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ENVIRONMENTAL IMPLICATIONS OF GROWTH RATE CHANGES IN *MONTASTREA ANNULARIS*: BISCAYNE NATIONAL PARK, FLORIDA

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ABSTRACT

Long-term annual growth rates were determined for 25 *Montastrea annularis* colonies at eight reef sites in Biscayne National Park, Florida. X-radiographs of slabbed coral cores revealed chronologies that averaged 113.5 years in length with a range of 40 to 242 years. A total of 2,837 annual growth increments were identified and measured. Dating of density bands was verified by visually crossdating fluorescent bands within the coral skeleton. Average accretion rates of individual colonies varied from 5.0 mm/yr in the northernmost sector of the Park to 11.3 mm/yr in the southernmost sector. Long-term growth rates of most corals in this study were greatest prior to about 1950 except for a major, 3-5 year, decline in the growth record of older corals centered around 1878. Waxing and waning coral growth rates are discussed in relation to natural and anthropogenic perturbations that impact this high latitude reef ecosystem. Attention is drawn to nutrients from sewage outfalls as a possible contributing factor to observed growth rate decline since 1950.

The purpose of this study is to establish a data base of long-term growth rates in *Montastrea annularis* from Biscayne National Park that will allow a comparison of the growth rate of this species before, during, and after periods of major alteration by man to the environment in and around Biscayne Bay. A brief outline of the nature of the changes brought to the area during development is compared with the observed annual rate of growth for corals from eight locations across the reef tract within the park. The setting of the park and individual coral sites are described in some detail so that environmental factors that may influence coral growth, but have not yet been measured, may be compared to growth rates when that data becomes available.

STUDY AREA

Biscayne National Park (24°25′N, 80°15′W) is at the southern tip of the Florida peninsula (Fig. 1). Designated as a National Monument in 1968 and elevated to National Park status in 1980, its present boundaries encompass 181,000 acres (73,250

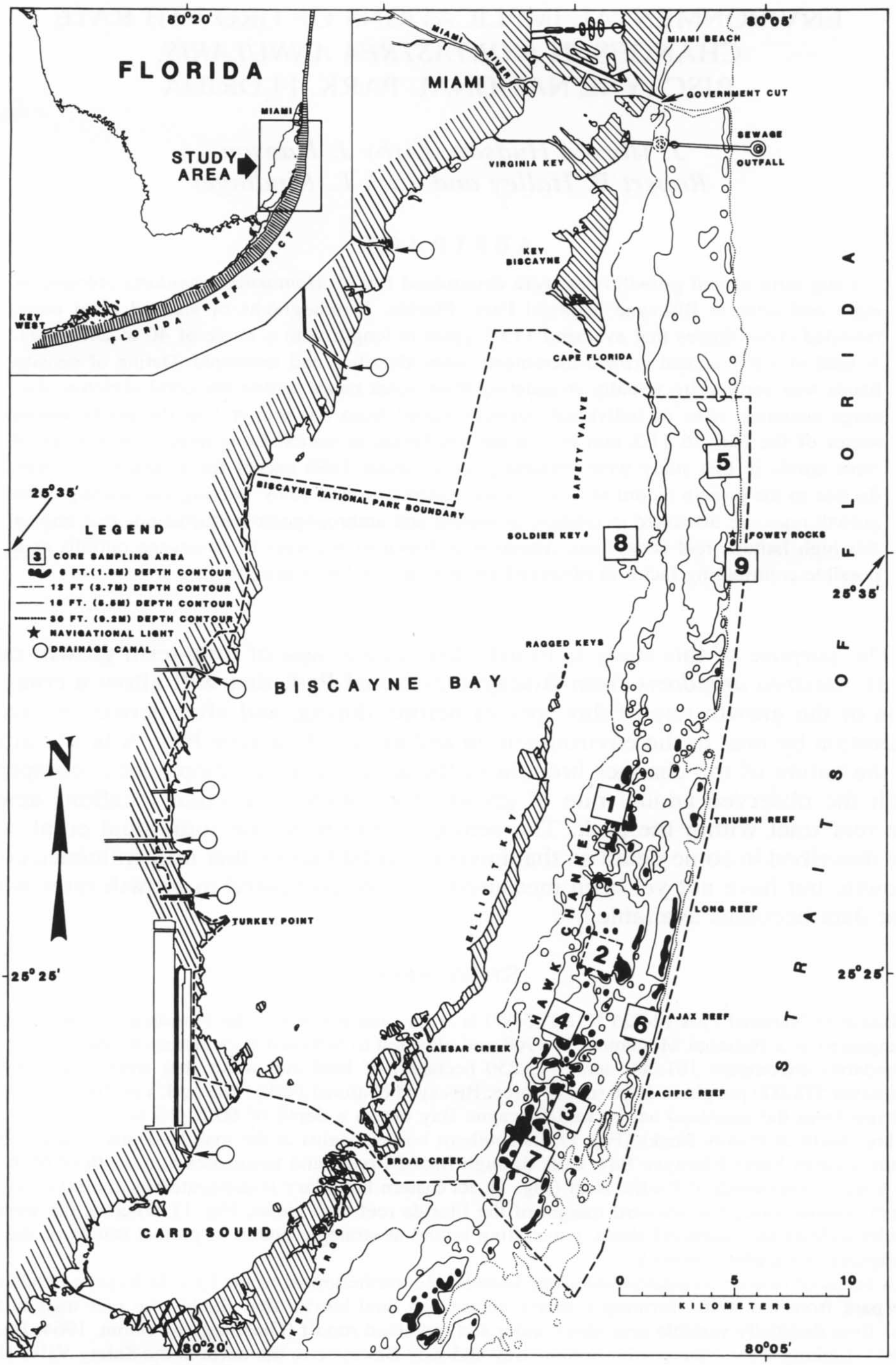


Figure 1. Map of study area.

hectares) of land and water that were visited by an estimated 578,000 people in 1986 (data source: Biscayne National Park). The park's northern boundary extends from the mainland across mid-Biscayne Bay out to a depth of 60 ft (18 m), a point 3.7 mi (6 km) north of Fowey Rocks (Fig. 1). Its southern border begins at the mainland just below Turkey Point, crosses lower Biscayne Bay, exits through Broad Creek, and terminates at a depth of 60 ft (18 m) 6 mi (9 km) south of Pacific Reef (Fig. 1). Its eastern boundary is delineated by the 60-ft (18 m) depth contour along the seaward margin of the Florida reef tract (inset, Fig. 1), whereas the western border follows the mainland shore, penetrating inland at strategic points to protect stands of the red mangrove, *Rhizophora mangle*.

A series of densely vegetated limestone islands (the northernmost of the Florida Keys) extends into the park from the south, forming a nearly continuous land barrier that shields the reef tract in this area from thermally variable near shore water and mainland runoff (Ginsburg and Shinn, 1964; Burns, 1985). Linking these islands with Soldier Key and Key Biscayne to the north is the Safety Valve (Fig. 1), a broad, shallow bank of carbonate sediment and seagrass that is dissected by numerous tidal channels (Wanless, 1976a). Seaward of these island barriers and the Safety Valve is Hawk Channel, a natural depression 4 to 14 m deep that extends from Miami to Key West. Offshore of Hawk Channel and out to a depth of 60 ft (18 m) is a complex mosaic of coral reefs that compose the northernmost extension of the Florida reef tract (Jaap, 1984). Inshore and partially enclosed by Elliott Key is Biscayne Bay (Fig. 1), a shallow (maximum depth 4 m) lagoon that is part of an embayment system connected by tidal passes, shoals, and dredged navigation channels to the Atlantic Ocean (Lee and Rooth, 1976). The least disturbed areas of the bay are within park boundaries. There is concern that northern Biscayne Bay (Fig. 1), an area greatly modified by past dredge-and-fill activities (Michel, 1976), could have long-term adverse effects on the natural resources of Biscayne National Park because of the northern bay's chronic turbidity (Wanless, 1976b).

Although Miami was founded in 1896, there were no major alterations to the marine environment until a ship channel, Government Cut (Fig. 1), was dredged in 1905 (Wanless, 1976b). This was followed by a series of extensive dredge-and-fill projects in the north Biscayne Bay area (upper Fig. 1) between 1919 and 1928 (Michel, 1976). During this 9-year period, artificial islands, channels, causeways, and much of modern Miami Beach were created. However, development was slowed by a destructive hurricane in 1926, and finally halted by the stock market crash of 1929. Changes to the marine environment from chronic turbidity and siltation during this period, although not recorded, must have been severe and widespread.

Further disturbance to the Biscayne Bay environment did not occur on a large scale until after World War II, when building materials again became available to developers (Michel, 1976). Construction of three major causeways, extensive bulk heading, and land fill on Key Biscayne and Virginia Key (Fig. 1) were some of the major

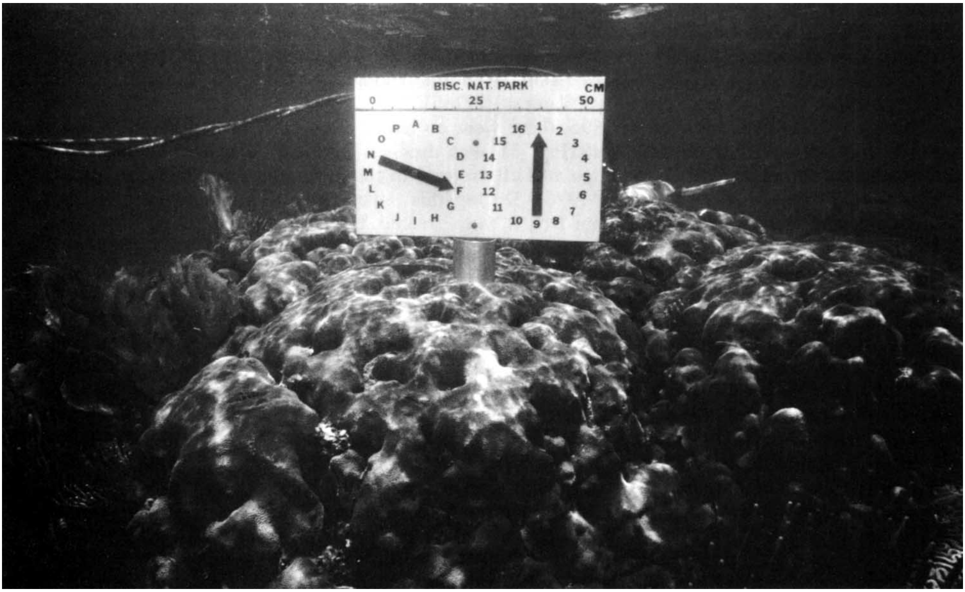


Figure 2. Photograph of coalesced *Montastrea annularis* colonies at station 1. Site marker is in core hole 1-F.

perturbations between 1945 and 1960. From 1960 to 1974, dredge-and-fill activities slowed considerably. During this period, however, a new port facility was built on old spoil banks alongside Government Cut. Freshly dredged material was used to elevate and enlarge the existing spoil islands that were created when the cut was dug and subsequently widened and deepened to accommodate deeper draft vessels. Finally, beach nourishment of Virginia Key in 1973 released large volumes of mud into nearby seagrass beds covering some beds as far away as 0.8 km (0.5 mi) with as much as 5 cm (2 in) of mud (Wanless, 1976b). According to Wanless (1976b), the most serious long-term impact of dredge-and-fill operations in Biscayne Bay appears to be the creation of artificial environments that continue to release fine mud into the bay for many years after the projects are completed.

In 1974, the State of Florida designated Biscayne Bay as an aquatic preserve, ending 72 years of man’s largely uncontrolled modifications to a unique and irreplaceable estuarine ecosystem.

METHODS

Growth rates of *Montastrea annularis* were determined by direct measurement of annually formed couplets of high and low density bands revealed in x-radiographs of slabbed coral cores (Knutson et al., 1972). This species is morphologically variable and previous experience (Hudson et al., 1976) taught that only large, hemispherical colonies similar to morphotype 2 of Knowlton et al. (1992) yield long, uninterrupted

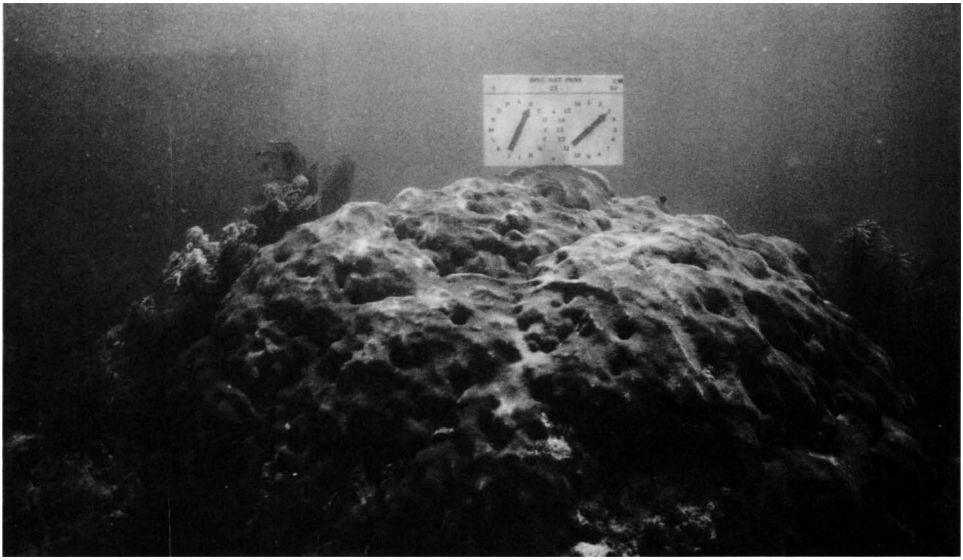


Figure 3. Photograph of *Montastrea annularis* at station 3. Site marker in core 3-B.

