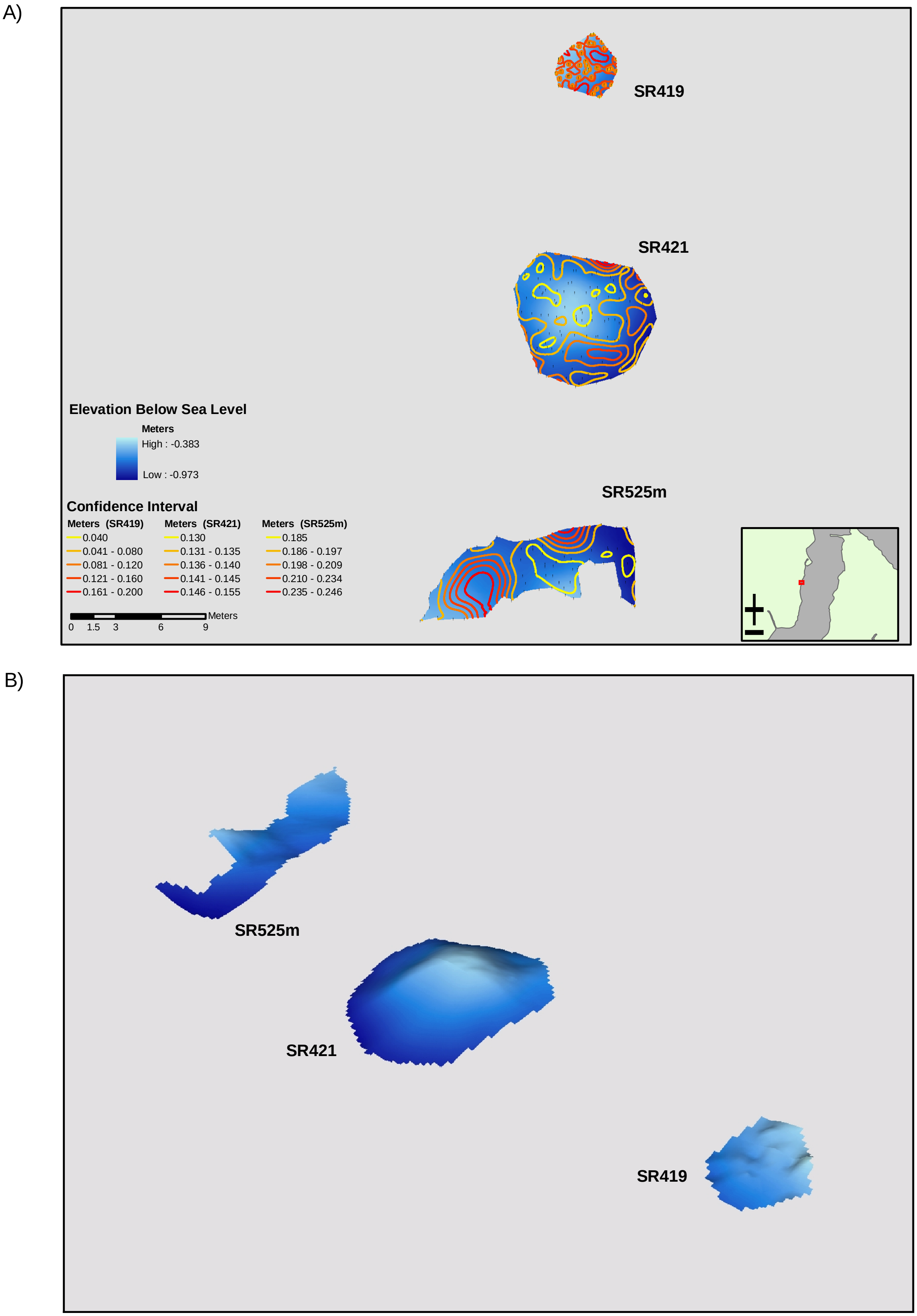


Figure A28. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR419, SR421, and SR525m. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR419, SR421, and SR525m based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

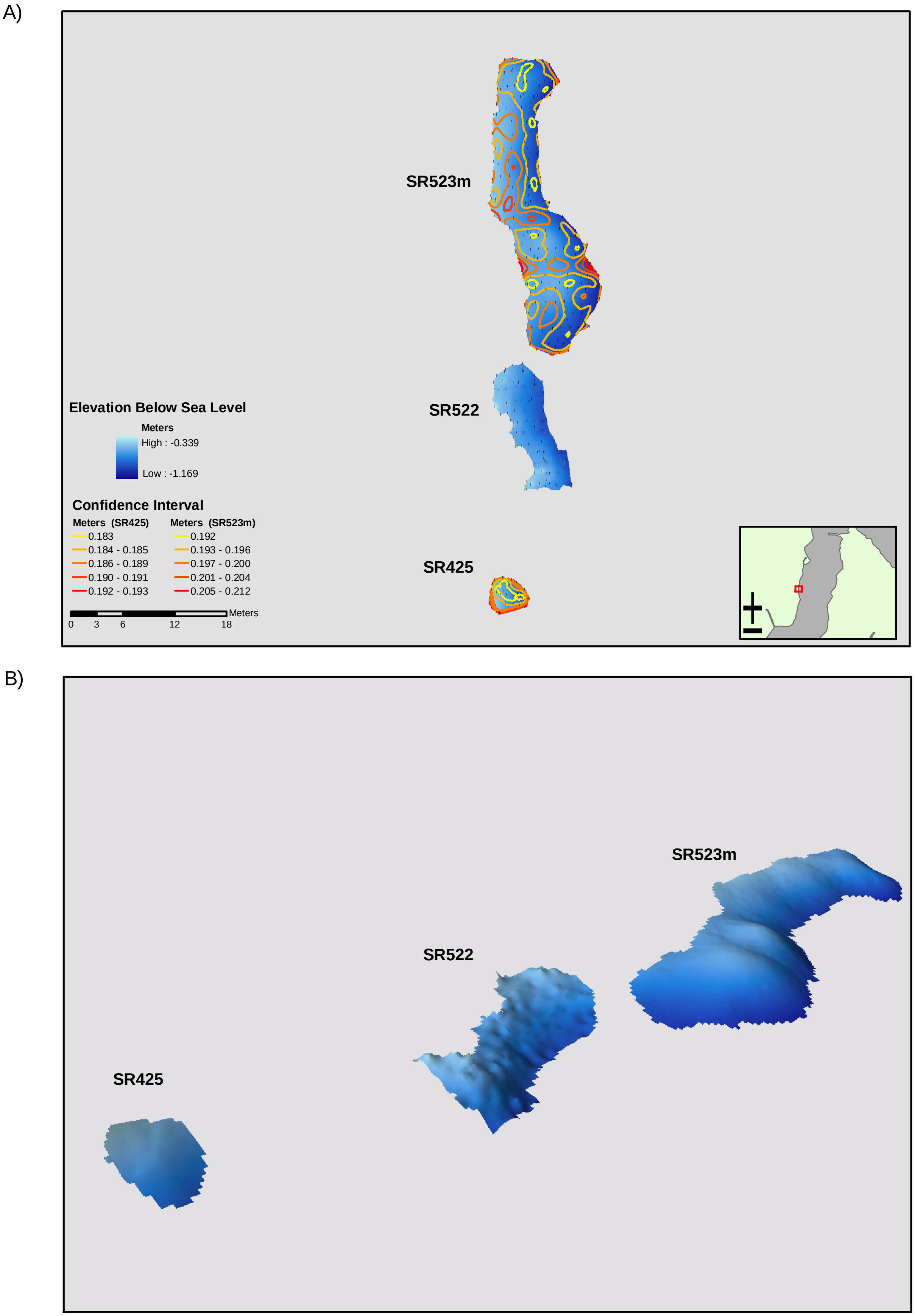


Figure A29. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR425, SR522, and SR523m. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR425, SR522, and SR523m based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

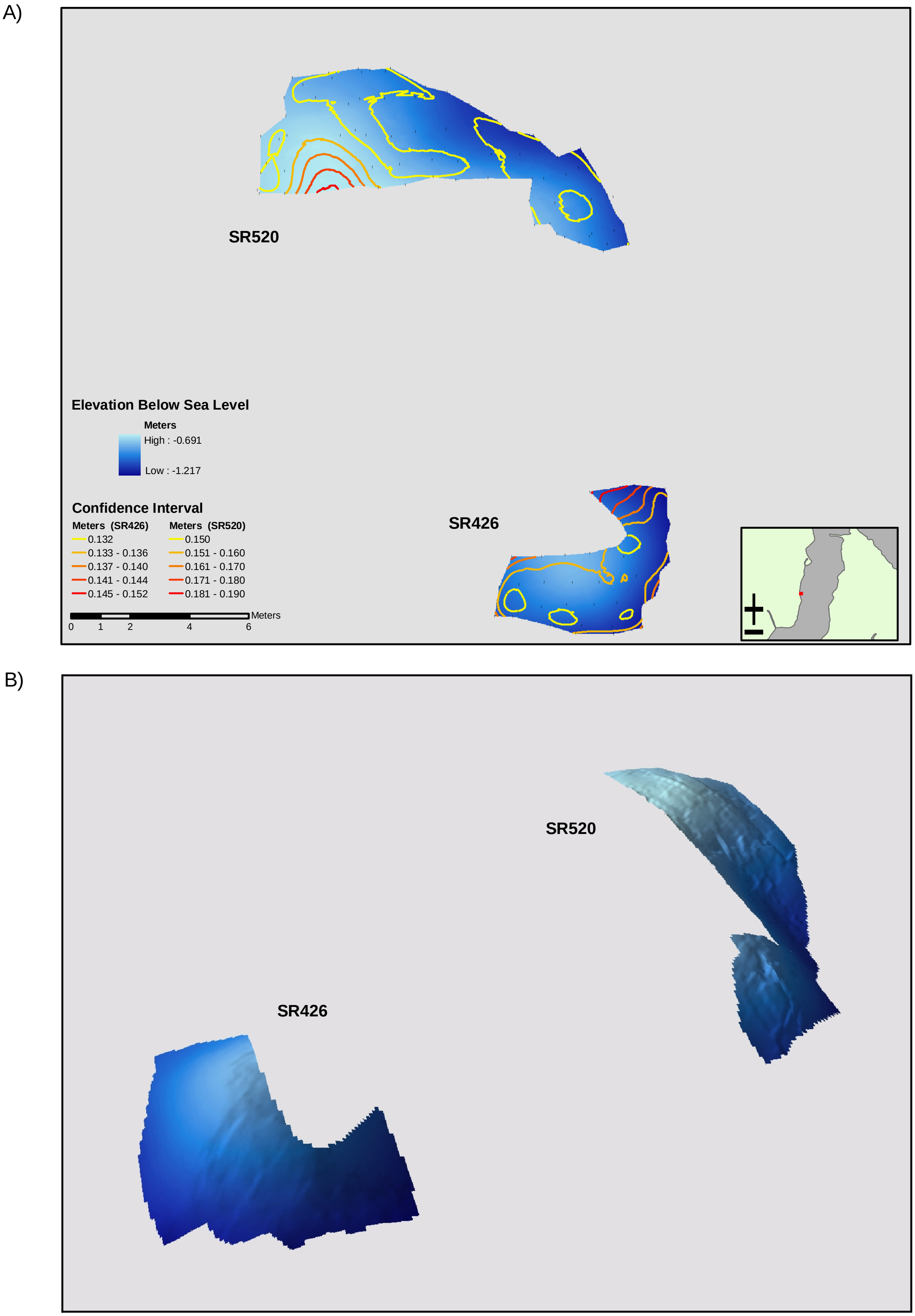


Figure A30. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR426 and SR520. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR426 and SR520 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

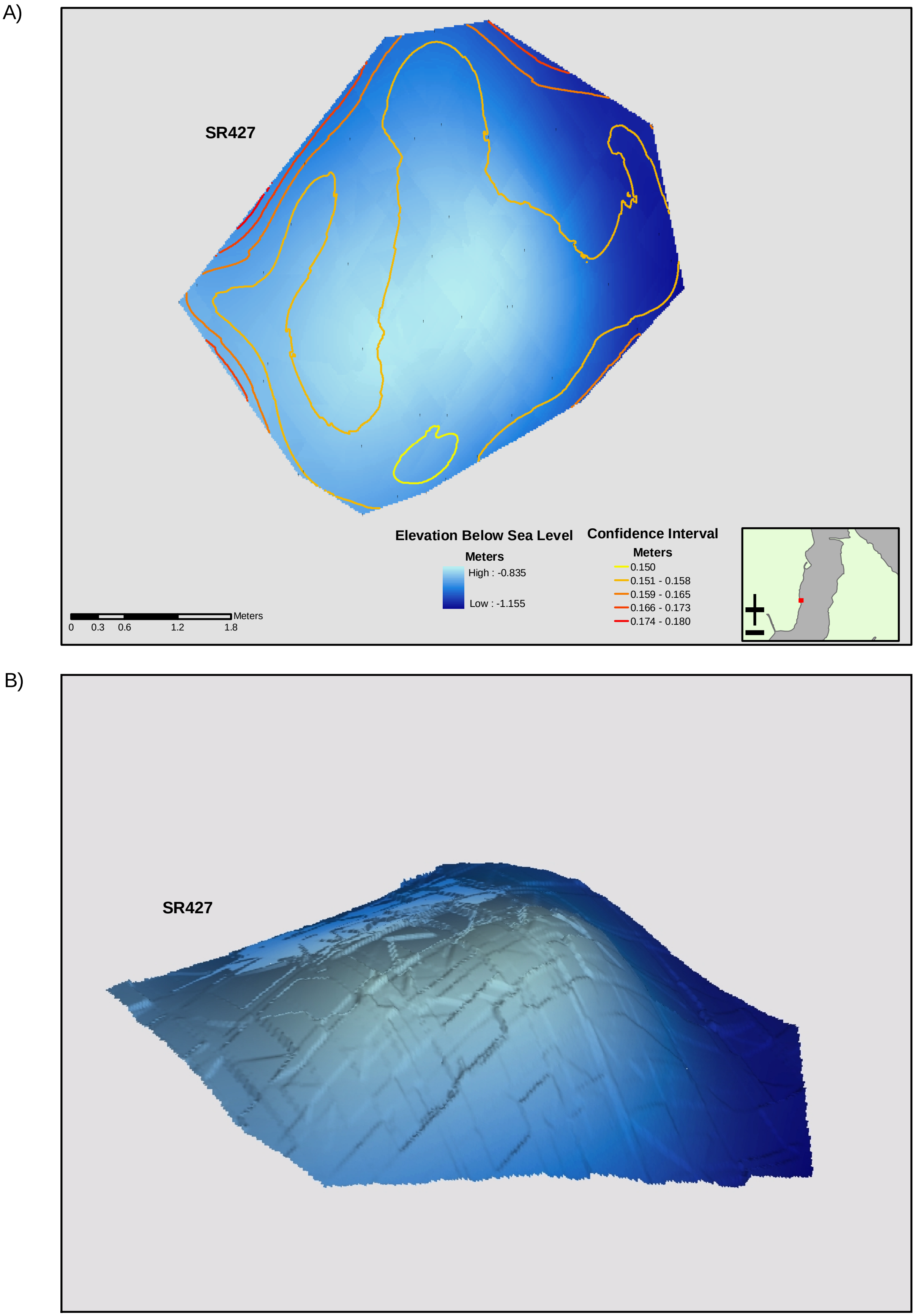


Figure A31. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR427. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR427 based on the predicted surface elevations. The vertical relief has been exaggerated 10x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

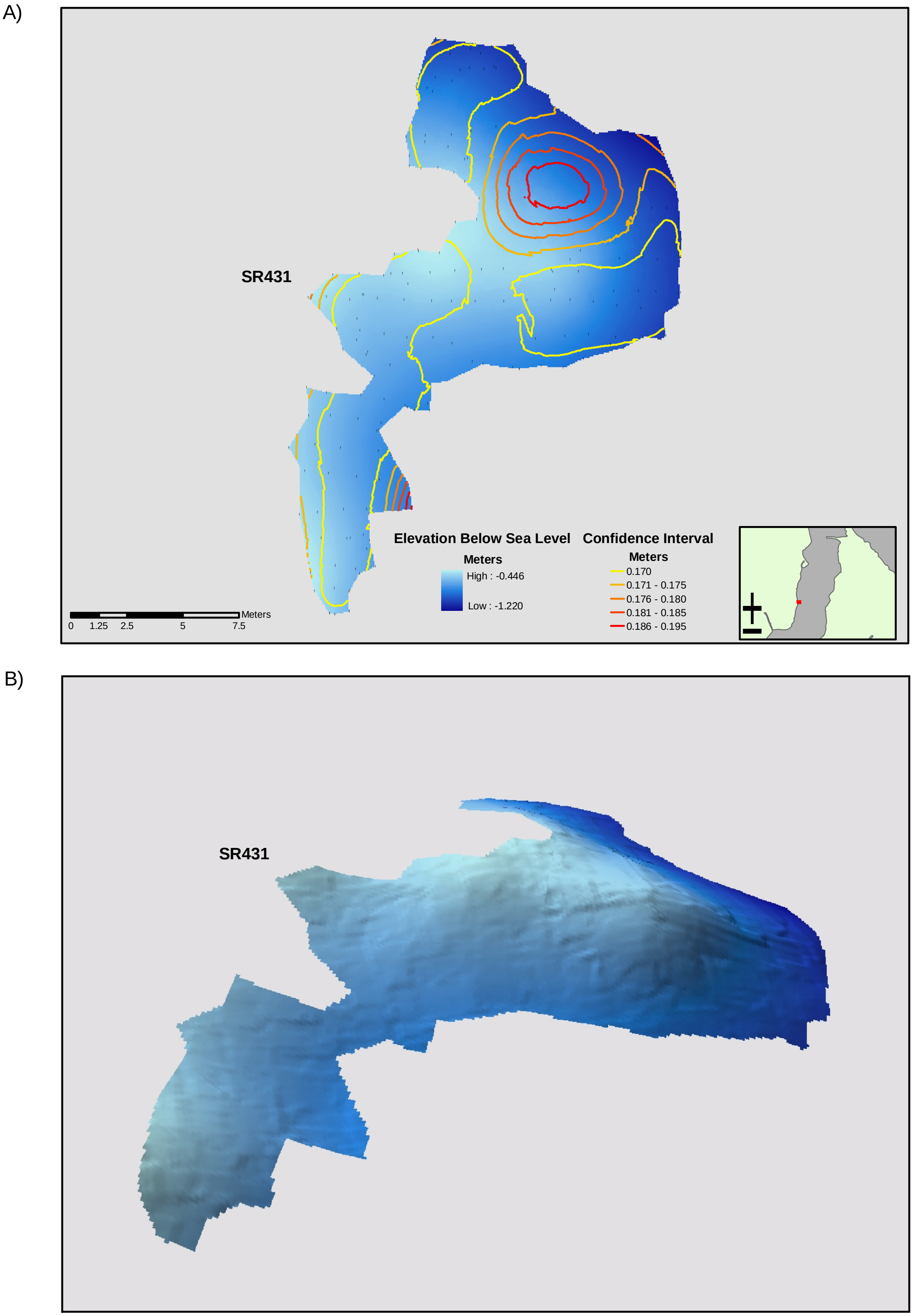
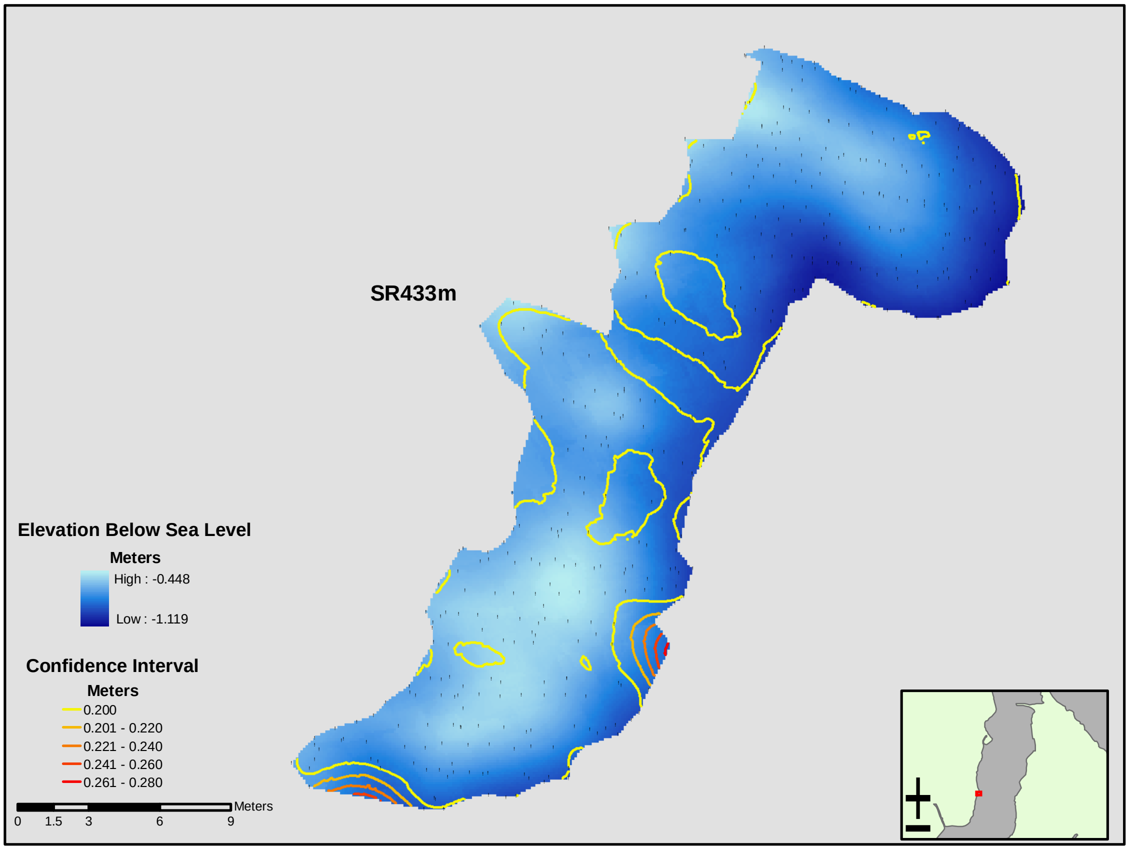


Figure A32. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR431. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR431 based on the predicted surface elevations. The vertical relief has been exaggerated 10x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

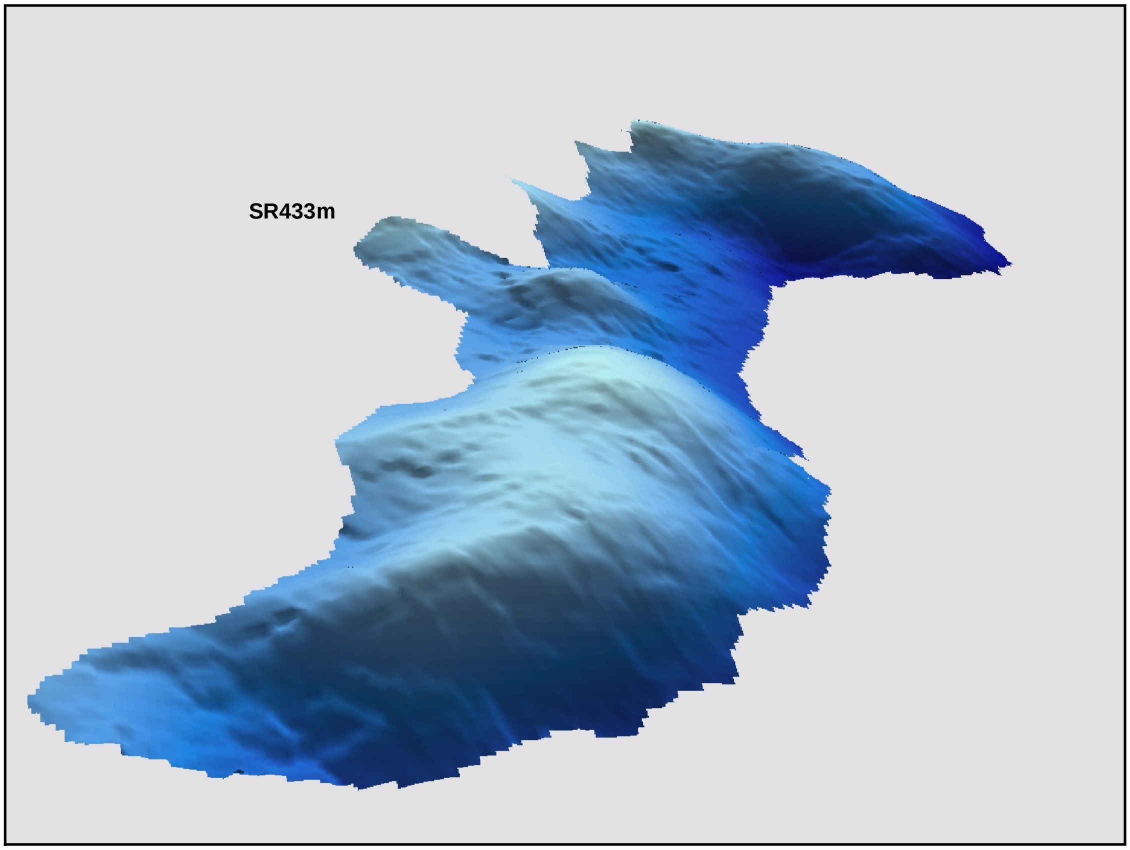


Figure A33. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR433m. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR433m based on the predicted surface elevations. The vertical relief has been exaggerated 10x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

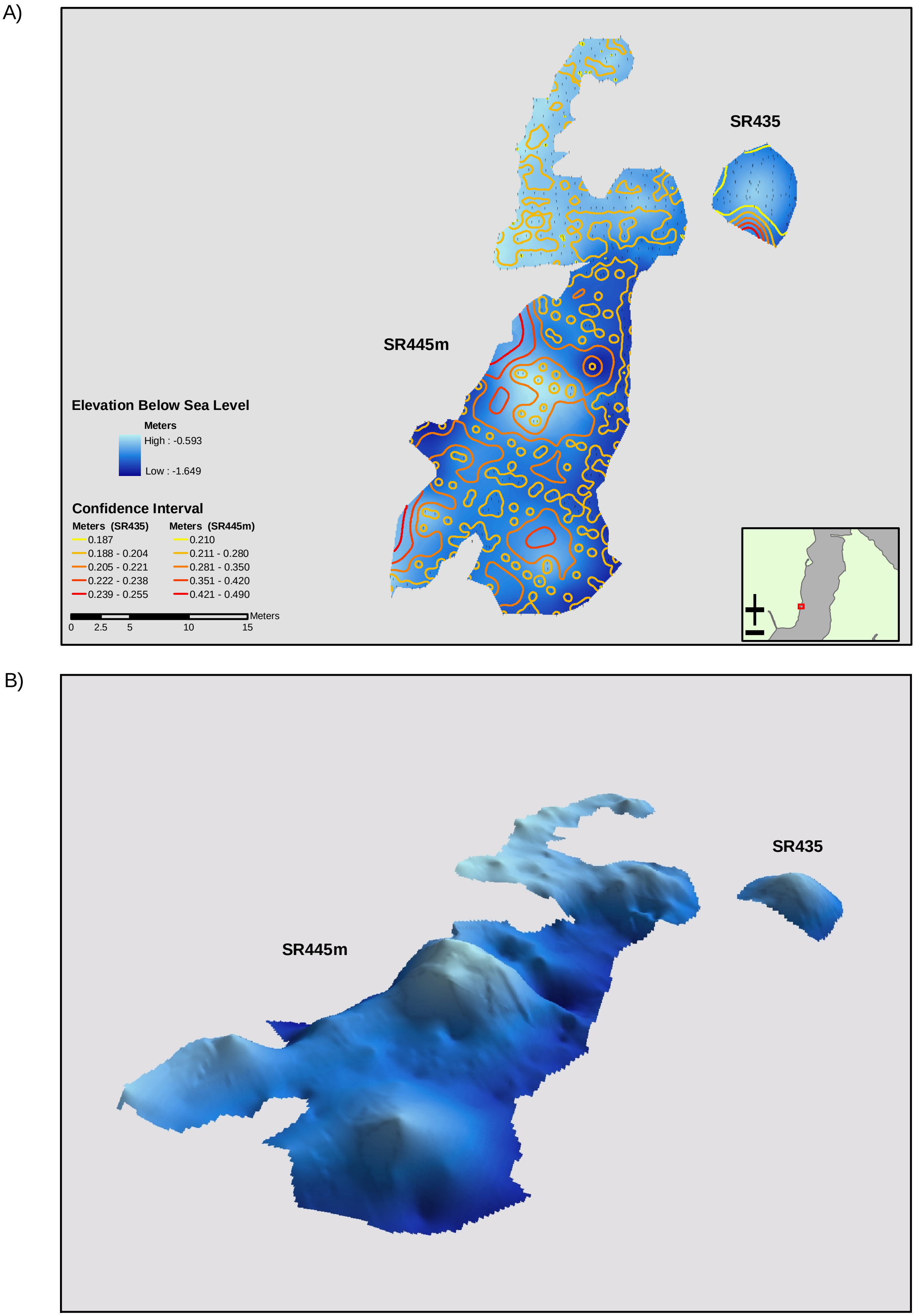


Figure A34. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR435 and SR445m. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR435 and SR445m based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

