ZOOARCHAEOLOGY OF CINNAMON BAY, ST. JOHN, U.S. VIRGIN ISLANDS: PRE-COLUMBIAN OVEREXPLOITATION OF ANIMAL RESOURCES

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The zooarchaeological remains from a stratigraphic sequence excavated from the ceremonial site of Cinnamon Bay, St. John, U.S. Virgin Islands, were studied. The samples were recovered using a fine-gauge (1/16 in) screen. During the course of this study, 443 minimum numbers of individuals and 99 species of vertebrates and invertebrates were identified. The fauna was analyzed by estimating the trophic level of reef, inshore, and pelagic zooarchaeological components from three strata representing the Monserrate (ca. A.D. 950), Santa Elena (ca. A.D. 570), and Chican (ca. A.D. 460) ceramic periods. The trophic level model shows an initial increase in the trophic level of taxa from the reef between the Monserrate and Santa Elena periods. This initial increase corresponds to the exponential growth of midden density. Relative to the earlier faunal assemblages, midden density and the mean trophic level of reef resources declines during the Chican period. Greater reliance on pelagic species from the deeper waters offshore and the increased use of mollusks from inshore habitats is also seen. The data show that at low levels of cultural complexity humans can alter their environments. This is particularly true of island biota where biological reservoirs are small.

Key words: caney, Caribbean, island biogeography, trophic level, zooarchaeology

This chapter presents a study of well-recovered zooarchaeological remains from the Cinnamon Bay site (12Vam-2-3), St. John, U.S. Virgin Islands (Fig. 1). The site contains a sequential record of human immigration and habitation that began nearly 1000 years ago (Wild 1999). Pre-Columbian people first occupied the site ca. A.D. 1000 and abandoned it by ca. A.D. 1490. For nearly 500 years Cinnamon Bay served as a ceremonial site that evolved into a Classic Taíno chief's offering place, or *caney* (Wild 1999). Early in the sixteenth century, the Spanish chronicler of the Indians, Bartolomé de las Casas, described the function of the caney as house of the kings where the "first fruits of the crops" were offered (las Casas 1909; Rouse 1992).

Over the past 50 years, Caribbean archaeology has focused on interpreting the material culture of the pre-Columbian people of the region, while zooarchaeological research has been relatively scarce. The field of zooarchaeology has evolved from providing simple presence or absence lists to a formal discipline that examines the interrelation of humans with their environment. Nonetheless, the ecology of Caribbean pre-Columbian people is not well understood and should be considered in its formative stages of development. Recent baseline zooarchaeological data are forming a body of information that may be used to ask and answer questions about the human ecology of pre-Columbian maritime people of the Caribbean (Wing 1995, 2001a, 2001b; Wing and Wing 1995, 2001).

Island ecosystems are particularly fragile and susceptible to human disturbances because their biological reservoirs are small and not easily replenished (MacArthur and Wilson 1967). Too frequently, the impact of humans on these systems is associated with incursions by Historic Period colonists, while little thought is given to the effects that pre-Columbian people could have had on the biota (Redford 1990). The scientific community has global data that indicate few plant or animal communities were unaffected by noncomplex societies (Jackson et al. 2001, Lepofsky et al. 1996; Steadman 1995; Wing 1995, 2001a, 2001b; Wing and Wing 1995, 2001). They concur that human contact, even at very low levels of cultural complexity, can degrade the environment (Quitmyer and Jones 2000). Such findings are in contrast to the widely held view that pre-industrial people had little affect on their environments. It appears that environmental degradation seen in the Caribbean