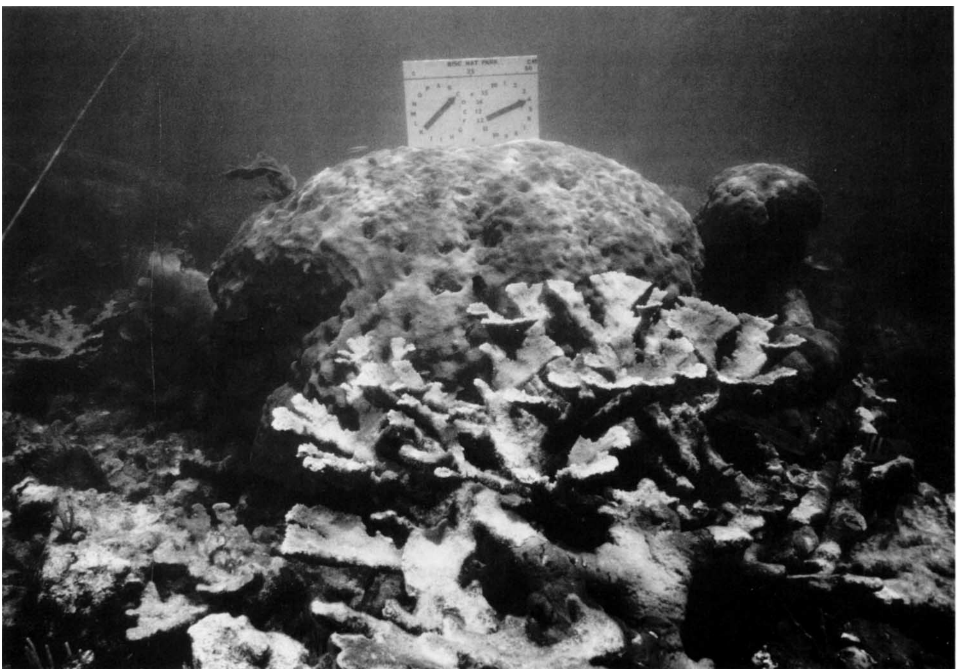


Figure 4. View of patch reef at station 4. Site marker is in *Montastrea annularis* core hole 4-C. Note abundance of *Acropora palmata*.

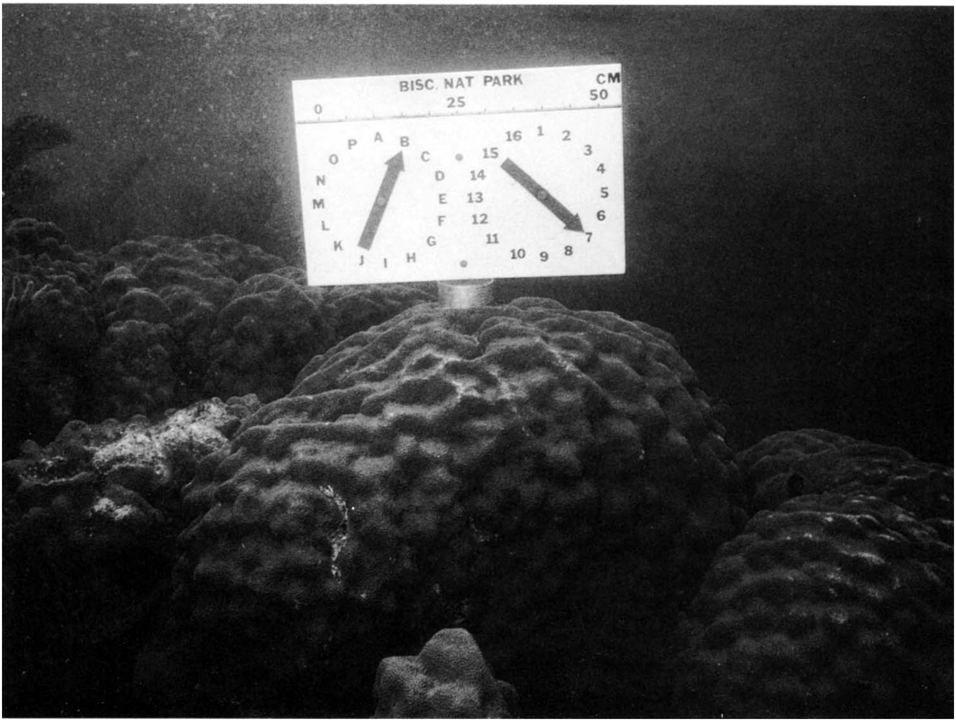


Figure 5. Group of *Montastrea annularis* colonies at station 7. Site marker is in core hole 7-B.

growth records. Cores were taken with a diver-operated hydraulic drill (Macintyre, 1975) between July and October 1986 to coincide with approximate timing of annual dense band formation in Florida *M. annularis* (Hudson et al., 1976). Core holes were sealed with pre-cast cement plugs to prevent bioerosion.

High quality aerial photomosaics of the reef tract were an invaluable aid in reducing the search area within the large (175+ km^2) expanse of coral reef, seagrass, and sand bottom of the park (Fig. 1).

Numbered sampling sites represent areas where several colonies were sampled, each colony at a site was designated alphabetically. Corals were located by towing a snorkeler at the surface behind an 8-m power boat. The variable nature of water transparency in Biscayne National Park limits this technique's usefulness to about 10 m of depth on an "average" day from July to September (our sampling period), when diving conditions on the reef tract are most favorable. For this reason, we were unable to survey considerable areas of the deeper (12-18 m) forereef zone along the park's eastern boundary (Fig. 1), an area where Burns (1985) reported finding "large >30 cm *M. annularis*." Since a size range was not given, it is not known if any individuals in

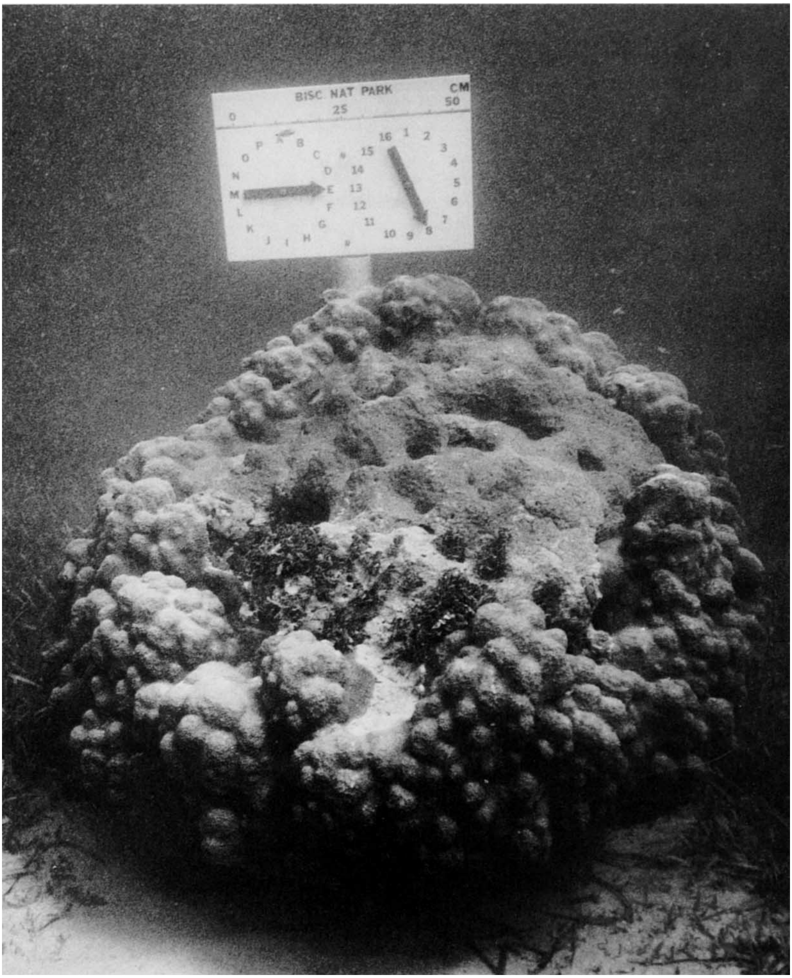


Figure 6. Photograph of isolated *Montastrea annularis* at station 8. Sand-seagrass (*Thallasia testudinum*) overlies hardground at base of coral. Bioeroded surface of coral faces inshore.

this area would have been suitable (1 m high) for our purposes.

Between 16 July and 4 October 1986, 38 *Montastrea annularis* were cored at nine locations within Biscayne National Park in water depths ranging from 2 to 8 m (Fig. 1). Of these, 25 colonies had continuous growth records ranging from 39 to 242 years that could be accurately measured. Fourteen of the 25 usable cores came from midshore patch reefs (stations 1, 4, 3, and 7) in the southeastern sector of the study area. The longest growth record (242 yrs, sta. 4E, Fig. 11) and greatest average annual growth rate (11.3 mm/yr, sta. 7E, Fig. 12) were from corals in this area. Of the 11

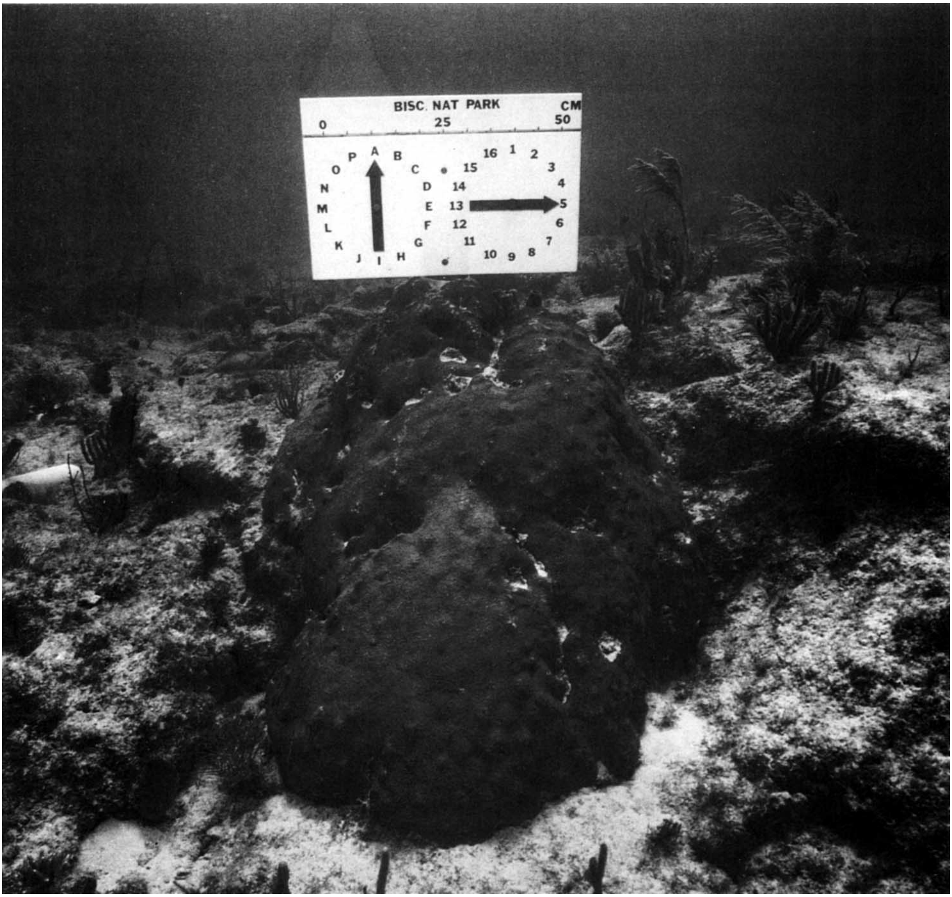


Figure 7. View of relict reef substrate at station 5. Core 5-A from this lone *Montastrea annularis* lies at left. Substrate and coral cover at station 9 (not pictured) are nearly identical to those shown here.

remaining cores, eight were collected on offshore reefs (sta. 5, 9, 6) along the park's eastern boundary (Fig. 1), and three were drilled at the inshore hardground site (sta. 8) off Soldier Key (Fig. 1).

Coring techniques, slabbing, x-radiography, and annual band measurement criteria used in this study were identical to those of Hudson (1981). Yearly assignments to annual bands were validated wherever possible by cross correlation with non-annual fluorescent bands that are widespread throughout these cores. Annual growth values (in mm) for each core were used to calculate a "site-average" time series of coral growth. "Normal" growth values were determined for each site, based on a 100-year average growth for the period 1840-1939. In the present discussion, the year indicated is the ending-year of the annual growth period. Thus, "1840" defines the 12-month

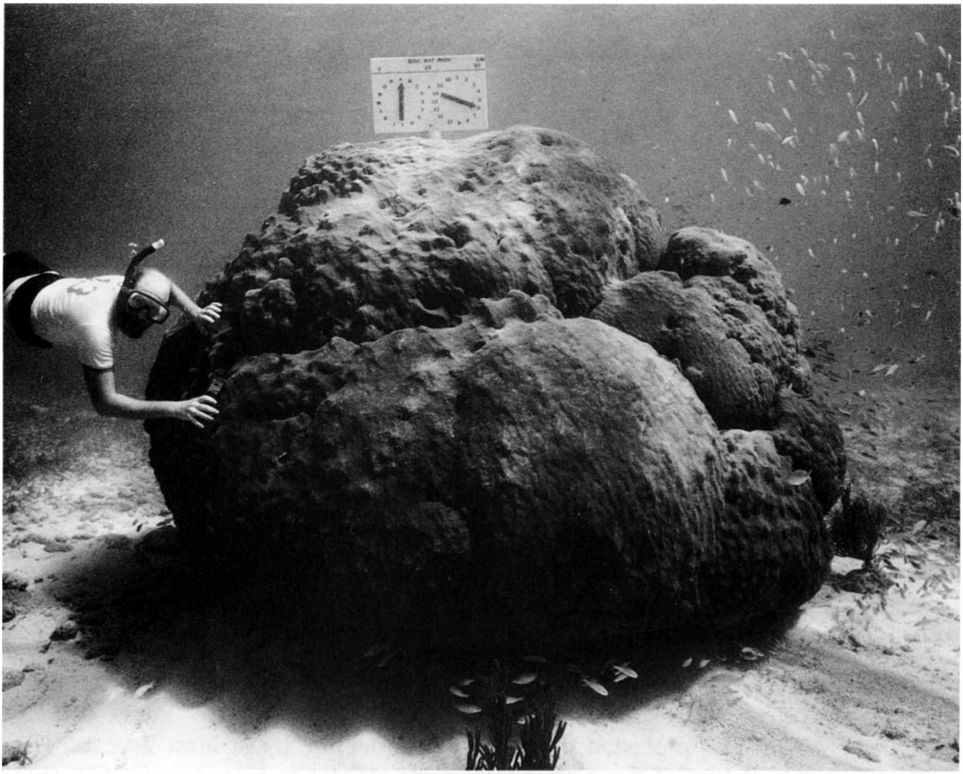


Figure 8. Station 6 (core 6-A) landward of Ajax Reef. Coral rubble and sparse seagrass, *Thalassia testudinum*, surround this impressive *Montastrea annularis*.

growth period from approximately September 1839 to September 1840. Deviations of the "site-average" annual growth from 100-year normal growth were calculated for each year of the entire period of record (1840-1986) in order to assess major changes in the growth rate of the corals with changing environmental conditions.