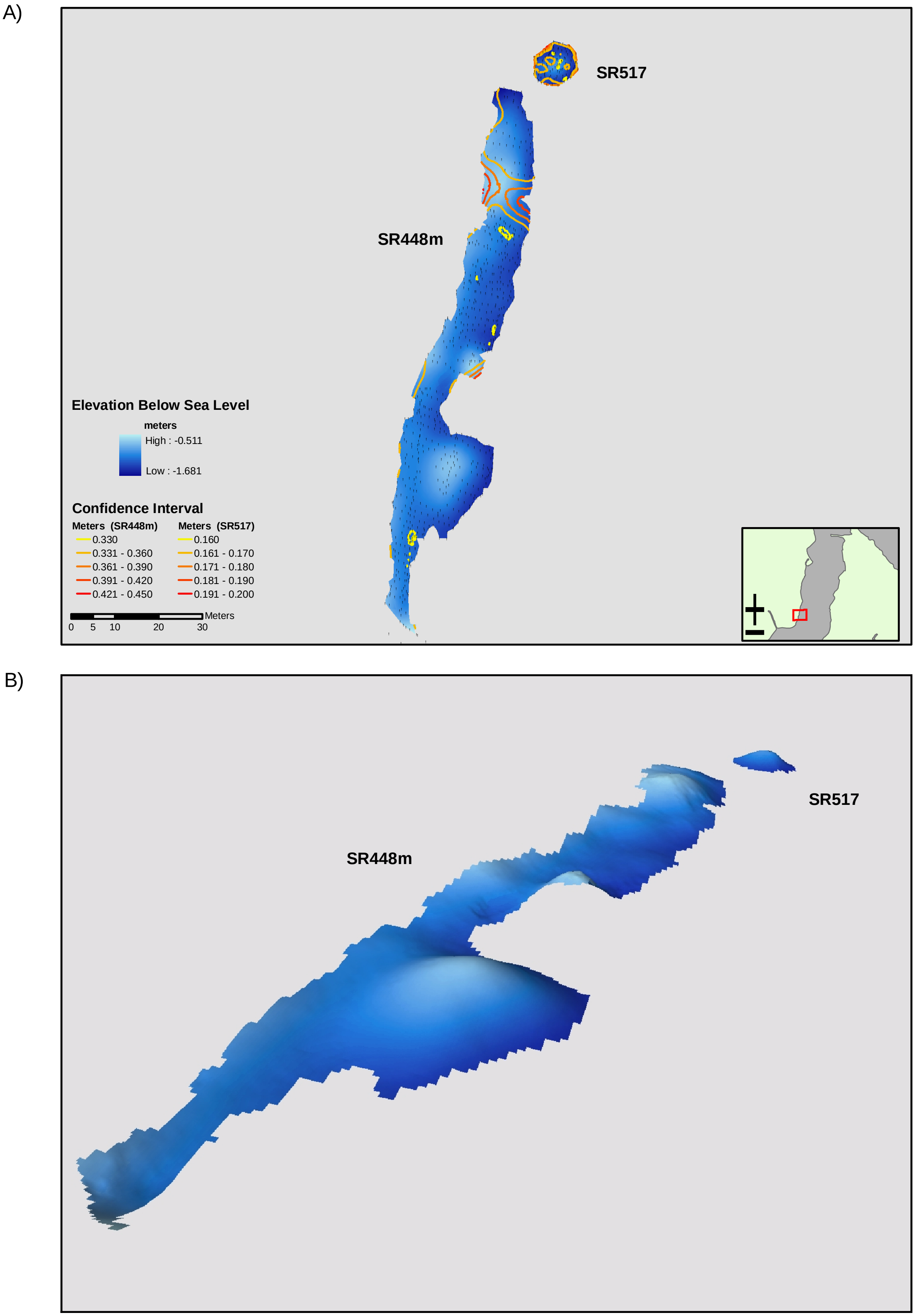
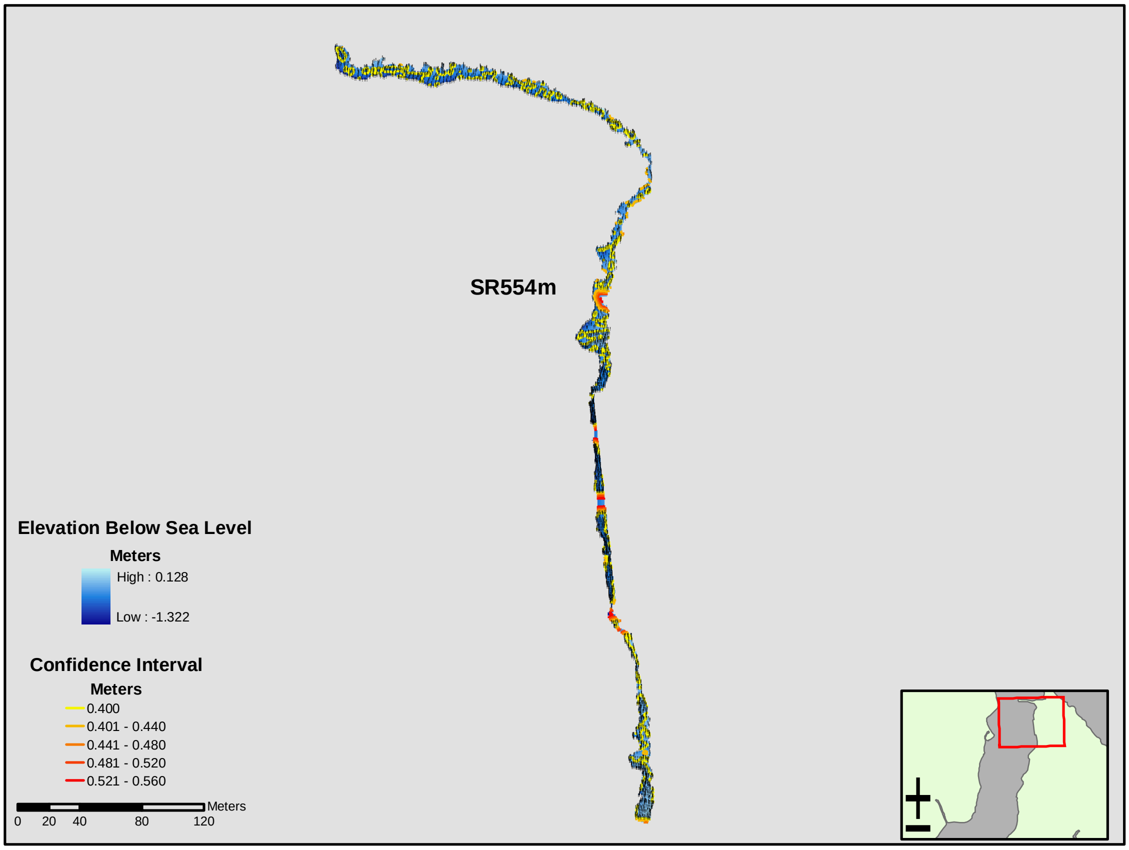


Figure A35. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR448m and SR517. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR448m and SR517 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

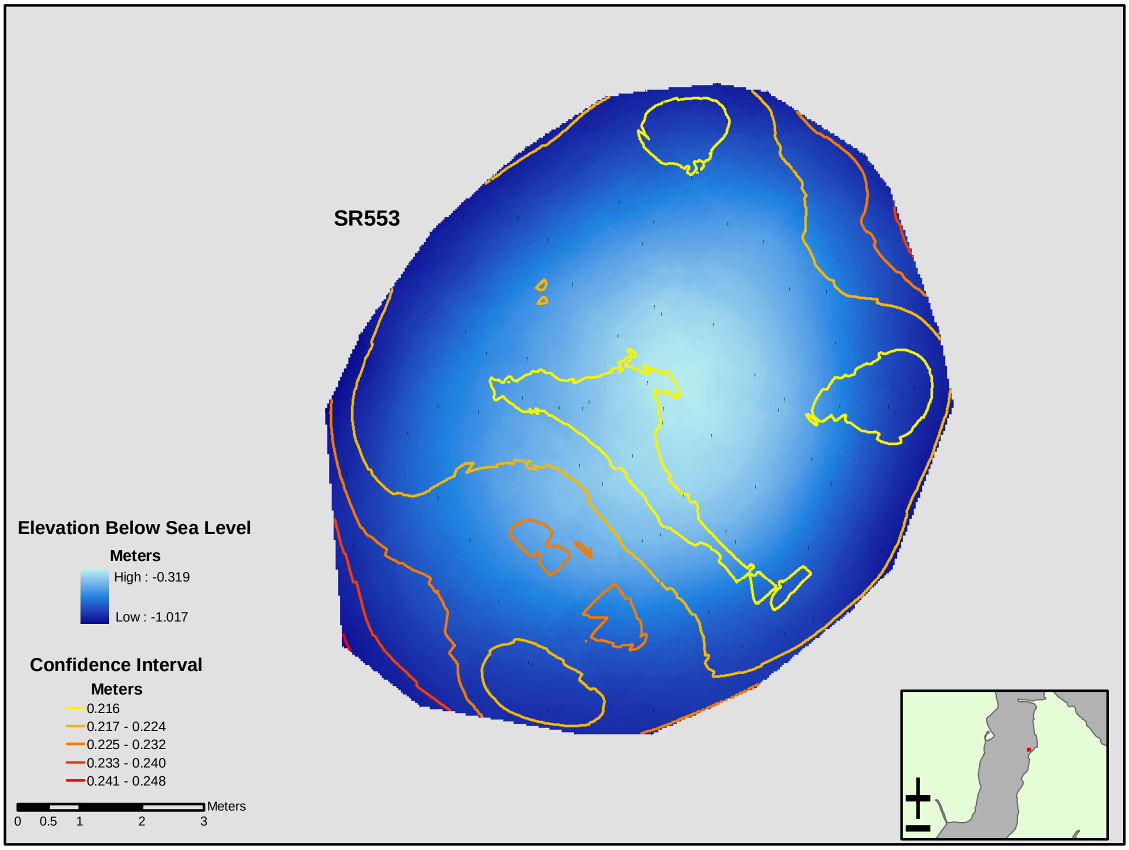
A)



B)

Figure A36. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR554m. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR554m based on the predicted surface elevations. The vertical relief has been exaggerated 2x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

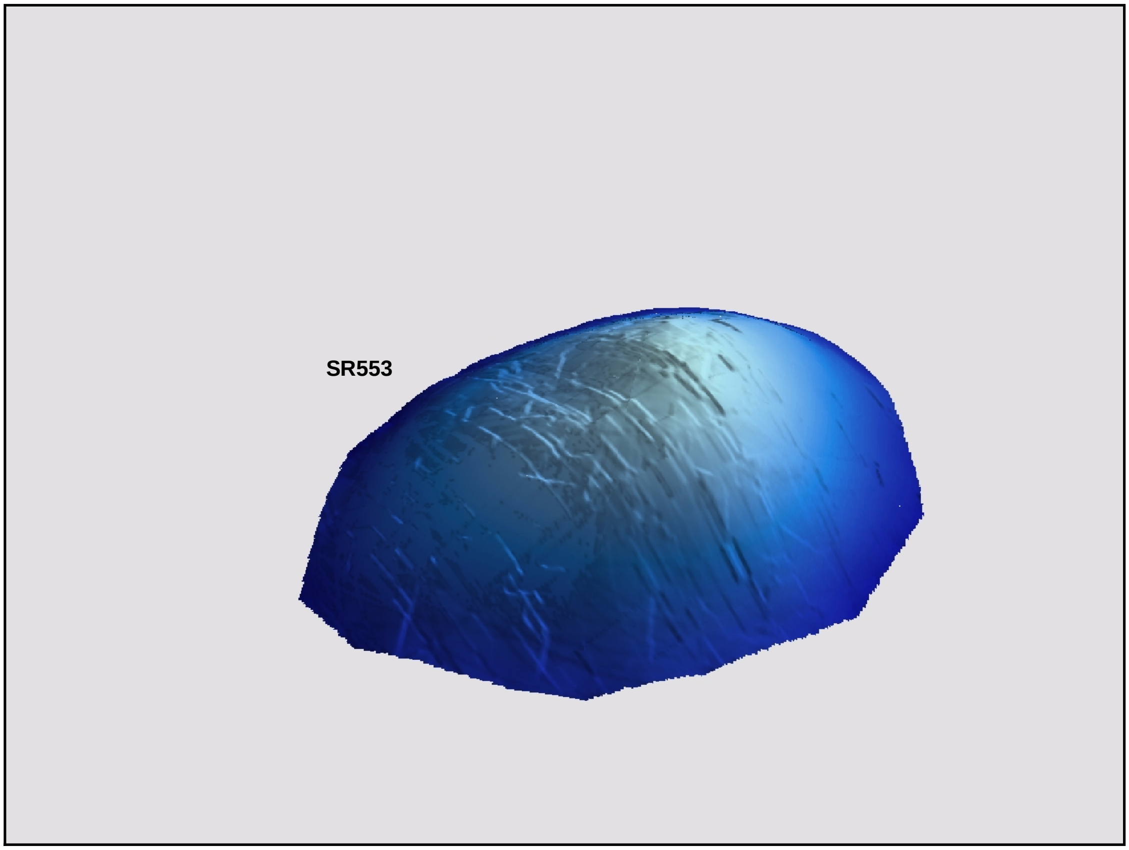


Figure A37. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR553. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR553 based on the predicted surface elevations. The vertical relief has been exaggerated 10x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

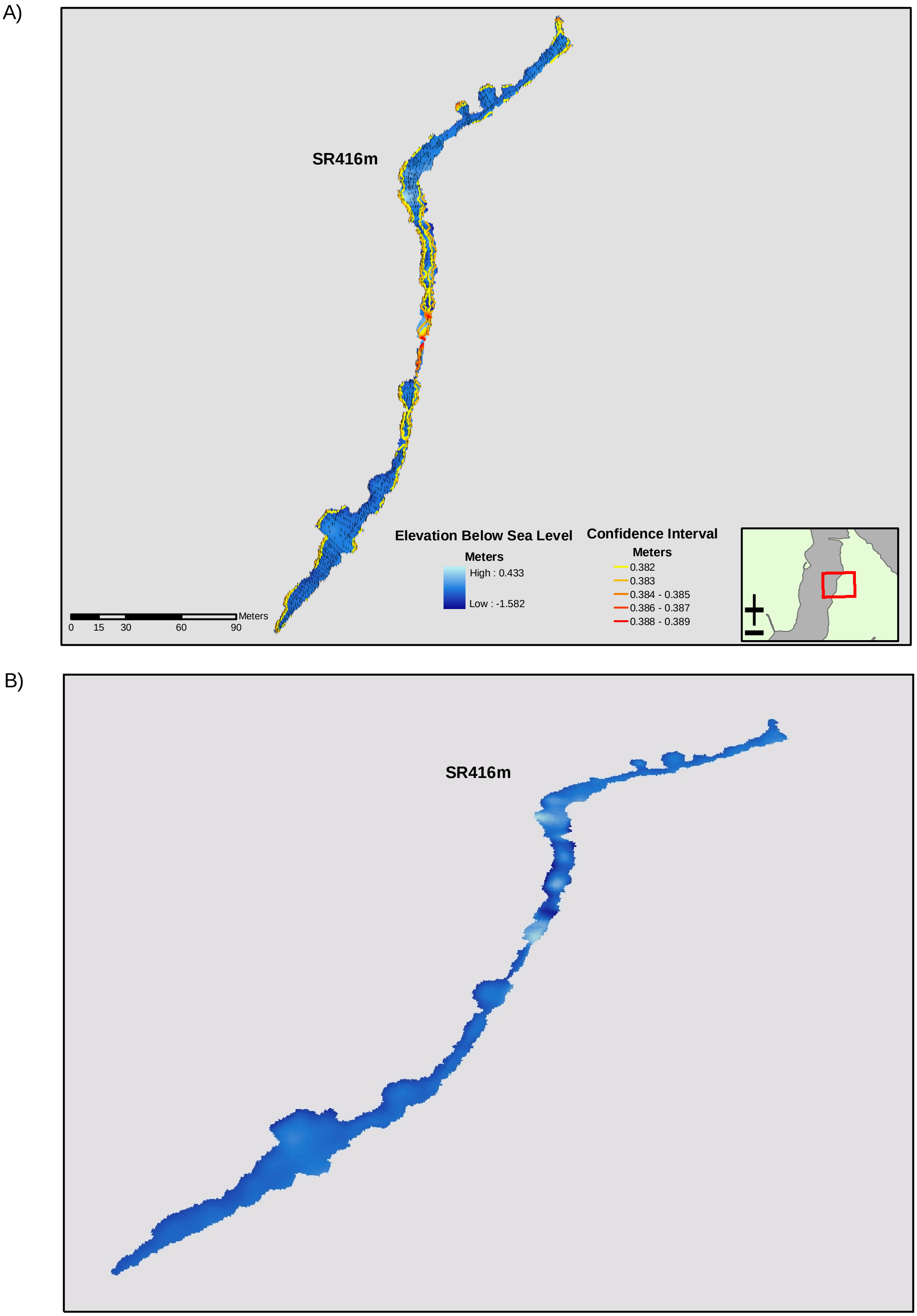


Figure A38. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR416m. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR416m based on the predicted surface elevations. The vertical relief has been exaggerated 10x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

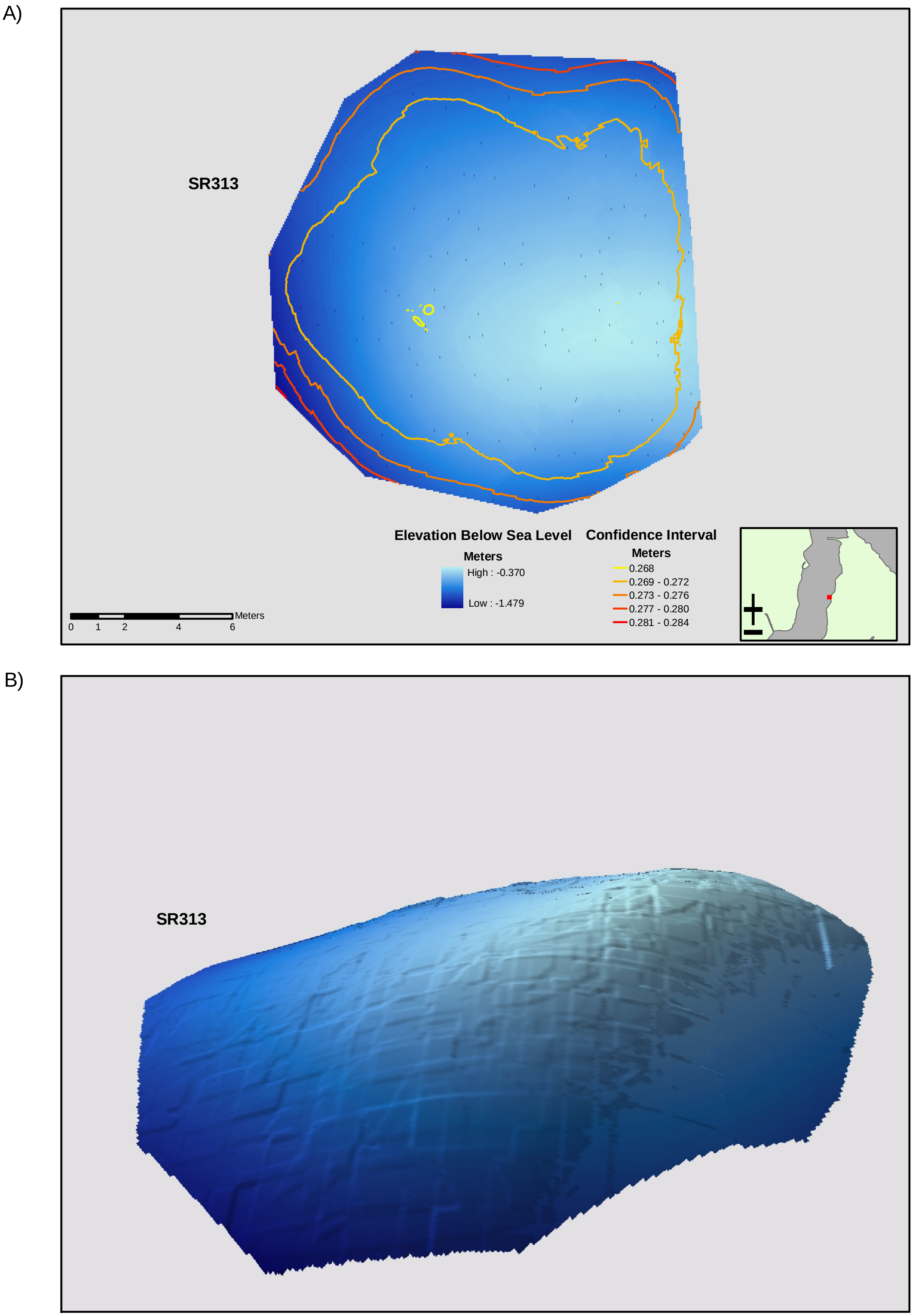


Figure A39. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR313. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR313 based on the predicted surface elevations. The vertical relief has been exaggerated 10x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

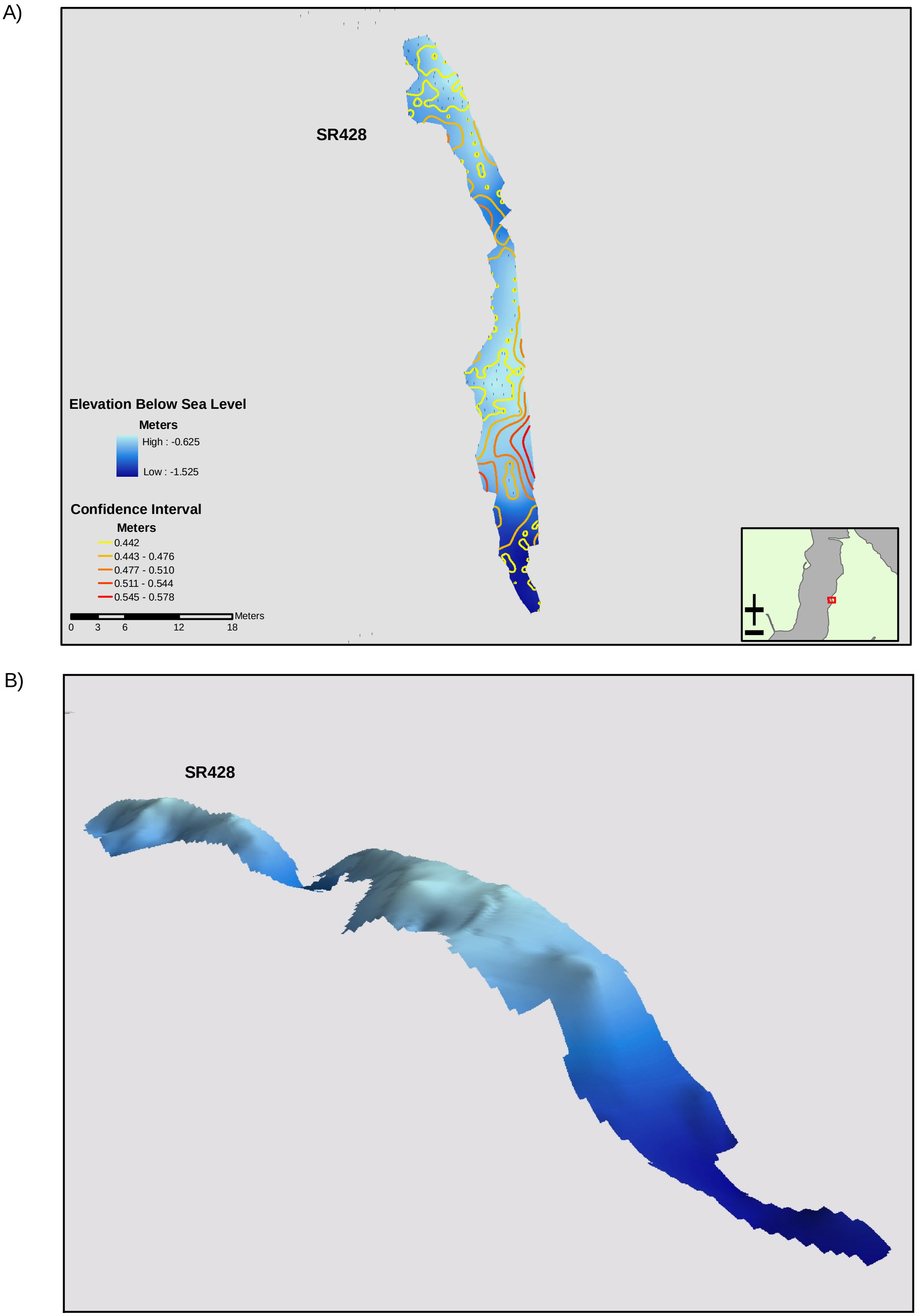


Figure A40. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR428. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR428 based on the predicted surface elevations. The vertical relief has been exaggerated 10x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

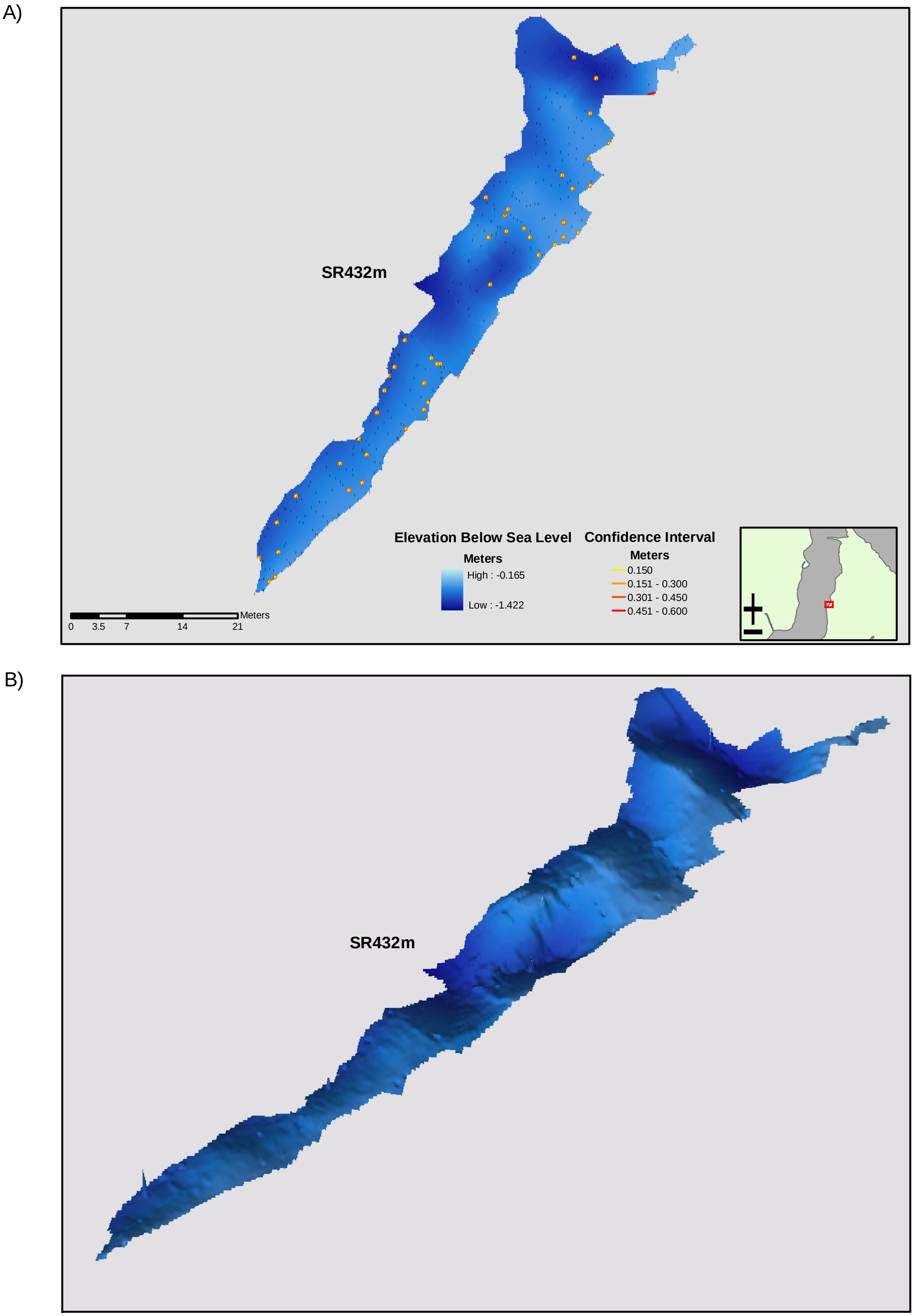
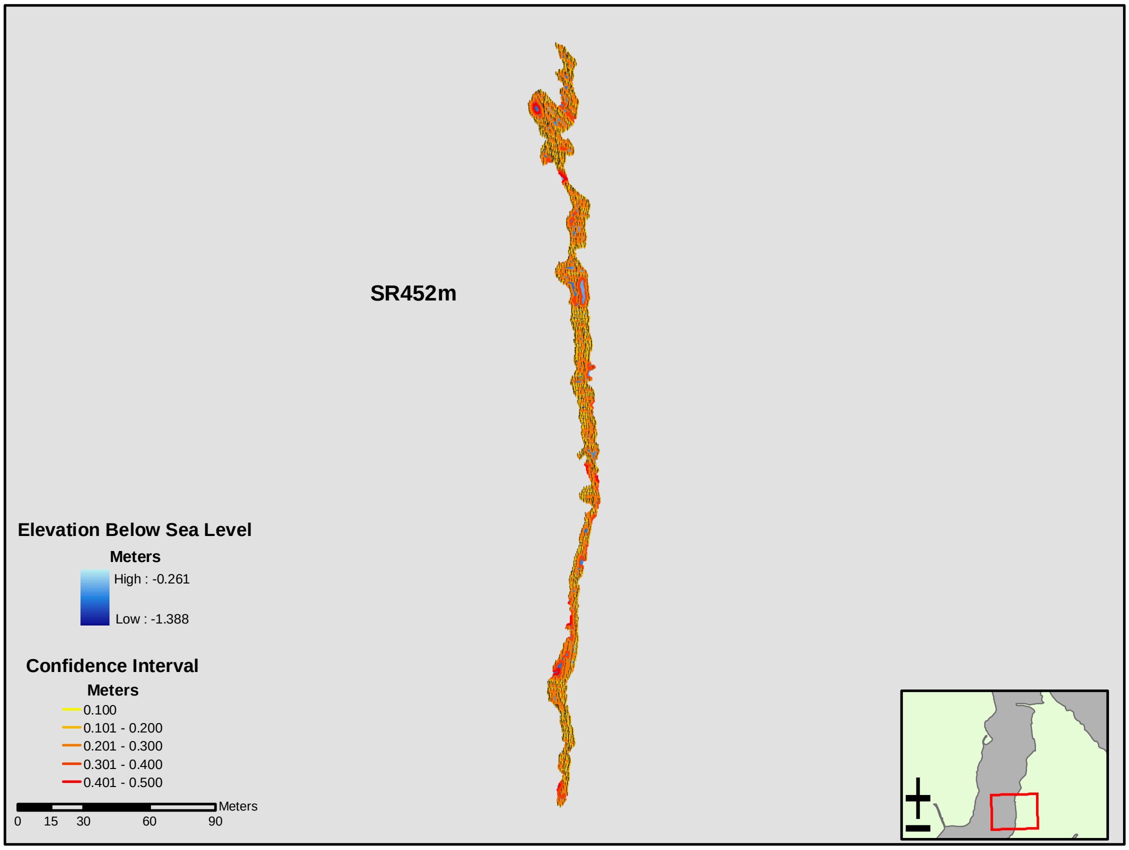


Figure A41. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR432m. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR432m based on the predicted surface elevations. The vertical relief has been exaggerated 10x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

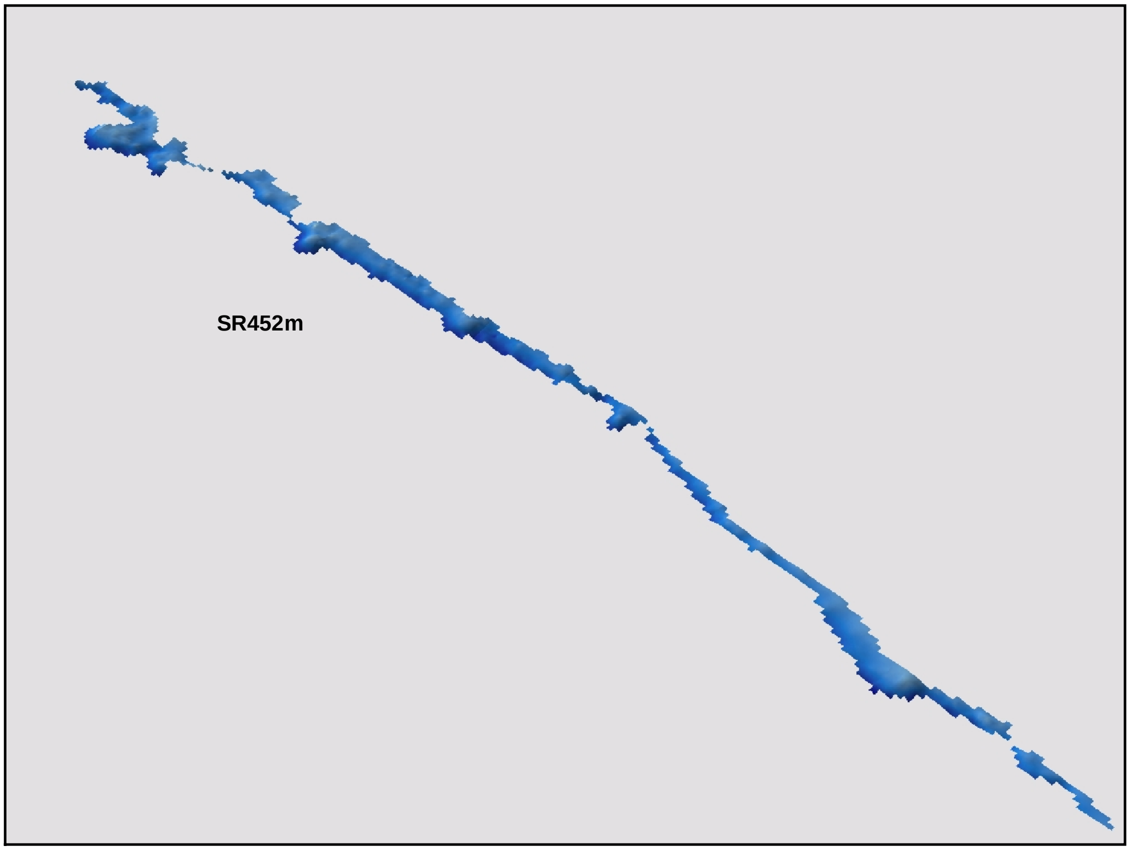


Figure A42. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR452m. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR452m based on the predicted surface elevations. The vertical relief has been exaggerated 2x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