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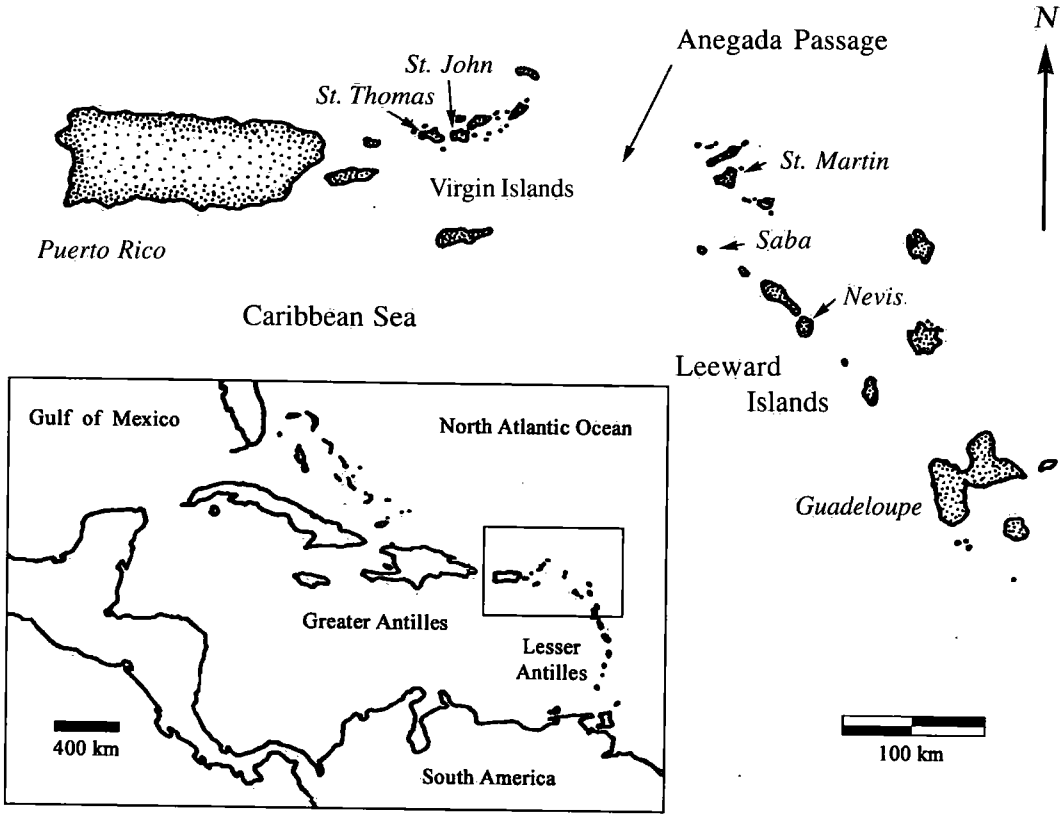


Figure 1. Map of the study area (redrawn from Wing 2001a).

started much earlier than otherwise believed (Jackson et al. 2001, Wing 2001b:481). The most dramatic evidence appears in faunal records of island midden deposits (Steadman 1995; Wing 1995, 2001a; Wing and Wing 1995, 2001).

The island groups of the Caribbean Basin are excellent zooarchaeological laboratories where pre-Columbian subsistence strategies can be examined against the constraints of the principles of island biogeography (MacArthur and Wilson 1967; Wing and Wing 1995, 1997). In the zooarchaeological record of the Lesser Antilles and the Virgin Islands, Wing (2001a:125) has reported changes in species abundance and sizes of animals from pre-Columbian midden deposits (St. Thomas, St. Martin, Saba, and Nevis) (Fig. 1). Archaeological evidence indicates that the faunal remains represent common, everyday subsistence activities. The changes observed in the zooarchaeological record correlate with the length of time the environment was exposed to humans, and not with the archaeological period (Wing 2001a, 2001b). Because of low growth rates, high natural mortality, and low recruitment, such territorial reef fish higher in the food web as the groupers (Serranidae) and snappers (Lutjanidae) are sensitive to even moderate exploitation. The numbers and average body size of these fish declined under human fishing pressure (Sale 1991; Wing 2001a:125). Further exacerbating their decline, territorial predators are easily caught with baited hooks and are readily attracted to baited fish traps (Wing 2001a, 2001b). As the size and relative frequency of reef predators decline, there is an increase in the catch of reef herbivores and omnivores in the zooarchaeological record (Wing 2001a:123). The resulting trend is a decline in the measured mean trophic level of reef resources between the early and late components of the sites. This is accompanied by an increased emphasis on taxa with large population reservoirs, such as herrings (Clupeidae), jacks (Carangidae), and tuna (Scrombridae), from inshore and pelagic habitats. A shift in technology is indicated in those instances where there is an increase in the relative abundance of tuna, because humans would need

watercraft to travel to inherently more dangerous offshore habitats (Wing 2001a:125). These trends accompany a three- to four-fold increase in archaeological site size and number (Wilson 1989).