A total of 2,837 annual growth increments (an average of 114 yrs/core) were identified and measured from x-radiographs of the 25 corals. A complete listing of growth rate measurements (in millimeters) for each coral is included in the Appendix.

Description of Coral Core Sites--Stations 1, 3, 4, and 7 are on well-developed mid-shelf patch reefs (Figs. 2-5) that are part of a discontinuous 3-km-wide band of reefs and shoals that borders the seaward margin of Hawk Channel in an area extending from off Broad Creek to the northern end of Elliott Key (Fig. 1). The reefs in this area of the park are the most diverse and healthy in terms of size and number of hard and soft coral species and for their potential for building three-dimensional reef framework. Water depth at the four sites ranged from 2 to 5 m.

It should be noted that core samples from station 2 (indicated by a dashed square in Fig. 1) could not be interpreted due to the high incidence of bioerosion in upper core sections. Some of the shallowest (2 m or less) patch reefs in the park are found in the vicinity of station 2. One large *M. annularis* was seen at this location with 3-5 cm of its (partly living) uppermost surface awash during a spring low-tide event. Scleractinians on Florida reefs, as a rule, are not subjected to air exposure during a normal tidal cycle.

Proceeding north from station 1 (Bache Shoal on navigation charts), the number of patch reefs, along the eastern (offshore) edge of Hawk Channel decreases rapidly, and except for some isolated examples, this system of mid-shelf reefs does not extend farther north than the Ragged Keys (Fig. 1). No corals suitable for coring were found in this area.

Station 8 (Fig. 6) off Soldier Key is somewhat of an anomaly in that it is the only site where large (1 m high) *M. annularis* were found on the west (inshore) side of Hawk Channel. In addition, the corals sampled there were growing not on a patch reef but on shallow (3- to 4-m deep) exposed bedrock. Of six colonies cored at this locality, only three had intact growth records; one (8F) had the shortest growth history (39 years) in the study because it was bioeroded.

The remaining sites, stations 5, 6, and 9 (Figs. 7, 8) are on offshore bank reefs that border the Straits of Florida along the park's eastern boundary. Station 5 is 3.5 km north of Fowey Rocks (Fig. 1) in an area of low-relief (0.5-1 m) relict-reef outcrops that presently support a diverse assemblage of octocorals and a restricted population of stony corals. *Montastrea annularis* in this locality occurs as widely separated (10-100 m apart) isolated colonies, most of which are 0.5 m or less in height. Several days of intense searching were necessary to locate and core seven large (1+m high) specimens in water depths that ranged from 6.1 to 8.1 m. Of these, only four corals had usable growth records. No *M. annularis* colonies suitable for coring were found between station 5 and the park's northeast boundary (Fig. 1). As noted by Jaap (1984), the Fowey Rocks area (cited by him as the region "south and west of Cape Florida") marks the northernmost extension of maximum coral reef development on the Florida reef tract. This reef's buildup to shoal-water depths (1.5 m) is comparable to that of most major bank reefs farther south in Biscayne National Park. There is little evidence, however, of active reef growth at Fowey Rocks today. It is interesting to note that a similar observation was made by T. Wayland Vaughan in the early 1900s (Vaughan, 1918).

Station 9 near Fowey Rocks (Fig. 1) is the only locality where *M. annularis* colonies suitable for coring were found seaward of major bank reefs. Large specimens were even more difficult to find here than at station 5. Two were located in the forereef area in water depths of 6.3 m (9A), and 8.1 m (9B), growing on heavily eroded, low-relief (0.24 m) rocky outcrops that appear to have been part of an earlier spur-and-

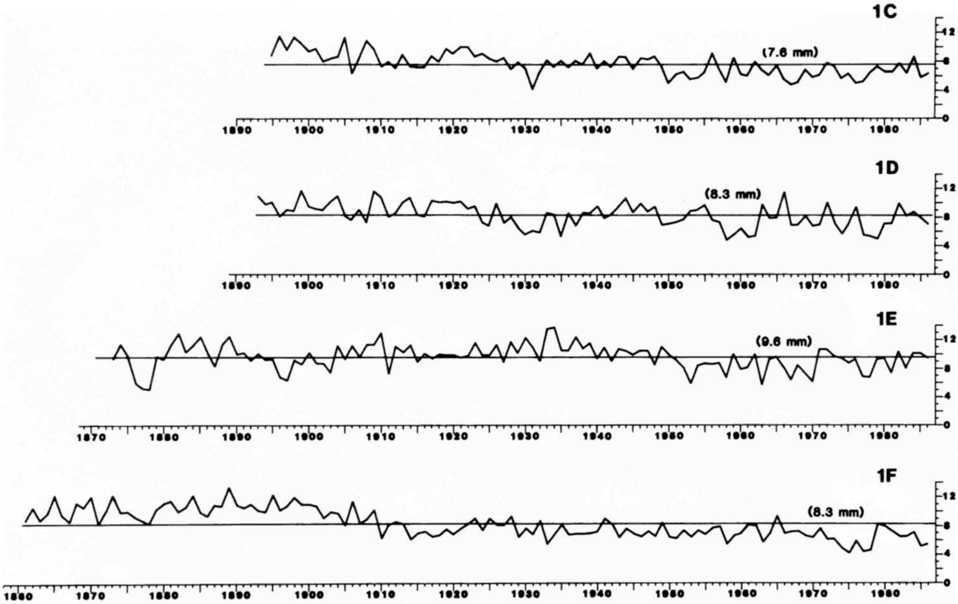


Figure 9. Line graphs of annual growth rates for *Montastrea annularis* colonies at Station 1.

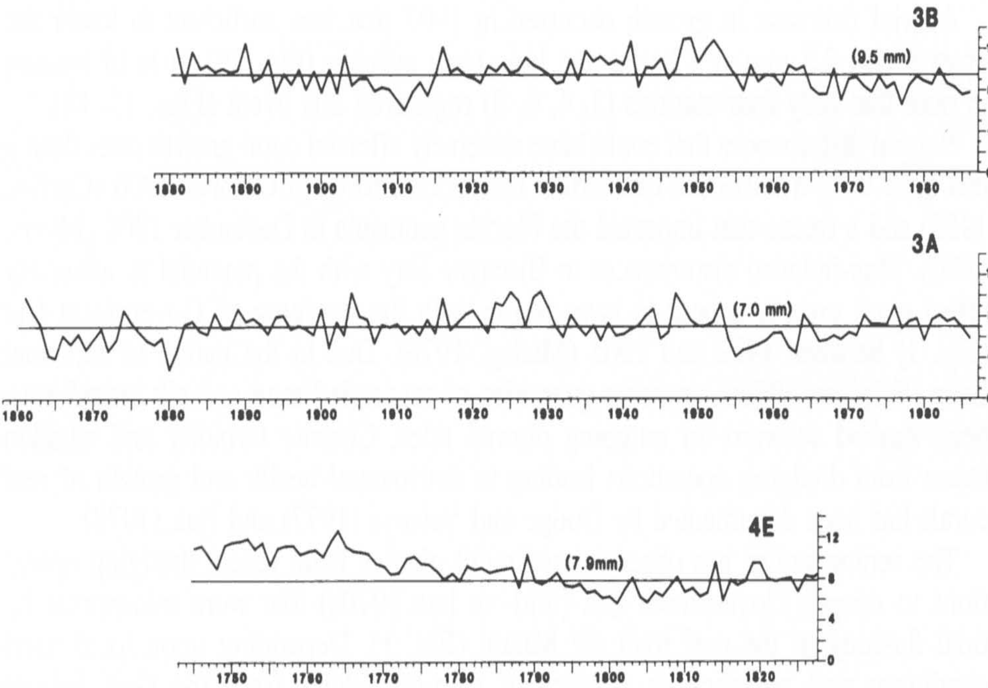


Figure 10. Line graphs of annual growth rates for individual *Montastrea annularis* colonies at Station 3.

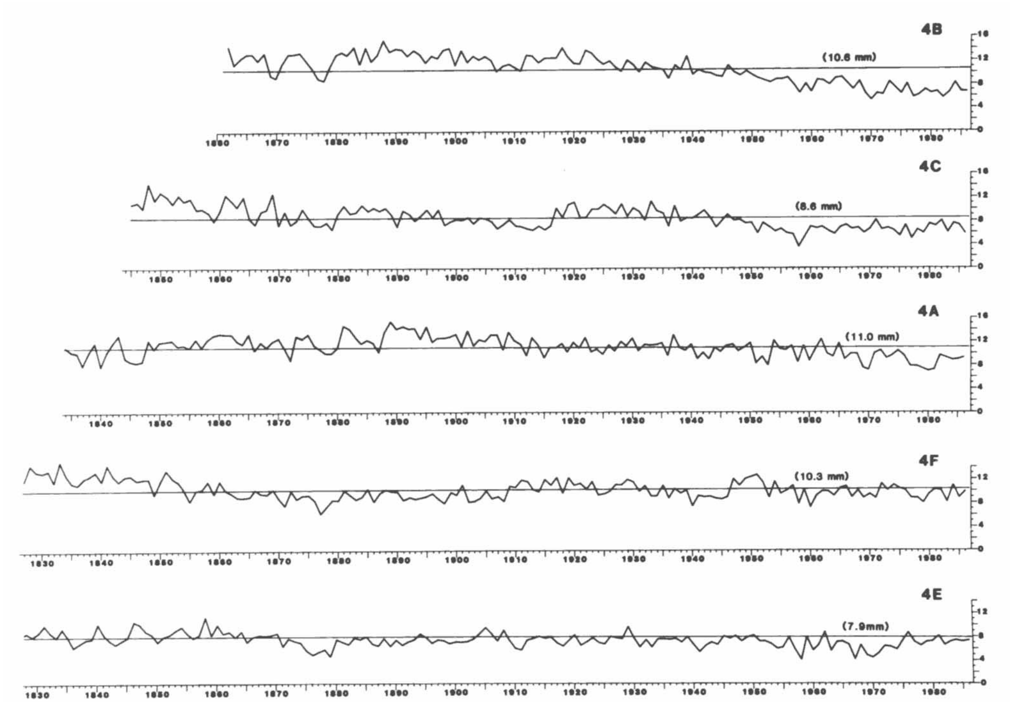


Figure 11. Line graphs of annual growth rates for individual *Montastrea annularis* colonies at Station 4.

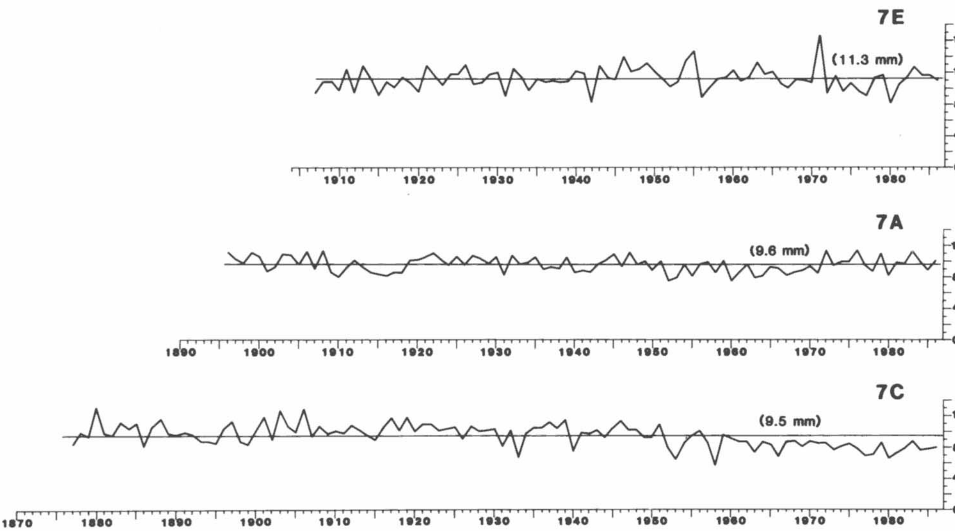


Figure 12. Line graphs of annual growth rates for individual *Montastrea annularis* colonies at Station 7.