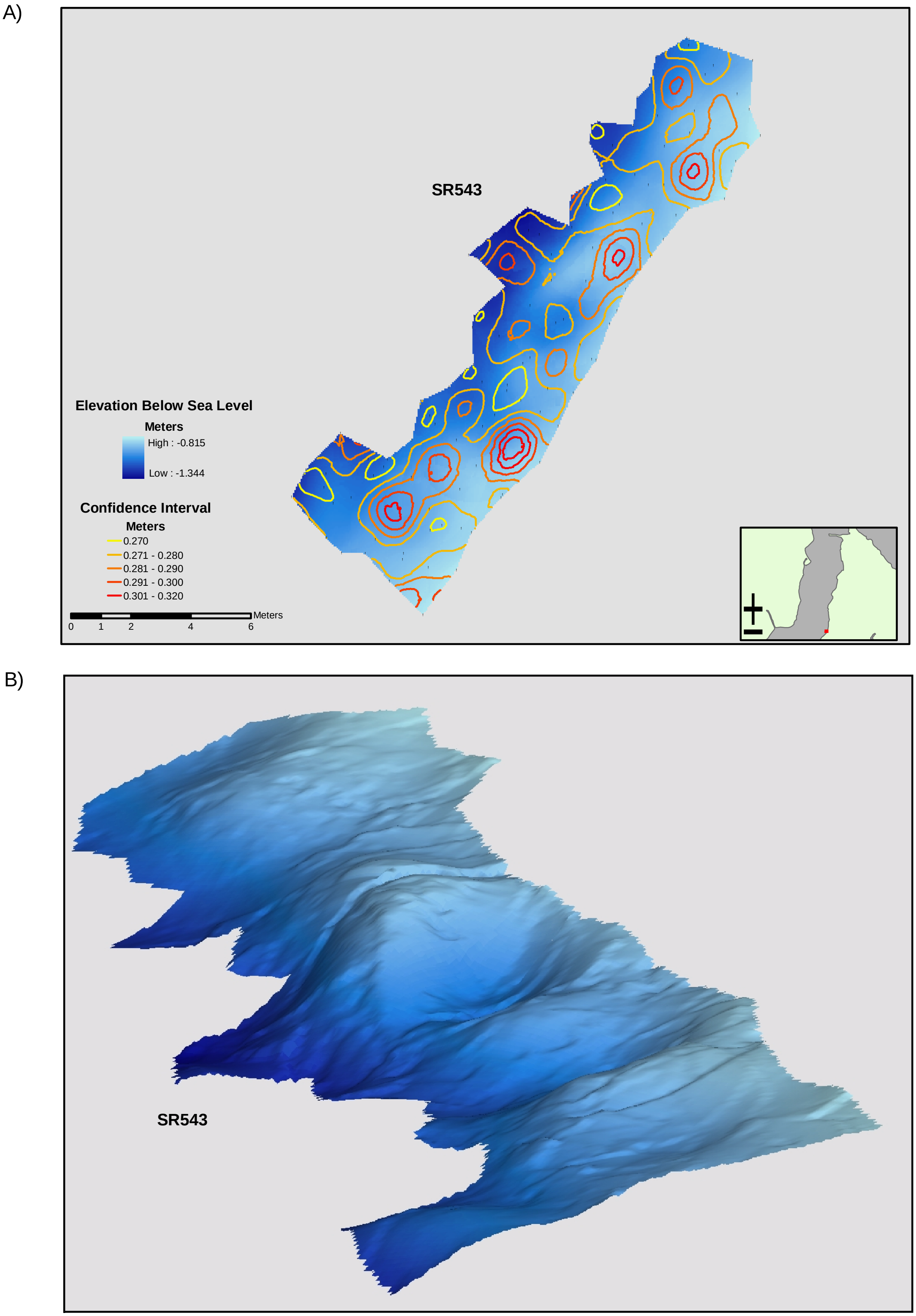


Figure A43. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR543. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR543 based on the predicted surface elevations. The vertical relief has been exaggerated 10x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

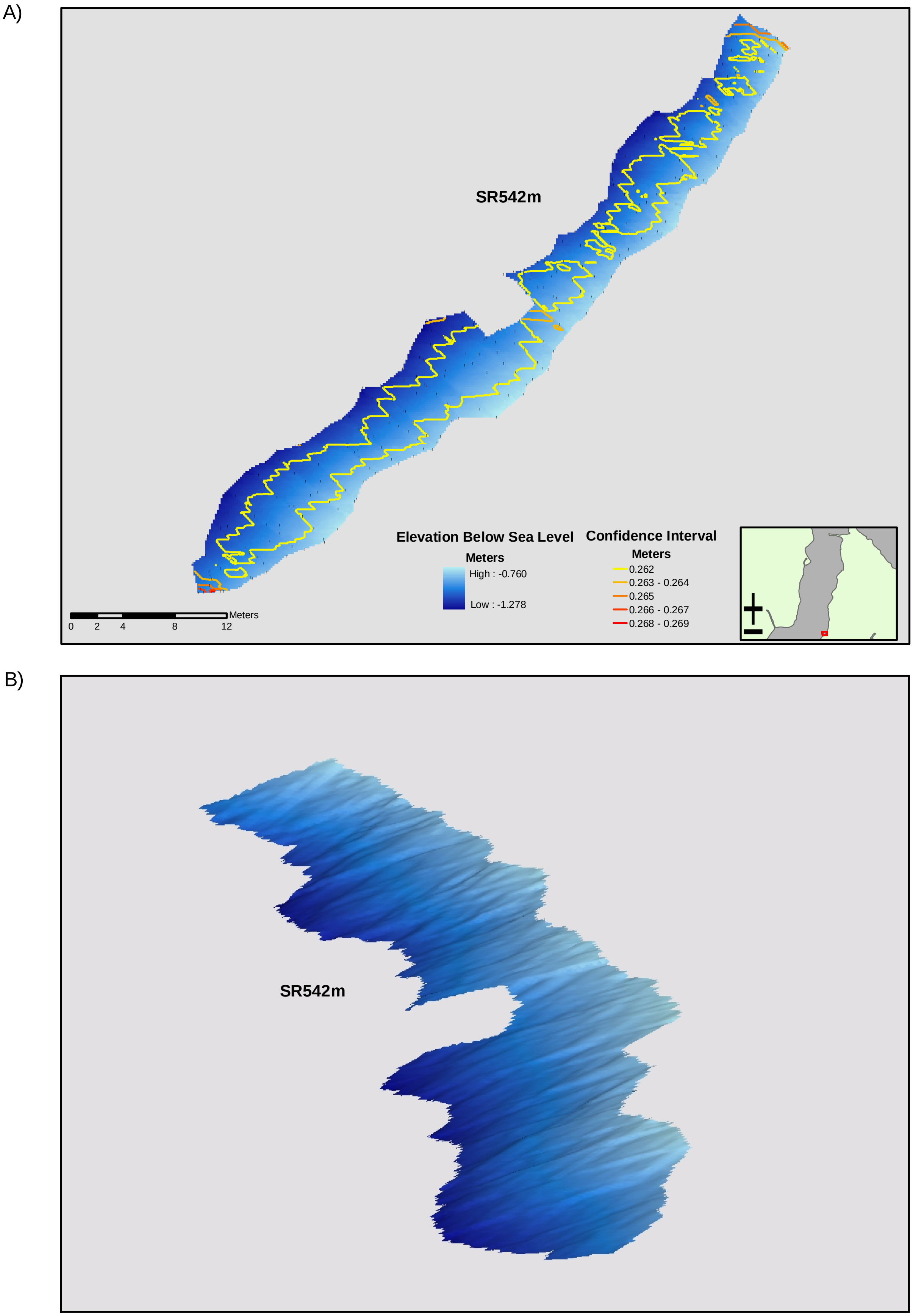


Figure A44. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR542m. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR542m based on the predicted surface elevations. The vertical relief has been exaggerated 7x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

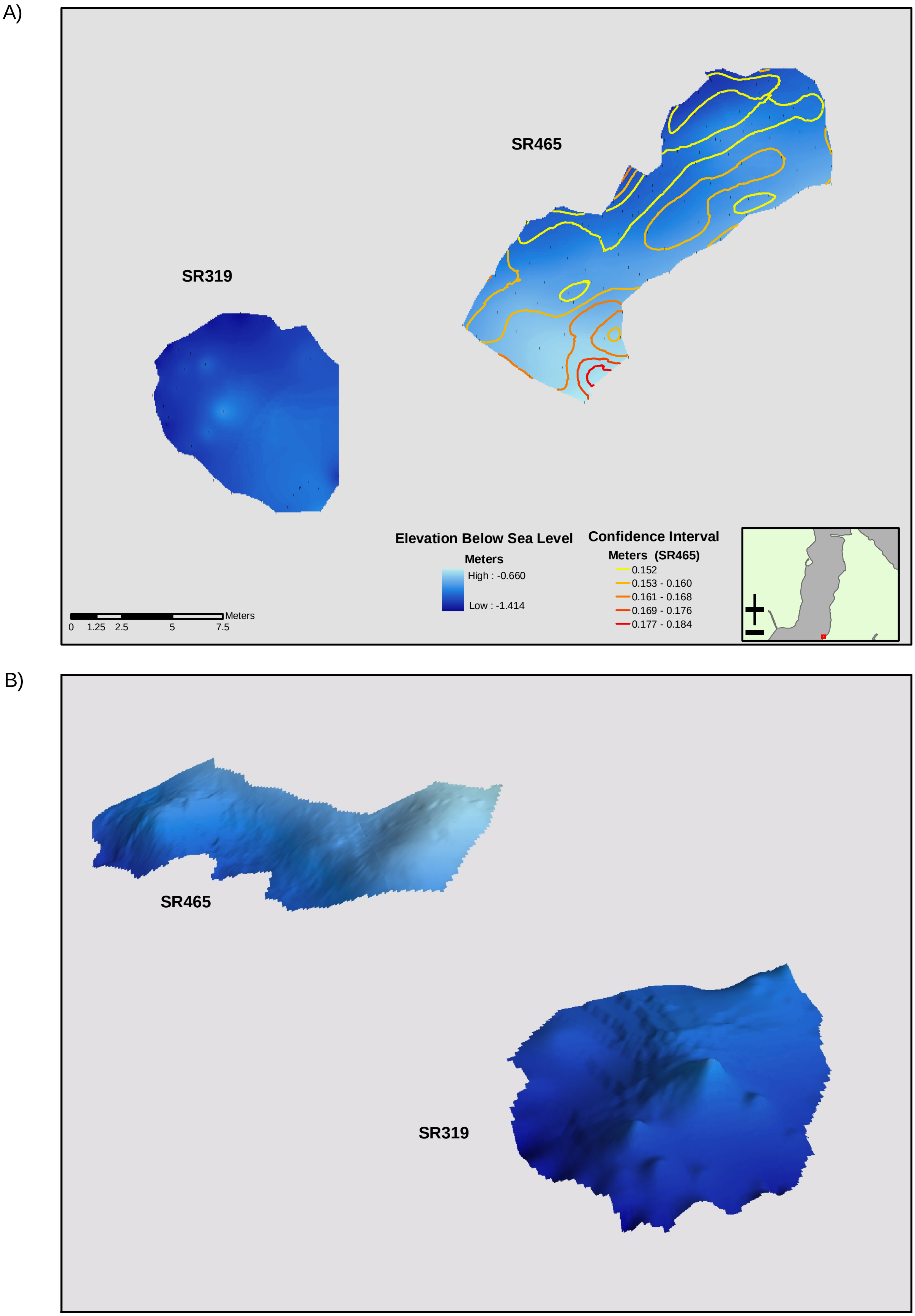


Figure A45. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR319 and SR465. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR319 and SR465 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

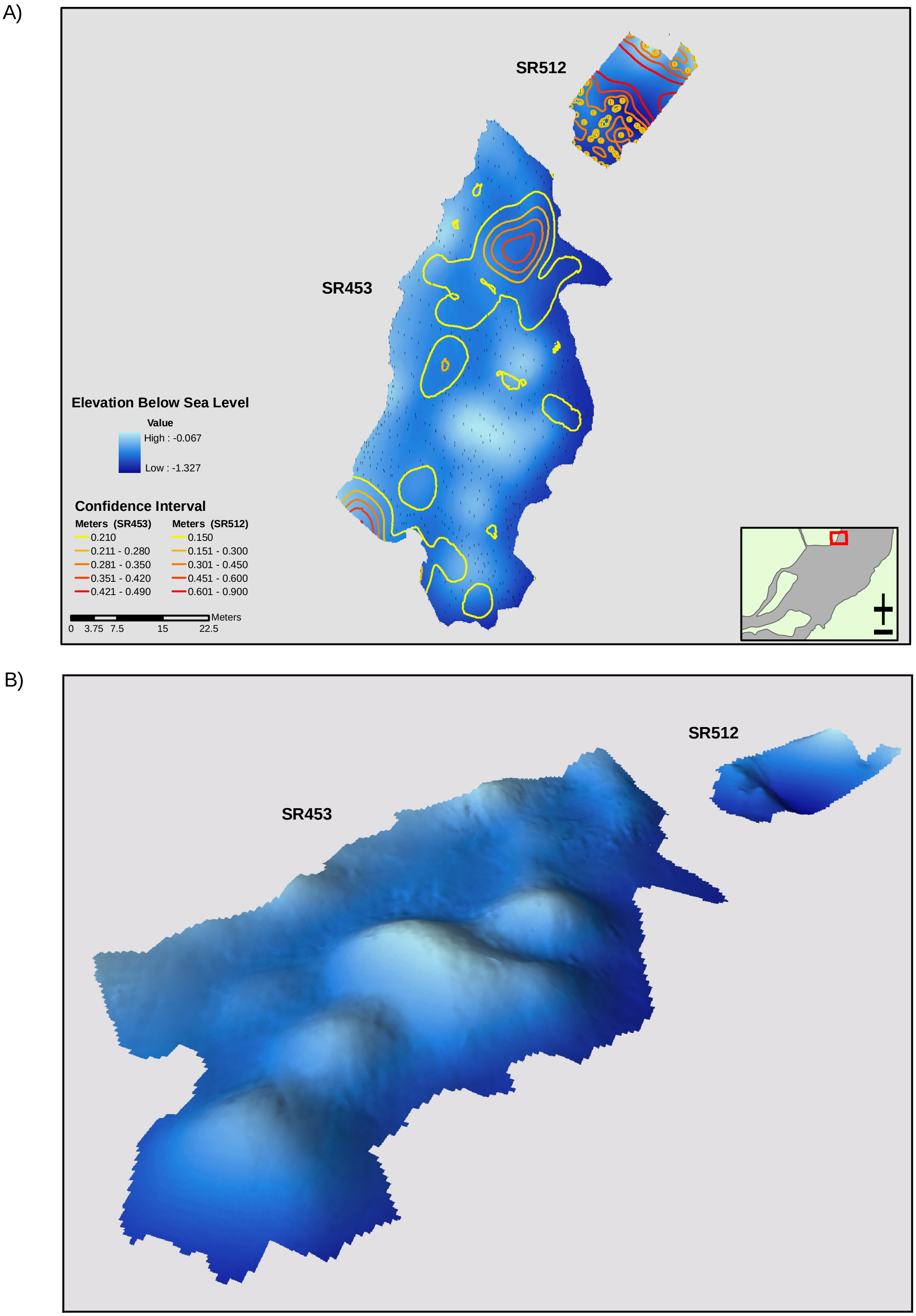


Figure A46. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR453 and SR512. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR453 and SR512 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

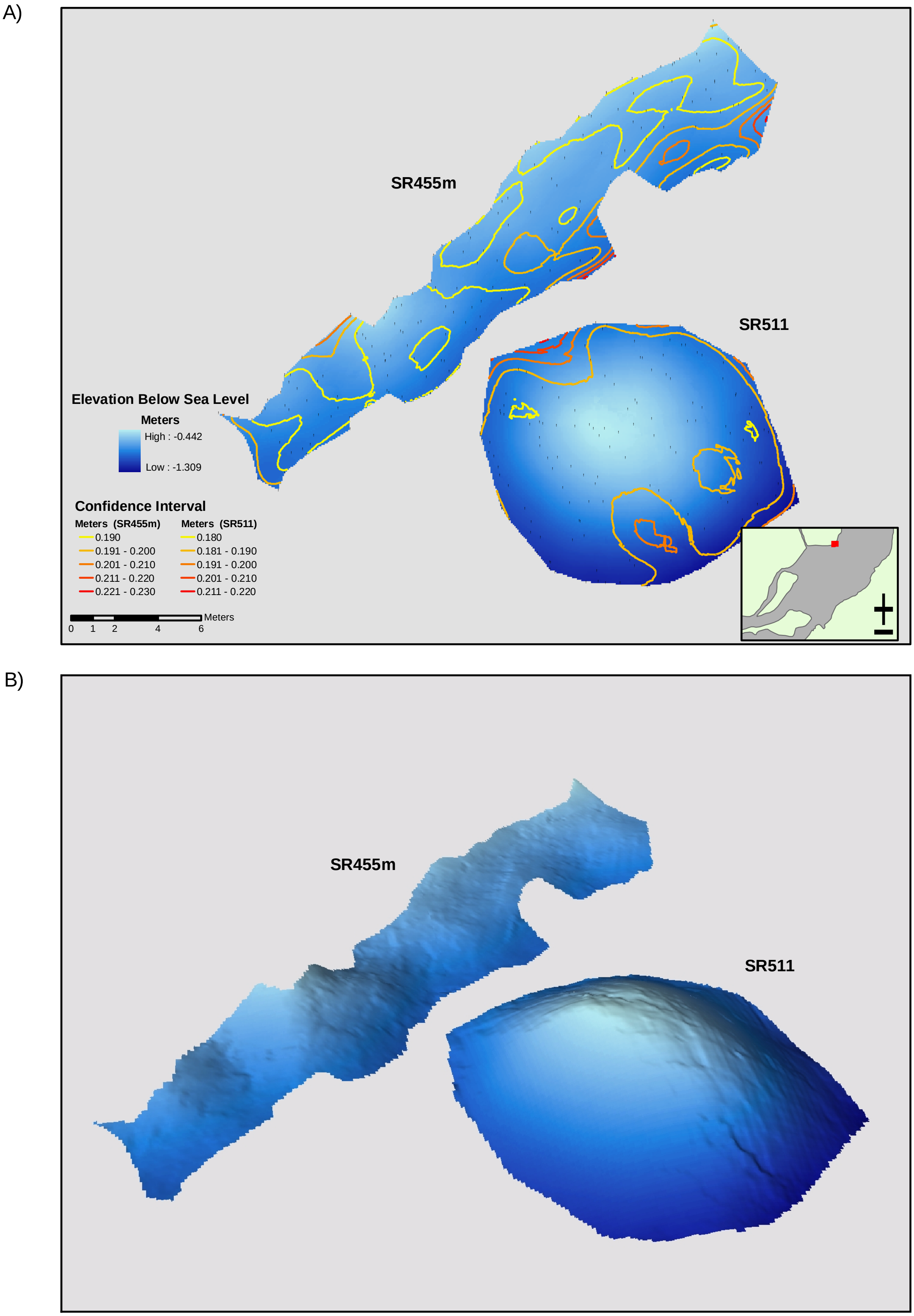
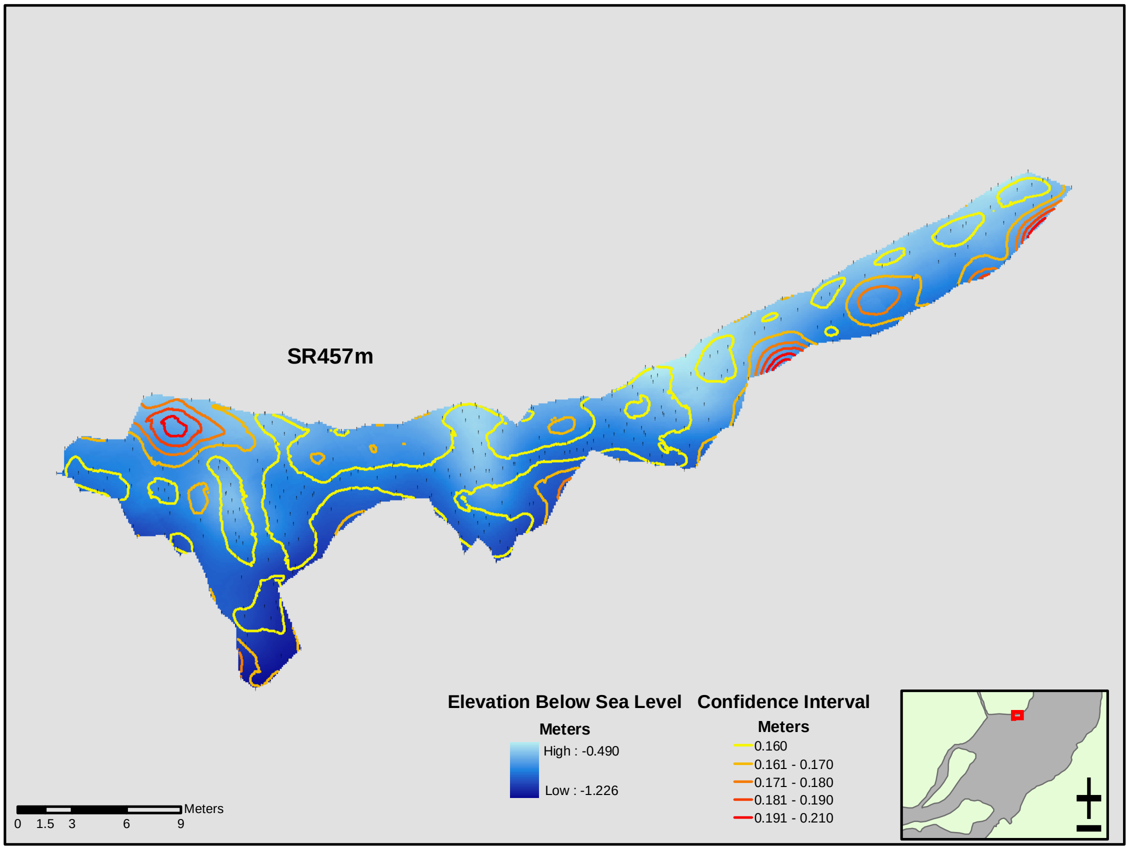


Figure A47. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR455m and SR511. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR455m and SR511 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

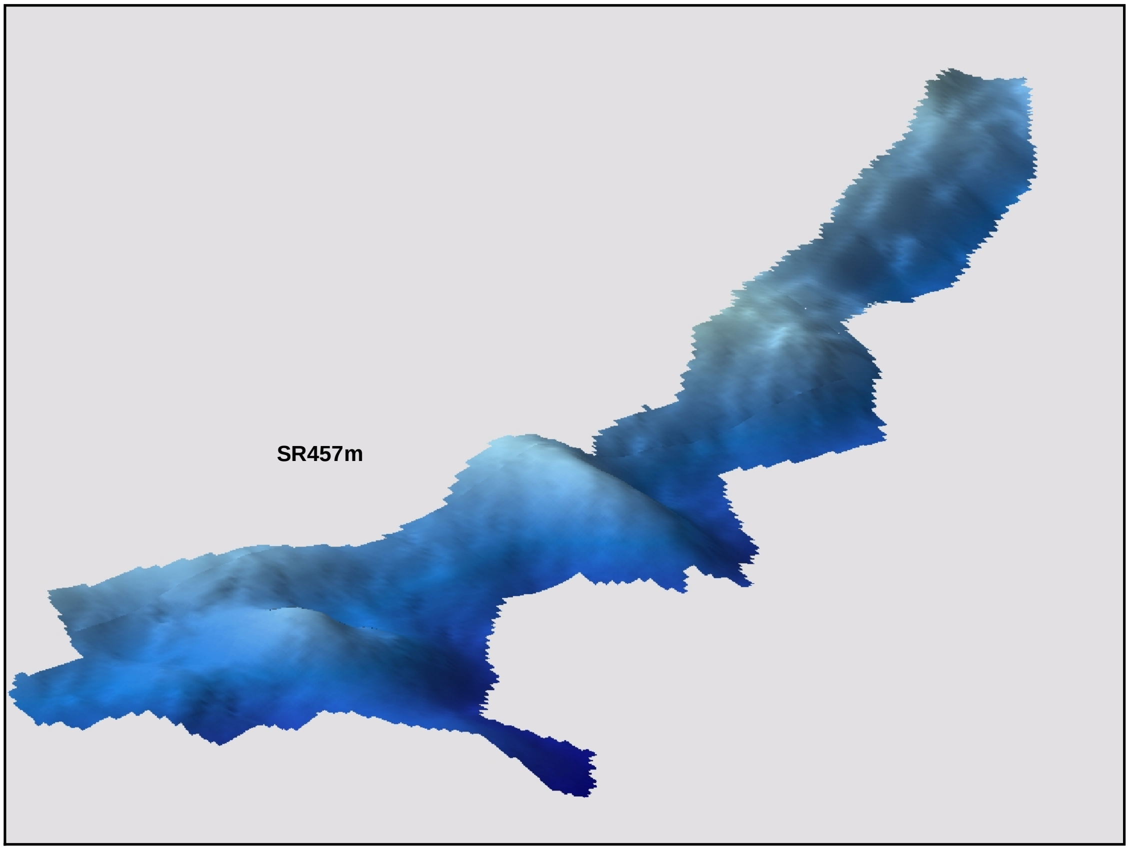


Figure A48. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR457m. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR457m based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

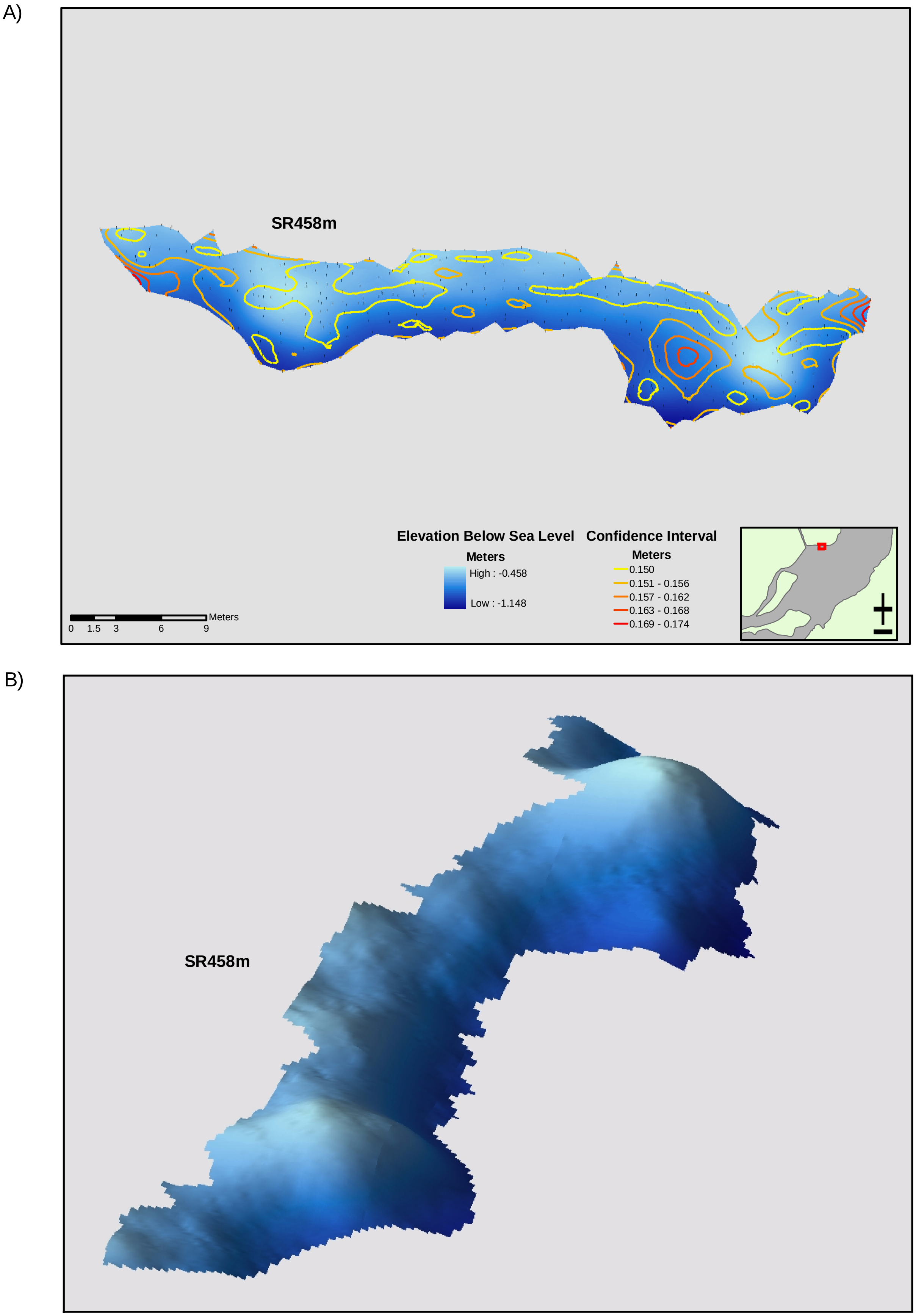


Figure A49. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR458m. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR458m based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

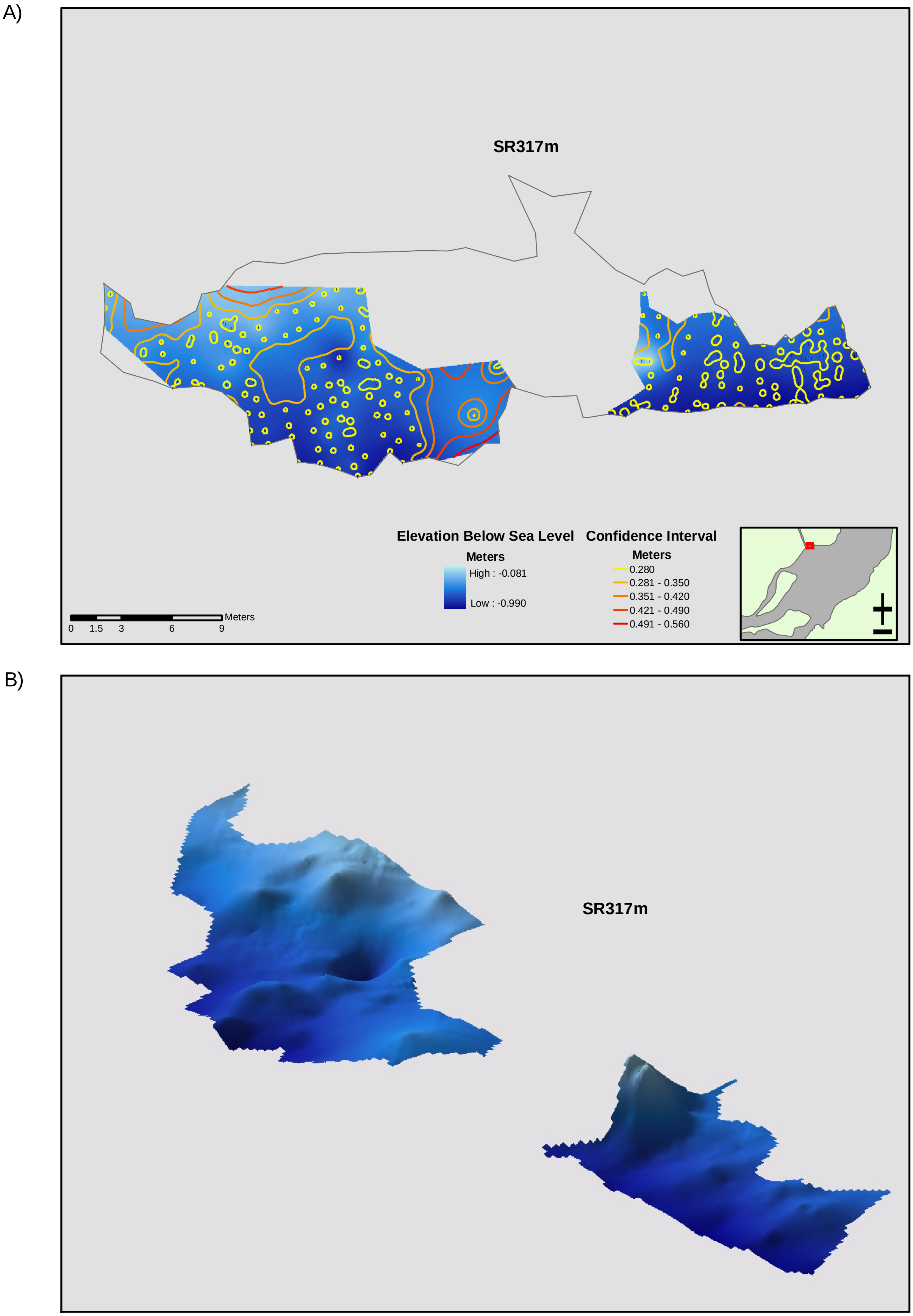


Figure A50. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR317m. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR317m based on the predicted surface elevations. The vertical relief has been exaggerated 10x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