Relative to the data outlined above, the following question arises: given that Cinnamon Bay functioned as a ceremonial site, do the site's faunal remains exhibit similar changes in size and quantity? In other words, are the food remains of the elites affected in similar ways by the over-exploitation of marine resources, or are they rendered immune by cultural processes that favor the elites? The focus of this study is to identify the animal remains that were used at Cinnamon Bay to next address three basic questions about Taíno subsistence behavior: 1) what animals species were being used, 2) how these animals were obtained, and 3) what evidence is there for anthropogenic changes in the local environment? This last question serves as a test of Wing's (2001a) model of sustainability of resources used by pre-Columbians on St. Thomas, St. Martin, Saba, and Nevis.

MATERIALS AND METHODS

Archaeological Context

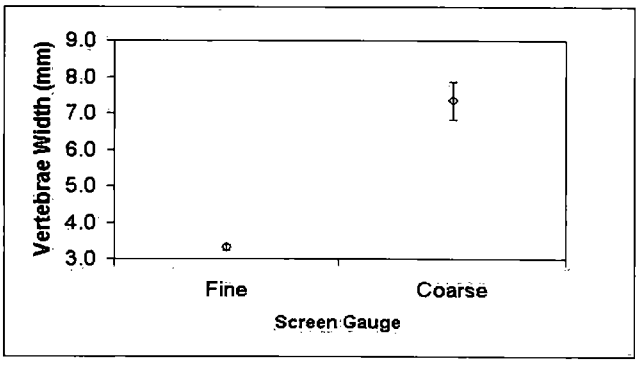
Gudmund Hatt (1924) first identified the prehistoric component of Cinnamon Bay in 1922. In the intervening years, researchers have continued to add information to the Cinnamon Bay archaeological record (Haviser 1978; Rutsch 1970; Stoutamire et al. 1980). In 1992 Ken Wild and Reigina Lebo, U.S. National Park Service, directed a systematic excavation of three 4 x 4 meter excavation units from the beachfront, then in danger of erosion. A well-preserved archaeological section was exposed where Elenan Ostionoid and Chican Ostionoid ceramic subseries were present (Rouse 1992; Wild 1999). Three ceramic styles occur within these two subseries (Table 1): Monserrate, found between 70 and 100 centimeters below surface (cmbs); Santa Elena, within the 30 to 70 cmbs levels; and Chican Ostionoid, identified between the present ground surface and 30 cmbs (Wild 1999). The Chican Ceramic Period is generally attributed to the Taíno people, who were the first to make contact with Columbus (Rouse 1992), while the Monserrate and Santa Elena ceramic periods represent the ancestors of the Taíno. The three ceramic styles are not mixed. Rather, they are well constrained in the stratigraphic sequence (Wild 1999) (Table1).

The archaeological data from Cinnamon Bay show that the site functioned as a ceremonial center for nearly 500 years (Wild 1999). From its beginning in the Monserrate Period, the site increased in importance. Just prior to European contact it evolved into a caney, or temple (Wild 1999). The sixteenth-century cleric, Bartolomé de las Casas (1909), was a primary observer of the Taíno and reported that the caney was separate from other structures. The caney was where ceremony and prayer were conducted by the elites. Food offerings were an important part of these rituals (las Casas 1909), so the Cinnamon Bay zooarchaeological record presents an important opportunity to elucidate the signatures of foods deposited in a well-defined ceremonial context.

Ceramic dates from the top and bottom of the 1992 Cinnamon Bay excavation place the accumulation of the 1 m formation between A.D. 1000 and 1490. A subsequent series of radiocarbon dates (Table 1) shows that the Monserrate, level 9 (80-90

Table 1. Carbon (^{14}C) dates analyzed from Cinnamon Bay, St. John, U.S. Virgin Islands (Wild 1999).

