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Seasonality, Labor Organization, and Monumental Constructions: An Otolith Study from Florida's Crystal River Site (8CI1) and Roberts Island Shell Mound Complex (8CI40 and 41)

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Seasonality, Labor Organization, and Monumental Constructions: An Otolith Study from Florida's Crystal River Site (8CI1) and Roberts Island Shell Mound Complex (8CI40 and 41)

by

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ABSTRACT

In recent decades, archaeological research has provided evidence that some mounds in the southeastern United States were constructed in short episodes. A large work force would have been required to accomplish these monumental projects. Shell mounds, in particular, provide an opportune type of architecture to investigate whether seasonal aggregations of laborers gathered at sites to engage in large-scale work projects because these mounds are constructed of aquatic resources that leave signatures for what time of year they were caught or harvested. This study investigates whether the residents of the Crystal River site (8CI1) and Roberts Island (8CI40 and 41) on Florida's Gulf Coast were participating in seasonal deposition events involving the construction of monumental architecture and if feasting acted as a mechanism to attract the needed labor force. Marginal increment analysis is performed on red drum (*Sciaenops ocellatus*) and spotted seatrout (*Cynoscion nebulosus*) to determine what time of year these fishes were captured and eventually deposited in midden and mound contexts.

CHAPTER ONE: INTRODUCTION

Accustomed to dealing with long spans of time, archaeologists have traditionally understood the material remains they study are often the product of gradual accumulations of past activities. However, archaeological research has shown the construction of the two largest prehistoric earthen mounds in the southeastern United States, Mound A at Poverty Point during the Late Archaic period (Ortmann and Kidder 2013) and Monks Mound at Cahokia during the Mississippian period (Schilling 2013), took place in short episodes, rather than the formerly accepted notion of gradual stages of accumulation over a long period of time. Likewise, archaeologists have discovered similar episodic construction techniques for shell mounds along the Southeastern coast throughout prehistory (Sassaman and Randall 2012; Thompson et al. 2015; Wallis et al. 2015). In order to accomplish these architectural feats, these moundbuilders would have required the ability to organize and coordinate a large work force. However, questions remain as to what mechanisms were used by these early fisher-hunter-gatherer groups to assemble the people required to construct these pieces of monumental architecture.

While the intentionality of monumental construction can be apparent at some sites, detecting archaeological signatures for short, episodic construction and organizational elements of the labor force used to facilitate such construction can be elusive. Season of capture studies, which estimate the season of the year an animal was killed, are beginning to offer new lines of evidence that are aiding in the ability to identify intentionality of monumental shell mound construction and possible indications of seasonal aggregations, especially when complimented by well-dated stratigraphic construction sequences (Monks 1981; Pluckhahn et al. 2015a, 2015b; Thompson and Andrus 2011; Thompson and Worth 2011; Thompson et al. 2015). However, these studies have focused principally on invertebrate remains. While shell is an extremely beneficial material to use, it is costly to conduct stable isotope analysis on a significant sample size. Therefore, conducting season of capture analysis on fish remains not only offers an additional line of evidence for seasonal deposition patterns, but it also provides a vertebrate study that can be applied to sites that lack an invertebrate component.

My research examines context-specific temporal patterns of fish use at two Middle and Late Woodland period sites on Florida's west-central Gulf Coast, the Crystal River site (8CI1) and Roberts Island Shell Mound Complex (8CI36, 37, 39, 40, 41, and 576) (see Figure 1.1). The goal of this thesis project is to test if residents of Crystal River and Roberts Island, and possibly participants from afar, were engaging in seasonal deposition events involving the construction of monumental architecture at these sites. The primary hypothesis I tested to address this question is that seasonal deposition patterns differ between midden and mound contexts because the mound material was deposited in short term events at specific times of the year, as was suggested by previous studies of oyster samples (Sampson 2015; Thompson and Pluckhahn 2010; Thompson et al. 2015). To test this hypothesis, I conducted season of capture analysis using marginal increment analysis on red drum (*Sciaenops ocellatus*) and spotted seatrout (*Cynoscion nebulosus*) otoliths recovered during previous excavations from midden and mound contexts at both sites.

While establishing whether context-specific seasonal deposition events were taking place at these sites is interesting and sheds light on prehistoric behavioral and exploitation patterns, this portion of my study was unable to address the second goal of this research. Specifically, I sought to investigate what mechanisms drove the people to participate in village construction projects and continually engage in seasonal aggregation events at Crystal River and Roberts Island. I propose that various forms of feasting events were used to attract local and distanced peoples to the sites, provide the labor needed to accomplish monumental feats, and participate in seasonally based ceremonial activities. To support my claim that feasting was an integral mechanism, I rely on the extensive research that has been summarized and conducted through the Crystal River Early Village Project (CREVAP). I also use the theoretical framework on feasting and labor mobilization outlined by Michael Dietler and Ingrid Herbich (2001:240-264) to demonstrate how feasting events at Crystal River and Roberts Island could have been used to attract the required labor force.

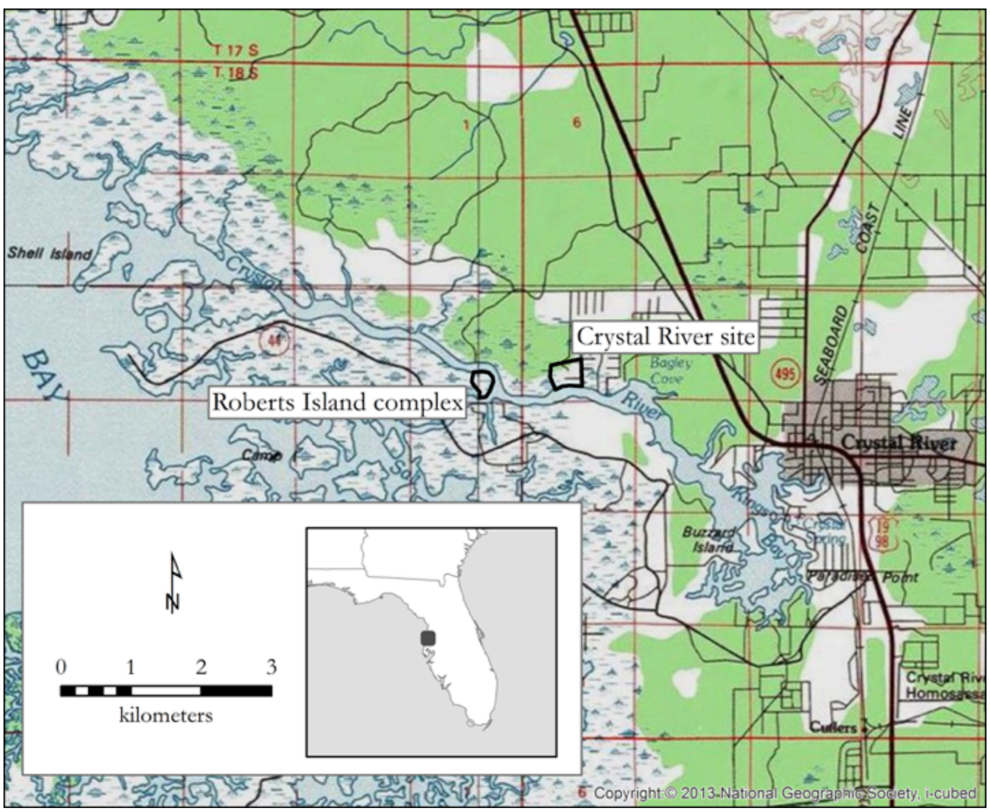

Figure 1.1. Map Showing Locations of Crystal River site (8CI1) and Roberts Shell Mound Complex (8CI40 and 41) (Map courtesy of Thomas J. Pluckhahn)

Prior to delving into the material, I now provide a brief synopsis for each chapter that follows this introduction. Chapter Two provides a brief summary of the archaeological sites, the research that has been conducted at each site, and the prehistoric environmental setting. Special attention is given to the chronological Bayesian model developed from CREVAP. This four-phase midden and five-phase mound construction model is used as the temporal framework for this study.

Chapter Three explores feasting. I begin by defining feasting and briefly discuss various types of feasts and the roles they play in society. Next, I offer an overview of Dietler and Herbich's (2001:240-264) theoretical framework on feasting and labor mobilization. As noted above, this framework is essential to addressing the secondary goal of this research that attempts to investigate what mechanisms were employed to organize the labor force needed to construct the various mounds at Crystal River and Roberts Island. Finally, I review literature that relates to feasting and mound building in the prehistoric Southeast. Knight (2001:311-333) has extended this perspective to implicate feasting in the emergence of platform mounds during the Middle Woodland period. Was feasting occurring at Crystal River and Roberts Island, and did it act as a mechanism to organize a voluntary labor force to construct monumental architecture? If mound construction was occurring in particular seasons, it implies shorter intervals and, by extension, the possibility that mound building was tied to feasting.

Chapter Four provides information on seasonality studies and otoliths. I begin with a brief discussion on the general application of seasonality research in archaeology and then give attention to the types of research commonly used by archaeologists in the southeastern United States to investigate seasonality through the analysis of aquatic resources (invertebrate and vertebrate). Next, I give a brief description of otoliths and modern applications of research. Then

I discuss common applications of otolith research in archaeology. Finally, I provide a literary review of otolith seasonality studies with emphasis placed on the various methods used to analyze otoliths, derive results, and form interpretations on seasonality patterns.

Chapter Five offers a detailed account of the methods used for this research. I briefly describe the field methods used by CREVAP to collect the material culture from Crystal River and Roberts Island. I also discuss in detail the various laboratory methods I used to sort, identify, and analyze the otoliths. Additionally, I provide habitat and life histories of the two fish species, red drum and spotted seatrout, used in this study. Further, I describe the types of statistical tests selected to explore the modern and archaeological otolith assemblages. To conclude this chapter, I discuss the methods that were used to develop the seasonality designations specific to this project.

Chapter Six reports all the data gleaned from my work in the laboratory and the results of the seasonality analysis. I begin by reporting the counts and identification of species from the archaeological otolith assemblages and the number of otoliths analyzed for this research. The chapter is then divided into two sections with each reporting the results of the red drum and spotted seatrout analyses. In each section, I report the results of the comparative analysis of the modern and archaeological assemblages and the results of the marginal increment analysis. I conclude by summarizing the seasonality results for each site and the phases of occupation.

Chapter Seven brings everything together and suggests new avenues of inquiry developed through this research. I discuss all the evidence to answer the research questions of this project. Were seasonal deposition events involving the construction of monumental architecture taking place at Crystal River and Roberts Island? The results of my study and the previous oyster study (Sampson 2015; Thompson and Pluckhahn 2010; Thompson et al. 2015) do indeed suggest that the construction of monumental architecture is tied to seasonal deposition events at these sites. Combined, evidence from both studies indicate spotted seatrout and oysters from mound contexts were harvested in cooler seasons while the same aquatic food remains from midden contexts seasonally varied, except during Phase 1 at Crystal River. However, the red drum seasonality results identify three otoliths from mound contexts at Roberts Island that indicated capture during warm times of the year, as well as six otoliths indicating capture during cooler months. Additionally, it is important to note that only a single spotted seatrout otolith indicating capture during the Cool Season from Mound A at Crystal River was added to existing evidence provided by the oyster study. Was feasting acting as a mechanism to organize the labor force needed to construct monumental architecture? While these sites lack the evidence Knight (2001:311-333) suggests for the tops of platform mounds serving as places to display feasting material, I present an argument based on the evidence from the seasonality studies that feasting did serve as a mechanism through collective work events (Dietler and Herbich 2001:240-258) that used communal consumption events to attract the needed labor force. Lastly, I offer direction on how to improve upon and expand otolith analyses in archaeological research, specifically in this region of the world.

CHAPTER TWO: BACKGROUND

The Sites

The Crystal River site and the Roberts Island Shell Mound Complex are located on the west-central peninsular Gulf Coast of Florida. The sites are slightly north of the small town of Crystal River in Citrus County, Florida. This region of peninsular Florida is part of the Gulf Coastal Lowlands, an area where the coastal swamps and terraces meet (Wolfe 1990:211). More specifically, this area of Florida is referred to as the Springs Coast. For additional environmental information pertaining to this area, see Pluckhahn and Thompson (2018:23-30) and Duke (2015:7-25) for extensive descriptions of the area's geology, ecology, and hydrology. Also, Jackson's (2016) study of the pollen record from Crystal River provides a detailed account of the plant remains and the human-environmental interaction that took place there and is summarized at the end of this chapter. His research also provides compelling evidence for prehistoric sea level oscillations in this region.

The Crystal River site makes up an 8-ha area and is situated roughly 4 km from the Gulf of Mexico. The site is situated on the north bank of the Crystal River, hence the site's name. The built landscape consists of at least two flat-topped ramped mounds (Mounds A and H), one burial mound (Mound G) and a burial complex comprised of several part (Mounds C-F), a comma-shaped midden, two small shell mounds (Mounds J and K), and a plaza (Pluckhahn et al. 2010) (see Figure 2.1).

Figure 2.1. Topographic Map of the Crystal River Site (Map courtesy of Thomas J. Pluckhahn)

Roberts Island, an anthropogenically constructed island, is positioned about one kilometer downstream from Crystal River. This site is located where the Salt River and Crystal River converge before emptying into the Gulf of Mexico. The Roberts Island complex consists of a 2-ha area with three platform mounds, a plaza, and extensive midden deposits (Pluckhahn et al. 2015a) (see Figure 2.2).

Figure 2.2. Topographic Map of Roberts Island Shell Mound Complex (Map courtesy of Thomas J. Pluckhahn)

Both sites sit at low elevations and are found on hydric hammocks (Pluckhahn and Thompson 2018:28). Additionally, they are both surrounded by wetland marshes and in close proximity to an abundance of estuarine resources. This variety and combination of exploitable ecosystems is indeed rare in this region. Milanich (1999:20) went as far as to say that the optimal location of Crystal River, and by extension Roberts Island, gave the inhabitants "an economic advantage over their neighbors." While the acknowledgement of prime prehistoric real estate is undoubtedly true, Pluckhahn and Thompson (2018:76-77) caution that Milanich's assertion oversimplifies the reasoning behind choosing this location. They also point to the emphasis placed on belief systems and ritual activity during the Middle Woodland period and how all would have impacted the decision to select this location for use. Further, when people first began transforming the land, Crystal River was a vacant ceremonial center where people came to bury the dead.

Early Archaeological Research

Crystal River has received extensive attention from the archaeological community beginning in 1903 when Clarence B. Moore conducted the first excavations (Pluckhahn et al. 2010). Moore's three excavation projects of 1903, 1906, and 1918 focused on unearthing burials located in the area of the site known as the Main Burial Complex (see Figure 2.1- Mounds C-F). Moore's excavations revealed an abundance of exotic artifacts made of cooper, meteoric iron, crystalline quartz, stone, and shell in association with the burials. This interesting assemblage suggests Crystal River is the most southern expression of involvement within the Hopewell Interaction Sphere, an archaeological tradition described by Pluckhahn and colleagues (2015a:2) as "a network of exchange and ceremony which connected distant communities across eastern North America."

Beginning in the 1930s, archaeologists debated the chronology of Crystal River based on the findings from Moore's research (Pluckhahn et al. 2010). The initial temporal confusion stemmed from poorly documented chronological sequences of artifact typologies and the built environment. Willey (1949:316-323) analyzed the ceramic assemblages from Moore's excavations and placed the occupation of Crystal River during both the Woodland and Mississippian periods.

Smith (1951) and Bullen (1951, 1953) disagreed with Willey's findings in part due to the site's platform mounds (Mounds A and H), a landscape feature which was then believed to be a hallmark of the later Mississippian archaeological time period (Pluckhahn et al. 2010). Smith conducted a series of small-scale excavations in the midden area, referred to as Area B, and in Mounds H, C, and E, as well as a surface collection on Mound A. Smith became confident in his chronological assertion of a Mississippian component at the site when he interpreted that part of the embankment of Mound C was constructed during the Late Weeden Island period. Bullen's work at Crystal River continued into the 1960s and focused on mapping the topography of the site and excavations were conducted in the midden area with the purpose of determining the number of periods the site was occupied. He also concluded that there were both Woodland and Mississippian components at the site.

During the 1950s, Bullen also visited and primarily collected cultural material from the surface at the Roberts Island Shell Mound Complex, formerly known as "Shell Mounds" (Weisman 1995b). The artifacts associated with this work are curated at the Florida Museum of Natural History. Bullen and Bullen (1961) published on the discoveries made at the site from their locally guided tour of the Crystal River area.

Over the next few decades, archaeological research at both Crystal River and Roberts Island decreased (Pluckhahn et al. 2010) but protection for the sites commenced. In 1962, the state of Florida acquired the land that the Crystal River site occupies, except for the land around Mound A and the lagoon which would eventually be acquired by the state following the area's development as a trailer park (Pluckhahn and Thompson 2018:35-40). In 1964, the state began clearing the site to create the Crystal River Archaeological State Park and museum we can visit today. The Crystal River site became a National Historic Landmark in 1990. Roberts Island, however, has yet to be placed on the National Register of Historic places despite its eligibility. The state of Florida has provided protection for the site by placing it within the Crystal River Preserve State Park.

Towards the end of the twentieth century and beginning of the twenty-first century, small research projects began again at these sites with some core sampling and salvage work in various areas of Crystal River (Ellis 2004, 2008; Glowacki 2002; Weisman 1992, 1995a; Wheeler 2001). These small projects revealed that portions of the site once believed destroyed were still intact. In 1995, Weisman and Newman conducted an archaeological survey of Roberts Island and reported on the archaeological significance of the site (Weisman 1995b). They determined that the site had great potential for archaeological research.

The Crystal River Early Village Project

In 2008, Thomas J. Pluckhahn, Victor D. Thompson, and Brent R. Weisman began the Crystal River Early Village Project (CREVAP), which started as a pilot study that included topographic and geophysical survey at Crystal River and Roberts Island (Pluckhahn and Thompson 2018:46). In 2010, they were awarded NSF funding to "examine the dynamic between cooperation and competition in the formation of early village societies" (Pluckhahn and Thompson 2018:47). Numerous publications have come from this research and are reported elsewhere (see Pluckhahn and Thompson 2018).

Below, I briefly summarize the research that my study is heavily based upon, including the five-phase mound building sequence (see Tables 2.1 and 2.2) (Pluckhahn and Thompson 2017), the four-phase midden construction sequence (see Table 2.3) (Pluckhahn and Thompson 2018; Pluckhahn et al. 2015b), the oyster seasonality study (Thompson et al. 2015), the research and analysis of the vertebrate and invertebrate assemblages (Compton 2014; Duke 2016; Little and Reitz 2015; Reitz and Brown 2015; Sampson 2015), and evidence to support feasting was taking place at these sites (Pluckhahn and Thompson 2018).

Table 2.1. Pluckhahn and Thompson's (2017) Bayesian Modeled Dates of Monumental Construction Phases at Crystal River and Roberts Island

	Time Period	Phase	Modeled Start			
			95%		68%	
Crystal River and Roberts Isand	Early Woodland	1	*1718 cal B.C.*	*876 cal B.C.*	*1263 cal B.C.*	*942 cal B.C.*
	Early/Middle Woodland	2	*743 cal B.C.*	*cal A.D. 150*	*258 cal B.C.*	*cal A.D 102*
	Middle Woodland	3	*cal A.D. 345*	*cal A.D. 534*	*cal A.D. 390*	*cal A.D. 480*
	Middle Woodland	4	*cal A.D. 486*	*cal A.D. 631*	*cal A.D. 532*	*cal A.D.607*
	Middle/Late Woodland	5	*cal A.D. 532*	*cal A.D. 1820*	*cal A.D. 604*	*cal A.D. 1056*

Table 2.2. Pluckhahn and Thompson's (2018:69) Bayesian Modeled Dates for Monumental Constructions at Crystal River and Roberts Island

Site	Mound	Construction Episodes	Mound Phase	Modeled Start				Modeled End			
				95%		68%		95%		68%	
Crystal River	A	1	3	*cal A.D. 357*	*cal A.D. 532*	*cal A.D. 398*	*cal A.D. 480*	*cal A.D. 394*	*cal A.D. 557*	*cal A.D. 437*	*cal A.D. 521*
		2	3	*cal A.D. 481*	*cal A.D. 548*	*cal A.D. 434*	*cal A.D. 579*	*cal A.D. 573*	*cal A.D. 920*	*cal A.D. 612*	*cal A.D. 739*
		3	5	*cal A.D. 578*	*cal A.D. 1756*	*cal A.D. 617*	*cal A.D. 940*	*cal A.D. 2548*		*cal A.D. 629*	*cal A.D. 1166*
	C	1	1	*2049 cal B.C.*	*899 cal B.C.*	*2043 cal B.C.*	*913 cal B.C.*	*772 cal B.C.*	*cal A.D. 478*	*766 cal B.C.*	*cal A.D. 471*
	E & F	1	1	*723 cal B.C.*	*cal A.D. 4*	*256 cal B.C.*	*42 cal B.C.*	*94 cal B.C.*	*cal A.D. 632*	*41 cal B.C.*	*cal A.D. 145*
	G	1	2	*483 cal B.C.*	*cal A.D. 222*	*80 cal B.C.*	*cal A.D. 125*	*cal A.D. 263*	*cal A.D. 1026*	*cal A.D. 372*	*cal A.D. 618*
	H	1	3	*cal A.D. 248*	*cal A.D. 526*	*cal A.D. 340*	*cal A.D. 475*	*cal A.D. 338*	*cal A.D. 524*	*cal A.D. 389*	*cal A.D. 495*
		2		*cal A.D. 403*	*cal A.D. 552*	*cal A.D. 425*	*cal A.D. 534*	*cal A.D. 426*	*cal A.D. 622*	*cal A.D. 451*	*cal A.D. 555*
	J	1	3	*cal A.D. 133*	*cal A.D. 634*	*cal A.D. 324*	*cal A.D. 628*	*cal A.D. 255*	*cal A.D. 646*	*cal A.D. 452*	*cal A.D. 634*
		2	4	*cal A.D. 426*	*cal A.D. 653*	*cal A.D. 561*	*cal A.D. 640*	*cal A.D. 558*	*cal A.D. 1013*	*cal A.D. 593*	*cal A.D. 688*
	K	1	3	*cal A.D. 280*	*cal A.D. 535*	*cal A.D. 335*	*cal A.D. 476*	*cal A.D. 331*	*cal A.D. 552*	*cal A.D. 390*	*cal A.D. 510*
		2	3	*cal A.D. 394*	*cal A.D. 569*	*cal A.D. 427*	*cal A.D. 541*	*cal A.D. 423*	*cal A.D. 721*	*cal A.D. 446*	*cal A.D. 566*
Roberts Island	A	1	5	*cal A.D. 791*	*cal A.D. 1115*	*cal A.D. 865*	*cal A.D. 1045*	*cal A.D. 925*	*cal A.D. 1168*	*cal A.D. 1046*	*cal A.D. 1168*
	B	1	5	*cal A.D. 1034*	*cal A.D. 1200*	*cal A.D. 1055*	*cal A.D. 1165*	*cal A.D. 1102*	*cal A.D. 1233*	*cal A.D. 1169*	*cal A.D. 1233*

Table 2.3. Pluckhahn and Thompson's (2018:68) Bayesian Modeled Dates for Midden Chronology at Crystal River and Roberts Island

Site	Time Period	Midden Phase	Modeled Start				Modeled End			
			95%		68%		95%		68%	
Crystal River and Roberts Island	Middle Woodland	1	*cal A.D. 69*	*cal A.D. 225*	*cal A.D. 125*	*cal A.D. 199*	*cal A.D. 144*	*cal A.D. 265*	*cal A.D. 180*	*cal A.D. 242*
	Middle Woodland	2	*cal A.D. 221*	*cal A.D. 321*	*cal A.D. 238*	*cal A.D. 292*	*cal A.D. 434*	*cal A.D. 544*	*cal A.D. 441*	*cal A.D. 499*
	Middle Woodland	3	*cal A.D. 478*	*cal A.D. 634*	*cal A.D. 521*	*cal A.D. 605*	*cal A.D. 663*	*cal A.D. 810*	*cal A.D. 671*	*cal A.D. 747*
	Late Woodland	4	*cal A.D. 723*	*cal A.D. 881*	*cal A.D. 779*	*cal A.D. 867*	*cal A.D. 891*	*cal A.D. 1060*	*cal A.D. 902*	*cal A.D. 982*

It is important to note that the phase-based mound and midden construction sequences were developed using Bayesian modeling techniques outlined by Bronk Ramsey (2009). The dates used to create these chronology models have been previously published (see Pluckhahn et al. 2015a, 2015b; Pluckhahn and Thompson 2017). In the discussion that follows, I use italics to distinguish modeled date ranges from reported conventional radiocarbon dates.

Mound Phase 1. Mound construction began at Crystal River between *1718 and 876 cal BC* (95%), likely between *1263 and 942 cal BC* (68%) (Pluckhahn and Thompson 2017). Figure 2.3 provides a depiction of the archaeological features from Mound Phase 1. Mound C, the circular embankment surrounding the Main Burial Complex, was the first architectural feature on the landscape. Moore (1903:379) describes it as standing 1.8 m high and 22.9 m wide and housing numerous burials with distinctive grave goods and interment patterning suggestive of varied cultural practices. Pluckhahn and Thompson's (2017) model suggests that construction of Mound C began between *2049 and 899 cal BC* (95%), probably between *2043 and 913 cal BC* (68%), and ended between *772 and 478 cal BC* (95%), likely between *766 and 471 cal BC* (68%). However, the researchers caution the model's preciseness on these chronological ranges due to the limited number and/or contamination from the marine reservoir effect of radiocarbon dates. Additionally, the ceramic analysis (Bullen 1965; Kemp 2015:53-57) preformed on this context's diverse assemblage showcases both early and late types and forms, including podal vessels and Weeden Island varieties respectively. Pluckhahn and Thompson (2018:79) believe, from limited radiocarbon dates, Mound G emerged as another burial area that was separated by a plaza from the Main Burial Complex. The model suggests construction of Mound G began between *483 cal BC and cal AD 222* (95%), likely between *80 cal BC and cal AD 125* (68%), and concluded between *cal AD 263 and 1026* (95%), probably between *cal AD 372 and 618* (68%). Interestingly, Mound G contained very few burial goods and none of the exotic Hopewellian types.

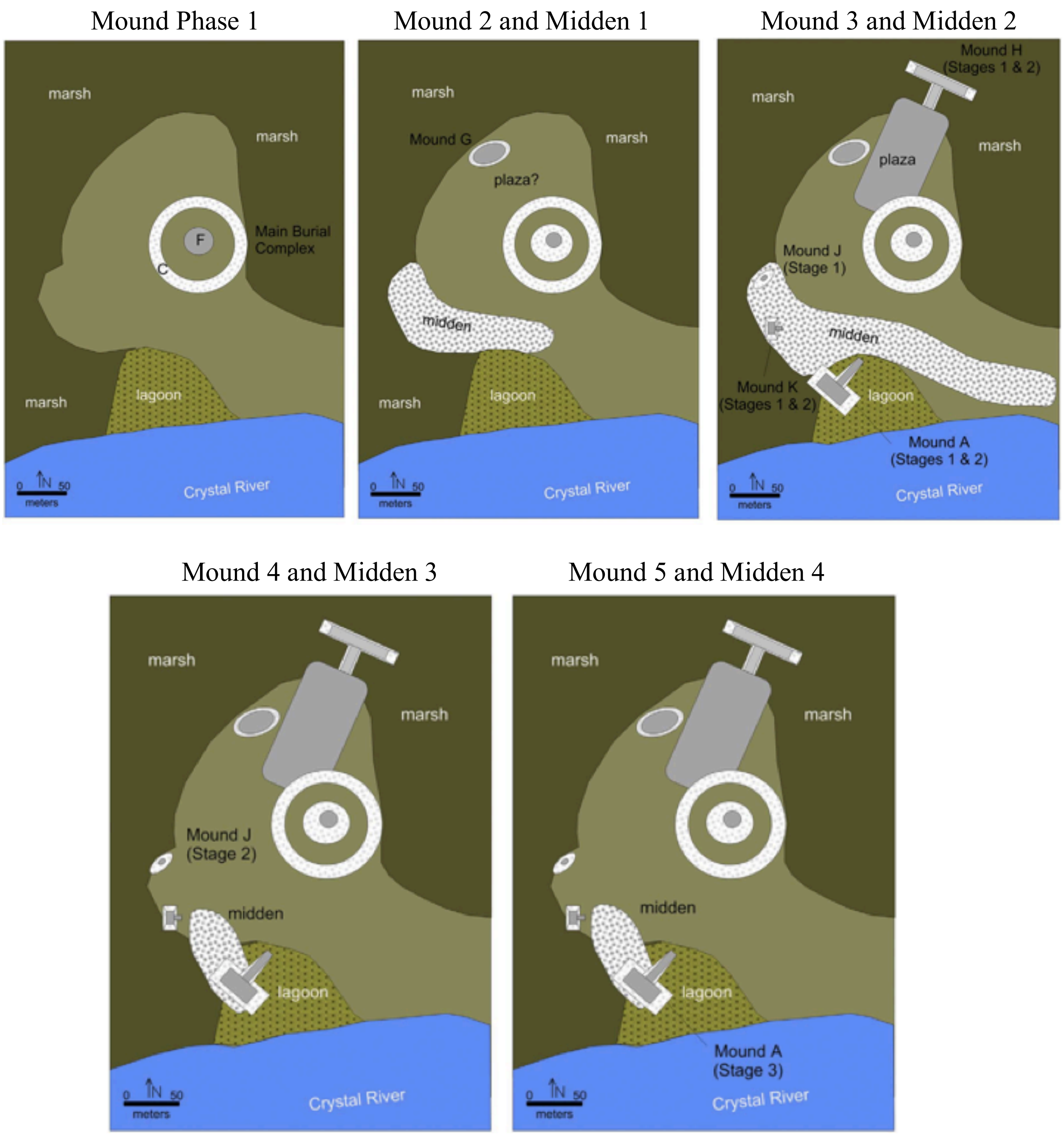

Figure 2.3. Mound and Midden Construction Phases at Crystal River (Map Adapted from Thompson and Pluckhahn 2017)

The next mound to appear on the landscape was Mound F, the central feature of the Main Burial Complex (Pluckhahn and Thompson 2017). Moore (1903:379) documented the dome-shaped construction as being 3.3 m high and 21.3 m at the base. Mound F, like Mound C, contained a varied assemblage of grave goods and burial treatments which lead researchers to draw a similar conclusion of extended use (Kemp 2015; Moore 1903:387-93). Pluckhahn and Thompson's (2017) model proposes that construction of Mound F commenced between *723 cal BC and cal AD 4* (95%), likely between *256 and 42 cal BC* (68%).

In sum, Pluckhahn and Thompson (2018:71-100) suggest from the evidence that during Mound Phase 1 Crystal River served as a vacant ceremonial center that engaged in an extensive northern network of interaction - The Hopewell Interaction Sphere. This assertion is evidenced by the absence of midden deposits dating to this period of site use and the exotic artifacts unearthed by Moore in the Main Burial Complex. Of note for this study, the researchers wonder what drove the people to congregate and invest labor in constructing and burying their dead in mounds at Crystal River. Pluckhahn and Thompson (2018:82-82) offer two possible reasons. First, the burial mounds served as territory markers, which have been suggested for other Hopewell sites and mounds. However, the researchers are reluctant to push this idea forward because it would stem from population pressure. Second, individuals began to garner power or leadership roles within the community or communities and were able to attract others willing to provide labor for large-scale construction projects like mounds. This idea has support from the exotic artifacts buried during this early period of site use. Pluckhahn and Thompson (2018:83) go on to state:

> monument construction at Crystal River was probably tied to communal feasting that involved copious quantities of oysters; along the base of Mound F, Moore

> (1903:382) noted a 'ledge of shell about 2 feet high and 20 feet broad' from the eastern margin to the center. This type of solidarity building through communal feasting, ceremony, and labor projects may have become particularly necessary when important people passed away, given that positions of leadership and other rights and responsibilities would need to be renegotiated.

This reason for site aggregation during the initial phase of site use will be tied into the discussion chapter of this thesis.

Mound Phase 2 and Midden Phase 1. The next wave of construction defined by Pluckhahn and Thompson's (2017) model of mound construction started between *743 and 150 cal BC* (95%), probably between *258 cal BC and cal AD 102* (68%). The earliest evidence of midden accumulation and village formation at Crystal River overlaps with this period of mound building. Pluckhahn and Thompson's (2018:102-103) midden model suggests accumulation began between *cal AD 69 and 125* (95%), but likely between *cal AD 125 and 199* (68%), and concluded between *cal AD 144 and 265* (95%), probably between *cal AD 180 and 242* (68%). The researchers describe the midden area during this phase as "an abbreviated version of its later crescent-shape, extending from the Mound J area at the north to the northern fringes of the lagoon" (Pluckhahn and Thompson 2018:103) (see Figure 2.3 for layout of Crystal River during Mound Phase 2 and Midden Phase 1).

The Phase 1 midden assemblage prompted Pluckhahn and Thompson (2018:101-116) to suggest Crystal River is first seasonally occupied by dispersed households and/or communities coming together at certain times of the year. This assertion is evidenced by fast midden accumulation of mainly food remains (Pluckhahn et al. 2015b), isotopic evidence from oyster shells in midden contexts that indicate being harvested in cooler months (Thompson et al. 2015), potters exhibiting differing communities of practice (Thompson 2016), varied burial practices suggesting change through time, different communities, and/or social differences (Pluckhahn and Thompson 2018:111-112), few features observed during excavations compared to later phases (Pluckhahn and Thompson 2018:101-102), and changes in the faunal assemblages (Little and Reitz 2015; Reitz and Brown 2015).

Of importance for this study, the analyzed faunal assemblage illustrates a preference for aquatic resources (Little and Reitz 2015; Reitz and Brown 2015) with a potential late phase shift that incorporated additional terrestrial animals. In total, 16,300 specimens were analyzed from Unit 1 (Little and Reitz 2015) and 4,440 vertebrate specimens were analyzed from Unit 5 (Reitz and Brown 2015). The Unit 1 assemblage contained an estimated 73 individuals, 32 of which are cartilaginous and bony fishes (Little and Reitz 2015). The most abundant fishes present are mullet (*Mugil* spp.), sheepshead (*Archosargus probatocephalus*), and common snappers (*Lutjanus* spp.). Interestingly, the entire faunal assemblage from Crystal River did not contain any mullet or common snapper otoliths and only had two sheepshead otoliths (see Figure 5.1 for complete list). The Unit 5 assemblage contained an estimated 26 individuals, 20 of which are aquatic animals (Reitz and Brown 2015). Mullet and sheepshead are the most abundant. This preference for aquatic resources and the numerous plummets found in the burial mounds suggests fish and fishing activities (mass capture through weirs and nets weighted done by plummets) played an integral part in feasting and ceremonial events.

Pluckhahn and Thompson (2018:112-116) deduce from the evidence unearthed from this phase of site use that Crystal River had shifted from a vacant ceremonial center to a place of seasonal aggregation at the beginning of this phase and then to an emergent sedentary village by the end of it. Additionally, they cautiously suggest a shift in the raw materials (from exotic to local) used to create the types of grave goods found associated with the burials in the mounds. This shift could be another sign indicative of local leaders emerging in the Crystal River community that had to negotiate new challenges as sedentism increased. Pluckhahn and Thompson (2018:116) believe “these challenges appear to have remained manageable mainly through the continued tradition of mortuary ceremonialism and feasting.”

Mound Phase 3 and Midden Phase 2. The constructed landscape of Crystal River and village activity changed dramatically during this period of occupation (see Figure 2.3 for site construction activity during Mound Phase 3 and Midden Phase 2). Pluckhahn and Thompson’s (2017) model proposes that mound construction began between *cal AD 345 and 534* (95%), probably between *cal AD 390 and 480* (68%), and concluded sometime between *cal AD 443 and 573* (95%), likely between *cal AD 476 and 550* (68%). Notably, the researchers’ model and evidence suggest that construction of all four platform mounds at the site commenced during this phase. The mounds appear to have been constructed in variety of episodes, with initial stages beginning with Mound K, followed by Mounds H, A, and J. Evidence also points to a second construction episode for Mounds K, H, and A occurring shortly thereafter. The labor that would have been required to undertake these monumental construction projects would have been considerable, especially considering the evidence that supports Mounds H and K were likely built in single episodes and the largest architectural feature in the village, Mound A, was likely built in three episodes (Pluckhahn and Thompson 2018:128-137).

Additionally, radiocarbon dates and ceramics from Mound G and the Main Burial Complex provide evidence that human interments not only continued during this phase but also carried on with previous traditions of differing burial practices between the Main Burial Complex and Mound G (Pluckhahn and Thompson 2018:126-127). These differences were exhibited by the scarcity of Weeden Island vessels in Mound G. Construction also occurred in the Main Burial Complex area with the addition of Mound E. However, there does appear to have been a shift in some burial practices, including the use of fully extended interments and secondary burials, oyster shells being placed over some burials, and large quantities of tools and adornment items made of shell. Of note for this study is the sheer volume of shell cups that were likely associated with ritual ceremonies and feasting events involving the consumption of the Black Drink.

The sizeable Phase 2 midden assemblage illustrates the marked increase in village activity, growth, and sedentism. Pluckhahn and Thompson's (2018:119-120) model suggests that midden accumulation began between *cal AD 221 and 321* (95%), probably between *cal AD 238 and 292* (68%), and ceased between *cal AD 434 and 544* (95%), likely between *cal AD 441 and 499* (68%). During this phase, the midden expanded to the extent that is observed at the park today.

A wealth of information regarding Phase 2 village life has come from the analysis of the collected midden material. Various research endeavors suggest rapid midden deposition (Pluckhahn et al. 2015b), year-round harvesting of oyster (Thompson et al. 2015), numerous features (Pluckhahn and Thompson 2018:121), the highest densities of stone and bone tools (O'Neal 2016:121-122), and ceramics with a unified crafting tradition (Pluckhahn and Thompson 2018:122) when compared to the other phases of occupation. Taken together, this evidence strongly supports Pluckhahn and Thompson's assertion that Crystal River was a permanent village.

The analyzed vertebrate faunal assemblage for Phase 2 provides insight into subsistence activities. Despite being limited to a single 1-x-1-meter unit (Unit 5, Trench 2), levels 2 – 10 date to this period of occupation (Reitz and Brown 2015). In total, 74,635 vertebrate specimens were analyzed with an estimated 324 individuals, 292 of which are aquatic. The hardhead catfish (*Ariopsis felis)*, mullet, and sheepshead species were identified in 12 of the 13 contexts. Mullet and sheepshead remain the most abundant fish species. Burning is the most common modification but noted as not being abundant within the overall assemblage. Reitz and Brown (2015:2) state that the "Phase 2 collection is moderately equitable in terms of both individuals and biomass, indicating that venison was but one source among many in a strategy strongly focused on fishes, particularly mullets." Duke's (2015:127) analysis of the Phase 2 invertebrate assemblage offers additional evidence for subsistence strategy that is heavily reliant on aquatic resources, specifically oyster.

Mound Phase 4 and Midden Phase 3. Following the construction boom of Phase 2, the inhabitants of Crystal River appear to have drastically decreased building projects (Pluckhahn and Thompson 2017). Pluckhahn and Thompson's (2018:161) research suggests that material was only added to Mound J and Mound A (see Figure 2.3 for site construction activity during Mound Phase 4 and Midden Phase 3). Their model proposes that Mound J's final construction episode occurred between *cal AD 426 and 653* (95%), likely between *cal AD 561 and 640* (68%) and Mound A is modeled to have dates between *cal AD 575 and 1758* (95%), likely between *cal AD 618 and 946* (68%). The completion of Mound A is a likely testament to the continued importance of activities, specifically potential ritual events, which took place at Crystal River during this terminal period of occupation. Pluckhahn and Thompson (2018:155) interpret from their research that people began moving away from Crystal River during this phase. However, it is important to note that activity at the site continued. A review of Moore's (1903) description of the burials and their associated goods in the Mound E platform and the circular embankment prompted Pluckhahn and Thompson (2018:160-161) to suggest that interments continued during this phase of occupation. Kemp's (2015) analysis of the ceramic assemblage associated with these contexts offers supporting evidence by noting specific Weeden Island types that are often associated with the Late Woodland period.

The Phase 3 midden assemblage at Crystal River also suggests a decrease in site activities (Pluckhahn et al. 2015b). Pluckhahn and Thompson's (2018:155) model suggests that midden material associated with Phase 3 was first deposited between *cal AD 478 and 634* (95%), likely between *cal AD 521 and 605* (68%), and concluded between *cal AD 663 and 810* (95%), probably between *cal AD 671 and 747* (68%). The midden assemblage is noticeably smaller than the preceding phases of occupation and is restricted to the area north of Mound A. Within this assemblage, there is a change in ceramic tempering (Thompson 2016) and a decreased midden deposition rate (Pluckhahn et al. 2015b). However, isotopic analysis of oyster provides evidence for a continuation of year-round occupation (Thompson et al. 2015). Unfortunately, analysis of the Phase 3 vertebrate faunal material has not been conducted so it is difficult to comment on the subsistence strategies at Crystal River.

As activity at Crystal River waned, Pluckhahn and Thompson (2018:156) found evidence that suggests activity at Roberts Island picked up. As depicted in Figure 2.4, the built environment on Roberts Island is not as grand or remotely comparable to that at Crystal River during this phase. Regardless of this comparison, early construction at Roberts Island is evidenced by a darker soil horizon found in several shovel tests between 70 – 100 cmbs that contained abundant artifacts but was sparse in shell (Pluckhahn et al. 2016). Their model suggests that midden accumulation began between *cal AD 521 and 605* (68%). Pluckhahn and colleagues (2015b) note that the midden deposition rate for Roberts Island suggests moderate accumulation that is comparable to that being deposited at Crystal River. Compton (2014) conducted faunal analysis on two shovel tests from Roberts Island. Unfortunately, Compton's analysis was conducted prior to the development of Pluckhahn and Thompson's phase-based model so the faunal assemblage was not separated into Phase 3 and 4. However, a brief review of the identified species suggests that subsistence activities emphasized an exploitation of aquatic resources.

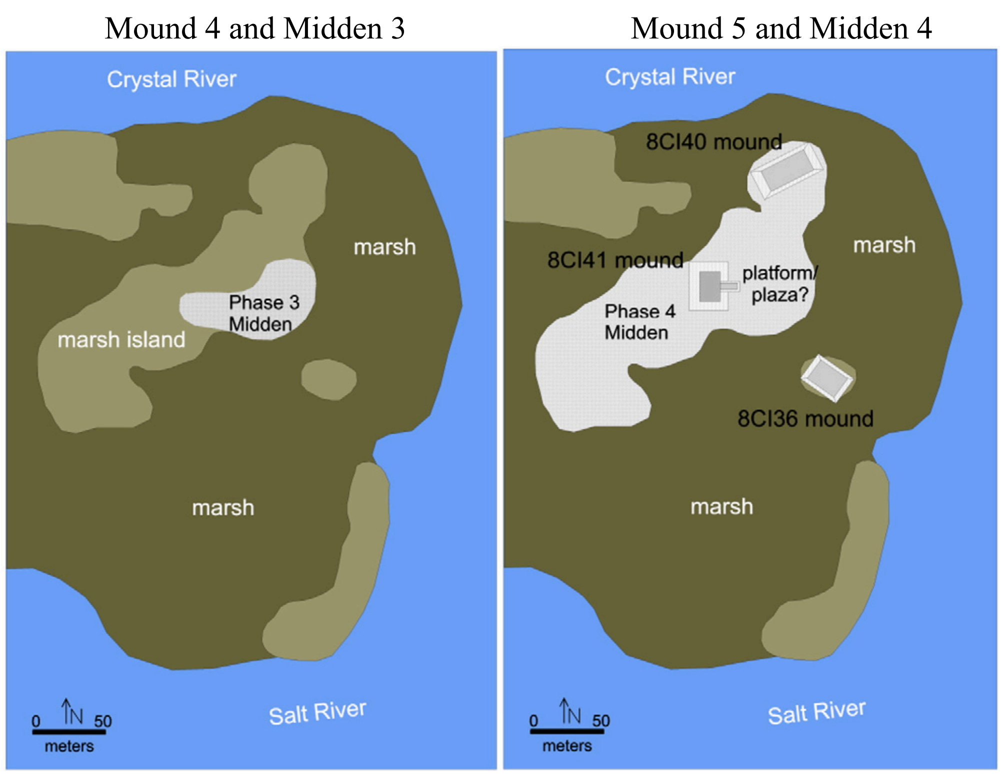

Figure 2.4. Mound and Midden Construction Phases at Roberts Island Shell Mound Complex (Map Adapted from Thompson et al. 2015)

Mound Phase 5 and Midden Phase 4. It appears that large-scale construction projects returned to the area during this period of occupation (Pluckhahn and Thompson 2018:175-204). At Crystal River, the Phase 4 midden assemblage suggests continued waning of occupation which is evidenced by a small area of slow accumulation to the north of Mound A (Pluckhahn et al. 2015b) and is illustrated in Figure 2.3. Pluckhahn and Thompson's (2018:169) model suggests that Phase 4 midden deposition at Crystal River and Roberts Island began between *cal AD 723 and 881* (95%), likely between *cal AD 779 and 867* (68%), and concluded between *cal AD 891 and 1060* (95%), likely between *cal AD 902 and 982* (68%). Pluckhahn and Thompson (2018:172) hypothesize that the Phase 4 occupation at Crystal River may have been from a "caretaker" household. However, the researchers admittedly believe this assertion may never be provable. Unfortunately, vertebrate faunal analysis has not been conducted on the material recovered from the Crystal River portion of the excavations for Phase 4, so it is impossible to accurately postulate about associated subsistence patterns.

During this period of occupation and construction, Roberts Island became the center of construction events (Pluckhahn and Thompson 2018:176-189). Pluckhahn and colleagues (2016) propose that Mound A, Mound B, and Mound C were built during this period (see Figure 2.4). Their model suggests that the construction of Mound A began between *cal AD 737 and 967* (68%) and ended between *cal AD 975 and 1231* (68%) and the construction of Mound B began between *cal AD 1025 and 1059* (25.8%) and *cal AD 1065 and 1155* (69.6%). Unfortunately, the limited testing and lack of dated material from Mound C have prevented the researchers from developing modeled construction dates.

The Roberts Island Phase 4 midden assemblage also suggests that activity increased (Pluckhahn and Thompson 2018:179-180). CREVAP shovel tests revealed a predominately oyster deposit measuring roughly one meter thick that blanketed around 1.7 hectares (4 acres) of the island. This midden deposit has a modeled start date between *cal AD 779 and 982* (68%) (Pluckhahn et al. 2015b). The midden ceramic assemblage backs the modeled date ranges with evidence of surface treatments that are indicative of the Late Woodland period (Thompson

2016:87). The Phase 4 faunal analyzed assemblages, vertebrate and invertebrate, for Roberts Island both suggest a diet that was heavily reliant of aquatic resources (Compton 2014; Duke 2015).

Crystal River and Roberts Island's Changing Climate and Environment

Interactions between humans and their environments are key to understanding and interrupting the material remains they left behind and the subsistence strategies they used to acquire edible resources. This section focuses on the climate and environmental data obtained through CREVAP, relying heavily on Jackson's (2016) research. I again use the chronological framework provided by Pluckhahn and Thompson's (2018:68-69) Mound and Midden Phases to discuss the evidence and changes that occurred while the people of Crystal River and Roberts Island interacted with their surroundings.

During Mound Phase 1 and Mound Phase 2 Midden Phase 1, the climate and environment along Florida's Gulf Coast changed with the onset of the Wulfert High transgressive sea-level period (Goodbred et al. 1998; Jackson 2016:98-100; Pluckhahn and Thompson 2018:74-75). This climatic shift included warmer temperatures, increased precipitation, and a rise in sea levels transformed the region and allowed for the environment to resemble the flora and fauna observed today. The development of brackish marshes and an estuary system with an abundance of exploitable resources likely aided in the ability for the peoples of Crystal River to make an easier transition from seasonal visits to the ceremonial/mortuary center to the establishment of their settled village life.

The botanical species identified by Jackson's (2016:99) archaeopalynology study indicates change from freshwater to brackish marsh plants and salt-tolerant tree species during the early phases at Crystal River. Jackson's analysis (2016:72-76) of pre-midden deposits indicates the area was full of freshwater-dependent and marsh taxa. The assemblage was dominated by false nettle (*Boehmeria cylindrical*), followed by cattail (*Typha* spp.), and, in much lesser quantities, *Eleocharis* spp., *Sagittaria* spp., *Saururus cernuus*, and *Cyperus* spp. The next deposited pre-midden zone identified in Jackson's study is a roughly 40 cm layer of sand that lacked a viable pollen assemblage to analyze. Jackson interprets this layer as an indication of at least one storm surge event. Following this large sand zone, Jackson identifies midden deposition that corresponds with Mound Phase 2 and Midden Phase 1. The arboreal assemblage consists of an abundance of *Palmae* phytoliths and pollen from Southern red cedar (*Juniperus silicicola*) and *Pinus* spp. The non-arboreal taxa are dominated again by false nettle and the non-arboreal obligate wetland taxa include a variety of oligohaline sedges and small amounts of cattail. Combined, Jackson interprets a shift from freshwater species to arboreal and non-arboreal species tolerant of higher salinity. This shift aligns with what can be expected during and following the Wulfert High sea level period.

The vertebrate faunal species identified by Little and Reitz (2015) and Reitz and Brown (2015) during Mound Phases 2 and 3 and Midden Phases 1 and 2 indicate a heavy reliance on aquatic resources many of which are found within estuary systems during at least some point in their life cycles, including mullet, red drum, spotted seatrout, sheepshead, common snappers, and hardhead catfish. Little and Reitz (2015:18) note "estuarine resources are subject to perturbations, especially as a result of large-scale environmental events." Thus, access to these fish species, as well as changes in growth rates, may be impacted by environmental and climatic changes. I will return to this point during my discussion in Chapter Five on the two species, red drum and spotted seatrout, used in this study.

During Mound Phase 3 and Midden Phase 2 at Crystal River, Jackson's (2016:76-77) research identifies a diverse assemblage of non-arboreal and non-arboreal obligate wetland taxa that indicate increased freshwater, a warm climate, and increased disturbance. The non-arboreal taxa include (in decreasing abundance) *Smilax* spp., goosefoot (*Amaranthaceae-Chenopodium*), American black nightshade (*Solanum americanum*), mustards (*Brassicaceae*), *Commelina* spp., and *Poaceae* grasses. The non-arboreal obligate wetland taxa include lizard's tail (*Saururus cernuus*) as the most abundant species, followed by pickerelweed (*Pontederia cordata*), a sedge species (*Rhychospora* spp.), and an arrowhead species (*Sagittaria* spp.). Additionally, Jackson identifies sponge spicules in this depositional layer and attributes their appearance to human activities.

The Mound Phase 4 and Midden Phase 3 assemblage suggests a change occurs in the area during this time, which corresponds with the Buck Key Low Stand observed in Southwest Florida and the wide-ranging Vandal Minimum climatic episode (Jackson 2016:80-83). The non-arboreal taxa are dominated by false nettle while the non-arboreal obligate wetland contains sedge species (*Cyperus* spp.), an arrowhead species (*Sagittaria* spp.), a variety of fern species, lizard's tail, and cattails. The arboreal assemblage is dominated by cedar but also includes wax myrtle (*Myrica cerifera*), coastal plain willow (*Salix caroliniana*), and pine. Jackson (2016:82) interprets that:

> the assemblage contains a clear oligohaline signature and suggests the local proliferation of transitional freshwater-oligohaline river-bank marshes (*Cyperus* spp*.*, *Typha* spp*.*, *Boehmeria c.*) with cedar, wax myrtle, oaks, and palms along the hammock-marsh interface. The abundant freshwater-dependent taxon in the

assemblage (e.g., *Sagittaria* spp., *Saururus c*., *Salix c*.) most likely represents the local presence of freshwater wetlands set back some distance from the river bank.

These changes in the type of species identified by Jackson align with a marked decrease in site activity at Crystal River and increased activity at Roberts Island. Pluckhahn and Thompson (2018:158-159) propose the movement away from Crystal River to Roberts Island could be related to the people wanting to stay in close proximity to a productive estuarine system. Delgado (2013) observed a decrease in oyster lengths in Midden Phases 3 and 4, which could be a result of the residents harvesting oysters earlier in their life cycles. Lulewicz and colleagues (2018) study on isotopes from oysters collected from the sites suggests collection of oysters in lower saline environments occurred during Midden Phases 1 and 2 (activity largely at Crystal River) and collection of oysters in higher saline environments occurred during Midden Phases 3 and 4 (activity largely at Roberts Island). Additionally, Duke and colleagues' (2020) comparison of the invertebrate and vertebrate assemblages through the midden phases at Crystal River and Roberts Island offers an additional line of evidence that subsistence strategies for aquatic resources changed. The researchers' analysis indicates the Roberts Island assemblage is less rich, less diverse, and less diverse than the Crystal River assemblage. Taken together, the combined evidence suggests changes occurred in numerous areas of the lives of the people that called this area home during Mound Phase 4 and Midden Phase 3.

Interestingly, during Mound Phase 5 and Midden Phase 4, some of the changes that occurred during the preceding phase continued on despite the return of warm temperatures, increased precipitation, and rising sea level that were brought on by the Medieval Warm Period and the La Costa High Stand (Jackson 2016:87; Pluckhahn and Thompson 2018:174). Jackson's (2016:86-94) study reveals a return of the non-arboreal and obligate wetland species that are tolerant of variations in temperature and precipitation. He notes a small but diverse arboreal assemblage, including *Palmae* phytoliths, Southern red cedar, oak, coastal plain willow, pine, and red mulberry. The non-arboreal assemblage is abundant with false nettle pollen and smaller amounts of *Commelina* spp., *Smilax* spp., and Asters. The non-arboreal obligate wetland assemblage, however, contains a variety of species, including different types of sedges (*Eleocharis* spp., *Cyperus* spp., and *Rhynchospora* spp.), an arrowhead species, lizard's tail, American white water-lily (*Nymphea odorata*), and a variety of fern species. Jackson interprets from these assemblages due to the high frequency of sedge species and a small arboreal assemblage that the wetlands near Crystal River "experienced substantial tidal influence in the tenth and perhaps eleventh centuries A.D.; however, the abundance of freshwater-dependent marsh plants… suggest that brackish water only rarely penetrated the wetlands lying landward of the midden ridge" (2016:91).

It is interesting to note that despite the return of favorable climate conditions during Mound Phase 5 and Midden Phase 4, the subsistence strategies for estuarine resources did not return to more a diversified assemblage. In fact, Duke and colleagues (2020) found there is an increased reliance on invertebrates, especially oyster, and a decrease in quantities of vertebrates at Roberts Island compared to Crystal River. Even fish are less represented in terms of biomass and MNI (minimum number of individuals).