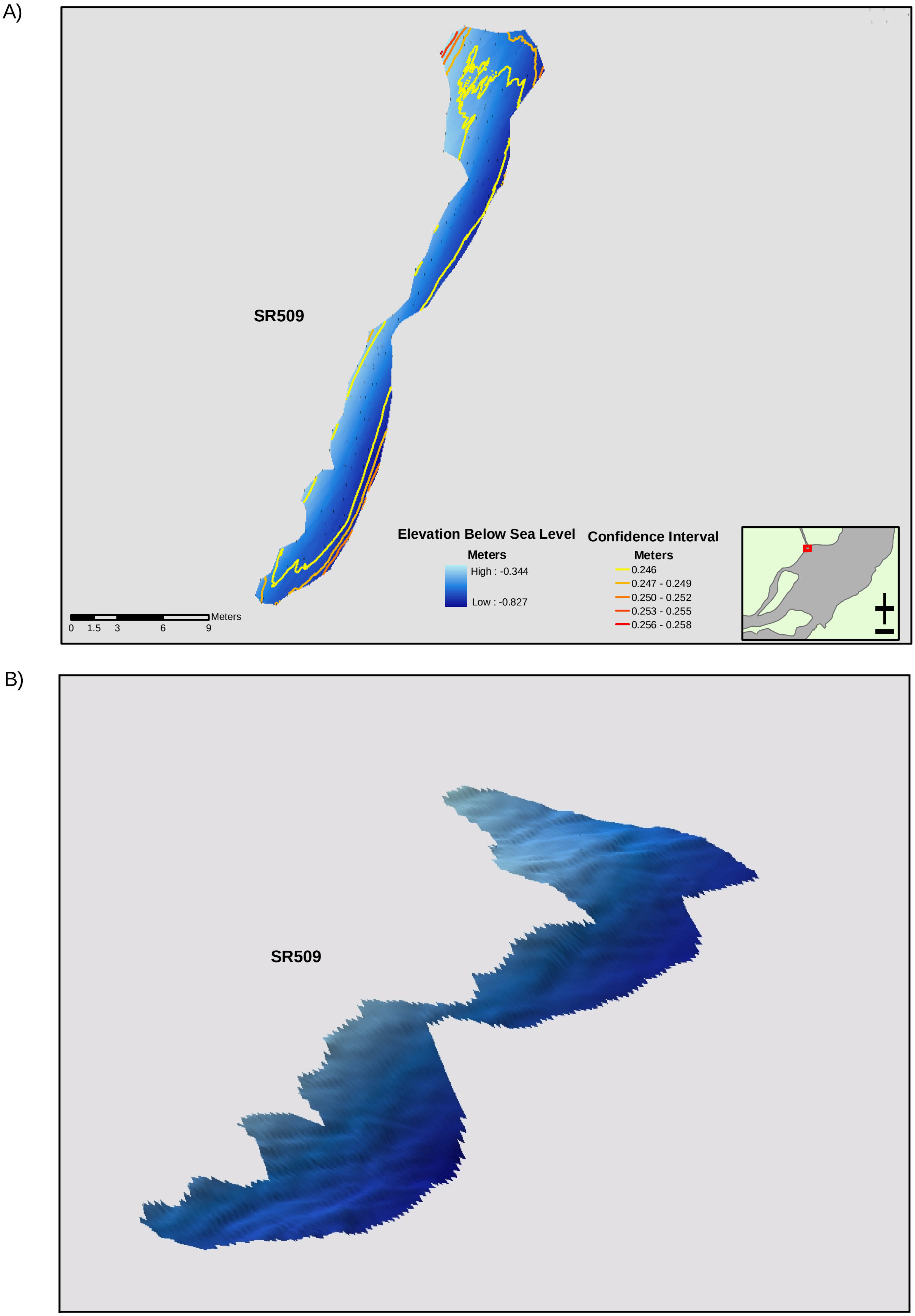


Figure A51. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR509. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR509 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

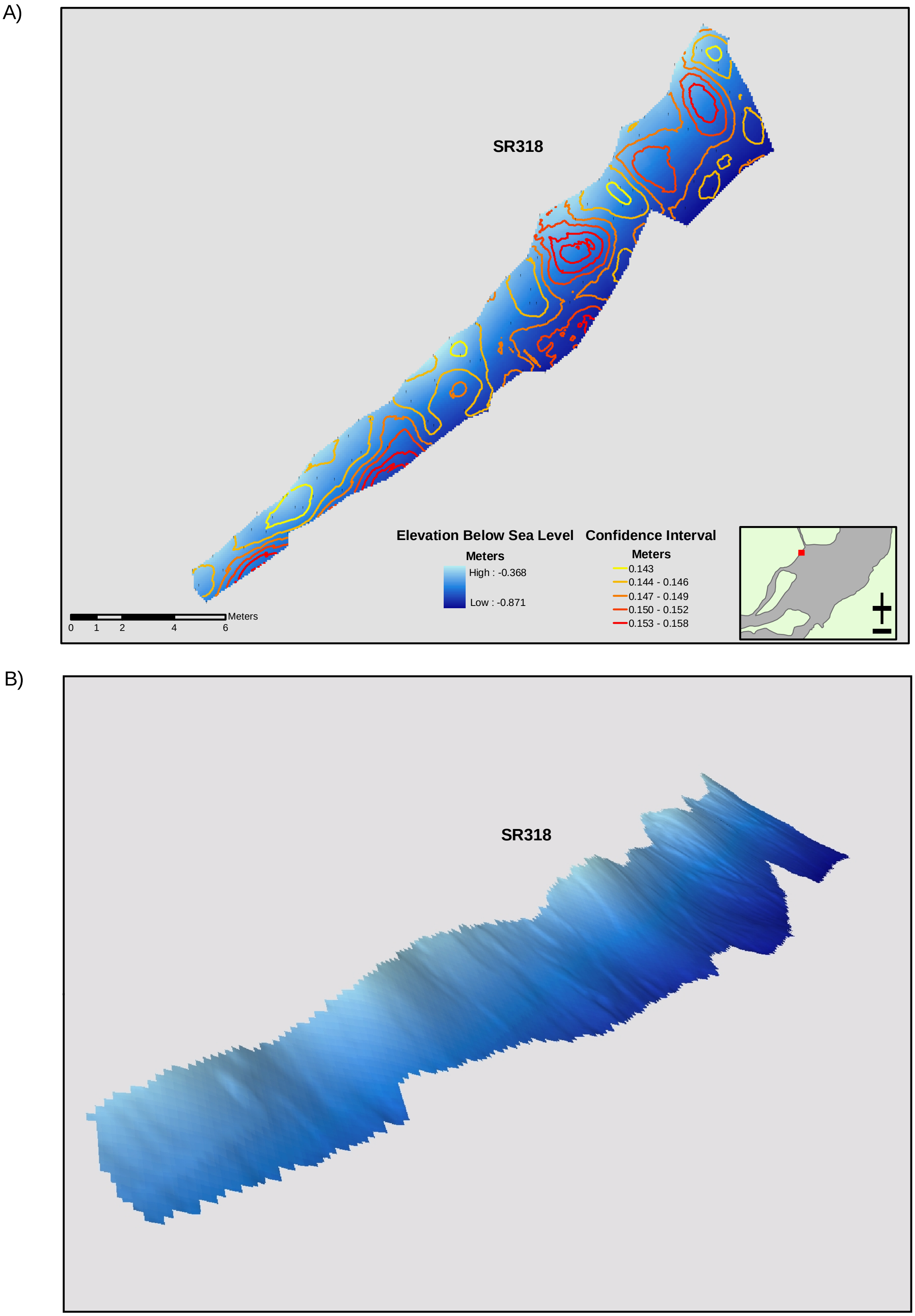


Figure A52. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR318. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR318 based on the predicted surface elevations. The vertical relief has been exaggerated 10x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

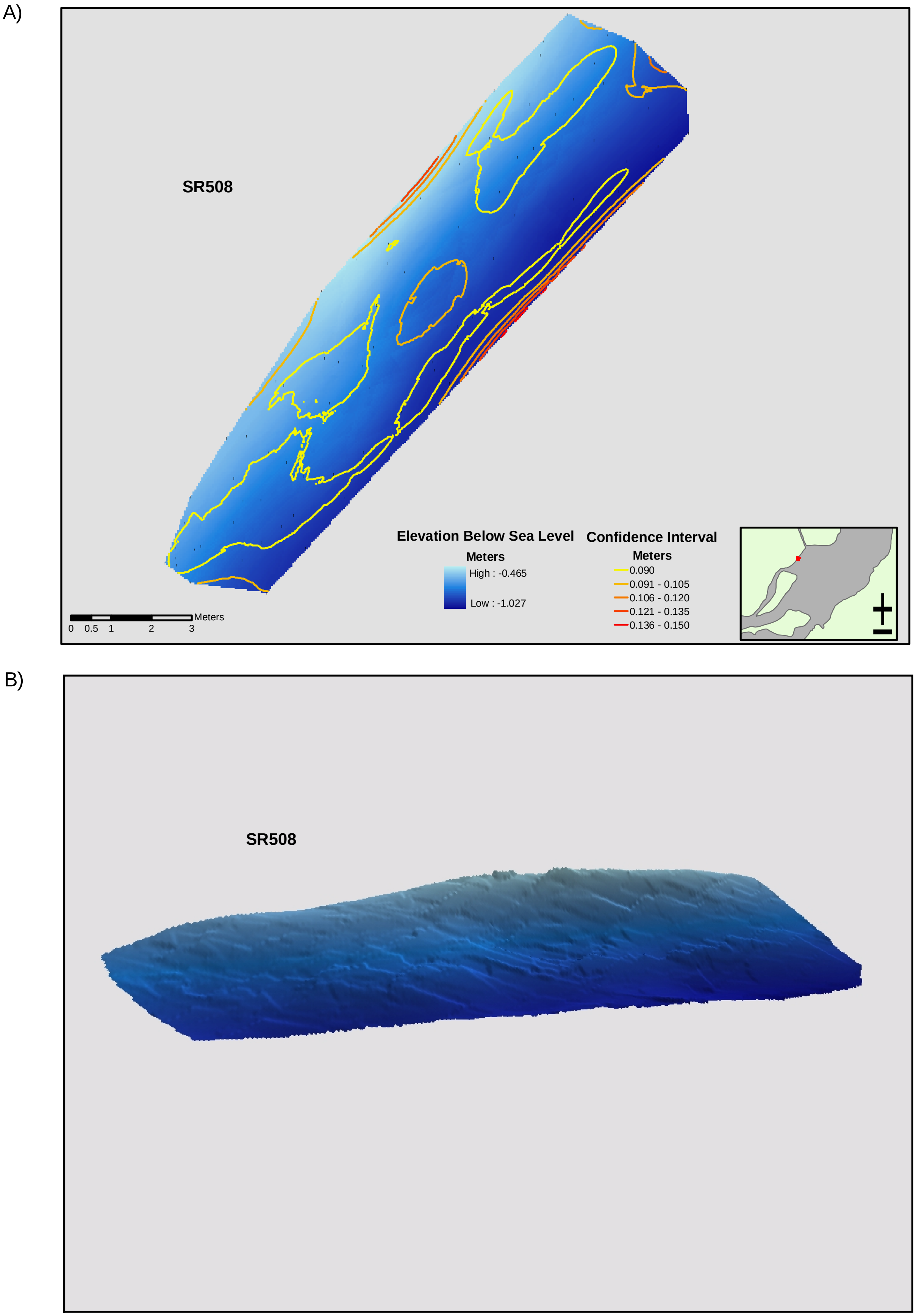


Figure A53. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR508. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR508 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

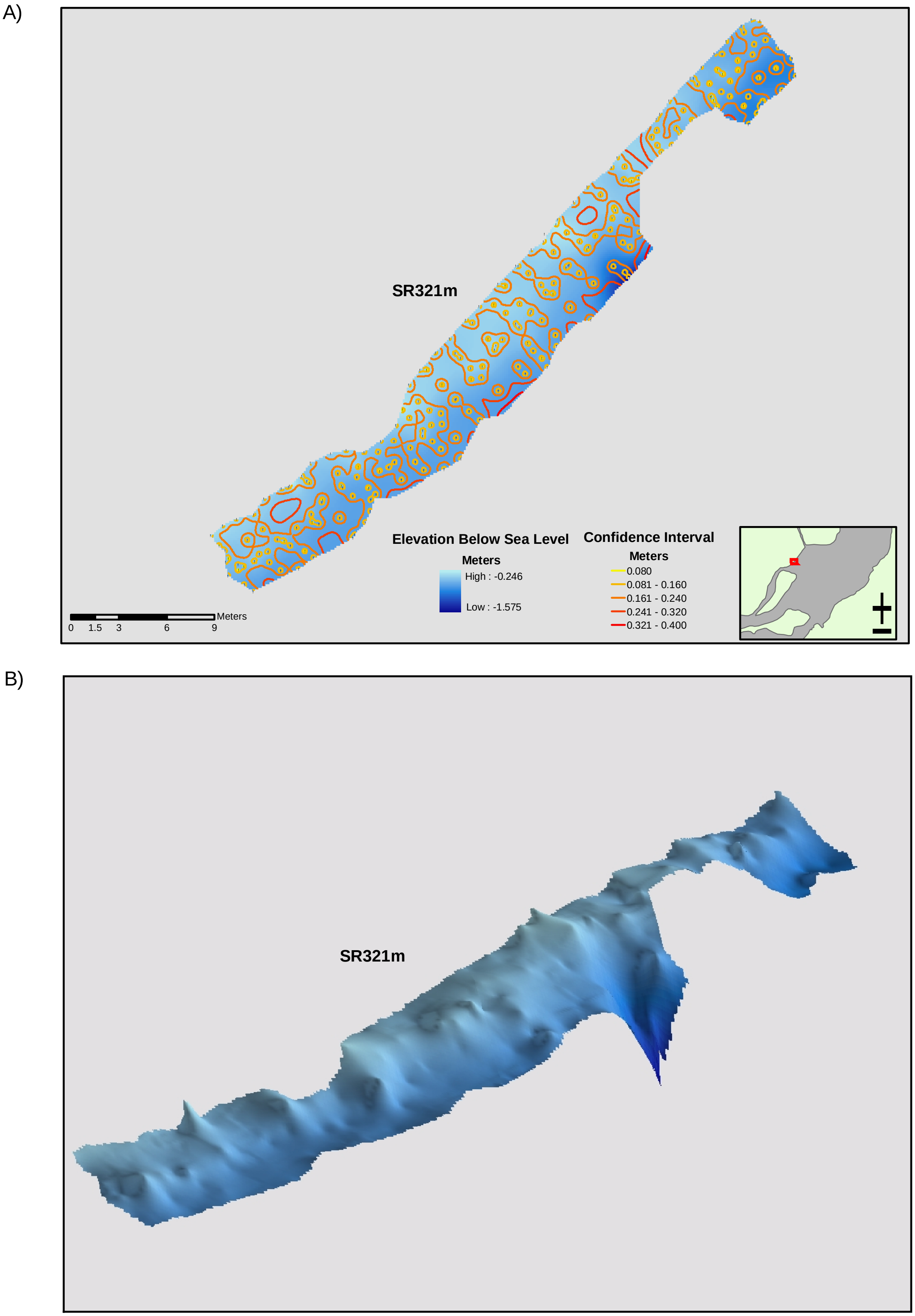
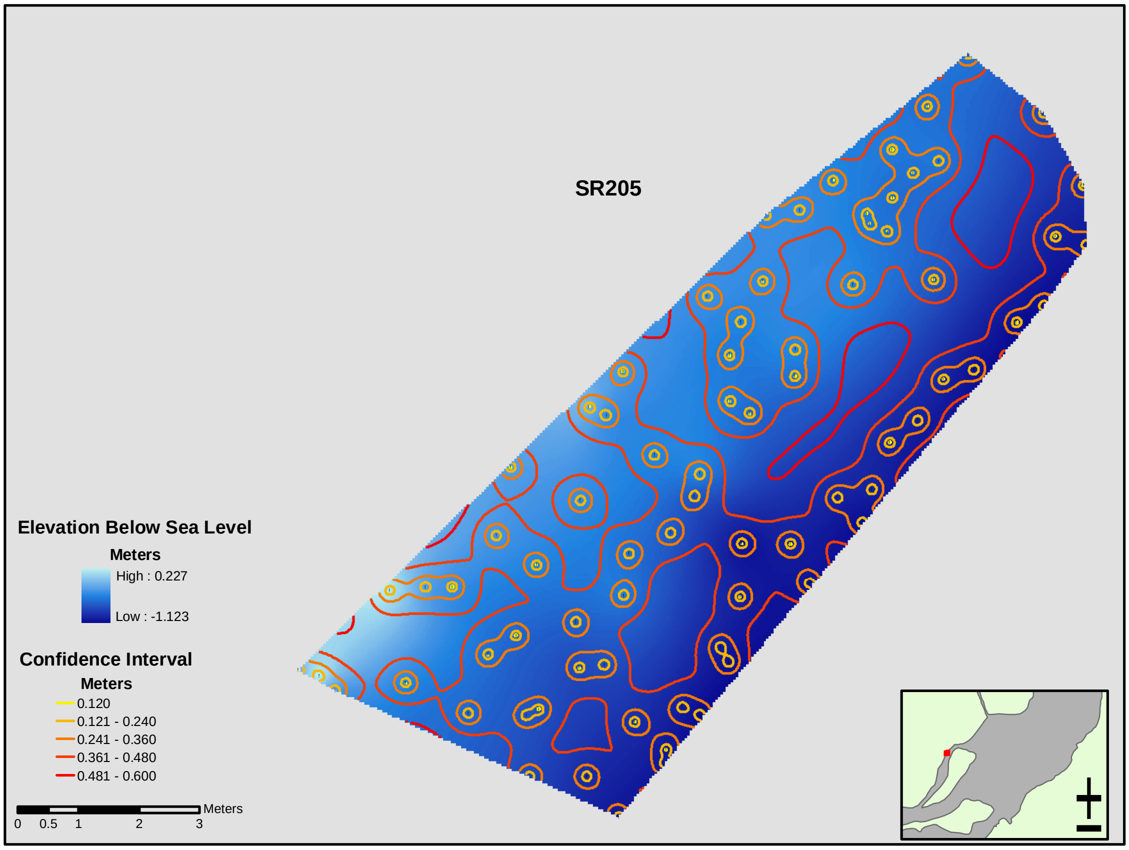


Figure A54. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR321m. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR321m based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

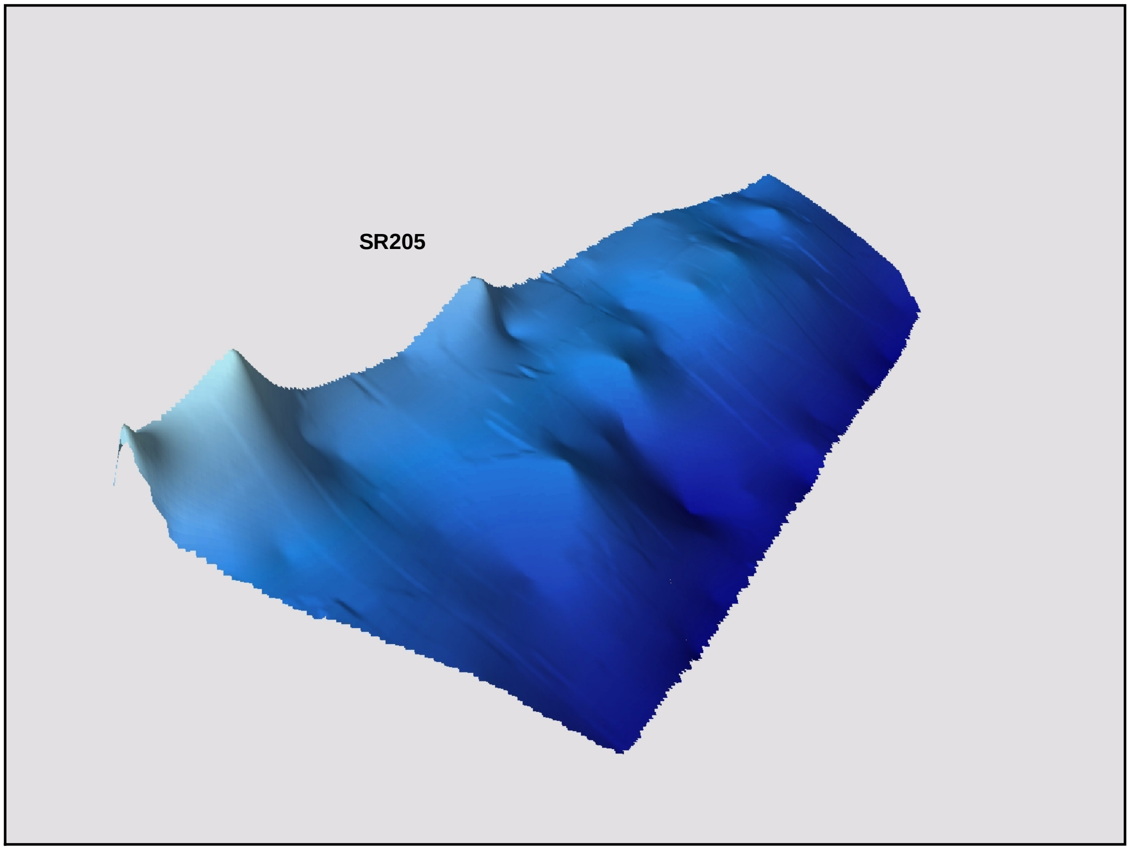


Figure A55. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR205. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR205 based on the predicted surface elevations. The vertical relief has been exaggerated 10x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

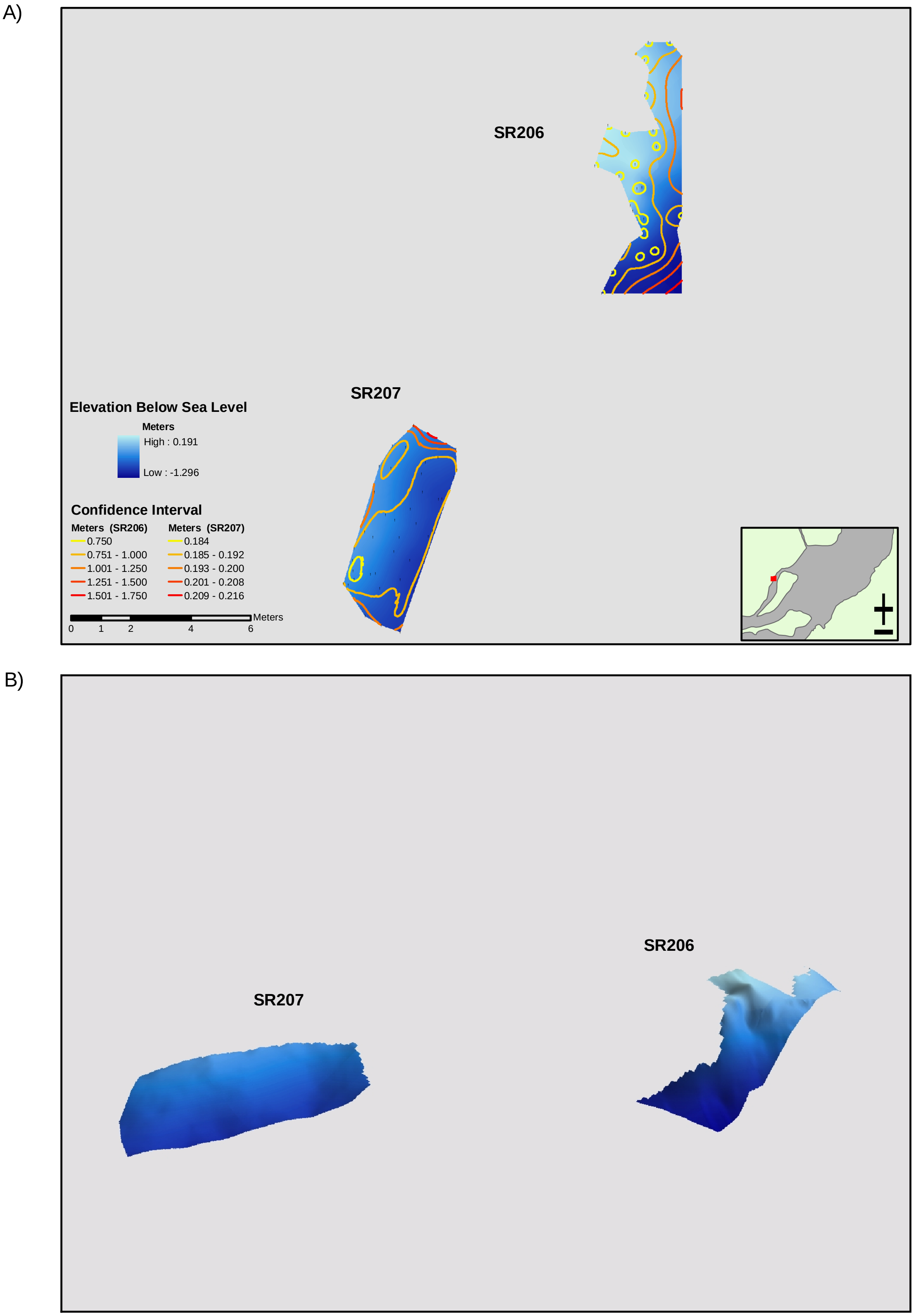


Figure A56. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR206 and SR207. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR206 and SR207 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

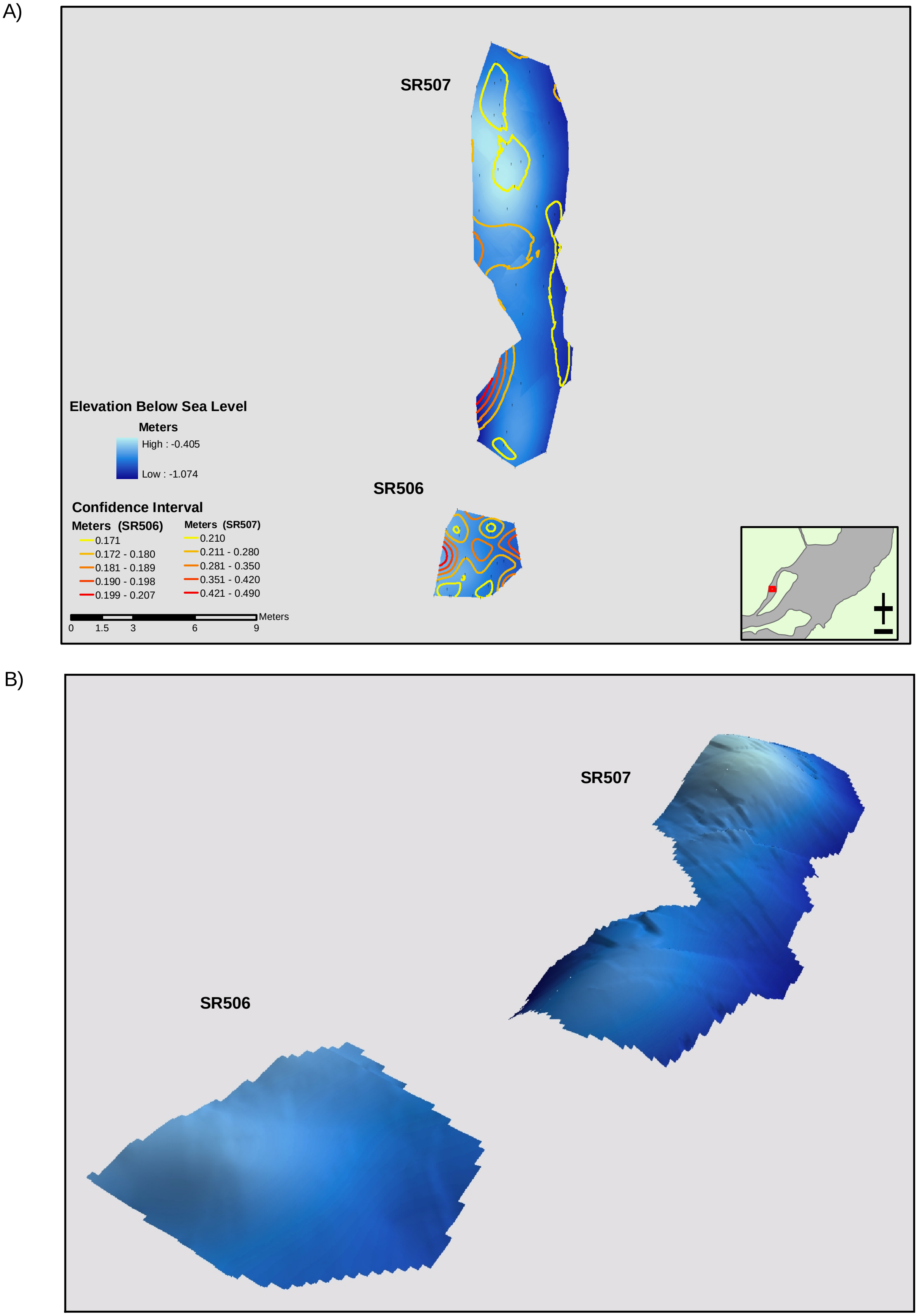


Figure A57. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR506 and SR507. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR506 and SR507 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