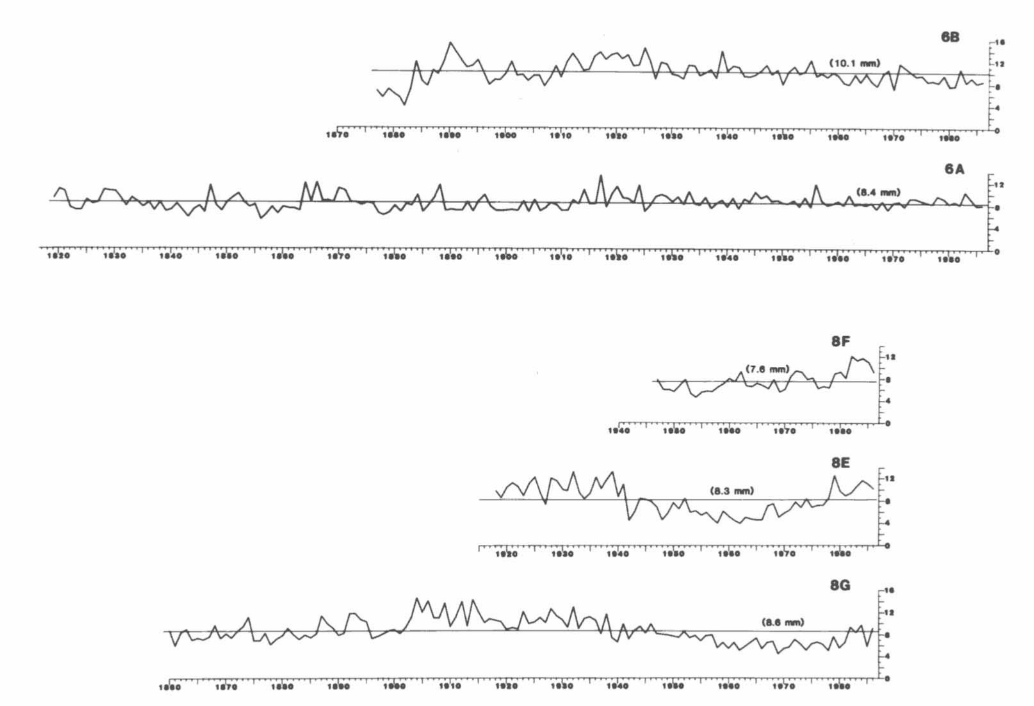


Figure 13. Line graphs of annual growth rates for individual *Montastrea annularis* colonies at Stations 6 and 8.

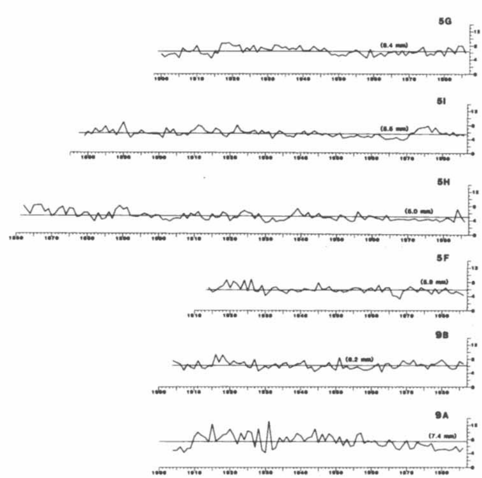


Figure 14. Line graphs of annual growth rates for individual *Montastrea annularis* colonies at Stations 5 and 9.

groove system (Shinn, 1963). Coral cover and diversity were similar to that described by Burns (1985) at comparable depths in forereef areas farther south in Biscayne National Park.

Station 6 on the inshore (backreef) edge of Ajax Reef (Fig. 1) was the only locality in a 25-km-long area of bank reefs (Fowey Rocks to Pacific Reef) where we were able to find *M. annularis* of sufficient size (1 m high) to meet our sampling criteria. Small (15-30 cm high) healthy *M. annularis* were occasionally seen at 4- to 10-m-depths on the seaward (forereef) side of most reefs, but were rarely seen on reef crests or in backreef areas. The substrate at station 6 is a mixture of coarse coralline sand and gravel to cobble-size coral debris. Dense beds of the seagrass *Thalassia testudinum* border both cored corals along their west (landward) side. Water depth at this site is 3.6 m at station 6A, and 4.2 m at station 6B.

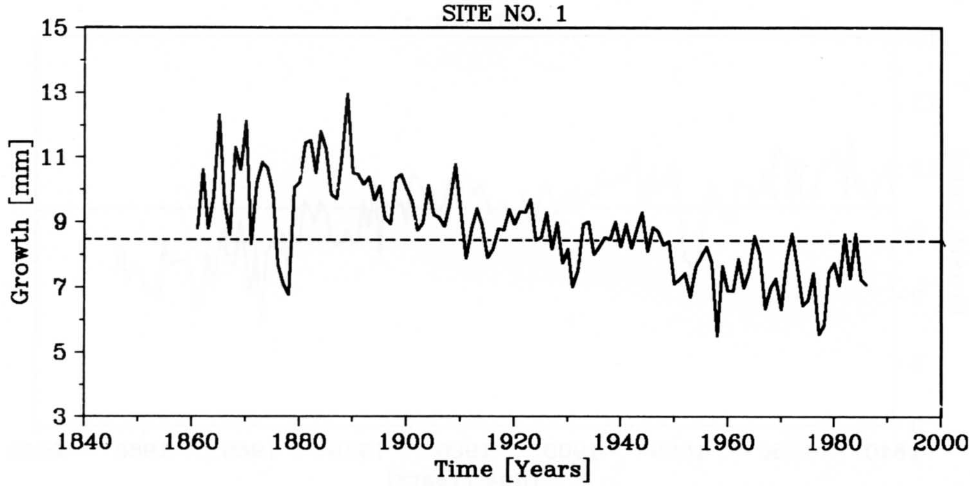
RESULTS

Line graphs of yearly growth for each of the *M. annularis* colonies used in this study are presented in Figures 9-14. Also included are graphs of average coral growth for the eight coring stations (Figs. 15-18) and an eight-site average that combines growth histories of the 25 corals into a single chronology (Fig. 19). An eight-site average graph of normalized growth based on one standard deviation is provided for comparison at the bottom of Figure 19.

For purposes of this report, only growth rate data from 1860 to 1986 will be discussed since only three stations (six corals) have records prior to the year 1860. At the 1862 level, however, six of eight stations (10 corals) are represented in the data base. All annual growth increments are tabulated in the Appendix.

DISCUSSION

A prominent feature of pre-1900 growth in Biscayne National Park *M. annularis* is an abrupt decline in growth rate of about 5 years' duration that is centered around the year 1878 (Fig. 19). Below average growth between 1875 and 1880 is present at 6 of 8 stations and is reflected as a 3.2-mm decrease below mean growth of the eight-site average (Fig. 19). What initiated such a precipitous decline is unknown, but a coincident perturbation, the "black water" event of 1878 at Dry Tortugas, 117 km west of Key West in Florida Keys, caused extensive mortality of reef fish and shoal water corals. It was reported in the 1878 log of the ACTIVA, the Tortugas' supply vessel, that the water "was very dark, like cypress water" (Feinstein et al., 1955). Source of the black water was thought to be surface run off of fresh water from the Everglades (Mayer, 1902). Longevity, geographic extent and composition of this lethal water mass remain unknown. Other natural disturbances include a hurricane that struck the Florida Keys in 1878 (Gentry, 1974) and a severe freeze that impacted Florida in 1880 (Myers, 1986). Prior to 1900, man's impact on the coastal waters



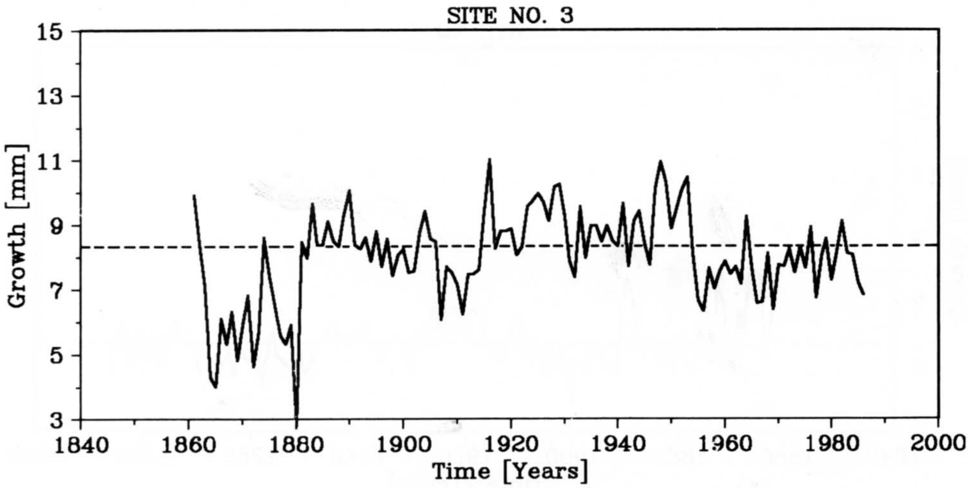


Figure 15. Line graphs of average annual growth rate for *Montastrea annularis* at Stations 1 and 3.

adjacent to Biscayne National Park were minimal (Michel, 1976); thus, it would seem unlikely that the perturbation of 1875-1880 was influenced by human activities.

After the decline of 1875-1880, growth rates of *M. annularis* at most stations rose sharply, and as indicated by the eight-site average (Fig. 19), reached a high of 9.9 mm/yr in 1889. Except for brief drops in 1898 and 1902, combined station growth rates from 1880 to 1906 were 0.5 to 1.6 mm/yr above the long-term growth rate average of 8.3 mm/yr (Fig. 19).

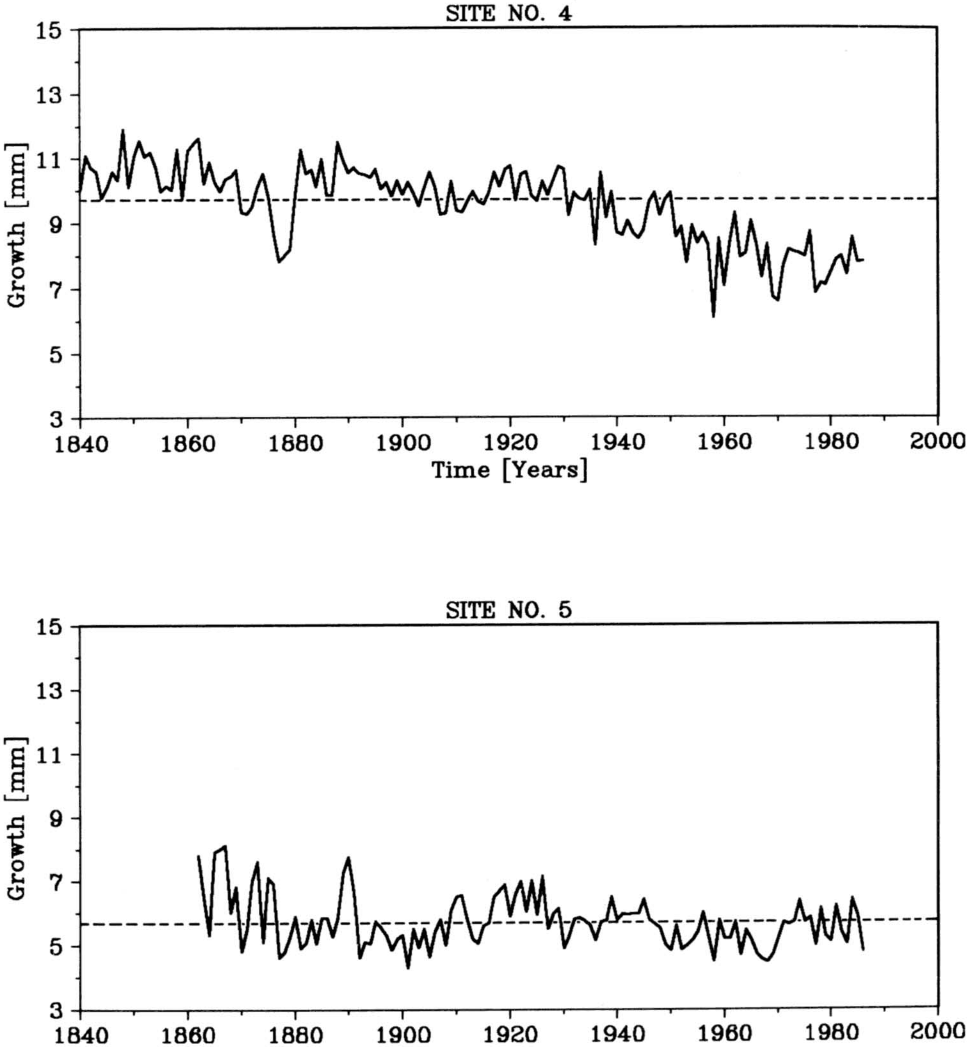
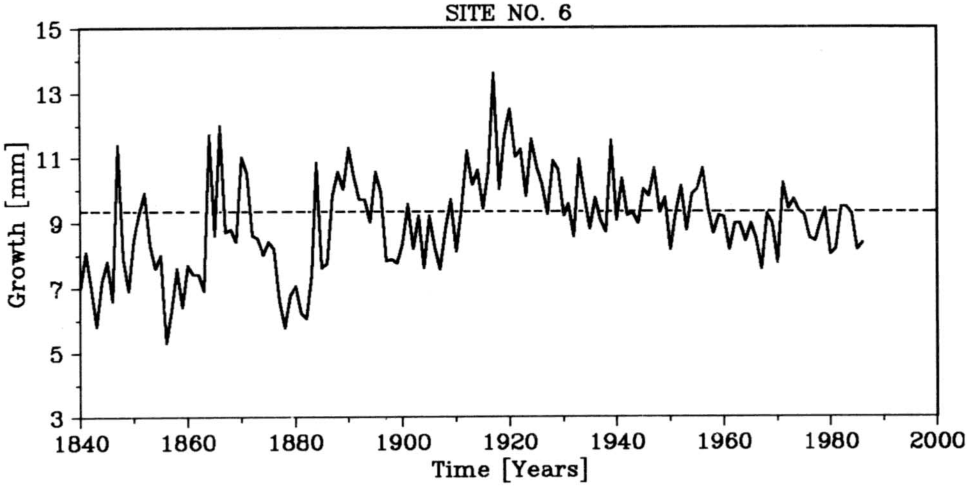


Figure 16. Line graphs of average annual growth rate for *Montastrea annularis* at Stations 4 and 5.