Another noteworthy line of evidence that warrants discussion here is Jackson's (2016:121-124) account on the botanical species not identified during his analysis. Jackson found no evidence to support a high reliance on *Amaranthaceae-Chenopodium* given the moderate number of pollen grains found in the assemblages. Also, Jackson found no pollen for several species that are included in the old eastern agricultural complex, including squash

(*Cucurbita pepo*), pepper (*Capsicum* spp.), and papaya (*Carica papaya*). However, Jackson does note that phytolith and macrobotanical analysis may reveal the presence of these species at Crystal River. There are two other notable plant species, maize (*Zea* mays) and yaupon holly (*Ilex vomitoria*), that were absent from the Crystal River pollen record. Jackson asserts that if maize had been growing in abundance in the area or even brought in through exchange or trade there would most likely have been pollen deposited. The absence of yaupon holly, the plant used to make ritually important and famous 'Black Drink' is very surprising, especially given the presence of shell cups unearthed by Moore during his excavations in the Main Burial Complex and the belief that Crystal River served as a regional civic ceremonial center.

CHAPTER THREE: FEASTING AND LABOR FRAMEWORK

Like many areas of anthropological and archaeological study, feasts have been afforded varying degrees of investigation and interpretation. The body of literature pertaining to this subject is indeed as grand as the events themselves. A brief overview of feasting research is provided to assist with "setting the table" for the more detailed discussion of the literature that pertains specifically to this research. Since the goal of this chapter is to provide the framework to address if feasting was a mechanism used to organize the labor force needed to construct monumental architecture at Crystal River and Roberts Island, I focus this discussion on selected research specific to this question.

Setting the Table

In the early 2000s, Michael Dietler and Brian Hayden (2001) were at the forefront of a push for archaeologists to start developing new and innovative ways of approaching, identifying, and interpreting feasts in the archaeological record. One of the most essential steps is to define the term. Hayden (2001:28) proposed "a feast be defined as any sharing between two or more people of special foods (i.e., foods not generally served at daily meals) in a meal for a special purpose or occasion." Dietler (2001:67) states a feast is "a form of public ritual centered around the communal consumption of food and drink." While both definitions are applicable to this research, the importance and inclusion of communal consumption, sharing of foods, special occasions, and rituals are essential for addressing the role feasting played at Crystal River and Roberts Island.

Archaeologists find it necessary to categorize the things we study. Feasts are no exception. Hayden (2001:38) provides a list of ten ways to categorize feasts:

1. symbolic content;
2. inferred functions (types of practical benefits);
3. size;
4. goals creating social bonds vs. achievement of more immediate, limited objectives;
5. the use prestige materials or other archaeological indicators;
6. participating, or core, social units;
7. horizontal vs. vertical social relationships between guests and host;
8. the kind of reciprocity involved;
9. the degree of obligation (social necessity vs. self-inflicted hosting);
10. seasonal or calendrical occurrences vs. life or economic conditions.

Hayden's list of the various components that can be categorized for feasting events succinctly conveys the vast field of study and the types of social, spiritual, economic, and political impacts these events may contain.

It has been documented throughout the world that feasts have served a variety of purposes throughout prehistory and history. Hastorf (2017:195) lists the numerous goals that be accomplished through feasting events, including:

> increasing group solidarity, payments of debts, collection of tribute, recalling past glories, amassing surplus labor, promoting prestige, displaying opulence, soliciting allies, frightening enemies, equilibrating and exchanging valuables, seeking marriage partners, celebrating a life passage, arbitrating disputes, maintaining social control, making peace, instigating war, communicating with the deities, and honoring the dead.

Of importance for this research is the inclusion of amassing surplus labor. However, the other purposes for feasts may have also been used at Crystal River and Roberts Island as well.

Collective Work Events and Woodland Period Mounds

An often-overlooked question in archaeology is who were the laborers who constructed monumental architecture and what motivated them to do so? Dietler and Herbich (2001:240) postulate that:

> The use of feasts to mobilize collective labor has been a widespread and fundamental economic practice of societies around the world. In fact, variants of the practice are so strikingly omnipresent in the ethnographic and historical literature that a good case can be made for acknowledging it both as virtually a universal feature among agrarian societies (e.g., see Erasmus 1956; Moore 1975; Uchendu 1970) and as nearly the exclusive means of mobilizing large voluntary work projects before the spread of the monetary economy and the capitalist commoditization of labor and creation of a wage labor market.

Dietler and Herbich (2001:241-246) also go on to "propose a model of 'collective work events' that serves as a basis for understanding both the 'conversion' functions of feasts and their potential for exploitation." Figure 3.1 outlines the continuum of these collective work events.

Work Exchange		Work Feast
+ + +	Labor Reciprocity Obligations	-
-	Temporal Finality of Exchange Transaction	+ + +
-	Lavishness of Hospitality	+ + +
-	Size of Work Group	+ + +
-	Social Distance of Labor Recruitment	+ + +
-	Potential for Exploitation	+ + +

Figure 3.1. Adapted Figure of Dietler and Herbich's (2001:242) Continuum for Collective Work Events

The researchers do not view or want these types of collective work events (CWEs) to be seen as opposing binary categories. Instead, they view these work event types as a continuum. Thus, the type and/or size of the project determines where on this continuum a work event will fall. Work exchange events rely on reciprocal relationships and are limited in the number of people they are able to mobilize. These events require little exchange of food or drink but carry the weight of the labor being returned at a later date. On the other end of the spectrum are work feasts "an event in which a group of people are called together to work on a specific project for a day (or more) and, in return, are treated to food and/or drink, after the host owns the proceeds of the day's labor" (2001:241). These types of feasts do not have a reciprocal component. The only requirement is that hosts treat the laborers to lavish amounts of food and/or beverage. They suggest these events can attract a diverse and very large group of people because "it is the scale of the hospitality- the copiousness and quality of the drink and food provided (and the reputation of the host for providing these in abundance) that draws people to participate rather than close social relationships" (2001:243). Further "work feasts were, and are, used to perform a wide variety of tasks for which the sheer multiplication of hands either allows a project to be done in a short space of time or enables a project that could not be undertaken otherwise" (2001:247).

So what evidence is there from sites in my study region and time period that directly tie feasting and mound activities during the Woodland period? Knight's (2001: 311-328) study on Woodland period platform mounds suggests the summits were used to display the grandeur of dried meats in the days leading up to feasting events. He asserts that feasting events were an integral means for alliance building by bringing together groups of people at specific times of the year. Knight's evidence to support his claim for feasting at these inland Woodland civic ceremonial centers with platform mounds is based on evidence of numerous postholes and post insertion ramps on the summits of mounds at numerous sites, including Kolomoki, McKeithen, Walling, Cold Springs, and Garden Creek. It is possible then that following a major construction project the host village would display an abundance of food atop these new constructions and invite participants to indulge themselves as compensation for their labor. Unfortunately, apart from Bullen's work, which is poorly documented, no excavations have been conducted on the summits of the mounds at Crystal River and Roberts Island. However, geophysical survey by Pluckhahn and Thompson on the surface of Mound H at Crystal River revealed no anomalies suggestive of features, although it seems likely that the presence of a dense shell deposit near the surface of the mound would have impeded the resolution of smaller anomalies (Thompson and Pluckhahn 2010).

Likely the best study to corroborate a connection between feasting and mound construction is Hyde and Wallis' (2020) seasonality study of faunal remains from mound and midden contexts at Garden Patch (8DI4), a Middle and Late Woodland civic ceremonial center on Florida's northern peninsular Gulf Coast. Hyde and Wallis begin by offering examples from around the world of feasting events that are tied to the construction of monumental architecture, including Hayden (2009), Iriarte and colleagues (2008), and Wallis and Blessing (2015). The researchers also note their support for Knight's (2001) assertion for feasting atop inland Woodland sites as a means of alliancing building. They also support the notion that these events were inclusive rather than exclusive given the lack of evidence during this period for "individual aggrandizement or political advancement" (Hyde and Wallis 2020:2). The results of their study offer multiple lines of evidence to support feasting events occurred in cooler seasons and primary deposition of this material occurred on one of the platform mounds at the site. The first line of evidence comes from a previous isotope study of oysters from mound contexts that contained signatures for harvesting during cooler months (Lulewicz et al. 2020). Second, Hyde and Wallis' (2020) analysis of faunal material unearthed from Mound II at the site consists mostly of primary deposits, which they argue is evidenced by the abundance of the toadfish (*Opsanus sp*.) and certain identified bird species that are not present in midden contexts. Third, many of the avian remains identified from Mound II are migratory and only present in this region during the cooler months of the year. Lastly, by combining the faunal evidence and radiocarbon assays from this mound, they suggest the entire construction of Mound II took place early in the site's history.

Both of these studies offer useful and powerful lines of evidence to support a connection between feasting events/remains and mound contexts at Middle Woodland civic ceremonial centers. They also both suggest that these events would have occurred at certain times of the year, and the Garden Patch study provides direct evidence that mirrors the results from Thompson and colleagues' (2015) study of oyster of winter harvest from Crystal River and Roberts Island mound contexts. However, these researchers suggest social ties and alliances were the mechanisms that brought the people together to take on these monumental construction projects. While I agree alliances likely played a significant role in daily and ritual activities at these sites, I do wonder and question whether they alone would have been able to gather the number of people needed to construct monuments found at some of these Middle Woodland centers (e.g., Mound A at Kolomoki and Mound A at Crystal River). Thus, I put forward the idea of Dietler and Herbich's (2001) work feasts/exchange continuum as a means for a village to attract a large enough group of outside participants to assist with these very large-scale projects. Additionally, I too agree with the current lack of evidence for individual political powers of authority as noted by Hyde and Wallis. However, Dietler and Herbich do not specifically state that having an individual political leader is a requirement for these collective work events. I envision these communal consumption events as an undertaking of the entire village, especially since it would have required the effort of many villagers to gather the resources to put on these elaborate events.

Collective Work Events Model Applied to Crystal River and Roberts Island

Dietler and Herbich's model (2001) has the potential to explain how the people of Crystal River and Roberts Island were able to attract the number of people needed to build the numerous large mounds located at these sites. According to their model, these collective work events would have relied on previously established alliances to recruit people from other villages and communities to come participate and the ability to host lavish communal consumption events. There is ample evidence of connections to other communities at Crystal River, including participation in Hopewell Interaction Sphere (Pluckhahn and Thompson 2018:71-100), regional trade of crafted shell ornaments and tools (Pluckhahn and Thompson 2018:148-149), and a study of skeletal remains from Crystal River suggest biological connections to the Yellow Bluffs mound site in South Florida (Kles 2013). Unfortunately, evidence for connections between Roberts Island and other communities are less evident. However, the case can be made that previous connections and alliances formed at Crystal River likely carried over to the residents of Roberts Island.

There is also growing evidence to support that feasting events were held at these sites and were linked to the construction of the monumental architecture. First, the results of Thompson and colleagues' (2015) oyster study showed oysters from mound contexts were collected in cooler months and deposited in mound contexts at both sites. Second, the results of Lulewicz and colleagues' (2018) oyster study showed oysters from mound contexts at Roberts Island were collected from higher saline contexts verses lower saline contexts that were deposited in midden areas. This result suggests certain oyster beds were restricted from harvesting for everyday consumption and only exploited for consumption that involved activities associated with the mounds, possibly adding ritual significance not only to the oyster but the shell too. Another possibility is that the restricted access to these oyster beds served as a means of developing a surplus of oysters so the community could more easily supply large-scale communal feasting events with food and construction materials.

Oysters were undoubtedly a major component of these feasts but certainly not the only source of protein. Fishes, terrestrial mammals, and birds were also likely key dishes served at these events. Drying and smoking were likely utilized as a way to preserve and prepare these resources for feasting events. However, I have also wondered if the lagoons at Crystal River and Roberts Island served as holding areas for fishes and as another way to accumulate a large surplus of foodstuffs for large-scale events. I believe the more lines of evidence that are discovered further strengthen the assertion that communal consumption events were taking place in cooler months and involved the construction of monumental architecture at Crystal River and Roberts Island. Thus, providing an additional fishy line (pun intended) of evidence from this study will bolster the validity of this claim.

CHAPTER 4: SEASONALITY STUDIES AND OTOLITHS

Archaeologists worldwide have long used seasonality studies to investigate inquiries about the past. Monks (1981) outlines the rationale for conducting seasonality studies, discusses the various methods used for estimating seasonality, and offers a tentative framework for this type of research. Despite being written more than three decades ago, Monks' summation of seasonality research continues to offer beneficial insight into these studies.

In the southeastern United States, archaeologists use seasonality studies to investigate a range of topics through a variety of analytical approaches. To illustrate this wide application, the following studies offer examples from all known pre-Columbian cultural periods in this region: Paleoindian site occupation and subsistence economies (Walker et. al 2001), Archaic period intentionality of monumental constructions (Colaninno 2012), Woodland period short-term mound events (Blitz et al. 2014) and Mississippian period ritual and feasting activities (Yerkes 2005).

While reviewing pertinent regional literature on analytical approaches for aquatic resources, three trends are apparent. First, numerous Southeastern archaeologists have used seasonality to address research questions pertaining to pre-Columbian coastal dwellers (see Colaninno 2012; Hadden 2015; Harke 2012; Thompson and Worth 2011; Reitz et al. 2013). Second, the preferred ecofacts to analyze are invertebrates (see Andrus 2012; Keene 2012; Quitmyer and Jones 2012). Third, isotopic analysis is the most popular analytical technique (see Cannarozzi 2012; Jones et al. 2012; Thompson et al. 2015). These trends are important because they inform other researchers on the applicability and the success of applied approaches and often suggest ideas and/or areas of research that need additional testing. For example, Andrus (2012:123-133) offers a review of invertebrate season of capture studies and calls for archaeologists to continue investigating the previously studied species and to expand to other species as well. In doing so, Andrus argues that additional research offers further lines of evidence, which build on each other and strengthen the interpretations.

In recent years, invertebrate seasonality studies have undoubtedly contributed to our understanding of pre-Columbian societies in the southeastern United States. However, fish remains have received considerably less attention, despite some species having seasonal migratory patterns that can be used to infer seasonality information and/or several skeletal elements (otoliths, scales, operculum, cleithrum, vertebrae, and fin spines) that can also be analyzed to determine seasonal information (Colley 2015; Monks 1981).

Since season of capture research on otoliths is the focus of this study, the remaining sections of this chapter will focus on otoliths. I begin by briefly discussing the biological makeup and physiology of otoliths and their modern applications. Then, I provide a review on the previous uses of otoliths in archaeological season of capture research with emphasis on studies conducted in the southeastern United States when applicable.

What are Otoliths and Their Modern Uses?

Otoliths, commonly referred to as earstones, are paired calcium carbonate structures located in the dorsal portion of the inner ear in teleost fishes and are used for hearing and balance (Campana 1999; VanderKooy 2009). These structures "are crystalline in nature and are built up and outward around a primordium/core region by the process of biomineralization, where calcium carbonate, mainly in the form of aragonite, is precipitated on a protein matrix of otolin"

(VanderKooy 2009:2-2). This process of biomineralization occurs daily (Pannella 1971; Peacock et al. 2016). It begins during the larval stage of development and continues till death. The deposited otolin is rarely reabsorbed or chemically altered during a fish's lifespan. Generally, the otolin layers that are deposited in cooler months, when growth is slower, are referred to as the opaque growth zone and/or annuli, while the layers that are deposited in warmer months, when growth is more rapid, are called the hyaline or translucent growth zone (VanderKooy 2009:2-2). Together, the successive opaque and hyaline growth zones are known as the annual growth zone and represent one year of growth. However, it is important to note that the deposition of the first annulus can differ between species and is not always deposited one year after hatching (see Murphy and Taylor 1990, 1991, 1994).

Fishes have three paired otoliths, including the sagitta, the asteriscus, and the lapillus (VanderKooy 2009). The sagittae are frequently the largest making them the most frequently used otoliths for fisheries science and archaeological studies (Andrus and Crowe 2002; VanderKooy 2009). In general, fish that live offshore tend to have smaller otoliths because they rely more on vision than sound, whereas nearshore species have larger otoliths because they depend more heavily on hearing due to the turbid water they frequent. Additionally, otoliths have distinctive morphological characteristics that enable identification to the species level, thus, making them extremely useful to archaeologists (Colley 1990).

Modern otoliths are commonly used in fisheries and marine science to investigate a variety of topics. Campana (2005) summarizes the relatively recent trends that are being used by researchers. These trends include microstructure analysis, annual age and growth studies, age validation and method assessments, population studies, fish hearing and balance research, allometric analysis of otoliths, identification of species, tracer and mass marking studies, trace element analysis, isotope research, environmental reconstructions, fossilized otoliths, general methods, and otolith physiology. Indeed, otoliths are contributing a wealth of knowledge to researchers interested in modern fishes and their environments.

Otoliths and Archaeology

Otoliths from archaeological contexts offer researchers with an abundance of data that can be used to address a variety of questions about past peoples and their environmental settings. Disspain and colleagues (2016) succinctly summarize the methods, applications, and technological advances associated with otoliths in archaeological studies and offer a perspective on the future of this type of research. They identify six areas of otolith research that have been used by archaeologists at sites spanning the globe. These areas of research include species identification, fish size, age structure, trace element analysis, isotope analysis, and edge increment analysis (Disspain et al. 2016:623). For each of these areas, Disspain and colleagues provide an overview of the methods, discuss methodological limitations, and offer examples of studies. This brief, yet thorough, summation of archaeological otolith research will hopefully encourage others to analyze fish earstones from more archaeofaunal assemblages.

During a review of pertinent regional literature, I observed that southeastern U.S. archaeologists have carried out investigations, albeit on a small scale, using all six areas of otolith research outlined by Disspain and colleagues (2016). In several instances, researchers use a combination of these areas to infer seasonal information about past fishing strategies, including Baker and Klippel (2008, 2009), Hadden (2015), and Reitz and colleagues (2012, 2013). Their use of combined approaches come as little surprise, since multiple lines of evidence only strengthen interpretations especially when attempting to determine season of capture for species found within archaeological assemblages.

Otolith Season of Capture Research

So, what exactly are season of capture studies? Season of capture, also referred to as season of death, is a type of research that uses incremental skeletal elements of animals to determine what time of year an animal died (Andrus and Crowe 2000; Casteel 1976:146-174; Monk 1981; Van Neer et al. 2004; Wheeler and Jones 1989:154-161). This approach enables archaeologists to make inferences about past hunting, harvesting, and fishing strategies. Researchers can also infer from season of capture information about when sites were being occupied, seasonally or year-round, and, possibly, when specific ancient events were taking place, like feasts.

External Otolith Analysis. One of the fundamental aspects of conducting zooarchaeological research is to determine the original body size of specimens in faunal assemblages. Often, researchers turn to allometric regressions to accomplish this task (Hadden 2015; Jackson et al. 2018; Reitz and Wing 2008:186-187; Wheeler and Jones 1989:139-148). Otoliths provide archaeologists with an ideal skeletal element to conduct size regression analysis (Gauldie 1988). Numerous otolith regression studies have been conducted and it has become common practice for southeastern U.S. zooarchaeologists to record otolith length, breadth, and width (see Baker and Klippel 2008). By conducting otolith regression analysis on modern otoliths with known body sizes, archaeologists can infer the original body size of the fishes in the assemblage and assign them to age cohorts. These age cohorts enable researchers to explore behavioral trends of identified species and investigate modern information for seasonal trends.

Hadden's (2015) research on pre-Columbian coastal subsistence practices of the northern Gulf Coast is the only study that just uses the external structure of otoliths to infer seasonality information. She uses otolith regression analysis to extrapolate fish sizes from measured dimensions of red drum recovered from Harrison Ring Midden (8BY1359) and Hare Hammock Ring Midden (8BY1347). Hadden was able to infer age from the estimated fish sizes and place the fishes into age cohorts. Her analysis suggests that two juvenile red drum are present in the Harrison Ring Midden assemblage and one young-of-year red drum is present in the Hare Hammock Ring Midden assemblage. Hadden deduces that the fishes from Harrison were likely caught during the spring, while the one at Hare Hammock was probably captured during late summer. Her seasonality predictions are based on the spawning season of red drum for the western coast of Florida, which takes place in September and October. Hadden acknowledges that her small sample size makes her interpretations tentative. However, she also analyzed numerous other species through a variety of other techniques to draw her overall interpretation of seasonality for these sites.

Hadden's (2015) approach illustrates that even a rather simple technique, measurements of otoliths in archaeofaunal assemblages, can produce meaningful information about past fishing strategies. This research also draws attention to two important caveats to consider when conducting seasonality studies. First, sample sizes of both archaeological and modern collections influence the reliability of the interpretations. Second, base knowledge about the species being studied is essential.

Internal Otolith Analysis. As noted earlier, the internal structures of otoliths provide archaeologists with a wealth of potential information. The first grouping of methods of otolith analysis is what I refer to as edge type analysis. There are two forms of research method: edge increment analysis and marginal increment analysis. These approaches have overlap but should be discussed independently since each method has advantages and limitations.

Edge increment analysis involves identifying the type of marginal edge, either hyaline or opaque, present on a cross-sectioned otolith (Disspain et al. 2016). In doing so, researchers can infer from comparisons to modern specimens, with known seasonal correlates, the season of capture for otoliths from archaeofaunal assemblages. This type of analysis is almost always paired with another analytical approach that provides data on fish age, length, and/or growth. Edge increment analysis is the most frequently used method to examine season of capture from archaeological otoliths.

Van Neer and colleagues (1999) examine otoliths and vertebrae of plaice (*Pleuronectes platessa*) from a 15th century site in Raversijde, Belgium to investigate these fishes' age structure, season of capture, and growth rate from a single depositional event context. Their goal was to compare the seasonality results between fish vertebrae and otoliths to see if similarities are apparent. Van Neer and colleagues took external measurement of the otoliths and vertebrae, aged the internal structures of the otoliths, recorded the type of edge (hyaline or opaque), and estimated fish lengths. The research shows that analysis of plaice vertebrae and otoliths provide similar results on age distributions, season of capture, and growth rates.

Higham and Horn's (2000) research on red cod (*Pseudophycis bachus*) otoliths compares seasonality information gathered through analyses discussed in the paper, including isotope seasonality data from blue mussels (*Mytilus edulis aoteanus*) that were recovered from the same archaeological context at a site in New Zealand at the mouth of the Shag River. The edge increment approach utilized in this study differs slightly from the previously discussed study by Van Neer and Colleagues (1999). Higham and Horn (2000) assign descriptive categories for the types of edges found on the otolith margins, for example a spring otolith had a "narrow-light" edge. These edge results were compared with edge results from 500 modern samples collected over a year period to determine season of capture. In doing so, the researchers found that seasonality results for both the red cod and blue mussels, which was determined through stable isotope analysis during a previous study, suggested agreement in Higham and Horn's interpretation of spring capture for the two species.

Andrews and colleagues (2003) conduct a season of capture study on a variety of species found along U.S. California coast to assess the reliability of edge increment analysis. The researchers conducted a controlled experiment to see if a reader could accurately classify season of capture from modern otoliths with known capture dates. They found that accurate determinations occurred only 32% of the time. Additionally, Andrews and colleagues noted ageing was not possible for 16% of the otoliths and assignment of edge type occurred for 74% of the otoliths. The authors criticize the subjectivity of the edge increment analysis and argue that extreme caution should be used when attempting this research.

Scartascini and colleagues (2015) examine whitemouth croaker (*Micropogonias furnieri*) otoliths to determine season of capture for specimens recovered from surface finds at various archaeological sites along the San Matias gulf coast of Argentina. The researchers use an extensive modern comparative collection to establish edge type seasonal patterns and find that opaque growth is only present September through February. Scartascini and colleagues perform poisson regression analysis and a general linear analysis on the modern edge types. From these statistical analyses, they were able to create a model for assigning season of capture: autumn and winter months have 100% hyaline, spring months have 10% opaque, and summer months have 70% opaque. Using this model, Scartascini and colleagues assessed the archaeological otoliths and found that 79% had opaque edges and 21% had hyaline edges. Scartascini and colleagues interpret from their analysis that whitemouth croaker were fished during the warmer months, primarily between November and January.

Baker and Klippel (2008) incorporated fairly extensive otolith analysis in their report of Phase III work that was conducted at the Plash Island site in Baldwin County, Alabama. The researchers use size regression analysis on modern otoliths of eight different species identified in the assemblage, including hardhead catfish (n=47), gafftopsail catfish (*Bagre marinus*) (n=44), Atlantic croaker (*Micropogonias undulates*) (n=64), sand seatrout (*Cynoscion arenarius*) (n=20), and spotted seatrout (n=39), to calculate body size. They were able to estimate the total length, fork length, standard length, and weight (g) for the archaeofaunal fishes by conducting this analysis and examine changes between the Middle Woodland, Late Woodland, and Mississippian components of the site. Additionally, Baker and Klippel took cross sections of numerous Atlantic croaker and spotted seatrout otoliths to examine their internal structure. Unfortunately, time constraints restricted their ability to analyze all the cross sections. However, they were able to analyze some and report on the observed margins and annuli. The researchers found that the Atlantic croaker from the Middle Woodland component of the site were around the age of one, but no seasonality information was inferred. The spotted seatrout otolith assemblage consisted of individuals ranging between two and five years of age and, based on a study from Galveston Bay, Texas, Baker and Klippel suggest the majority of these fishes were captured during early spring because annuli were observed on or near the margin. Furthermore, these researchers compared growth rates of the Atlantic croaker with a small sample of modern otoliths. Baker and Klippel (2008:282) note that the archaeological specimens appear to have "much more spaced growth lines than a sample of five sectioned modern otoliths." They infer from this observation that potential harvesting pressures could be the culprits of this phenomenon.

The studies discussed above that use the edge increment analysis provide very useful information and cautions about this analytical technique. Van Neer and colleagues (1999) study illustrates how multiple lines of evidence from multiple species analyzed through different techniques can be used to help substantiate seasonality interpretations. However, this study did not use a modern comparative collection to determine seasonality, which is problematic and decreases the reliability of the study. Higham and Horn's (2000) research provides useful insight into the benefits of creating classifications for the edge types and comparing the edge type observations with large modern comparative collections. Andrew and colleagues (2003) cautionary study emphasizes the difficulties of edge increment analysis and the subjectivity of the results. However, it is important to note several concerns I observed with their analysis, including lack of adequate reference collections and/or publications with established marginal edge type information and the use of "assumptions…made based on the general seasonal growth patterns observed in otoliths" (Andrews et al. 2003:72). Scartascini and colleagues (2015) demonstrate the benefits of conducting statistical analyses to formulate models for modern otolith datasets to assist with classification of seasonal information for archaeological specimens. Additionally, their research, again, shows the advantages of having large modern reference collections. Lastly, Baker and Klippel's (2008) study on otoliths from the Alabama Gulf Coast provides extremely valuable information for my research since there is overlap between the species they investigate. Their research is the only study I have found in the southeastern United States that incorporates edge increment analysis on archaeological otoliths. Baker and Klippel noted that some of the otolith margins were difficult to assign edge types, which they attribute to taphonomic issues. This observation is significant because it restricts a researcher's ability to determine whether a hyaline of opaque margin is present. There are a few concerns with the study, including seasonal estimations for the spotted seatrout are based on modern specimens with an unknown sample size from Texas and the sample size for the size regression analysis is somewhat small for the species. In summation, edge increment analysis provides archaeologists with a useful tool to interpret season of capture information from archaeofaunal assemblages, but the limitations and difficulties associated with this technique must be considered.

Marginal increment analysis, the method used in my study, entails measuring the outer most growth band of a cross-sectioned otolith and making comparisons to modern specimens with known seasonal correlates to infer seasonal information. Unfortunately, this approach has not received nearly as much attention as the previously discussed edge increment analysis or the forthcoming discussion on otolith isotope analysis. I was only able to locate one archaeological study that incorporates this approach, despite modern fisheries research that suggests it is the most reliable age validation method (see Geffen 1992 [for overall validation]; see Bedee et al. 2003, Hoff and Fuiman 1993, Murphy and Taylor 1990, 1991, 1994, and Powell and Laban 2000 [for validation of species in this study]).

Van Neer and colleagues (2004) return to their research on otoliths excavated from a 15th century fishing village site in Raversijde, Belgium. This study includes multiple analyses on plaice and haddock (*Melanogrammus aeglefinus*) recovered from multi-depositional contexts and a single-event deposit. Van Neer and colleagues strengthened the validity of this study by using a very large modern comparative collection that included specimens collected over a two-year period from two locations, the Central North Sea and the Eastern Channel. The researchers determined the edge increment types for 4595 plaice and 1297 haddock. They observed that both edge types could be found on plaice otoliths in every month of the year, although at differing frequencies. Additionally, Van Neer and colleagues observed differences between collection locations and between years. Furthermore, they noted differences in age cohorts with younger fish commencing rapid growth zones (hyaline) earlier than adults. Van Neer and colleagues (2004:462) surmise that "only crude seasonality estimates may be conducted using the H/O [hyaline/opaque] ration and they will always be unreliable." Their results from the edge increment analysis of the modern haddock are similar to the plaice.

Van Neer and colleagues (2004) also use marginal increment analysis to examine monthly marginal widths of modern plaice to investigate whether seasonality information can be derived from this approach. They measure 387 fishes collected over a two-year period and measure the distance between the annuli. The researchers calculate and report the mean monthly width for individuals with the third and fourth annuli closest to the margin. The number of specimens averaged for each month varies between 6 and 26 for fishes with three annuli and varies between 4 and 15 for fishes with four annuli. From this analysis, Van Neer and Colleagues (2004:465) conclude the "marginal increment measurement corresponds to practically all months of the year." Additionally, they observe differences between the growth rates (expressed by annuli widths) of the modern and archaeological plaice otoliths. This observation of faster growth in the modern specimens has been attributed to over exploitation and harvesting pressures of fishes, which was also noted by Baker and Klippel's (2008) examination of Atlantic croaker. While this assertion of differing growth patterns offers important information to modern fisheries, it causes an added bias to an already complicated analytical approach.

Van Neer and colleagues (2004:466) offer "[a]n alternative approach is to express the observed marginal increments as a function of another measurement from the same otolith sample. This could reduce the variation linked with many of the factors described above." The researchers attempted this technique by comparing the widths of the marginal and preceding growth zones. Van Neer and colleagues perform regression analysis on the second and third growth bands and on the fourth and fifth growth bands and find no significant correlation between either dataset. Thus, the researchers basically conclude that this alternative approach has more uncertainty than the marginal increment analysis.

Van Neer and colleagues (2004) provide a third approach to produce meaningful seasonality data from the marginal increment widths. The researchers propose that distributions of absolute values could produce meaningful results with caution of variation still present in yearly and geographic differences. They suggest that single deposition events, like pit features, should produce a unimodal distribution. Additionally, Van Neer and colleagues postulate that archaeological otoliths from multi-depositional contexts that span long periods of time should have distributions with multiple peaks. Thus, the researchers hypothesize that the shape of the distribution could offer reliable seasonality data. Van Neer and colleagues (2004:466) go on to state "[a]s a second step, and in the case of a unimodal distribution of marginal increments, it is possible to compare the position of the mean or modus with that of the distribution of complete increments for the same full growth ring." The researchers apply this technique to the single-event assemblage of plaice from the medieval fishing village. Their findings suggest that the fishes were caught at the beginning of the growing season, an assertion based on the placement of the distribution with respect to the mean widths of the corresponding annuli. However, Van Neer and colleagues are concerned that the inter-annual growth rate will have an impact on the results and interpretation.

Van Neer and colleagues (2004) offer one more approach to try and elicit meaningful information from the marginal width data. They suggest comparing the marginal increment distributions with distributions of corresponding complete rings. For example, the fifth complete growth zone should be compared with fifth marginal growth zone. The researchers apply this technique to the single-event assemblage and the multi-depositional contexts. They find, again, that the single event assemblage suggests season of capture occurred at the beginning of the growing season. Similarly, the other site-wide assemblage suggests the majority of fishes were also caught during the beginning of the growing season but smaller quantities representing other seasons were identified as well. To further validate these results, Van Neer and colleagues (2004) randomly selected 13 otoliths for isotope analysis from all analyzed assemblages. The results support the interpretation of specimens being caught at the beginning of the growing season and assign a late winter/early spring designation. Given the positive results of this approach, I implemented a similar strategy to produce meaningful data for this study.

Van Neer and colleagues (2004) conclude that producing reliable results and accurate inferences regarding season of capture is dependent on what time of year people were exploiting fishes of the same species in large numbers, the sample size of study assemblage, and the context of specimens being analyzed. They contend that single deposition event contexts will produce the most reliable interpretations and/or repeated seasonal events. Additionally, Van Neer and colleagues believe that the best estimates for seasonality occur when season of capture results correspond with the fast growth period.

Van Neer and colleagues' (2004) study of medieval fishing patterns provides a comprehensive analysis of not only the assemblages they are studying but also of the analytical techniques they are using to infer season of capture information. However, two observations are noteworthy. First, the sample size of modern plaice for the marginal increment was low given they had analyzed 4595 for the edge increment analysis. They eliminated 91.5% of the specimens that were readily available for marginal increment analysis. Additionally, there was not a single month with a sample size of 30 and only 25% of the months had sample sizes of 15 or more. Van Neer and colleagues acknowledge the use of a larger modern comparative collection could improve the reference curve but immediately doubted the likelihood of that occurring. Second, the researchers often made broad sweeping statements about the various approaches that were attempted. They stated the edge increment analysis only produces crude estimates and the marginal increment analysis yields indeterminate results of all months for a single specimen. Based on the results from this study, it is true that some of these approaches were not successful at reliably identifying season of capture for plaice and haddock. However, this does not mean these approaches will not work for other species. Overall, Van Neer and colleagues' (2004) research on plaice and haddock otoliths provides a thorough investigation of marginal increment analysis. The variety of ways the researchers analyzed the data offers multiple techniques for extracting meaningful information about seasonality.

The third internal otolith analysis is stable isotope analysis. Briefly, this analysis is possible because fish precipitate their otoliths in oxygen isotope equilibrium with the surrounding habitat water (Andrus and Crowe 2002; Devereux 1967). In doing so, the otolith oxygen isotope composition is influenced by temperature, salinity, and the isotopic makeup of the surrounding water (Colaninno 2012; Disspain et al 2016; Wang et al. 2013). Temperature has been found to have the most impact on the isotopes because as temperature increases the uptake in $\delta^{18}O$ decreases in otoliths. However, salinity fluctuations also influence otolith oxygen isotope composition. Thus, results can at times be difficult to interpret for fishes given their movement between areas and age cohorts. For the best results, ontological histories are created for each analyzed specimen by tracking the changes of $\delta^{18}O$ over the course of the life.

This well-established method has been used in numerous archaeological studies, some of which are discussed below, and modern studies (see Campana 1999, 2004, 2005 [for general overview], Dorval 2007 [for spotted seatrout], Rooker et al. 2010 [for red drum]). Since similar processes are undertaken when conducting stable isotope analysis and the method is well known, the discussion of otolith studies below focuses attention on the results derived from this approach and any notable limitations and/or cautions that are observed.

Before delving into the case study literature on archaeological otoliths and stable isotope analysis, it is important to discuss a study that has serious implications for this type of research. Andrus and Crowe (2002) investigated the impact prehistoric cooking methods have on otolith chemistry through a variety of controlled experiments. The researchers removed one otolith from the fishes' head for their control sample and then performed a variety of cooking techniques on the fish carcass and its remaining otolith, including direct placement on the fire, roasting over coals, roasting in an oven, boiling in seawater, and boiling in fresh water. Once cooking methods were carried out, Andrus and Crowe conducted visual inspections of the otoliths to determine whether the treated otoliths showed evidence of the applied cooking procedure. They found that only the otoliths that were directly exposed to an open fire showed indications of heat treatment. Andrus and Crowe then performed stable isotope analysis on the control samples and the "cooked" samples. The analysis revealed archaeological otoliths that exhibit burning, external discoloration and chalky appearance, have experienced internal alterations. These alterations include crystallization of the aragonite structure transforming it into calcite and changes in the $\delta^{13}C$ and $\delta^{18}O$. Andrus and Crowe conclude that discolored and chalky otoliths should not be used in archaeological studies that are attempting to ascertain information through stable isotope analysis.

Reitz and colleagues (2009) used stable isotope analysis of $\delta^{18}O$ on sea catfish (*Galeichthys peruvianus*) otoliths from Peru to investigate ancient fishing strategies. One of the research goals was to determine whether people were living at two coastal sites, Ostra and Sitio Siches, seasonally or year-round. By investigating site seasonality for these Early and Middle Preceramic Period sites, the researchers were able to better determine the antiquity of the Peruvian fishing economy and the impact from anthropogenic influences on marine resources. Reitz and colleagues conducted stable isotope analysis on a total of 11 specimens, consisting of sea catfish otoliths and cockle valves (*Trachycardium procerum*). The results of the study suggested year-round occupation occurred at both sites. In establishing season of occupation, the researchers were able to offer additional insight into the long-term exploitation of marine resources that has been occurring in Peru for thousands of years. Additionally, Reitz and colleagues were able to make interpretations on differences between the modern and ancient climates from their isotope analyses. The researchers noted that the data from Ostra suggest annual temperature is comparable to that experienced today. However, the data also suggest that the range in temperature is larger. At Sitio Siches, the data show similarity between modern and ancient annual temperatures and temperature ranges. In summation, Reitz and colleagues deduced from their study that the emphasis of aquatic resource exploitation to support a sedentary subsistence economy along the Peruvian coast goes back thousands and thousands of years but no recorded evidence indicates harvesting pressures paralleled to the scale of the past century.

Hufthammer and colleagues (2010) used stable isotope analysis to explore settlement patterns and mobility at two Mesolithic sites in Norway through the examination of cod (*Gadus morhua*) otoliths. The researchers hypothesize that the mobile inhabitants had short-term camps that were seasonally occupied. To investigate this assumption, Hufthammer and colleagues conducted a season of capture study on otoliths recovered from sites they presume are examples of seasonal occupations. The high $\delta^{18}O$ results suggest the cod from both sites were caught when waters were at or near the coldest temperatures of the year, late winter/early spring. Hufthammer and colleagues conclude that the Skipshelleren rock-shelter and Skoklefald sites were occupied in late winter/early spring suggesting seasonal occupation but that the latter site also contains species highly abundant during summer and autumn.

Moving to the southeastern U.S., Colaninno's (2012) study uses stable isotope analysis to determine season of capture from modern and pre-Columbian hardhead catfish and Atlantic croaker otoliths. The analyzed archaeological otoliths are from four Late Archaic Period shell rings on modern day St. Catherines Island and St. Simons Island, Georgia. Colaninno is investigating whether these shell rings were intentional constructions of monumental architecture or gradual accumulations of everyday refuse. Additionally, her research focuses on the applicability of using these fish species to assess season of capture.

Colaninno's (2012) thorough study illustrates the complexity of analyzing fish otoliths, especially those from fishes that frequent estuarine environments off the Georgia coast. She finds through ontological examination of $\delta^{18}O$ that 75% of the modern hardhead catfish otoliths accurately predict season of capture, compared with 83% of the modern Atlantic croaker otoliths. Colaninno uses Andrus and Crowe's (2008) yearly average of $\delta^{18}O_{water}$ from the modern waters of St. Catherines Island and Grossman and Ku's (1986) aragonite precipitation equation to calculate temperature from the $\delta^{18}O_{otolith}$. She interprets that the archaeological otoliths suggest year-round occupation at three of the shell ring sites and data from one shell ring are inconclusive. Colaninno deduces from her research that the shell rings were constructed from gradual accumulations of everyday refuse. This assertion corresponds with other seasonality interpretations from these sites (see Reitz et al. 2012, Thompson and Worth 2011).

Before moving on, Colaninno's study (2012) offers perspective on limitations and other analytical techniques for identifying season of capture from otoliths. She notes Shackleton's (1973) observation that older specimens often lack incremental growth bands that are wide enough for accurate isotopic testing. Colaninno hypothesizes that some of the samples used in her study did not have wide enough marginal growth bands or the growth increments do not accurately reflect seasonal proxies and/or a year of growth. She concludes that only younger fishes should be used in studies. Colaninno also discusses the applicability of otolith edge increment analysis to interpret season of capture. Her visual analysis of the marginal growth zone offered inconclusive results for both the modern hardhead catfish and Atlantic croaker otoliths. She reports that all hardhead catfish otoliths had "dark or fast" marginal growth bands from fishes caught during the months of May, June, July, August, and September. She tentatively infers hardhead catfishes deposit their annuli during spring or summer but cautions the reliability of her assessment given the lack of data from fall and winter seasons. Colaninno does not rule out the possibility that edge increment analysis could offer an additional method for interpreting season of capture but states additional modern sampling must be conducted to validate or nullify the use of this method.

Staying in the Southeast, Reitz and colleagues (2013) conducted a comprehensive study of subsistence practices and seasonality along the Gulf of Mexico's northern coast. Specifically, they sought insight into Middle and Late Woodland Period subsistence practices and settlements patterns of this area. The interdisciplinary study included the use of multiple analytical techniques on material recovered from the Plash Island and Bayou St. John sites, which are found today near Mobile Bay in Alabama. Of note here, Reitz and colleagues targeted specimens for analysis from feature contexts and, in most cases, tested a variety of species within these contexts. Also, noteworthy, Baker and Klippel's (2008) study, discussed previously in this chapter, is part of this research project.

Reitz and colleagues (2013) conducted stable isotope analysis on four hardhead catfish, two gafftopsail catfish, and one sea catfish (Ariidae) specimen from the Plash Island site and one hardhead catfish from the Bayou St. John site. Unfortunately, the gafftopsail and Ariidae specimens did not produce interpretable results. However, the hardhead catfish otoliths produced $\delta^{18}O$ curves with clear oscillations indicative of seasonal changes. Thus, Reitz and colleagues interpreted from the $\delta^{18}O$ that hardhead catfish were captured in spring, summer, and winter at Plash Island, and one was captured during the fall at Bayou St. John. Combined with numerous lines of other evidence, the researchers report that Plash Island and Bayou St. John have strong seasonal indicators for the winter, spring, and summer. However, they also report indications of fall were present just on a much lesser scale than the other seasons. Reitz and colleagues continue to work towards combining and interpreting all the information gleaned from this project and intend on publishing their findings.

One additional study warrants discussion in this section since it provides pertinent information for this research. Wang and colleagues (2013) employ isotope sclerochronology to expand their exploration of Pre-Columbian climate change in southwest Florida (see Surge and Walker 2005, Walker and Surge 2006, Walker et al. 1995, Wang et al. 2011). The researchers selected two species, hardhead catfish and southern quahog (*Mercenaria campechiensis*), to investigate climate change between the Roman Warm Period (300 B.C. – A.D. 550) and the Vandal Minimum (A.D. 550 – A.D. 800). Wang and colleagues' (2013:235) ontological assessment of seasonal $\delta^{18}O$ for hardhead catfish indicates "[p]ositions of prominent growth lines are coincident with or close to the most positive $\delta^{18}O_{otolith}$ values, suggesting that the growth rate decreased in winter." The researchers use the $\delta^{18}O_{otolith}$ and $\delta^{18}O_{shell}$ results and statistical analyses to make comparisons between climate conditions of the Roman Warm Period, the Vandal Minimum, and today. Wang and colleagues (2013:240) conclude from multiple lines of evidence that southwest Florida experienced "cooling and drying" across these climatic episodes.

In summation, the stable isotope studies demonstrate the wide use of this analytical technique not only in the southeastern United States but also around the world. The ontological approach used to develop $\delta^{18}O$ life histories for ancient fishes is indeed useful for not only archaeological studies on season of capture but also for paleoenvironmental and modern fisheries research. As noted by many of the researchers, this analytical approach certainly has drawbacks and limitations. First, stable isotope analysis is expensive. For example, to develop an ontological pattern of $\delta^{18}O_{otolith}$, a researcher analyzes 17 samples for four growth zones at a rate of $25 per sample and spends $1,700 per otolith. Second, studies often have small samples sizes of archaeological otoliths and even smaller sample sizes for modern specimens from which comparisons are drawn. This is likely due to the cost. Third, older adult specimens are excluded from being considered for analysis because growth bands are not wide enough to test, thus, creating a bias in the test assemblage. And fourth, unknown pre- and post-depositional processes could be influencing the $\delta^{18}O$. However, despite these complications, $\delta^{18}O$ analysis is an extremely useful tool that offers great potential for future studies.

CHAPTER FIVE: METHODS

Seasonality studies provide archaeologists with a means of examining seasonal rhythms of site use and gain knowledge of past environmental settings (Monks 1981). Here, I first discuss the field methods used by CREVAP to obtain the archaeological materials. Then I describe how the modern comparative collections were created. Next, I give brief life histories for the two species used in this study, red drum and spotted seatrout. Lastly, I describe in detail the laboratory and statistical analyses I used to obtain the seasonality data.

Field Methods

The Crystal River site has been the focus of several archaeological investigations. The field methods discussed below focus on the techniques used during the 2008–2013 field seasons of CREVAP. The fieldwork at Crystal River consisted of mapping, geophysical survey, trench excavations, and coring, while fieldwork at Roberts Island included mapping, geophysical survey, site-wide shovel testing, and trench excavations.

Crystal River Coring and Excavations

The CREVAP team utilized two subsurface exploratory techniques, coring and trench excavations, to gain understanding of site construction and use at Crystal River. Soil cores were taken during the 2011 field season using a GeoProbe Model 6620DT hydraulic coring system and a Vibracore machine (Jackson 2016; Norman 2014). Figure 5.1 provides the location of the 58 soil core samples that were taken in specific site areas, including the plaza, the midden, the swamp and marsh areas that border the site, and the summits of Mounds A, H, J, and K. The

GeoProbe cores were taken in 114 cm sections; however, the depth of some of the mounds required up to nine sections be taken to reach limestone substrate. The mound cores were essential for this project because they represent the only CREVAP material collected from these proveniences.

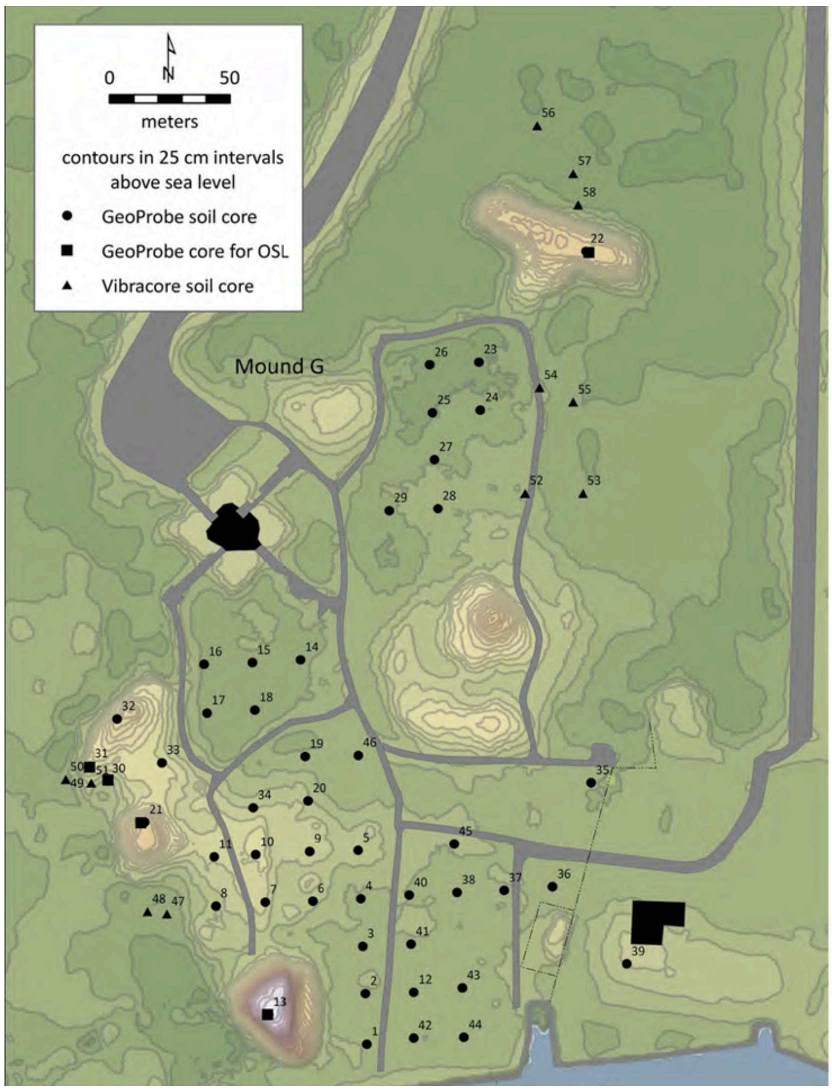

Figure 5.1. Locations of CREVAP Cores at Crystal River (Map courtesy of Thomas J. Pluckhahn)

CREVAP geophysical survey and coring of Crystal River provided important data that informed project leaders on where to place trench excavation units (Pluckhahn et al. 2010; Thompson and Pluckhahn 2010); researchers intentionally avoided placing excavation units in the areas of the Main Burial Complex (Mounds C-F) and Mound G because they did not want to encounter human remains. Figure 5.2 provides the location of the four trenches within the presumed midden areas of the site. Trench 1 consisted of a 1-x-4-m trench, while Trenches 2, 3, and 4 were each 1-x-2-m units (Pluckhahn et al. 2015b). The fill from test units was screened with 3.18-mm (0.125-inch) mesh and bagged with corresponding provenience information; in the lab, one unit from each trench was subsequently rescreened with 6.35-mm (0.25-inch) mesh and the smaller materials were discarded. The trench units were excavated in 10-cm arbitrary and/or natural levels with final depths ranging between 130-160 cm (Duke 2015; Pluckhahn et al. 2015b).

Figure 5.2. Locations of CREVAP Trenches at Crystal River (Map courtesy of Thomas J. Pluckhahn)

Roberts Island Shovel Tests and Excavations

CREVAP subsurface exploration at Roberts Island consisted of site-wide shovel tests and three trenches (Pluckhahn et al. 2015b). Figure 5.3 provides the locations of the shovel tests and trenches at both Roberts Island sites (8CI40 and 41). The 17 shovel tests measured 50-x-50-cm and were spaced at 20-m intervals. When possible, shovel tests were excavated to a depth of 100-cm and extended an additional 30-50-cm to explore the depth of the assemblage. The excavated material was screened with 3.18-mm (0.125-inch) mesh and bagged with documentation of corresponding provenience information. The shovel tests were excavated in arbitrary 10-cm levels, unless identifiable anthropogenic lenses were discernable.

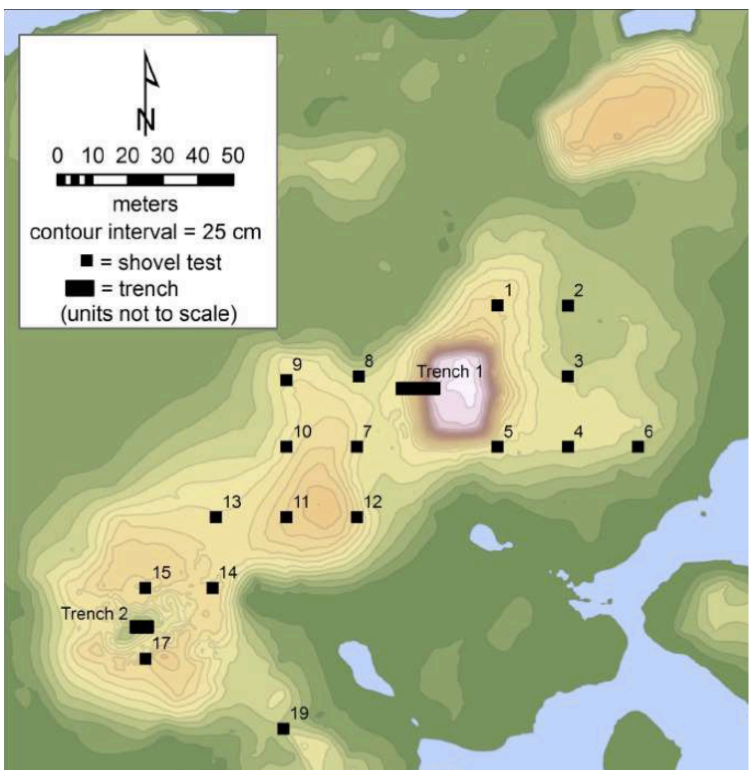

Figure 5.3. Locations of Shovel Tests and Trenches at Roberts Island (Map courtesy of Thomas J. Pluckhahn)

Additionally, the CREVAP team excavated a total of three trenches: two trenches at 8CI41 and one trench at 8CI40 (Pluckhahn et al. 2016). Trench 1 measured 1 x 6 m and was placed on the western side of Mound A. Trench 2 consisted of a 1-x-2-m excavation located in the assumed "water court" (Pluckhahn et al. 2015b). Trench 3 was positioned on the southwestern corner of Mound B and measured 1 x 4 m. All trench units were excavated in arbitrary 10-cm levels unless distinguishable cultural levels were apparent. The excavated material was screened with 3.18-mm (0.125-inch) mesh and bagged with documentation of corresponding provenience information.

Modern Fish Collections

As discussed previously, this project requires large comparative sets of modern specimens to infer seasonal information from the archaeological otoliths. Florida Fish and Wildlife Conservation Commission's (FWC) Fish and Wildlife Research Institute (FWRI) monitors several species that are also found in coastal Florida archaeological assemblages. FWC's Fisheries Independent Monitoring (FIM) and Fisheries Dependent Monitoring (FDM) programs collect a variety of species from various locations along Florida's Gulf coast throughout the year. FWRI's Age and Growth Lab analyzes the otoliths, spines, and scales of the fishes collected from this program. FWC's FIM and FDM programs collected the modern data on red drum and spotted seatrout used in this study between 2001 and 2015.

Over the years, the Age and Growth Lab has collected different types of data on the species they monitor. From 2001 to 2008, otolith growth bands were measured, ages were calculated, and the edge types, hyaline or opaque, were recorded. These data serve as the main source of information to compare with the archaeological specimens. From 2008 to present, otoliths were aged and the edge type was assigned a categorical number between 1 and 4. A rating of 1 indicates there is no marginal increment and a new annulus is present on the edge. If a sample was classified as 2, it denotes the presence of a small marginal increment, roughly one-third of the previous growth band. A rating of 3 indicates that there is an average marginal increment, roughly two-thirds of the previous growth band. Finally, a classification of 4 indicates there are a large marginal increment, more than two-thirds of the previous growth band. The lab also uses the same methods described below to measure, calculate, and record the interior growth bands of the otoliths. These methods are discussed extensively shortly. The data generated by the work done by the people at FWC's FWRI are invaluable and should be used by archaeologists more often for comparisons between prehistoric and modern assemblages.