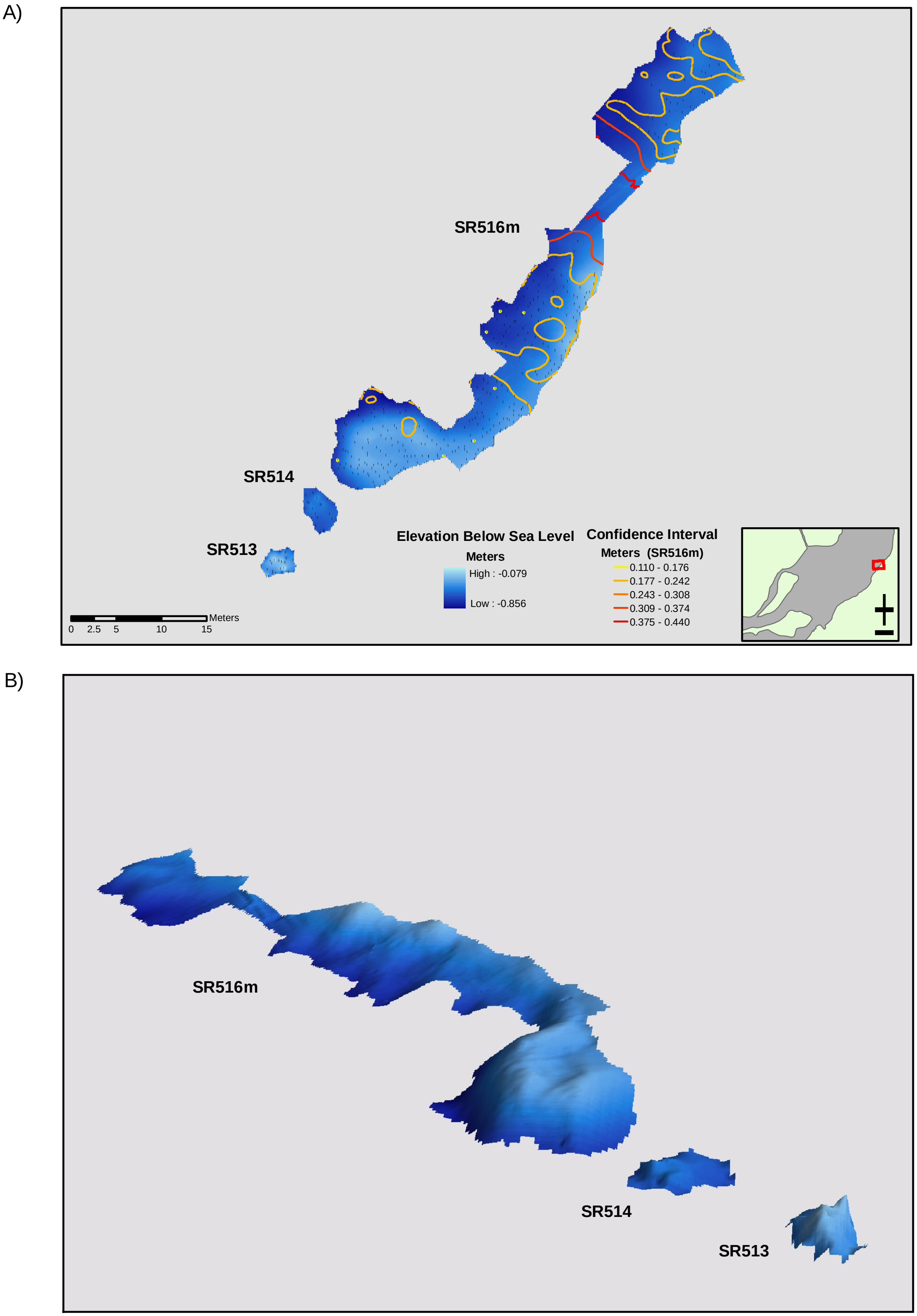
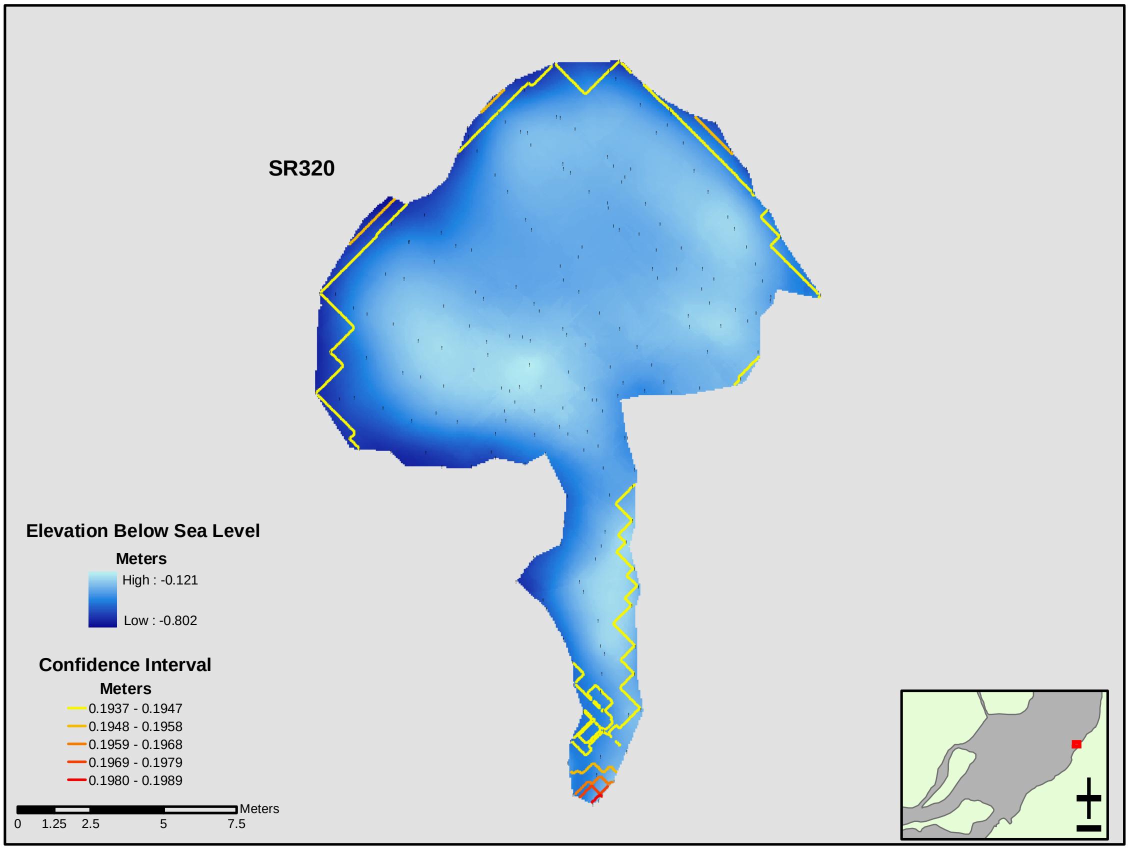


Figure A58. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR513, SR514, and SR516m. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR513, SR514, and SR516m based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

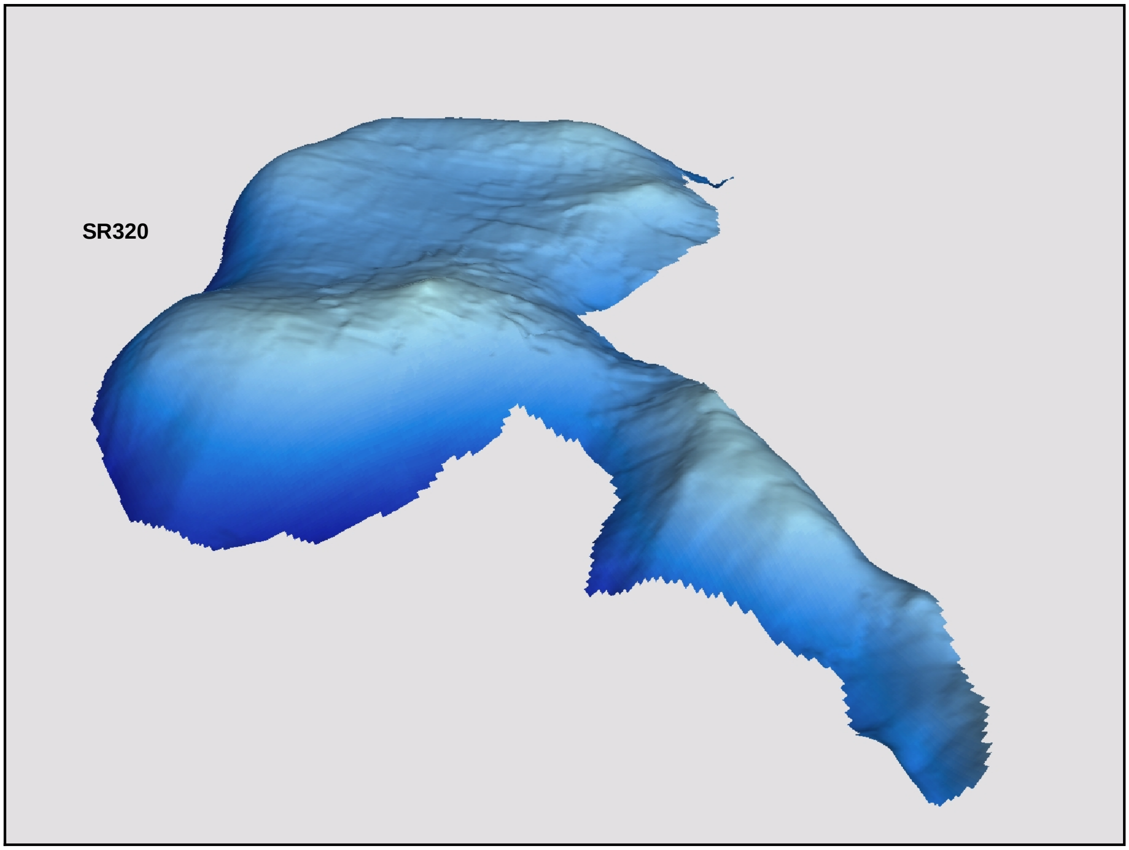


Figure A59. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR320. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR320 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

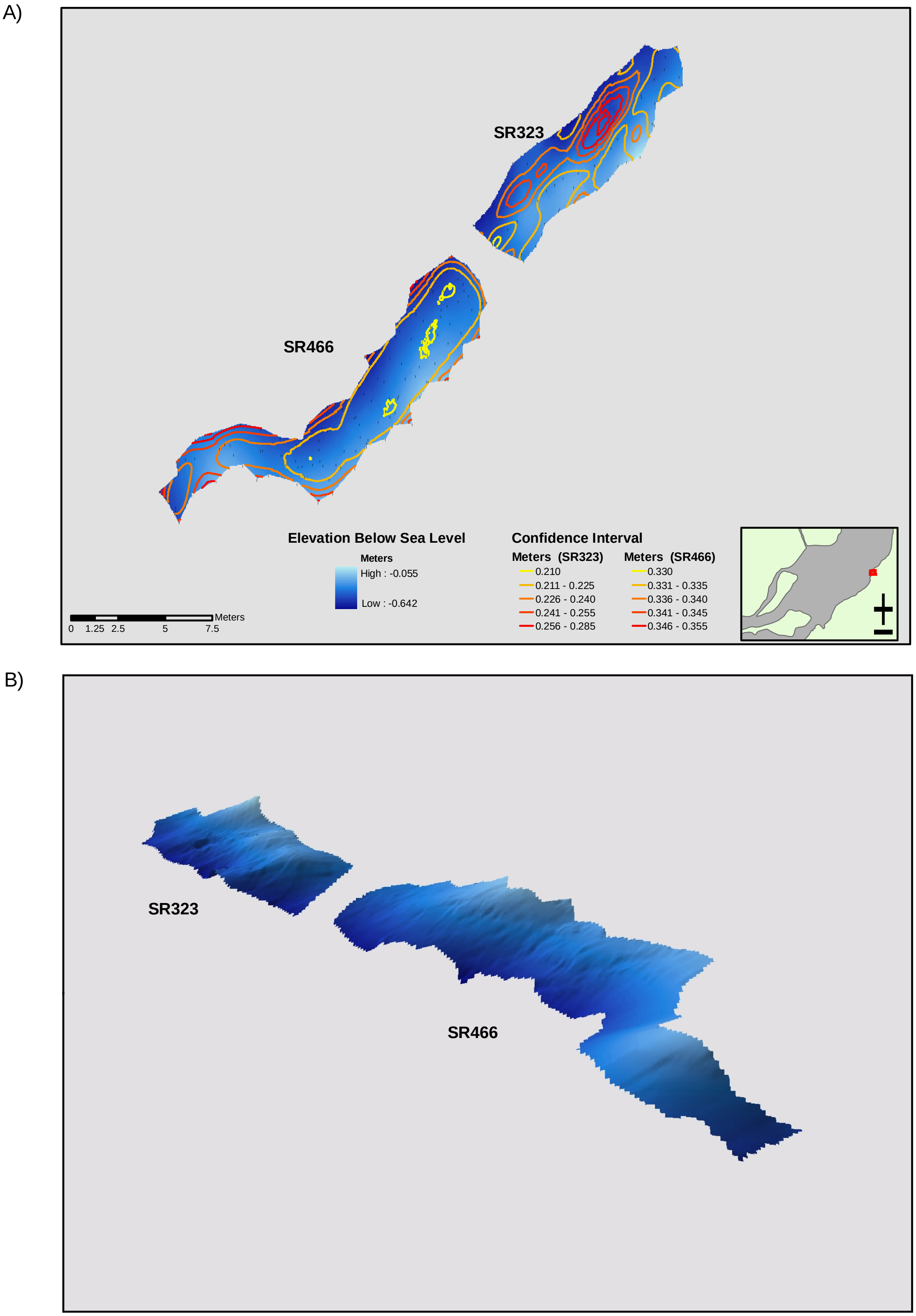


Figure A60. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR323 and SR466. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR323 and SR466 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

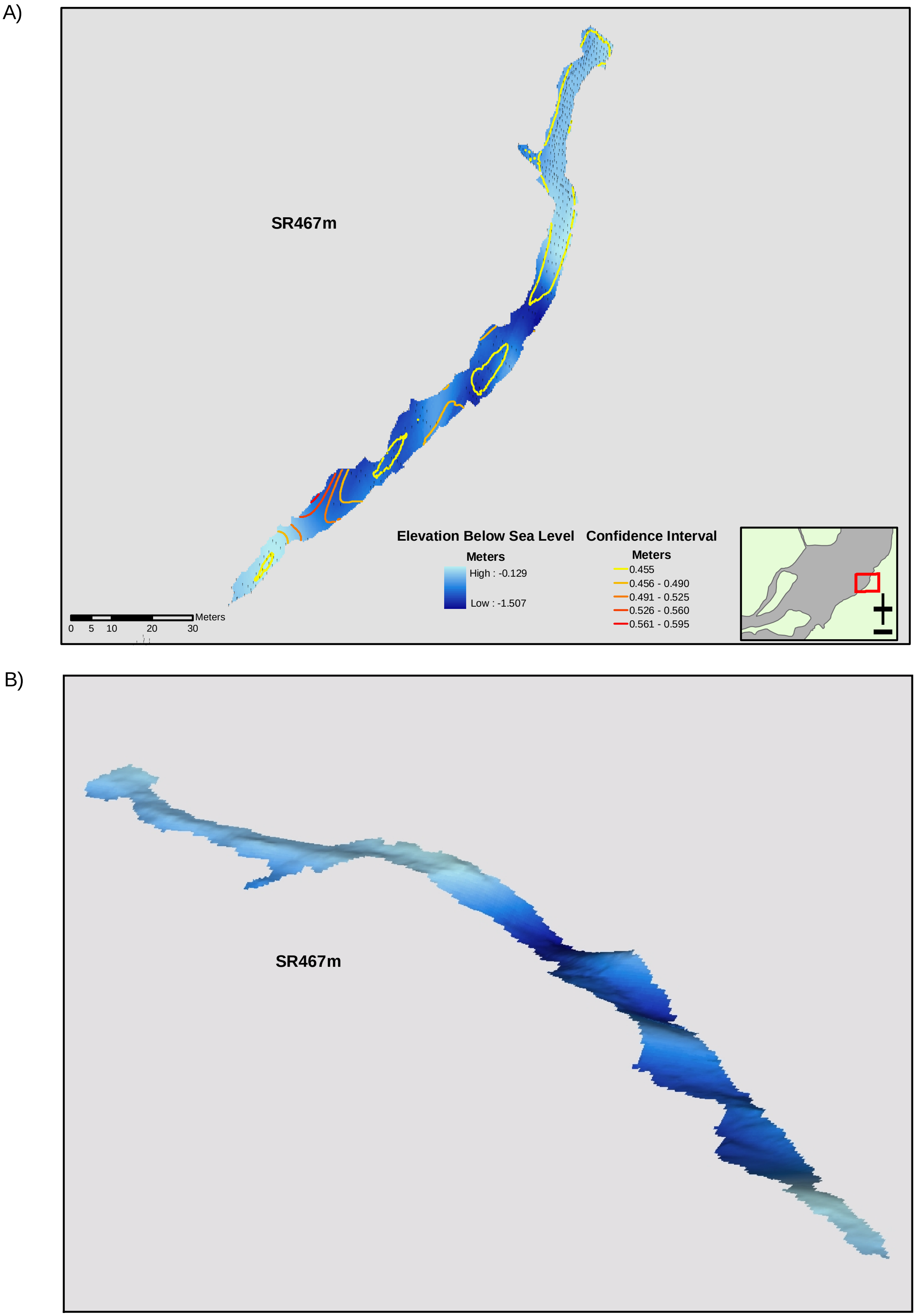
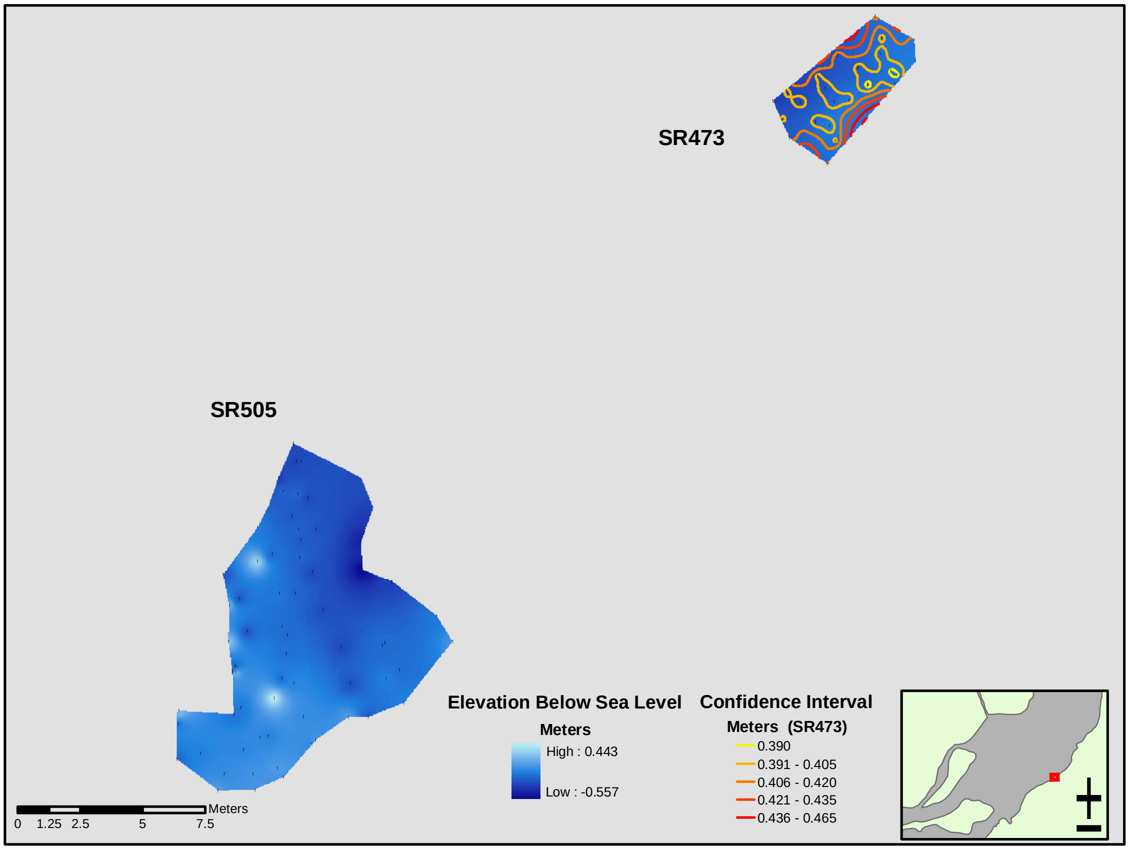


Figure A61. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR467m. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR467m based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

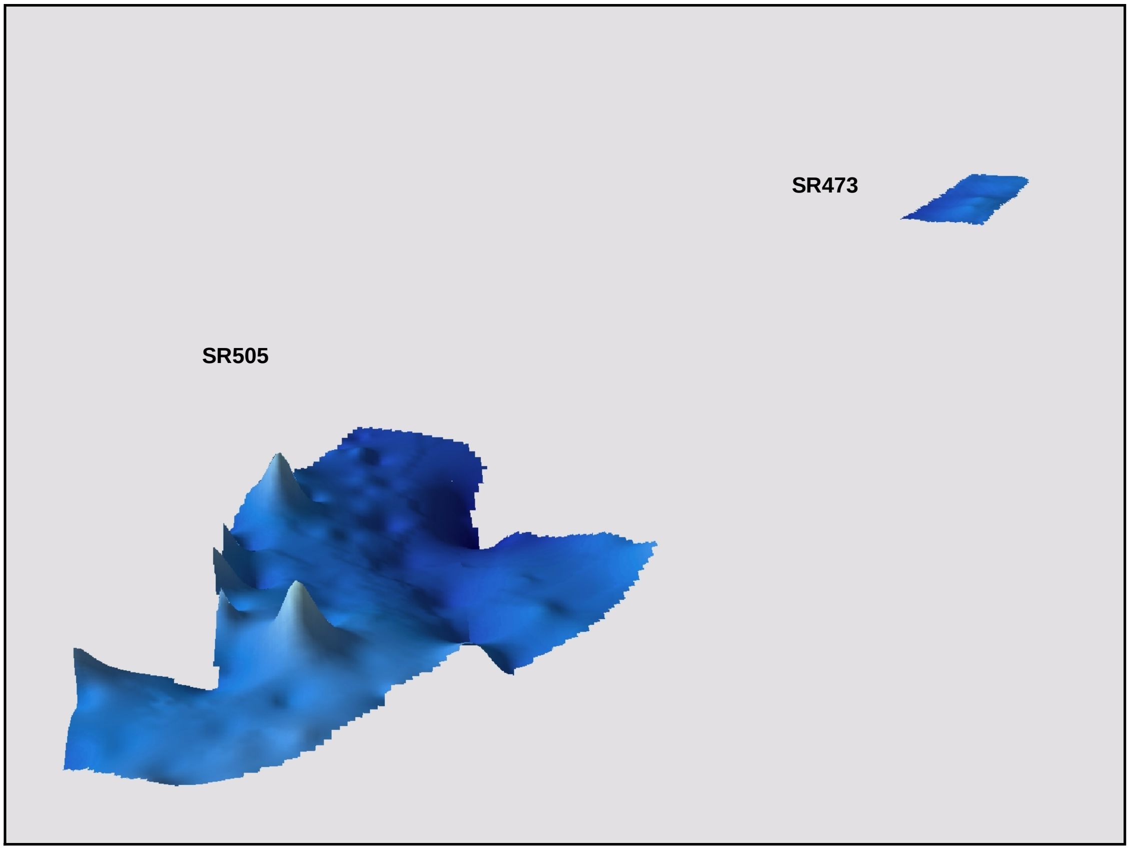


Figure A62. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR473 and SR505. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR473 and SR505 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

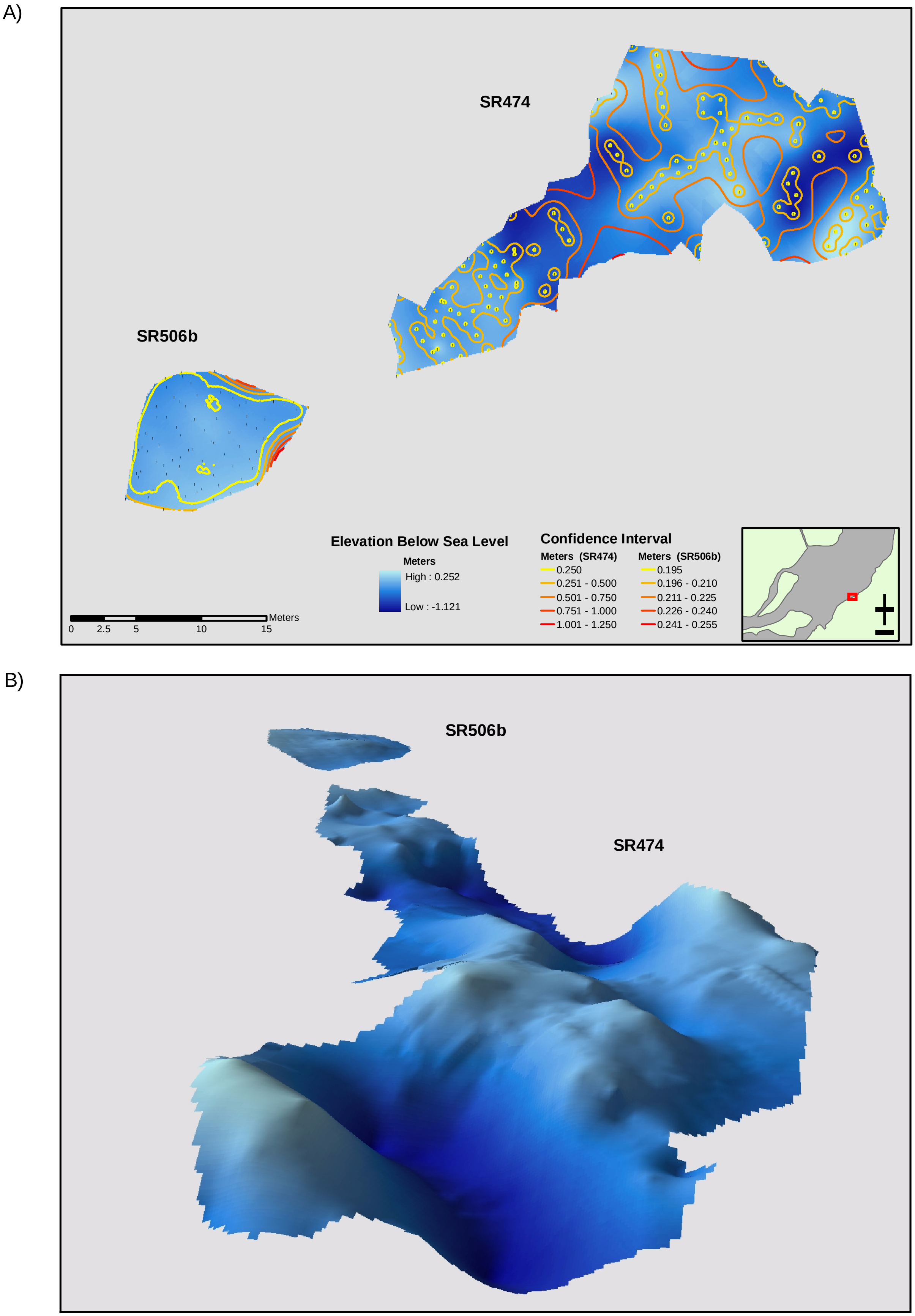


Figure A63. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR474 and SR506b. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR474 and SR506b based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

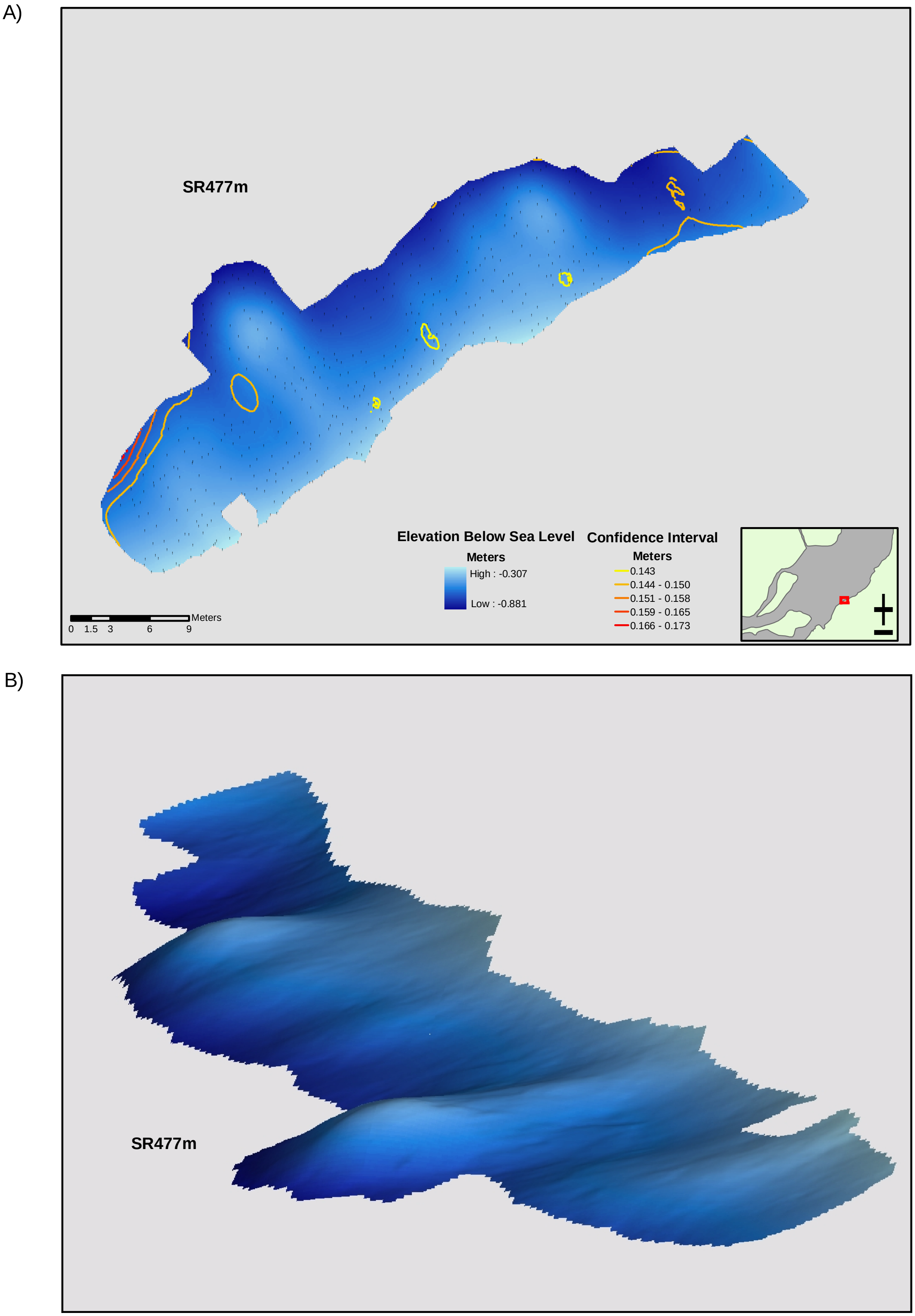


Figure A64. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR477m. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR477m based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