A brief decrease in growth occurred in 1907 that was sufficient to lower the growth rate 0.5 mm/yr below the long-term average (Fig. 19). It is of interest to note that only four stations (3, 4, 6, 9) registered this event (Figs. 15-18).
Natural disturbances that could have adversely affected coral growth rates during this time were a hurricane that struck the Florida Keys in October 1906 (Corliss, 1953) and a freeze that impacted the Florida peninsula in December 1906 (Myers, 1986). Man-induced disturbances to Biscayne Bay with the potential to adversely affect coral growth appear



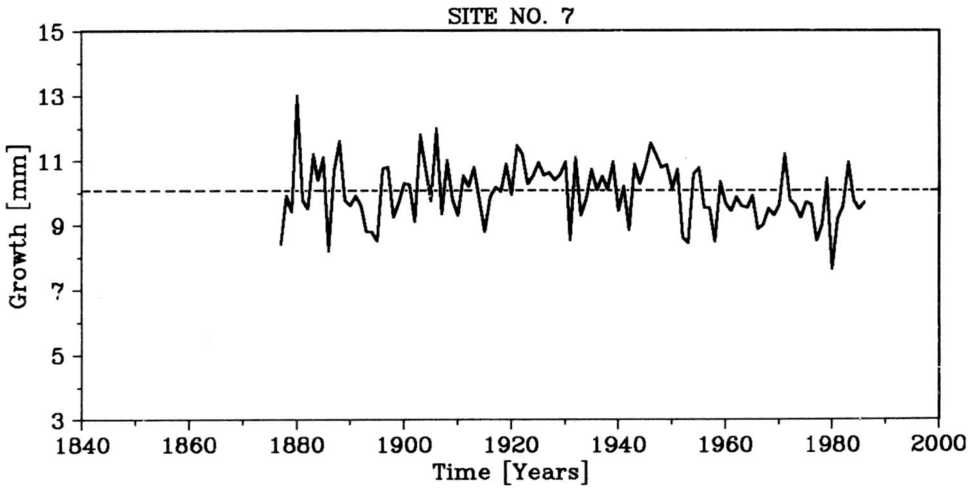


Figure 17. Line graphs of average annual growth rate for *Montastrea annularis* at Stations and 6 and 7.

to have begun with the dredging of Government Cut (Fig. 1) between 1902 and 1905 (Michel, 1976). Due to the nature of sediment there (Wanless, 1976a), massive quantities of suspended mud and silt would have been flushed seaward on outgoing diurnal tides. Chronic turbidity and siltation stress from dredging operations leading to detrimental health and growth of reef corals has been documented by Dodge and Vaisnys (1977) and Bak (1978).

The senior author has observed sediment plumes from recent dredging operations to deepen

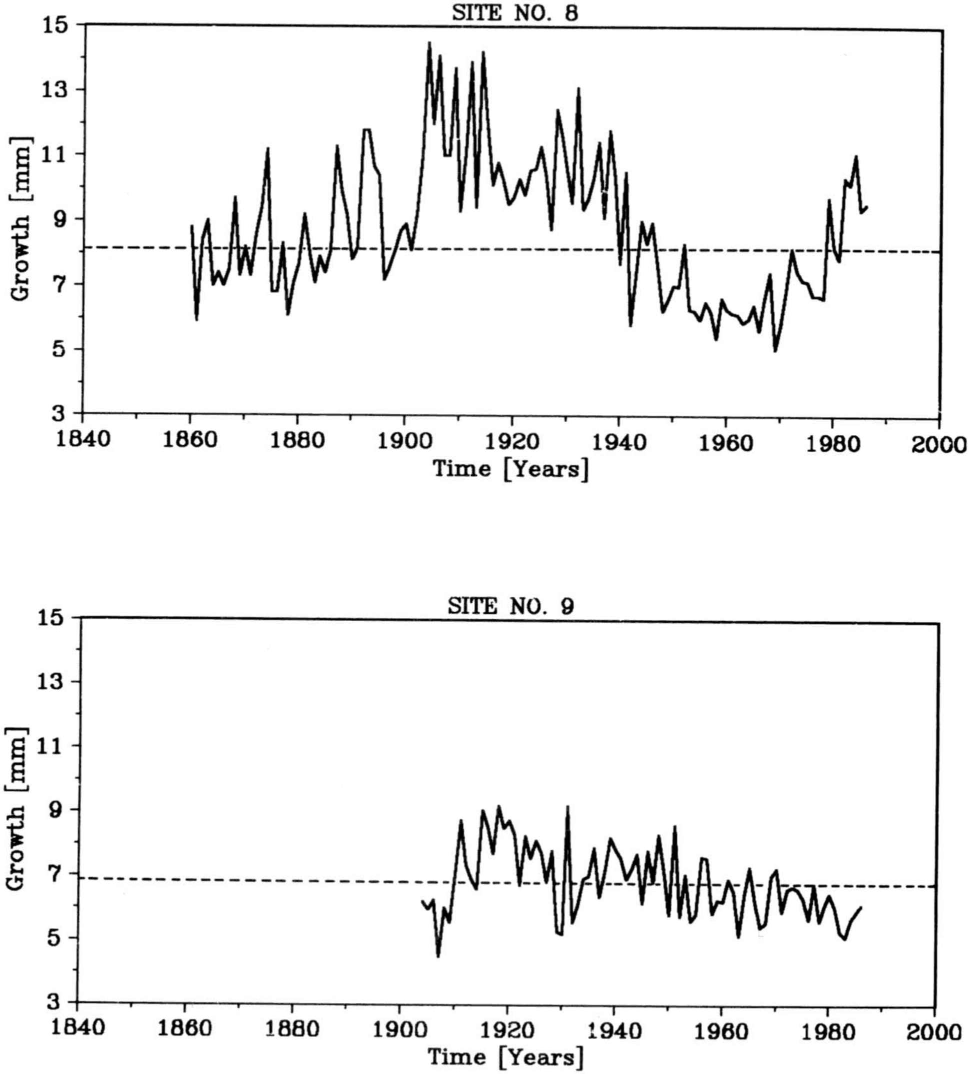
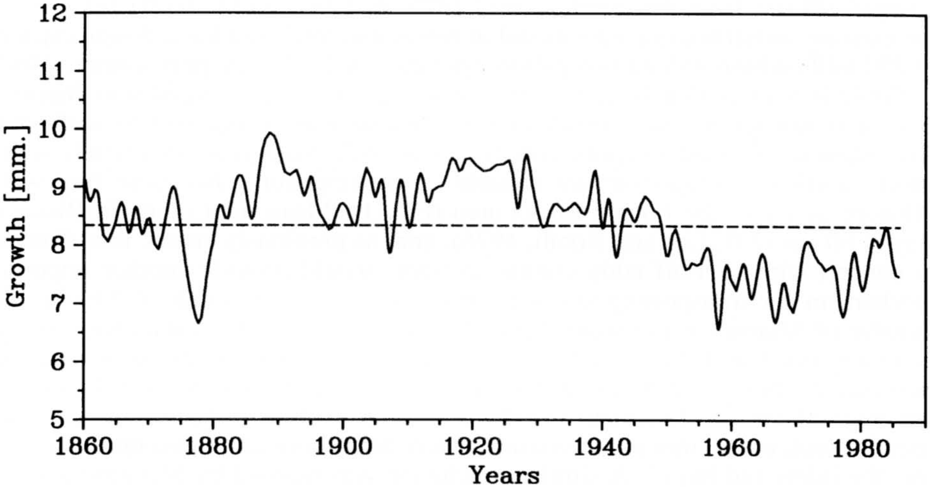


Figure 18. Line graphs of average annual growth rate for *Montastrea annularis* at Stations and 8 and 9.

Government Cut (mid- to late 1970s) that were transported by tidal flushing to the reef tract off Miami (Fig. 1). Depending upon local wind conditions and presence or absence of spin-off eddies from the Gulf Stream (southward-flowing counter currents; Lee and Mayer, 1977), the plume would disperse to the north or south as it was carried offshore. In this instance, however, dredging (1902-1905) preceded the growth rate decline by at least 2 years. Furthermore, corals at two of three sites (sta. 5, 8) closest to Government Cut (Fig. 1) did not experience a decrease in growth rate. Negative effects on growth from the hurricane



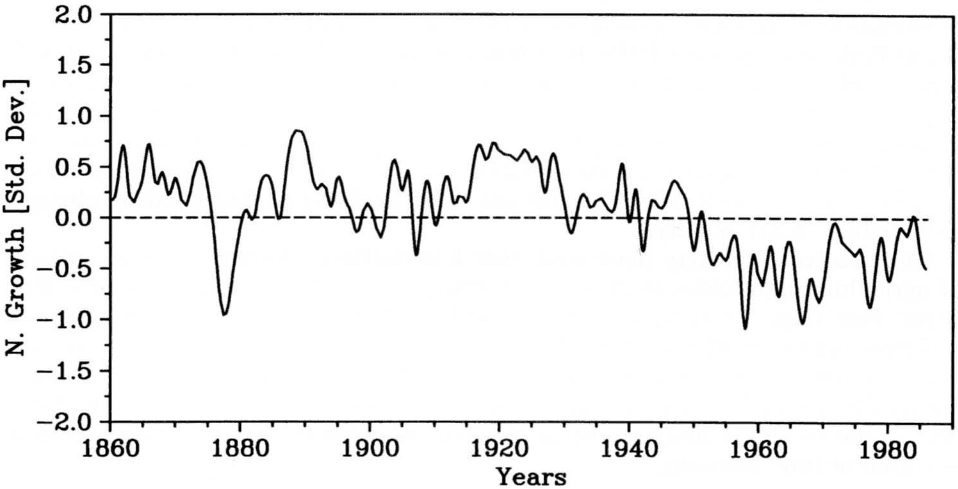


Figure 19. (upper) Line graph of average annual growth rate (8-site average) for *Montastrea annularis* in Biscayne Bay National Park. (lower) Line graph of 8-site average annual growth rate (1 standard deviation) for *Montastrea annularis* in Biscayne Bay National Park. Compare with graph above.

and freeze also seem questionable. Turbidity, siltation, and mechanical damage from a hurricane would presumably have affected corals at all stations, not just four. Effects of cold, on the other hand, would most likely have been registered by corals at station 8, the site closest to a source of chilled nearshore water (Walker et al., 1982). However, station 8 reveals no decline in growth.

Between 1910 and 1930, above average growth rates prevailed at all stations (Figs. 15-18) and can best be seen in the eight-site average (Fig. 19). This 20-yr period of unusually high skeletal accretion rates is contemporaneous with the 1919-1928 period of massive dredge-and-fill activity in northern Biscayne Bay. This apparent paradox may be explained in part by the distance of stations from the turbidity-siltation source and the weak nature of nearshore currents in the Miami area. According to Lee and Mayer (1977), nearshore currents off Miami are near zero with a range of 10 to 30 cm/sec and they state that "current directions paralleled the coast, either to the north or south, depending on whether the wind had a component from the south or north, respectively" (p. 199). Warzeski (1976) reports that sediment transport to the south in the Biscayne Bay region is caused by northerly winds of winter cold fronts that impact south Florida an average of 30 to 40 times per year.

Spin-off eddies from the Gulf Stream, as previously mentioned, could also provide a mechanism to transport sediments south. These disturbances were first described by Lee (1970, 1975) as small-diameter (10-30 km) cyclonic-edge eddies that form along the inshore front of the Florida Current. Counterclockwise rotation of these water masses generate a southerly current on their inshore side that can last for 2 to 10 days. Over a 9-month period (February to December, 1973), 45 current reversals were recorded off Miami by Lee and Mayer (1977). Since observed eddy currents in the Miami area apparently do not extend inshore closer than about 10 km (Lee and Mayer, 1977), tidal flushing is required to move sediment-laden waters offshore to be entrained south by the eddy counter current.

Between 1930 and 1950, growth rates of *M. annularis* in Biscayne National Park averaged 8.5 mm/yr, 0.7 mm/yr less than the preceding 20-year period of favorable growth conditions (Fig. 19). This reduction in rate of growth continues at most stations for the next 34 years. The eight-site average from 1950 to 1984 was only 7.5 mm/yr, 1 mm/yr below the previous 20-year average. Not until 1984 did the average growth rate recover to the long-term mean (Fig. 19).

Stations closest to the mainland (8, 1, 4; Figs. 15-18) experienced the most prolonged and severe decline in growth during this period. Offshore sites (stations 5, 9, 6; Figs. 16-18) and stations 3 and 7 (Figs. 15-17), on the other hand, had fewer years of less severely depressed growth during the same time interval. Note that stations 3 and 7 are not shielded by offshore bank reefs, thus allowing Florida Straits water to reach them relatively unimpeded. Proximity of the above five stations to the tempering effects of Florida Straits water is presumed to be responsible for the observed differences in growth reduction and recovery between inshore and offshore sites. The severity and chronic nature of depressed growth rates throughout the study area, however, strongly suggest a gradual degradation of reef tract water quality. Furthermore, a comparison of station growth rate averages between 1930 and 1984 reveals that the three inshore sites closest to Miami (stations 8, 1, 4; Fig. 1) registered the greatest decrease in growth rate over the longest time interval (Figs. 15-18).