Red Drum and Spotted Seatrout: Species Profiles

Red drum, also commonly known as red fish, are euryhaline fish found along the Atlantic Ocean and Gulf of Mexico coasts (Buskil 2017). They can be found as far north as Cape Cod, Massachusetts all the way south to Tuxpan, Mexico. Red drum have a diverse habitat range that includes estuaries, bays, sandy bottoms, river mouths, surf zones, seagrass beds, oyster bottoms, and continental shelf waters. However, juvenile red drum (ages young-of-year to three or four) live mainly in estuaries, near river mouths, and shallow coastal waters. Adults live primarily in open coastal waters except when they return between mid-August to mid-November to spawn near tidal inlets and estuaries. In addition to a diverse habitat range, red drum are able to tolerate a range of water temperatures (39 to 93 degrees Fahrenheit). This species is also able to tolerate wide ranges of salinity, from freshwater to high saline waters. Red drum have lifespans that can last as long as 50 years and grow to be 155-cm in total length, but the average size is 100-cm.

Spotted seatrout, also called speckled seatrout, are actually not members of the trout family despite their name (Bester 2021). They belong to the drum family. Like the red drum, spotted seatrout are euryhaline fish found in waters from Cape Cod, Massachusetts, around the southern tip of Florida, and throughout the Gulf of Mexico. Spotted seatrout spend their entire lives primarily in estuaries around sandy bottoms and seagrass beds, but have also been observed in shallow coastal waters, salt marshes, bays, and rivers (Bester 2021; Whaley et al. 2016). However, some research (Murphy and Taylor 1994) suggests these fishes do migrate far from the estuaries they spawned in while others (Bester 2021) report they rarely do. Spotted seatrout are usually found in deeper areas of estuarine waters in winter months and seagrass beds during the summer months. Spawning season occurs between March through September. Spotted seatrout have lifespans that generally range between eight to ten years. They usually grow to 100-cm in total length.

A recent study (Whaley et al. 2016) looked at the influence of environmental perturbation on juvenile red drum and spotted seatrout in Tampa Bay, Florida. Given the documented perturbations that occurred in the past at Crystal River and Roberts Island, and, Little and Reitz's (2015) warning of their impact on estuarine species, this study merits attention. This study investigates the impact from three major types of environmental events (an acid spill, droughts resulting in high freshwater inflow, and a major red tide plume) that occurred in Tampa Bay at different times between 1996-2008. Whaley and colleagues sought to determine the impact these events had on these species and to see how long it took for them to recover. There are no doubts the residents of Crystal River and Roberts Island did not need to worry about an acid spill impacting these species in the estuaries, and, an argument could be made that given the absence of modern fertilizers during prehistoric times, red tide plumes may not have occurred either. However, since it has not been proven, I included the impact the red tide event and the droughts had on these two fish species populations.

Whaley and colleagues (2016) found that after the 2000 drought both smaller-sized juvenile groups of red drum and spotted seatrout first showed signs of recovery in their abundance, but it took a few years before their spatial distribution began to recover. The larger-sized juvenile group of red drum, however, first showed signs of recovery in spatial distribution but abundance remained low for an additional two years. The larger-sized juvenile group of spotted seatrout was also relatively low in both abundance and spatial distribution, but unlike the other groupings, this group showed progressive signs of recovery in abundance and spatial distribution during each year following the drought.

The red tide event of 2005 had the most severe and lasting impacts on the populations of these species (Whaley et al. 2016). And to make matters worse for recovery, Tampa Bay experienced another drought in the years following the red time event. Their research indicated that both juvenile groupings of red drum and spotted seatrout experienced severe declines in both abundance and spatial distribution. The data collected on the juvenile red drum groupings never showed corresponding signs of recovery in abundance and spatial distribution prior to 2008 conclusion of this study. Notably, the smaller-sized juvenile grouping of red drum showed a decline in abundance that was five times lower than a prior red tide event. The larger-sized juvenile grouping of red drum experienced even more profound declines in both abundance and spatial distribution. The smaller-sized grouping of juvenile spotted seatrout showed declines in spatial distribution and experienced levels five times lower in abundance. However, by the conclusion of this study, they began to show signs of recovery. The larger-sized grouping of juvenile spotted seatrout had the largest restriction of spatial distribution and suffered declines in abundance as well following the red tide event. This grouping showed signs of recovery in the year following the red tide, but with the onset of the drought declines occurred again. By the conclusion of this study, this grouping had yet to show signs of recovery.

In sum, this study provides important information on how modern juveniles of these two species respond to single and concurrent environmental perturbations. The results suggest that droughts have lasting impacts on both their spatial distributions and abundances. Further, when concurrent perturbations occur the impacts seem to last longer than single events. For my research, this could help in understanding differences that occur between the age classes of the modern and prehistoric populations or between the populations of the sites. Unfortunately, this study did not examine differences between the otolith growth bands of fishes caught during these events and compare them with otolith growth bands from fishes that were not impacted by environmental events. However, maybe a future study could examine this issue since some of the modern otoliths used in this study were caught in Tampa Bay during these years. It would indeed be interesting to compare the otolith growth band widths of these environmentally impacted modern fishes to prehistoric otolith growth bands widths that are believed to have come from a time archaeologists suspect were caught during a period of environmental flux.

Laboratory Methods

Sorting and Identification

In Pluckhahn's Southeast Archaeology Lab at the University of South Florida Tampa, I sorted through the pre-sorted faunal material, mound soil cores, column samples, and feature soil samples for otoliths collected during CREVAP. Additionally, I examined the Crystal River faunal material housed at the Florida Bureau of Archaeological Research in Tallahassee and the Florida Museum of Natural History in Gainesville.

Initial species identification for all archaeological otoliths occurred as I sorted through the faunal material. I used a variety of sources to identify the fish species represented in the assemblages, including the type collections at FWRI's Age and Growth Lab and Pluckhahn's Southeastern Archaeology Lab. I also used numerous publications, including Simons (1986), Georgia Department of Natural Resources (2004) and VanderKooy and Guindon-Tisdael (2009).

Species identification can be challenging if species share common characteristics. For the southeastern United States, archaeologists have three sources for species identification, including type collections at various universities and museums, published guides (Simons 1986), and an online database provided by the Florida Fish and Wildlife Conservation Commission (2021). Simons (1986) provides a detailed and photographic guide of otoliths commonly recovered during archaeological investigations. The guide consists primarily of fishes from the Sciaenidae family; however, other pertinent species are included as well. Importantly, Simons offers species specific descriptions of morphological characteristics to aid in the identification process. These detailed accounts are quite useful when trying to identify the difference between species with very similar overall otolith shapes. For example, hardhead catfish and gafftopsail catfish otoliths are extremely similar. Simons illustrates the different angles of the rostrum for the species, hardhead catfish have a 91-degree angle and gafftopsail catfish have an 84-degree angle. Luer (2007:216) also comments on observable differences between these species:

> hardhead catfish otoliths have a rounded outline, a bulged or domelike cross section (one side relatively flat, the other side bulged), and a pronounced prorostrum (with a wide base) that projects from the middle of one edge at a right angle to the long axis of the otolith. In contrast, gafftopsail catfish otoliths have a slightly elongated outline, a cross section that is flatter, and a prorostrum that is

smaller and angled toward one corner at a ca. 45-degree angle to the long axis of the otolith.

Another pertinent example are the otoliths of juvenile spotted seatrout and sand seatrout, also known as weakfish, which are also very similar in shape and appearance. Simons (1986:144) notes the differences on the lateral surfaces with spotted seatrout otoliths being "knobby swelling opposite the cauda of the sulcus… and the thickness-to-length ratio is 4.6" and weakfish otoliths as being "smooth with a swelling opposite the cauda of the sulcus… and the thickness-to-length ratio is 4.7".

The Ariidae species, hardhead catfish and gafftopsail catfish, were distinguished using Surge and Walker's (2005:184) approach "based on the angle between the spur and the crest of the dorsal margin." Hardhead catfish specimens exhibit about a 90^{o} angle while the gafftopsail catfish closer is to a 75^{o} angle. Additionally, the internal structures of these two species differ since the gafftopsail catfish grows faster than hardhead catfish. Furthermore, I consulted staff from FWRI's Age and Growth Lab to aid with species identification. To verify the accuracy of species identification, I identified species on three separate occasions without knowledge of previous taxonomic classification. In Chapter 6 (see Table 6.1), I provide the species counts for each site and context. Once all otoliths were identified to either species or family, I selected red drum and spotted seatrout for season of capture analysis based on their abundance within the targeted contexts and the available modern data to make comparisons.

Subsampling

Archaeological otoliths selected for analysis had to meet certain criteria. Previous season of capture research showed that preservation and prehistoric cooking methods alter otolith chemistry and/or the aragonite structure (Andrus and Crowe 2002; Peacock et al. 2016).

Therefore, otoliths that exhibit burning, chalkiness, or discoloration were avoided as much as possible for this study. Figure 5.4 provides a picture of otoliths that exhibit these alterations. The pilot study for this project indicated that most prehistoric otoliths have retained their internal growth bands and can be used for the marginal increment analysis. However, there were two exceptions. First, specimens with an iron-like concretion material on the exterior were avoided due to changes in the crystalline structure of the otolith. Second, otoliths that were damaged on the surface area near the core and marginal edge were avoided because accurate measurements were unable to be taken. Additionally, I targeted otoliths from midden, mound, and feature contexts that were associated with previously dated material to reduce expenses of the project and to make more direct comparisons with the oyster season of capture analysis.

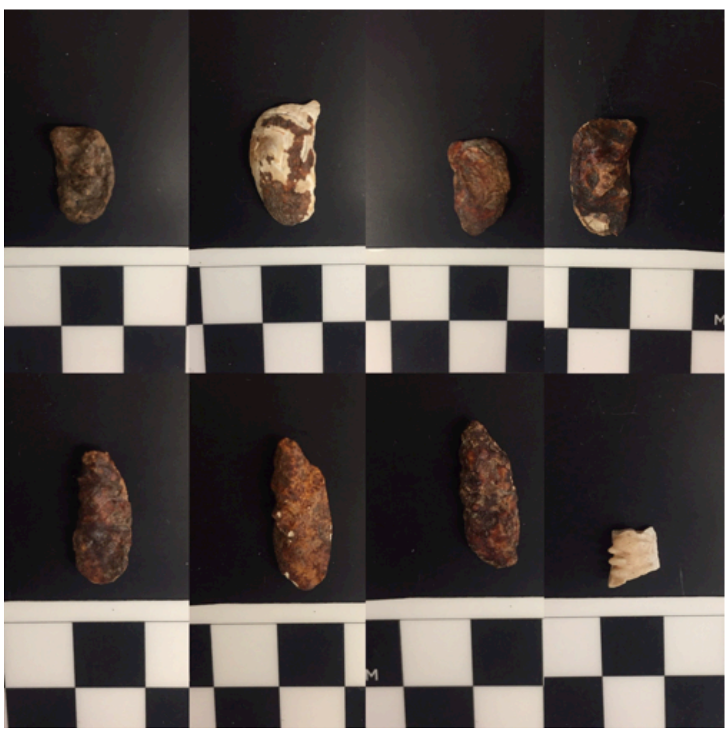

Figure 5.4. Photographs of Red Drum (top) and Spotted Seatrout (bottom) Otoliths Excluded from Analysis Due to Alterations or Breakage

The initial goal was to select 30 archaeological red drum and spotted seatrout otoliths from each context and phase for marginal increment analysis. This goal offered statistically adequate sample sizes for each phase and contexts of both sites. The number of otoliths for the marginal increment analyses was primarily dependent on otolith condition and the number of otoliths available for each site, context, and phase. My initial sample size goal proved unattainable given the limited amount of material collected from Crystal River mound contexts and the deteriorated condition of several otoliths. Thus, a new goal of fifteen otoliths per context was used, except for Crystal River mound contexts.

Additionally, a particular side of otoliths, either right or left, is typically analyzed when conducting season of capture analysis to avoid sampling from the same fish twice (Colaninno 2012; Disspain et al 2015; Higham and Horn 2000; Peacock et al. 2016; Van Neer et al. 2004). However, in some instances due to the few number of otoliths recovered from contexts, both rights and lefts were analyzed given a significant difference in otolith weight, shape, and/or age.

Analysis Preparation

All otoliths used in this study underwent substantial preparation at FWRI's Age and Growth Lab and John Arthur's Archaeology Lab at the University of South Florida Saint Petersburg (USFSP). The methods outlined below follow the general instructions employed by previous researchers conducting season of capture analysis on archeological otoliths (see Colaninno 2012; Higham and Horn 2000; Peacock et al. 2016; Scartascini 2015; Van Neer et al. 2004).

All archaeological otoliths were cleaned at the USFSP Archaeology Lab. The otoliths were submerged in a vial with distilled water for 24 hours, gently scrubbed with a nylon-polyester brush, and then rinsed again with distilled water (Colaninno 2012:84). This process was repeated when necessary to carefully clean the exterior surface of the otoliths. After cleaning, the otoliths were dried for a minimum of 24 hours. Figure 5.5 provides before and after pictures of red drum and spotted seatrout otoliths used in this study.

Once otoliths were cleaned, I followed Reitz and Wing's (2008:158-159, 176-178I) protocols for recording primary data and for conducting incremental structure analysis. I developed a database of the archaeological samples that provided reference numbers for each otolith, as well as species. I also documented the following information for each otolith: weight, measurements, side, photographed number, and provided a general description of the otoliths' condition.

Figure 5.5. Before and After Cleaning Procedures of Spotted Seatrout Otolith

Once archaeological otoliths were cleaned, dried, and all pertinent information was documented, otoliths were transferred to FWRI's Age and Growth Lab for cross sectioning, ageing, and measuring. There are two different otolith mounting methods commonly used: embedding and direct mounting. The pilot study conducted for this project suggested embedding archaeological otoliths was the preferred method because it protected the often-fragile marginal edge of the otoliths. Thus, embedding was used for all archaeological otoliths.

I followed the embedding procedures and guidelines used by FWRI Age and Growth Lab researchers and described by VanderKooy and Guindon-Tisdael (2009). The embedding media required certain laboratory protocols be followed when mixing components due to potentially hazardous fumes and skin irritations. Thus, the mixing process was conducted under a fume hood and protective gloves were worn.

I combined a 5:1.1 ratio by weight of Araldite resin (Araldite-D-US) and hardener (Hardener HY 956 EN/US) to create the embedding media. First, the Araldite was slowly poured into a disposable plastic cup and weighed. It was then placed on a hot plate and warmed to 60^{o}C to reduce viscosity. The heated Araldite was returned to the scale and the hardener was added, keeping in mind the 5:1.1 ratio by weight. The mixture was then placed on a stir plate and thoroughly mixed with a magnetic stir bar.

The Araldite epoxy mixture was poured into embedding molds in two steps. A false bottom was first created by adding a very small amount of the epoxy mixture to the bottom of the mold. The mold was then either placed in an oven and baked for 1 hour at 60^{o}C or left overnight to harden. Once the false bottoms had hardened, otoliths were placed in a mold and covered completely with the Araldite mixture. A toothpick was then used to release and pop air bubbles within the epoxy mixture and to position the otoliths so the long axis was parallel to the sides of the mold (VanderKooy and Guindon-Tisdael 2009:3-4). The epoxy-covered otoliths were then placed under the fume hood and left overnight to harden.

Bullet mold trays are generally used to embed small and fragile modern otoliths. Unfortunately, the bullet mold cavities, in most cases, were not deep enough to accommodate the thickness of the otoliths used in this study. As a result, I used three different mold tray types (bullet mold trays, mini-ice cube trays, and stick ice cube trays) to embed the archaeological otoliths. The embedding mold cavities were assigned codes in order to track where archaeological otoliths were placed. Once embedded otoliths were removed from mold trays, they were affixed with hot glue to a piece of card stock. The otolith identification number was written on the card stock.

The final step in the analysis preparation process involved marking the location of the otolith core. By marking the otolith core, it ensures accurate readings and measurements can be obtained to determine season of capture. The core of embedded otoliths was marked with a permanent marker.

Otolith Thin Sectioning

Once otoliths were embedded and affixed to card stock, I used a Buehler Isomet low-speed diamond wafering saw to take three 0.5-mm thin sections of the transverse plane of each otolith (Hufthammer 2010; Surge and Walker 2005; VanderKooy and Guindon-Tisdael 2009). The otoliths were attached to the saw chuck with a clip and positioned to ensure 90^{o} cross sections of the otolith cores were obtained; failure to cut at a 90^{o} angle causes doublets to form on the thin sections, making annulus identification difficult. Figure 5.6 depicts the sawing process of a red drum otolith.

Figure 5.6. Photogragh of Thin Sectioning Process on a Red Drum Otolith

After cutting, each thin section was washed with distilled water and dried. The three thin sections were then placed on a microscope slide and examined under a binocular microscope with reflected light to verify the core was obtained in one of the three thin sections. When necessary, thin sections that contained the otolith core were polished using a variety of polishing paper, 600, 800, 1000, and 1200 grit carbide sheets, to smooth the surface of the otolith thin sections and enhance visibility of the opaque and hyaline growth rings. Once smoothed and polished, thin sections were rinsed with distilled water again to remove remaining particles and placed on a microscope slide to dry overnight.

The final step in analysis preparation included affixing dried otolith thin sections to microscope slides. All otolith thin sections were placed on a microscope slide, covered in Flotexx, and dried overnight. The Flotexx further enhances clarity of the otolith growth bands and secured the thin sections to the microscope slide for analysis.

Marginal Increment Analysis

The marginal increment analysis (MIA) also took place at FWC's FWRI Age and Growth Lab. This analytical approach examines the outer most hyaline or opaque growth band of an otolith thin section to make inferences on season of capture. First, I viewed these specimens under a binocular microscope to determine whether any pre- or post-depositional processes had altered the interior of the selected archaeological otoliths. Otoliths that had breakage on and/or near the core or the marginal had to be eliminated from the study because measurements could not be taken on them. Additionally, any discoloration within the interior of the otoliths that obstructed the ability to identify annuli or make accurate measurements had to be excluded from this study.

Next, I used a Leica MZ12 stereo microscope with an attached digital camera to take measurements of all archaeological otolith thin sections; a combination of transmitted and reflected light was used depending on which light source offered the best clarity of the growth bands. The digital images were then analyzed with a computer program, Image Pro. This image processing software allowed for the measurement of growth bands in millimeters and, then, calculated fish ages for each specimen by counting the identified growth rings (VanderKooy and Guindon-Tisdael 2009). To reduce reader error and increase repeatability of the method, I measured each otolith thin section three times and took the average of the measurements. Additionally, staff members from FWRI's Age and Growth Lab volunteered their time and checked my measurements and answered my countless questions.

Otolith measurements were taken from the core to the marginal edge. The measurement line was placed as close to the sulcul groove on the dorsal end of each specimen. Figure 5.7 provides a picture of me analyzing a spotted seatrout otolith and a red drum otolith. Modern fishery science recognizes that the first annuli, opaque growth bands, can be difficult to identify and varies among species (Georgia Department of Natural Resources Coastal Resources Division 2004). False marks occur when a fish experiences rapid growth after birth, stress, spawning events, and/or environmental changes and can easily be mistaken for an annulus by the untrained eye. Additionally, doublets occur when the otolith was sectioned at an off angle and can be mistaken for annuli. To avoid counting and measuring distances between true annuli and false marks or doublets, a comparison between the dorsal and ventral sides of the sulcul groove was conducted which often aided in determinations. Occasionally, determinations were extremely difficult and guidance from FWRI's otolith ageing experts was sought.

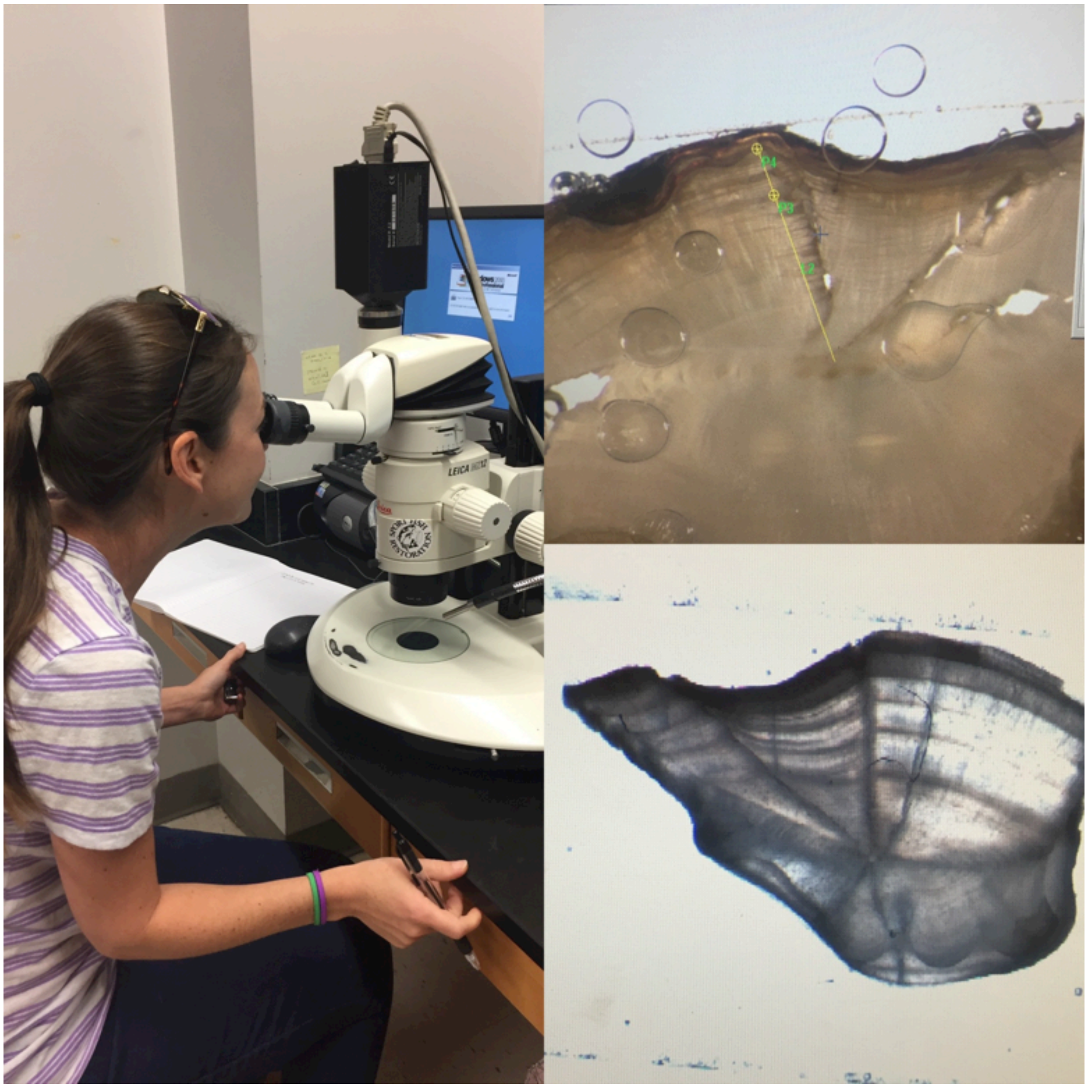

Figure 5.7. Photographs of Otolith Growth Band Measuring Procedures. Elizabeth Southard (author) using Microscope to Examine Otolith Thin Sections. Measuring and Analysis of Red Drum Otolith (top right) and Spotted Seatrout Otolith (bottom right)

The growth band distance measurements were automatically transferred into a Microsoft Excel database. I created three databases of archaeological otolith growth band measurements for each of the species. Using these measurements, I calculated the growth band widths by subtracting one annulus or the marginal edge distance from the proceeding annulus. As mentioned previously, FWRI’s Age and Growth Lab provided the databases of measurements for the modern red drum and spotted seatrout species.

The databases of the archaeological otoliths for each species were sorted by context, phase, and fish age. The databases of the modern otoliths provided by FWRI were sorted by catchment location, season of capture, date of capture, and fish age. In doing so, this approach enabled several statistical tests to be conducted on the data using IBM's SPSS software to ensure accurate and reliable results were produced.

To investigate the data and make seasonal determinations, I first created histograms of the sorted modern data to see the shapes of the distributions. These histograms offered insight into the additional types of statistical analyses that could be performed. The histograms also served as comparisons for the archaeological specimens to determine which modern monthly distributions most accurately matched that of the prehistoric otolith edge widths.

Van Neer and colleagues (2004) suggest that catchment location potentially impacts annuli formation. This assertion may indeed be important for the analysis of the spotted seatrout species since genetic studies suggested that these fish stay in localized areas throughout life and are easily susceptible to overfishing (Gold and Richardson 1998). Thus, I performed numerous student t-tests on the data provided by FWRI that was obtained from seven locations along Florida's Gulf Coast to determine whether populations of red drum and spotted seatrout were similar or different. Additionally, to account for Van Neer and colleagues' final warning regarding differences in growth rates between fish age groups, I performed student t-tests to examine similarities and differences between age classes. Lastly, I also performed student t-tests to compare the modern and archaeological otolith measurements to determine whether these populations are similar, thus offering an additional validation for the results and assigning caution when necessary for making seasonal designations.

The next part of the marginal increment analyses requires that the modern data are reported first because they provide the needed information to assign seasonal designations for the archaeological otoliths. I present graphical representations of the mean widths and sample sizes for each annulus by month. The purpose of these graphs is to illustrate: first, whether there is a clear pattern to the mean widths of the marginal increments from month to month; and second, the months in which new annuli are formed. If the marginal increments increase from month to month in the modern assemblage, as I expect, then I can reasonably assume that archaeological otoliths likely follow the same pattern. This pattern is important for the analyses of otoliths with annuli that were flagged as having statistically different annuli width means from the modern assemblage.

Next, histograms are presented for the grouped monthly modern marginal increment widths. I grouped the data based loosely on Palmiotto's (2016) monthly seasonal groupings with early and late utilized to differentiate between the cool and warm seasons. Since the climate of Florida exhibits much less pronounced seasonality than much of North America, I modified her categories slightly after investigating the spread of data from monthly histograms of both species (see Appendix A for red drum and Appendix B for spotted seatrout).

I use bar graphs to illustrate the assignment of seasonal designations for the archaeological otoliths. These graphs include the marginal increment measurements for the archaeological otoliths, the marginal increment widths for the various seasonal groupings I created, and the mean annuli widths for the corresponding annulus. I also rely heavily of the spread of the data from the histograms to assign seasonal designations. Caution is necessary in cases where the modern sample sizes are low. Care is also warranted when assigning seasonal designations for otoliths with marginal increment measurements that correspond with more than one seasonal grouping; some otoliths may be assigned to two seasonal groupings.

CHAPTER SIX: RESULTS

An Overview of the Crystal River and Roberts Island Otolith Assemblages

The total number of otoliths recovered from excavations at Crystal River and Roberts Island was 1942. The 1119 otoliths from Crystal River included three specimens from two of the mounds and 1116 from the four trenches in midden contexts. The 823 otoliths from Roberts Island included 353 specimens from the two mounds, 210 from the water court area, and 260 from midden contexts. Table 6.1 provides the counts for each species from the various contexts within the sites.

Table 6.1. Crystal River and Roberts Island Otolith Assemblages by Contexts

Species	Crystal River							Roberts Island					TOTAL
	Mounds		Midden Trenches					Mounds		Water Court	Midden	Total	
	A	K	1	2	3	4	Total	A	B				
Ariopsis felis	1	1	90	22	110	97	321	76	108	113	140	437	758
Archosargus probatocephalus	0	0	1	0	1	0	2	0	0	0	0	0	2
Ariidae	0	0	111	18	50	123	302	29	52	80	48	209	511
Bairdiella chrysoura	0	0	4	0	0	4	8	14	3	0	14	31	39
Bagre marinus	0	0	9	3	4	14	30	15	20	7	41	83	113
Cynoscion nebulosus	1	0	12	2	13	181	209	8	6	2	10	26	235
Cynoscion	0	0	7	1	2	94	104	4	4	1	0	9	113
Micropogonias undulatus	0	0	3	0	3	14	20	0	0	0	1	1	21
Pogonias cromis	0	0	5	1	3	6	15	0	3	4	2	9	24
Sciaenidae	0	0	3	1	1	8	13	1	0	0	0	1	14
Sciaenops ocellatus	0	0	10	1	7	63	81	5	5	3	4	17	98
Unidentified	0	0	4	2	1	7	14	0	0	0	0	0	14
TOTAL	2	1	259	51	195	611	1119	152	201	210	260	823	1942

Eight species of fish were represented by 1382 otoliths; 560 otoliths unfortunately lacked identifiable traits to be able to determine species identification but were able to be assigned family designations. Fourteen otolith fragments were completely unidentifiable to species or family. However, these otolith fragments contained morphological features consistent with the proximal or distal surfaces of otoliths, thus allowing them to be included in the overall otolith assemblage count.

While providing counts of otoliths for the various species and contexts is important, examination of the relative proportions of the otoliths is essential for truly understanding and analyzing the assemblage. Table 6.2 provides these results for each context of the sites. Examination of the assemblage indicates fishes of the Ariidae family, including hardhead catfish and gafftopsail catfish, make up 71.2% of the entire otolith assemblage with 58.3% at Crystal River and 88.6% at Roberts Island. Clearly, it would be advantageous and beneficial to conduct seasonality analysis on at least one of these species; however, this was not feasible due to a lack of modern comparative collection.

The next most abundant taxon represented in the assemblage is the Sciaenidae family, which includes red drum and spotted seatrout. This family makes up 36.3% of the otoliths from Crystal River, with 18.7% identified as spotted seatrout, 9.2% identified as the Cynoscion genus, 7.2% identified as red drum, and 1.2% identified as the Sciaenidae family. Only 6.4% of the otolith assemblage from Roberts Island was identified to the Sciaenidae family, with 3.1% identified as spotted seatrout, 1% identified as the Cynoscion genus, 2% identified as red drum, and .1% identified as the Sciaenidae family. While these percentages are not nearly as robust as the Ariidae assemblage, the modern comparative collections of red drum and spotted seatrout provided by FWC make these two species ideal for seasonality analysis. Of note for this research is the abundance of otoliths recovered from Trench 4 at Crystal River. When compared to the other trenches, an argument can be made that this area could represent two activities: disposal of feasting remains or a fish processing area. As mentioned briefly in Chapter Three, the location of this trench would have been close to the lagoon at Crystal River that may have been used as a place to store fishes.

Table 6.2. Relative Proportions of Otoliths by Species and Contexts at Crystal River and Roberts Island

Species	Crystal River						Roberts Island			
	Mounds		Midden Trenches				Mound		Water Court	Midden
	A	K	1	2	3	4	A	B		
Ariopsis felis	50. 0	100. 0	34. 7	43. 1	56. 4	15. 9	50. 0	53. 7	53. 8	53. 8
Archosargus probatocephalus	0. 0	0. 0	0. 4	0. 0	0. 5	0. 0	0. 0	0. 0	0. 0	0. 0
Ariidae	0. 0	0. 0	42. 9	35. 3	25. 6	20. 1	19. 1	25. 9	38. 1	18. 5
Bairdiella chrysoura	0. 0	0. 0	1. 5	0. 0	0. 0	0. 7	9. 2	1. 5	0. 0	5. 4
Bagre marinus	0. 0	0. 0	3. 5	5. 9	2. 1	2. 3	9. 9	10. 0	3. 3	15. 8
Cynoscion nebulosus	50. 0	0. 0	4. 6	3. 9	6. 7	29. 6	5. 3	3. 0	1. 0	3. 8
Cynoscion	0. 0	0. 0	2. 7	2. 0	1. 0	15. 4	2. 6	2. 0	0. 5	0. 0
Micropogonias undulatus	0. 0	0. 0	1. 2	0. 0	1. 5	2. 3	0. 0	0. 0	0. 0	0. 4
Pogonias cromis	0. 0	0. 0	1. 9	2. 0	1. 5	1. 0	0. 0	1. 5	1. 9	0. 8
Sciaenidae	0. 0	0. 0	1. 2	2. 0	0. 5	1. 3	0. 7	0. 0	0. 0	0. 0
Sciaenops ocellatus	0. 0	0. 0	3. 9	2. 0	3. 6	10. 3	3. 3	2. 5	1. 4	1. 5
Unidentified	0. 0	0. 0	1. 5	3. 9	0. 5	1. 1	0. 0	0. 0	0. 0	0. 0
TOTAL	100. 0	100. 0	100. 0	100. 0	100. 0	100. 0	100. 0	100. 0	100. 0	100. 0

In total, 122 otoliths or 6% of the entire archaeological otolith assemblage were selected for analysis. Table 6.3 provides the counts for each species and the percent analyzed from each context. However, it is important to note two things. First, four red drum and seven spotted seatrout otoliths had to be excluded after initial analysis preparation. These otoliths either experienced breakage during the thin-sectioning process or the interior of the otolith was discolored from post-depositional processes, which made it impossible to measure and identify the annuli. Figure 6.1 illustrates examples of these occurrences. Second, the goal of analyzing at least fifteen specimens of each species from all contexts was not achieved. The main reason for not reaching this goal was lack of representative samples of otoliths from both taxa. Another contributing factor was the condition of many of the otoliths.

Table 6.3. Total Number and Percent of Red Drum and Spotted Seatrout Otoliths Analyzed by Contexts

Species	Crystal River							Roberts Island					TOTAL
	Mounds		Midden Trenches					Mounds		Water Court	Midden	Total	
	A	K	1	2	3	4	Total	A	B				
Cynoscion nebulosus	1	0	8	1	8	35	53	7	5	1	9	22	75
Sciaenops ocellatus	0	0	4	1	7	19	31	4	5	3	4	16	47
TOTAL	1	0	12	2	14	54	83	11	10	4	12	37	122
Excluded	0	0	1	0	0	7	8	0	0	1	2	3	11
Precent by Context	50%	0%	4%	4%	7%	8%	7%	7%	5%	1%	4%	4%	6%

Figure 6.1. Examples of Otoliths Excluded from Analysis. Red Drum Otolith (left) with Interior Breakage and Spotted Seatrout Otolith (right) wirh Post-Depositional Alterations and Breakage

Red Drum: Results

Annuli Count and Width Comparative Collections

I conducted several analyses to determine whether the archaeological and modern annuli widths for the red drum assemblages are statistically comparable. First, I analyzed the archaeological assemblage for the number of annuli present on each otolith. This analysis informs what modern annuli will be used to compare with the archaeological assemblage. Table 6.4 provides the number of annuli present on each archaeological red drum otolith. The analysis indicates the Crystal River and Roberts Island assemblages both consist primarily of adolescent fishes, a few young-of-year, and a single older adult. The exploitation of these fish ages by the fisher-hunter-gatherer communities aligns with what is to be expected for red drum caught in estuary systems because after this age red drum spend more time coastal waters (Buskill 2017).

Descriptive statistics and independent samples t-tests were used to explore differences in the datasets and compare the means of the annuli widths for the Crystal River and Roberts Island otolith assemblages. These analyses were necessary because the limited size of the site assemblages required they be combined to have a sample of prehistoric otoliths of adequate size for comparisons with the modern datasets, and I wanted to be certain there were no significant differences in the site assemblages before combining them. Otoliths that did not have one fully developed annulus were excluded from this portion of analysis. Additionally, the outer most growth bands of all the otoliths were not included since these are incomplete (however, these will be used for the marginal increment analysis to determine seasonality, described below).

Table 6.4. Crystal River and Roberts Island Red Drum Assemblages with Annuli Counts

Otolith ID	Site	Site Location	FS #	Annuli Present	Otolith ID	Site	Site Location	FS #	Annuli Present
CRMI 6	CR	Midden	694	4	CRMI 169	CR	Midden	1141	2
CRMI 7	CR	Midden	694	1	CRMI 170	CR	Midden	1141	2
CRMI 19	CR	Midden	653	Removed	CRMI 171	CR	Midden	1135	2
CRMI 29	CR	Midden	624	0	CRMI 172	CR	Midden	1135	1
CRMI 43	CR	Midden	700	2	CRMI 173	CR	Midden	1156	2
CRMI 75	CR	Midden	1091	0	CRMI 174	CR	Midden	1156	2
CRMI 76	CR	Midden	1091	1	CRMI 175	CR	Midden	1156	3
CRMI 77	CR	Midden	1091	0	RIMI 11	RI	Midden	245	1
CRMI 78	CR	Midden	1091	1	RIMI 12	RI	Midden	245	0
CRMI 79	CR	Midden	1094	2	RIMI 32	RI	Midden	42	2
CRMI 80	CR	Midden	1103	1	RIMI 45	RI	Water Court	45	0
CRMI 81	CR	Midden	1115	0	RIMI 46	RI	Water Court	251	1
CRMI 157	CR	Midden	1073	1	RIMI 47	RI	Water Court	256	2
CRMI 158	CR	Midden	1093	0	RIMI 54	RI	Midden	247	Removed
CRMI 159	CR	Midden	1113	15	RIMI 60	RI	Midden	247	2
CRMI 160	CR	Midden	1118	Removed	RIMO 10	RI	Mound A	209	2
CRMI 161	CR	Midden	1119	1	RIMO 11	RI	Mound A	219	0
CRMI 162	CR	Midden	1119	2	RIMO 12	RI	Mound A	183	2
CRMI 163	CR	Midden	1142	2	RIMO 44	RI	Mound A	186	1
CRMI 164	CR	Midden	1142	4	RIMO 47	RI	Mound B	592	3
CRMI 165	CR	Midden	1144	3	RIMO 68	RI	Mound B	606	0
CRMI 166	CR	Midden	1145	2	RIMO 69	RI	Mound B	606	2
CRMI 167	CR	Midden	1145	3	RIMO 77	RI	Mound B	600	0
CRMI 168	CR	Midden	1141	Removed	RIMO 78	RI	Mound B	600	1

Table 6.5 provides the descriptive statistics for the assemblages. The results suggest a possible difference between the two assemblages in the width of the growth band between the first to second annuli. Specifically, the mean width of this growth band is notably lower in the sub-assemblage from Crystal River.

The results of the independent samples t-tests are provided in Table 6.6. The test confirms there is a statistically significant difference ($t(20) = -2.77$, $p = 0.012$) between the first annulus to the second annulus of the Crystal River and Roberts Island red drum otoliths. I will consider this difference again when I combine these sub-assemblages and compare them to the modern assemblage, as it indicates the need for caution in determining seasonality designations.

Table 6.5. Descriptive Statistics for Crystal River and Roberts Island Red Drum Assemblages

Site	Annuli	N	Mean	Std Dev	Std Error	Median	Variance	Min	Max	Range
Crystal River	Core to 1st	23	1.41	0.16	0.03	1.39	0.02	1.07	1.72	0.65
	1st to 2nd	15	0.42	0.09	0.02	0.45	0.01	0.25	0.59	0.33
	2nd to 3rd	6	0.34	0.06	0.02	0.34	0.00	0.24	0.14	0.17
	3rd to 4th	3	0.29	0.04	0.02	0.27	0.00	0.26	0.34	0.07
Roberts Island	Core to 1st	11	1.41	0.07	0.02	1.42	0.01	1.27	1.53	0.26
	1st to 2nd	7	0.53	0.08	0.03	0.51	0.01	0.44	0.67	0.23

Table 6.6. Results of Independent Samples T-Test for Crystal River and Roberts Island Red Drum Assemblages

Otolith Annuli Area	Site	N	Levene's Test for Equality of Variance			Independent Samples Test								
						t-test for Equality of Means								
						t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		Hypothesis test	
				F	Sig						Lower	Upper	Accept Null	Reject Null
Core to 1st Annulus	Crystal River	23	Equal variances assumed	2.84	0.10	-0.12	32.00	0.91	-0.01	0.05	-0.11	0.09	t(32)=-0.12, p=.0.906	
	Roberts Island	11	Equal variances not assumed			-0.15	31.99	0.88	-0.01	0.04	-0.09	0.07		
1st Annulus to 2nd Annulus	Crystal River	15	Equal variances assumed	0.60	0.45	-2.77	20.00	0.01	-0.12	0.04	-0.20	-0.03		t(20)=-2.77, p=0.012
	Roberts Island	7	Equal variances not assumed			-2.90	13.26	0.01	-0.12	0.04	-0.20	-0.03		
2nd Annulus to 3rd Annulus	Crystal River	6	Equal variances assumed			-2.34	5.00	0.07	-0.14	0.06	-0.29	0.01	t(5)=-2.34, p=0.066	
	Roberts Island	1	Equal variances not assumed						-0.14					

Next, the Crystal River and Roberts Island red drum otolith sub-assemblages were combined and compared to the modern assemblage. Descriptive statistics and independent samples t-tests were utilized again to compare the datasets. Table 5.7 provides the results for the descriptive statistics. As noticed in the descriptive statistics for the Crystal River and Roberts Island assemblages, the data suggest that even when the prehistoric sub-assemblages are combined, the difference in the means for the first annulus to the second annulus is present here as well.

Table 6.7. Descriptive Statistics for Prehistoric and Modern Red Drum Assemblages

Time Period	Annuli	N	Mean	Std Dev	Std Error	Median	Variance	Min	Max	Range
Prehistoric	Core to 1st	34	1.41	0.13	0.02	1.41	0.02	1.07	1.72	0.65
Modern		7224	1.43	0.13	0.00	1.43	0.02	0.81	2.09	1.28
Prehistoric	1st to 2nd	22	0.46	0.10	0.02	0.47	0.01	0.25	0.67	0.41
Modern		3914	0.54	0.08	0.00	0.54	0.01	0.16	0.86	0.70
Prehistoric	2nd to 3rd	7	0.36	0.07	0.03	0.35	0.01	0.24	0.48	0.24
Modern		1417	0.42	0.06	0.00	0.42	0.00	0.21	0.63	0.42
Prehistoric	3rd to 4th	3	0.29	0.04	0.02	0.27	0.00	0.26	0.34	0.07
Modern		826	0.32	0.06	0.00	0.32	0.00	0.15	0.52	0.37
Modern	4th to 5th	683	0.23	0.05	0.00	0.23	0.00	0.08	0.43	0.35
Modern	16th to 17th	185	0.12	0.02	0.00	0.11	0.00	0.06	0.19	0.13

The results of the independent samples t-tests for the prehistoric and modern red drum otolith assemblages are provided in Table 6.8. The results indicate a significant difference between the means of two annuli. The analysis of the first annulus to the second annulus indicates there is a significant difference in the mean widths between the prehistoric and modern assemblages ($t(3934)=-5.26$, $p=0.000$). The analysis of the second annulus to third annulus also revealed a significant difference in the means ($t(1422)=-2.77$, $p=0.006$).

Table 6.8. Results of Independent Samples T-Test for Prehistoric and Modern Red Drum Assemblages

Otolith Annuli Area	Time Period	N	Levene's Test for Equality of Variance			Independent Samples Test: t-test for Equality of Means								
				F	Sig	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	Upper	Hypothesis test: Accept Null	Reject Null
Core to 1st Annulus	Prehistoric	34	Equal variances assumed	0.20	0.65	-0.90	7256	0.37	-0.02	0.02	-0.06	0.02	t(7256)=-0.90, p=0.370	
	Modern	7224	Equal variances not assumed			-0.88	33.30	0.39	-0.02	0.02	-0.07	0.03		
1st Annulus to 2nd Annulus	Prehistoric	22	Equal variances assumed	2.93	0.09	-5.26	3934	0.00	-0.09	0.02	-0.12	-0.06		t(3934)=-5.26, p=0.000
	Modern	3914	Equal variances not assumed			-3.99	21.14	0.00	-0.09	0.02	-0.14	-0.04		
2nd Annulus to 3rd Annulus	Prehistoric	7	Equal variances assumed	0.00	0.95	-2.77	1422	0.01	-0.06	0.02	-0.11	-0.02		t(1422)=-2.77, p=0.006
	Modern	1417	Equal variances not assumed			-2.32	6.04	0.06	-0.06	0.03	-0.13	0.00		
3rd Annulus to 4th Annulus	Prehistoric	3	Equal variances assumed	0.79	0.38	-0.74	827.00	0.46	-0.03	0.04	-0.10	0.04	t(827)=-0.74, p=0.461	
	Modern	826	Equal variances not assumed			-1.14	2.04	0.37	-0.03	0.02	-0.13	0.07		
1st Annulus to 2nd Annulus	Crystal River	15	Equal variances assumed	2.09	0.15	6.15	3927	0.00	0.13	0.02	0.09	0.17		t(3927)=6.151, p=0.000
	Modern	3914	Equal variances not assumed			5.16	14.08	0.00	0.13	0.02	0.07	0.18		
	Roberts Island	7	Equal variances assumed	0.02	0.89	0.35	3919	0.73	0.01	0.03	-0.05	0.07	t(3919)=0.345, p=0.730	
	Modern	3914	Equal variances not assumed			0.33	6.02	0.76	0.01	0.03	-0.07	0.09		
2nd Annulus to 3rd Annulus	Crystall River	6	Equal variances assumed	0.86	0.36	-3.36	1421	0.00	-0.08	0.03	-0.13	-0.04		t(1421)=-3.36, p=0.001
	Modern	1417	Equal variances not assumed			-3.72	5.05	0.01	-0.08	0.02	-0.14	-0.03		
	Roberts Island	1	Equal variances assumed	.	.	0.91	1416	0.36	0.06	0.06	-0.06	0.18	t(1416)=0.909, p=0.363	
	Modern	1417	Equal variances not assumed			.	.	.	0.06	.	.	.		

To examine these differences further, I conducted additional independent samples t-tests to compare the archaeological sub-assemblages from each site to the modern dataset. This analysis indicated that the difference is the result of smaller width of the growth bands of the Crystal River otoliths. The results show there is a significant difference between the first annulus to the second annulus of the Crystal River and modern red drum otoliths ($t(3927)=6.151$, $p=0.000$). The results also show a significant difference between the second annulus to the third annulus of the Crystal River and modern red drum otoliths ($t(1421)=-3.36$, $p=0.001$), although it must be noted that there is only a single otolith from Roberts Island to compare to the modern assemblage for the second annulus to the third annulus. While a small sample size from Roberts Island could be the reason for the difference, another plausible explanation is that these fishes experienced an environmental disturbance. As noted earlier with Jackson's (2016:65-97) research, numerous climatic and environmental shifts occurred during the timespan of these sites being occupied, including the Wulfert High Stand, the Roman Warm Period, the Buck Key Low, and the Vandal Minimum.

In sum, the annuli widths of the archaeological and modern assemblages correspond well, with the exception of the aforementioned two annuli from the Crystal River assemblage. Since the means of these two annuli are smaller, it will be necessary to account for the differences when assigning seasons for these Crystal River otoliths. There are a variety of reasons that could account for the differences between these two assemblages, including change within growth rates of the species over time, harvesting pressure, aforementioned environmental disturbances or small sample sizes. Unfortunately, the answer to this question cannot be answered through this research but could be explored with future research. Additionally, the bimodal distributions during the cooler months is confirmed and represents the conclusion of one annulus forming (the opaque growth zone associated with less activity and growth during cooler months) and the beginning of a new annulus forming (the hyaline zone begins again as activity and increases as temperatures warm and more food is available).

Marginal Increment Analysis and Results

Figures 6.2 – 6.6 display the mean marginal increment widths for the calendar months of modern red drum otoliths. Visual analyses of these graphs suggest increased growth by months, except for the months of September and November, for otoliths with the fourth annulus present. However, it is important to note that several months either have no representative samples or small sample sizes. Therefore, caution must be taken when assigning underrepresented months.

Further, these seasonal designations for the archaeological otoliths with measurements that fall within these graphs suggest that new annuli are formed during the months of December through March for all annuli, with the exception again of the fourth annulus. The dip in annuli marginal increment widths during the months of September and November may suggest the fifth annulus begins development earlier than the preceding annuli. Examination of the histograms in the next section will shed light on whether this is true.

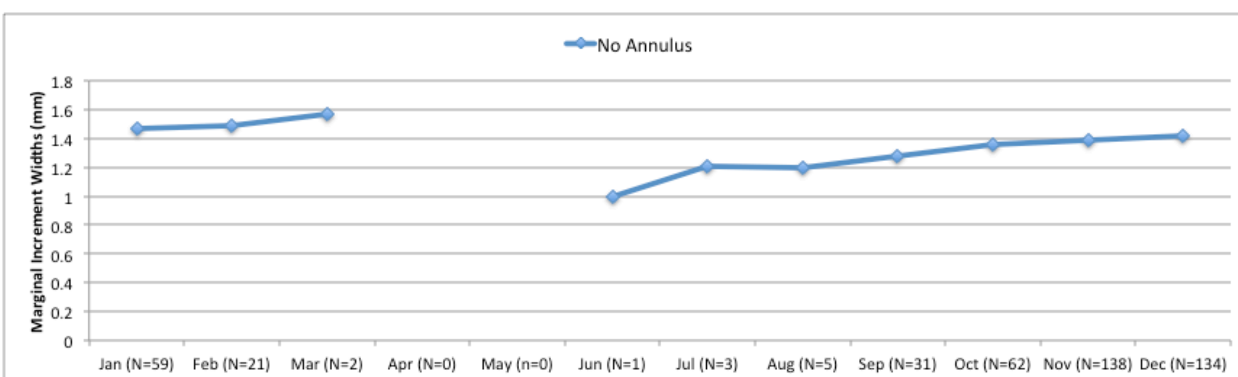

Figure 6.2. Means of Monthly Marginal Increment Widths for Red Drum Otoliths with No Annulus Present

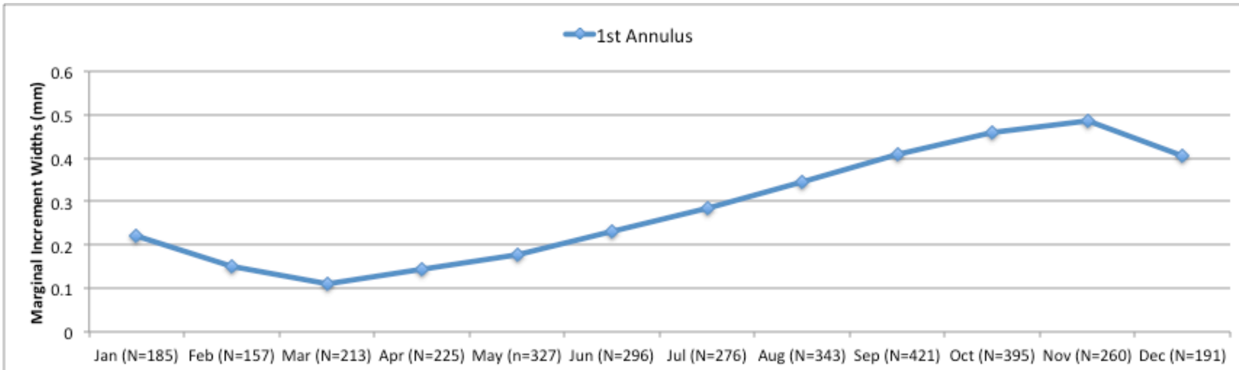

Figure 6.3. Means of Monthly Marginal Increment Widths for Red Drum Otoliths with One Annulus Present

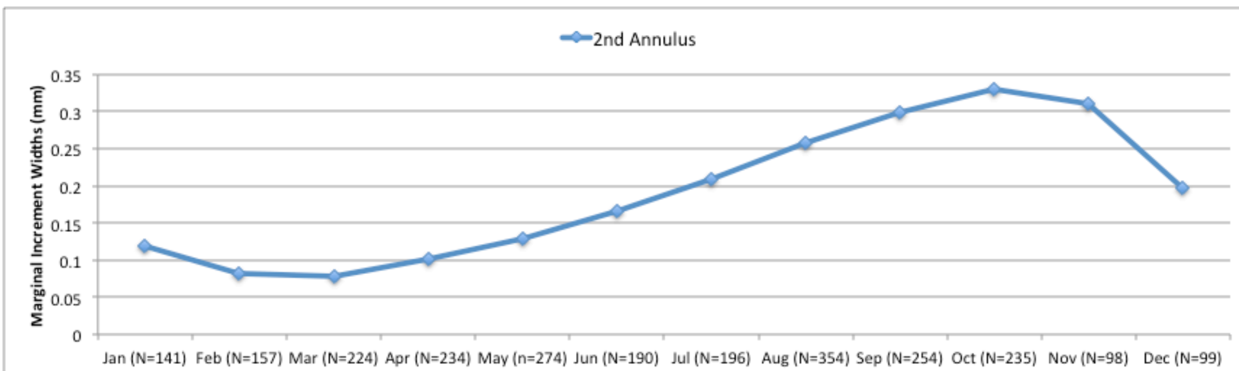

Figure 6.4. Means of Monthly Marginal Increment Widths for Red Drum Otoliths with Two Annuli Present

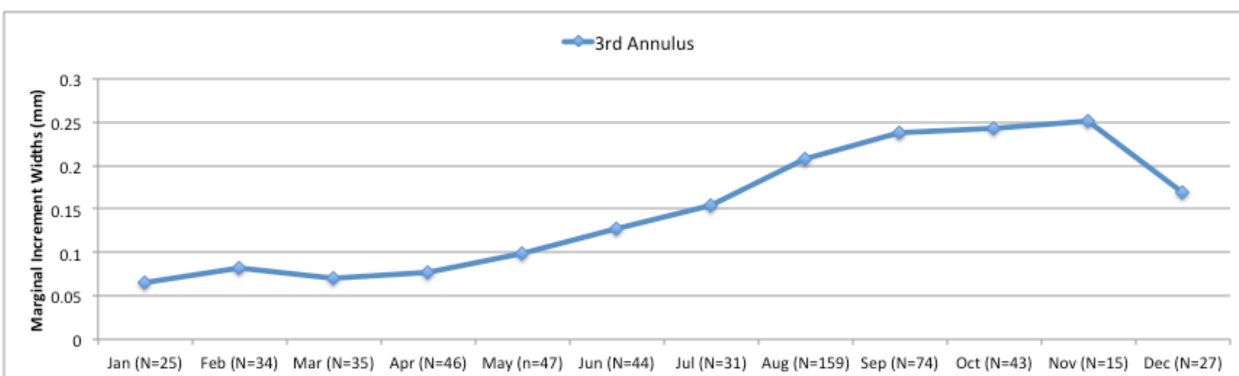

Figure 6.5. Means of Monthly Marginal Increment Widths for Red Drum Otoliths with Three Annuli Present

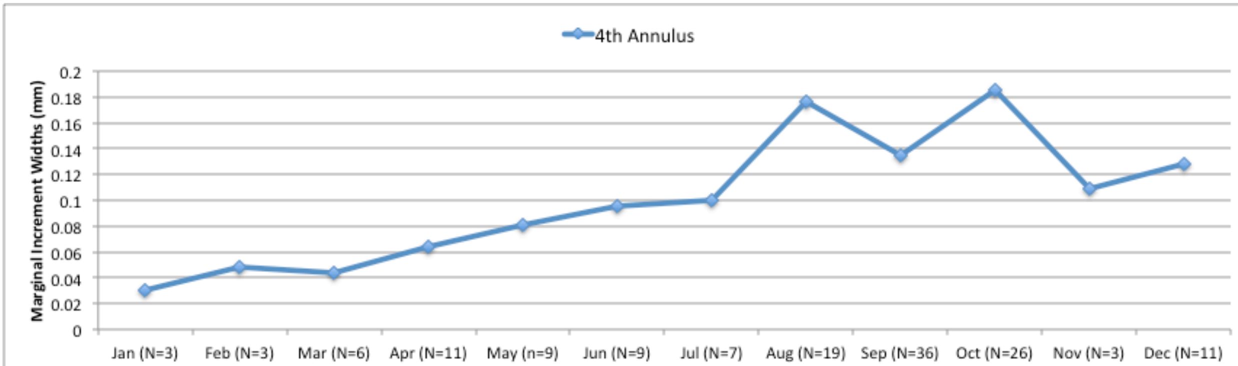

Figure 6.6. Means of Monthly Marginal Increment Widths for Red Drum Otoliths with Four Annuli Present

The spread of the monthly marginal increments is a crucial element of the analysis. Appendix A provides the descriptive statistics and histograms for each month and fish age group. These monthly histograms were used, in conjunction with Palmiotto's (2016) study, to create the histograms for the seasonally grouped modern marginal increments of red drum otoliths presented in Figures 6.7 - 6.11 (see Appendix A for associated descriptive statistics).