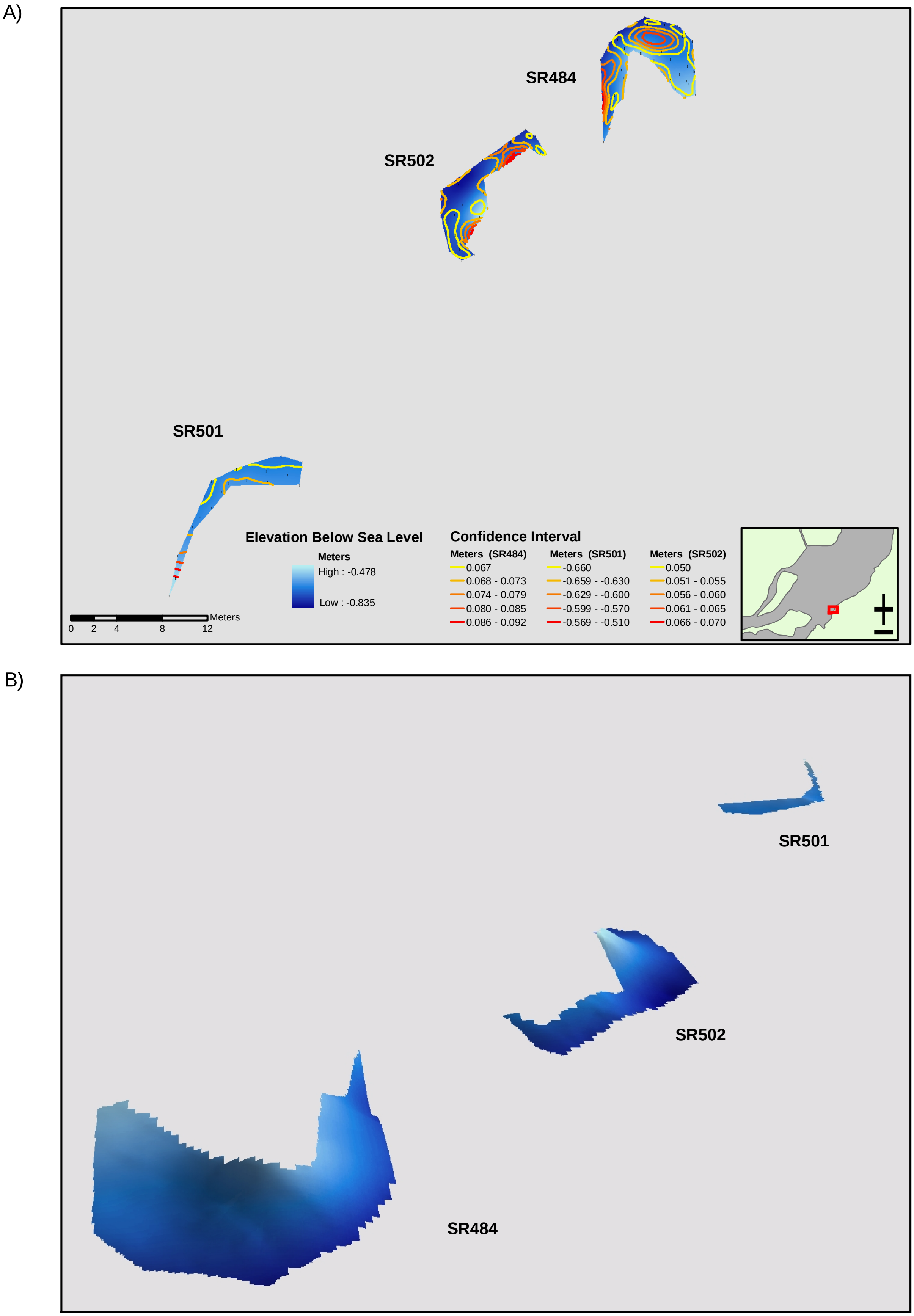


Figure A65. A) Predicted surface elevation, surface confidence interval and location of data points for reefs SR484, SR501, and SR502. Elevation is shown as meters below sea level. A 95% confidence interval was calculated separately for each reef's predicted surface and is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reefs SR484, SR501, and SR502 based on its predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

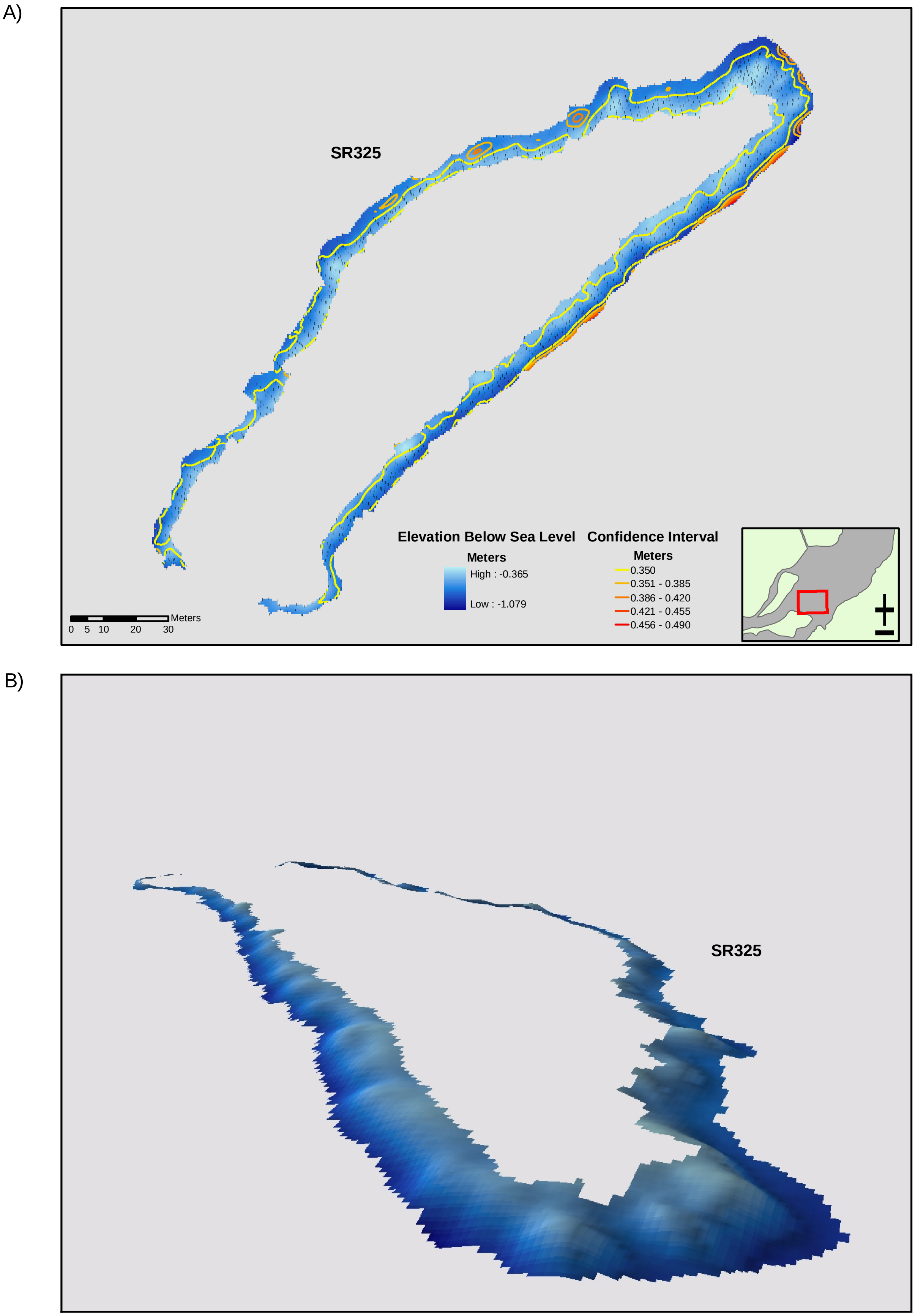
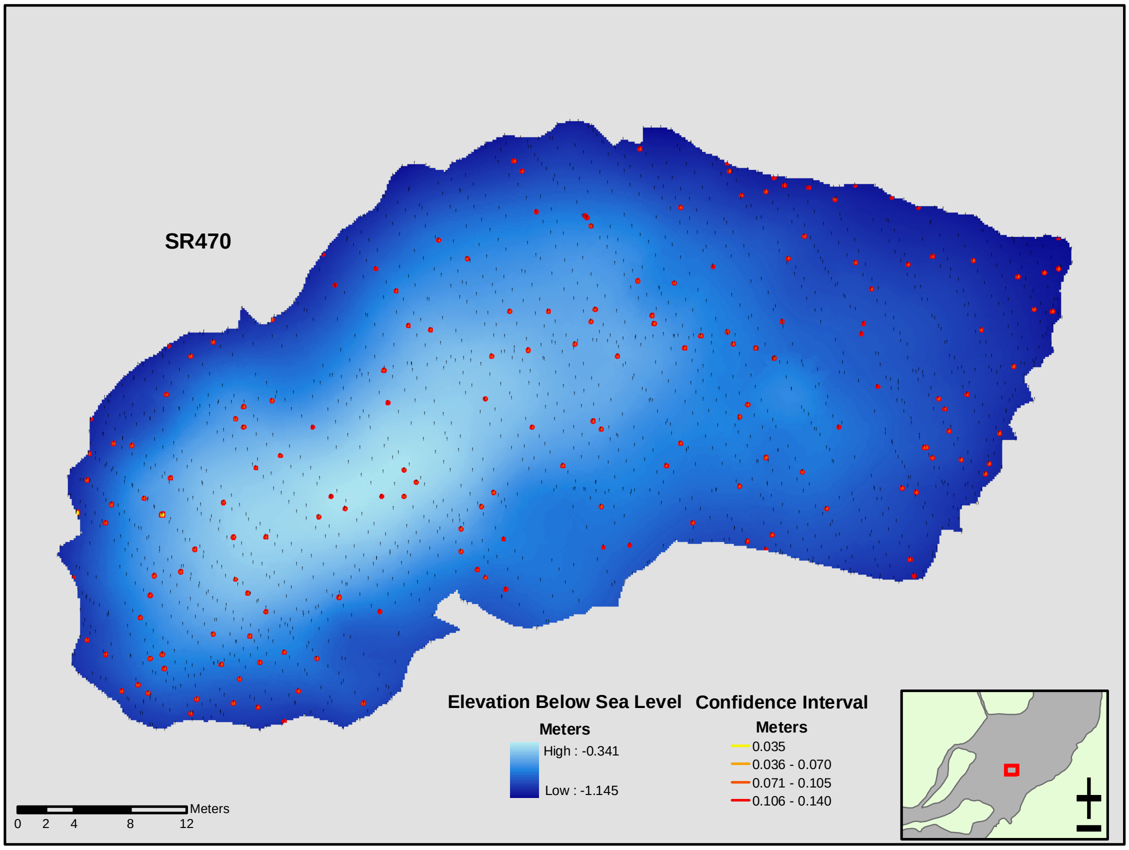


Figure A66. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR325. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR325 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

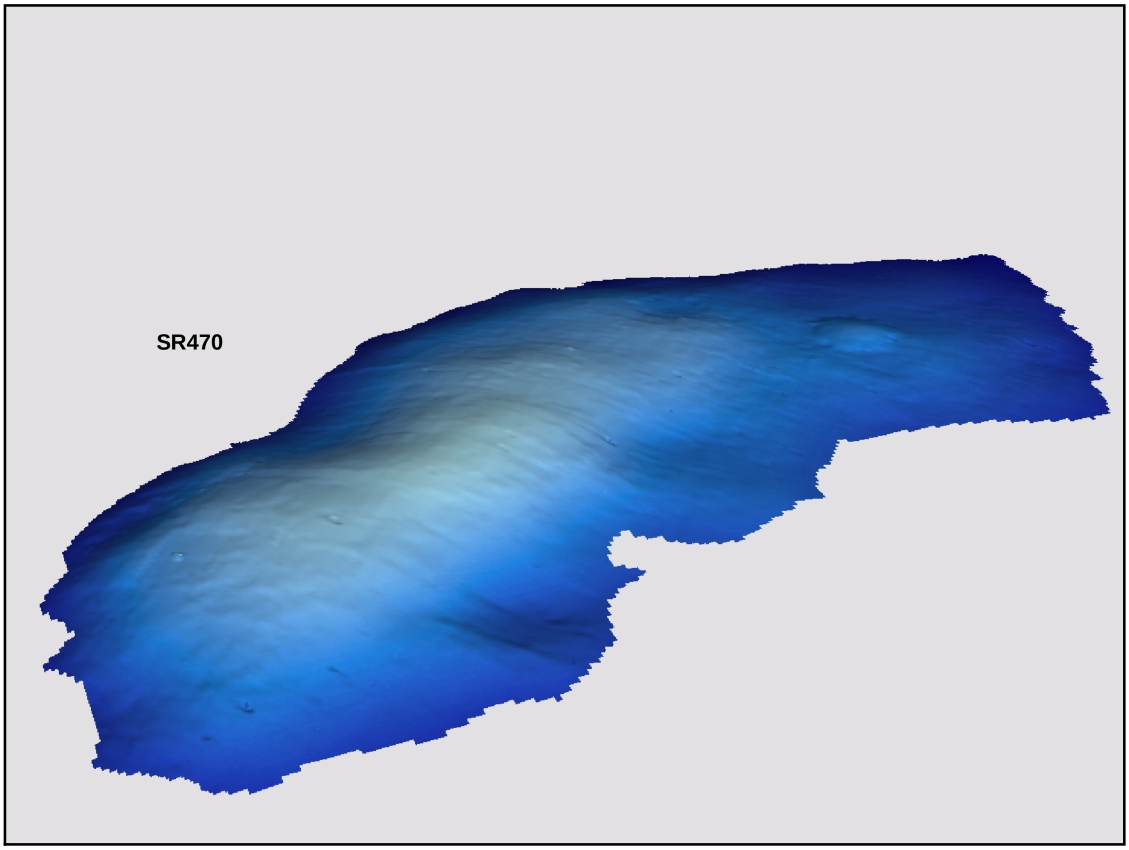


Figure A67. A) Predicted surface elevation, surface confidence interval and location of data points for reef SR470. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SR470 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

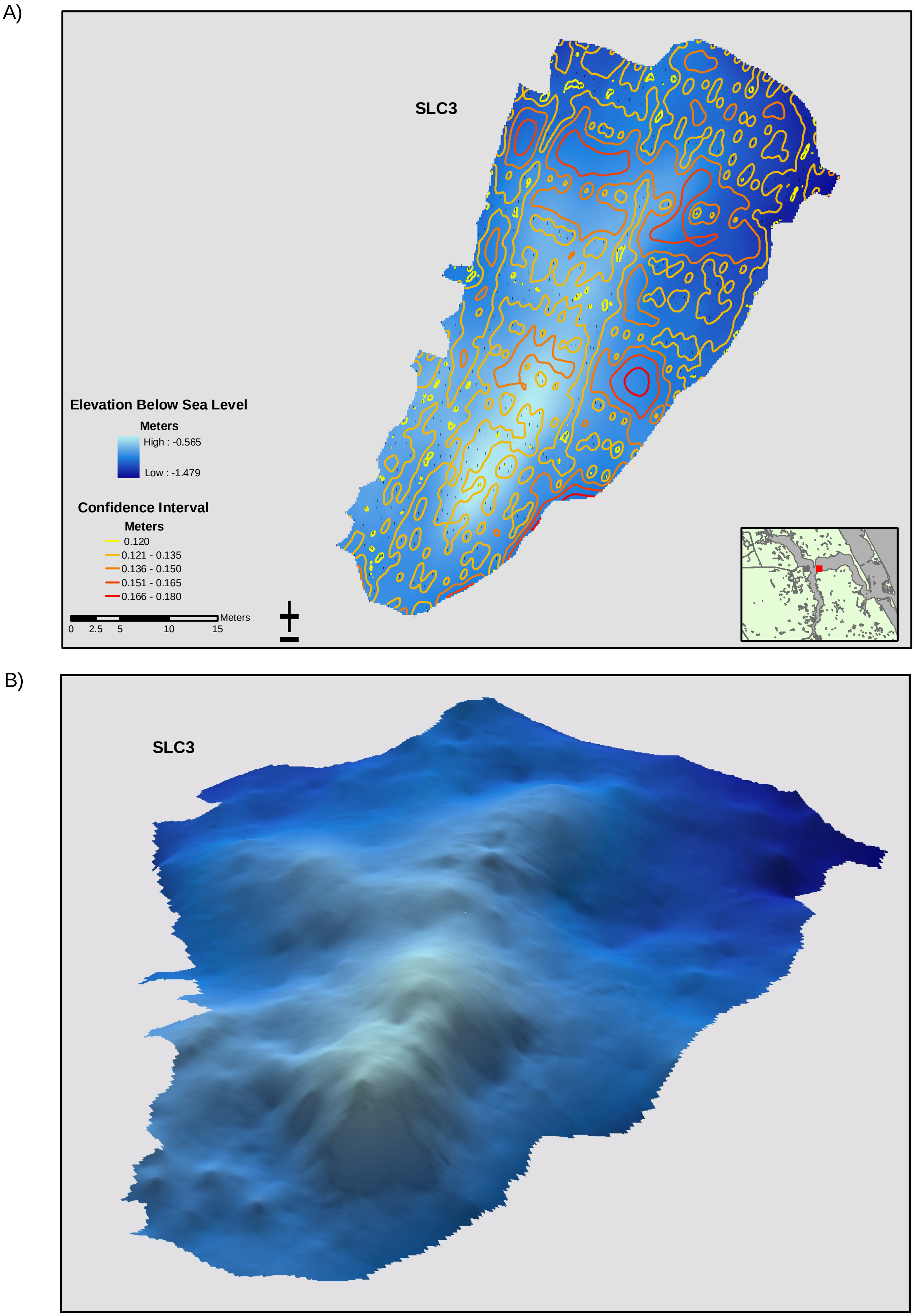


Figure A68. A) Predicted surface elevation, surface confidence interval and location of data points for reef SLC3. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SLC3 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

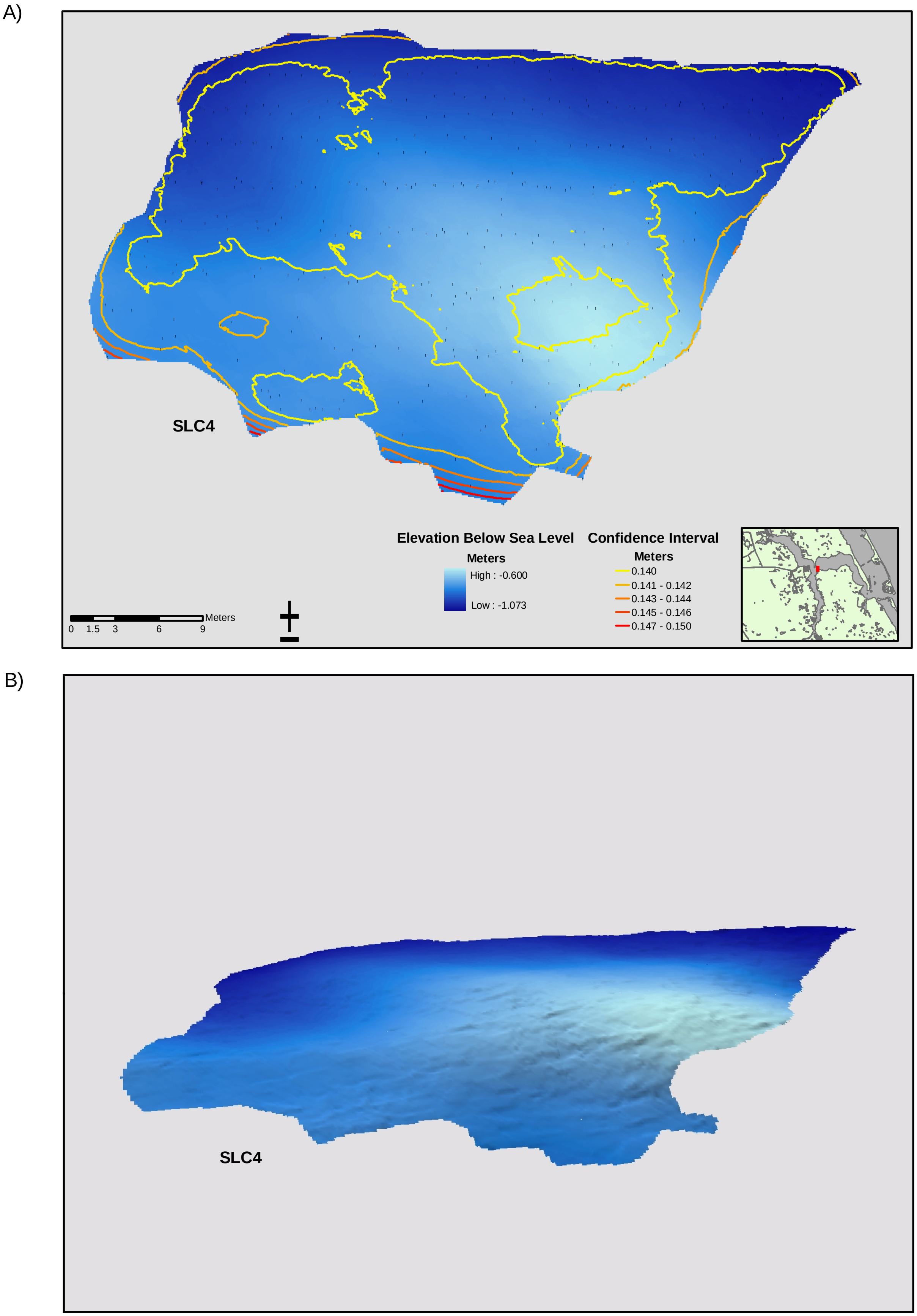


Figure A69. A) Predicted surface elevation, surface confidence interval and location of data points for reef SLC4. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surfaceis represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SLC4 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

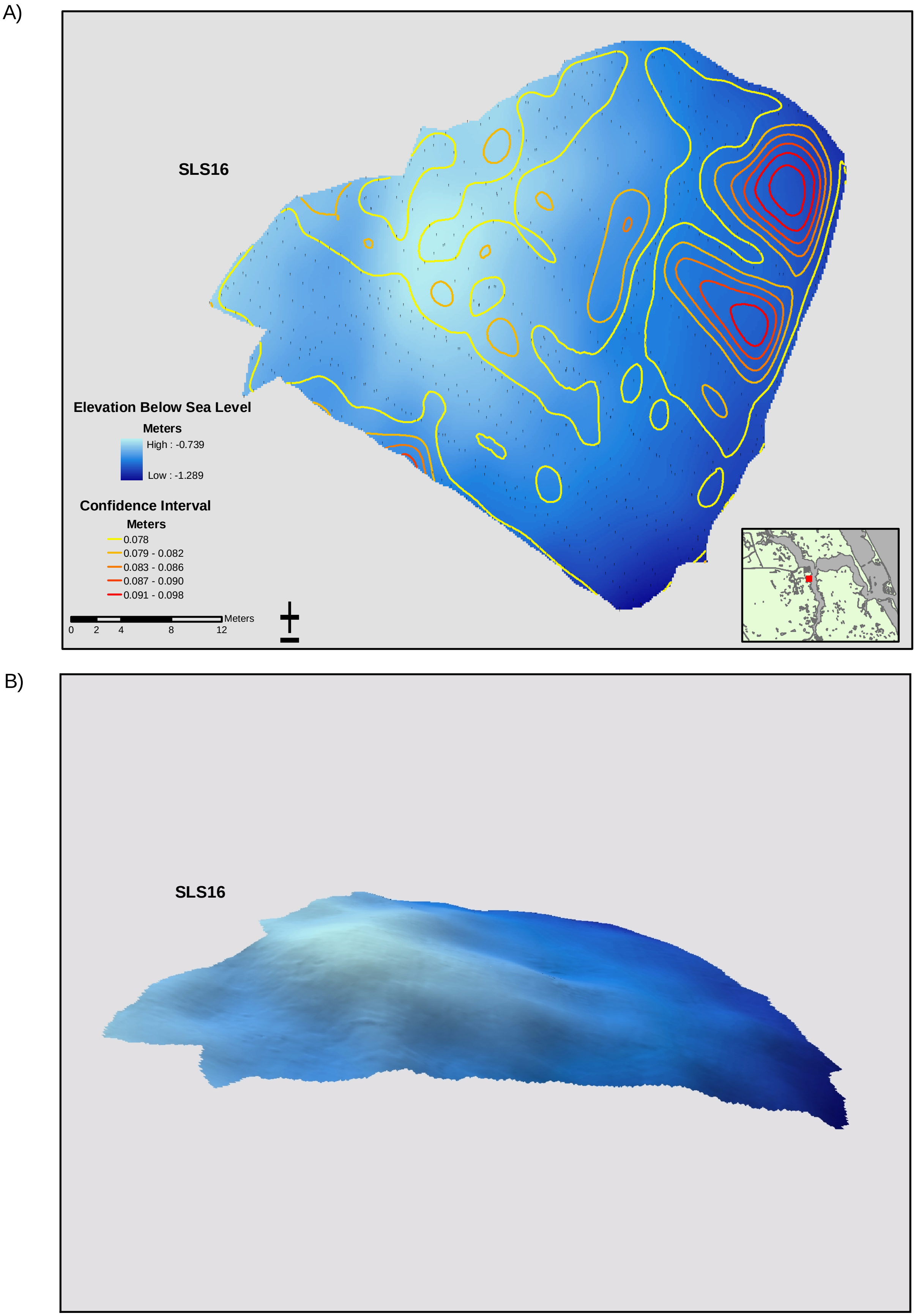


Figure A70. A) Predicted surface elevation, surface confidence interval and location of data points for reef SLS16. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SLS16 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

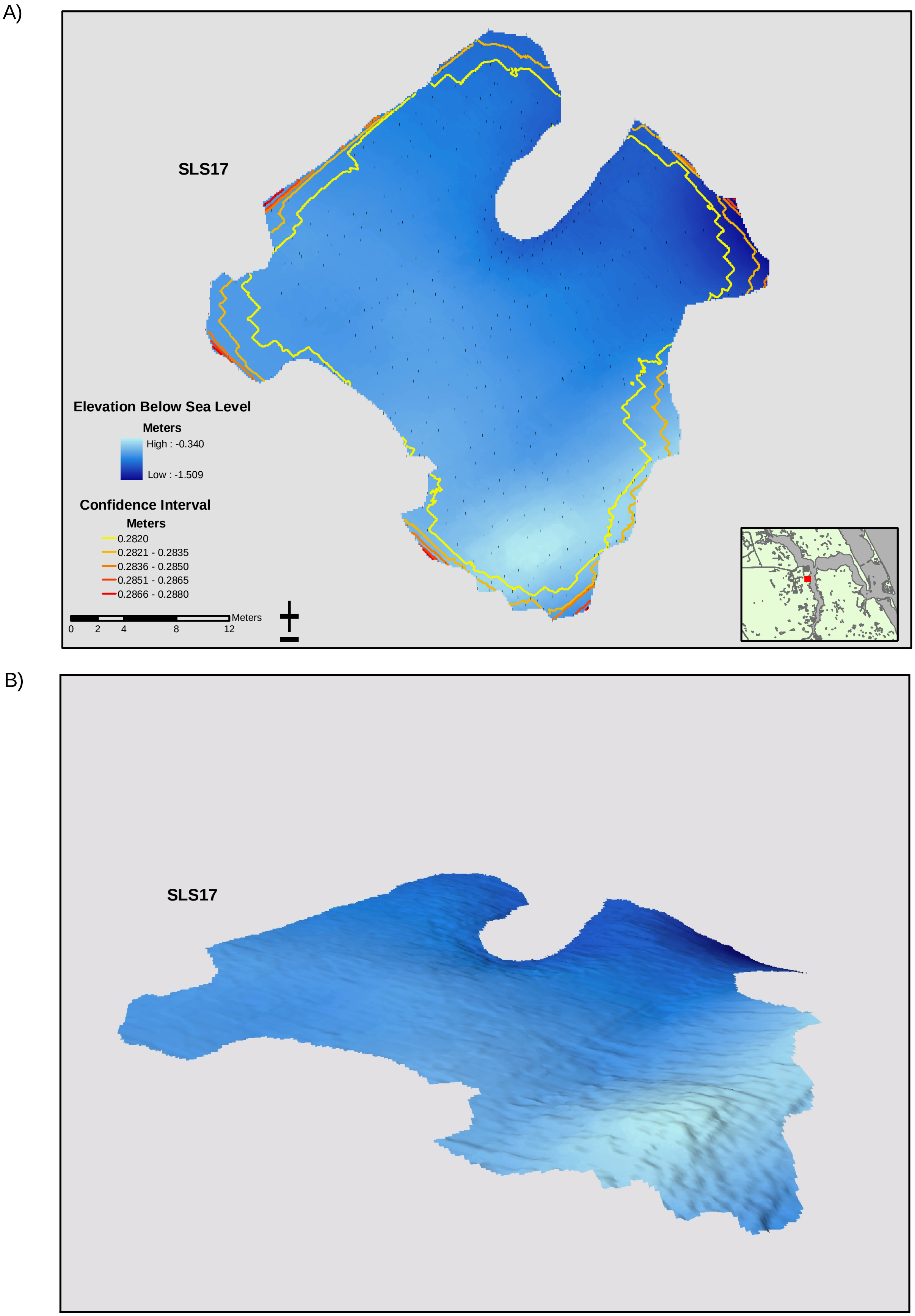
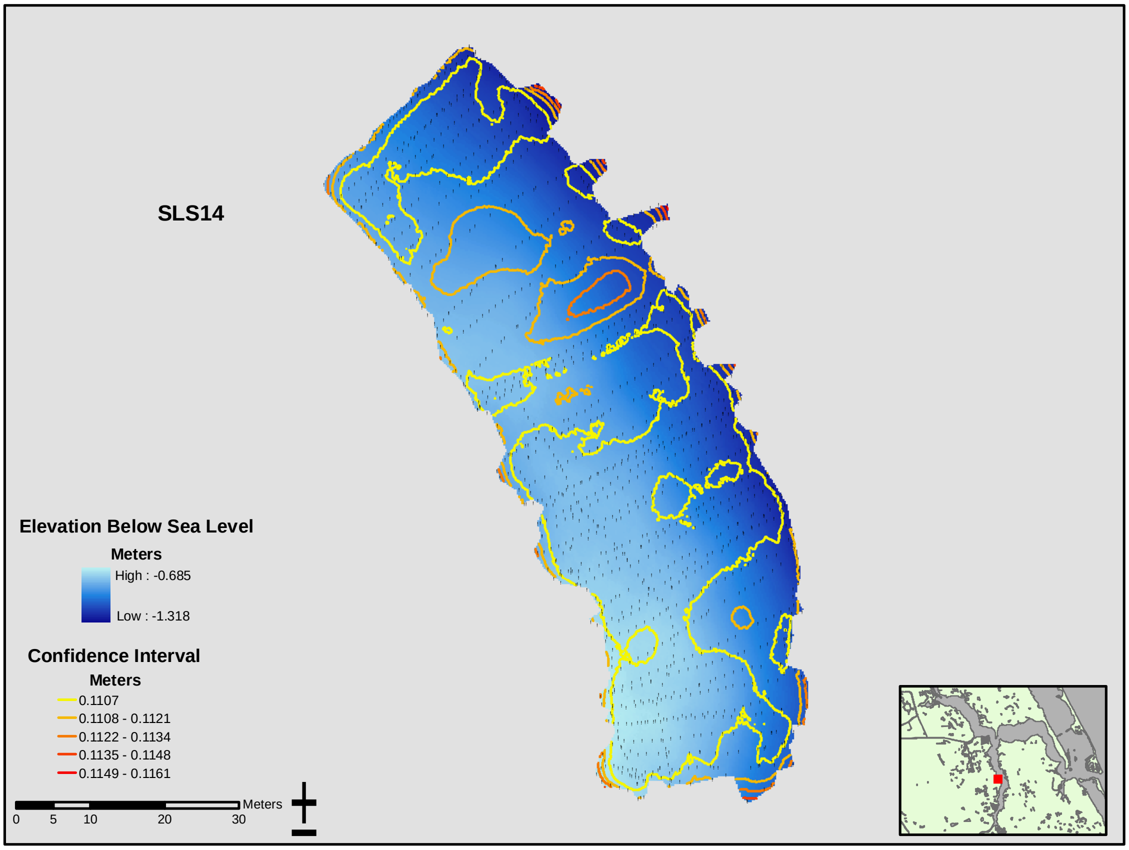


Figure A71. A) Predicted surface elevation, surface confidence interval and location of data points for reef SLS17. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SLS17 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