During the period of slowest coral growth (1950-1984), water quality in Biscayne Bay was affected by the continued development of Miami and by a 20% reduction in freshwater runoff into the bay, a result of water management practices implemented after severe flooding of southeast Florida in 1947 (Buchanan and Klein, 1976). By far, the most deleterious of these impacts was the dumping of raw sewage into Biscayne Bay. Between 1900 and 1950, the population of Miami increased from 1,681 to 249,276 people, and by 1955 some 114 million to 189 million liters (30 to 50 million gallons) of untreated waste were discharged daily into northern Biscayne Bay (McNulty, 1970). This practice ended in 1956 with the construction of a sewage treatment plant on Virginia Key (Fig. 1). Treated waste was pumped offshore to a depth of 5 m (16 ft) through a 1,405-m-long (4,600 ft) outfall pipe. This outfall (represented by a circle of broken lines in Fig. 1) discharged effluent from this location until 1977. A 4,354-m (14,260 ft) extension to the existing outfall became operational in November 1977 and has a design capacity of 200 million liters (55 million gallons) per day (A. E. Austin, pers. comm., 1987).

While it is clear that large volumes of sewage were discharged into Biscayne Bay, it is not known how much of this effluent was transported to reef areas. According to H. Wanless (pers. comm., 1988), cold front-generated winds with a strong northerly component are capable of moving north Biscayne Bay water offshore as far as the Fowey Rocks area (Fig. 1). Mean tidal range in Biscayne Bay is 60 cm (2 ft; Lee and Rooth, 1976), and, as previously stated, tidal flushing in concert with spin-off eddy counter currents would provide another important mechanism for transporting sewage effluent to reef areas south of Miami. The transfer of Miami's waste water from Biscayne Bay to the Virginia Key sewage treatment plant in 1956 served to remove a serious pollution problem from one area and concentrate it in another. In a report on the movement of effluent from the original outfall, D'Amato (1973, p. 82) stated that "Miami's waste water spends much of its time in the coastal waters near shore and often makes its way into the inlets and bays." A similar conclusion was reached by McGuire and Lee (1973), who reported on the use of ocean outfalls along Florida's southeast coast. As a result of these studies, an extension was added to the outfall in 1977 that moved it offshore to its present location at the 30-m (100 ft) isobath.

It is our contention that domestic sewage from the Miami area has been a major contribution to reduced growth rates of *Montastrea annularis* in Biscayne National Park since at least 1930. It is noteworthy that the lowest levels of growth rates at all stations (except sta. 7) are contemporaneous with the existence of the original Virginia Key sewage outfall that operated from 1956 to 1977. It is also significant that a recovery in growth rate is indicated on the eight-site average (Fig. 19) that corresponds to the outfall extension in 1977. This recovery is best illustrated at Station 8 (Fig. 18), the site most likely to be impacted by changes in nearshore water quality.

Other factors that may have contributed to declining growth rates are: runoff of agricultural pesticides from nearby farming areas via drainage canals into Biscayne Bay (Fig. 1); reduction in availability of fresh-water to estuarine areas; sediment plumes in Hawk Channel (Fig. 1) stirred up by deep draft private vessels and commercial tugboat traffic; and chronic low-level turbidity from developed areas of Biscayne Bay. These topics should be considered in future research efforts and should include a study of chemical compounds bound up in the coral skeleton at different time horizons.

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Year	1C	1D	1E	1F	3A	3B	4A	4B	4C	4E	4F	9A	9B	5F	5G	5H	5I	6A	6B	7A	7C	7D	7E	8E	8F	8G
	Core Number																									
1986	6.3	7.0	9.5	5.5	5.9	7.7	9.3	6.7	5.8	7.4	9.9	5.5	6.7	4.4	6.0	3.6	5.1	8.1	8.6	10.1	8.0	0.0	11.0	10.2	9.2	9.2
1985	5.8	7.9	10.1	5.2	6.9	7.5	8.9	6.7	7.3	7.2	8.8	4.4	7.4	5.0	8.0	5.0	5.5	8.0	8.3	8.9	7.8	0.0	11.7	11.1	11.1	5.8
1984	8.6	8.8	10.1	7.1	7.8	8.3	8.8	8.2	7.6	7.4	10.8	6.0	5.3	5.5	8.0	7.2	5.0	9.2	9.3	10.0	7.6	0.0	11.7	11.7	11.8	9.7
1983	6.3	8.2	8.0	6.5	7.5	8.7	9.2	6.5	6.1	7.1	8.1	5.1	5.1	4.8	5.7	3.6	6.0	10.5	8.4	11.3	8.8	0.0	12.7	10.7	11.4	8.3
1982	7.7	9.9	10.4	6.5	8.1	10.1	9.6	5.6	8.0	6.6	10.1	4.8	5.7	5.1	6.9	4.4	5.1	8.2	10.7	9.6	7.8	0.0	11.3	9.5	12.2	9.3
1981	6.5	7.1	7.4	7.2	7.7	8.6	7.2	6.7	7.1	8.1	10.2	5.2	6.9	6.5	7.6	4.8	5.9	8.7	7.7	9.8	7.2	0.0	10.5	8.9	8.1	6.5
1980	6.5	7.1	9.5	7.9	5.6	8.9	6.9	6.4	7.5	7.2	9.4	5.1	7.8	5.7	5.0	4.1	5.5	8.4	7.6	8.2	6.5	0.0	8.2	9.8	9.3	5.5
1979	7.3	5.0	9.3	8.2	7.8	9.3	7.4	7.0	5.9	7.1	7.9	5.0	7.1	4.8	6.6	3.7	5.9	9.2	9.6	11.0	8.5	0.0	11.8	12.6	9.0	7.6
1978	6.6	5.4	6.8	4.6	7.5	8.5	7.8	6.1	6.5	6.5	8.8	4.7	6.5	6.2	6.6	4.4	7.3	9.7	8.3	8.7	7.0	0.0	11.4	8.5	6.4	5.0
1977	5.2	5.6	6.9	4.4	6.8	6.6	7.8	5.7	4.9	7.0	8.7	6.9	6.6	4.6	5.3	4.0	6.0	8.2	8.6	9.5	6.9	0.0	9.1	7.2	6.7	6.2
1976	5.0	9.4	9.4	5.9	9.0	8.8	9.5	8.0	7.3	8.7	10.1	6.1	5.2	5.6	5.8	4.3	7.7	8.5	8.5	11.4	7.8	0.0	9.7	7.2	6.3	6.6
1975	6.3	7.1	8.8	4.2	7.1	8.2	10.4	6.3	5.4	7.3	10.4	6.3	6.3	6.0	5.2	4.3	7.3	8.8	9.6	10.0	8.4	0.0	10.7	6.8	8.3	6.3
1974	5.6	5.7	9.5	4.9	7.2	9.4	9.6	7.4	6.4	5.8	11.0	6.6	6.6	6.5	7.7	4.1	7.2	9.2	9.5	10.0	8.1	0.0	9.6	8.5	8.0	5.1
1973	7.4	7.2	9.7	6.2	7.2	7.8	9.1	8.3	6.8	6.2	10.1	7.2	6.1	5.2	6.8	4.0	6.9	9.2	10.2	9.5	7.7	0.0	11.6	6.9	9.3	6.2
1972	7.8	10.0	10.7	6.1	8.1	8.4	10.5	6.1	6.5	6.4	11.3	5.4	7.8	6.1	6.1	4.5	5.8	7.8	11.0	11.3	8.5	0.0	9.5	7.9	9.5	7.1
1971	6.1	7.0	10.7	7.6	6.1	9.3	10.0	6.4	8.1	5.2	8.7	5.2	6.6	6.9	5.9	4.3	5.7	8.7	11.7	8.5	8.5	0.0	16.6	6.5	8.4	5.7
1970	5.8	6.8	6.2	6.4	6.4	9.1	7.1	5.2	6.6	4.4	9.5	7.7	6.8	6.0	6.4	4.1	4.2	8.5	7.0	9.4	8.7	0.0	10.8	5.9	6.2	5.4
1969	6.8	8.2	7.4	6.6	5.7	7.0	7.6	6.4	5.9	4.8	8.8	6.4	7.6	5.6	5.2	4.3	3.7	7.2	10.7	8.8	8.0	0.0	11.1	5.1	5.7	4.4
1968	5.1	7.0	8.5	7.3	6.1	10.1	9.9	8.4	6.8	6.5	10.1	5.0	6.1	3.3	6.5	4.3	3.8	8.7	9.8	8.6	8.7	0.0	11.2	7.6	8.0	6.7
1967	4.8	6.9	6.4	7.2	5.6	7.6	9.9	7.0	6.6	4.1	8.9	5.4	5.4	4.1	5.3	4.3	4.4	7.3	7.8	8.2	8.7	0.0	10.1	7.2	6.2	6.5
1966	5.5	11.4	8.2	6.9	5.5	7.6	8.9	8.1	7.3	6.6	10.8	7.0	5.4	4.2	6.4	4.2	4.1	8.4	8.5	9.1	6.8	0.0	10.7	4.7	6.9	5.3
1965	7.4	8.0	9.6	9.3	7.1	8.2	11.7	9.1	6.9	7.1	10.5	7.9	6.7	6.5	6.1	4.0	4.0	8.0	9.9	9.3	8.3	0.0	12.1	4.7	7.3	7.3
1964	6.0	7.9	9.2	6.9	8.2	10.3	9.3	9.0	5.8	7.0	9.1	6.2	6.6	6.5	6.0	5.4	3.9	8.4	8.4	8.2	8.6	0.0	11.8	4.8	6.7	6.5
1963	6.7	9.7	5.7	5.8	4.4	9.9	9.9	7.9	6.3	5.6	9.9	6.1	4.2	5.2	5.0	4.0	4.5	8.1	9.8	7.9	7.4	0.0	13.4	5.1	6.8	5.7
1962	7.9	5.4	10.0	8.1	5.0	10.4	12.3	8.6	7.0	8.7	9.9	6.4	6.7	7.2	5.9	4.5	5.3	9.9	8.0	9.5	8.7	0.0	11.4	4.0	9.4	5.0
1961	6.0	5.2	8.1	8.2	6.4	8.5	10.6	8.7	6.7	6.5	9.2	7.8	6.0	5.5	5.4	4.6	5.3	8.0	8.3	8.6	8.7	0.0	11.0	4.5	7.5	6.5
1960	6.2	6.5	7.9	6.9	6.3	9.4	8.7	6.6	7.0	5.6	7.3	7.2	5.2	6.5	4.7	5.1	4.4	8.7	9.6	7.5	9.1	0.0	12.4	5.3	8.1	5.4
1959	8.5	5.5	10.0	6.6	5.6	9.5	11.3	8.0	5.2	7.8	10.2	7.6	4.9	6.1	6.9	5.3	4.8	8.3	10.1	10.0	9.6	0.0	11.4	6.3	7.1	6.5
1958	5.1	4.8	6.7	5.4	5.2	8.8	8.5	6.4	3.5	4.1	7.8	6.9	4.8	5.0	4.4	4.1	4.5	8.0	9.3	8.5	5.7	0.0	11.2	4.2	6.5	5.5
1957	7.0	7.3	8.8	7.9	4.9	10.4	11.3	7.8	5.7	5.8	10.9	9.8	5.3	6.2	5.1	5.0	4.6	8.8	10.0	9.9	8.5	0.0	10.2	5.0	5.7	7.9
1956	9.1	7.6	8.6	7.7	4.7	7.9	10.5	9.1	5.9	7.8	10.0	9.4	5.8	6.5	6.0	6.4	5.1	11.8	9.5	9.7	10.0	0.0	8.9	6.0	5.8	7.8
1955	6.5	9.7	8.7	6.8	4.0	9.3	10.7	8.8	6.7	6.1	9.5	6.3	5.4	6.5	6.8	3.7	4.6	7.6	12.4	8.1	9.4	0.0	14.8	5.5	5.6	6.8
1954	5.7	9.0	8.4	7.4	5.8	10.4	12.1	8.8	6.2	5.9	11.6	6.0	5.2	6.0	6.2	3.6	4.7	9.4	10.3	9.6	8.5	0.0	13.6	6.3	4.6	7.8
1953	5.5	8.8	6.0	6.4	9.1	11.8	7.9	8.3	7.0	6.7	8.9	8.1	6.0	5.4	6.0	4.1	4.4	7.7	9.8	7.9	6.5	0.0	10.9	6.1	5.3	7.4
1952	6.5	7.7	8.2	7.3	7.4	12.8	9.4	8.7	7.7	7.1	11.4	6.2	5.3	5.2	5.0	5.0	4.2	8.9	11.3	7.5	8.0	0.0	10.3	8.5	7.9	8.5
1951	6.2	7.3	9.2	6.2	7.0	12.0	8.2	9.0	5.9	7.0	12.7	8.8	8.4	5.9	5.4	5.4	5.7	8.3	10.3	10.0	10.9	0.0	11.3	6.7	6.8	7.4
1950	5.0	7.1	9.9	6.4	7.0	10.7	11.7	9.6	7.7	8.1	12.4	6.8	4.8	5.3	5.1	3.8	5.1	8.4	7.9	9.0	9.2	0.0	12.2	7.8	5.7	7.6
1949	7.3	6.9	11.0	8.4	7.6	13.0	10.9	10.2	7.6	7.8	12.0	8.8	5.6	5.7	5.6	4.2	4.6	8.9	10.6	10.1	9.2	0.0	13.3	5.8	6.1	7.9
1948	8.6	9.5	8.5	6.5	9.0	12.9	10.3	9.5	8.3	7.1	10.9	9.6	7.0	6.8	5.4	4.8	5.0	8.8	9.8	9.6	10.2	0.0	12.5	4.6	6.1	8.0
1947	8.2	8.8	10.5	7.3	10.2	10.0	11.5	10.0	8.1	8.0	12.0	7.7	5.9	6.1	6.4	4.6	5.5	9.8	11.5	11.1	10.2	0.0	12.2	7.0	7.9	8.1
1946	8.4	9.9	10.5	6.5	6.4	9.1	11.3	11.2	9.1	7.6	8.9	9.6	6.0	6.1	7.3	4.6	5.1	9.3	10.3	9.3	11.3	0.0	14.0	8.0	−0.1	9.9
1945	6.9	8.7	9.9	6.9	5.8	11.0	10.2	9.2	8.0	7.9	8.6	7.2	5.1	7.9	6.5	5.8	5.5	10.4	9.6	10.9	10.4	0.0	11.2	8.4	−0.1	8.2
1944	8.5	10.6	10.5	7.6	8.7	10.1	11.0	9.4	6.9	6.5	8.7	11.0	4.4	5.6	7.0	5.0	6.2	8.6	9.3	10.1	9.2	0.0	11.5	8.6	−0.1	9.4
1943	8.6	9.4	10.8	6.3	8.0	10.2	9.0	9.9	8.6	6.9	9.1	8.7	5.8	5.8	7.9	4.5	5.6	9.2	9.4	9.7	10.1	0.0	12.9	6.0	−0.1	8.7
1942	7.2	8.4	9.0	8.2	7.1	8.3	10.1	10.0	9.8	6.4	9.0	8.4	5.4	6.0	6.8	6.0	4.9	7.4	11.0	8.6	9.7	0.0	8.2	4.5	−0.1	7.1
1941	8.0	7.8	10.9	9.0	6.7	12.6	9.0	10.5	9.0	5.3	9.2	7.5	7.6	6.2	6.5	5.0	6.1	9.4	11.3	8.8	9.8	0.0	12.0	11.1	−0.1	9.9
1940	7.0	9.5	9.3	7.2	6.2	10.4	11.4	9.6	8.4	6.6	7.5	9.0	6.7	5.5	6.5	5.7	5.4	7.7	10.4	8.5	7.5	0.0	12.3	8.9	−0.1	6.5
1939	9.1	8.5	11.5	6.9	6.1	10.9	10.4	12.7	8.5	7.9	10.2	9.7	6.7	5.3	8.0	7.2	5.5	8.9	14.1	10.5	11.4	0.0	11.0	13.4	−0.1	7.3
1938	7.5	8.7	10.8	6.8	7.4	10.5	10.9	10.4	7.9	6.9	9.6	8.2	6.1	5.9	6.9	5.8	4.4	8.3	9.1	9.0	10.4	0.0	10.9	11.9	−0.1	11.7
1937	8.1	6.8	12.4	6.8	5.6	11.3	13.1	11.2	10.5	7.5	10.4	7.2	5.5	6.0	7.3	4.8	4.8	7.5	10.6	9.2	11.2	0.0	11.1	10.2	−0.1	8.0
1936	7.2	8.5	10.5	6.7	7.1	10.8	9.5	8.9	7.0	7.4	8.8	8.8	7.0	4.8	6.8	4.2	4.7	9.5	10.0	8.9	10.4	0.0	10.9	12.4	−0.1	10.5
1935	8.1	5.3	10.5	8.1	6.1	11.8	11.7	10.5	9.4	7.5	10.9	7.3	6.7	5.5	7.6	3.7	5.6	8.0	9.6	10.5	10.4	0.0	11.3	9.5	−0.1	11.2
1934	7.2	8.3	13.7	6.8	7.0	8.9	11.4	10.7	9.7	7.5	9.1	8.4	5.4	5.8	7.3	3.8	6.1	8.3	11.3	9.8	9.7	0.0	9.9	8.5	−0.1	10.9
1933	8.2	8.6	13.5	5.4	8.1	11.0	11.3	10.9	11.2	6.1	9.1	5.6	6.6	6.7	8.0	3.4	5.3	10.4	11.5	9.6	6.7	0.0	11.6	9.7	−0.1	9.0
1932	6.4	5.8	9.1	8.7	5.9	8.8	11.4	11.7	8.1	7.4	10.9	4.9	6.2	6.5	8.2	4.5	4.0	8.2	8.9	10.7	10.1	0.0	12.6	13.2	−0.1	13.0