Analysis	Level	cmbs	B.P.	A.D.	Mean A.D.	sigma	Ceramic Period
Beta	1	0-10	~460	1490	-	-	Chican
no date—fauna analyzed	2	10-20	-	-	-	-	Chican
Beta 69973	3	20-30	570±70	1290-1450	1370	2σ	Chican
no date—fauna analyzed	4	30-40	-	-	-	-	Santa Elena
no date	5	40-50	-	-	-	-	Santa Elena
Beta 73413	6	50-60	520±70	1300-1485	1393	2σ	Santa Elena
no date	7	60-70	-	-	-	-	Santa Elena
no date	8	70-80	-	-	-	-	Monserrate
Beta 69974	9	80-90	860±80	1020-1290	1155	2σ	Monserrate
Beta—fauna analyzed	10	90-100	~950	1000	-	-	Monserrate



Descriptive Statistics	Level 4, FS 111 Fine	Level 4, FS 111 Coarse
Mean	3.32	7.35
Standard Deviation	1.60	2.36
Range	1.04-16.32	1.88-16.32
Sample n	1528	80
95% CI	0.08	0.52
MIN of 95% CI	3.24	6.83
MAX of 95% CI	3.40	7.87

Figure 2. Lateral width (mm) of fish vertebrae (mm) from Unit 1, level 4, Cinnamon Bay, St. John, U.S. Virgin Islands. The error bars represent the 95% confidence interval about the mean comparing screen gauge recovery using fine (1/4-1/16 in) and coarse (1/4 in) gauge screens.

cmbs), was deposited between A.D.1020 and 1290 (Beta 69974); Santa Elena, level 6 (50–60 cmbs), between A.D. 1300 and 1485 (Beta 73413); and the Chican, level 3 (20-30 cmbs), between A.D. 1290 and 1475 (Beta 69973). The radiometric (^{14}C) dates indicate that, relative to the Santa Elena and Chican strata, the Monserrate levels probably formed quite slowly. In fact, the level 3 and 6 (30 cm) carbon dates overlap in time, perhaps representing only a few years of midden accumulation. The archaeological data do not seem to provide information about why Cinnamon Bay was abandoned after A.D.1490.

ZOOARCHAEOLOGICAL METHODS

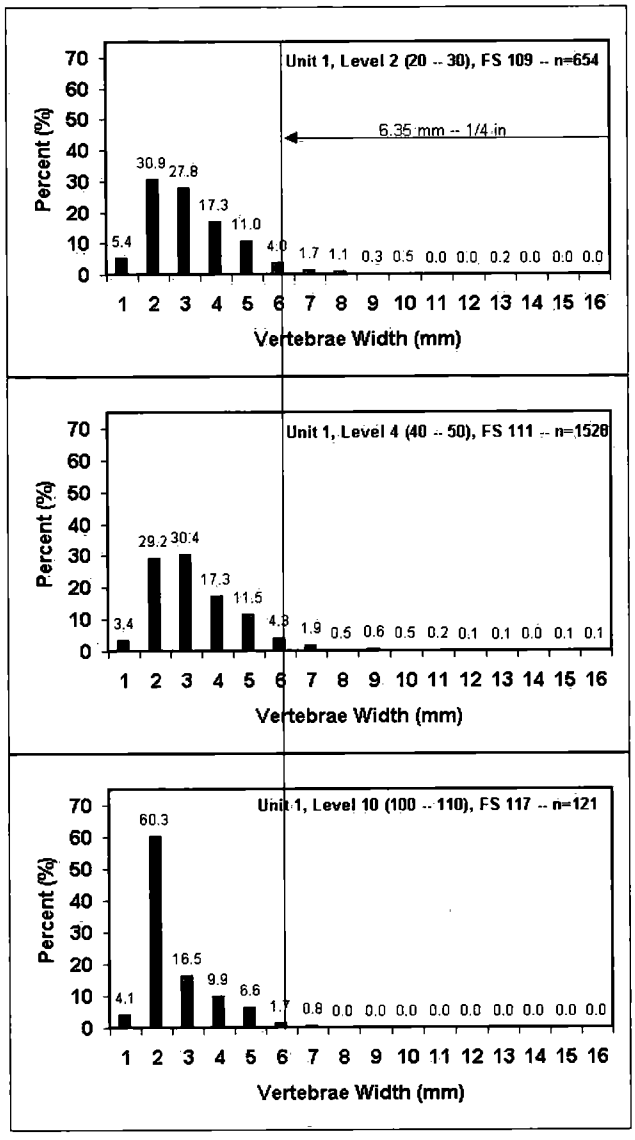
Three 4 x 4 meter excavation units were opened in 1998 at Cinnamon Bay (Wild 1999). These excavations were preparatory to taking a series of midden samples in the summer of 1999. Ken Wild and Irvy R. Quitmyer provided oversight of the sampling.