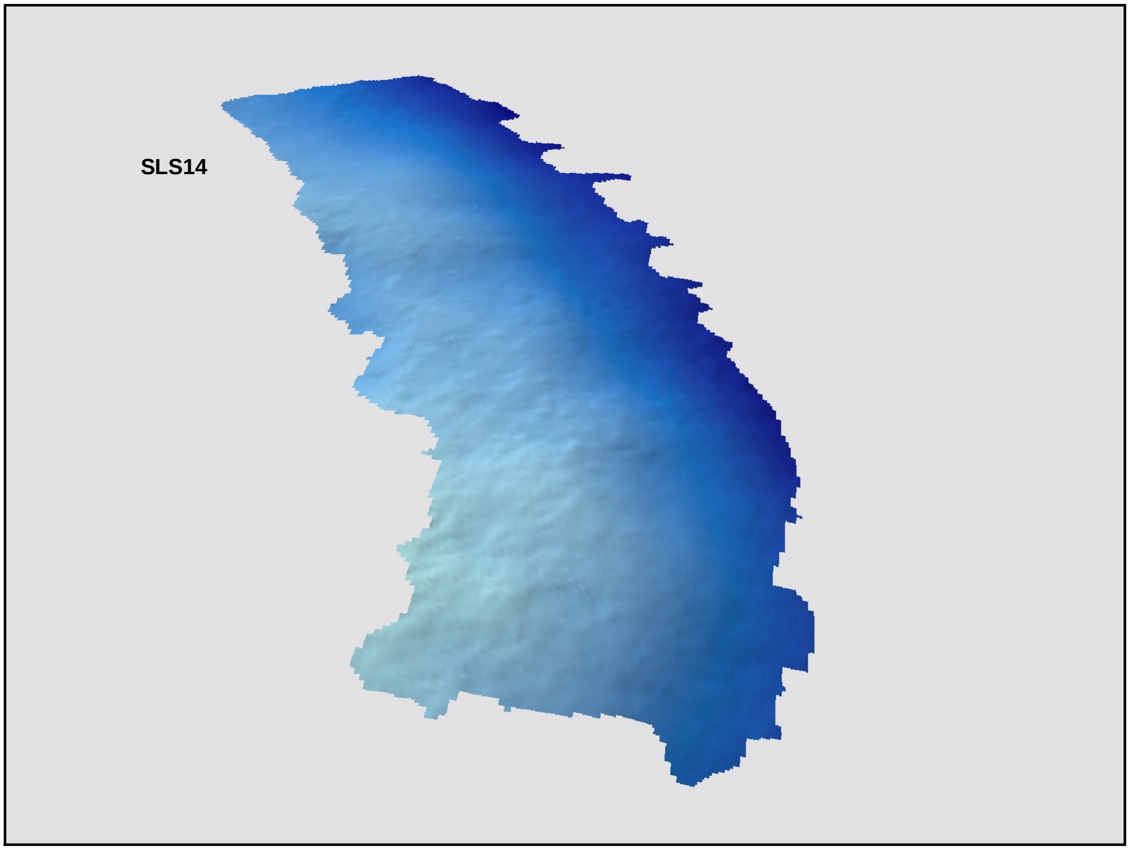
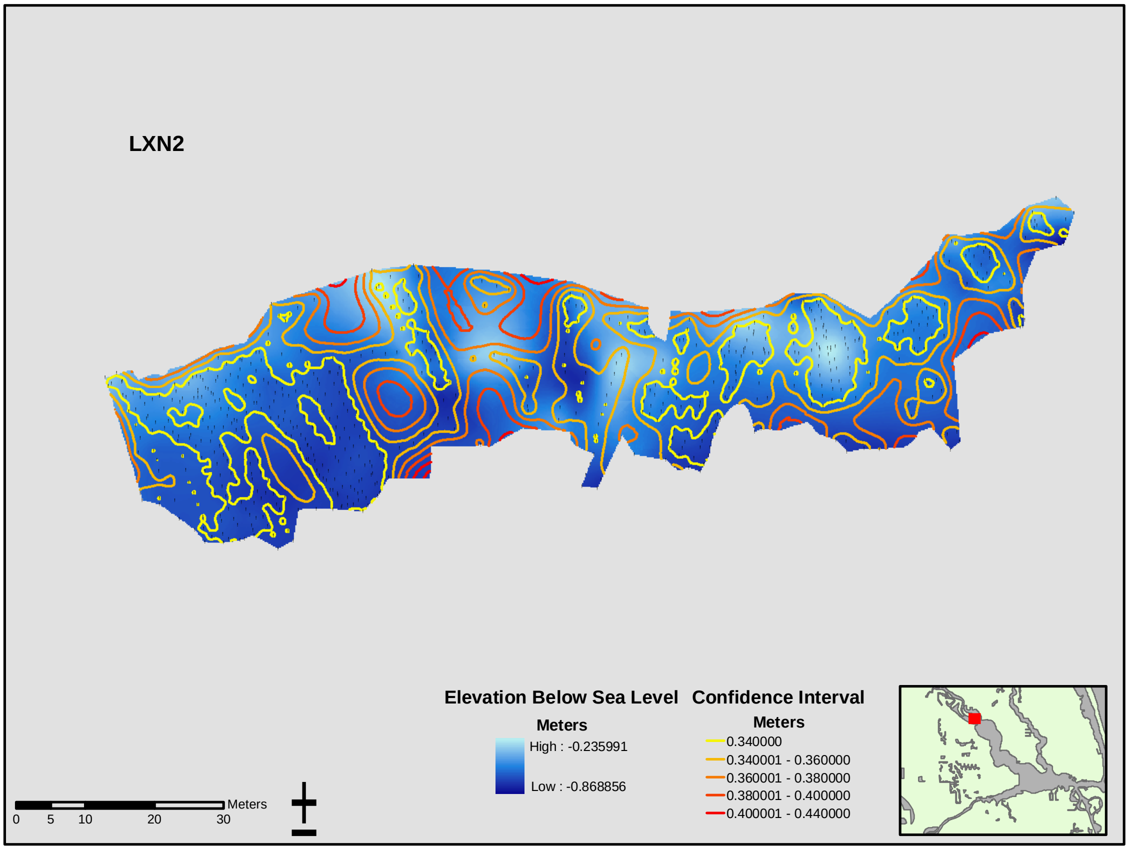


Figure A72. A) Predicted surface elevation, surface confidence interval and location of data points for reef SLS14. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef SLS14 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

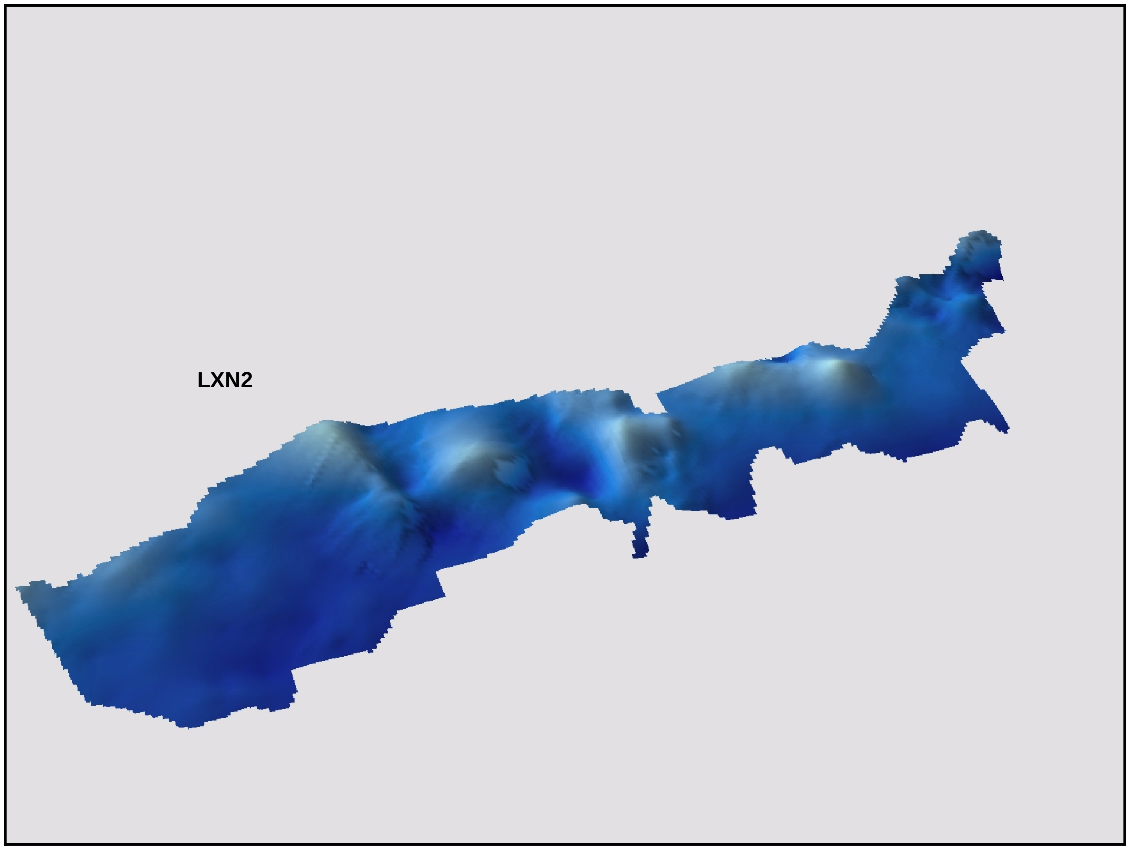
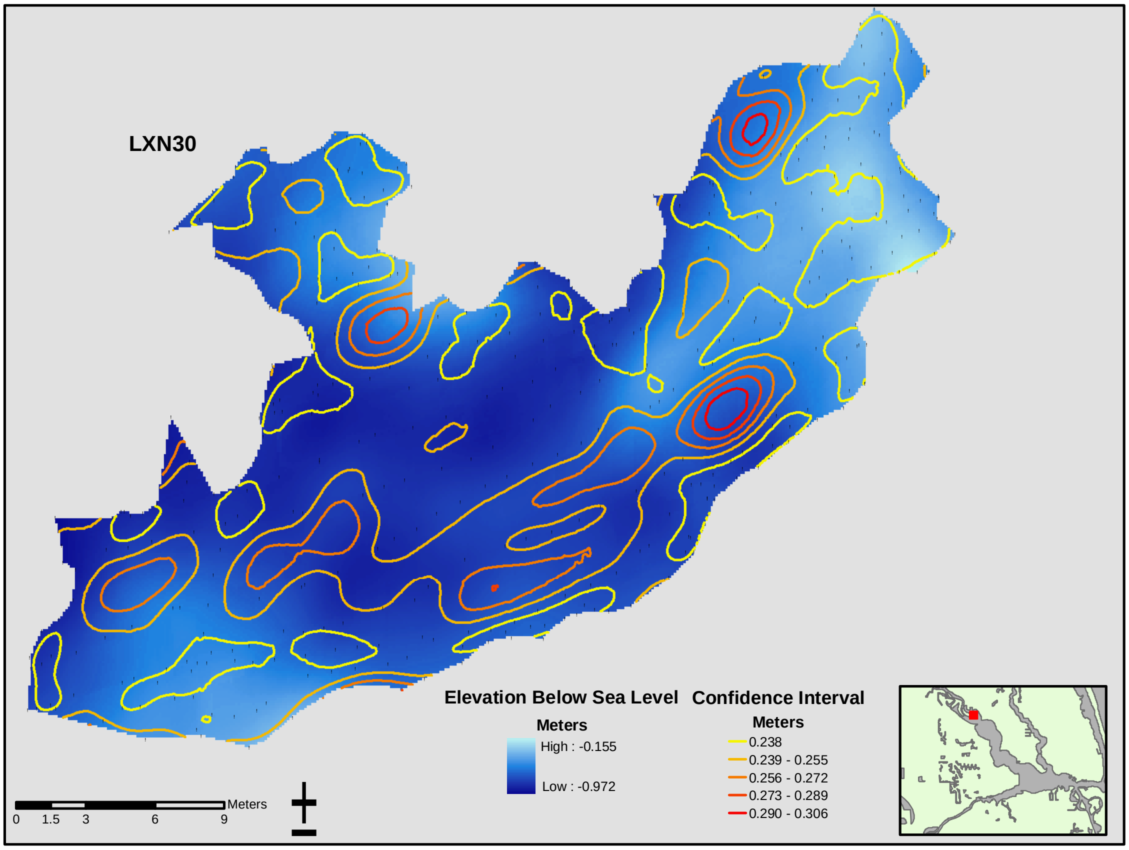


Figure A73. A) Predicted surface elevation, surface confidence interval and location of data points for reef LXN2. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef LXN2 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

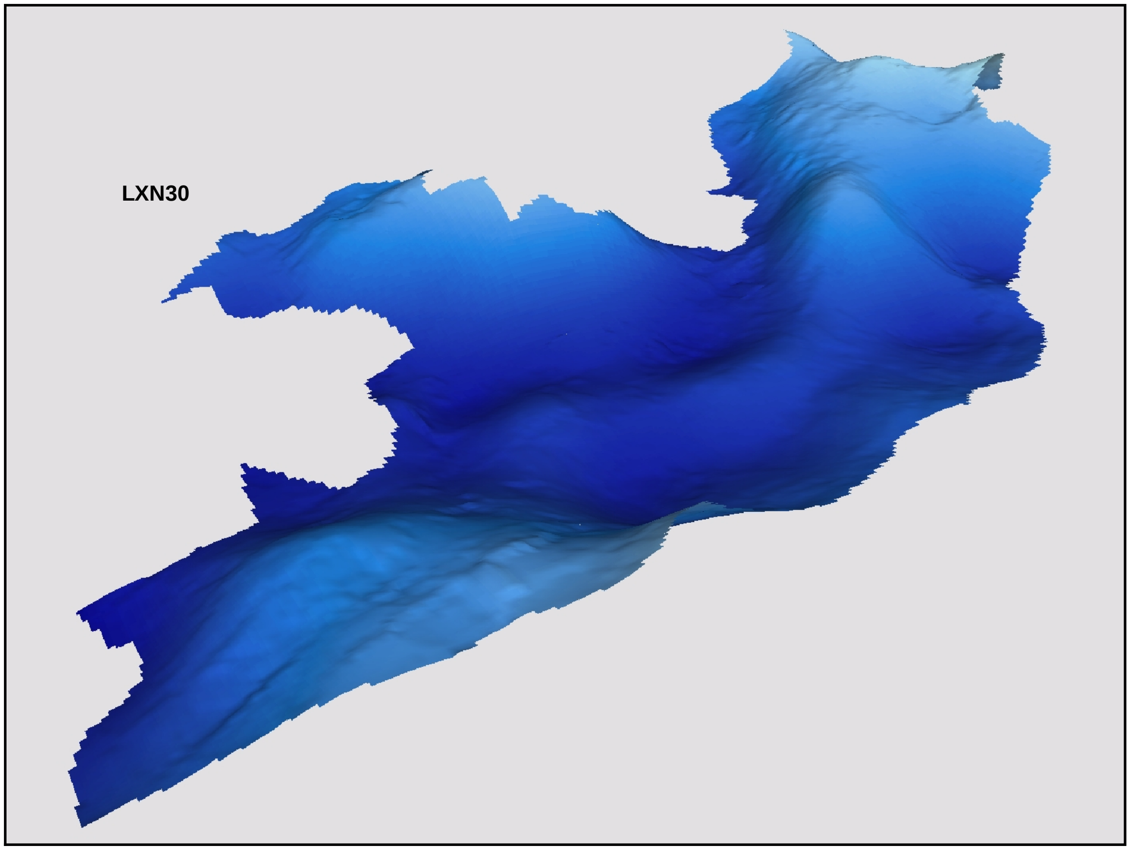


Figure A74. A) Predicted surface elevation, surface confidence interval and location of data points for reef LXN30. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef LXN30 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

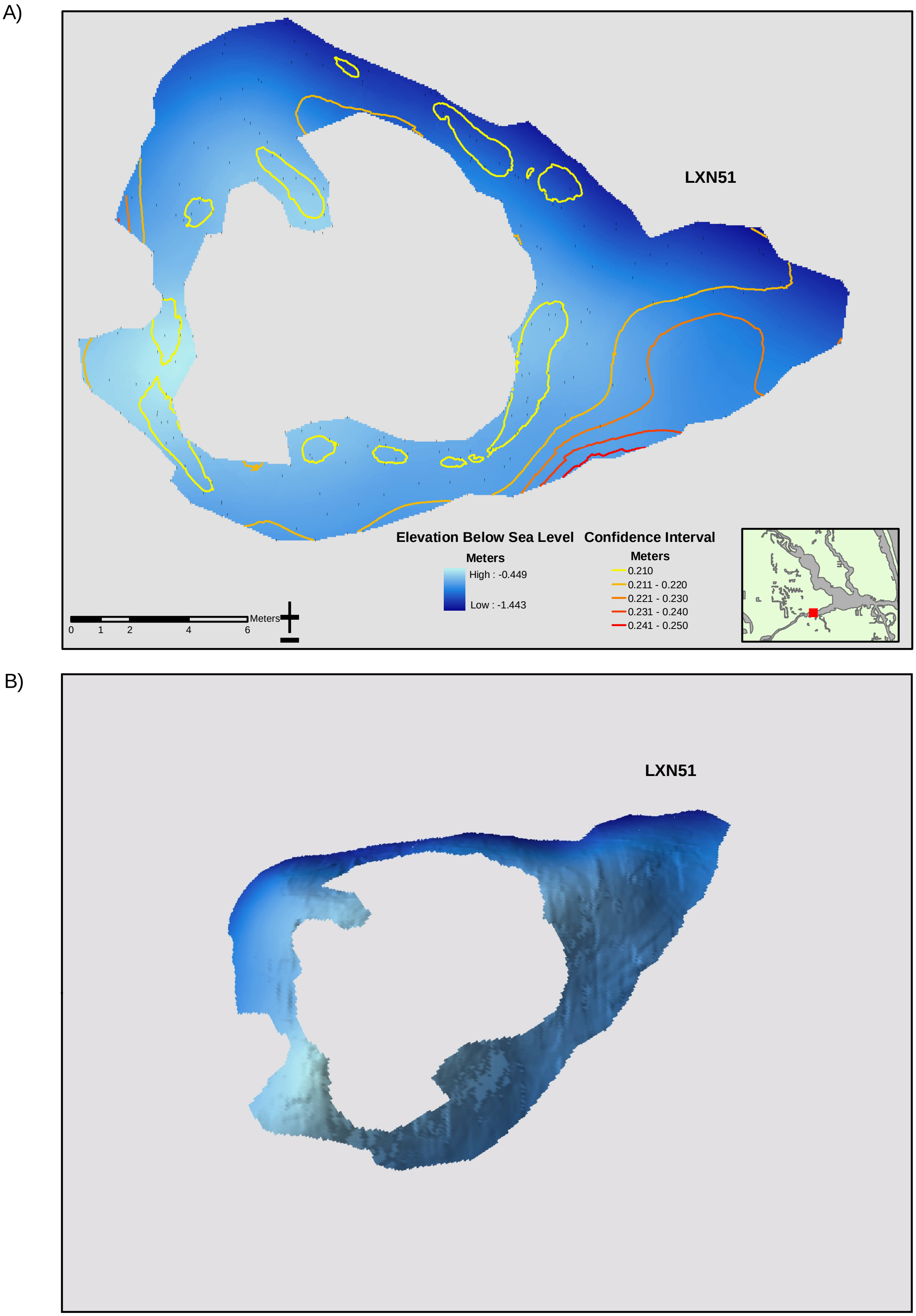


Figure A75. A) Predicted surface elevation, surface confidence interval and location of data points for reef LXN51. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef LXN51 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

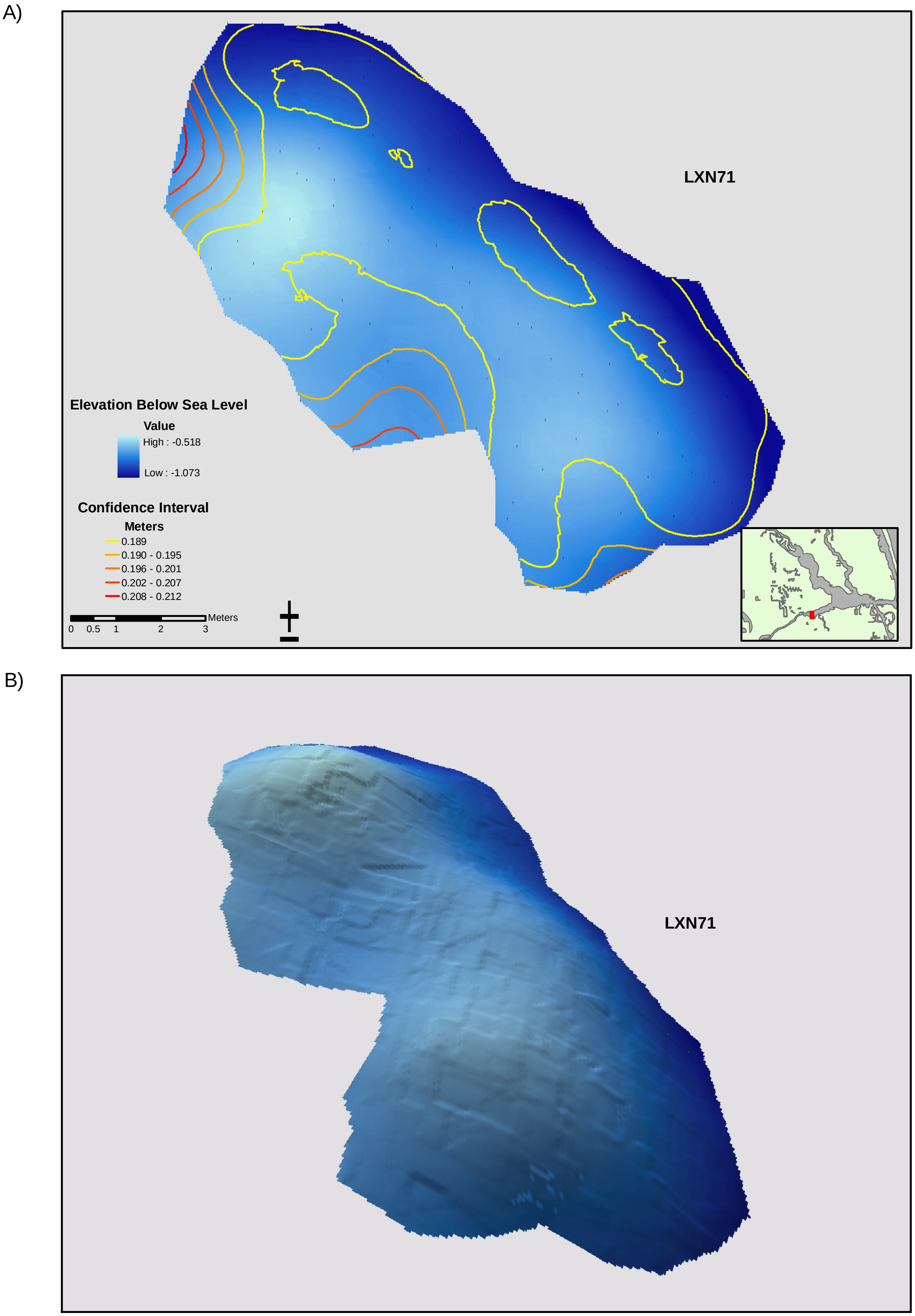
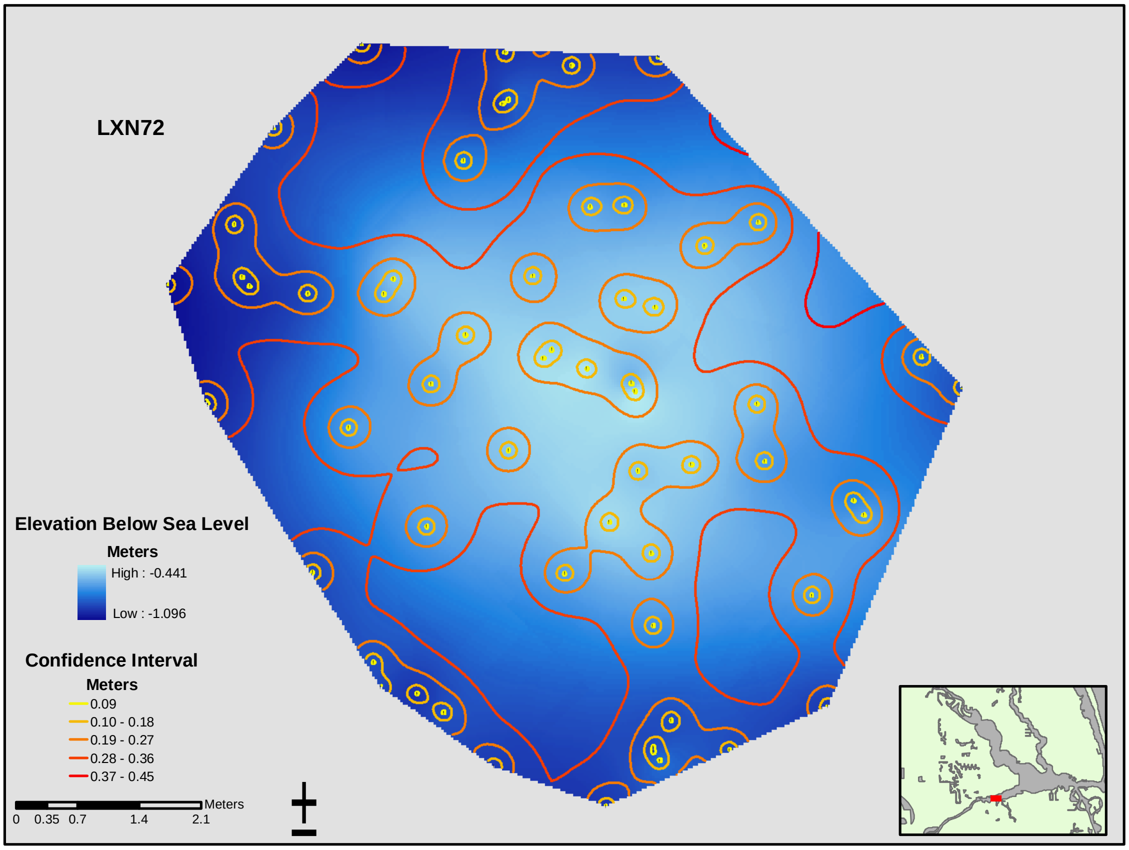


Figure A76. A) Predicted surface elevation, surface confidence interval and location of data points for reef LXN71. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef LXN71 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

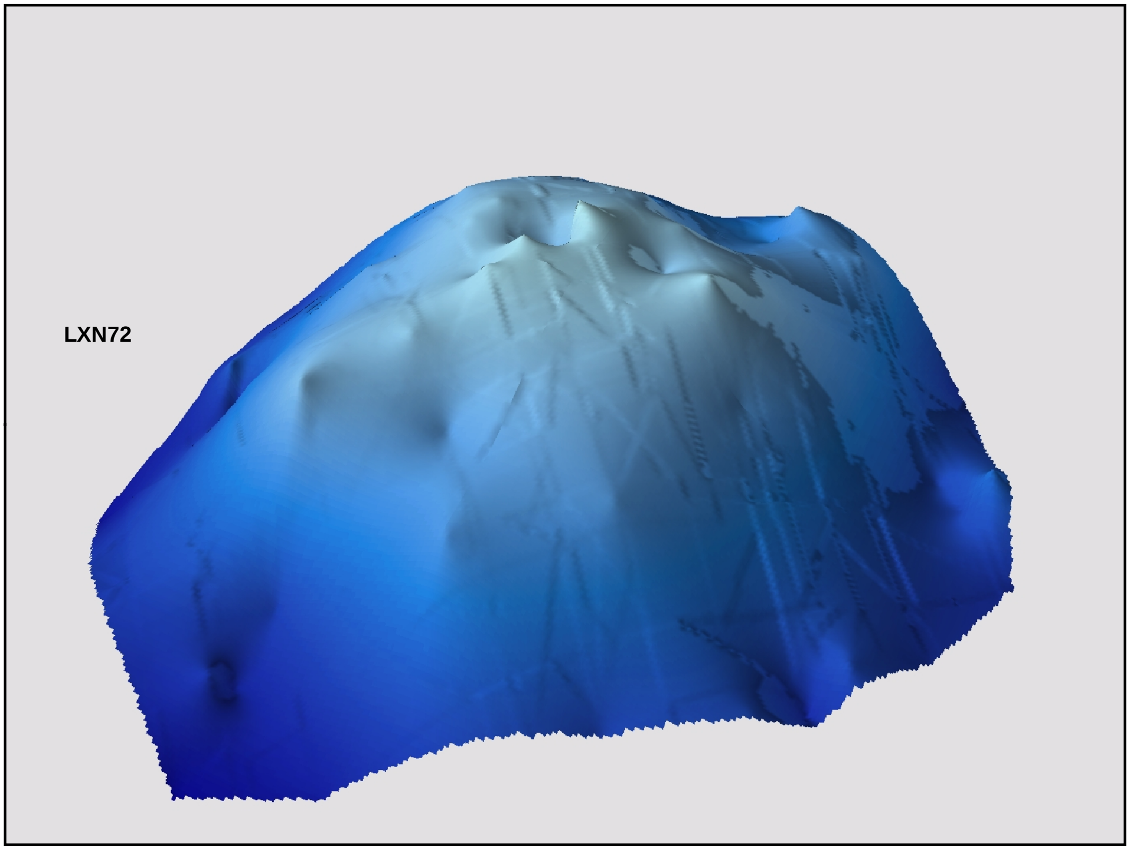


Figure A77. A) Predicted surface elevation, surface confidence interval and location of data points for reef LXN72. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef LXN72 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

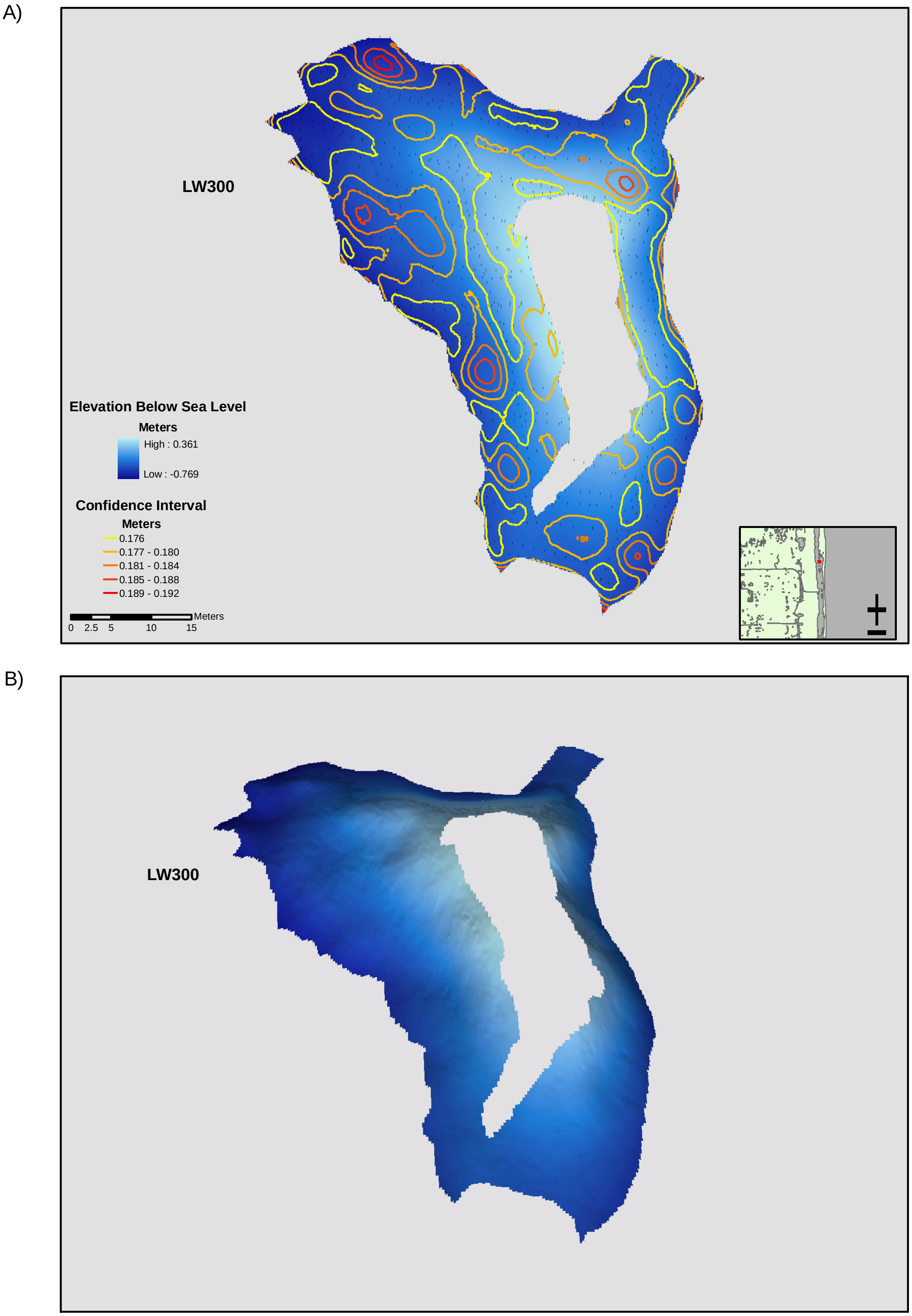


Figure A78. A) Predicted surface elevation, surface confidence interval and location of data points for reef LW300. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef LW300 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