Appendix Table 1. Annual coral growth (mm).

Appendix Table 1. Continued.

Year	1C	1D	1E	1F	3A	3B	4A	4B	4C	4E	4F	9A	9B	5F	5G	5H	5I	6A	6B	7A	7C	7D	7E	8E	8F	8G
	Core Number																									
1931	4.1	6.1	11.0	6.8	7.0	8.7	10.4	10.0	9.7	6.1	9.9	13.1	5.3	5.1	6.5	3.4	5.9	9.5	9.6	8.2	8.2	0.0	9.2	9.9	−0.1	9.2
1930	7.0	5.6	12.4	7.7	8.9	9.6	12.5	11.3	10.3	7.6	11.5	4.4	6.0	4.2	6.8	3.1	5.5	8.6	9.8	10.5	10.3	0.0	12.1	10.2	−0.1	10.7
1929	7.9	6.5	10.2	6.4	10.4	10.1	11.2	12.1	8.8	9.6	11.9	5.2	5.3	7.2	7.0	4.0	6.3	9.6	11.6	9.7	10.1	0.0	11.9	11.7	−0.1	11.4
1928	6.9	8.0	11.7	9.3	9.8	10.5	11.9	10.2	10.9	7.5	11.0	11.0	4.6	5.4	7.5	5.7	5.2	9.9	11.9	10.4	10.0	0.0	10.8	12.3	−0.1	12.6
1927	8.5	7.2	8.9	8.1	7.0	11.2	10.3	10.9	9.2	7.7	11.1	5.7	7.9	5.5	6.0	4.2	6.3	9.6	8.9	10.7	10.6	0.0	10.6	7.4	−0.1	10.1
1926	8.0	9.8	11.3	8.1	9.5	9.9	11.4	12.0	10.2	7.9	9.9	10.0	5.5	8.9	8.0	5.8	5.9	8.0	12.3	9.5	9.1	0.0	13.0	9.6	−0.1	11.1
1925	8.4	6.8	9.9	9.0	10.3	9.6	9.8	11.5	10.8	6.6	9.5	10.5	5.7	5.5	6.6	6.0	5.6	6.8	14.6	10.5	10.5	0.0	11.8	12.4	−0.1	10.2
1924	9.1	7.3	9.9	7.4	8.9	10.6	10.7	12.2	10.0	6.9	9.3	7.9	7.2	8.5	7.3	6.5	5.7	11.7	11.4	9.5	10.3	0.0	11.8	11.3	−0.1	9.9
1923	8.7	9.5	11.6	9.0	9.3	9.8	10.2	13.3	10.0	7.7	11.6	9.8	6.7	6.1	6.0	5.9	6.1	8.3	11.3	10.2	10.1	0.0	10.5	9.0	−0.1	12.1
1922	10.0	9.2	9.8	8.2	6.3	10.3	12.7	13.8	8.6	7.0	10.3	6.6	6.8	7.5	8.2	4.4	7.8	9.2	13.3	11.0	10.9	0.0	11.7	10.7	−0.1	8.9
1921	10.0	10.2	9.5	7.6	7.4	8.7	10.8	11.4	8.5	6.4	11.3	9.1	7.5	8.3	7.8	4.6	5.7	9.4	12.6	10.5	11.0	0.0	12.9	11.4	−0.1	9.2
1920	9.0	10.0	9.9	6.8	8.5	9.2	11.8	11.6	11.2	8.1	11.0	11.0	6.5	6.4	8.0	3.6	5.5	11.4	13.6	10.1	10.0	0.0	9.7	10.6	−0.1	8.9
1919	9.8	10.2	9.9	7.6	8.1	9.5	10.1	12.7	10.8	7.2	12.3	9.5	7.5	8.7	8.8	5.6	4.4	10.0	13.4	10.0	11.9	0.0	10.8	8.7	−0.1	10.3
1918	8.0	10.1	10.1	6.7	7.4	10.2	11.7	14.3	8.6	6.3	9.6	9.3	9.1	7.0	8.6	6.1	5.0	7.6	12.4	8.5	10.1	0.0	11.5	10.0	−0.1	10.5
1917	8.8	10.4	9.5	6.5	6.7	9.8	10.9	12.5	10.2	6.9	12.3	8.3	7.1	6.5	8.6	4.6	6.3	13.4	13.8	8.5	11.7	0.0	10.3	−0.1	−0.1	10.8
1916	7.2	8.1	10.1	7.3	9.8	12.2	11.0	12.5	7.2	7.8	11.0	7.7	9.4	5.7	5.7	4.4	6.9	8.2	13.0	8.1	10.5	0.0	11.0	−0.1	−0.1	10.1
1915	7.2	8.3	9.0	7.1	6.3	9.4	9.2	12.5	6.5	7.6	12.0	12.2	5.9	5.2	6.1	5.6	5.5	8.2	10.6	8.3	8.9	0.0	9.2	−0.1	−0.1	12.0
1914	7.3	10.7	11.3	6.2	7.7	7.5	11.4	11.8	7.2	7.9	9.9	7.2	6.0	6.5	4.4	3.7	5.6	10.8	10.4	8.6	9.5	0.0	11.3	−0.1	−0.1	14.2
1913	9.0	10.0	10.3	8.3	6.1	8.8	12.6	12.9	6.5	7.5	10.3	8.6	5.2	−0.1	5.7	3.8	6.1	8.1	12.2	9.3	10.2	0.0	12.9	−0.1	−0.1	9.4
1912	7.0	8.5	11.1	8.6	7.0	7.9	9.6	13.0	6.8	7.2	11.7	9.2	5.5	−0.1	5.5	4.5	7.4	8.9	13.5	10.1	10.8	0.0	9.7	−0.1	−0.1	13.9
1911	8.0	8.0	7.3	8.2	6.3	6.1	11.6	10.3	7.2	5.6	11.9	10.1	7.4	−0.1	5.7	6.2	7.7	7.0	11.9	9.2	9.8	0.0	12.6	−0.1	−0.1	11.1
1910	7.3	10.8	13.0	6.3	7.3	7.0	12.1	10.9	7.3	5.9	10.6	8.9	5.2	−0.1	8.0	5.1	6.4	7.0	9.2	8.0	10.1	0.0	9.8	−0.1	−0.1	9.3
1909	9.9	11.6	11.4	10.2	6.9	8.1	13.6	11.5	8.3	7.2	10.8	5.5	5.6	−0.1	6.5	5.7	6.1	8.0	11.4	8.6	9.8	0.0	11.0	−0.1	−0.1	13.7
1908	10.9	7.2	11.4	8.9	7.1	8.3	10.5	11.2	7.5	8.9	8.3	5.5	6.5	−0.1	6.2	4.0	4.8	8.5	9.1	11.3	10.7	0.0	11.0	−0.1	−0.1	11.0
1907	8.5	9.0	9.6	8.3	5.4	6.7	13.1	10.2	6.7	7.1	9.1	4.2	4.8	−0.1	6.3	5.6	5.5	7.5	7.6	9.0	9.4	0.0	9.6	−0.1	−0.1	11.0
1906	6.3	7.6	11.2	11.4	7.7	9.2	13.1	12.2	8.0	8.4	8.8	5.9	6.6	−0.1	7.3	4.1	4.9	7.0	9.5	11.1	12.9	0.0	−0.1	−0.1	−0.1	14.1
1905	11.3	8.2	9.3	8.1	7.9	9.2	12.0	12.8	8.5	9.4	10.1	4.9	7.0	−0.1	4.5	4.4	5.0	8.9	9.5	9.6	9.9	0.0	−0.1	−0.1	−0.1	12.0
1904	8.6	10.9	11.2	9.8	10.2	8.6	12.4	12.3	8.6	8.3	8.8	4.9	7.5	−0.1	5.7	4.2	6.6	6.7	8.5	10.8	10.7	0.0	−0.1	−0.1	−0.1	14.5
1903	8.4	10.1	7.4	10.0	6.1	11.4	11.3	12.9	7.6	7.4	8.3	−0.1	−0.1	−0.1	5.7	3.5	5.6	8.7	9.7	10.9	12.7	0.0	−0.1	−0.1	−0.1	11.0
1902	8.0	9.0	8.7	9.2	7.4	7.7	13.8	11.8	8.8	7.0	8.2	−0.1	−0.1	−0.1	5.5	4.0	7.0	6.9	9.5	9.2	9.0	0.0	−0.1	−0.1	−0.1	9.2
1901	9.8	9.2	8.8	10.8	4.9	10.1	11.2	13.8	8.2	6.9	11.1	−0.1	−0.1	−0.1	4.8	3.9	4.2	7.1	12.0	8.6	11.9	0.0	−0.1	−0.1	−0.1	8.1
1900	9.4	9.5	10.2	11.0	8.7	7.8	13.2	11.3	8.4	7.0	9.4	−0.1	−0.1	−0.1	5.6	5.1	5.2	7.0	9.7	10.5	10.1	0.0	−0.1	−0.1	−0.1	8.9
1899	10.5	11.7	8.6	11.0	6.2	9.9	12.8	14.2	8.0	6.7	9.8	−0.1	−0.1	−0.1	−0.1	5.2	5.2	6.9	8.6	11.0	8.4	0.0	−0.1	−0.1	−0.1	8.7
1898	11.4	8.8	9.2	11.9	6.8	8.0	12.6	13.9	7.4	7.2	8.0	−0.1	−0.1	−0.1	−0.1	4.4	5.3	7.0	8.7	9.7	8.8	0.0	−0.1	−0.1	−0.1	8.1
1897	9.6	9.0	6.4	10.7	7.1	10.0	12.6	12.5	10.0	7.4	8.7	−0.1	−0.1	−0.1	−0.1	5.2	5.4	7.8	7.8	10.3	11.3	0.0	−0.1	−0.1	−0.1	7.6
1896	11.3	8.1	6.8	10.2	6.8	8.6	11.9	13.0	8.7	6.8	9.7	−0.1	−0.1	−0.1	−0.1	5.6	5.5	9.8	10.0	11.1	10.4	0.0	−0.1	−0.1	−0.1	7.2
1895	8.8	10.0	9.3	12.3	8.0	9.6	14.5	11.8	10.0	7.8	9.2	−0.1	−0.1	−0.1	−0.1	5.2	6.3	8.8	12.3	−0.1	8.5	0.0	−0.1	−0.1	−0.1	10.4
1894	−0.1	9.8	9.2	10.0	7.9	7.8	12.4	13.2	9.0	8.4	8.9	−0.1	−0.1	−0.1	−0.1	4.8	5.3	6.8	11.2	−0.1	8.8	0.0	−0.1	−0.1	−0.1	10.7
1893	−0.1	10.9	10.1	10.2	6.2	11.0	14.3	13.9	8.1	7.4	8.7	−0.1	−0.1	−0.1	−0.1	4.9	5.3	8.5	10.9	−0.1	8.8	0.0	−0.1	−0.1	−0.1	11.8
1892	−0.1	−0.1	9.2	11.1	7.2	9.3	14.2	12.9	9.3	7.1	9.0	−0.1	−0.1	−0.1	−0.1	5.0	4.2	7.0	12.4	−0.1	9.6	0.0	−0.1	−0.1	−0.1	11.8
1891	−0.1	−0.1	10.3	10.6	7.8	8.9	14.6	14.0	9.8	6.5	8.6	−0.1	−0.1	−0.1	−0.1	7.3	6.0	7.0	13.8	−0.1	9.9	0.0	−0.1	−0.1	−0.1	8.2
1890	0.0	−0.1	10.0	11.0	7.5	12.6	14.2	14.2	7.0	7.4	9.0	−0.1	−0.1	−0.1	−0.1	6.8	8.7	7.2	15.4	−0.1	9.6	0.0	−0.1	−0.1	−0.1	7.8
1889	0.0	−0.1	12.5	13.4	8.7	10.0	15.4	13.7	9.2	6.4	10.0	−0.1	−0.1	−0.1	−0.1	7.8	6.7	7.0	13.0	−0.1	9.8	0.0	−0.1	−0.1	−0.1	9.2
1888	0.0	−0.1	11.4	10.8	6.8	9.8	13.7	15.5	10.3	7.6	10.3	−0.1	−0.1	−0.1	−0.1	6.9	4.9	11.5	9.6	−0.1	11.6	0.0	−0.1	−0.1	−0.1	9.9
1887	0.0	−0.1	8.4	11.0	6.8	10.2	10.2	13.0	9.8	6.4	9.8	−0.1	−0.1	−0.1	−0.1	4.0	6.5	9.3	10.4	−0.1	10.7	0.0	−0.1	−0.1	−0.1	11.3
1886	0.0	−0.1	10.2	9.5	8.3	9.9	11.8	12.0	10.4	6.7	8.3	−0.1	−0.1	−0.1	−0.1	6.0	5.7	7.9	7.6	−0.1	8.2	0.0	−0.1	−0.1	−0.1	8.1
1885	0.0	−0.1	12.5	10.0	6.2	10.5	12.3	14.4	9.8	7.9	10.4	−0.1	−0.1	−0.1	−0.1	4.2	7.5	6.7	8.5	−0.1	11.1	0.0	−0.1	−0.1	−0.1	7.4
1884	0.0	−0.1	11.3	12.3	6.5	10.2	11.7	11.5	10.8	7.4	9.1	−0.1	−0.1	−0.1	−0.1	3.9	6.2	9.8	11.9	−0.1	10.4	0.0	−0.1	−0.1	−0.1	7.9
1883	0.0	−0.1	10.3	10.7	7.5	11.8	12.8	14.3	9.6	7.7	8.7	−0.1	−0.1	−0.1	−0.1	5.7	5.9	7.9	6.9	−0.1	11.2	0.0	−0.1	−0.1	−0.1	7.1
1882	0.0	−0.1	12.9	10.1	7.2	8.7	14.1	13.0	9.4	6.6	9.5	−0.1	−0.1	−0.1	−0.1	3.3	6.9	8.2	3.9	−0.1	9.5	0.0	−0.1	−0.1	−0.1	8.0
1881	0.0	−0.1	11.4	11.5	4.7	12.2	14.8	13.6	10.7	7.0	10.2	−0.1	−0.1	−0.1	−0.1	4.6	5.2	6.8	5.6	−0.1	9.8	0.0	−0.1	−0.1	−0.1	9.2
1880	0.0	−0.1	9.3	11.2	2.8	−0.1	11.0	13.1	9.3	7.4	8.5	−0.1	−0.1	−0.1	−0.1	5.8	6.0	7.9	6.2	−0.1	13.0	0.0	−0.1	−0.1	−0.1	7.7
1879	0.0	−0.1	9.7	10.4	5.9	−0.1	10.0	11.1	6.6	4.6	8.6	−0.1	−0.1	−0.1	−0.1	5.8	4.7	6.5	7.0	−0.1	9.4	0.0	−0.1	−0.1	−0.1	7.1
1878	0.0	−0.1	5.1	8.4	5.3	−0.1	10.0	8.8	7.9	5.8	7.5	−0.1	−0.1	−0.1	−0.1	4.8	−0.1	6.0	5.5	−0.1	9.9	0.0	−0.1	−0.1	−0.1	6.1
1877	0.0	−0.1	5.3	8.9	5.6	−0.1	10.8	9.2	7.3	5.4	6.3	−0.1	−0.1	−0.1	−0.1	4.6	−0.1	6.5	6.7	−0.1	8.4	0.0	−0.1	−0.1	−0.1	8.3