My analysis divides the samples into the following categories: Cool Season (December, January, and February); Late Cool Season (March); Early Warm Season (April and May); Late Warm Season (June, July, August, and September); and Early Cool Season (October and November). The first general observation from these histograms is that the otoliths with no annulus present do not appear to follow the same general pattern as the other annuli. The distributions suggest that seasonal designations will have to be broad for the archaeological otoliths with no annulus present and can only be defined between cool months (December, January, February, March, October, and November) and warm months (June, July, and August). This pattern could be a result of the low sample sizes available from the modern comparative assemblage. However, it is also possible that young-of-year fishes exhibit a wider range of growth rates throughout the months of the year due to differing hatch dates.

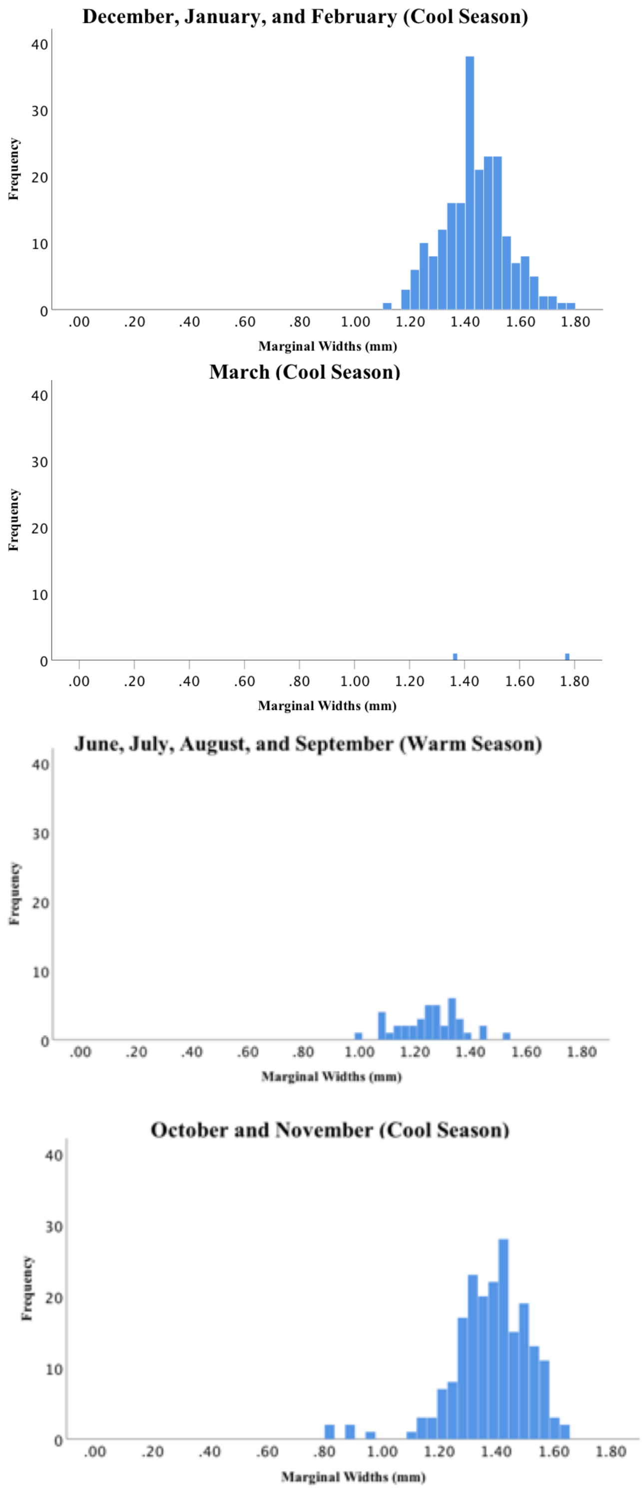

Figure 6.7. Seasonal Histograms for Red Drum with No Annulus Present

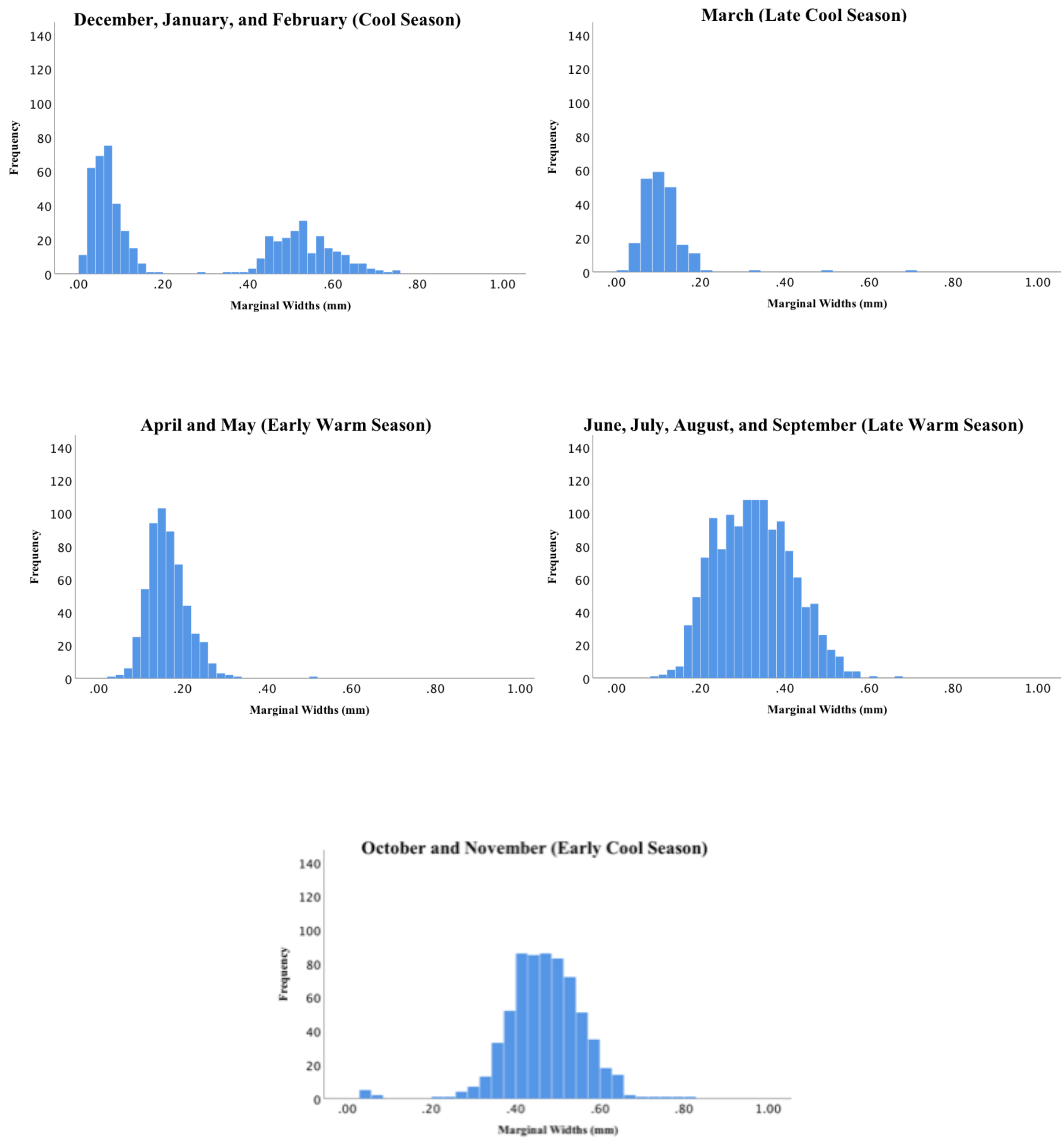

Figure 6.8. Seasonal Histograms for Red Drum with One Annulus Present

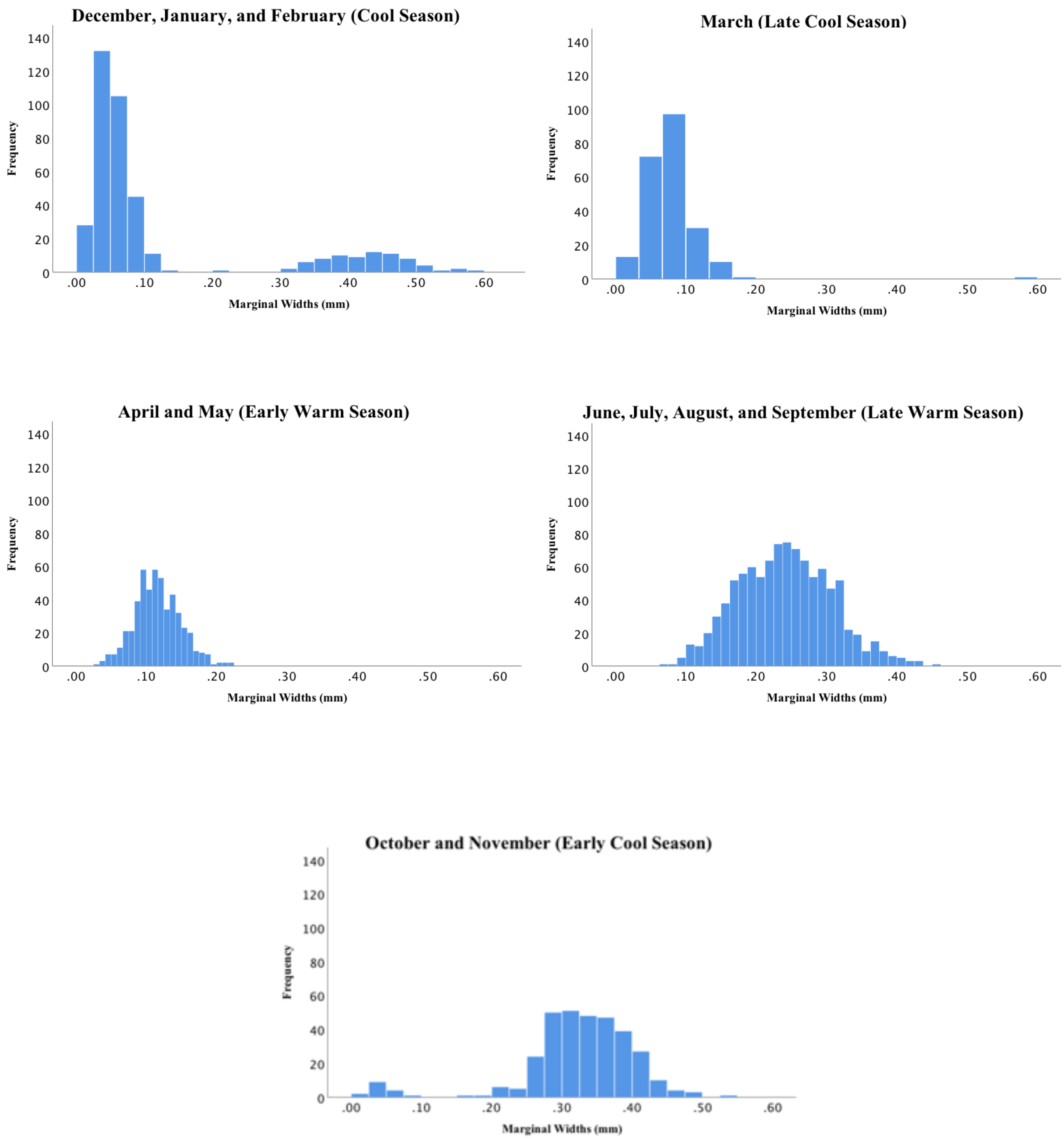

Figure 6.9. Seasonal Histograms for Red Drum with Two Annuli Present

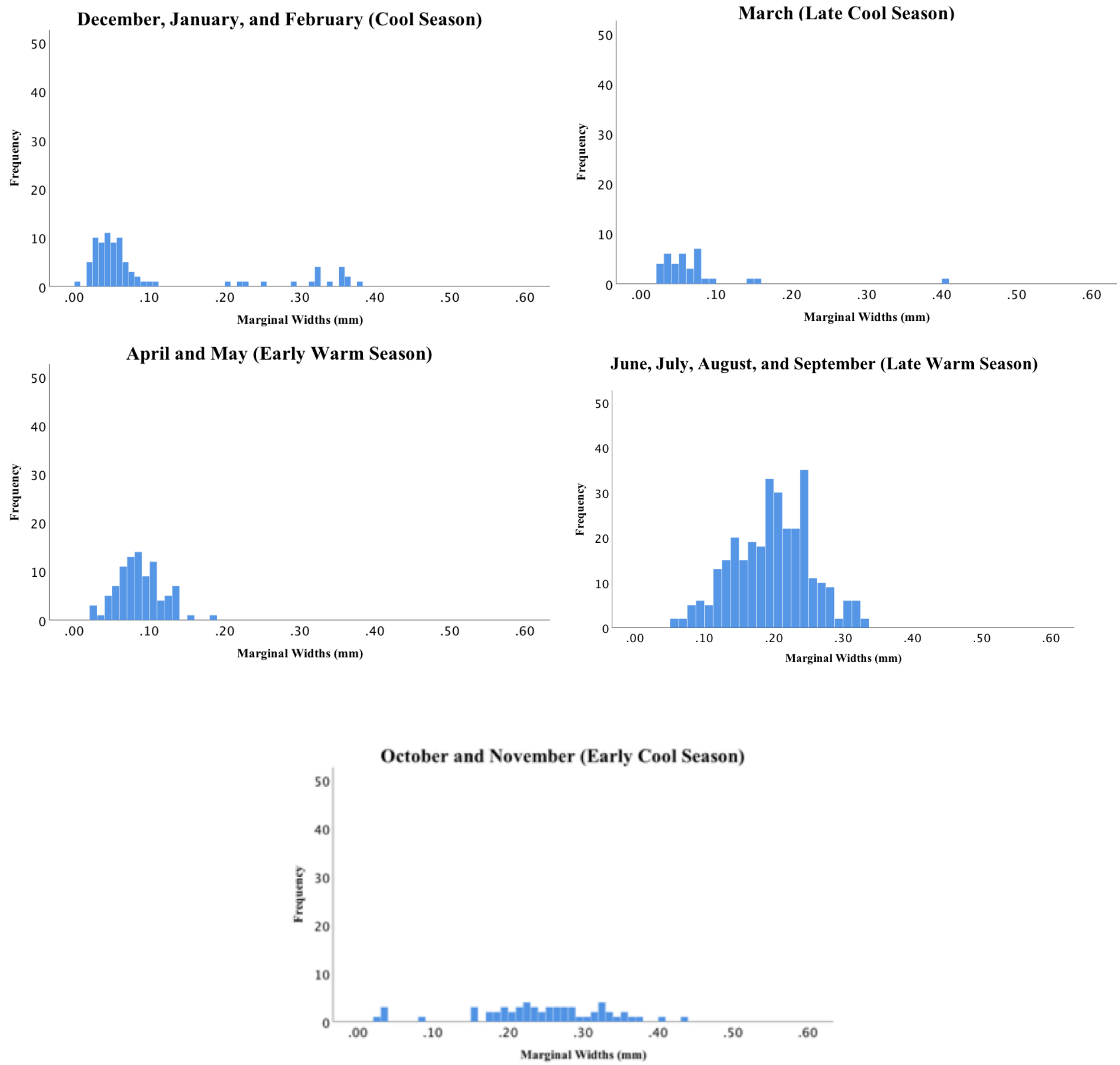

Figure 6.10. Seasonal Histograms for Red Drum with Three Annuli Present

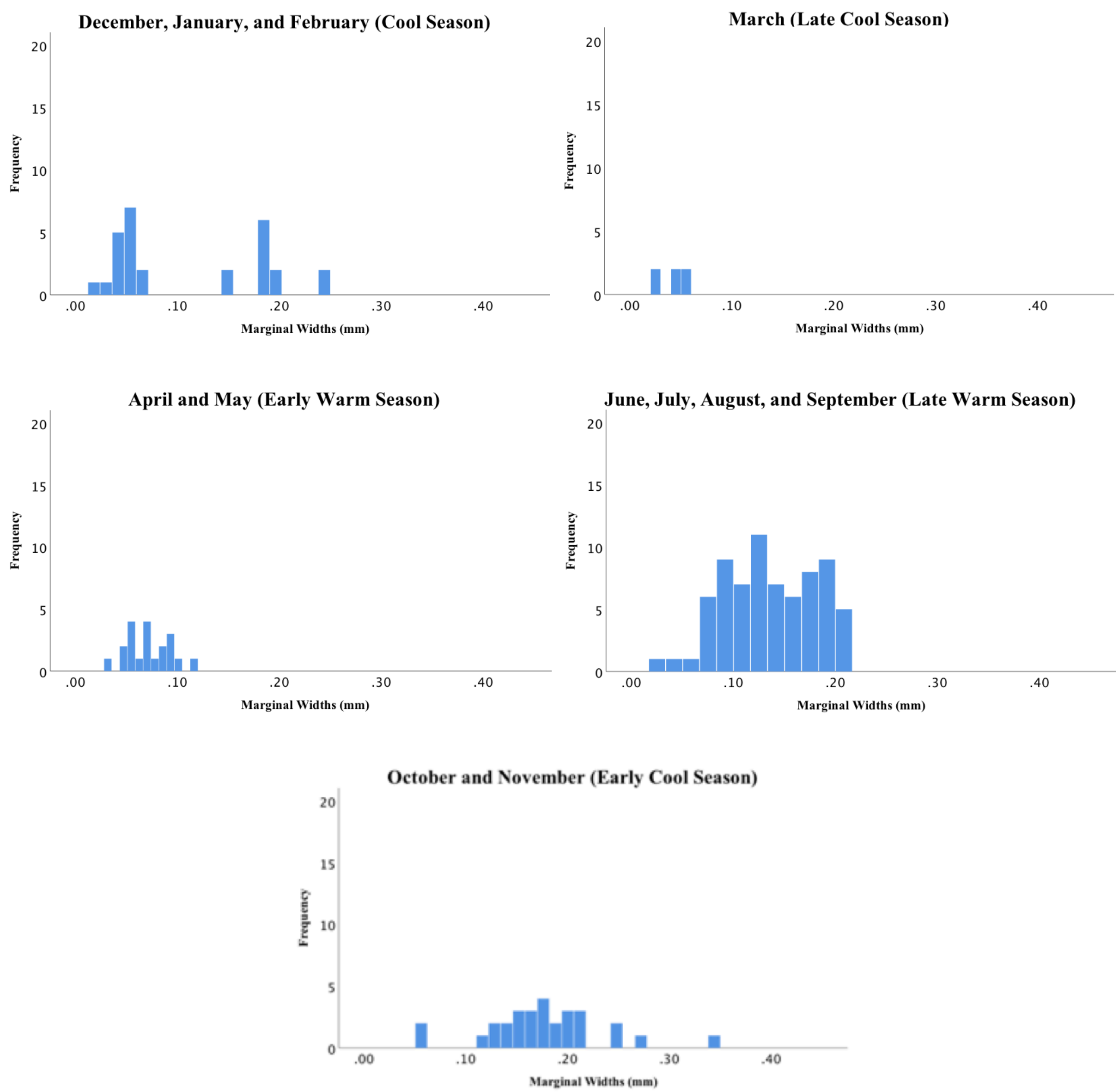

Figure 6.11. Seasonal Histograms for Red Drum with Four Annuli Present

Second, otoliths with annuli one, two, three, and four present appear to follow the same general patterns. During the months of December, January, February, and March, the distributions are split between the left side of the histograms, which suggests new annulus growth, and the right side of the histograms, which suggests the conclusion of growth for the annulus. These months correspond with two of Palmiotto's (2016) seasonal groupings. Thus, the designations of Cool Season (December – February) and Late Cool Season (March) are used for the seasonal designation of the archaeological otoliths with these measured marginal increment widths. April and May, Palmiotto's (2016) Warm Dry season, consist of marginal increment widths that suggest early growth for the annuli and is designated the Early Warm Season. During the months of June, July, August, and September, the marginal increment widths have shifted to the midpoint of growth for the annuli. Palmiotto (2016) refers to this grouping of months as the Warm Wet season but, here, is designated the Late Warm Season. October and November have marginal increment widths that have shifted past the midpoint and begin to align with the means of the annuli; this shift suggests that growth is still occurring but has slowed and nearing completion. Additionally, there appear to be a few otoliths that with very low marginal increment widths, suggesting new annuli can form during these months. These occurrences, however, do not appear to be the norm. Palmiotto (2016) has these months grouped with December and January, however, I have separated these months and designated October and November as the Early Cool Season since it aligns better with the growth patterns.

Next, I integrate the previously described analyses to assign seasonality for the archaeological otoliths. Figures 6.12 – 6.16 present the marginal increment widths of the archaeological red drum otoliths, the mean marginal increment widths for the seasonal groupings, and the mean widths of the corresponding annulus for each site, the combined archaeological sub-assemblages, and the modern assemblage.

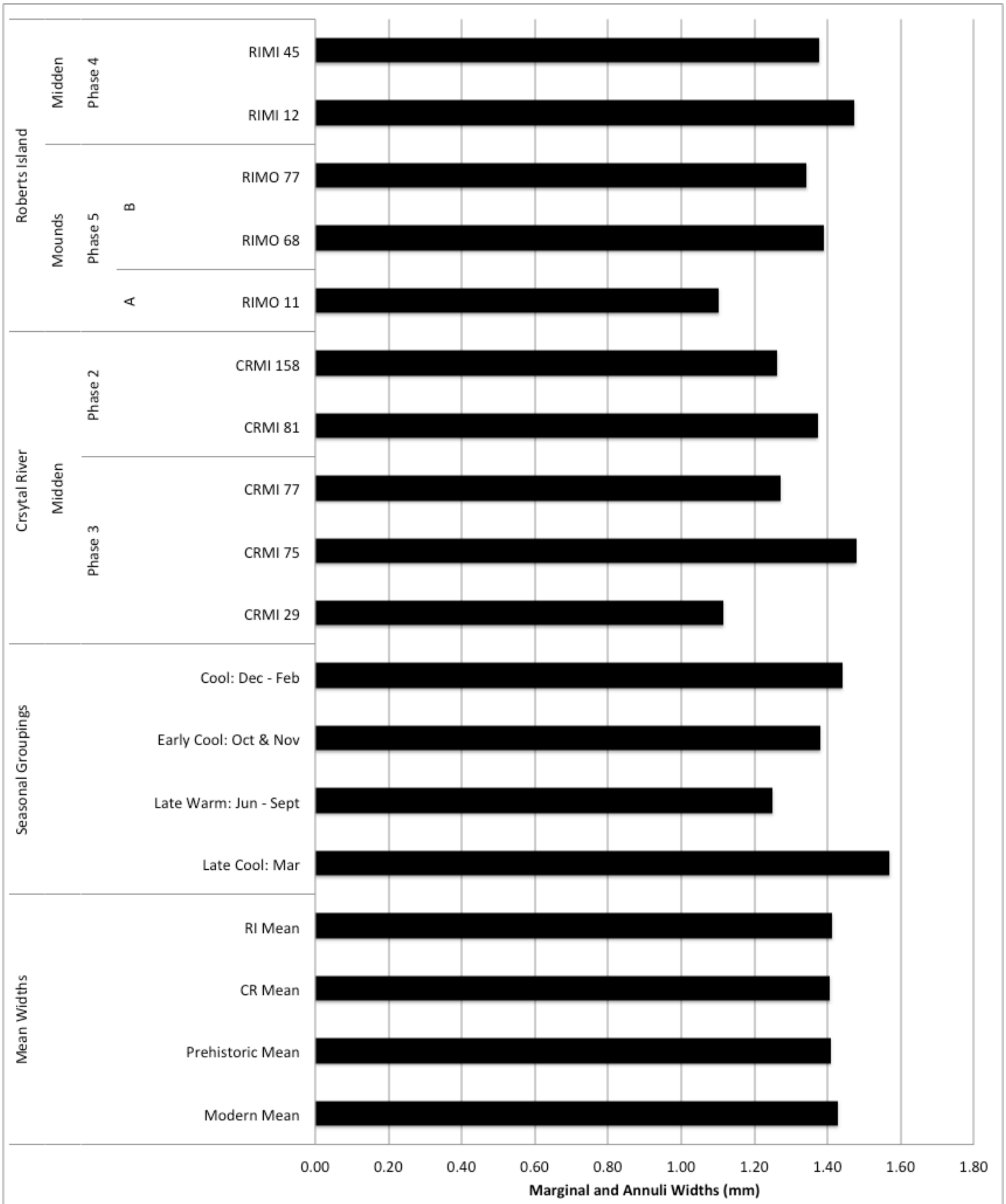

Figure 6.12. Bar Graph of Red Drum with No Annulus Present. Graph includes: Marginal Widths (mm) of Archaeological Otoliths with Temporal and Site Contexts, Marginal Widths (mm) for Seasonal Groupings, and Mean Annuli Widths (mm) for Sites and Time Periods

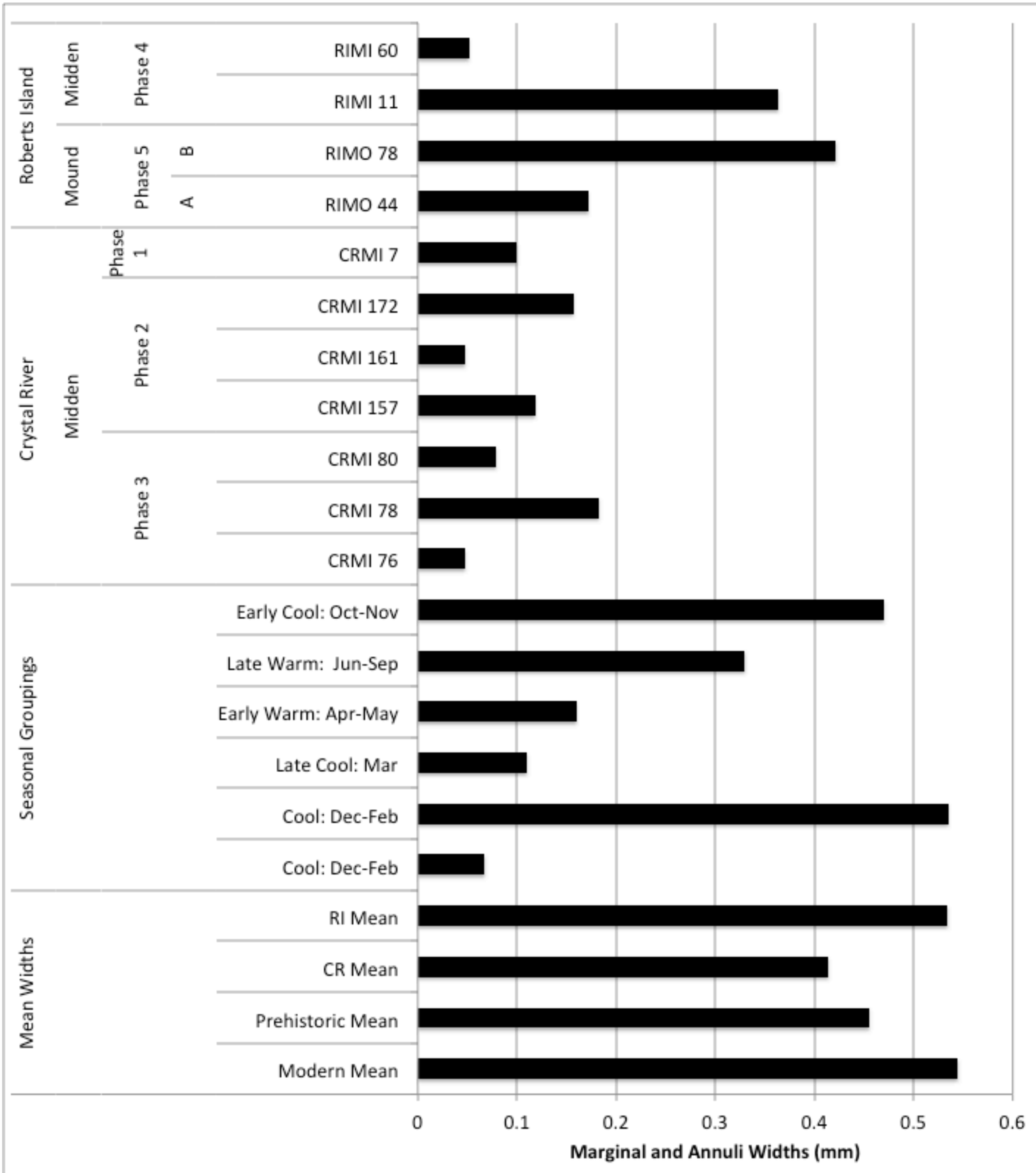

Figure 6.13. Bar Graph of Red Drum with One Annulus Present. Graph includes: Marginal Widths (mm) of Archaeological Otoliths with Temporal and Site Contexts, Marginal Widths (mm) for Seasonal Groupings, and Mean Annuli Widths (mm) for Sites and Time Periods

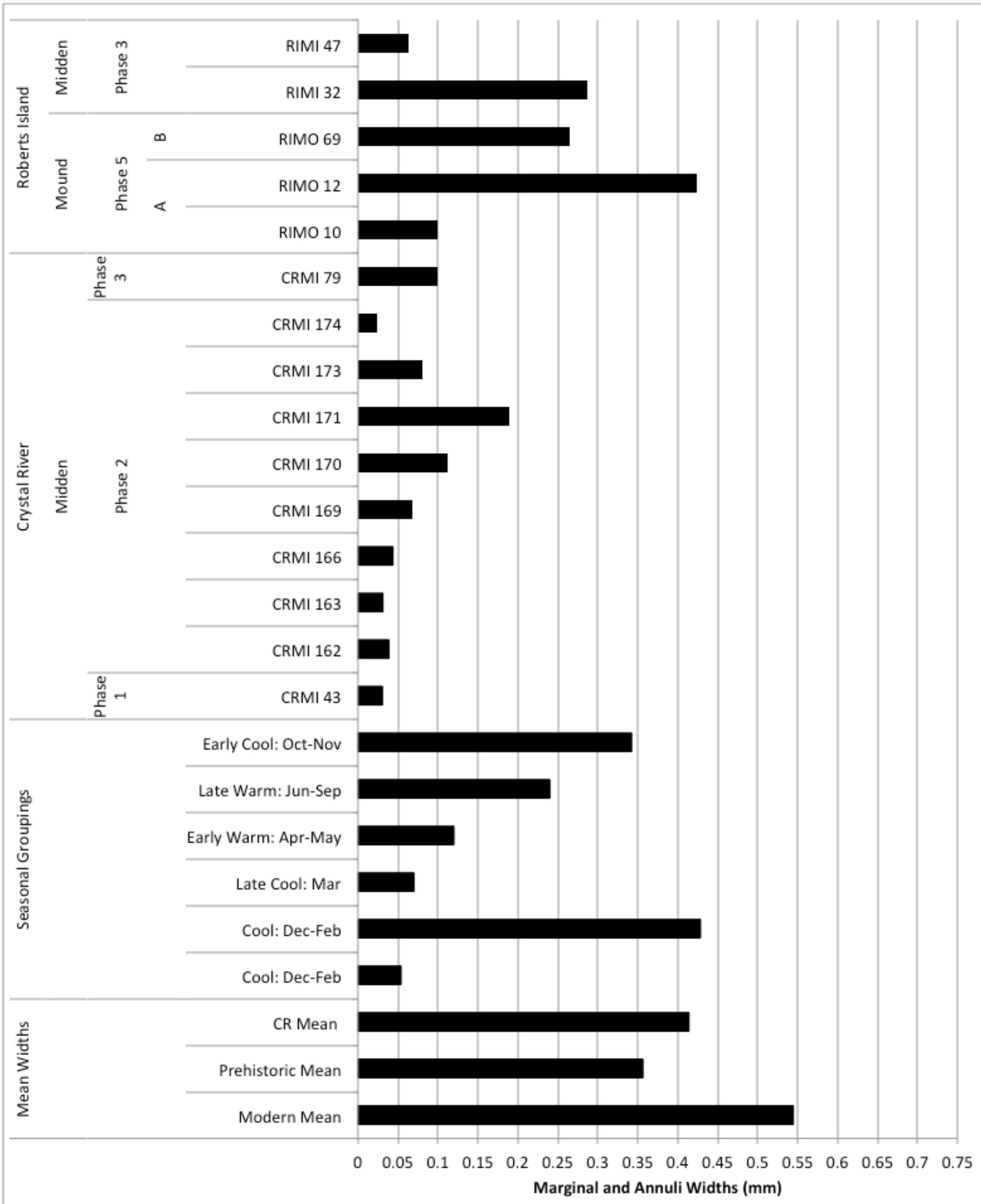

Figure 6.14. Bar Graph of Red Drum with Two Annuli Present. Graph includes: Marginal Widths (mm) of Archaeological Otoliths with Temporal and Site Contexts, Marginal Widths (mm) for Seasonal Groupings, and Mean Annuli Widths (mm) for Sites and Time Periods

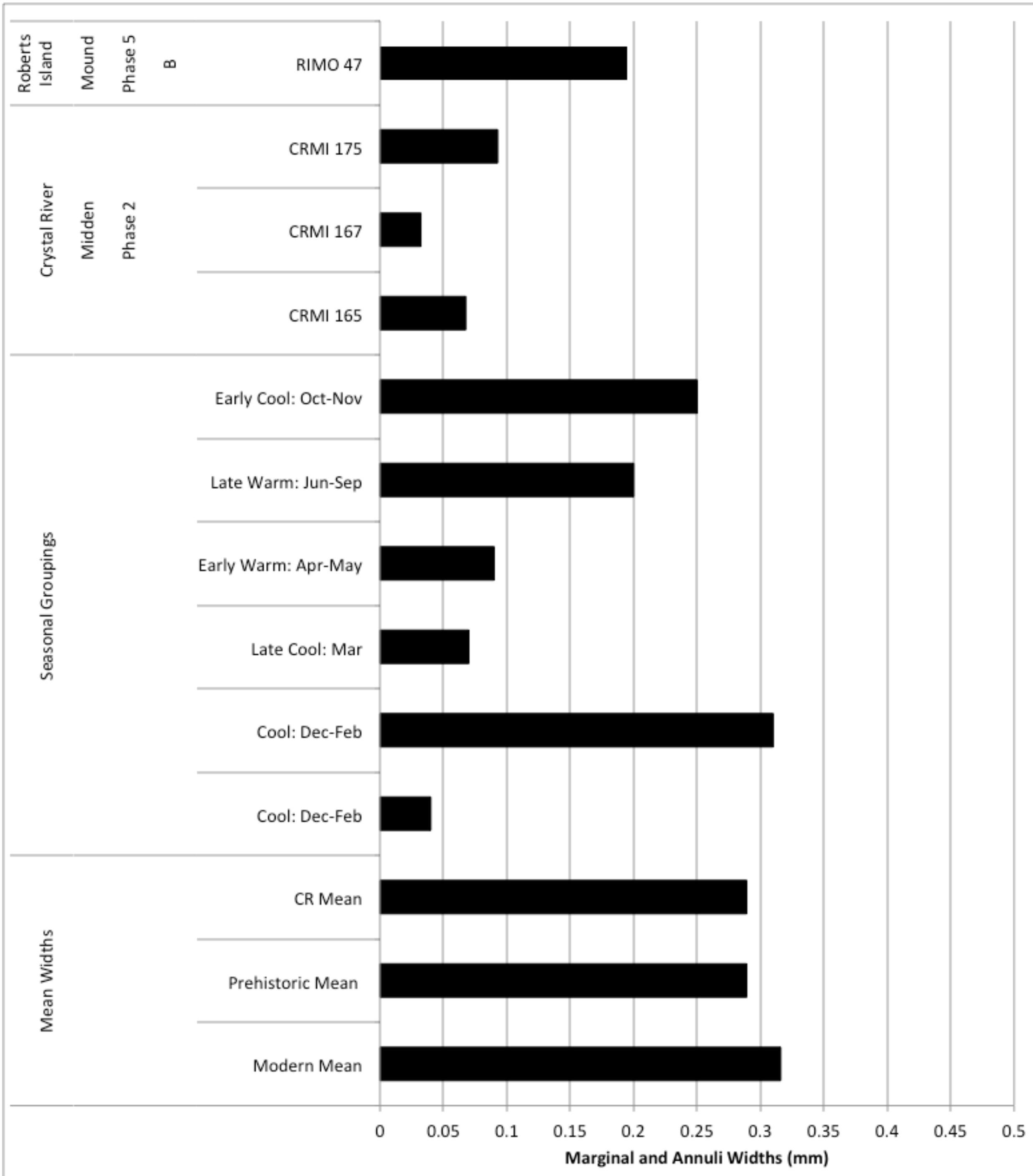

Figure 6.15. Bar Graph of Red Drum with Three Annuli Present. Graph includes: Marginal Widths (mm) of Archaeological Otoliths with Temporal and Site Contexts, Marginal Widths (mm) for Seasonal Groupings, and Mean Annuli Widths (mm) for Sites and Time Periods

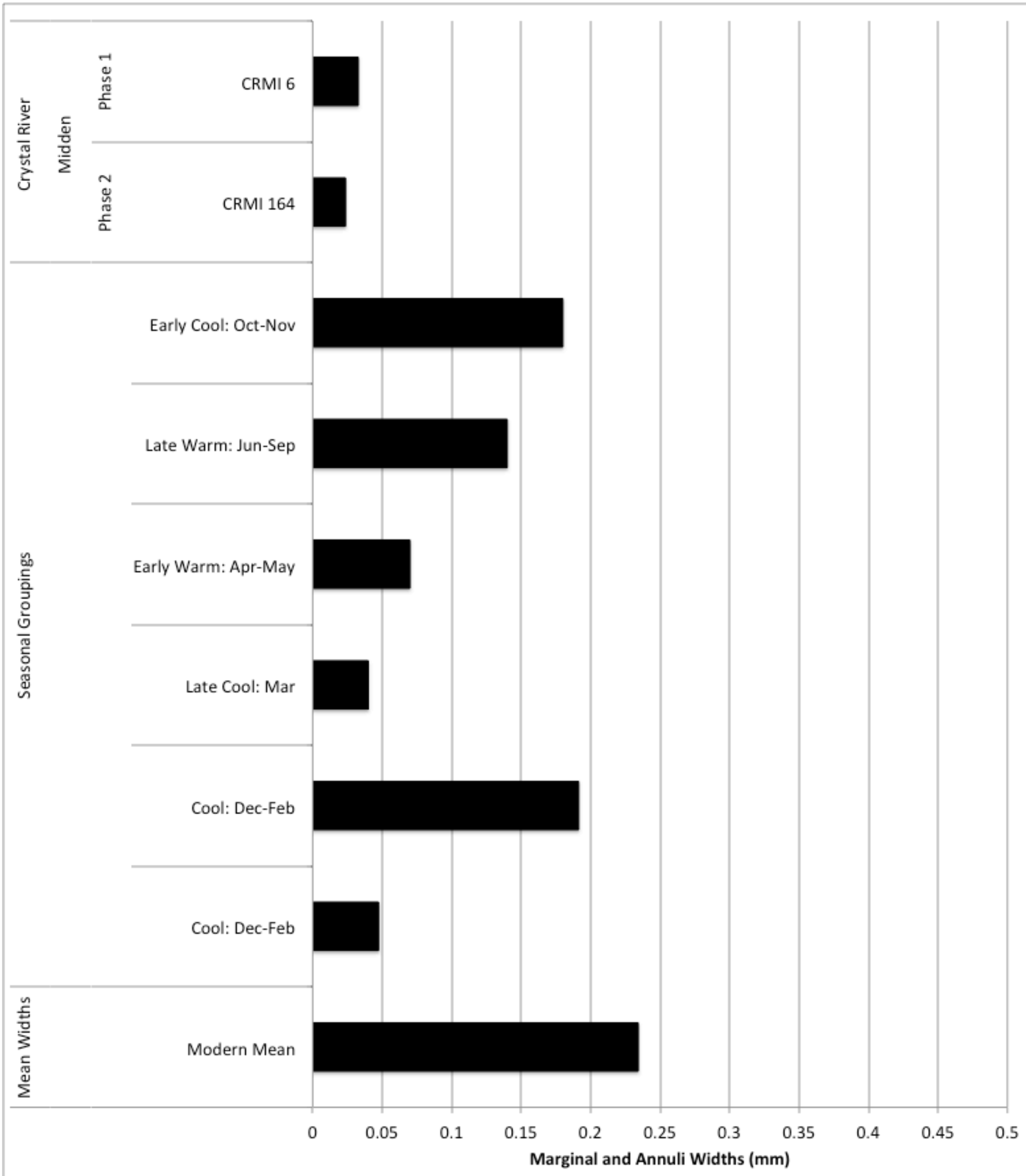

Figure 6.16. Bar Graph of Red Drum with Four Annuli Present. Graph includes: Marginal Widths (mm) of Archaeological Otoliths with Temporal and Site Contexts, Marginal Widths (mm) for Seasonal Groupings, and Mean Annuli Widths (mm) for Sites and Time Periods

These results are organized by annuli count and site. Contextual information, including area of the sites and occupational phase, are also provided. This presentation of the results is a crucial step for assigning seasonal determinations. However, it is difficult to discern meaningful and interpretive information because it is organized by annuli. I am able to easily infer that red drum with no annulus were caught in both warm and cool months at both sites. Additionally, red drum otoliths with one annulus from both sites are present for all types of seasonal designations. Further, the same variety of seasons is found with red drum otoliths that have two annuli present, except it lacks evidence for capture during the Early Cool Season. Red drum otoliths with three annuli present indicate harvesting during the Late Warm, Early Cool, and Cool Seasons when site assemblages are combined. Lastly, red drum otoliths with four annuli present, only found in the Crystal River sub-assemblage, indicate they were caught in the Cool and Late Cool Seasons. Taken all together, these seasonality results suggest that red drum were at some point caught during all seasons by the peoples that once lived at or visited these sites.

Red Drum Seasonality Results Summary

Using all the aforementioned results, Figure 6.17 presents a clear picture of the seasons red drum were captured at Crystal River and Roberts Island. The results offer interesting insight into the larger discussion of activities that were taking place at these sites. First, Pluckhahn and Thompson (2018:103) believe the site was only seasonally occupied during the beginning of Mound Phase 2 and Midden Phase 1 at Crystal River, an assertion supported by their oyster study (Thompson et al. 2015). The evidence from this study further supports that assertion with all three red drum otoliths recovered from the earliest midden contexts (lowest levels of Trenches 1 and 2) indicating capture during the cooler months of the year. Second, the quantity and seasonal designations for the otoliths recovered from Mound Phase 3 and Midden Phase 2 contexts at Crystal River also supports Pluckhahn and Thompson's (2018:153-154) belief that during this occupation period the site was inhabited throughout the year and activity at the site was at its pinnacle. Third, the results also support Pluckhahn and Thompson's (2018:166-167) assertion that activities declined at Crystal River during Mound Phase 4 and Midden Phase 3, which are evidenced by the decrease in quantity of otoliths. They suggest from their extensive research that the site was still occupied throughout the year but possibly only by residents of higher status individuals who remained at Crystal River to take care of the mounds and perform rituals. Results from my red drum study supports their notion that the site was still occupied during both cool and warm seasons. Unfortunately, no red drum otoliths were analyzed for this study from Mound Phase 5 Midden Phase 4 contexts at Crystal River.

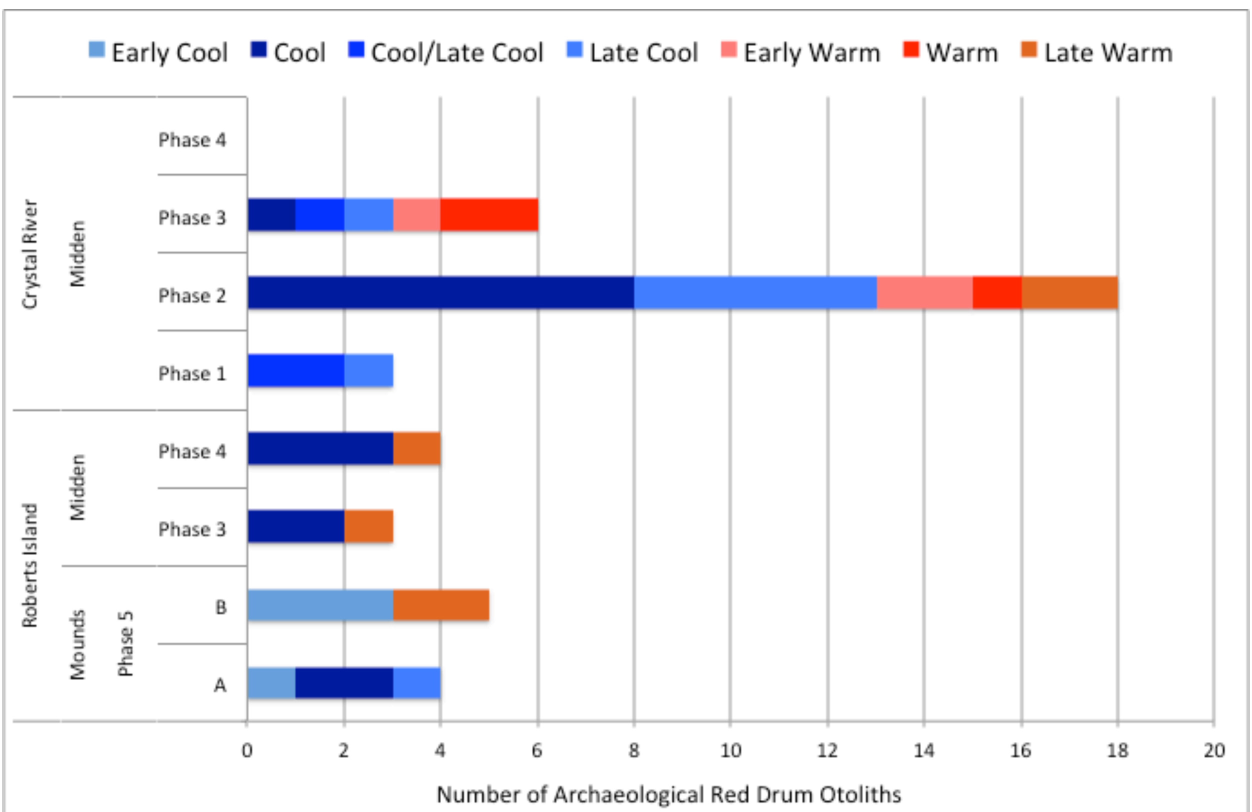

Figure 6.17. Crystal River and Roberts Island Seasonality Results for Red Drum

The red drum otoliths from Roberts Island provide additional insight into activity at this site. As noted in Chapter 2, activity at Roberts Island increased during Mound Phase 4 and Midden Phase 3. Pluckhahn and Thompson (2018:159) observed in their shovel tests an abundance of artifacts recovered in the lower levels and interrupt from this evidence that occupation and construction began at this site during these intervals, albeit on a small scale. While the Roberts Island red drum otolith assemblage is very small (N=3), it does suggest the site was at least occupied during both cool and warm seasons.

The final phase of construction and habitation of Roberts Island occurs in Mound Phase 5 and Midden Phase 4. Pluckhahn and Thompson (2018:168-193) believe that during this period both mounds were constructed during cooler months (Thompson et al. 2015) and Roberts Island became the new civic ceremonial center in the area. The complete red drum assemblage for this phase remains relatively small (N=11) and suggests an increase in activity when compared to the preceding phase's assemblage. The red drum seasonality results from mound contexts suggest agreement for Mound A, with cooler month signatures. However, my data disagree with their assessment of Mound B, with both late warm and early cool seasonal designations.

Spotted Seatrout: Results

Annuli Count and Width Comparative Collections

As with the analysis of the red drum assemblage, my first analytical step for the spotted seatrout assemblages was to determine the number of annuli present on each archaeological seatrout otolith from Crystal River and Roberts Island. In both of these assemblages, the analysis suggests that adult spotted seatrout were targeted most frequently. In fact, only two otoliths had less than two annuli present in both archaeological assemblages. Table 6.9 provides the number of annuli present on each archaeological spotted seatrout. This preference could be a sign of the size nets that were used to capture this species. The presence of a wider range of age groupings with this species is not too surprising since spotted seatrout spend almost their entire lives in estuaries and around rivers (Bester 2021).

Table 6.9. Crystal River and Roberts Island Spotted Seatrout Otoliths and Number of Annuli Present

Otolith ID	Site Location	FS #	Annuli Present	Otolith ID	Site Location	FS #	Annuli Present
CRMI 4	Midden	695	3	CRMI 142	Midden	1150	3
CRMI 5	Midden	694	3	CRMI 143	Midden	1148	4
CRMI 10	Midden	681	2	CRMI 144	Midden	1148	2
CRMI 13	Midden	670	2	CRMI 145	Midden	1135	5
CRMI 18	Midden	655	2	CRMI 146	Midden	1135	3
CRMI 27	Midden	624	3	CRMI 147	Midden	1156	5
CRMI 28	Midden	624	3	CRMI 148	Midden	1156	4
CRMI 33	Midden	611	3	CRMI 149	Midden	1156	5
CRMI 40	Midden	673	4	CRMI 150	Midden	1154	3
CRMI 67	Midden	1086	5	CRMI 151	Midden	1154	3
CRMI 68	Midden	1088	4	CRMI 152	Midden	1154	6
CRMI 69	Midden	1089	5	CRMI 153	Midden	1149	0
CRMI 70	Midden	1089	2	CRMI 154	Midden	1149	2
CRMI 71	Midden	1091	2	CRMI 155	Midden	1149	Removed
CRMI 72	Midden	1107	3	CRMI 156	Midden	1168	Removed
CRMI 73	Midden	1105	2	CRMO 2	Mound A	SS546	7
CRMI 74	Midden	1132	3	RIMI 52	Midden	247	Removed
CRMI 122	Midden	1085	4	RIMI 59	Midden	127	4
CRMI 123	Midden	1106	3	RIMI 60	Midden	132	2
CRMI 124	Midden	1114	2	RIMI 61	Midden	205	2
CRMI 125	Midden	1114	3	RIMI 62	Midden	263	4
CRMI 126	Midden	1118	4	RIMI 63	Midden	276	3
CRMI 127	Midden	1118	3	RIMI 64	Midden	276	4
CRMI 128	Midden	1119	Removed	RIMI 65	Water Court	251	Removed
CRMI 129	Midden	1119	Removed	RIMI 66	Midden	176	5
CRMI 130	Midden	1119	4	RIMI 67	Midden	132	4
CRMI 131	Midden	1142	3	RIMO 13	Mound A	155A	5
CRMI 132	Midden	1142	1	RIMO 14	Mound A	164	4
CRMI 133	Midden	1144	3	RIMO 15	Mound A	164	4
CRMI 134	Midden	1145	2	RIMO 16	Mound A	219	2
CRMI 135	Midden	1145	Removed	RIMO 26	Mound A	219	7
CRMI 136	Midden	1145	6	RIMO 27	Mound A	219	2
CRMI 137	Midden	1145	3	RIMO 37	Mound A	157	5
CRMI 138	Midden	1141	4	RIMO 45	Mound B	591	5
CRMI 139	Midden	1141	5	RIMO 49	Mound B	603	7
CRMI 140	Midden	1141	5	RIMO 55	Mound B	604	6
CRMI 141	Midden	1146	2	RIMO 67	Mound B	606	4

Table 6.10. Descriptive Statistics for Crystal River and Roberts Island Spotted Seatrout Assemblages

Site	Annuli	N	Mean	Std Dev	Std Error	Median	Variance	Min	Max	Range
Crystal River	Core to 1st	45	0.97	0.12	0.02	0.97	0.01	0.67	1.19	0.52
	1st to 2nd	44	0.62	0.09	0.01	0.62	0.01	0.31	0.79	0.48
	2nd to 3rd	31	0.43	0.06	0.01	0.44	0.00	0.28	0.53	0.26
	3rd to 4th	15	0.36	0.04	0.01	0.34	0.00	0.30	0.41	0.11
	4th to 5th	9	0.32	0.04	0.01	0.31	0.00	0.25	0.36	0.11
	5th to 6th	3	0.29	0.09	0.05	0.25	0.01	0.22	0.40	0.17
Roberts Island	Core to 1st	20	1.01	0.12	0.03	1.03	0.02	0.76	1.22	0.46
	1st to 2nd	20	0.62	0.07	0.02	0.62	0.01	0.48	0.77	0.29
	2nd to 3rd	15	0.42	0.06	0.02	0.41	0.00	0.32	0.56	0.23
	3rd to 4th	14	0.38	0.05	0.01	0.39	0.00	0.28	0.49	0.20
	4th to 5th	7	0.30	0.04	0.02	0.31	0.00	0.22	0.37	0.14
	5th to 6th	3	0.29	0.02	0.01	0.30	0.00	0.27	0.31	0.04
	6th to 7th	2	0.24	0.01	0.01	0.24	0.00	0.23	0.25	0.01

Descriptive statistics and independent samples t-tests were utilized again to explore differences in the datasets and compare the means of the annuli widths for the Crystal River and Roberts Island assemblages. Table 6.10 summarizes the results of the descriptive statistics. The analysis suggests there could be a statistically significant difference between one of the growth band widths of the two assemblages. Specifically, the mean growth band widths from the core to the first annulus appear smaller at Crystal River than Roberts Island.