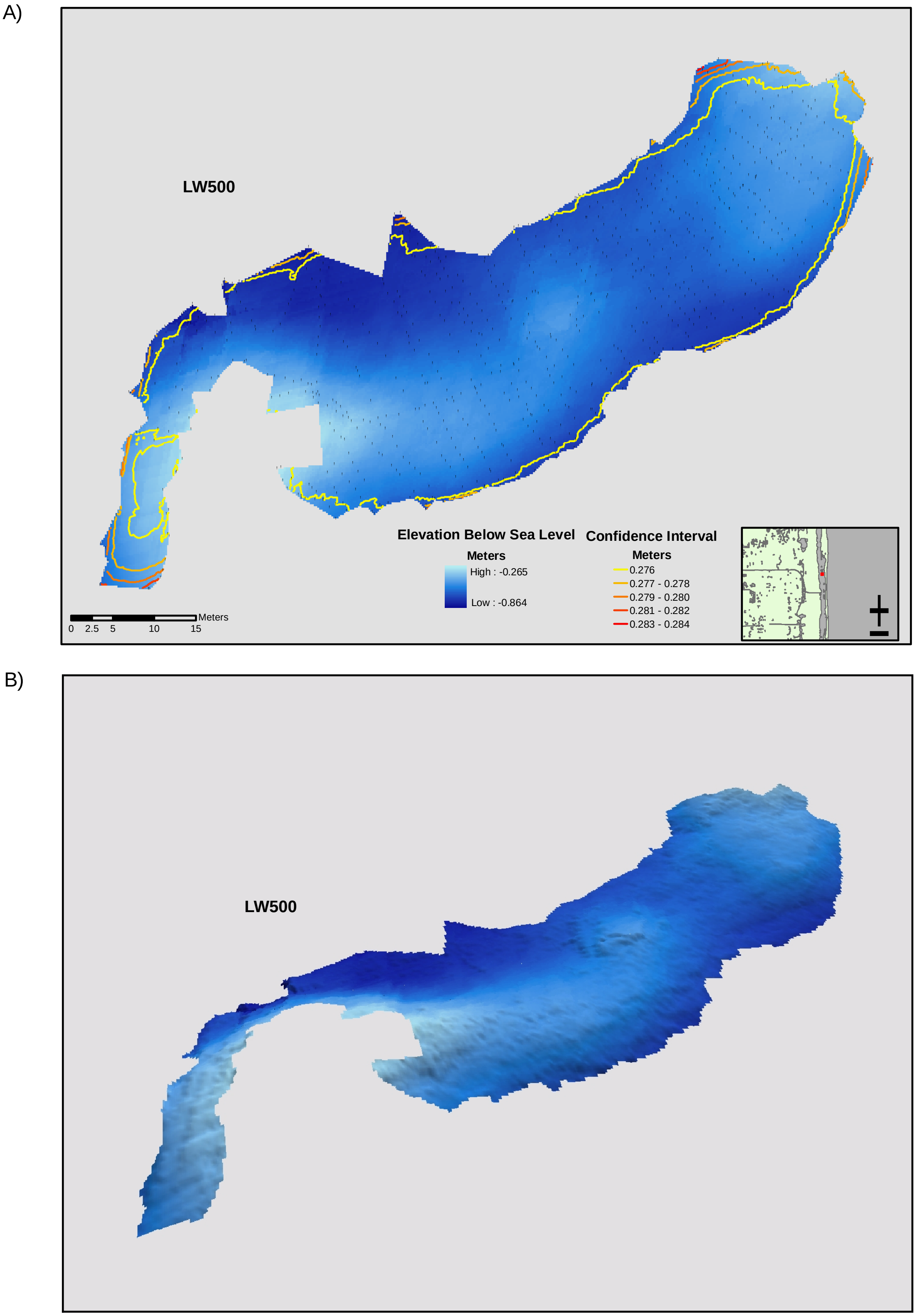


Figure A79. A) Predicted surface elevation, surface confidence interval and location of data points for reef LW500. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef LW500 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

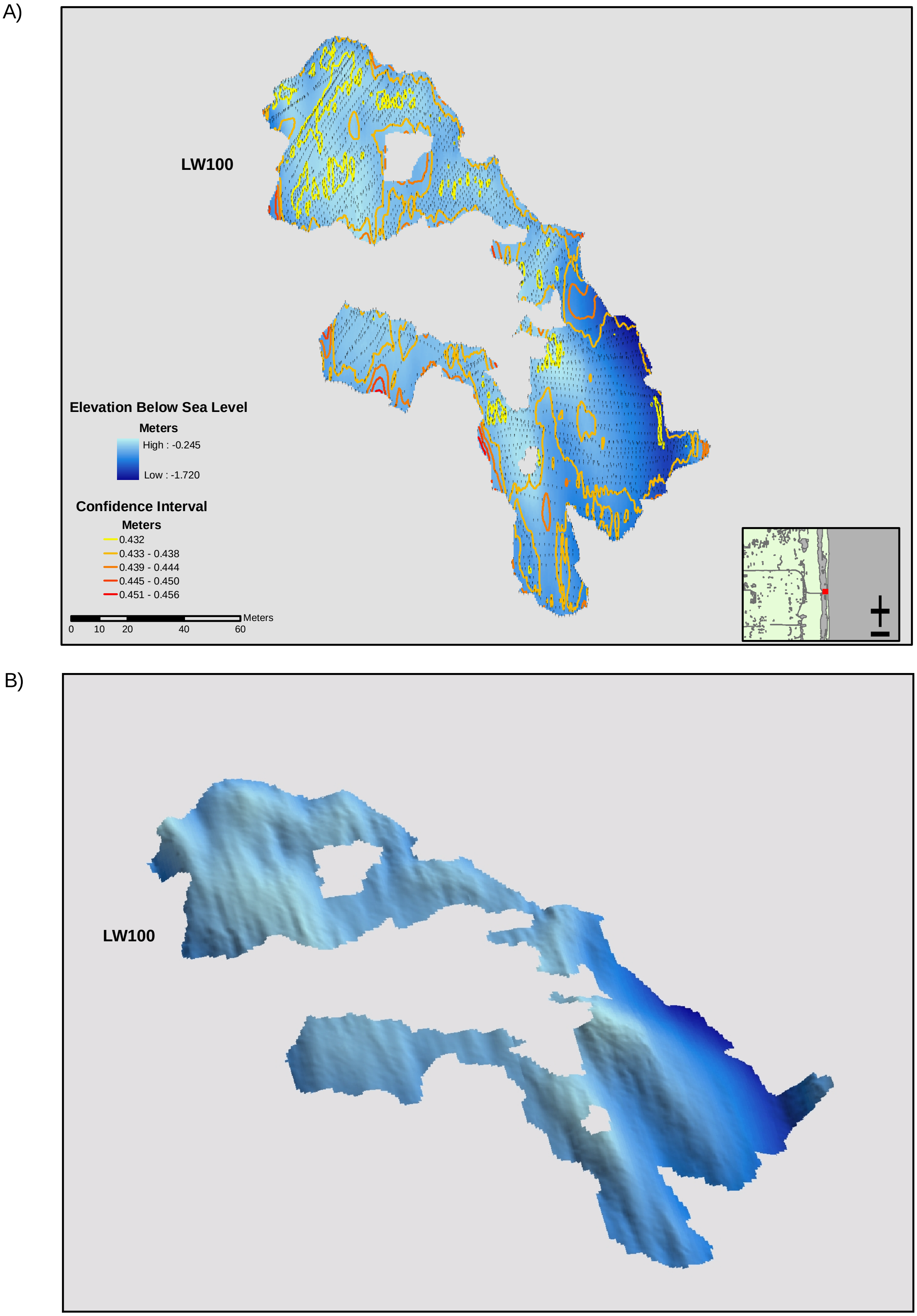
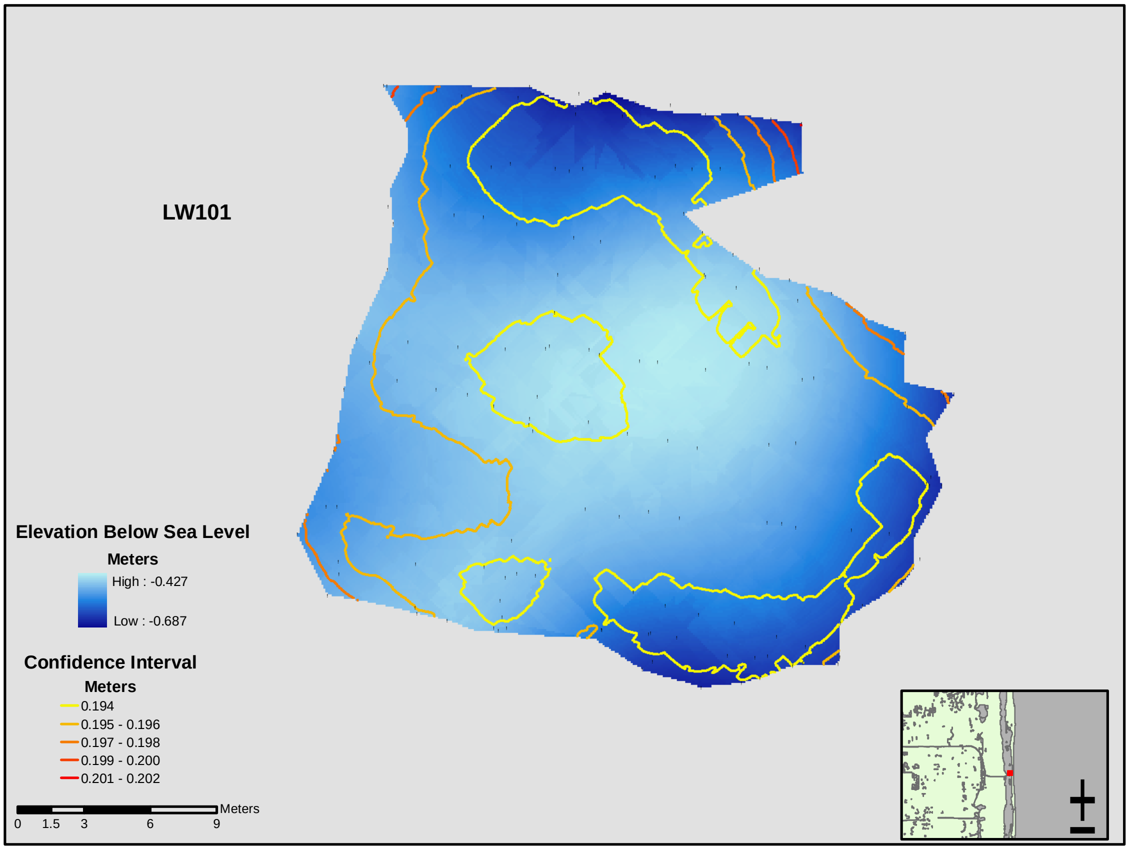


Figure A80. A) Predicted surface elevation, surface confidence interval and location of data points for reef LW100. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef LW100 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

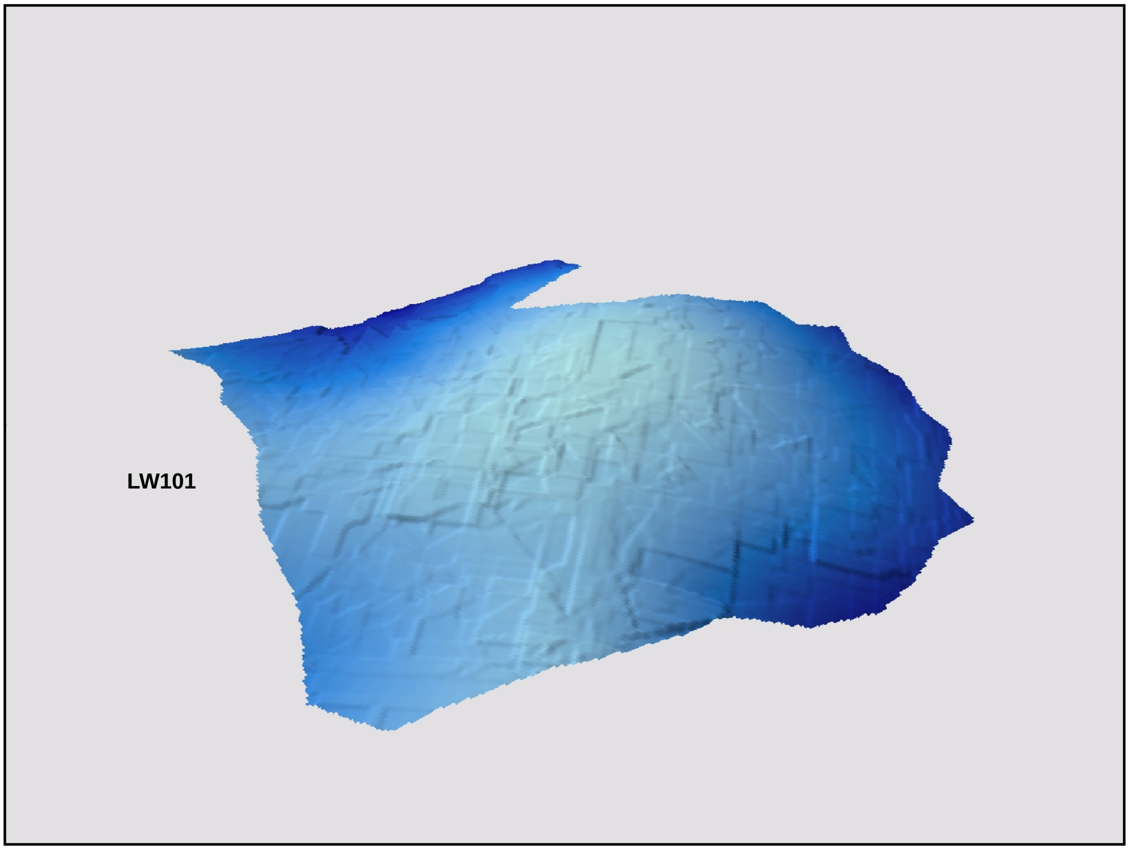
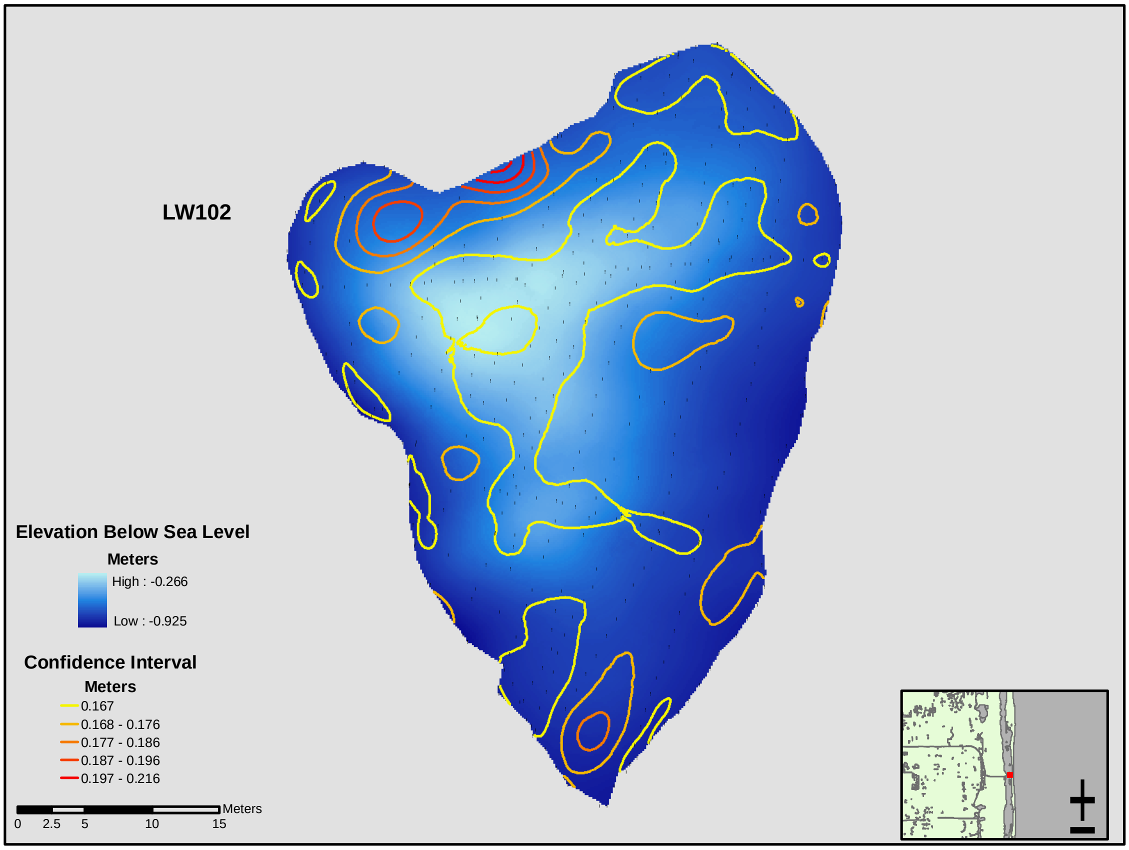


Figure A81. A) Predicted surface elevation, surface confidence interval and location of data points for reef LW101. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef LW101 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

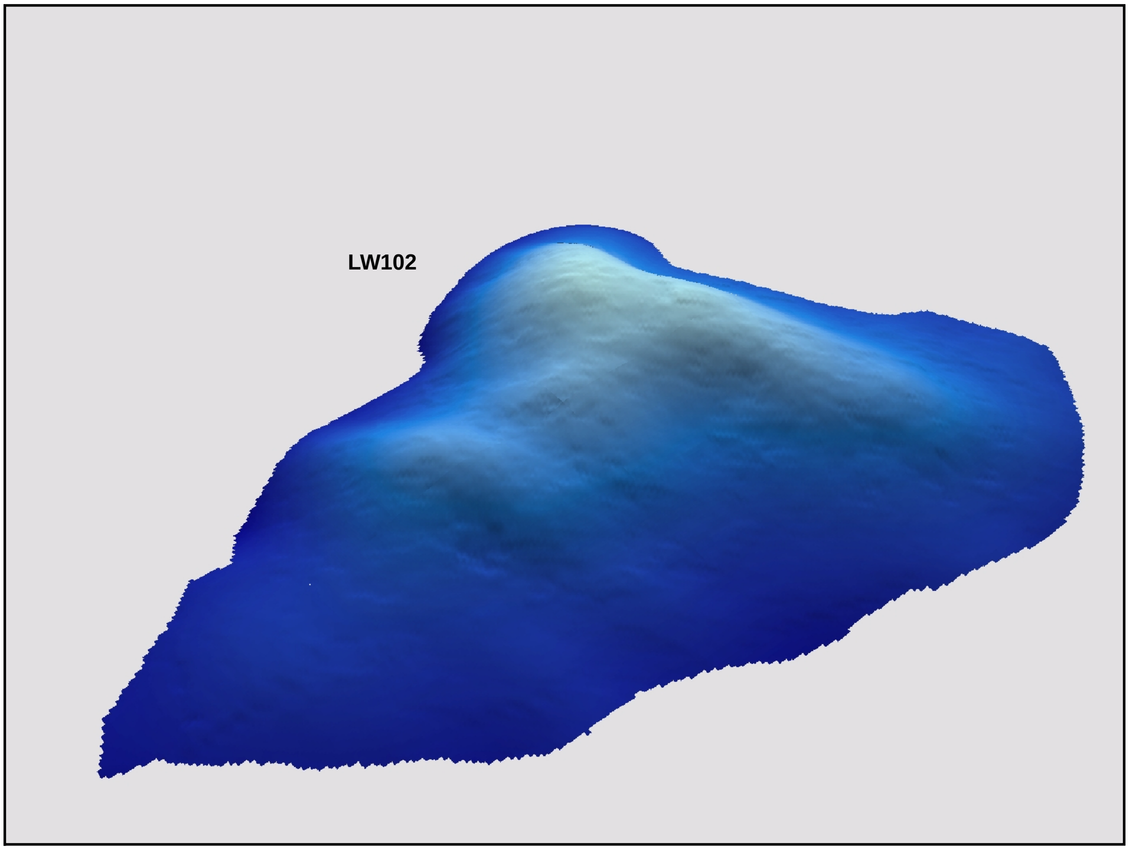


Figure A82. A) Predicted surface elevation, surface confidence interval and location of data points for reef LW102. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef LW102 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

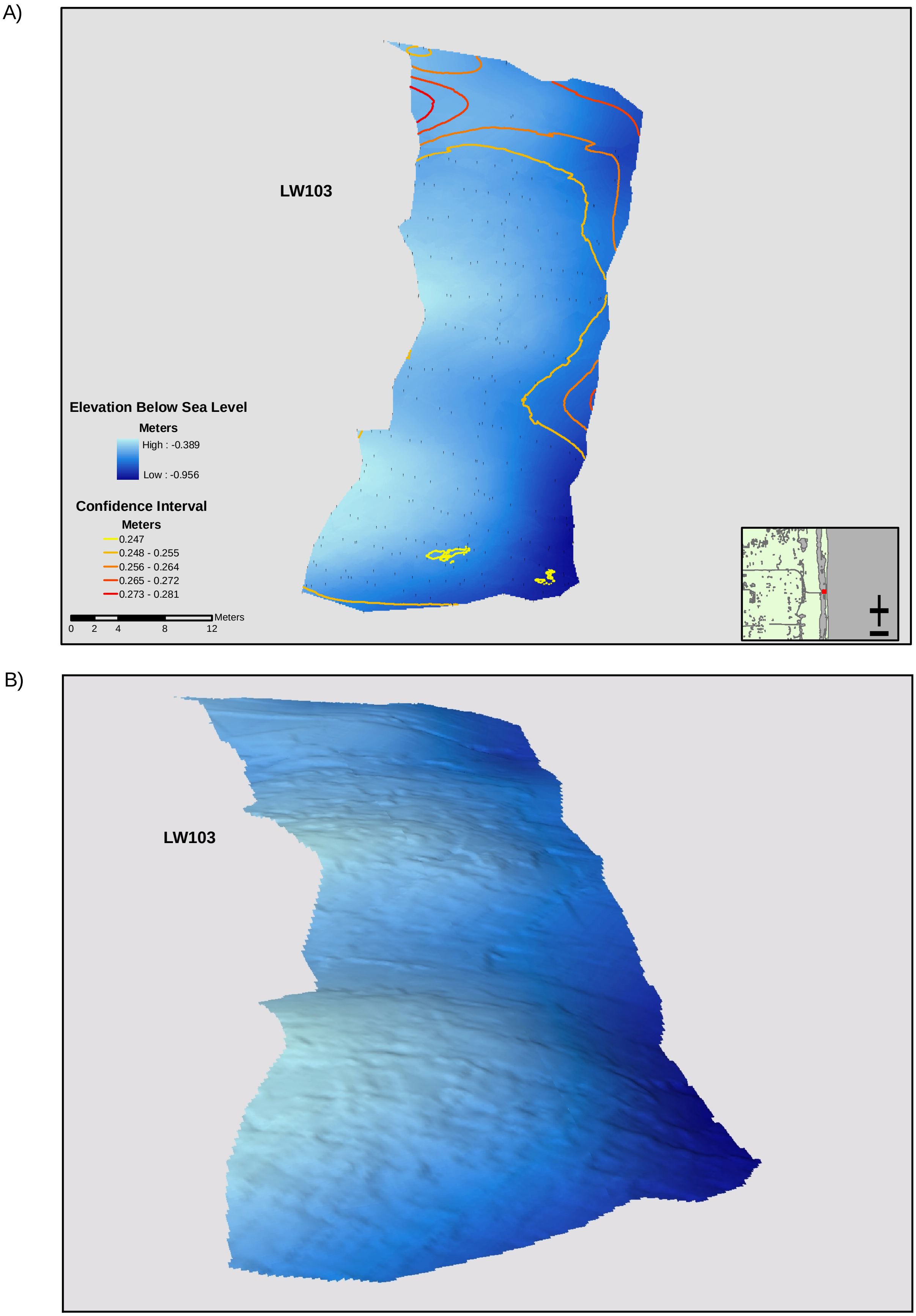
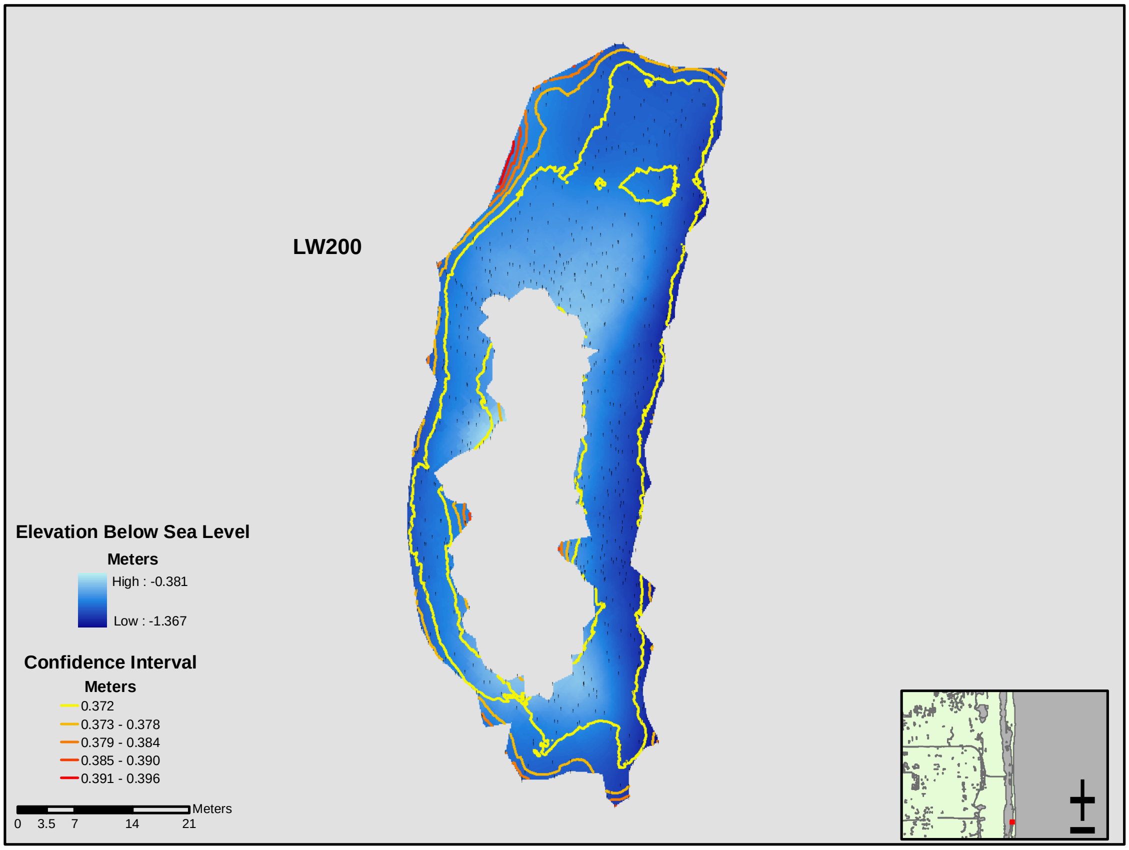


Figure A83. A) Predicted surface elevation, surface confidence interval and location of data points for reef LW103. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef LW103 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.

A)



B)

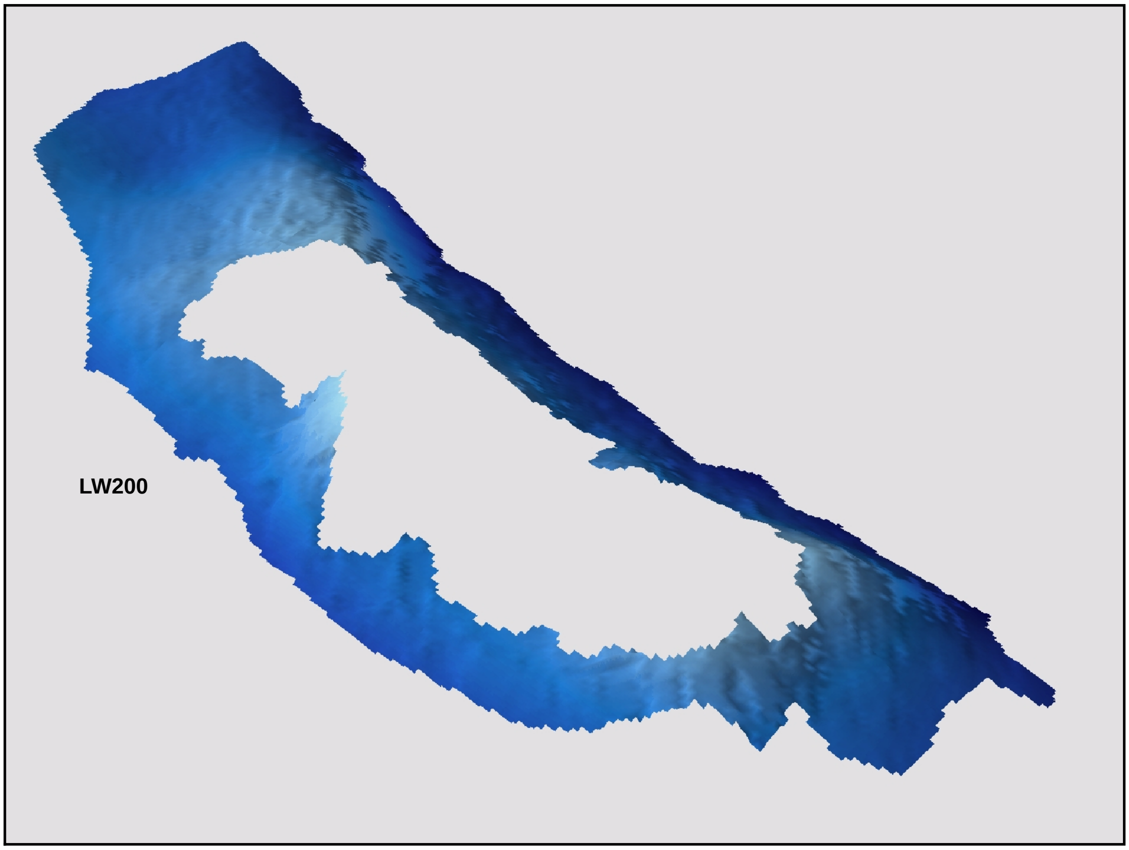


Figure A84. A) Predicted surface elevation, surface confidence interval and location of data points for reef LW200. Elevation is shown as meters below sea level. A 95% confidence interval for the predicted surface is represented by contour lines. Location of data points are shown as single points. B) The three-dimensional model of reef LW200 based on the predicted surface elevations. The vertical relief has been exaggerated 5x to show more detail, but the actual height contours remain as described in the Figure A elevation legend.