Year	Core Number 1C	1D	1E	1F	3A	3B	4A	4B	4C	4E	4F	9A	9B	5F	5G	5H	5I	6A	6B	7A	7C	7D	7E	8E	8F	8G
1876	0.0	−0.1	6.0	9.4	6.5	−0.1	11.5	11.0	7.4	4.9	8.6	−0.1	−0.1	−0.1	−0.1	6.9	−0.1	8.2	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	6.8
1875	0.0	−0.1	9.7	10.1	7.4	−0.1	13.3	12.2	8.6	5.6	9.4	−0.1	−0.1	−0.1	−0.1	7.1	−0.1	8.4	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	6.8
1874	0.0	−0.1	11.3	10.0	8.6	−0.1	12.5	13.5	10.2	6.9	9.4	−0.1	−0.1	−0.1	−0.1	5.1	−0.1	8.0	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	11.2
1873	0.0	−0.1	9.3	12.4	5.7	−0.1	13.0	13.4	8.2	7.2	8.8	−0.1	−0.1	−0.1	−0.1	7.6	−0.1	8.5	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	9.4
1872	0.0	−0.1	−0.1	10.2	4.6	−0.1	8.9	13.3	7.5	7.6	10.2	−0.1	−0.1	−0.1	−0.1	7.0	−0.1	8.6	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	8.6
1871	0.0	−0.1	−0.1	8.3	6.8	−0.1	11.0	11.6	9.7	6.3	7.7	−0.1	−0.1	−0.1	−0.1	5.5	−0.1	10.5	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	7.3
1870	0.0	−0.1	−0.1	12.1	5.9	−0.1	12.6	9.2	7.4	8.5	8.9	−0.1	−0.1	−0.1	−0.1	4.8	−0.1	11.0	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	8.2
1869	0.0	−0.1	−0.1	10.6	4.8	−0.1	12.2	9.7	12.7	8.1	10.4	−0.1	−0.1	−0.1	−0.1	6.8	−0.1	8.4	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	7.3
1868	0.0	−0.1	−0.1	11.3	6.3	−0.1	11.1	13.4	10.0	8.0	9.6	−0.1	−0.1	−0.1	−0.1	6.0	−0.1	8.8	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	9.7
1867	0.0	−0.1	−0.1	8.6	5.3	−0.1	12.0	12.1	9.7	8.2	9.7	−0.1	−0.1	−0.1	−0.1	8.1	−0.1	8.7	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	7.5
1866	0.0	−0.1	−0.1	9.6	6.1	−0.1	10.6	13.3	7.5	8.0	10.4	−0.1	−0.1	−0.1	−0.1	8.0	−0.1	12.0	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	7.0
1865	0.0	−0.1	−0.1	12.3	4.0	−0.1	13.3	13.3	8.6	7.1	9.1	−0.1	−0.1	−0.1	−0.1	7.9	−0.1	8.6	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	7.4
1864	0.0	−0.1	−0.1	9.8	4.3	−0.1	11.6	12.7	12.1	8.9	9.0	−0.1	−0.1	−0.1	−0.1	5.3	−0.1	11.7	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	7.0
1863	0.0	−0.1	−0.1	8.8	7.1	−0.1	12.1	11.5	10.4	7.9	9.1	−0.1	−0.1	−0.1	−0.1	6.5	−0.1	6.9	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	9.0
1862	0.0	−0.1	−0.1	10.6	8.4	−0.1	13.3	14.5	11.6	8.8	9.8	−0.1	−0.1	−0.1	−0.1	7.8	−0.1	7.4	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	8.4
1861	0.0	−0.1	−0.1	8.8	9.9	−0.1	13.3	−0.1	13.6	8.5	10.3	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.4	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	5.9
1860	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	13.4	−0.1	9.7	10.0	11.8	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.7	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	8.8
1859	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	13.2	−0.1	8.0	8.2	9.6	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	6.4	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	−0.1
1858	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	12.5	−0.1	9.6	11.2	11.8	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.6	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	−0.1
1857	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	11.1	−0.1	10.2	8.3	10.4	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	6.3	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	−0.1
1856	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	12.5	−0.1	10.1	7.7	10.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	5.3	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	−0.1
1855	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	11.0	−0.1	11.9	8.5	8.4	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	8.0	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	−0.1
1854	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	11.5	−0.1	11.5	9.7	10.3	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.6	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	−0.1
1853	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	11.4	−0.1	12.5	9.1	11.7	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	8.3	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	−0.1
1852	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	12.3	−0.1	11.1	8.3	12.4	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	9.9	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	−0.1
1851	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	12.2	−0.1	12.3	8.0	13.6	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	9.3	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	−0.1
1850	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	12.1	−0.1	13.0	7.1	11.9	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	8.5	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	−0.1
1849	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	10.8	−0.1	11.7	8.4	9.5	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	6.9	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	−0.1
1848	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	12.2	−0.1	14.3	8.9	12.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.9	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	−0.1
1847	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	8.7	−0.1	10.3	10.1	12.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	11.4	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	−0.1
1846	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	8.5	−0.1	11.3	10.5	12.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	6.6	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	−0.1
1845	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	8.8	−0.1	11.0	7.8	12.8	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.8	−0.1	−0.1	−0.1	0.0	−0.1	−0.1	−0.1	−0.1
1844	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	9.3	−0.1	−0.1	7.3	12.7	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.2								
1843	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	13.1	−0.1	−0.1	6.7	11.9	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	5.8								
1842	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	11.9	−0.1	−0.1	7.4	12.8	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.0								
1841	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	10.4	−0.1	−0.1	8.3	14.5	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	8.1								
1840	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	7.9	−0.1	−0.1	10.2	11.9	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.0								
1839	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	11.8	−0.1	−0.1	7.6	13.4	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	6.8								
1838	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	10.3	−0.1	−0.1	7.5	12.7	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	8.4								
1837	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	8.0	−0.1	−0.1	6.8	12.3	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	6.9								
1836	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	10.2	−0.1	−0.1	6.1	11.3	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	8.4								
1835	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	10.3	−0.1	−0.1	8.0	11.6	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.6								
1834	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	11.2	−0.1	−0.1	9.5	13.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	8.5								
1833	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	8.7	−0.1	−0.1	7.9	15.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	9.2								
1832	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	7.6	−0.1	−0.1	8.7	11.7	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.7								
1831	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	7.9	−0.1	−0.1	10.0	13.7	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	9.3								
1830	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	8.4	−0.1	−0.1	8.8	13.4	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	10.3								
1829	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	8.0	13.6	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	10.4								
1828	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	8.6	14.6	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	10.6								
1827	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	8.1	12.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	8.4								
1826	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	8.3	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	8.2								
1825	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	6.8	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	8.9								
1824	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	8.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.0								
1823	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	8.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.0								
1822	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.8	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.4								

Appendix Table 1. Continued.

Appendix Table 1. Continued.

Year	Core Number 1C	1D	1E	1F	3A	3B	4A	4B	4C	4E	4F	9A	9B	5F	5G	5H	5I	6A	6B	7A	7C	7D	7E	8E	8F	8G
1821	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	8.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	10.4								
1820	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	9.6	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	10.8								
1819	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	9.6	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	9.2								
1818	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.8	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1								
1817	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.4	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1								
1816	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	7.9	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1								
1815	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	5.9	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1								
1814	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	9.7	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1								
1813	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	6.7	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1								
1812	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	6.3	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1								

Data continued below

Year	Core number 4E	4F	9A	9B	5F	5G	5H	5I	6A
1811	7.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1810	6.8	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1809	8.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1808	7.4	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1807	6.4	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1806	6.8	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1805	5.8	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1804	6.3	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1803	8.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1802	7.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1801	5.7	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1800	6.4	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1799	6.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1798	6.9	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1797	6.7	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1796	7.6	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1795	7.4	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1794	7.5	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1793	8.7	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1792	8.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1791	7.6	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1790	7.9	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1789	10.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1788	7.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1787	9.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1786	9.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1785	8.9	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1784	8.7	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1783	9.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1782	9.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1781	9.3	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1780	7.9	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1

Year	Core number 4E	4F	9A	9B	5F	5G	5H	5I	6A
1779	8.6	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1778	8.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1777	8.9	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1776	9.5	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1775	9.6	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1774	10.3	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1773	10.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1772	8.6	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1771	8.5	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1770	9.4	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1769	9.6	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1768	10.5	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1767	10.7	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1766	10.8	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1765	11.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1764	12.7	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1763	11.7	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1762	10.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1761	10.9	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1760	10.7	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1759	10.5	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1758	11.3	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1757	11.3	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1756	11.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1755	9.4	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1754	11.5	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1753	11.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1752	11.9	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1751	11.7	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1750	11.6	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1749	11.3	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1748	9.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1747	10.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1746	11.2	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
1745	11.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1