The results of the independent samples t-tests are provided in Table 6.11. The test reveals there are not any statistically significant differences between the mean growth band widths of the two assemblages. These results differ from the red drum results, which indicated a difference between the growth bands from the first annulus to the second annulus. It is difficult to postulate why spotted seatrout did not have these same differences given that these fish species occupy the same habitats (Bester 2021; Buskill 2017). Whaley and colleagues' (2016) study of these species following environmental disturbances did suggest that spotted seatrout had a shorter recovery time following perturbations. However, their study was conducted on young-of-year fishes and not these older-juvenile age groups.

Table 6.11. Results of Independent Samples T-Test for Archaeological Spotted Seatrout Assemblages

Otolith Annuli Area	Site	Group Statistics				Levene's Test for Equality of Variance			Independent Samples Test: t-test for Equality of Means					95% Confidence Interval of the Difference		Hypothesis test	
		N	Mean	Std. Deviation	Std. Error Mean		F	Sig	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper	Accept Null	Reject Null
Core to 1st Annulus	Crystal River	45	.971	.117	.017	Equal variances assumed	0.03	0.87	-1.35	63	0.18	-0.04	0.03	-0.11	0.02	t(63)=-1.35, p=0.181	
	Roberts Island	20	1.014	.124	.028	Equal variances not assumed			-1.32	34.67	0.19	-0.04	0.03	-0.11	0.02		
1st Annulus to 2nd Annulus	Crystal River	44	.623	.089	.013	Equal variances assumed	0.3	0.58	0.33	62	0.75	0.01	0.02	-0.04	0.05	t(62)=0.326, p=0.746	
	Roberts Island	20	.616	.072	.016	Equal variances not assumed			0.35	45.18	0.73	0.01	0.02	-0.03	0.05		
2nd Annulus to 3rd Annulus	Crystal River	31	.434	.062	.011	Equal variances assumed	0.54	0.47	0.75	44	0.46	0.01	0.02	-0.02	0.05	t(44)=0.748, p=0.458	
	Roberts Island	15	.420	.059	.015	Equal variances not assumed			0.76	28.67	0.46	0.01	0.02	-0.02	0.05		
3rd Annulus to 4th Annulus	Crystal River	15	.357	.035	.009	Equal variances assumed	1.08	0.31	-1.22	27	0.23	-0.02	0.02	-0.05	0.01	t(27)=-1.22, p=0.233	
	Roberts Island	14	.377	.053	.014	Equal variances not assumed			-1.2	22.37	0.24	-0.02	0.02	-0.06	0.01		
4th Annulus to 5th Annulus	Crystal River	9	.316	.037	.012	Equal variances assumed	0.18	0.68	0.57	14	0.58	0.01	0.02	-0.03	0.05	t(14)=0.566, p=0.58	
	Roberts Island	7	.305	.041	.016	Equal variances not assumed			0.56	12.2	0.59	0.01	0.02	-0.03	0.05		
5th Annulus to 6th Annulus	Crystal River	3	.287	.095	.055	Equal variances assumed	8.22	0.05	-0.12	4	0.91	-0.01	0.06	-0.16	0.15	t(2.185)=-0.12, p=913	
	Roberts Island	3	.294	.020	.012	Equal variances not assumed			-0.12	2.185	0.91	-0.01	0.06	-0.23	0.21		

Table 6.12. Descriptive Statistics for Prehistoric and Modern Spotted Seatrout Assemblages

Time Period	Annuli	N	Mean	Std Dev	Std Error	Median	Variance	Min	Max	Range
Prehistoric	Core to 1st	65	0.98	0.12	0.01	1.00	0.01	0.67	1.22	0.55
Modern		4150	1.00	0.18	0.00	1.02	0.03	0.30	1.61	1.31
Prehistoric	1st to 2nd	64	0.62	0.08	0.01	0.62	0.01	0.31	0.79	0.48
Modern		3386	0.66	0.12	0.00	0.63	0.01	0.37	1.17	0.80
Prehistoric	2nd to 3rd	46	0.43	0.06	0.01	0.43	0.00	0.28	0.56	0.28
Modern		1781	0.43	0.05	0.00	0.42	0.00	0.26	0.76	0.50
Prehistoric	3rd to 4th	29	0.37	0.05	0.01	0.37	0.00	0.28	0.49	0.20
Modern		874	0.38	0.06	0.00	0.38	0.00	0.22	0.76	0.54
Prehistoric	4th to 5th	16	0.31	0.04	0.01	0.31	0.00	0.22	0.37	0.14
Modern		303	0.33	0.04	0.00	0.32	0.00	0.23	0.45	0.22
Prehistoric	5th to 6th	6	0.29	0.06	0.02	0.28	0.00	0.22	0.40	0.17
Modern		94	0.30	0.03	0.00	0.30	0.00	0.23	0.39	0.17
Prehistoric	6th to 7th	2	0.24	0.01	0.01	0.24	0.00	0.23	0.25	0.01
Modern		30	0.29	0.04	0.01	0.29	0.00	0.18	0.37	0.20
Modern	7th to 8th	5	0.31	0.02	0.01	0.31	0.00	0.27	0.32	0.05

Next, I combine the Crystal River and Roberts Island spotted seatrout otolith sub-assemblages and compare them to the modern assemblage. Table 6.12 provides the descriptive statistics data. Initial inspection did not suggest any major differences between the archaeological and modern datasets. However, the fifth to sixth and sixth to seventh annuli have low sample sizes, which pose the possibility for differences to emerge between the prehistoric and modern means. Additionally, there were no otoliths in the archaeological sub-assemblages that had a completed seventh annulus so comparisons could not be made between the prehistoric and modern assemblage. Thus, the results for spotted seatrout with seven annuli present must be viewed as cautionary since I lacked the ability to make comparisons between these assemblages.

The results of the independent samples t-tests for the prehistoric and modern spotted seatrout otolith assemblages are provided in Table 6.13. The results indicate a significant difference between the means of the first to second annulus of the prehistoric and modern assemblages ($t(67.672)=-3.3$, $p=0.002$). To explore this difference further, the Crystal River and Roberts Island were again separated and an additional independent samples t-test was performed to see if the difference occurred in both or just one of the assemblages. The results of this second test revealed there are statistically significant differences in the mean annuli widths between the modern assemblage and the sub-assemblages from both Crystal River ($t(44.922)=2.404$, $p=0.020$) and Roberts Island assemblage ($t(19.594)=2.477$, $p=0.022$). However, like the differences observed in the red drum assemblages, this only means that the difference must be accounted for when assigning seasonal determinations for this annulus in both archaeological assemblages.

It is again difficult to offer a reason for this difference but a few reasonable explanations could be from a growth pattern change between prehistoric and modern times, harvesting pressures, or environmental disturbances. Red drum and spotted seatrout both are important modern recreational fish species (Bester 2021; Buskill 2017) so modern exploitation pressures could be causing growth rates to increase. The study by Whaley and colleagues (2016) that examined how these species responded to environmental perturbations offers another plausible explanation. There could have been environmental disturbances in the past that disrupted growth rates of fishes in this age grouping. However, additional studies are necessary to confirm or refute this as a possible explanation.

Table 6.13. Result of Independent Samples T-Test for Archaeological and Modern Spotted Seatrout Assemblages

Otolith Annuli Area	Time /Site	N	Levene's Test for Equality of Variance			Independent Samples Test: t-test for Equality of Means								
						t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		Hypothesis test	
				F	Sig						Lower	Upper	Accept Null	Reject Null
Core to 1st Annulus	Prehistoric	65	Equal variances assumed	16.57	0.00	-0.74	4213	0.46	-0.02	0.02	-0.06	0.03	t(68.765)=-1.11, p=0.272	
	Modern	4150	Equal variances not assumed			-1.11	68.77	0.27	-0.02	0.02	-0.05	0.01		
1st Annulus to 2nd Annulus	Prehistoric	64	Equal variances assumed	10.99	0.00	-2.41	3448	0.02	-0.04	0.01	-0.06	-0.01		t(67.672)=-3.3, p=0.002
	Modern	3386	Equal variances not assumed			-3.30	67.67	0.00	-0.04	0.01	-0.06	-0.01		
2nd Annulus to 3rd Annulus	Prehistoric	46	Equal variances assumed	2.14	0.14	0.23	1825	0.82	0.00	0.01	-0.01	0.02	t(1825)=0.228, p=0.82	
	Modern	1781	Equal variances not assumed			0.20	46.75	0.84	0.00	0.01	-0.02	0.02		
3rd Annulus to 4th Annulus	Prehistoric	29	Equal variances assumed	1.02	0.31	-1.44	901.00	0.15	-0.02	0.01	-0.04	0.01	t(901)=-1.44, p=0.15	
	Modern	874	Equal variances not assumed			-1.77	30.96	0.09	-0.02	0.01	-0.03	0.00		
4th Annulus to 5th Annulus	Prehistoric	16	Equal variances assumed	0.87	0.35	-1.75	317.00	0.08	-0.02	0.01	-0.04	0.00	t(317)=-1.75, p=0.081	
	Modern	303	Equal variances not assumed			-1.91	16.98	0.07	-0.02	0.01	-0.04	0.00		
5th Annulus to 6th Annulus	Prehistoric	6	Equal variances assumed	3.55	0.06	-0.67	98.00	0.51	-0.01	0.02	-0.04	0.02	t(98)=-0.67, p=0.508	
	Modern	94	Equal variances not assumed			-0.40	5.20	0.71	-0.01	0.03	-0.07	0.05		
6th Annulus to 7th Annulus	Prehistoric	2	Equal variances assumed	0.92	0.35	-1.70	30.00	0.10	-0.05	0.03	-0.10	0.01	t(30)=-1.7, p=0.099	
	Modern	30	Equal variances not assumed			-4.65	3.62	0.01	-0.05	0.01	-0.08	-0.02		
1st Annulus to 2nd Annulus	Crystal River	44	Equal variances assumed	6.33	0.01	1.86	3428	0.06	0.03	0.02	0.00	0.07		t(44.922)=2.404, p=0.020
	Modern	3386	Equal variances not assumed			2.40	44.92	0.02	0.03	0.01	0.01	0.06		
	Roberts Island	20	Equal variances assumed	4.90	0.03	1.54	3404	0.12	0.04	0.03	-0.01	0.09		t(19.594)=2.477, p=0.022
	Modern	3386	Equal variances not assumed			2.48	19.59	0.02	0.04	0.02	0.01	0.07		

Marginal Increment Analysis and Results

Figures 6.18 – 6.25 display the monthly mean marginal increment widths for the modern spotted seatrout otoliths (see Appendix B for corresponding descriptive statistics and histograms). Visual analyses of these graphs suggest increased growth throughout most of the months. There are four annuli that require attention. First, otoliths with no annulus present require mentioning since several months have few to no modern samples to represent the monthly mean marginal widths. Fortunately, there is only one otolith from Crystal River with no annulus present. Second, otoliths with the second annulus present indicate a minute drop off between the months of September and October. This decline may be the result of new annuli forming during the month of October. The other annulus with a slight drop off in mean marginal width is the fifth annulus. The dip occurs between the months and August and September. Small sample sizes could be the reason for this drop off but new annuli forming cannot be ruled without more rigorous statistical examination. Lastly, the otoliths with seven annuli present lack a robust modern dataset to compare against. There is an indication that this growth band follows the same general pattern of increased growth commencing throughout the year.

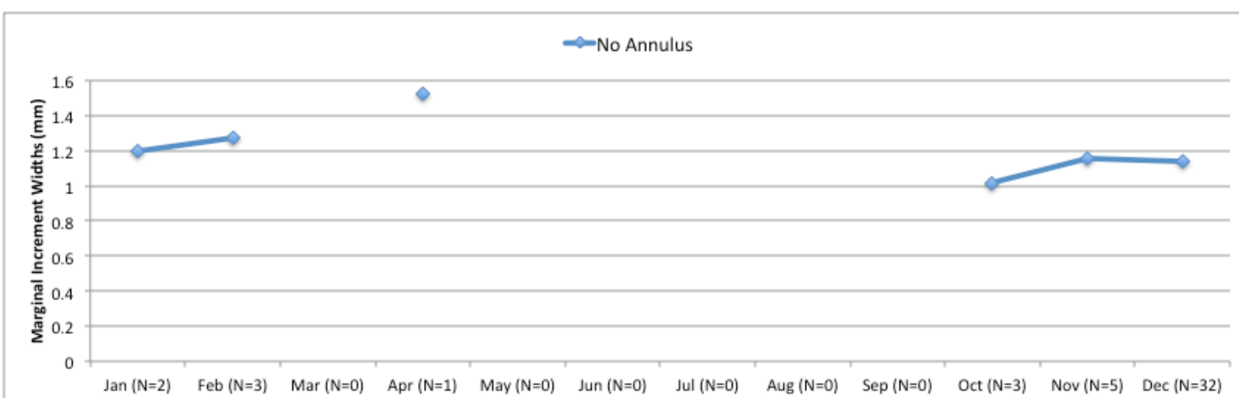

Figure 6.18. Means of Monthly Marginal Increment Widths for Spotted Seatrout with No Annulus Present

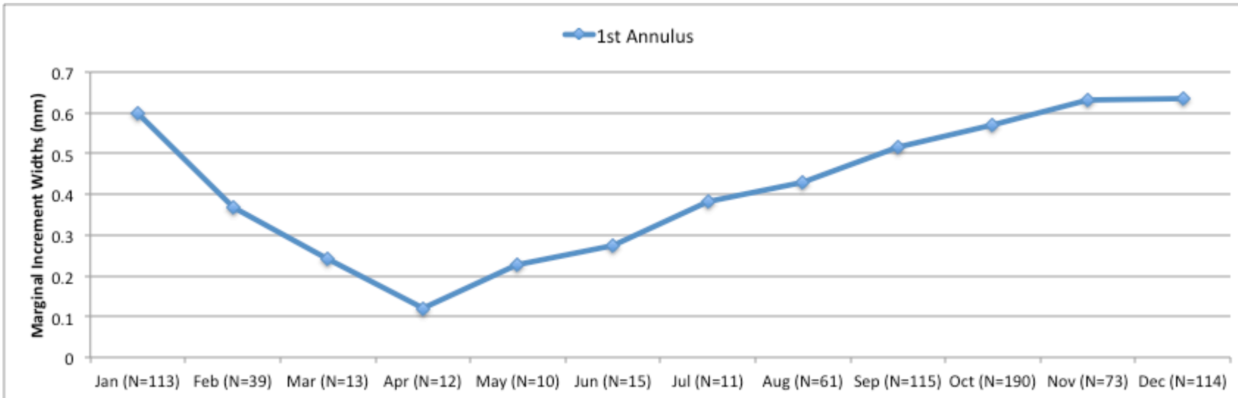

Figure 6.19. Means of Monthly Marginal Increment Widths for Spotted Seatrout with One Present

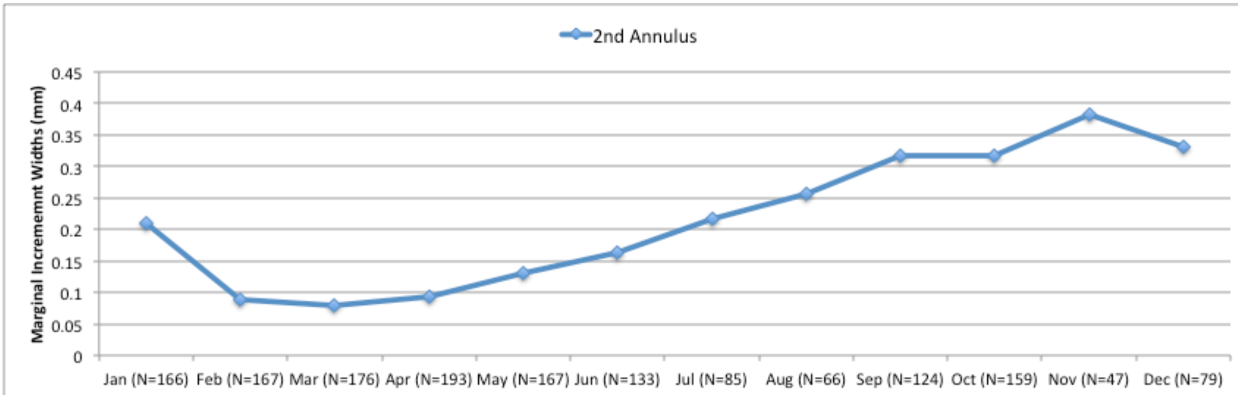

Figure 6.20. Means of Monthly Marginal Increment Widths for Spotted Seatrout with Two Annuli Present

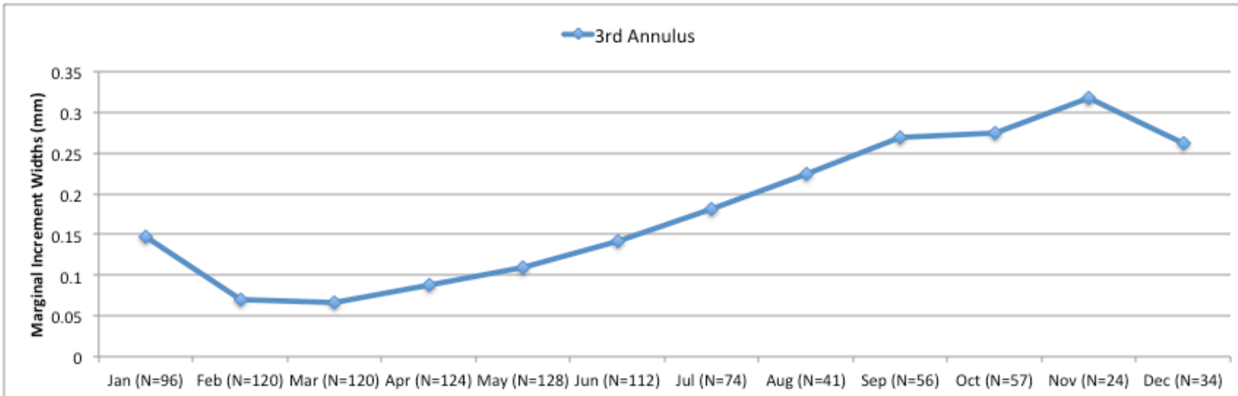

Figure 6.21. Means of Monthly Marginal Increment Widths for Spotted Seatrout with Three Annuli Present

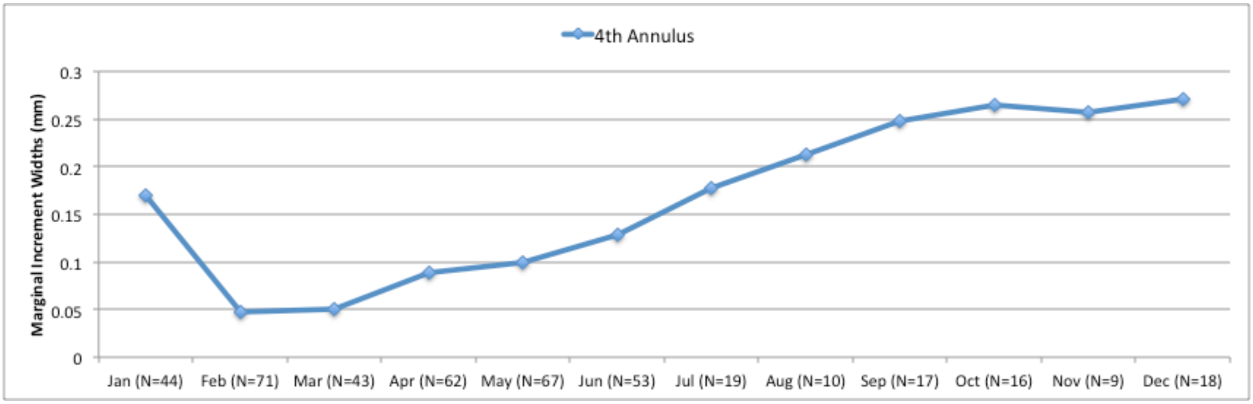

Figure 6.22. Means of Monthly Marginal Increment Widths for Spotted Seatrout with Four Annuli Present

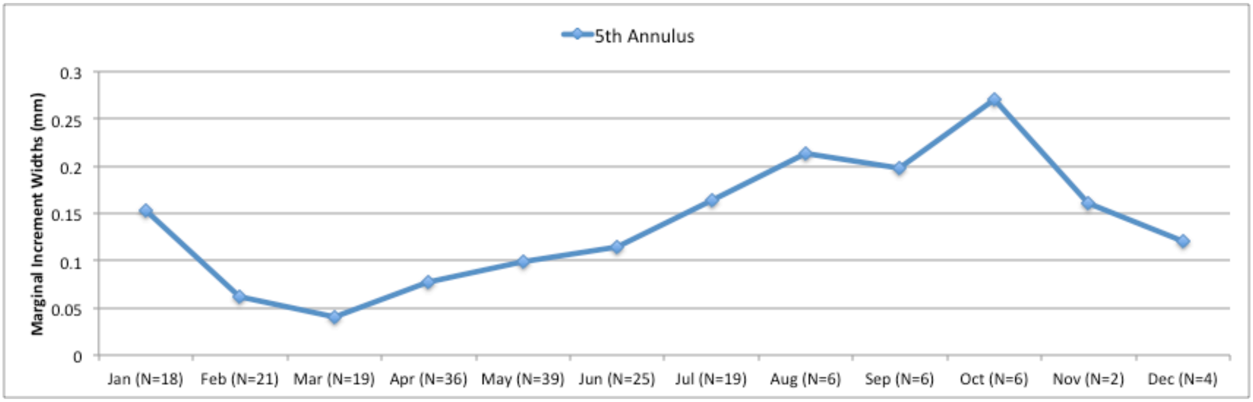

Figure 6.23. Means of Monthly Marginal Increment Widths for Spotted Seatrout with Five Annuli Present

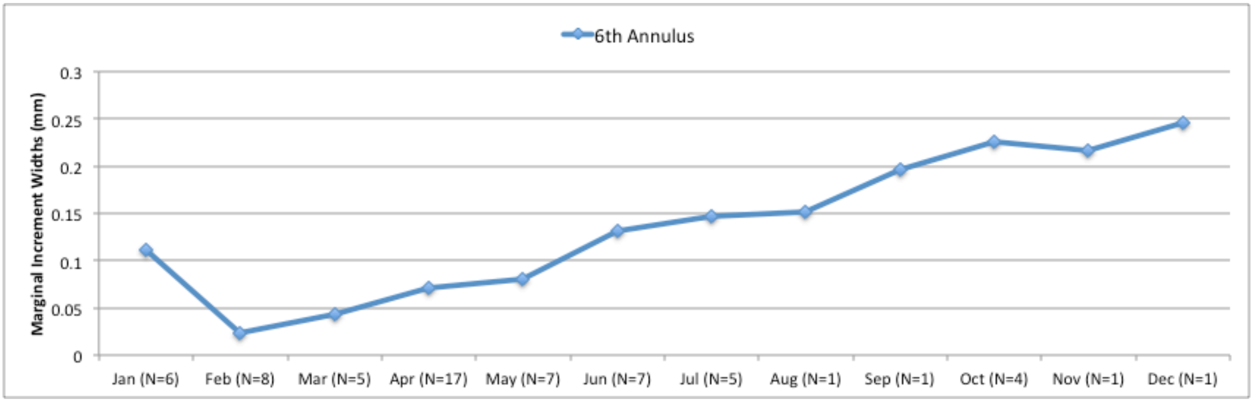

Figure 6.24. Means of Monthly Marginal Increment Widths for Spotted Seatrout with Six Annuli Present

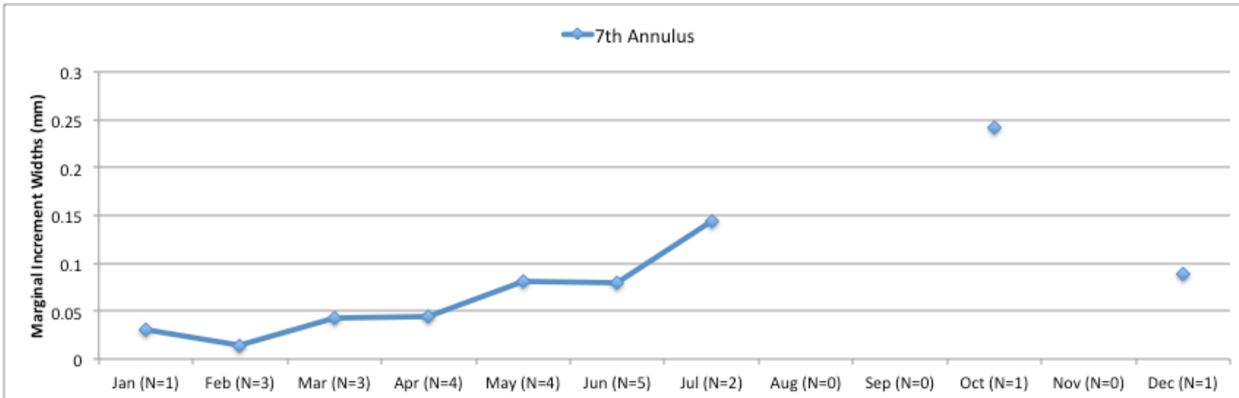

Figure 6.25. Means of Monthly Marginal Increment Widths for Spotted Seatrout Seven Annuli Present

Figures 6.26 – 6.33 provide all the seasonally grouped histograms for the modern marginal increments of spotted seatrout otoliths. As previously mentioned, Appendix B contains the associated descriptive statistics for these seasonal groupings, as well the descriptive statistics and histograms for the individual months for each age group which informed my decision on how to create the seasonally grouped histograms.

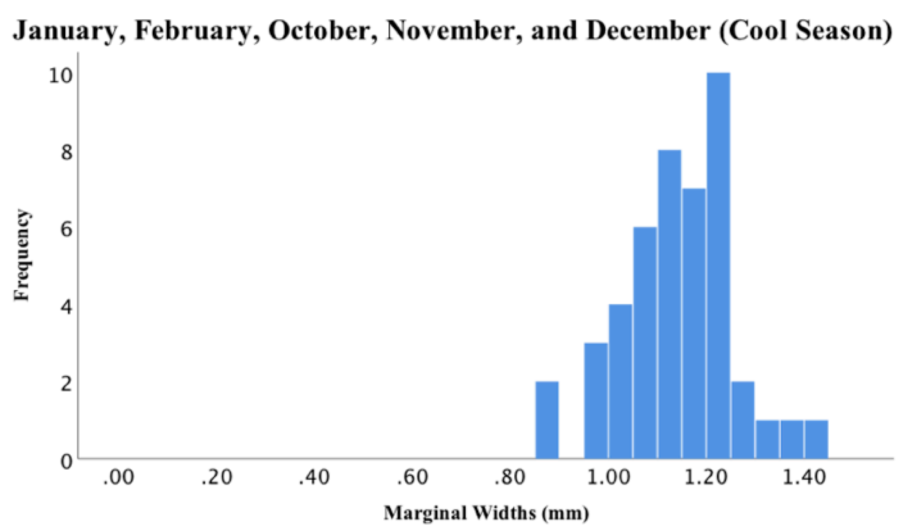

Figure 6.26. Seasonal Histogram for Spotted Seatrout with No Annulus Present. No Data Available for Other Months

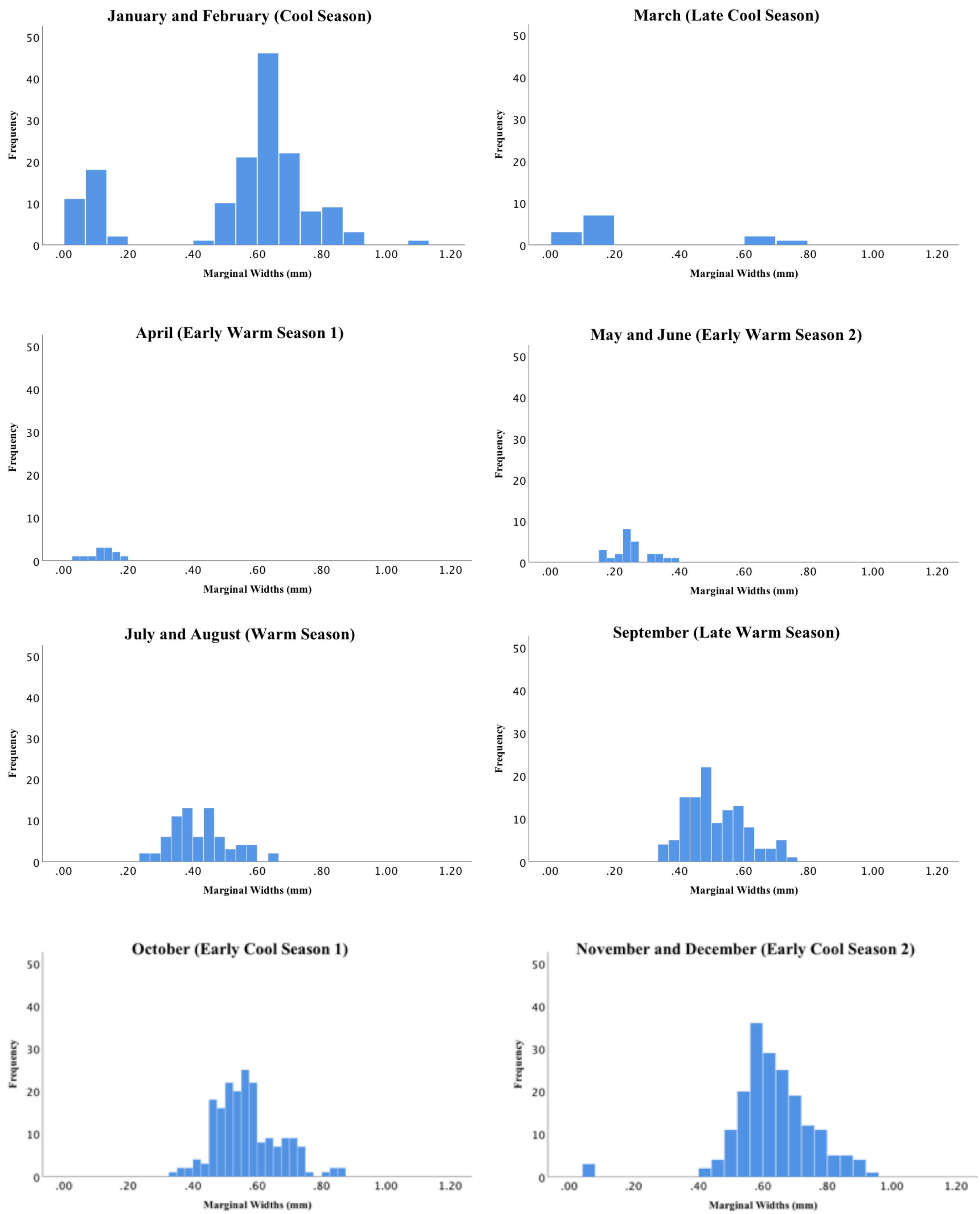

Figure 6.27. Seasonal Histograms for Spotted Seatrout with One Annulus Present

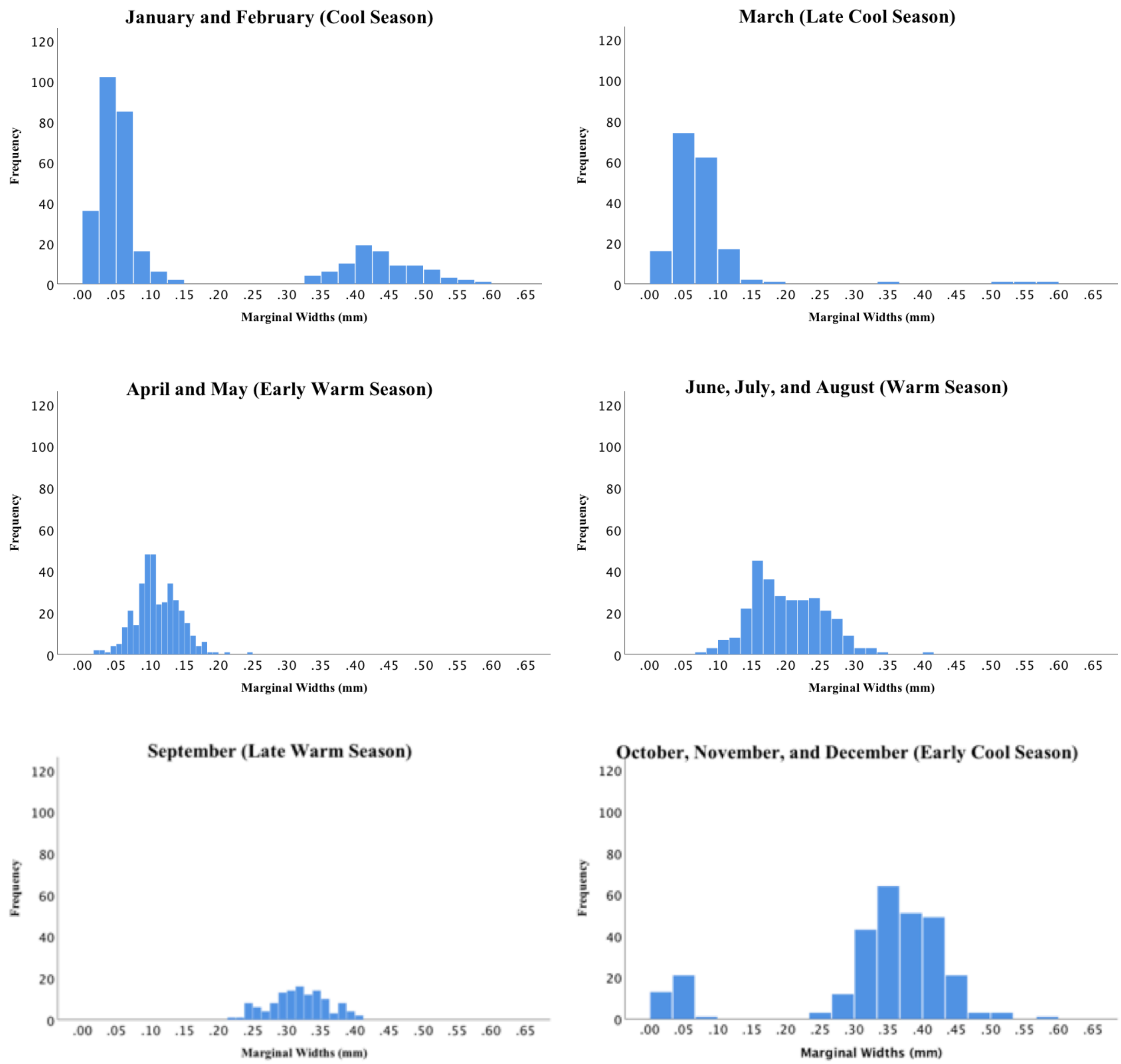

Figure 6.28. Seasonal Histograms for Spotted Seatrout with Two Annuli Present

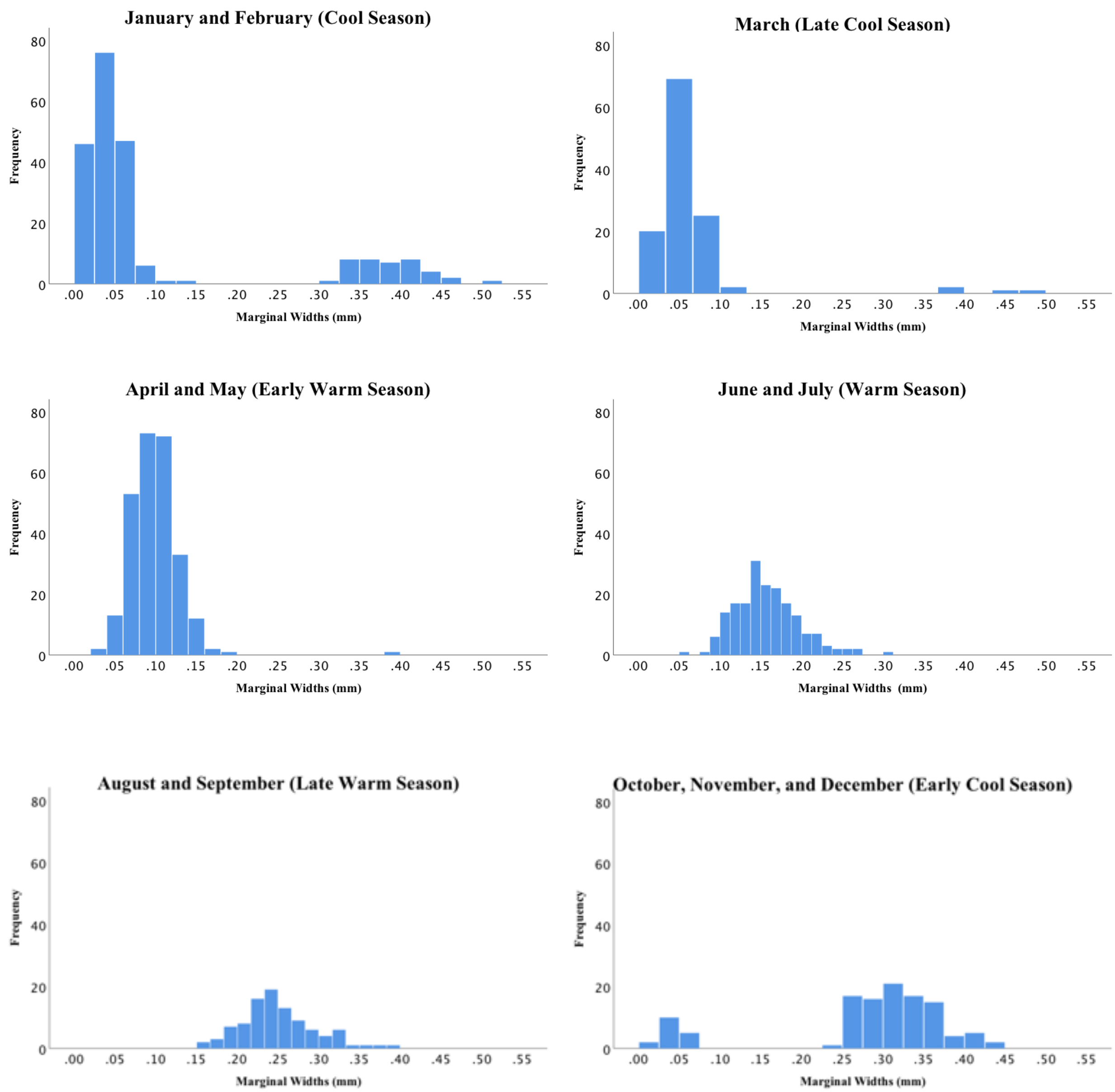

Figure 6.29. Seasonal Histograms for Spotted Seatrout with Three Annuli Present

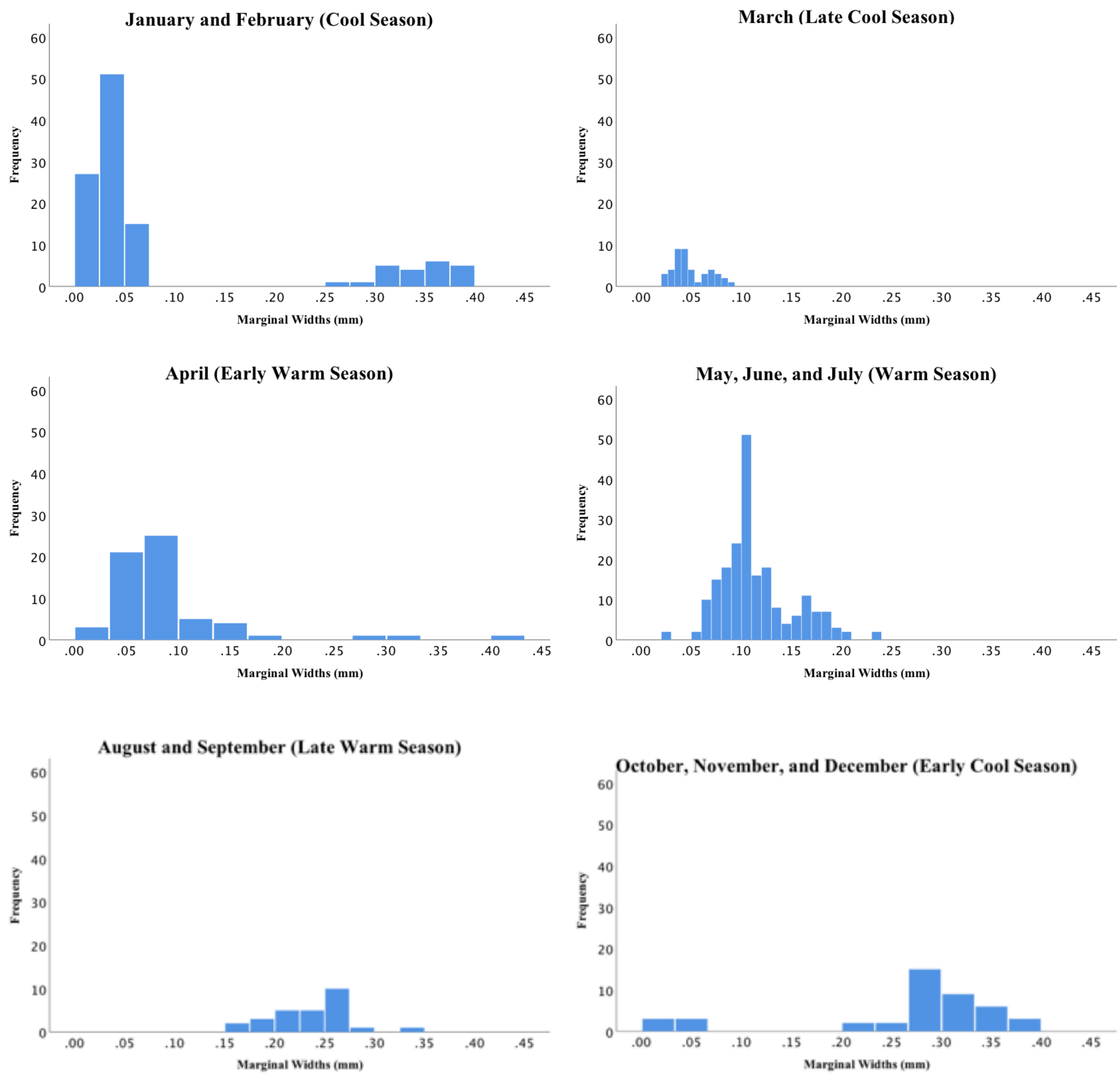

Figure 6.30. Seasonal Histograms for Spotted Seatrout with Four Annuli Present

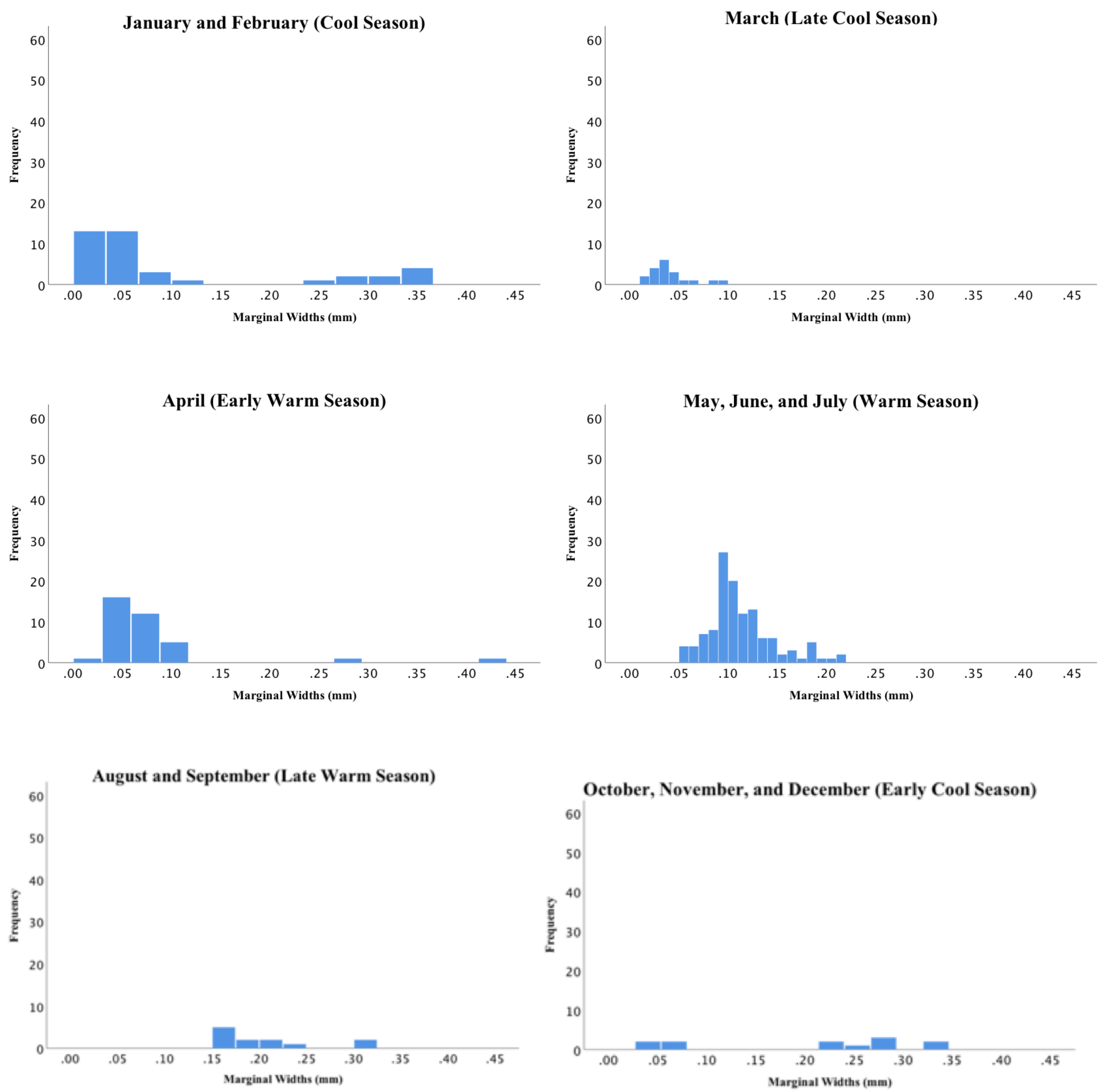

Figure 6.31. Seasonal Histograms for Spotted Seatrout with Five Annuli Present

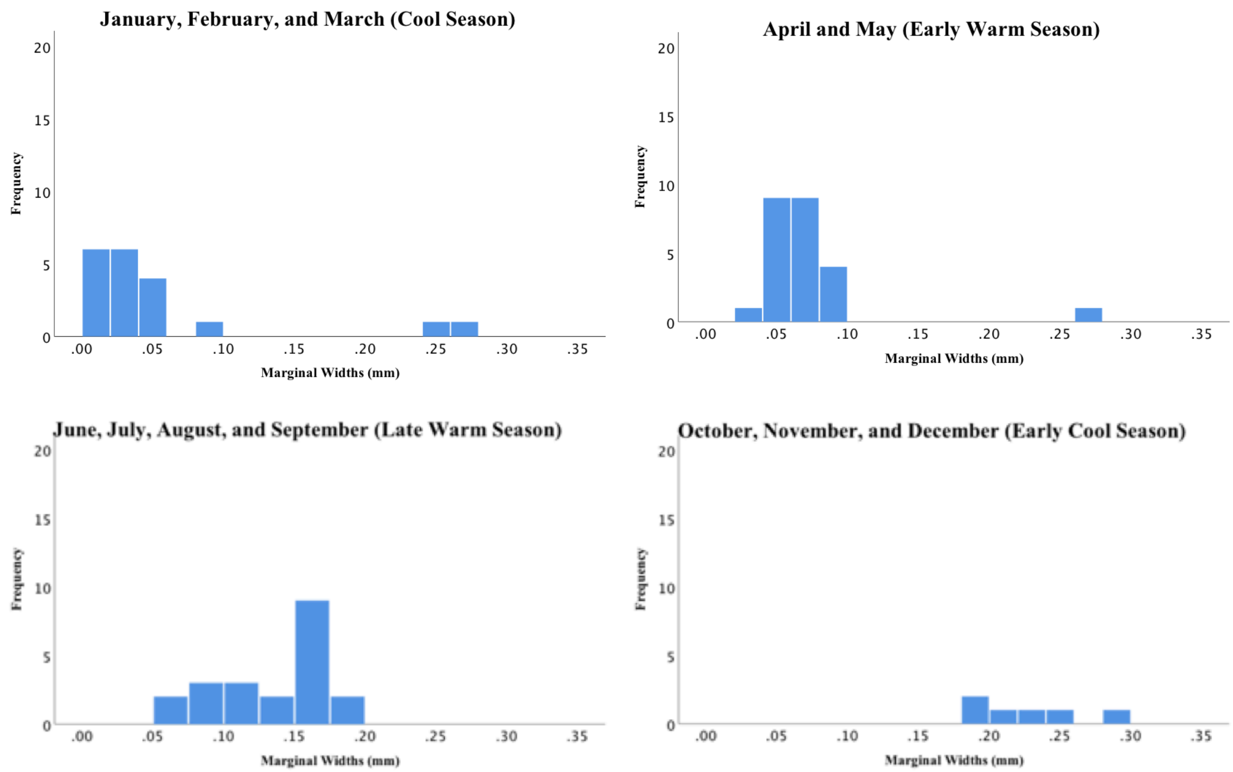

Figure 6.32. Seasonal Histograms for Spotted Seatrout with Six Annuli Present

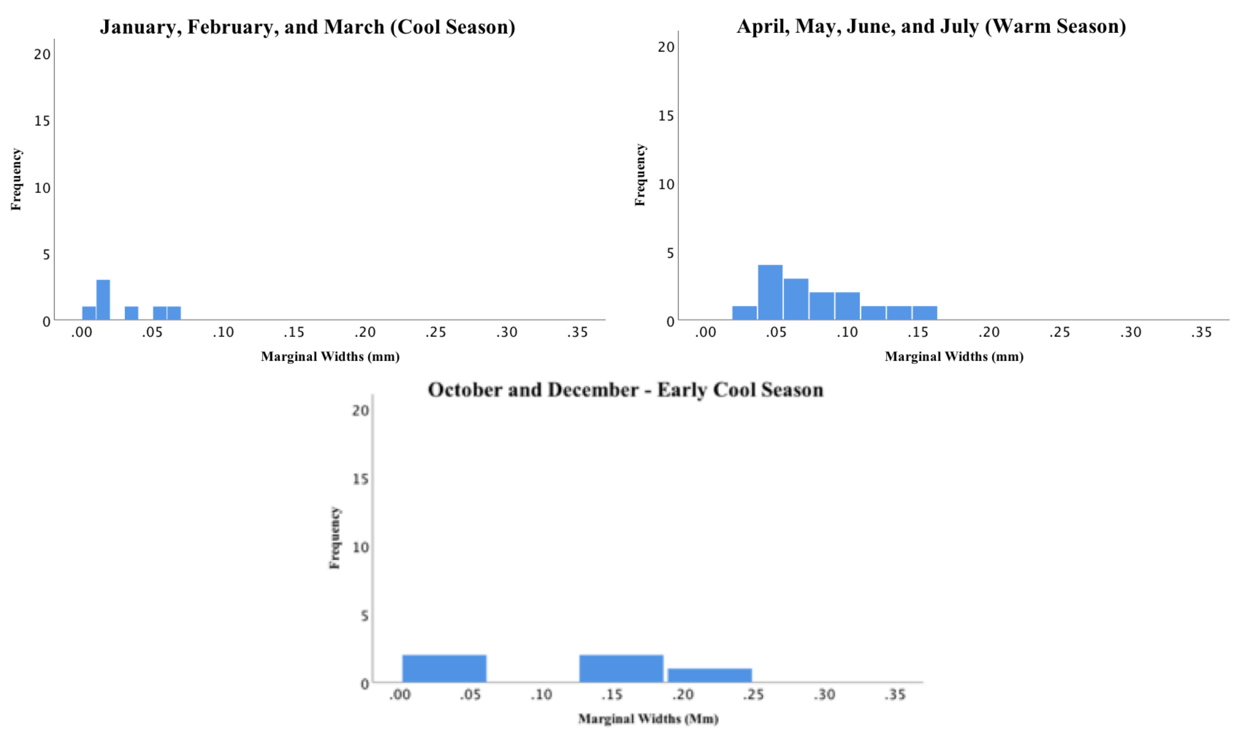

Figure 6.33. Seasonal Histograms for Spotted Seatrout with Seven Annuli Present

The histograms reveal a general pattern for most of the annuli. Like the red drum assemblages, annuli are formed during the cool months of the year and new growth begins as temperatures warm and activity and food consumption increase. For most annuli, these events occur primarily in January and February (the Cool Season) but infrequently occur during October, November, and December (the Early Cool Season) and March (the Late Cool Season). The histograms illustrate the termnation and commencement of annuli with bimodal distributions. Annuli growth begins to increase markedly during April and May (the Early Warm Season) and reaches rapid growth during June, July, and August (the Warm Season) and September (the Late Warm Season). Additionallly, there are a few instances where monthly groupings have the same seasonal designation. I used this approach to refine when growth was occurring and to better illustrate and designate the archaeological otoliths. The last general observation worthy of mention is the seasonal groupings where annuli are beginning and concluding have impacted means. Thus, reliance is placed more on the histograms when assigning seasonal designations in these instances.

It is also important to note that there are exceptions to the general pattern and some annuli do not have all seasonal designations represented. For example, spotted seatrout otoliths that have no annulus present are only represented by a single cool season because the modern assemblage only contained one specimen from warm months. Otoliths with one annulus present are a little tricky to separate into seasonal groupings. The data suggest the first annulus is most often created during the months of January and February (the designated Cool Season) and March (the designated Late Cools Season). However, the initial growth after the annulus is created occurs during January, February, March, and April. The inclusion of the month of April presents a problem because temperatures are warmer than the preceding months. Fortunately, these issues have little impact on this study because the archaeological assemblages only contain one otolith with each of these marginal width types.

Below, I combine all aforementioned analyses and assign seasonality for each archaeological otolith. Figures 6.34 – 6.45 use bar graphs to illustrate the marginal increment widths for the archaeological spotted seatrout, the mean marginal increment widths of the seasonal groupings, and the mean annuli widths for the corresponding annulus. As previously noted for the red drum, this organization style of the results offers general information.

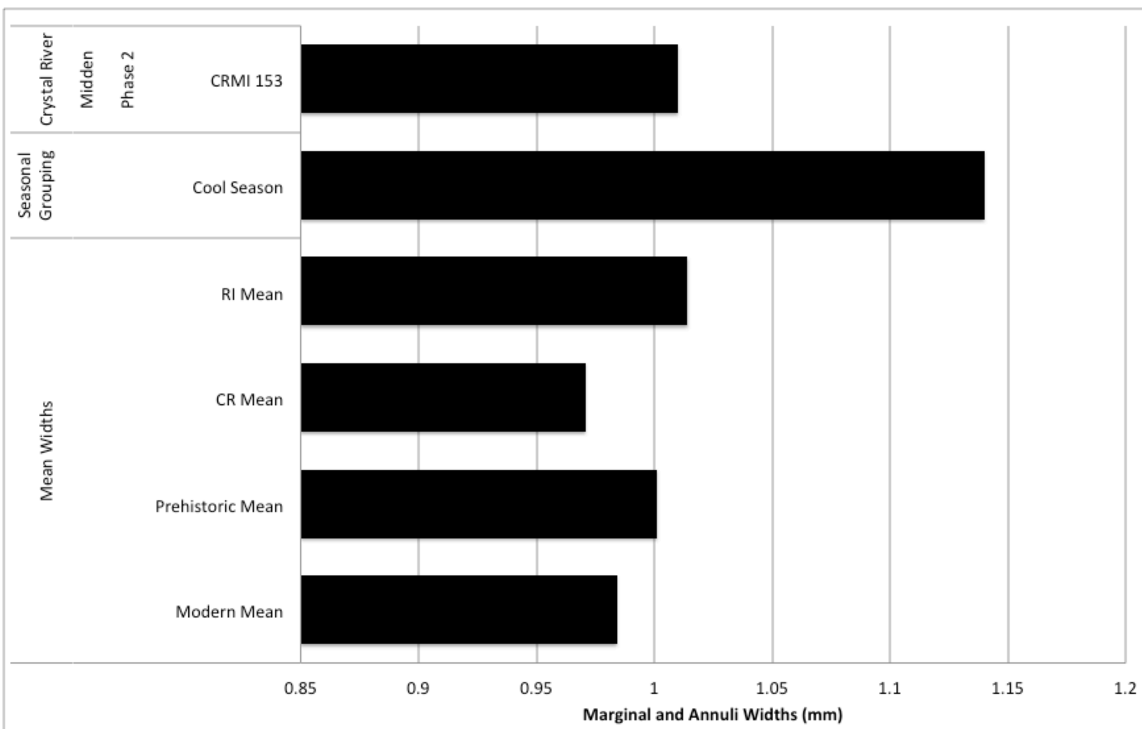

Figure 6.34. Bar Graph of Spotted Seatrout with No Annulus Present. Graph inlcudes: Marginal Widths (mm) of Archaeological Otoliths with Temporal and Site Context, Marginal Widths (mm) for Seasonal Groupings, and Mean Annuli Widths (mm) for Sites and Time Periods

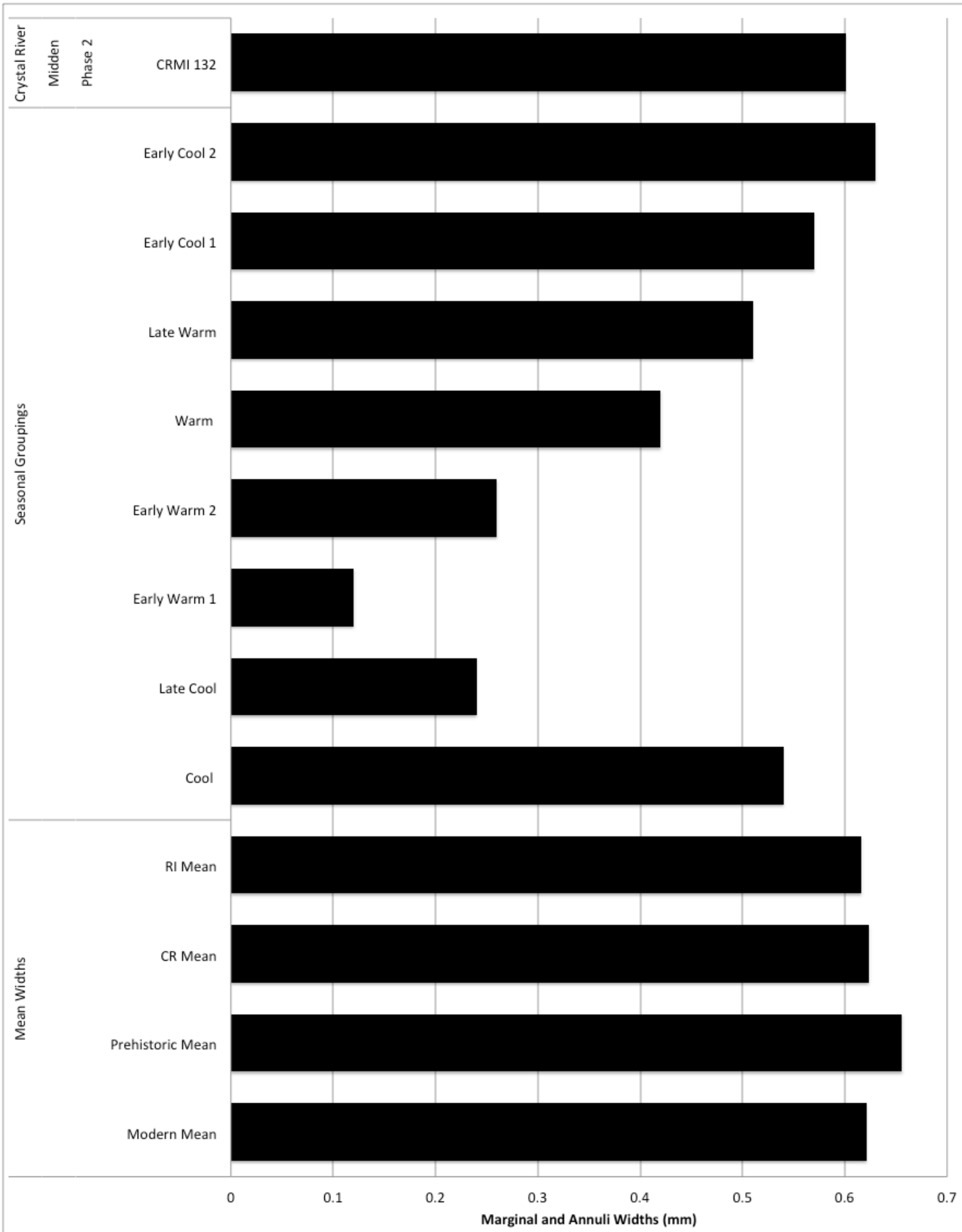

Figure 6.35. Bar Graph of Spotted Seatrout with One Annulus Present. Graph includes: Marginal Widths (mm) of Archaeological Otoliths with Temporal and Site Context, Marginal Widths (mm) for Seasonal Groupings, and Mean Annuli Widths (mm) for Sites and Time Periods

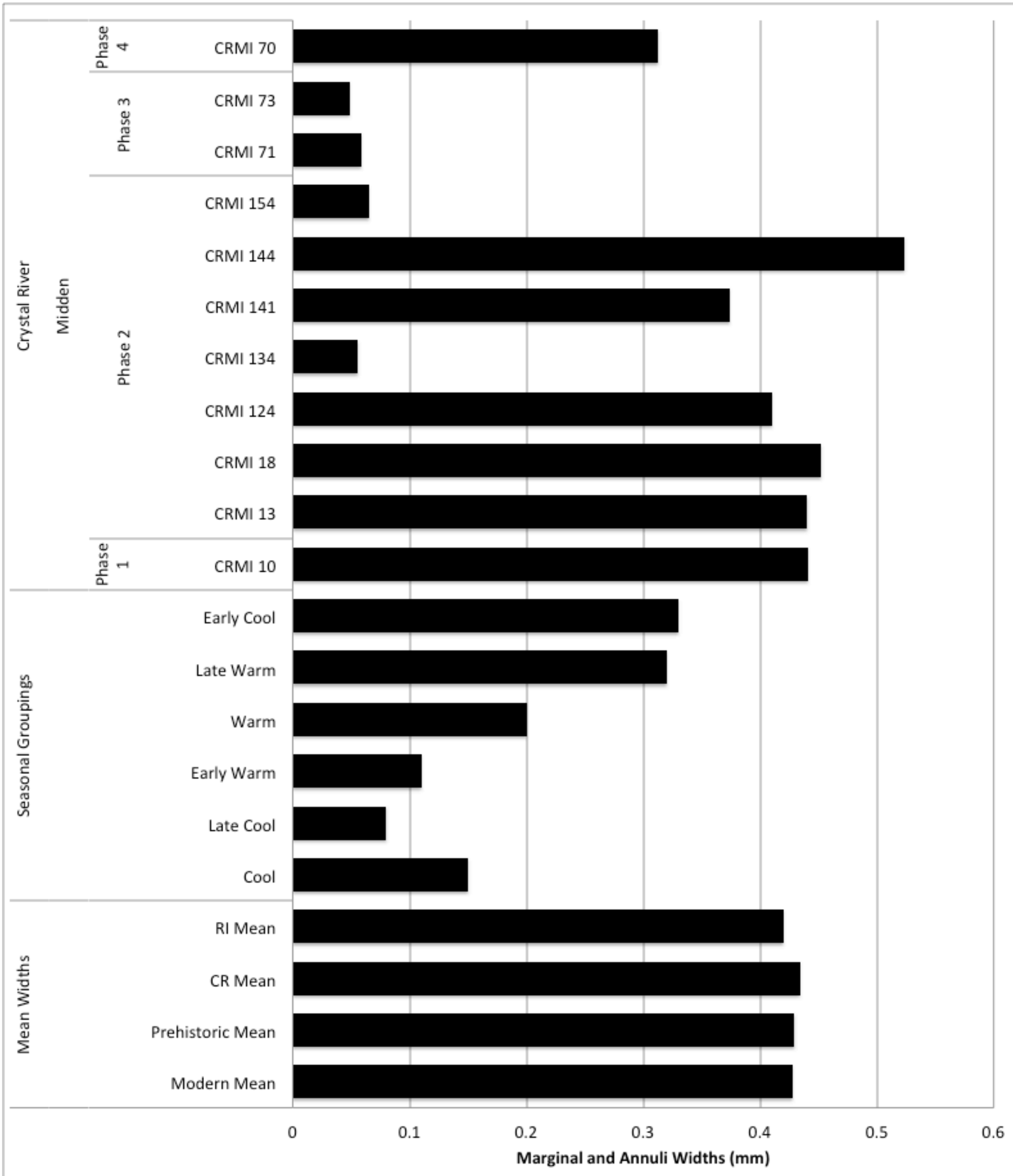

Figure 6.36. Bar Graph of Spotted Seatrout with Two Annuli Present from Crystal River. Graph includes: Marginal Widths (mm) of Archaeological Otoliths with Temporal and Site Context, Marginal Widths (mm) for Seasonal Groupings, and Mean Annuli Widths (mm) for Sites and Time Periods

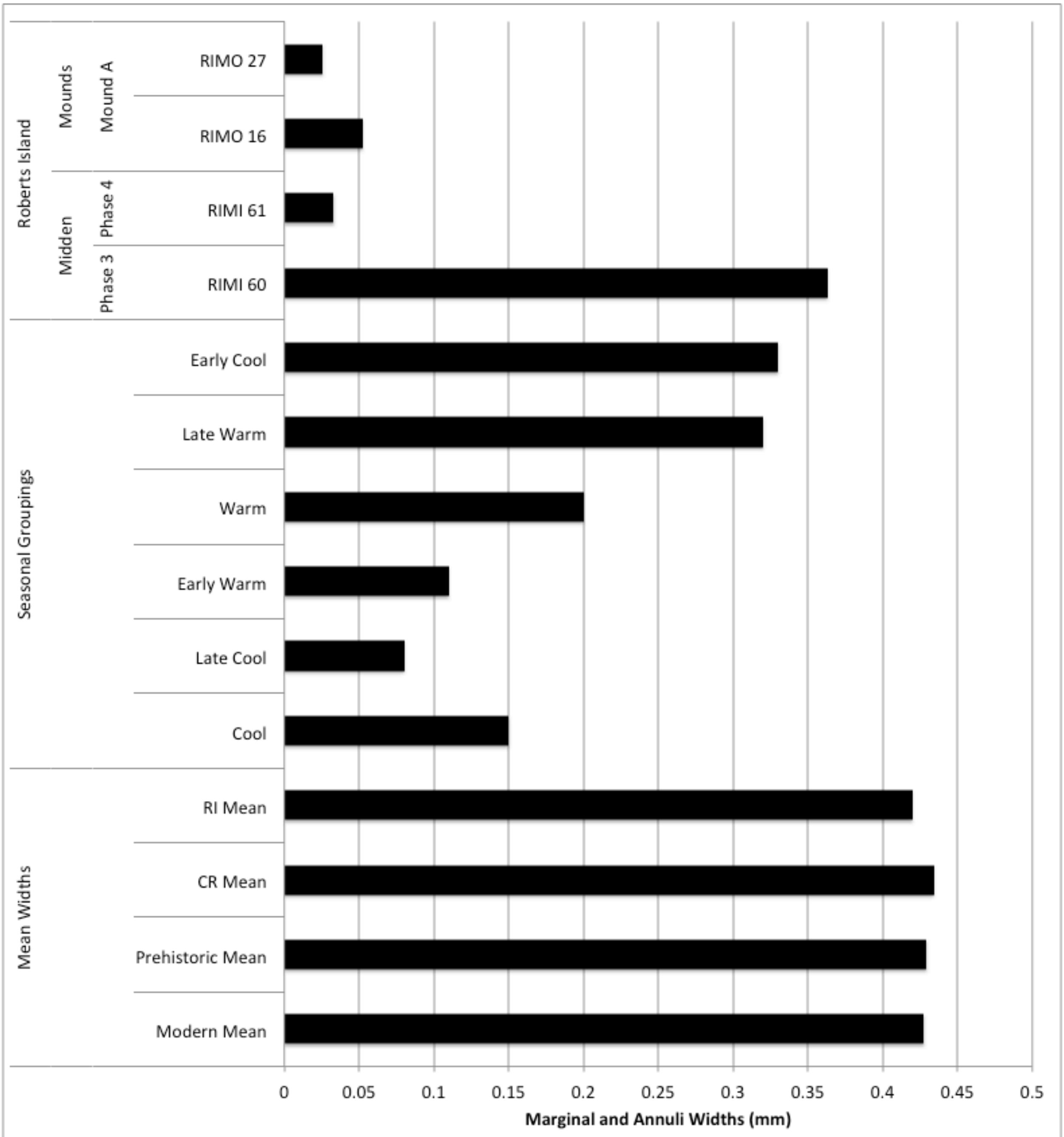

Figure 6.37. Bar Graph of Spotted Seatrout with Two Annuli Present from Roberts Island. Graph includes: Marginal Widths (mm) of Archaeological Otoliths with Temporal and Site Context, Marginal Widths (mm) for Seasonal Groupings, and Mean Annuli Widths (mm) for Sites and Time Periods

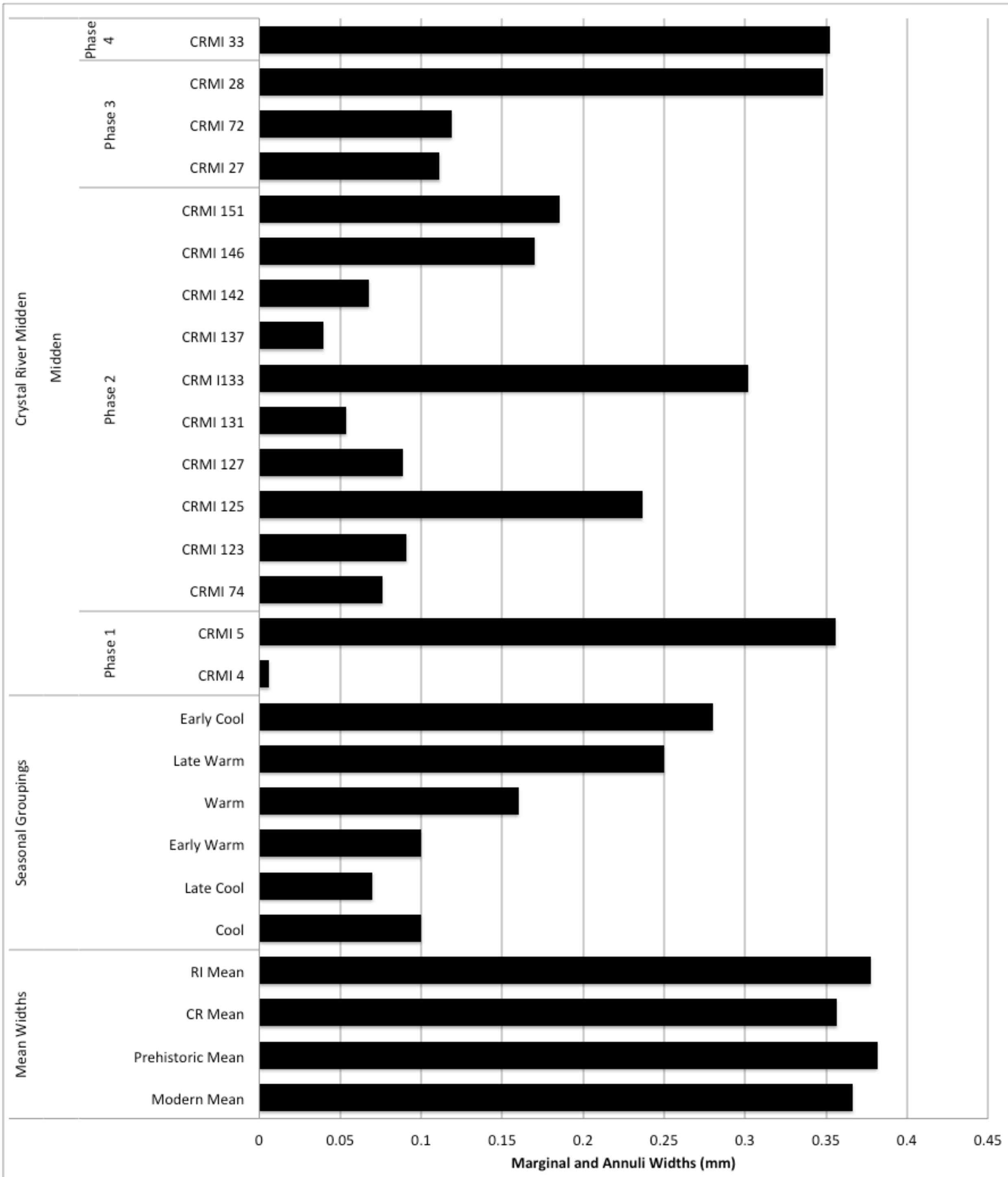

Figure 6.38. Bar Graph of Spotted Seatrout with Three Annuli Present from Crystal River. Graph includes: Marginal Widths (mm) of Archaeological Otoliths with Temporal and Site Context, Marginal Widths (mm) for Seasonal Groupings, and Mean Annuli Widths (mm) for Sites and Time Periods

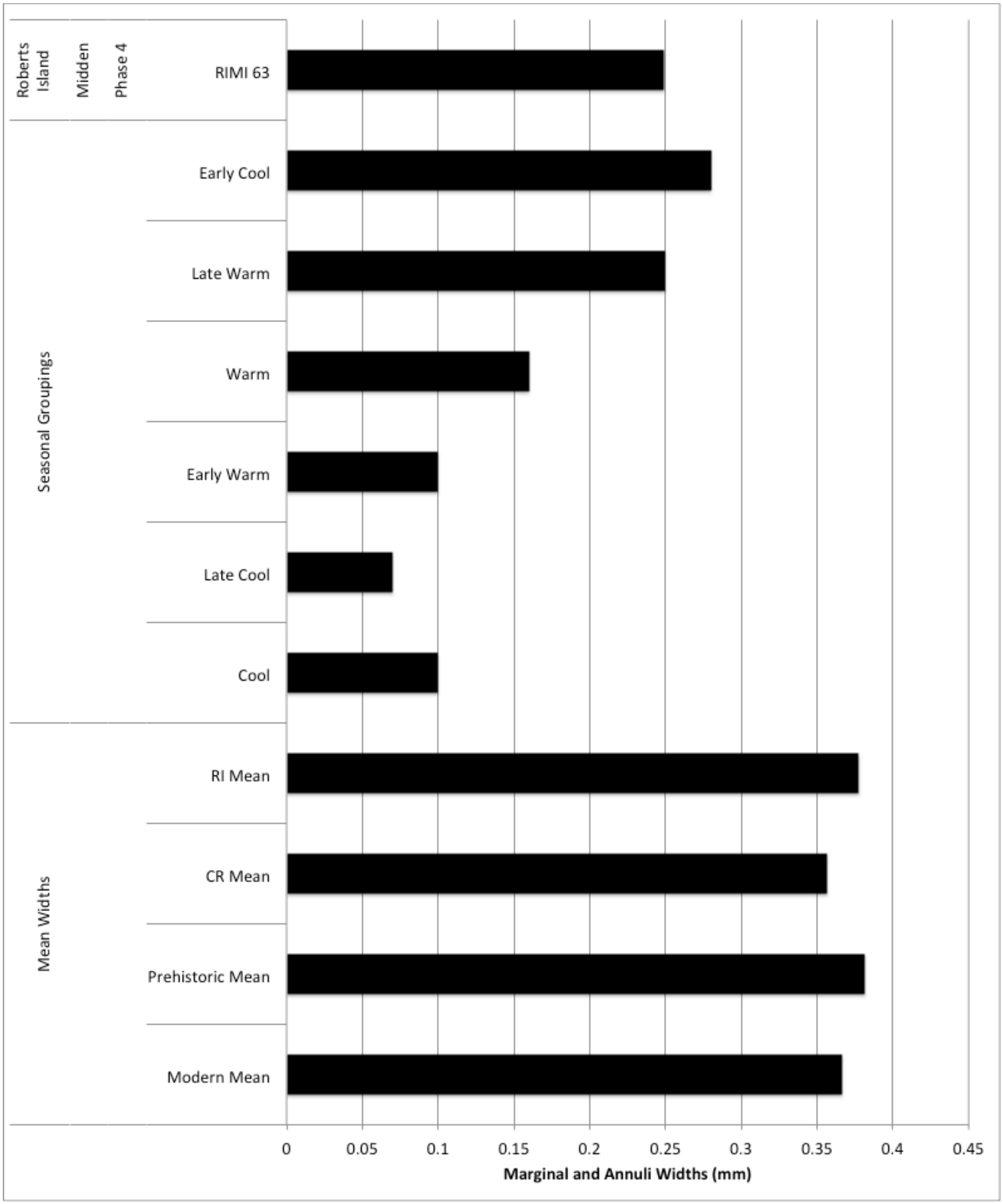

Figure 6.39. Bar Graph of Spotted Seatrout with Three Annuli Present from Roberts Island. Graph includes: Marginal Widths (mm) of Archaeological Otoliths with Temporal and Site Context, Marginal Widths (mm) for Seasonal Groupings, and Mean Annuli Widths (mm) for Sites and Time Periods

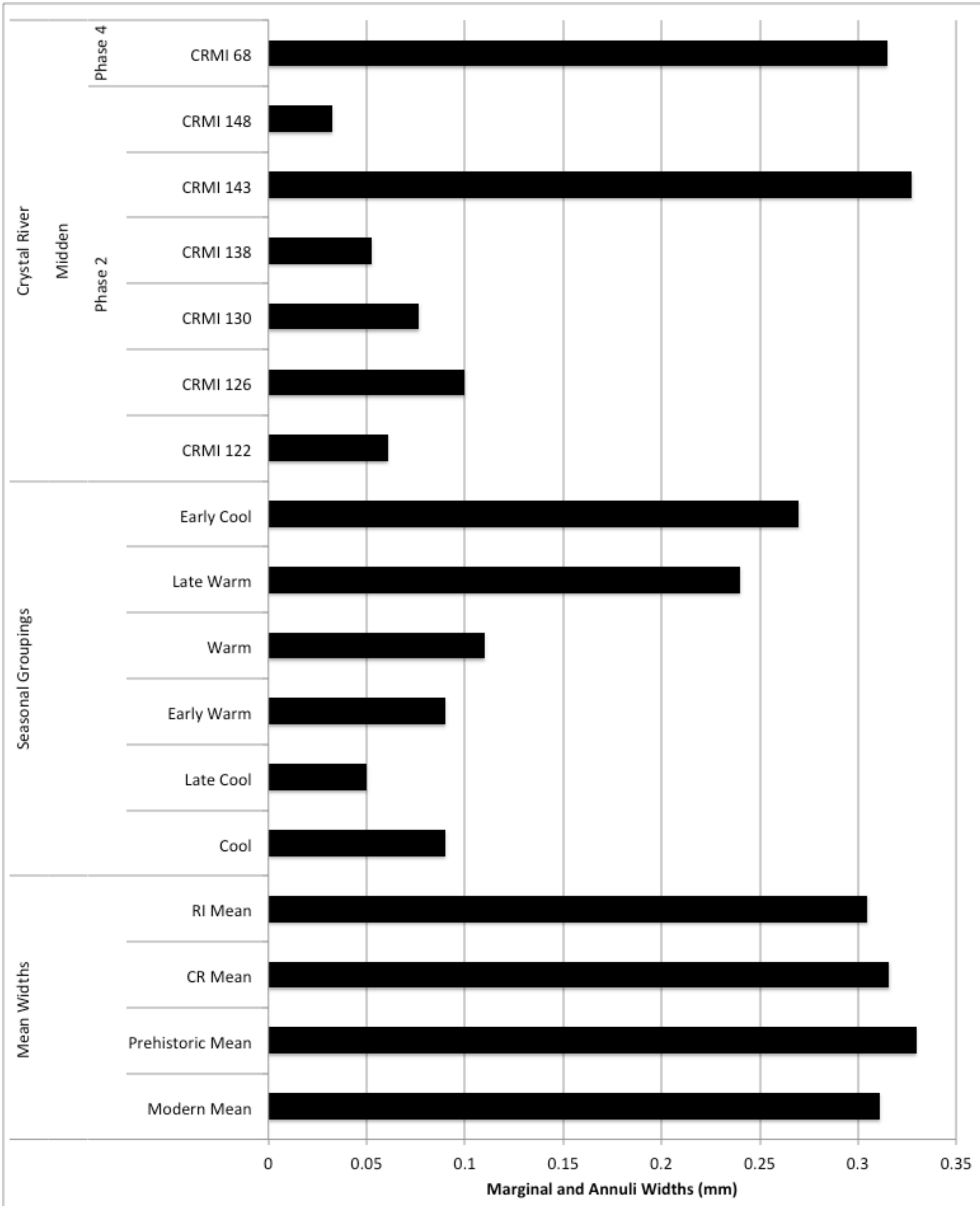

Figure 6.40. Bar Graph of Spotted Seatrout with Four Annuli Present from Crystal River. Graph includes: Marginal Widths (mm) of Archaeological Otoliths with Temporal and Site Context, Marginal Widths (mm) for Seasonal Groupings, and Mean Annuli Widths (mm) for Sites and Time Periods

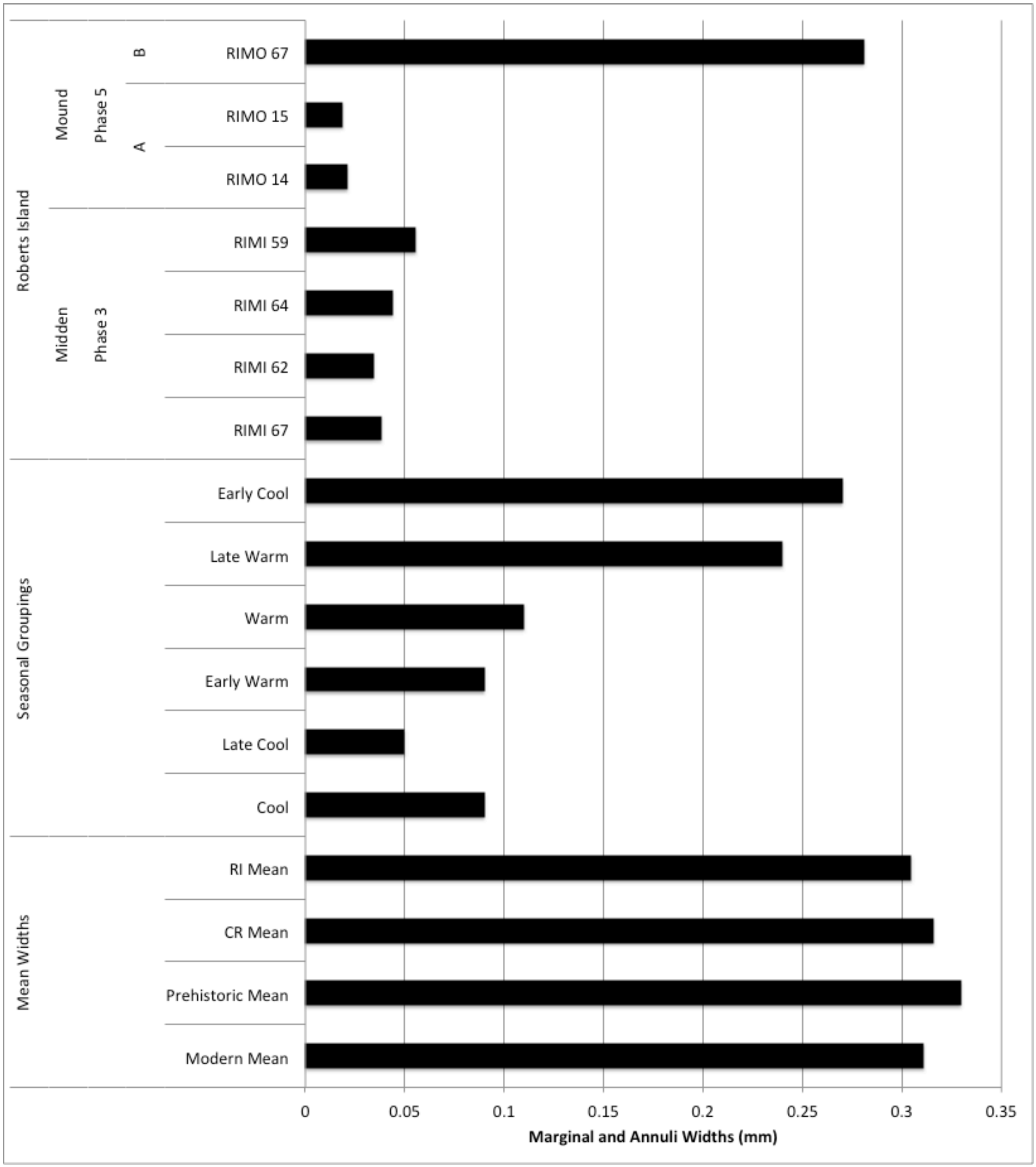

Figure 6.41. Bar Graph of Spotted Seatrout with Four Annuli Present from Roberts Island. Graph includes: Marginal Widths (mm) of Archaeological Otoliths with Temporal and Site Context, Marginal Widths (mm) for Seasonal Groupings, and Mean Annuli Widths (mm) for Sites and Time Periods

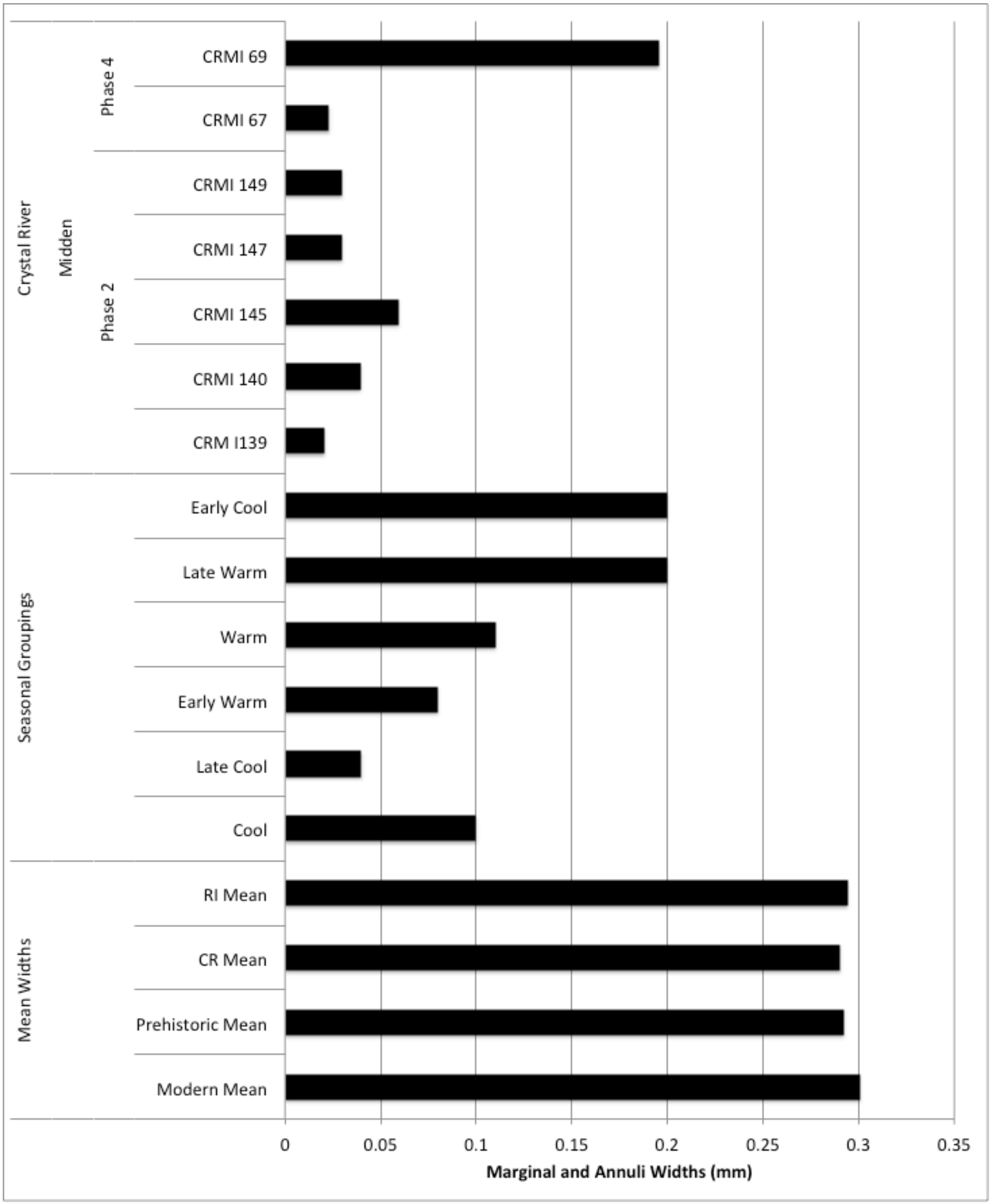

Figure 6.42. Bar Graph of Spotted Seatrout with Five Annuli Present from Crystal River. Graph includes: Marginal Widths (mm) of Archaeological Otoliths with Temporal and Site Context, Marginal Widths (mm) for Seasonal Groupings, and Mean Annuli Widths (mm) for Sites and Time Periods

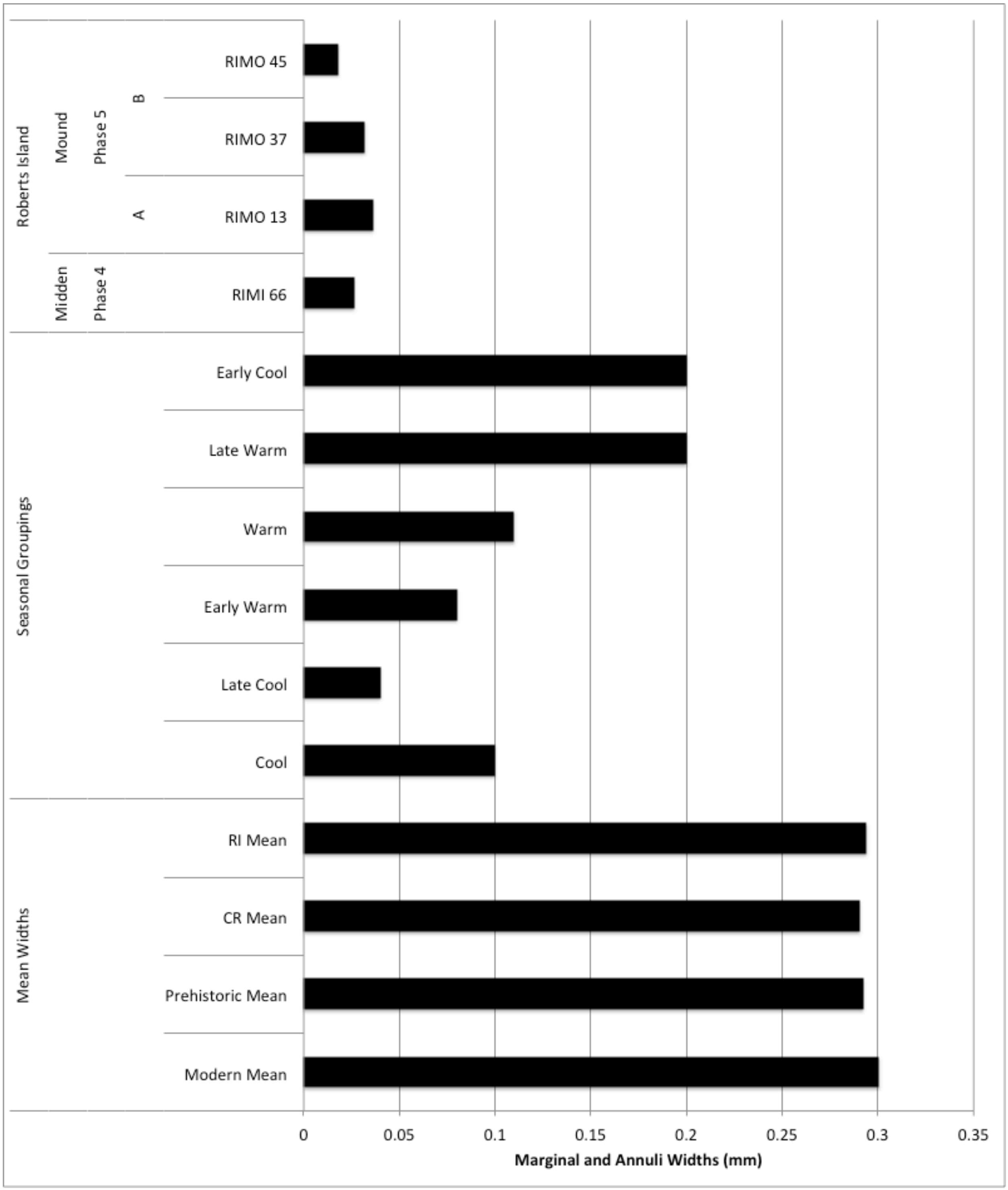

Figure 6.43. Bar Graph of Spotted Seatrout with Five Annuli Present from Roberts Island. Graph includes: Marginal Widths (mm) of Archaeological Otoliths with Temporal and Site Context, Marginal Widths (mm) for Seasonal Groupings, and Mean Annuli Widths (mm) for Sites and Time Periods

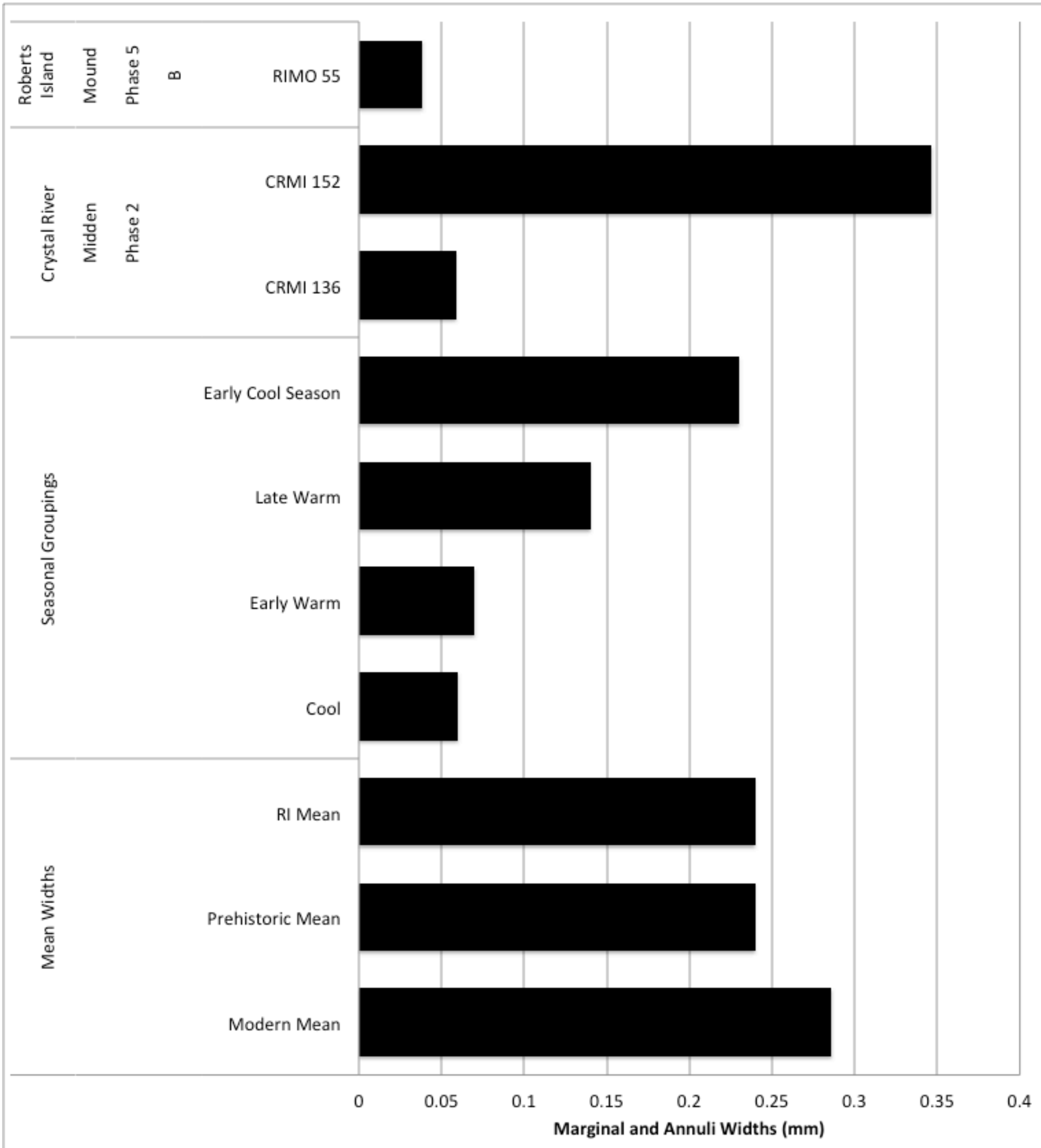

Figure 6.44. Bar Graph of Spotted Seatrout with Six Annuli Present. Graph includes: Marginal Widths (mm) of Archaeological Otoliths with Temporal and Site Context, Marginal Widths (mm) for Seasonal Groupings, and Mean Annuli Widths (mm) for Sites and Time Periods

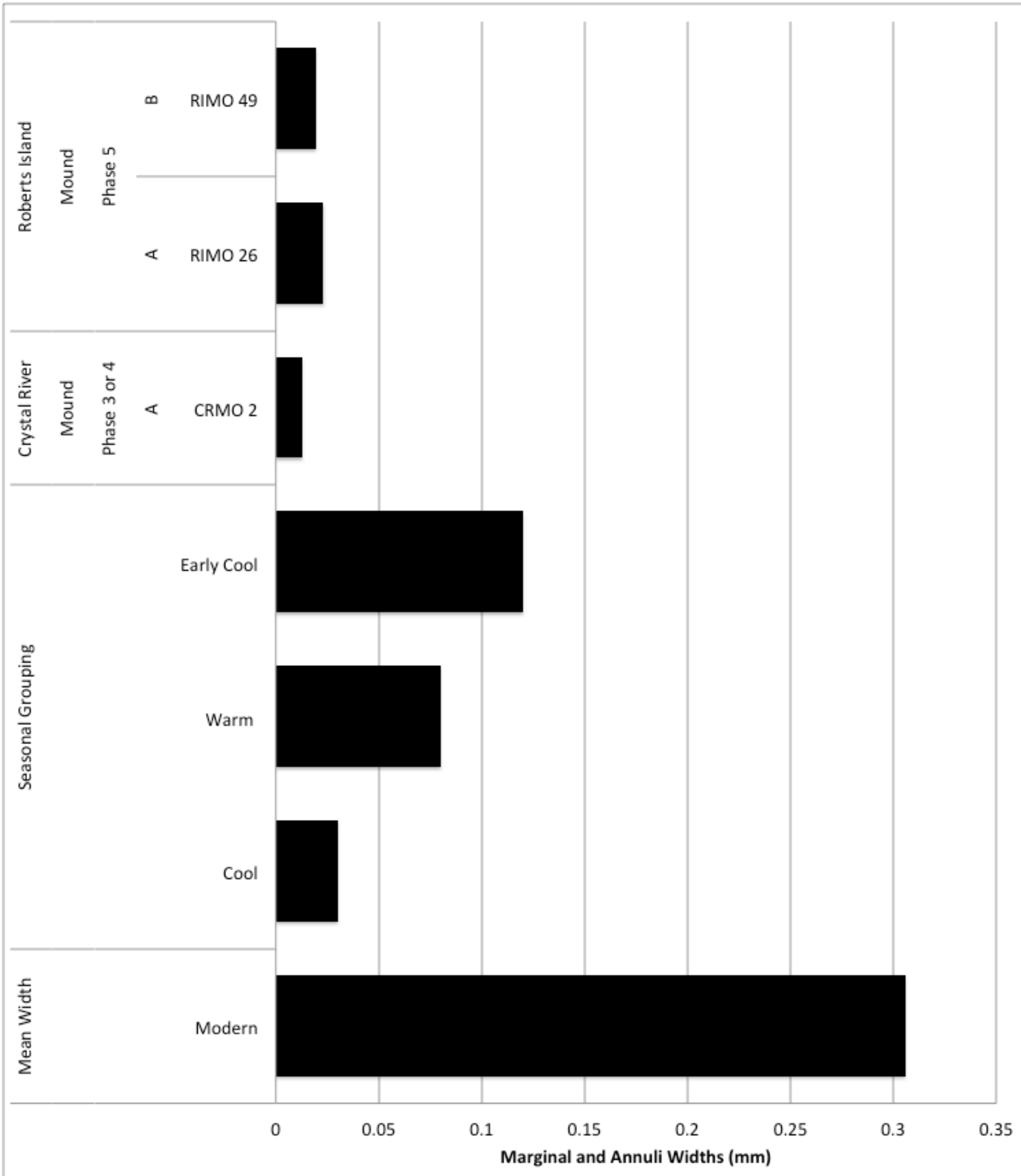

Figure 6.45. Bar Graph of Spotted Seatrout with Seven Annuli Present. Graph includes: Marginal Widths (mm) of Archaeological Otoliths with Temporal and Site Context, Marginal Widths (mm) for Seasonal Groupings, and Mean Annuli Widths (mm) for Sites and Time Periods

The analyses performed on the spotted seatrout otolith with no annulus present suggest capture during the cool season. This designation is evidenced by the marginal width surpassing the average mean width of all spotted seatrout otoliths recovered from Crystal River, as well as the prehistoric and modern mean. Additionally, the width of this otolith falls well within the spread of the data provided by the Cool Season histogram. The spotted seatrout otolith with one annulus present has a marginal width measuring between the two designated Early Cool Seasons, which offers plenty of evidence to support this designation. It is important to recall here, these two annuli were the ones that required caution due to the limited number of modern fishes caught in warm seasons for otoliths with no annulus present and the challenges of developing the seasonal groupings and the statistically significant differences in the mean between the modern assemblage and both sites assemblages for otoliths with one annulus present. However, I believe there is enough evidence to support the seasonal designations for these two otoliths.

There is a major increase in the number of otoliths analyzed and reported on with two annuli present from the assemblages, which suggests fishes of this size and above were likely most frequently targeted. This pattern could be indicative of the size nets used by the peoples of Crystal River and Roberts Island; however, I cannot rule that this suggestion is due to sampling bias. Interestingly, all but one of these otoliths indicates capture during cooler seasons. Furthermore, all occupation phases are represented in these sub-assemblages. These trends continue with spotted seatrout otoliths that have three annuli present, except there are no otoliths representing Roberts Island in Midden Phase 3. Regardless, these results reveal there is more variation in the seasonal designations since all seasons were assigned for this annuli cohort. The sub-assemblage of spotted seatrout otoliths with four annuli present is comparable in size to the preceding annuli but seasonal variation is less. The results suggest these fishes were caught mostly in cooler months but by no means exclusively. Spotted seatrout otoliths with five annuli present continue the trend of more caught during cooler months but two otoliths indicate capture during warm seasons. The quantities of otoliths for the remaining two annuli are much smaller than the preceding four annuli cohorts. This observation is not too surprising given the known ten-year lifespan of this species (Bester 2021). The results for spotted seatrout with six annuli present suggest capture during three seasons, including the Cool Season, the Early Cool/Cool Season, and the Early Warm Season. Lastly, spotted seatrout otoliths with seven annuli present appear to be only caught during the Cool Season. Interestingly, these three otoliths were recovered from the three mound contexts that are represented in this study.

In summation, this initial description of the result for the Crystal River and Roberts Island spotted seatrout assemblages offer insight into past activities surrounding this species. First, the results provide evidence that spotted seatrout were captured during all seasons at both sites. Second, all occupation phases from the sites are represented in these sub-assemblages. And, lastly, there is evidence to support a preference for adult fishes, especially those with two to five annuli present.

Spotted Seatrout Results Summary

Combining all spotted seatrout results, Figure 6.46 presents an informative picture of the seasons these fishes were captured and subsequently discarded at Crystal River and Roberts Island. The results reveal intriguing information about when activities were and were not occurring at these two important Middle and Late Woodland civil ceremonial centers.

Following chronology of the sites, I found additional evidence to support Pluckhahn and Thompson's (2018:103-104) belief that during Midden Phase 1 at Crystal River the site was initially seasonally visited in cooler months only and then transitioned to year-round occupation as the early village emerged towards the end of this phase. All three spotted seatrout otoliths that were analyzed from these contexts have marginal widths consistent with capture during the Cool Season (January and February) and provides an additional line of evidence to support Pluckhahn and Thompson's interpretation of the activity of the hunter-fisher-gather activity at Crystal River during Mound Phase 2 and Midden Phase 1.

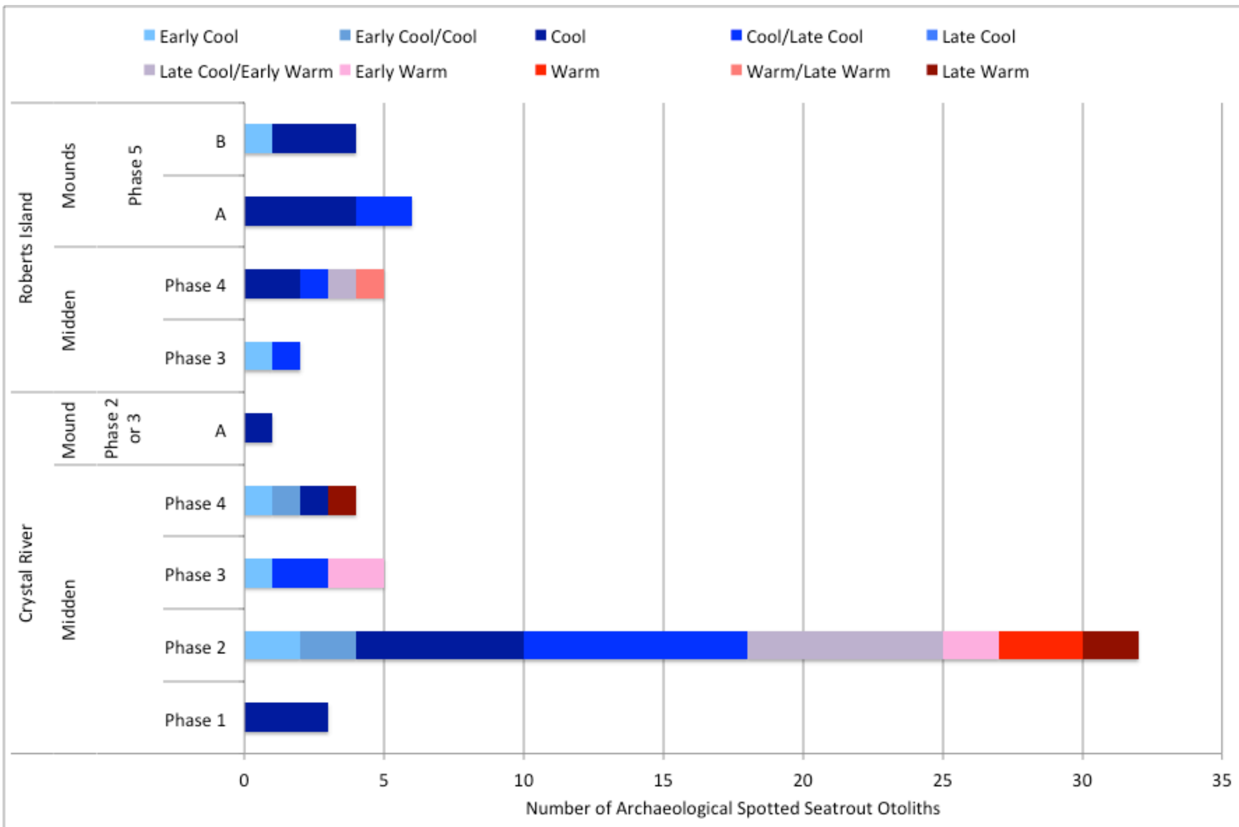

Figure 6.46. Crystal River and Roberts Island Spotted Seatrout Seasonality Results Organized by Context and Phase

During Midden Phase 2 at Crystal River, the sub-assemblage of spotted seatrout otoliths offers further evidence to support year-round occupation of the site since every seasonal designation is present. There is also evidence from these results that illustrates a marked increase in the quantity of this Phase's otolith sub-assemblage. This observation aligns with Pluckhahn and Thompson's (2018:119-121,153-154) assertion, based on site construction activity, midden accumulation rates, and material culture evidence, that Crystal River was no longer a vacant ceremonial center and early village but had transformed into a sedentary village and a regional civic ceremonial center. The sole otolith from Crystal River mound contexts likely dates to this phase of occupation. The otolith was found in the core sample taken from Mound A (Core 13, sec 3, Strat XI). Pluckhahn and Thompson (2018:133-137) are cautious regarding their interpretation of this genuinely monumental piece of architecture due to its complicated stratigraphy and potential to have repurposed midden material included during its construction. Likewise, I am cautious to make a grandiose assertion that this single otolith provides evidence that the second construction episode of Mound A occurred in the Cool Season (as indicated by my seasonality results). It is however extremely tempting to infer winter construction since Thompson and colleagues' (2015) oyster study provides ample evidence to support their belief that construction of the other mounds at Crystal River occurred in cooler months. Also noteworthy is the concentration of otoliths from Trench 4, the vast majority of which are from Phase 2. Given the abundance of otoliths, the seasonal signatures indicating year-round and proximity to the lagoon and the river, I propose that this area very likely served as a fish processing area during Midden Phase 2.

After this height in village and regional activity, Pluckhahn and Thompson (2018:166-167) report a sharp decline during the Mound Phase 4 and Midden Phase 3 period at Crystal River. Interestingly, a drop off in quantity of otoliths occurs at this time as well, thus, providing an additional line of evidence to support waning activity. Despite the decline, the spotted seatrout results from this phase also supports their evidence for continued year-round occupation of the site (Thompson et al. 2015).

The final documented occupation at Crystal River, Mound Phase 5 and Midden Phase 4, is the area north of Mound A. Pluckhahn and Thompson (2018:172) observed another decrease in midden accumulation and little, if any, mound construction at this time. They interrupted from the evidence gathered at the site that the area was possibly occupied by a caretaker population or family group. The spotted seatrout results from this period indicate year-round occupation and supports their claim that a site activity had a decreased, which is evidenced by a decrease in the number of otoliths.

The spotted seatrout assemblage from Roberts Island sheds new light on the activities that took place here. During Mound Phase 4 and Midden Phase 3, Pluckhahn and Thompson (2018:156-159) found evidence that this area began to be inhabited. They postulate a few reasons for the possible move to this location, including environmental changes that could have impacted the availability of the fish species used in this study. The limited seasonality results, only two otoliths were analyzed from the midden area, suggest use during the Cool and Late Cool Seasons. The next phase of occupation at Roberts Island, Mound Phase 5 and Midden Phase 4, suggests a proverbial boom of construction and site activity. Pluckhahn and Thompson (2018:171) point out the oddity of Roberts Island fluorescence given the absence of mound building taking place elsewhere in the region. Nevertheless, Mounds A, B, and C were constructed during this phase and Pluckhahn and Thompson (2018:181-186) interpret from their research that Mounds A and B were constructed in single episodes during cooler months. The spotted seatrout seasonality results provide additional evidence to support this claim. All spotted seatrout otoliths recovered from mound contexts at Roberts Island indicated capture during cooler seasons. There is additional evidence, albeit small when compared to the height of activity at Crystal River, which suggests year-round occupation from midden contexts.

CHAPTER SEVEN: CONCLUDING DISCUSSION AND FUTURE RESEARCH

Discussion

In the preceding chapter, I discussed separately the seasonality results of the red drum and spotted seatrout assemblages from Crystal River and Roberts Island. While these discussions painted two pictures of activities at these sites, combining the results offers better evidence to address the main questions of this research. Figures 7.1 and 7.2 show the combined seasonality results for the red drum and spotted seatrout assemblage and provide the associated temporal and contextual information. Figure 7.1 demonstrates again the amount of activity that occurred at Crystal River during Mound Phase 3 and Midden Phase 2 when the majority of the construction projects were taking place. Additionally, by combining the Mound Phase 5 and Midden Phase 4 results from Roberts Island (n=29), there is a clear indication of year-round occupation at the site and the second highest count of otoliths for a phase. This result illustrates and offers supporting evidence for Roberts Island becoming the new focus of construction and activity for the local fisher-hunter-gatherers.

Figure 7.2 presents the combined seasonality results in a slightly different light through percentages of each seasonal designation for the various phases and contexts. This portrayal of the results indicates these species were caught more in the cooler seasons than warmer seasons. This observation is interesting since both species can be caught year-round in estuarine waters (Bester 2021; Buskill 2017), only because the red drum assemblage consisted of fishes ages (0-4) as older red drum fish move to coastal waters during certain times of the year.

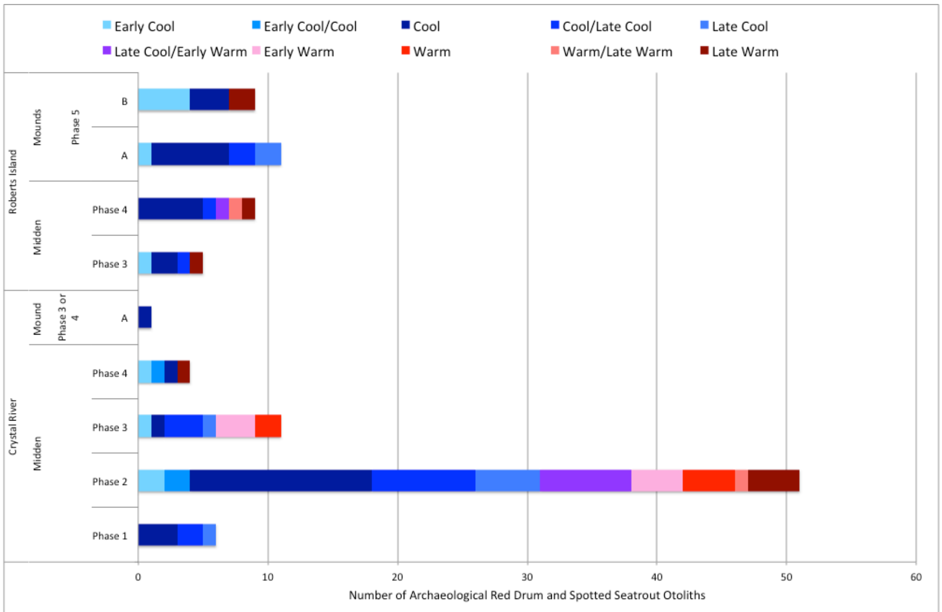

Figure 7.1. Combined Seasonality Results of Red Drum and Spotted Seatrout by Context and Phase

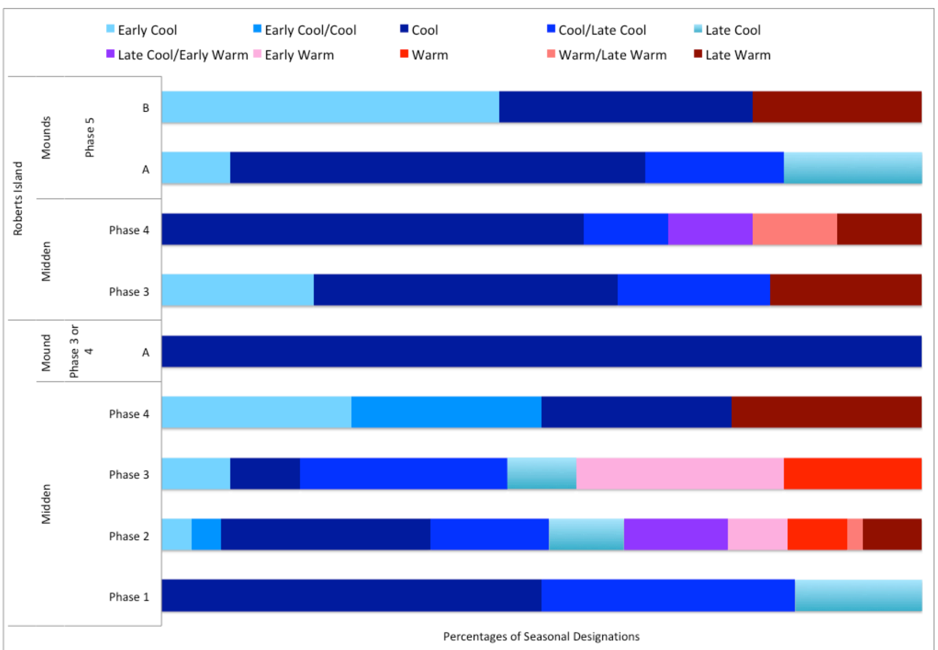

Figure 7.2. Percentages of Combined Seasonality Results for Red Drum and Spotted Seatrout by Context and Phase

Aside from these initial observations, I am now able to delve more deeply into the results and address my main research questions. First, were seasonal deposition events involving the construction of monumental architecture taking place at Crystal River and Roberts Island? Second, did feasting act as a mechanism to organize the labor needed to construct monumental architecture? The combined results from this study provide further evidence that seasonal deposition events were taking place at these sites and a link between these activities and monumental construction is clearer. The results from Crystal River Mound Phase 2 and Midden Phase 1 all have signatures for capture during cooler months of the year. During this time, Crystal River was transitioning to an early village steeped in traditions from the preceding period when the site was used as a burial ground. The evidence suggests people gathered at the site, feasted on oysters, fishes, and high-status mammals (Little and Reitz 2015; Pluckhahn and Thompson 2018:105-106; Reitz and Brown 2015), worked on construction projects in the Main Burial Complex and Mound G (Pluckhahn and Thompson 2018:111-113), and began to show symbolic connections to the local area by selecting marine shell pendants as common burial good (Pluckhahn and Thompson 2018:112-113). Applying Dietler and Herbich's (2001:240-258) collective work events model to this time, I postulate that the smaller-scale projects were likely closer to the work exchange end of the continuum. My assertion is based on the evidence from Crystal River that suggests two communities were coming together, thus requiring reciprocal cooperation in site activities to enhance connection between groups and to the land. The scale of these early construction projects was smaller than ones that occurred in the next phase, so a large labor force was not needed. However, catchment practices, even in this phase, would have required a good amount of people to catch fish in weirs, nets, or traps and collect oysters for communal consumption. It is quite possible that these subsistence practices helped to bring these groups together and solidify a bond.

There is one noteworthy line of evidence that provides additional support for this interpretation. In the interval preceding Midden Phase 1, when Crystal River is believed to have been a vacant ceremonial center for mortuary practices, many of the individuals who were interred in the burial mound were buried with plummets made from a variety of materials, some local and some exotic. Plummets were attached to the bottom of nets that were used to capture large quantities of fish. Perhaps, in a few cases, the plummets associated with these early burials represent a link to a fishing ritual that included catching fishes for the feasting and construction events that were held during the cooler months of the year. However, there is plenty of evidence to support that the majority of the plummets associated with burials were personal adornment items that were traded between communities (Thompson et al. 2017).

Based on all this evidence, I put forward the idea that an important tradition was established early on at Crystal River that would continue through occupation at Roberts Island. During cooler months of the year, groups near and far would gather at Crystal River, work together to catch and collect resources for a feast, engage in construction projects that included using the feasting remains as building material, and perform mortuary rituals to honor those that had passed.

The evidence provided from the otolith seasonality results to support the continuance of this tradition in Mound Phase 3 and Midden Phase 2 at Crystal River is somewhat less direct. Unfortunately, only one spotted seatrout otolith was available for this study from mound contexts. The results did offer tenuous support for the construction of Mound A in cooler months. However, given that there is only one otolith and Pluckhahn and Thompson (2018:133-137) caution the possible use of repurposed midden in Mound A's construction fill, I consider this evidence inconclusive. Still, there is alternative evidence that can be used to support my assertion that this feasting and construction tradition in cooler months continued. First, Thompson and colleagues' (2015) oyster study provided ample evidence that the oysters found in the construction of the mounds at Crystal River were collected during cooler seasons. This evidence shows a direct connection. Second, the human interments during this time are reported to have an abundance of grave goods made of shell, particularly plummets. As I noted above, these may indicate the importance of mass-capture fishing techniques, although there are alternative interpretations of these plummets.

In the absence of a more robust assemblage of otoliths from mound contexts, I turn attention to otoliths from midden contexts to provide an indirect line of evidence for support. Trench 4 at Crystal River contained an abundance of otoliths (see Tables 5.1 and 5.2) when compared to the other investigated areas of the site. Nearly 55% of all otoliths were recovered from this context. I believe, as noted earlier, given Trench 4's proximity to the lagoon and Crystal River and the abundance of otoliths recovered, this area was likely used to process fish during this period. The seasonality results from this trench show that both red drum and spotted seatrout were captured and their remains were deposited throughout the year. While this information is useful, a refined examination of the results by levels and features provides an intriguing supposition. In Level 8 of Units 9 and 10 of Trench 4, a number of loci were identified. These loci, locus G, locus E, and locus H, all contained spotted seatrout caught during cooler months. While this could simply be evidence of a mundane fish-processing event, it could also be the signature of a feasting event. Regardless really of when this event took place and if the fishes were part of an everyday meal or a communal consumption event, this context illustrates that mass capture events were taking place at Crystal River during cooler months and this phase of occupation. Therefore, based on the direct and indirect lines of evidence discussed here, I argue that there is evidence to support my notion for the continuation of feasting and construction in cooler months was taking place during this time. Also, given the large-scale construction projects that took place during Mound Phase 3 and Midden Phase 2 the likelihood of purely work exchange events is less likely. I propose based on the aforementioned evidence that during this phase the villagers of Crystal River held work feasts to recruit the labor needed to construct Mounds H and K entirely and the initial stages of Mounds A and J. They would have relied on the established tradition of inviting connected communities to come during the cooler months of the year and aid them with these monumental projects. In return, the Crystal River villagers would have spoiled their guests with copious amount of oysters, fishes, and other resources.

Attention now shifts down river to the next major prehistoric construction events at Roberts Island. Was the tradition of feasting and construction in cooler months continued there? The combined seasonality results from Mound A suggest a continuation of some traditions. This assertion is based on the evidence that all fishes were captured during cooler months of the year thus aligning with the oyster study (Thompson et al. 2015). Another line of intriguing evidence is the other oyster study (Lulewicz et al. 2018) that indicated oysters in mound contexts were harvested from higher saline oyster beds as opposed to the oysters deposited in midden contexts that came from lower saline oyster beds. The potential of restricted access to oyster beds could suggest the villagers of Roberts Island were using these beds as a way to create surplus and prepare for large feasting events. It is also possible these higher saline oyster beds had ritual power associated with them and their shells gave the mounds additional significance. Unfortunately, it is difficult to say whether plummets were still included in burials or traded with other communities from people associated with this site because a burial area has not been found at Roberts Island. However, I believe the other aforementioned evidence provides suitable support that some form of collective work events were taking place at Roberts Island. I am hesitant to say exactly where on the work exchange/work feast continuum these events would fall but there is sufficient evidence at a minimum to support that members of the Roberts Island village could have hosted large-scale feasting events and they definitely needed a large labor force to accomplish the monumental tasks that were accomplished.

The results derived from Mound B at Roberts Island, however, do not fully support a continuance of this tradition. The spotted seatrout recovered from the mound were all captured during cooler months, but the red drum assemblage is split between signatures for warm and cooler months. Two of the red drum otoliths were captured during the Late Warm season while the other three otoliths in this sub-assemblage were captured in the Early Cool season. Perhaps these two red drum fishes had slower growth rates than usual and were caught in cooler months like the rest of the fishes deposited in this context. There is also the possibility that some repurposed midden material was used in the construction of Mound B. Another plausible explanation is that other rituals were performed on Mound B during warmer times of the year after construction was complete and the otoliths migrated down into the original construction material. Despite the evidence from Roberts Island Mound B, I believe a strong argument has been presented that connects feasting and construction events in cooler months together at these sites.

Future Research

The application of otolith research in the southeastern United States has been somewhat limited. I believe this is due in part to some of the caution regarding otolith studies that has been expressed in several seminal publications (see Andrus and Crowe 2002 and Colaninno 2012). However, there have also been publications that illustrate how beneficial otolith studies may be to a variety of research areas, including the previously discussed Baker and Klippel (2008) study of fishes on Alabama's Gulf Coast and Hadden's (2015) study on Florida's Panhandle coast. Other research areas that may be addressed through the analysis of otoliths are fish size estimates, changes in fish populations over time, over-harvesting, age studies, net size, paleo-environment, and subsistence. Indeed, the data collected in this study can be used to conduct many of the studies just listed, beyond the seasonality that was the focus of my research.

In regard to this study and these sites, I regret not being able to investigate the two of the dominant fish species at the site, mullet and hardhead catfish. Unfortunately, mullet otoliths are small, fragile, and can be easily be mistaken for fragmented oyster to the untrained eye. If excavations are ever continued at Crystal River and/or Roberts Island, I would make the case that 100% collection of column samples should be obtained from excavated contexts and have trained lab technicians carefully examine the material for mullet otoliths. FWC's FWRI has a large modern mullet collection that could be used for comparisons.

In regard to hardhead catfish, additional research should be conducted using isotope analysis to help clarify whether their otoliths exhibit seasonal patterns. This species seems to be found at countless archaeological sites on the Gulf Coast and their otoliths preserve well, which makes it a prime candidate for local and regional studies. Unfortunately, the villagers of Crystal River and Roberts Island captured hardhead catfish with a very large range of ages. I realized this during my pilot study when catfishes ranged between young-of-year to eighteen years old. FWC's FWRI does not collect modern data or perform otolith analyses on this species and after I did the math on what it would take for me to develop a statistically sufficient monthly marginal width database to compare to the archaeological otoliths… I decided that might be a bit too much for a Master's thesis.

To conclude, in addition to refining our understanding of the nature of feasting and mound construction at Crystal River and Roberts Island, this research has demonstrated the value otoliths have to the discipline of archaeology. I hope fellow researchers in the Southeast see the applicability of the methods used in this study and conduct similar analyses on other fish species.

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APPENDICES

Appendix A: Red Drum

This appendix provides tables of descriptive statistics and monthly histograms for all age groups of red drum examined in this study. Histograms for each age group are set to the same scale and the mean growth band width that corresponds with that annulus is displayed on each graph. Note that some age groups may have months missing due to no modern specimens being collected. All raw measurements can be obtained by contacting the Age and Growth Lab at Florida's Fish and Wildlife Research Institute

Arrangement of Descriptive Tables and Histograms for Individual Months:

Red Drum

- No Annulus Present
- 1 Annulus Present
- 2 Annuli Present
- 3 Annuli Present
- 4 Annuli Present

Arrangement of Descriptive Statistics Tables:

Red Drum

- No Annulus Present
- 1 Annulus Present
- 2 Annuli Present
- 3 Annuli Present
- 4 Annuli Present

Descriptive Statistics and Histograms for Individual Months of Modern Red Drum Marginal Increments

Table A1. Descriptive Statistics for Marginal Increments of Red Drum with No Annulus Present for Each Calendar Month

	Month	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Red Drum No Annulus Present	January	59	1.472	0.015	1.442	1.502	1.470	1.474	0.013	0.114	1.220	1.770	0.550	0.140	0.283	0.311	0.112	0.613
	February	21	1.489	0.035	1.417	1.561	1.495	1.490	0.025	0.158	1.130	1.740	0.610	0.190	-0.709	0.501	0.389	0.972
	March	2	1.570	0.204	-1.020	4.159	NA	1.570	0.083	0.288	1.370	1.770	0.410	NA	NA	NA	NA	NA
	April	0	NA															
	May	0	NA															
	June	1	1.000	NA														
	July	4	1.206	0.053	0.979	1.434	NA	1.257	0.008	0.092	1.100	1.260	0.160	NA	-1.726	1.225	NA	NA
	August	5	1.201	0.035	1.104	1.298	1.203	1.231	0.006	0.078	1.080	1.270	0.180	0.140	-0.940	0.913	-0.671	2.000
	September	31	1.276	0.020	1.235	1.317	1.274	1.279	0.013	0.112	1.080	1.540	0.460	0.160	0.082	0.421	-0.146	0.821
	October	62	1.354	0.017	1.321	1.388	1.362	1.365	0.017	0.132	0.820	1.560	0.740	0.170	-1.117	0.304	2.958	0.599
	November	138	1.391	0.011	1.369	1.414	1.400	1.404	0.018	0.135	0.820	1.640	0.820	0.160	-1.327	0.206	4.008	0.410
	December	134	1.412	0.009	1.394	1.430	1.412	1.413	0.011	0.106	1.170	1.720	0.550	0.150	-0.008	0.209	-0.167	0.416

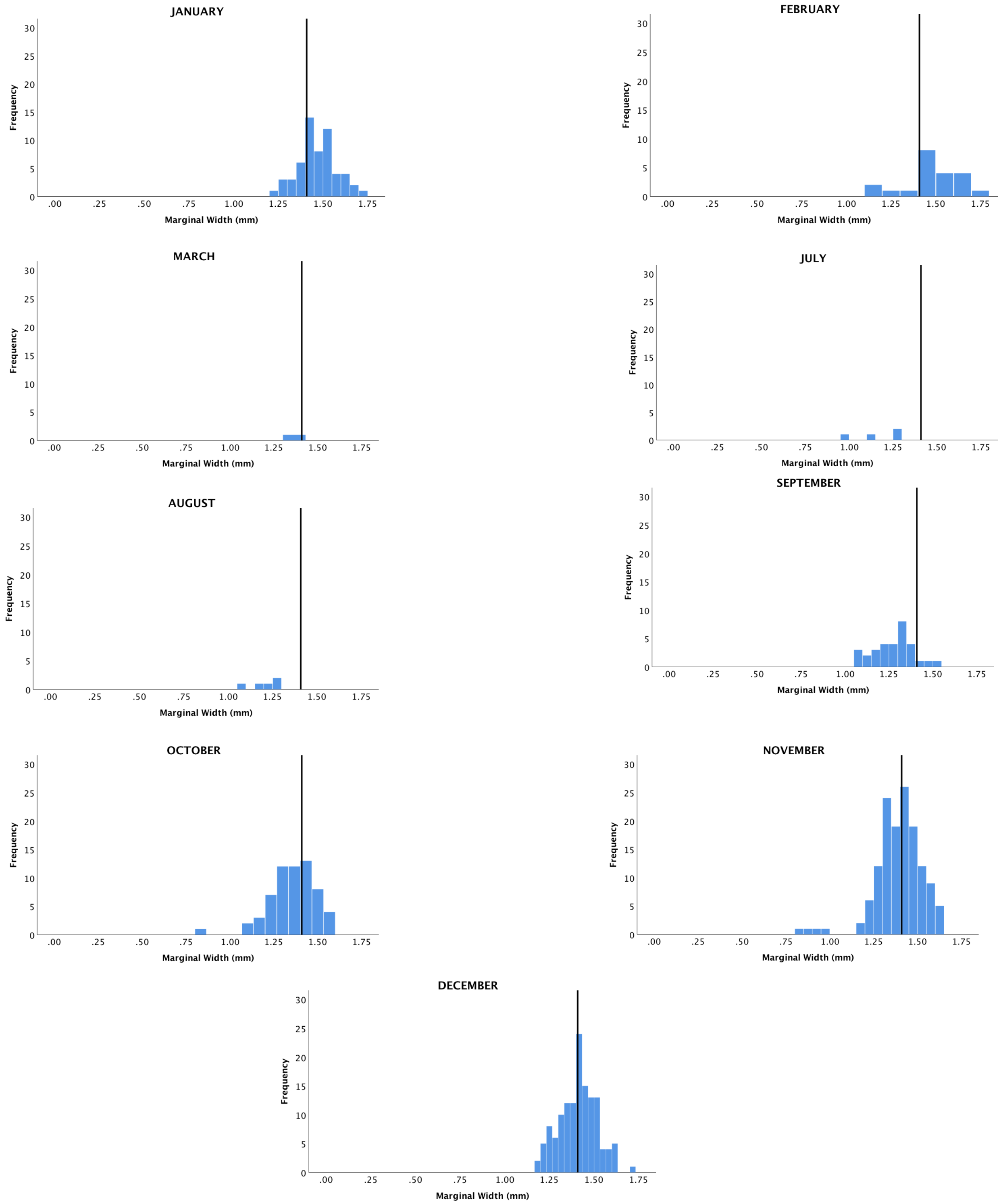

Figure A1. Monthly Histograms of Marginal Increments for Modern Red Drum with No Annulus Present

Table A2. Descriptive Statistics for Marginal Increments of Red Drum with One Annulus Present for Each Calendar Month

	Month	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Red Drum 1 Annulus Present	January	185	0.222	0.016	0.189	0.254	0.208	0.088	0.050	0.223	0.010	0.730	0.720	0.420	0.807	0.179	-1.105	0.355
	February	157	0.151	0.015	0.122	0.180	0.131	0.071	0.034	0.186	0.010	0.720	0.710	0.070	1.816	0.194	1.668	0.385
	March	213	0.109	0.004	0.101	0.118	0.104	0.100	0.004	0.063	0.020	0.710	0.690	0.050	5.387	0.167	45.040	0.332
	April	225	0.144	0.003	0.138	0.150	0.141	0.138	0.002	0.045	0.050	0.510	0.460	0.050	2.661	0.162	18.919	0.323
	May	327	0.177	0.002	0.172	0.182	0.176	0.174	0.002	0.045	0.040	0.320	0.290	0.060	0.402	0.135	0.222	0.269
	June	296	0.230	0.003	0.225	0.236	0.229	0.229	0.002	0.048	0.100	0.430	0.340	0.060	0.477	0.142	0.809	0.282
	July	276	0.285	0.003	0.279	0.292	0.285	0.284	0.003	0.057	0.100	0.470	0.370	0.080	0.061	0.147	-0.093	0.292
	August	343	0.345	0.003	0.339	0.352	0.344	0.343	0.004	0.062	0.200	0.540	0.340	0.080	0.331	0.132	0.070	0.263
	September	421	0.408	0.003	0.401	0.414	0.407	0.405	0.004	0.066	0.230	0.670	0.440	0.090	0.218	0.119	0.350	0.237
	October	395	0.458	0.004	0.451	0.466	0.457	0.451	0.006	0.080	0.220	0.790	0.570	0.100	0.328	0.123	0.845	0.245
	November	260	0.486	0.007	0.473	0.499	0.493	0.492	0.011	0.107	0.040	0.820	0.780	0.110	-1.541	0.151	5.878	0.301
	December	191	0.406	0.016	0.374	0.437	0.411	0.496	0.049	0.222	0.020	0.750	0.730	0.460	-0.790	0.176	-0.977	0.350

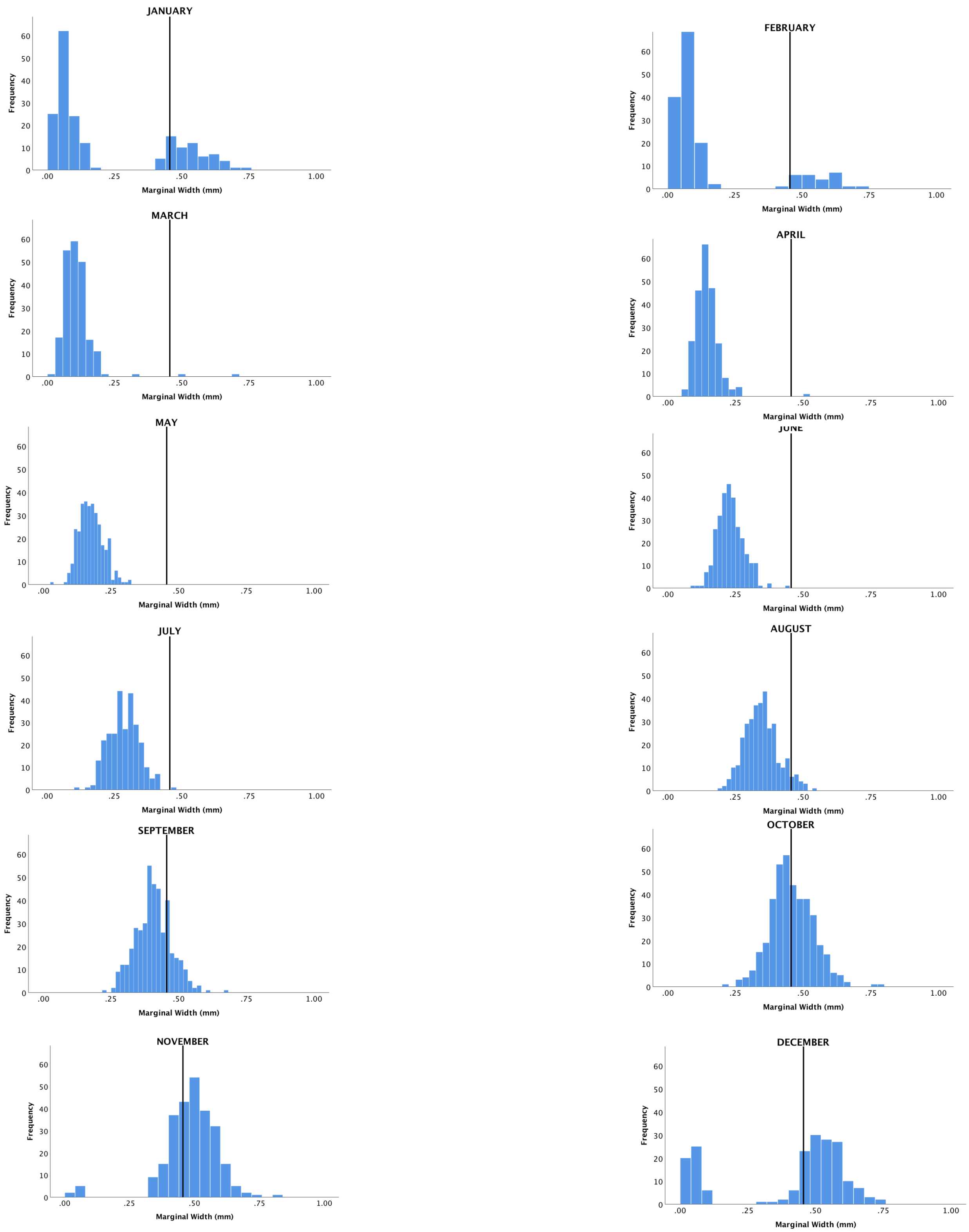

Figure A2. Monthly Histograms of Marginal Increments for Modern Red Drum with One A Present

Table A3. Descriptive Statistics for Marginal Increments of Red Drum with Two Annuli Present for Each Calendar Month

	Month	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Red Drum 2 Annuli Present	January	141	0.119	0.013	0.094	0.145	0.103	0.054	0.024	0.155	0.010	0.580	0.560	0.040	1.771	0.204	1.432	0.406
	February	157	0.083	0.007	0.068	0.097	0.066	0.061	0.008	0.091	0.010	0.550	0.540	0.040	3.612	0.194	12.944	0.385
	March	224	0.078	0.003	0.072	0.084	0.075	0.077	0.002	0.045	0.020	0.580	0.560	0.040	6.093	0.163	64.992	0.324
	April	234	0.102	0.002	0.098	0.105	0.101	0.100	0.001	0.029	0.030	0.190	0.160	0.040	0.204	0.159	0.039	0.317
	May	274	0.128	0.002	0.124	0.132	0.127	0.124	0.001	0.031	0.040	0.220	0.190	0.040	0.326	0.147	0.316	0.293
	June	190	0.166	0.003	0.161	0.172	0.166	0.166	0.002	0.039	0.070	0.290	0.210	0.050	0.248	0.176	0.101	0.351
	July	196	0.209	0.003	0.202	0.216	0.207	0.203	0.002	0.048	0.110	0.420	0.310	0.060	0.922	0.174	1.887	0.346
	August	354	0.258	0.002	0.253	0.262	0.257	0.256	0.002	0.043	0.150	0.410	0.260	0.050	0.377	0.130	0.510	0.259
	September	254	0.300	0.003	0.293	0.306	0.300	0.302	0.003	0.053	0.160	0.450	0.290	0.060	0.094	0.153	0.056	0.304
	October	235	0.330	0.004	0.323	0.337	0.331	0.327	0.003	0.054	0.170	0.540	0.370	0.080	0.059	0.159	0.502	0.316
	November	98	0.310	0.013	0.285	0.336	0.317	0.350	0.017	0.129	0.020	0.500	0.470	0.100	-1.219	0.244	0.432	0.483
	December	99	0.197	0.019	0.160	0.234	0.190	0.058	0.035	0.187	0.020	0.520	0.510	0.360	0.478	0.243	-1.638	0.481

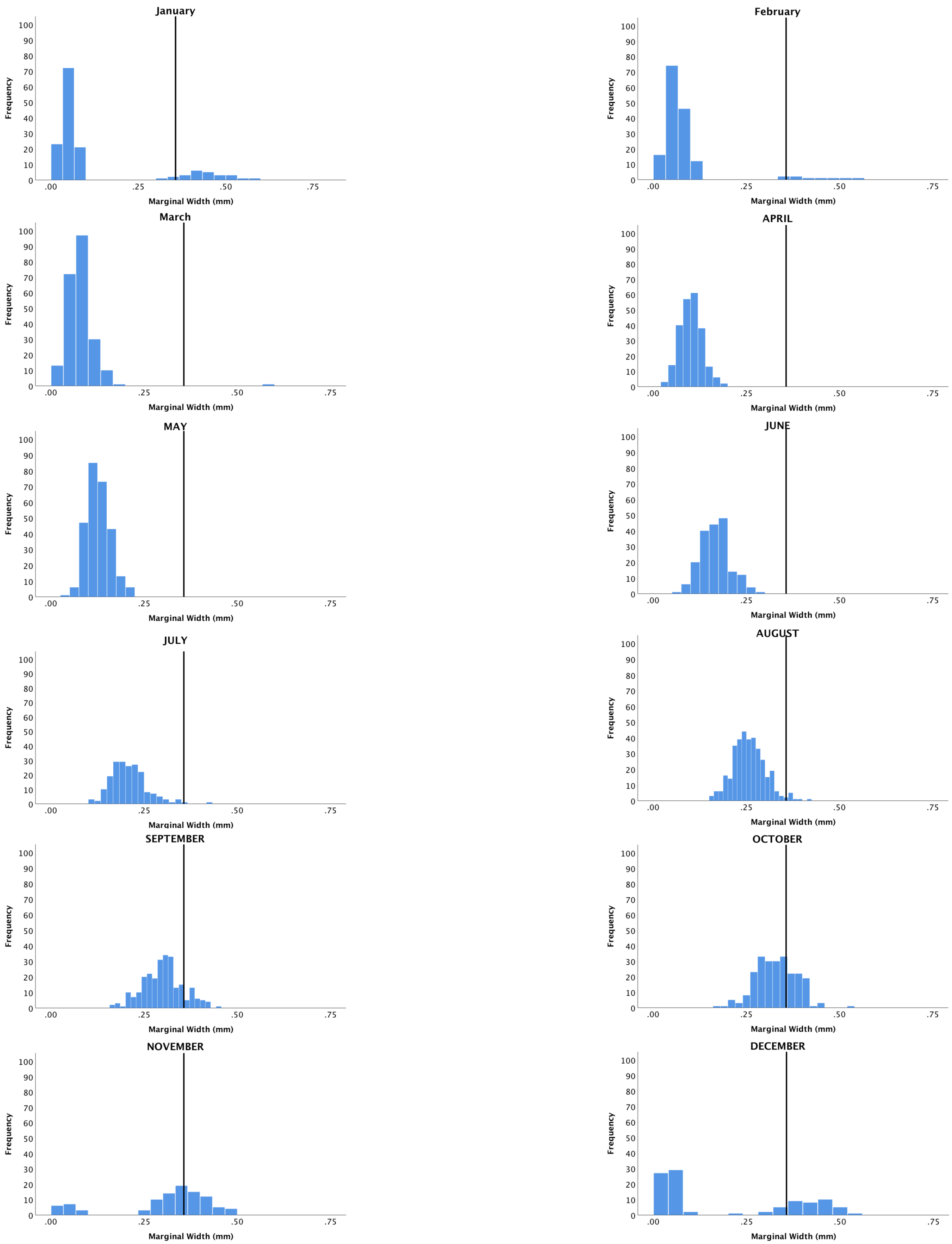

Figure A3. Monthly Histograms of Marginal Increments for Modern Red Drum with Two Annuli Present

Table A4. Descriptive Statistics for Marginal Increments of Red Drum with Three Annuli Present for Each Calendar Month

	Month	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Red Drum 3 Annuli Present	January	25	0.065	0.014	0.035	0.095	0.052	0.048	0.005	0.072	0.020	0.360	0.340	0.030	3.371	0.464	12.052	0.902
	February	34	0.083	0.015	0.052	0.114	0.071	0.057	0.008	0.088	0.000	0.360	0.360	0.030	2.497	0.403	5.531	0.788
	March	35	0.070	0.011	0.048	0.092	0.060	0.057	0.004	0.065	0.020	0.400	0.380	0.040	4.259	0.398	21.293	0.778
	April	46	0.076	0.004	0.068	0.085	0.076	0.074	0.001	0.029	0.020	0.140	0.110	0.030	0.468	0.350	-0.246	0.688
	May	47	0.099	0.004	0.091	0.107	0.098	0.096	0.001	0.026	0.040	0.180	0.140	0.020	0.614	0.347	1.340	0.681
	June	44	0.127	0.005	0.116	0.137	0.126	0.130	0.001	0.035	0.060	0.210	0.150	0.050	0.034	0.357	-0.476	0.702
	July	31	0.154	0.007	0.141	0.168	0.154	0.144	0.001	0.037	0.080	0.230	0.150	0.060	0.428	0.421	-0.727	0.821
	August	159	0.209	0.003	0.202	0.215	0.209	0.210	0.002	0.041	0.080	0.310	0.240	0.050	-0.215	0.192	0.518	0.383
	September	74	0.237	0.006	0.226	0.249	0.238	0.241	0.002	0.050	0.100	0.330	0.230	0.060	-0.228	0.279	0.008	0.552
	October	43	0.243	0.009	0.224	0.262	0.244	0.238	0.004	0.061	0.090	0.360	0.280	0.080	-0.049	0.361	-0.149	0.709
	November	15	0.251	0.037	0.171	0.331	0.253	0.300	0.021	0.145	0.030	0.440	0.410	0.310	-0.710	0.580	-0.992	1.121
	December	27	0.169	0.028	0.112	0.226	0.165	0.058	0.021	0.144	0.020	0.380	0.360	0.290	0.322	0.448	-1.895	0.872

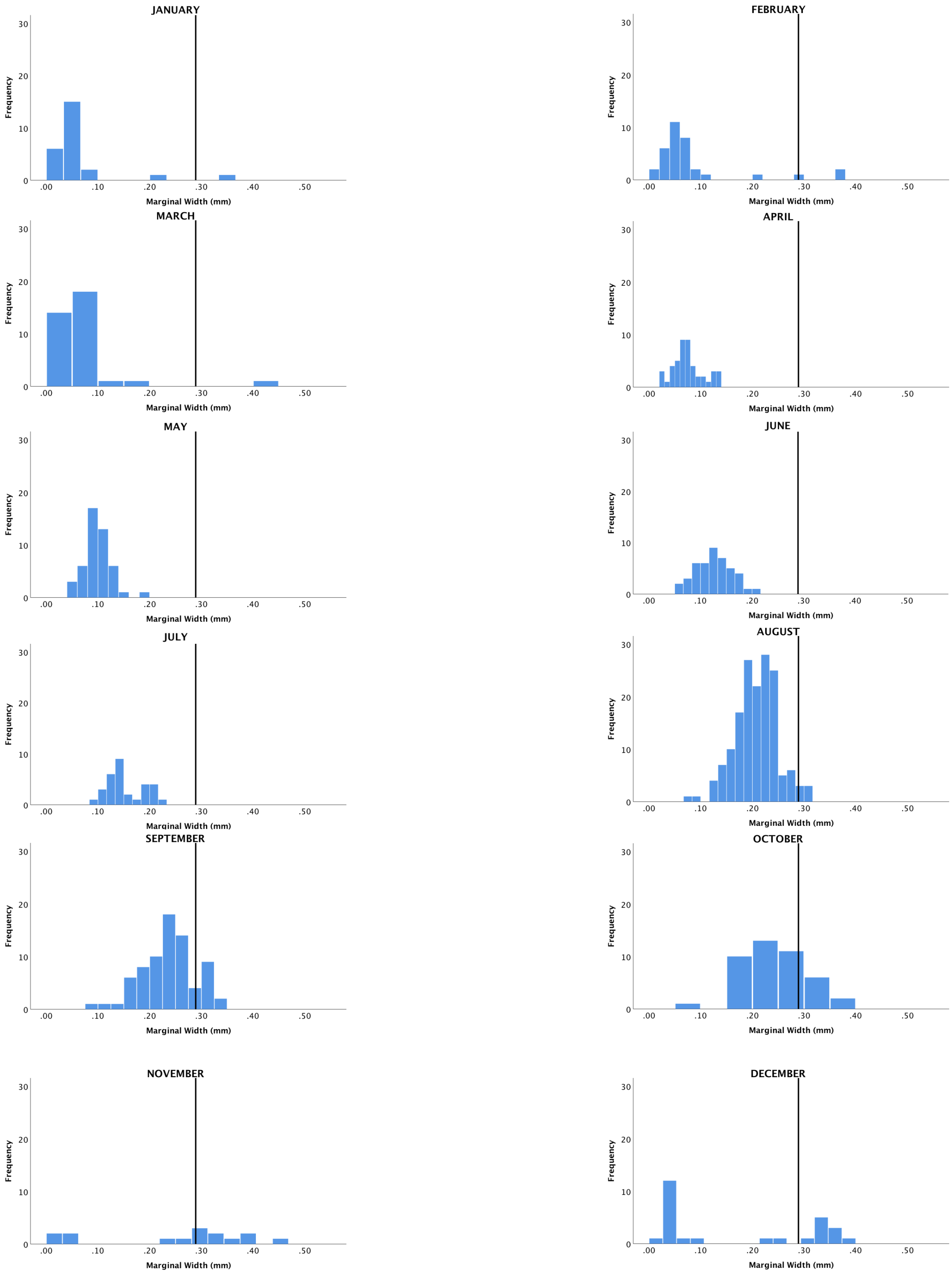

Figure A4. Monthly Histograms of Marginal Increments for Modern Red Drum with Three Annuli Present

Table A5. Descriptive Statistics for Marginal Increments of Red Drum with Four Annuli Present for Each Calendar Month

	Month	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Red Drum 4 Annuli Present	January	3	0.030	0.004	0.013	0.047	NA	0.031	0.000	0.007	0.020	0.040	0.010	NA	-0.544	1.225	NA	NA
	February	3	0.048	0.000	0.047	0.049	NA	0.048	0.000	0.001	0.050	0.050	0.000	NA	1.721	1.225	NA	NA
	March	6	0.044	0.006	0.028	0.060	0.044	0.049	0.000	0.015	0.020	0.060	0.030	0.030	-0.617	0.845	-1.811	1.741
	April	11	0.064	0.006	0.050	0.077	0.064	0.057	0.000	0.020	0.030	0.100	0.070	0.020	0.290	0.661	0.148	1.279
	May	9	0.081	0.007	0.064	0.098	0.081	0.086	0.001	0.022	0.050	0.120	0.070	0.030	-0.009	0.717	-0.512	1.400
	June	9	0.095	0.016	0.058	0.133	0.096	0.086	0.002	0.049	0.020	0.160	0.140	0.090	-0.055	0.717	-1.175	1.400
	July	7	0.100	0.008	0.081	0.119	0.100	0.098	0.000	0.020	0.070	0.130	0.060	0.030	0.328	0.794	-0.111	1.587
	August	19	0.176	0.006	0.165	0.188	0.177	0.180	0.001	0.024	0.130	0.210	0.080	0.050	-0.519	0.524	-1.007	1.014
	September	36	0.134	0.007	0.121	0.148	0.134	0.128	0.002	0.040	0.070	0.210	0.140	0.060	0.268	0.393	-0.872	0.768
	October	26	0.186	0.010	0.166	0.205	0.182	0.177	0.002	0.049	0.110	0.340	0.230	0.050	1.497	0.456	3.248	0.887
	November	3	0.109	0.051	-0.111	0.328	NA	0.058	0.008	0.088	0.060	0.210	0.150	NA	1.732	1.225	NA	NA
	December	11	0.128	0.023	0.077	0.179	0.127	0.152	0.006	0.076	0.040	0.250	0.210	0.130	0.063	0.661	-1.846	1.279

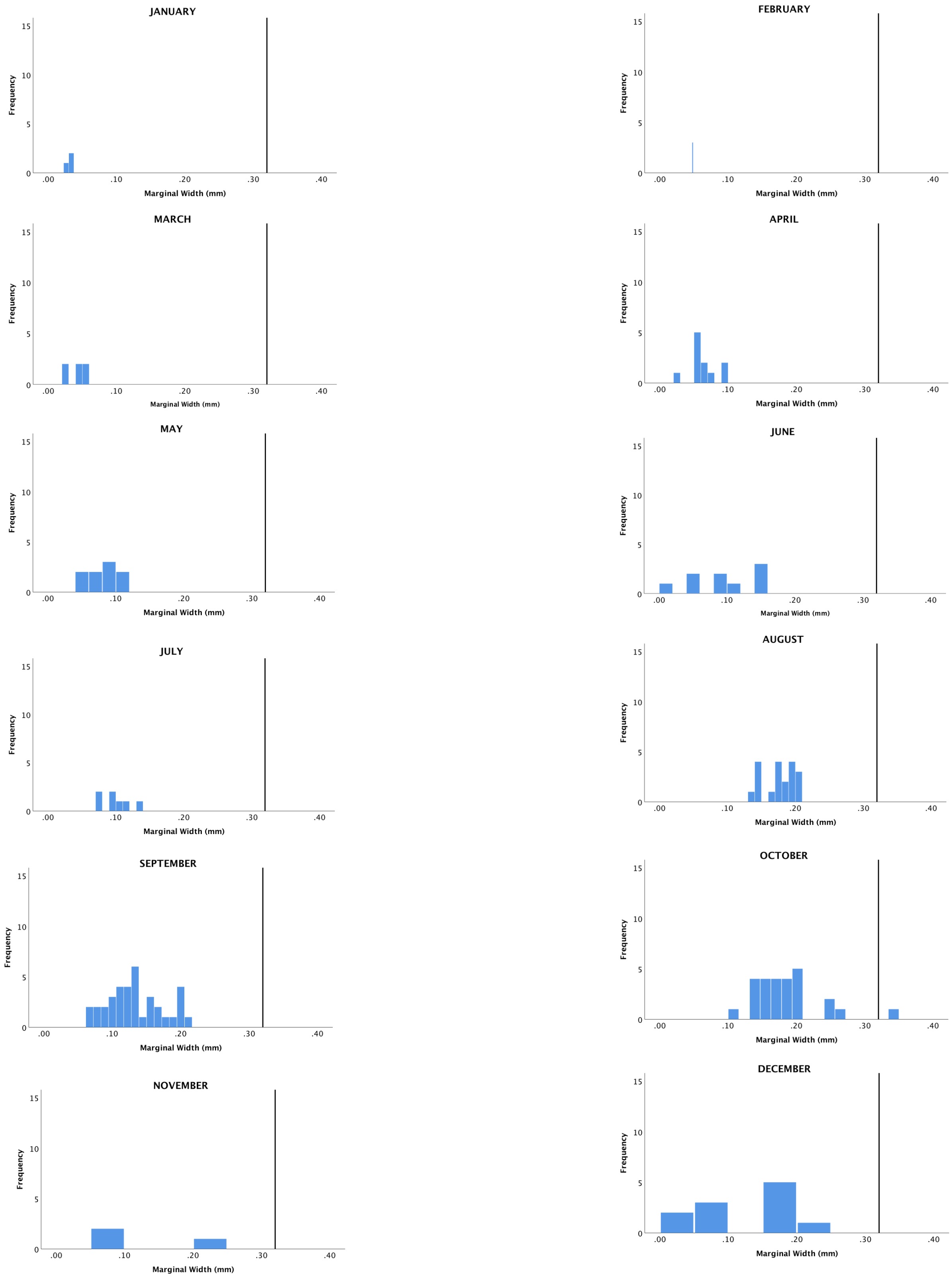

Figure. A5. Monthly Histograms of Marginal Increments for Modern Red Drum with Four Annuli Present

Descriptive Statistics Tables for Modern Red Drum Seasonal Groupings

Table A6. Descriptive Statistics for Monthly Seasonal Groupings of Red Drum with No Annulus Present

	Season	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Red Drum No Annulus Present	Cool (December - February)	214	1.436	0.008	1.420	1.452	1.435	1.430	0.014	0.118	1.130	1.770	0.640	0.150	0.079	0.166	0.059	0.331
	Cool (March)	2	1.570	0.204	-1.020	4.159	NA	1.570	0.083	0.288	1.370	1.770	0.410	NA	NA	NA	NA	NA
	Warm (June - September)	40	1.255	0.018	1.218	1.291	1.253	1.265	0.013	0.115	1.000	1.540	0.540	0.160	0.025	0.374	0.040	0.733
	Cool (October and November)	200	1.380	0.010	1.361	1.399	1.388	1.395	0.018	0.135	0.820	1.640	0.820	0.170	-1.218	0.172	3.406	0.342

Table A7. Descriptive Statistics for Monthly Seasonal Groupings of Red Drum with One Annulus Present

	Season	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Red Drum 1 Annulus Present	Cool (December - February)	533	0.267	0.010	0.247	0.287	0.258	0.106	0.057	0.238	0.010	0.750	0.740	0.460	0.399	0.106	-1.630	0.211
	Late Cool (March)	213	0.109	0.004	0.101	0.118	0.104	0.100	0.004	0.063	0.020	0.710	0.690	0.050	5.387	0.167	45.040	0.332
	Early Warm (April and May)	552	0.164	0.002	0.160	0.168	0.162	0.158	0.002	0.048	0.040	0.510	0.470	0.060	1.079	0.104	4.764	0.208
	Late Warm (June - September)	1336	0.327	0.002	0.322	0.332	0.326	0.324	0.008	0.090	0.100	0.670	0.580	0.130	0.213	0.067	-0.413	0.134
	Early Cool (October and November)	655	0.469	0.004	0.462	0.477	0.471	0.468	0.009	0.092	0.040	0.820	0.780	0.110	-0.680	0.095	3.868	0.191

Table A8. Descriptive Statistics for Seasonal Groupings with Two Annuli Present

	Season	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Red Drum 2 Annuli Present	Cool (December - February)	397	0.124	0.008	0.109	0.139	0.109	0.057	0.022	0.150	0.010	0.580	0.560	0.050	1.658	0.122	1.069	0.244
	Late Cool (March)	224	0.078	0.003	0.072	0.084	0.075	0.077	0.002	0.045	0.020	0.580	0.560	0.040	6.093	0.163	64.992	0.324
	Early Warm (April and May)	508	0.116	0.001	0.113	0.119	0.115	0.115	0.001	0.033	0.030	0.220	0.200	0.040	0.255	0.108	0.186	0.216
	Late Warm (June - September)	994	0.241	0.002	0.237	0.246	0.240	0.241	0.004	0.066	0.070	0.450	0.380	0.100	0.168	0.078	-0.246	0.155
	Early Cool (October and November)	333	0.324	0.005	0.315	0.333	0.332	0.333	0.007	0.083	0.020	0.540	0.520	0.080	-1.572	0.134	4.009	0.266

Table A9. Descriptive Statistics for Seasonal Groupings of Red Drum with Three Annuli Present

	Season	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Red Drum 3 Annuli Present	Cool (December - February)	86	0.104	0.012	0.080	0.129	0.095	0.053	0.013	0.113	0.000	0.380	0.380	0.050	1.512	0.260	0.618	0.514
	Late Cool (March)	35	0.070	0.011	0.048	0.092	0.060	0.057	0.004	0.065	0.020	0.400	0.380	0.040	4.259	0.398	21.293	0.778
	Early Warm (April and May)	93	0.088	0.003	0.082	0.094	0.088	0.086	0.001	0.030	0.020	0.180	0.160	0.040	0.304	0.250	0.204	0.495
	Late Warm (June - September)	308	0.198	0.003	0.192	0.205	0.198	0.200	0.003	0.056	0.060	0.330	0.270	0.080	-0.104	0.139	-0.300	0.277
	Early Cool (October and November)	58	0.245	0.012	0.222	0.269	0.248	0.249	0.008	0.089	0.030	0.440	0.410	0.110	-0.579	0.314	0.610	0.618

Table A10. Descriptive Statistics for Seasonal Groupings of Red Drum with Four Annuli Present

	Season	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Red Drum 4 Annuli Present	Cool (December - February)	28	0.109	0.014	0.080	0.138	0.106	0.060	0.006	0.075	0.020	0.250	0.220	0.140	0.468	0.441	-1.510	0.858
	Late Cool (March)	6	0.044	0.006	0.028	0.060	0.044	0.049	0.000	0.015	0.020	0.060	0.030	0.030	-0.617	0.845	-1.811	1.741
	Early Warm (April and May)	20	0.071	0.005	0.061	0.082	0.071	0.068	0.000	0.022	0.030	0.120	0.090	0.040	0.229	0.512	-0.434	0.992
	Late Warm (June - September)	71	0.137	0.005	0.126	0.148	0.138	0.133	0.002	0.045	0.020	0.210	0.190	0.080	-0.226	0.285	-0.692	0.563
	Early Cool (October and November)	29	0.178	0.011	0.156	0.199	0.177	0.172	0.003	0.057	0.060	0.340	0.280	0.060	0.407	0.434	2.120	0.845

Appendix B: Spotted Seatrout

This appendix provides tables of descriptive statistics and monthly histograms for all age groups of spotted seatrout examined in this study. Histograms for each age group are set to the same scale and the mean growth band width that corresponds with that annulus is displayed on each graph with a bold black line. Note that some age groups may have months missing due to no modern specimens being collected. All raw measurements can be obtained by contacting the Age and Growth Lab at Florida's Fish and Wildlife Research Institute.

Arrangement of Descriptive Tables and Histograms for Individual Months:

Spotted Seatrout

- No Annulus Present
- 1 Annulus Present
- 2 Annuli Present
- 3 Annuli Present
- 4 Annuli Present
- 5 Annuli Present
- 6 Annuli Present
- 7 Annuli Present

Arrangement of Descriptive Statistics Tables for Seasonal Groupings:

Spotted Seatrout

- No Annulus Present
- 1 Annulus Present
- 2 Annuli Present
- 3 Annuli Present
- 4 Annuli Present
- 5 Annuli Present
- 6 Annuli Present
- 7 Annuli Present

Descriptive Statistics and Histograms for Individual Months of Modern Spotted Seatrout Marginal Increments

Table B1. Descriptive Statistics for Marginal Increments of Spotted Seatrout with No Annulus Present for Each Calendar Month

	Month	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Spotted Seatrout No Annulus Present	January	2	1.200	0.023	0.908	1.492	NA	1.200	0.001	0.032	1.180	1.220	0.050	NA	NA	NA	NA	NA
	February	3	1.274	0.078	0.938	1.611	NA	1.306	0.018	0.135	1.130	1.390	0.270	-1.002	1.225	NA	NA	NA
	March	0	NA															
	April	0	NA															
	May	0	NA															
	June	0	NA															
	July	0	NA															
	August	0	NA															
	September	0	NA															
	October	3	1.017	0.061	0.755	1.279	NA	1.059	0.011	0.106	0.900	1.100	0.200	-1.501	1.225	NA	NA	NA
	November	5	1.155	0.026	1.082	1.227	1.153	1.134	0.003	0.059	1.100	1.250	0.150	0.100	1.137	0.913	0.606	2.000
	December	32	1.137	0.020	1.096	1.179	1.137	1.155	0.013	0.115	0.880	1.430	0.550	0.200	-0.037	0.414	0.272	0.809

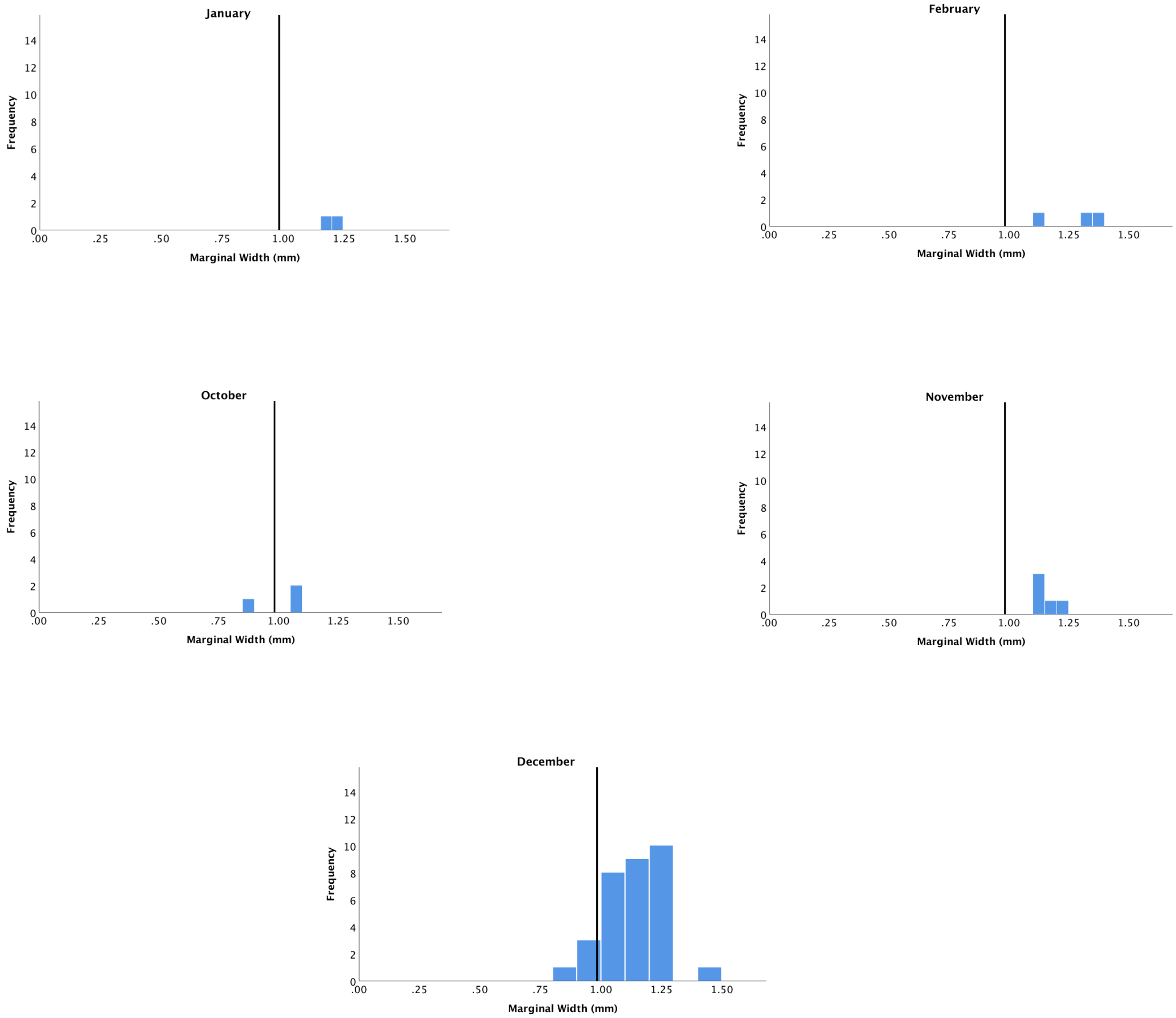

Figure B1. Monthly Histograms of Marginal Increments for Modern Spotted Seatrout with No Annulus Present

Table B2. Descriptive Statistics for Marginal Increments of Spotted Seatrout with One Annulus Present for Each Calendar Month

	Month	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Spotted Seatrout 1 Annulus Present	January	113	0.600	0.017	0.566	0.634	0.615	0.623	0.034	0.183	0.050	0.910	0.860	0.130	-1.780	0.227	3.337	0.451
	February	39	0.369	0.052	0.263	0.475	0.353	0.138	0.107	0.327	0.010	1.070	1.060	0.570	0.465	0.378	-1.317	0.741
	March	13	0.242	0.069	0.091	0.393	0.227	0.126	0.062	0.250	0.040	0.710	0.670	0.300	1.384	0.616	0.063	1.191
	April	12	0.121	0.012	0.094	0.147	0.122	0.124	0.002	0.042	0.040	0.180	0.140	0.050	-0.635	0.637	0.081	1.232
	May	10	0.228	0.017	0.189	0.267	0.226	0.226	0.003	0.055	0.160	0.340	0.180	0.090	0.615	0.687	0.502	1.334
	June	15	0.275	0.015	0.244	0.306	0.274	0.263	0.003	0.056	0.180	0.380	0.190	0.090	0.622	0.580	-0.372	1.121
	July	11	0.382	0.016	0.347	0.417	0.382	0.381	0.003	0.052	0.300	0.460	0.160	0.080	-0.040	0.661	-1.082	1.279
	August	61	0.430	0.012	0.406	0.453	0.428	0.433	0.008	0.092	0.250	0.640	0.390	0.130	0.323	0.306	-0.506	0.604
	September	115	0.514	0.009	0.497	0.531	0.511	0.495	0.009	0.093	0.340	0.730	0.400	0.130	0.473	0.226	-0.332	0.447
	October	190	0.569	0.007	0.555	0.583	0.566	0.555	0.010	0.098	0.340	0.860	0.520	0.120	0.549	0.176	0.363	0.351
	November	73	0.632	0.010	0.611	0.653	0.628	0.617	0.008	0.090	0.470	0.870	0.410	0.130	0.740	0.281	0.312	0.555
	December	114	0.634	0.014	0.607	0.661	0.641	0.626	0.021	0.144	0.050	0.950	0.900	0.130	-1.348	0.226	5.484	0.449

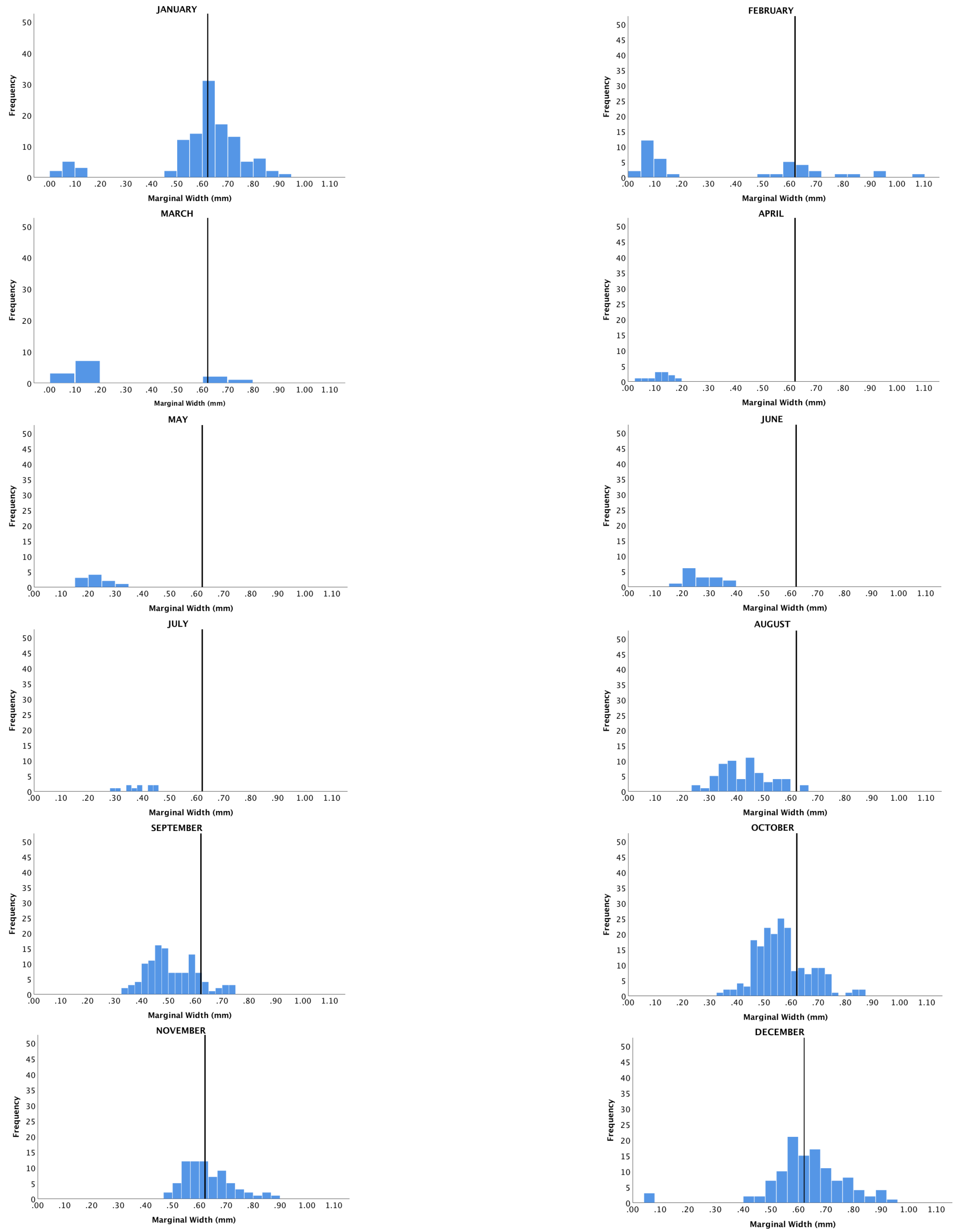

Figure B2. Monthly Histograms of Marginal Increments for Modern Spotted Seatrout with One Annulus Present

Table B3. Descriptive Statistics for Marginal Increments of Spotted Seatrout with Two Annuli Present for Each Calendar Month

	Month	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Spotted Seatrout 2 Annuli Present	January	166	0.211	0.015	0.181	0.240	0.203	0.075	0.038	0.195	0.010	0.590	0.580	0.360	0.451	0.188	-1.630	0.375
	February	167	0.089	0.010	0.070	0.108	0.072	0.048	0.015	0.124	0.010	0.570	0.560	0.030	2.549	0.188	5.006	0.374
	March	176	0.078	0.005	0.068	0.089	0.069	0.066	0.005	0.072	0.010	0.570	0.560	0.040	5.302	0.183	32.224	0.364
	April	193	0.093	0.002	0.089	0.096	0.093	0.092	0.001	0.025	0.020	0.180	0.150	0.030	0.092	0.175	0.765	0.348
	May	167	0.131	0.002	0.127	0.135	0.130	0.131	0.001	0.027	0.060	0.240	0.180	0.040	0.517	0.188	1.436	0.374
	June	133	0.163	0.003	0.158	0.168	0.163	0.162	0.001	0.032	0.070	0.310	0.240	0.030	0.476	0.210	3.100	0.417
	July	85	0.217	0.005	0.208	0.227	0.216	0.219	0.002	0.044	0.120	0.410	0.290	0.050	0.937	0.261	3.712	0.517
	August	66	0.256	0.004	0.249	0.264	0.256	0.254	0.001	0.032	0.180	0.340	0.160	0.030	0.221	0.295	0.450	0.582
	September	124	0.318	0.004	0.311	0.326	0.318	0.322	0.002	0.042	0.220	0.410	0.190	0.050	-0.130	0.217	-0.514	0.431
	October	159	0.317	0.009	0.300	0.334	0.326	0.344	0.012	0.107	0.020	0.510	0.480	0.070	-1.801	0.192	2.429	0.383
	November	47	0.381	0.010	0.361	0.402	0.388	0.391	0.005	0.071	0.020	0.470	0.450	0.070	-2.871	0.347	13.467	0.681
	December	79	0.331	0.017	0.297	0.366	0.338	0.379	0.024	0.155	0.010	0.570	0.560	0.120	-1.162	0.271	-0.091	0.535

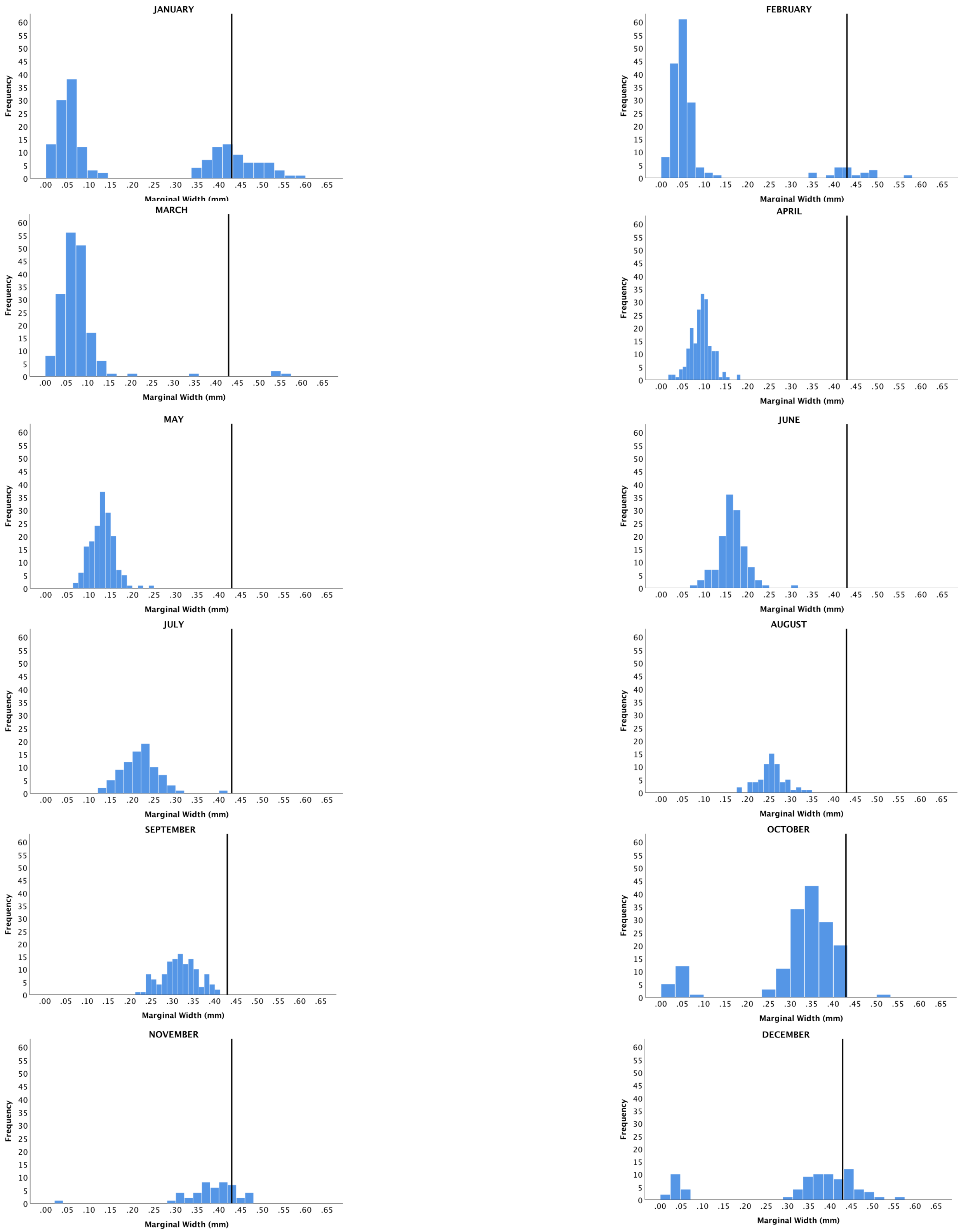

Figure B3. Monthly Histograms of Marginal Increments for Modern Spotted Seatrout with Two Annuli Present

Table B4. Descriptive Statistics for Marginal Increments of Spotted Seatrout with Three Annuli Present for Each Calendar Month

	Month	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Spotted Seatrout 3 Annuli Present	January	96	0.148	0.016	0.115	0.180	0.139	0.053	0.026	0.161	0.010	0.460	0.450	0.320	0.842	0.246	-1.176	0.488
	February	120	0.070	0.009	0.052	0.087	0.053	0.047	0.010	0.098	0.010	0.500	0.500	0.030	3.171	0.221	9.083	0.438
	March	120	0.066	0.007	0.053	0.079	0.054	0.054	0.005	0.071	0.020	0.480	0.460	0.030	4.699	0.221	22.887	0.438
	April	124	0.088	0.003	0.081	0.094	0.085	0.085	0.001	0.036	0.030	0.390	0.360	0.030	4.883	0.217	39.593	0.431
	May	138	0.109	0.002	0.106	0.113	0.109	0.108	0.000	0.022	0.060	0.180	0.120	0.030	0.628	0.206	0.589	0.410
	June	112	0.142	0.003	0.137	0.148	0.142	0.139	0.001	0.031	0.060	0.220	0.160	0.050	0.161	0.228	-0.287	0.453
	July	74	0.181	0.005	0.171	0.190	0.180	0.173	0.002	0.041	0.100	0.310	0.210	0.050	0.478	0.279	0.587	0.552
	August	41	0.225	0.006	0.212	0.238	0.222	0.220	0.002	0.040	0.150	0.340	0.190	0.040	1.129	0.369	2.085	0.724
	September	56	0.270	0.005	0.259	0.280	0.267	0.265	0.002	0.039	0.200	0.380	0.180	0.050	0.813	0.319	0.725	0.628
	October	57	0.275	0.012	0.251	0.299	0.283	0.298	0.008	0.091	0.020	0.410	0.390	0.060	-1.946	0.316	3.196	0.623
	November	24	0.317	0.019	0.279	0.356	0.327	0.336	0.008	0.092	0.040	0.420	0.380	0.070	-2.135	0.472	4.871	0.918
	December	34	0.262	0.024	0.214	0.311	0.265	0.312	0.019	0.138	0.020	0.450	0.420	0.290	-0.770	0.403	-0.951	0.788

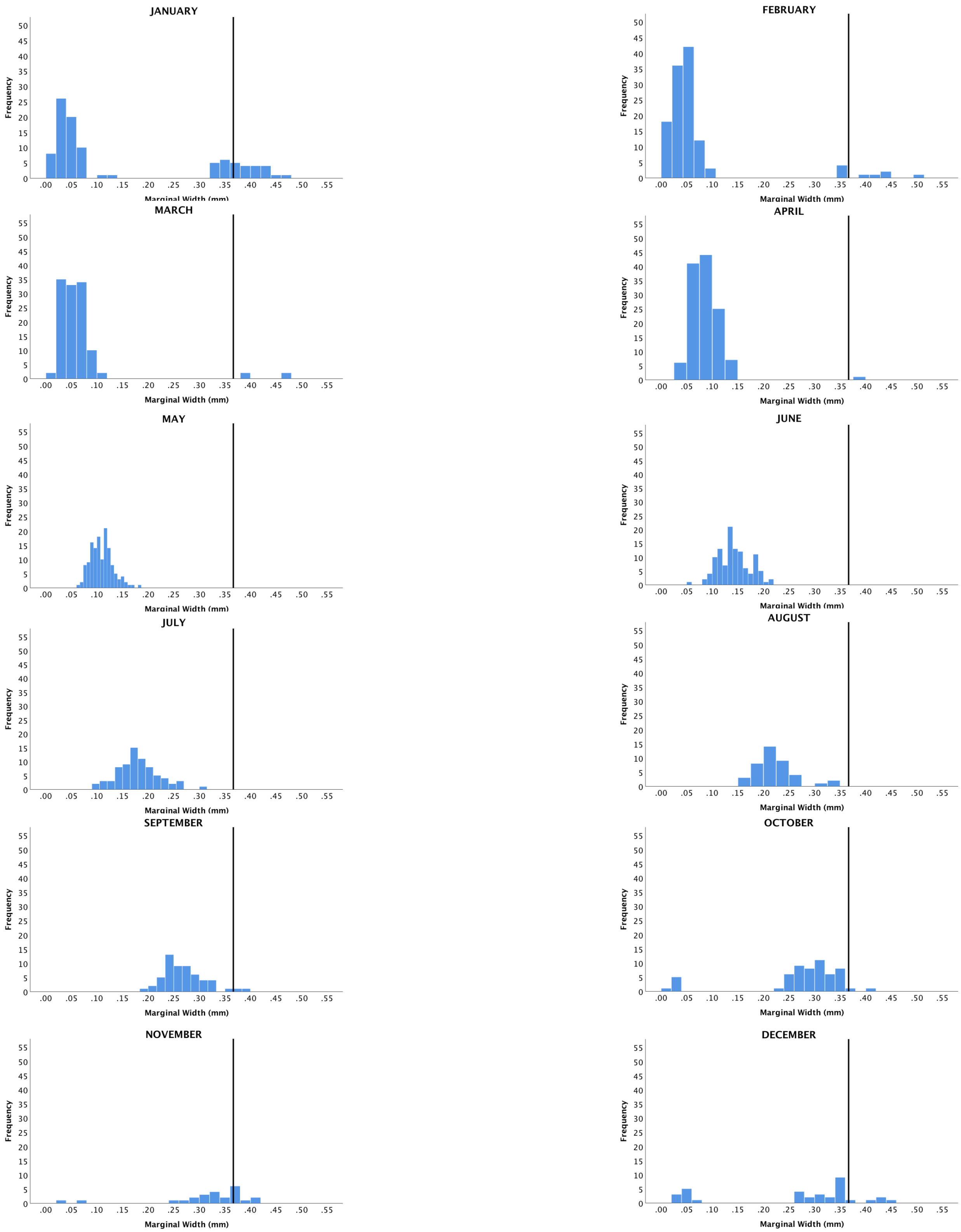

Figure B4. Monthly Histograms of Marginal Increments for Modern Spotted Seatrout with Three Annuli Present

Table B5. Descriptive Statistics for Marginal Increments of Spotted Seatrout with Four Annuli Present for Each Calendar Month

	Month	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Spotted Seatrout 4 Annuli Present	January	44	0.170	0.024	0.123	0.218	0.167	0.053	0.025	0.157	0.020	0.400	0.380	0.310	0.344	0.357	-1.870	0.702
	February	71	0.048	0.008	0.032	0.063	0.036	0.038	0.004	0.065	0.010	0.370	0.360	0.030	4.221	0.285	17.839	0.563
	March	43	0.050	0.003	0.045	0.055	0.049	0.046	0.000	0.018	0.020	0.090	0.070	0.030	0.604	0.361	-0.499	0.709
	April	62	0.088	0.008	0.072	0.105	0.079	0.070	0.004	0.066	0.020	0.410	0.390	0.040	3.050	0.304	11.042	0.599
	May	67	0.100	0.003	0.093	0.106	0.098	0.100	0.001	0.026	0.030	0.180	0.160	0.030	0.578	0.293	1.978	0.578
	June	53	0.128	0.004	0.120	0.136	0.128	0.124	0.001	0.029	0.080	0.190	0.110	0.050	0.370	0.327	-0.882	0.644
	July	19	0.177	0.007	0.162	0.193	0.178	0.182	0.001	0.032	0.100	0.240	0.140	0.030	-0.423	0.524	1.188	1.014
	August	10	0.213	0.013	0.183	0.242	0.213	0.199	0.002	0.041	0.150	0.280	0.120	0.070	0.266	0.687	-1.344	1.334
	September	17	0.248	0.007	0.233	0.264	0.246	0.253	0.001	0.030	0.210	0.330	0.120	0.040	1.326	0.550	3.226	1.063
	October	16	0.265	0.018	0.228	0.303	0.274	0.277	0.005	0.071	0.030	0.340	0.310	0.060	-2.570	0.564	8.407	1.091
	November	9	0.258	0.044	0.156	0.360	0.264	0.305	0.018	0.133	0.030	0.370	0.340	0.200	-1.392	0.717	0.349	1.400
	December	18	0.270	0.024	0.219	0.322	0.277	0.294	0.011	0.103	0.050	0.370	0.320	0.060	-1.544	0.536	1.253	1.038

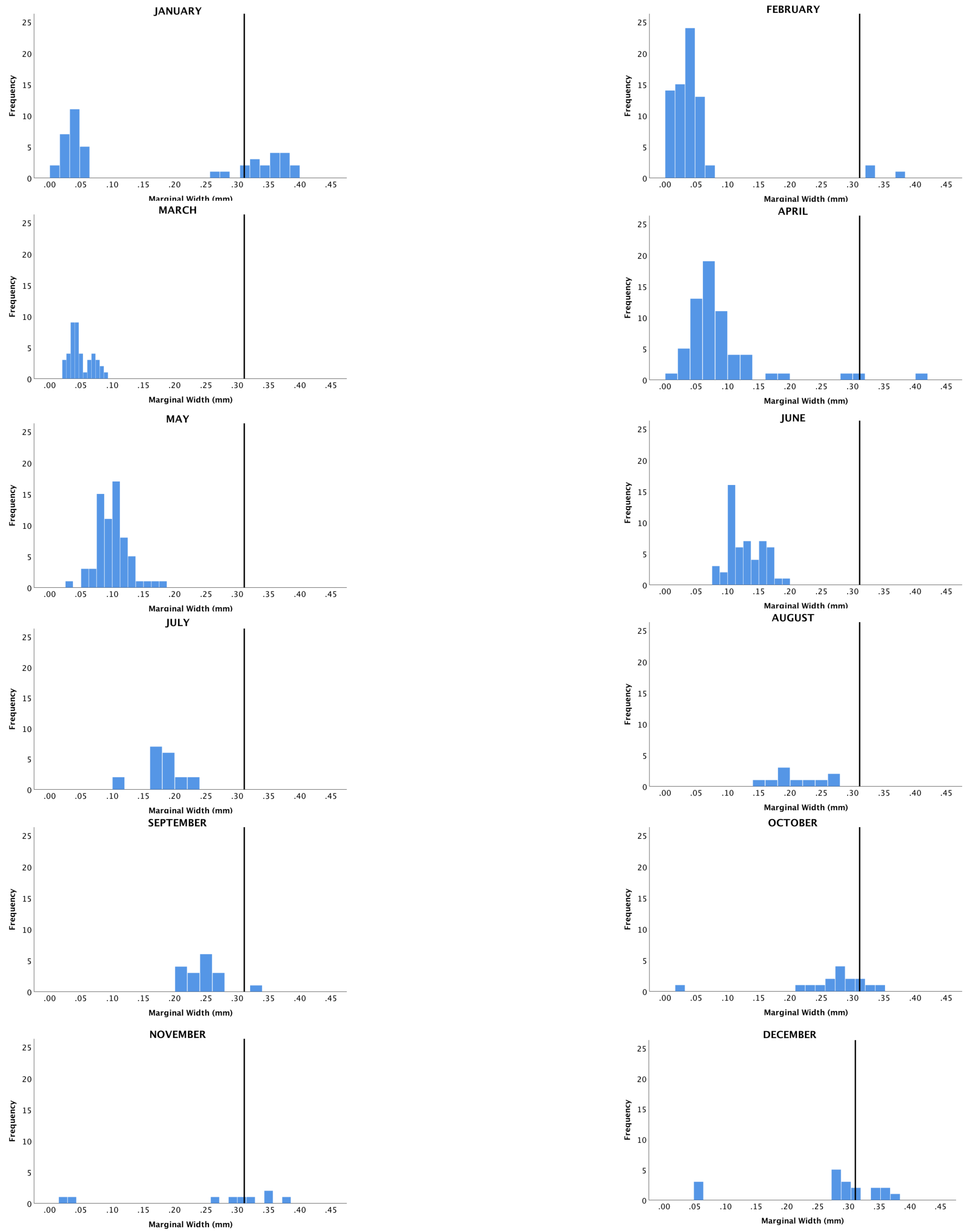

Figure B5. Monthly Histograms of Marginal Increments for Modern Spotted Seatrout with Four Annuli Present

Table B6. Descriptive Statistics for Marginal Increments of Spotted Seatrout with Five Annuli Present for Each Calendar Month

	Month	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Spotted Seatrout 5 Annuli Present	January	18	0.153	0.034	0.080	0.225	0.149	0.057	0.021	0.145	0.010	0.360	0.340	0.290	0.487	0.536	-1.856	1.038
	February	21	0.062	0.017	0.027	0.097	0.051	0.039	0.006	0.076	0.010	0.300	0.290	0.050	2.609	0.501	6.289	0.972
	March	19	0.040	0.005	0.030	0.051	0.039	0.038	0.000	0.021	0.010	0.090	0.080	0.020	1.098	0.524	0.914	1.014
	April	36	0.077	0.012	0.052	0.102	0.064	0.061	0.005	0.073	0.010	0.430	0.420	0.030	3.843	0.393	16.242	0.768
	May	39	0.099	0.004	0.091	0.107	0.098	0.093	0.001	0.025	0.050	0.180	0.130	0.030	0.936	0.378	2.477	0.741
	June	25	0.114	0.005	0.105	0.123	0.112	0.114	0.001	0.023	0.080	0.180	0.110	0.020	1.334	0.464	3.194	0.902
	July	19	0.164	0.006	0.151	0.178	0.164	0.160	0.001	0.028	0.130	0.210	0.090	0.040	0.484	0.524	-0.894	1.014
	August	6	0.213	0.021	0.159	0.267	0.210	0.194	0.003	0.052	0.170	0.300	0.130	0.080	1.302	0.845	1.065	1.741
	September	6	0.197	0.022	0.141	0.254	0.194	0.176	0.003	0.054	0.150	0.300	0.150	0.070	1.916	0.845	3.850	1.741
	October	6	0.270	0.015	0.232	0.307	0.269	0.270	0.001	0.036	0.230	0.320	0.090	0.070	0.329	0.845	-0.810	1.741
	November	2	0.160	0.121	-1.377	1.697	NA	0.160	0.029	0.171	0.040	0.280	0.240	NA	NA	NA	NA	NA
	December	4	0.121	0.068	-0.096	0.336	0.114	0.066	0.018	0.136	0.030	0.320	0.290	0.230	1.877	1.014	3.605	2.619

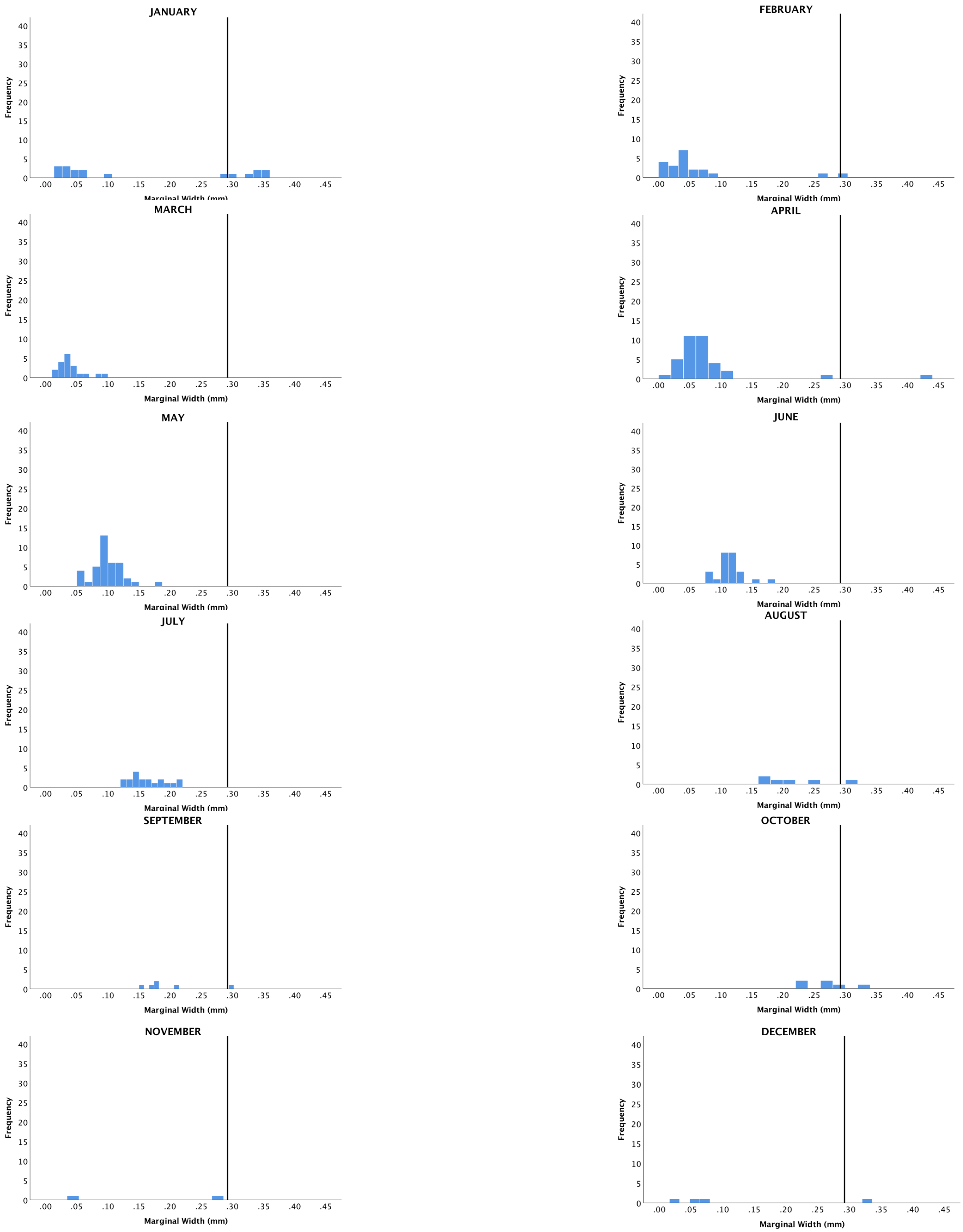

Figure B6. Monthly Histograms of Marginal Increments for Modern Spotted Seatrout with Five Annuli Present

Table B7. Descriptive Statistics for Marginal Increments of Spotted Seatrout with Six Annuli Present for Each Calendar Month

	Month	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Spotted Seatrout 6 Annuli Present	January	6	0.112	0.046	-0.006	0.230	0.109	0.065	0.013	0.112	0.010	0.260	0.260	0.220	0.720	0.845	-1.894	1.741
	February	8	0.024	0.006	0.010	0.037	0.022	0.014	0.000	0.016	0.010	0.060	0.040	0.030	1.247	0.752	0.445	1.481
	March	5	0.043	0.004	0.031	0.054	0.043	0.040	0.000	0.009	0.030	0.050	0.020	0.020	0.085	0.913	-1.263	2.000
	April	17	0.071	0.013	0.043	0.099	0.062	0.058	0.003	0.054	0.030	0.270	0.240	0.030	3.692	0.550	14.534	1.063
	May	7	0.080	0.004	0.071	0.089	0.080	0.079	0.000	0.010	0.060	0.090	0.030	0.010	-0.905	0.794	1.152	1.587
	June	7	0.132	0.017	0.091	0.173	0.134	0.146	0.002	0.044	0.050	0.170	0.120	0.070	-0.897	0.794	-0.180	1.587
	July	5	0.146	0.020	0.092	0.201	0.147	0.160	0.002	0.044	0.090	0.200	0.100	0.080	-0.308	0.913	-2.123	2.000
	August	1	0.152	NA														
	September	1	0.196	NA														
	October	4	0.225	0.023	0.152	0.298	0.224	0.215	0.002	0.046	0.190	0.280	0.100	0.090	0.833	1.014	-1.254	2.619
	November	1	0.216	NA														
	December	1	0.246	NA														

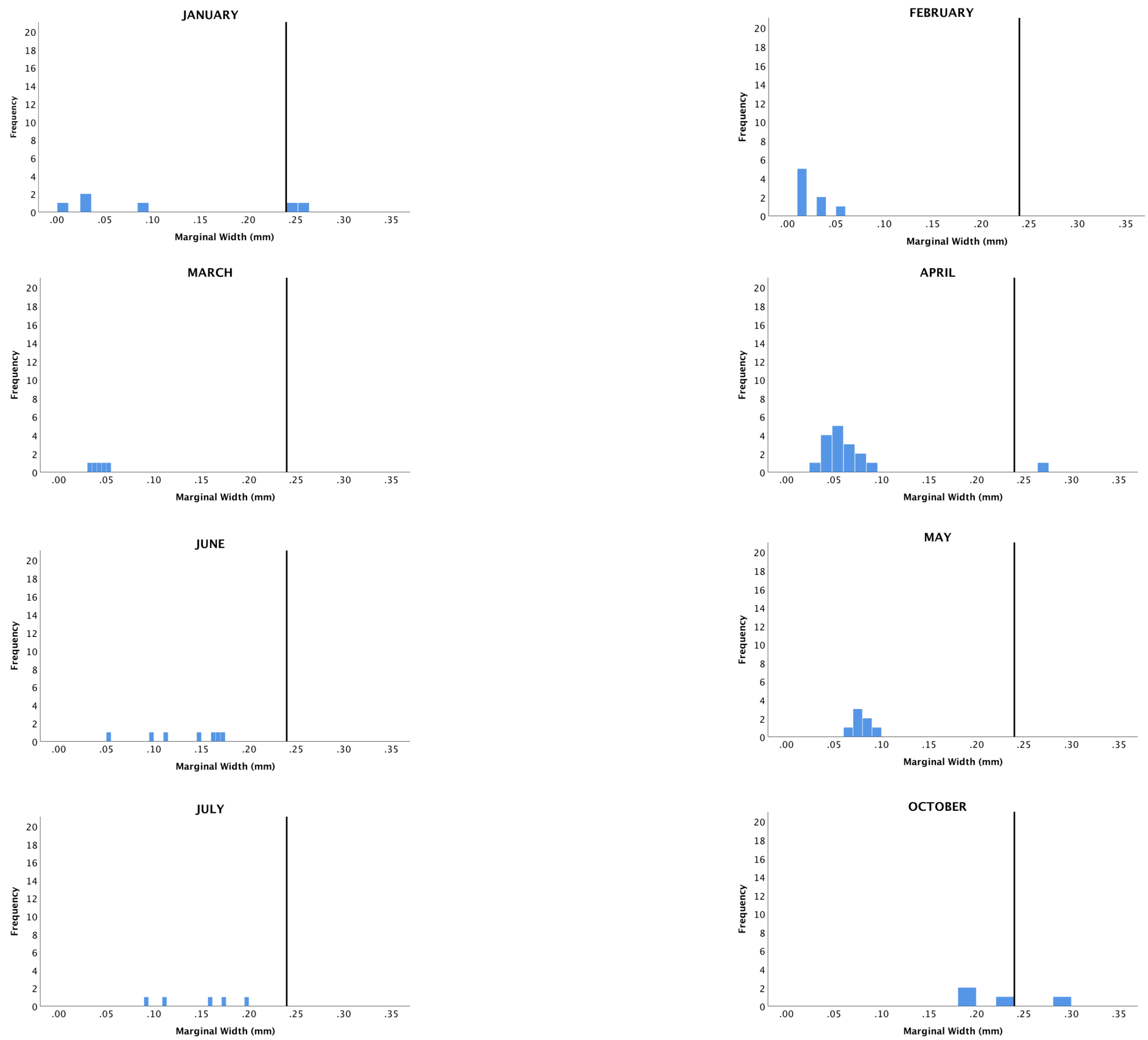

Figure B7. Monthly Histograms of Marginal Increments for Modern Spotted Seatrout with Six Annuli Present

Table B8. Descriptive Statistics for Marginal Increments of Spotted Seatrout with Seven Annuli Present for Each Calendar Month

	Month	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Spotted Seatrout 7 Annuli Present	January	1	0.0305	NA														
	February	3	0.0144	0.00196	0.006	0.0228	NA	0.0135	0	0.00339	0.01	0.02	0.01	NA	1.039	1.225	NA	NA
	March	3	0.0424	0.01783	-0.0344	0.1191	NA	0.0528	0.001	0.03089	0.01	0.07	0.06	NA	-1.349	1.225	NA	NA
	April	4	0.045	0.00997	0.0133	0.0768	0.0451	0.0458	0	0.01994	0.02	0.07	0.05	0.04	-0.197	1.014	-0.943	2.619
	May	4	0.0808	0.0067	0.0595	0.1021	0.0804	0.0767	0	0.0134	0.07	0.1	0.03	0.02	1.612	1.014	3.031	2.619
	June	5	0.0789	0.01656	0.0329	0.1249	0.077	0.0557	0.001	0.03703	0.05	0.14	0.08	0.06	1.417	0.913	1.161	2
	July	2	0.1441	0.01717	-0.074	0.3623	NA	0.1441	0.001	0.02428	0.13	0.16	0.03	NA	NA	NA	NA	NA
	August	0	NA															
	September	0	NA															
	October	1	0.242															
	November	0	NA															
	December	2	0.0893	0.06626	-0.7527	0.9313	NA	0.0893	0.009	0.09371	0.02	0.16	0.13	NA	NA	NA	NA	NA

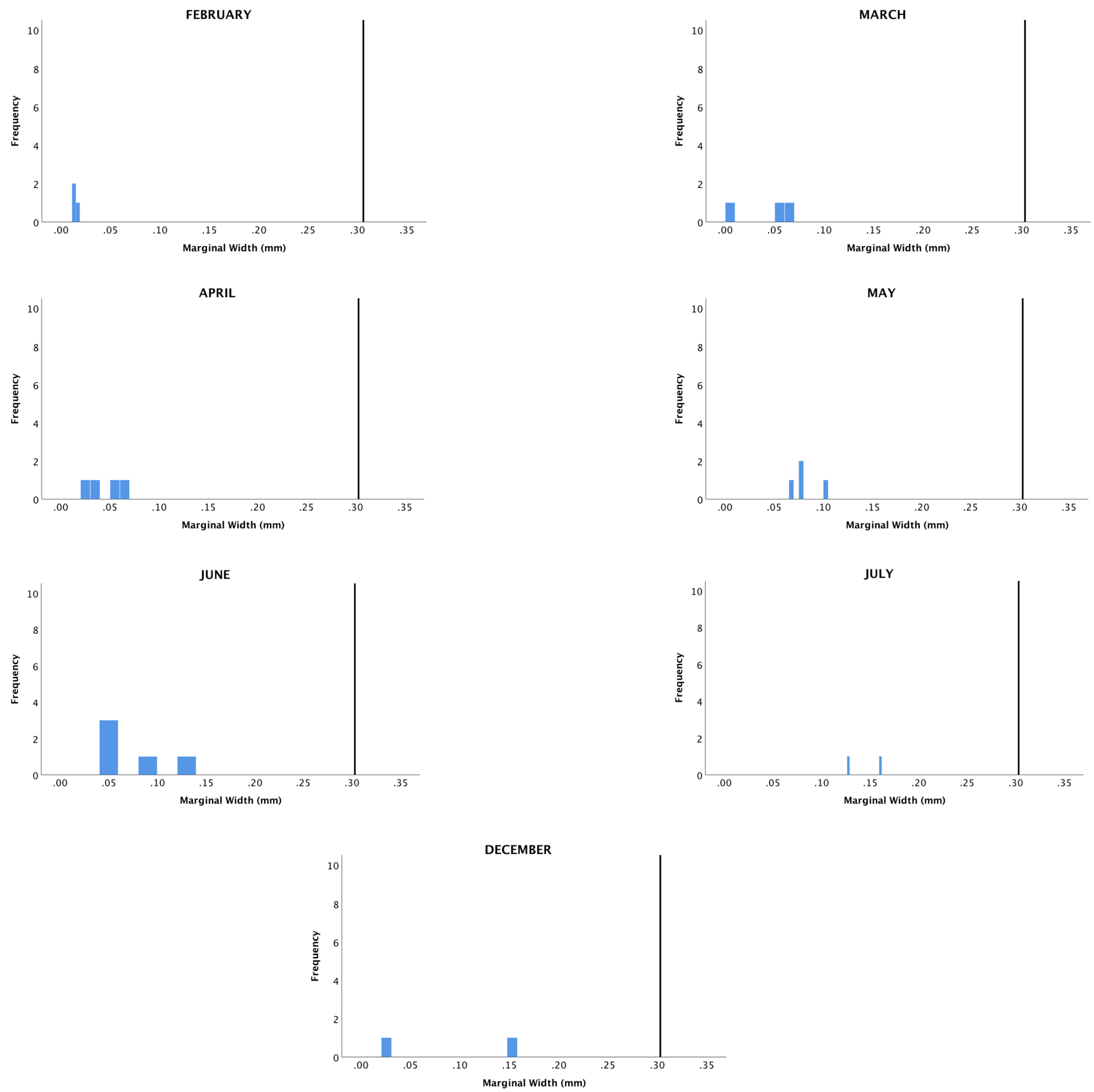

Figure B8. Monthly Histograms of Marginal Increments for Modern Spotted Seatrout with Seven Annuli Present

Descriptive Statistics Tables for Modern Spotted Seatrout Seasonal Groupings

Table B9. Descriptive Statistics for Monthly Seasonal Groupings of Spotted Seatrout with No Annulus Present

Spotted Seatrout No Annulus Present	Season	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
	Cool (October - January)	45	1.143	0.017	1.108	1.178	1.143	1.147	0.013	0.116	0.880	1.430	0.550	0.170	-0.051	0.354	0.318	0.695

Table B10. Descriptive Statistics for Monthly Seasonal Groupings of Spotted Seatrout with One Annulus Present

	Season	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Spotted Seatrout 1 Annulus Present	Cool (January and February)	152	0.541	0.020	0.501	0.580	0.548	0.617	0.062	0.249	0.010	1.070	1.060	0.150	-0.962	0.197	-0.141	0.391
	Late Cool (March)	13	0.242	0.069	0.091	0.393	0.227	0.126	0.062	0.250	0.040	0.710	0.670	0.300	1.384	0.616	0.063	1.191
	Early Warm (April)	12	0.121	0.012	0.094	0.147	0.122	0.124	0.002	0.042	0.040	0.180	0.140	0.050	-0.635	0.637	0.081	1.232
	Early Warm 2 (May and June)	25	0.256	0.012	0.232	0.281	0.255	0.245	0.004	0.059	0.160	0.380	0.220	0.060	0.466	0.464	-0.141	0.902
	Warm (July and August)	72	0.423	0.010	0.402	0.443	0.420	0.413	0.008	0.088	0.250	0.640	0.390	0.130	0.452	0.283	-0.307	0.559
	Late Warm (September)	115	0.514	0.009	0.497	0.531	0.511	0.495	0.009	0.093	0.340	0.730	0.400	0.130	0.473	0.226	-0.332	0.447
	Early Cool 1 (October)	190	0.569	0.007	0.555	0.583	0.566	0.555	0.010	0.098	0.340	0.860	0.520	0.120	0.549	0.176	0.363	0.351
	Early Cool 2 (November and December)	187	0.633	0.009	0.615	0.651	0.636	0.619	0.016	0.126	0.050	0.950	0.900	0.130	-1.124	0.178	6.147	0.354

Table B11. Descriptive Statistics for Monthly Seasonal Groupings of Spotted Seatrout with Two Annuli Present

	Season	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Spotted Seatrout 2 Annuli Present	Cool (January and February)	333	0.150	0.010	0.131	0.169	0.137	0.055	0.030	0.174	0.010	0.590	0.580	0.310	1.165	0.134	-0.442	0.266
	Late Cool (March)	176	0.078	0.005	0.068	0.089	0.069	0.066	0.005	0.072	0.010	0.570	0.560	0.040	5.302	0.183	32.224	0.364
	Early Warm (April and May)	360	0.110	0.002	0.107	0.114	0.110	0.107	0.001	0.032	0.020	0.240	0.220	0.040	0.267	0.129	0.553	0.256
	Warm (June - August)	284	0.201	0.003	0.195	0.207	0.200	0.195	0.003	0.052	0.070	0.410	0.340	0.080	0.420	0.145	0.184	0.288
	Late Warm (September)	124	0.318	0.004	0.311	0.326	0.318	0.322	0.002	0.042	0.220	0.410	0.190	0.050	-0.130	0.217	-0.514	0.431
	Early Cool (October - December)	285	0.332	0.007	0.318	0.346	0.340	0.360	0.014	0.120	0.010	0.570	0.560	0.090	-1.572	0.144	1.713	0.288

Table B12. Descriptive Statistics for Monthly Seasonal Groupings of Spotted Seatrout with Three Annuli Present

	Season	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Spotted Seatrout 3 Annuli Present	Cool (January and February)	216	0.104	0.009	0.086	0.122	0.091	0.048	0.018	0.135	0.010	0.500	0.500	0.040	1.673	0.166	1.065	0.330
	Late Cool (March)	120	0.066	0.007	0.053	0.079	0.054	0.054	0.005	0.071	0.020	0.480	0.460	0.030	4.699	0.221	22.887	0.438
	Early Warm (April and May)	262	0.099	0.002	0.095	0.103	0.098	0.097	0.001	0.032	0.030	0.390	0.360	0.040	3.185	0.150	28.029	0.300
	Warm (June and July)	186	0.158	0.003	0.152	0.163	0.156	0.154	0.002	0.040	0.060	0.310	0.250	0.050	0.608	0.178	0.762	0.355
	Late Warm (August and September)	97	0.251	0.005	0.242	0.260	0.249	0.242	0.002	0.045	0.150	0.380	0.230	0.050	0.555	0.245	0.359	0.485
	Early Cool (October - December)	115	0.280	0.010	0.260	0.300	0.286	0.308	0.012	0.108	0.020	0.450	0.430	0.080	-1.376	0.226	0.956	0.447

Table B13. Descriptive Statistics for Monthly Seasonal Groupings of Spotted Seatrout with Four Annuli Present

	Season	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Spotted Seatrout 4 Annuli Present	Cool (January and February)	115	0.095	0.012	0.072	0.118	0.083	0.039	0.015	0.124	0.010	0.400	0.390	0.030	1.598	0.226	0.730	0.447
	Late Cool (March)	43	0.050	0.003	0.045	0.055	0.049	0.046	0.000	0.018	0.020	0.090	0.070	0.030	0.604	0.361	-0.499	0.709
	Early Warm (April)	62	0.088	0.008	0.072	0.105	0.079	0.070	0.004	0.066	0.020	0.410	0.390	0.040	3.050	0.304	11.042	0.599
	Warm (May - July)	206	0.114	0.003	0.109	0.119	0.113	0.106	0.001	0.036	0.030	0.240	0.210	0.040	0.808	0.169	0.671	0.337
	Late Warm (August and September)	27	0.235	0.007	0.220	0.250	0.235	0.237	0.001	0.038	0.150	0.330	0.180	0.050	0.078	0.448	0.758	0.872
	Early Cool (October - December)	43	0.266	0.015	0.236	0.296	0.273	0.293	0.010	0.098	0.030	0.370	0.340	0.060	-1.595	0.361	1.551	0.709

Table B14. Descriptive Statistics for Monthly Seasonal Groupings of Spotted Seatrout with Five Annuli Present

	Season	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Spotted Seatrout 5 Annuli Present	Cool (January and February)	39	0.104	0.019	0.065	0.143	0.095	0.046	0.015	0.121	0.010	0.360	0.340	0.080	1.290	0.378	-0.118	0.741
	Late Cool (March)	19	0.040	0.005	0.030	0.051	0.039	0.038	0.000	0.021	0.010	0.090	0.080	0.020	1.098	0.524	0.914	1.014
	Early Warm (April)	36	0.077	0.012	0.052	0.102	0.064	0.061	0.005	0.073	0.010	0.430	0.420	0.030	3.843	0.393	16.242	0.768
	Warm (May - July)	122	0.112	0.003	0.106	0.118	0.110	0.106	0.001	0.034	0.050	0.210	0.160	0.040	0.953	0.219	0.865	0.435
	Late Warm (August and September)	12	0.205	0.015	0.173	0.237	0.202	0.179	0.003	0.051	0.150	0.300	0.150	0.060	1.292	0.637	0.482	1.232
	Early Cool (October - December)	12	0.202	0.034	0.128	0.276	0.205	0.249	0.014	0.116	0.030	0.320	0.290	0.230	-0.634	0.637	-1.539	1.232

Table B15. Descriptive Statistics for Monthly Seasonal Groupings of Spotted Seatrout with Six Annuli Present

	Season	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Spotted Seatrout 6 Annuli Present	Cool (January - March)	19	0.056	0.017	0.022	0.091	0.048	0.035	0.005	0.072	0.010	0.260	0.260	0.040	2.399	0.524	5.030	1.014
	Early Warm (April and May)	24	0.074	0.009	0.055	0.093	0.067	0.065	0.002	0.046	0.030	0.270	0.240	0.020	3.954	0.472	17.842	0.918
	Late Warm (June - September)	21	0.139	0.009	0.120	0.158	0.141	0.152	0.002	0.042	0.050	0.200	0.140	0.070	-0.671	0.501	-0.478	0.972
	Early Cool (October - December)	6	0.227	0.015	0.188	0.266	0.226	0.226	0.001	0.037	0.190	0.280	0.100	0.070	0.522	0.845	-0.387	1.741

Table B16. Descriptive Statistics for Monthly Seasonal Groupings of Spotted Seatrout with Seven Annuli Present

	Season	N	Mean		95% Confidence Interval for Mean		5% Trimmed Mean	Median	Variance	Std. Deviation	Minimum	Maximum	Range	Interquartile Range	Skewness		Kurtosis	
			Statistic	Std. Error	Lower Bound	Upper Bound									Statistic	Std. Error	Statistic	Std. Error
Spotted Seatrout 7 Annuli Present	Cool (January - March)	7	0.029	0.009	0.008	0.050	0.028	0.018	0.001	0.023	0.010	0.070	0.060	0.040	0.985	0.794	-0.586	1.587
	Warm (April - July)	15	0.079	0.010	0.058	0.101	0.078	0.070	0.001	0.039	0.020	0.160	0.140	0.050	0.801	0.580	0.139	1.121
	Early Cool (October and December)	5	0.120	0.043	0.002	0.238	0.118	0.156	0.009	0.095	0.020	0.240	0.220	0.180	0.049	0.913	-1.875	2.000