Sampling and Sieving

Ten 50 x 50 x 10 cm superimposed samples were taken from the southeast corner of Unit 1. Each sample was water-sieved in the field through a nested pair of screens measuring 1/4 in (6.35 mm) and 1/16 in (1.6 mm) gauge. Samples were allowed to air dry before packing and transport to the Florida Museum of Natural History. Prior to study, the samples were fumigated for 24 hours with the inorganic compound, Vikane™ (sulfuryl fluoride). One sample from each of the ceramic components was randomly selected for study: FS 117, level 10 (90-100 cmbs); FS 111, level 4 (30-40 cmbs); and FS 109, level 2 (10-20 cmbs) (Table 1).

The use of fine-gauge screens in faunal recovery represents an important advance in the study of zooarchaeological remains (Reitz and Wing 1999:119-121). Historically, archaeologists have used 1/4 in gauge screens (coarse) in faunal recovery without realizing the possible ramifications of this choice. In the field, the skeletal remains of large animals are highly visible, while it is difficult to see the remains of small taxa lost through coarse-gauge screens. Without the benefit of analysis, it is easy to be misled into believing that large taxa, such as mammals, shellfish, and large fish, were the mainstay of the assemblage. When fine screen (1/16 in) is used in the recovery of fauna from sites associated with aquatic habitats, without exception the remains of small fishes represent a major part of the sample (Reitz and Quitmyer 1988; Reitz and Wing 1999; Wing and Quitmyer 1985). Screening experiments from sites representing several cultural periods and across the southeastern United States and Caribbean confirms this observation (Quitmyer and Massaro 2000; Reitz and Quitmyer 1988; Reitz and Wing 1999; Russo et al. 1991; Wing and Quitmyer 1985).

To illustrate the importance of fine-gauge screen faunal recovery at Cinnamon Bay, the lateral width (mm) of all unbroken fish vertebral centra from level 4 (FS 111) were measured with a Max Cal™ caliper attached to a personal computer. Max Cal™ caliper software facilitated the entry of the data into the Microsoft spreadsheet Excel™ where descriptive statistics and graphs could be produced (figs. 2 and 3). The 95% confidence calculated around the mean of the fish vertebrae from the 1/4 in gauge screen (coarse) was compared to those recovered in the nested screens measuring 1/4 in and 1/16 in gauge (fine) (Fig. 2).



Two significant observations can be drawn from the measured fish vertebra data. First, 96% of the Cinnamon Bay level 4 fish vertebrae are smaller than 1/4 in (6.35 mm) and would have been lost during sieving if fine-gauge screen had not been used (Fig. 2). The same is true for all three samples of the measured fish vertebrae (Fig. 3). Second, the mean and 95% confidence interval of fish vertebrae recovered in the 1/4 in gauge screen and in the 1/4 to 1/16 in gauge screens is significantly different ($P \leq 0.05$) (Fig. 2). The mean lateral width of the vertebrae from the fine screen (1/4 and 1/16 in gauge combined) is 3.32 mm (n = 1,528) and those from the coarse screens (1/4 in) average 7.35 mm (n = 80). At the 95% confidence interval of each of the two samples, they do not overlap ($P \leq 0.05$), thus illustrating that they are statistically significant and cannot be adequately compared (Fig. 2). The use of screens of different gauges in faunal recovery yields very different results, which, in turn, affect the interpretation of subsistence behavior. The choice of screen size affects not only the recovery of representative size classes, but also the kinds of taxa, the number of taxa, and the count of minimum numbers of individuals that may be lost through coarse-gauge screen.

A comparison of the percentage of individuals recovered from level 2 in the coarse-gauge screen (1/4 in) versus those recovered in the fine screen (1/4-1/16 in) supports the use of fine-gauge screen sieving (Fig. 4). Fauna recovered in the coarse-gauge screen is represented by 178 minimum number of individuals (MNI) and 40 taxa, while fine-gauge sieving yields 256 MNI and 66 taxa. Percentage of

Unit 1, Level 2 (20 — 30 cmbs), FS 109

Vertebrae width (mm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	n
n	35	202	182	113	72	26	11	7	2	3	0	0	1	0	0	0	654
%	5.4	30.9	27.8	17.3	11.0	4.0	1.7	1.1	0.3	0.5	0.0	0.0	0.2	0.0	0.0	0.0	

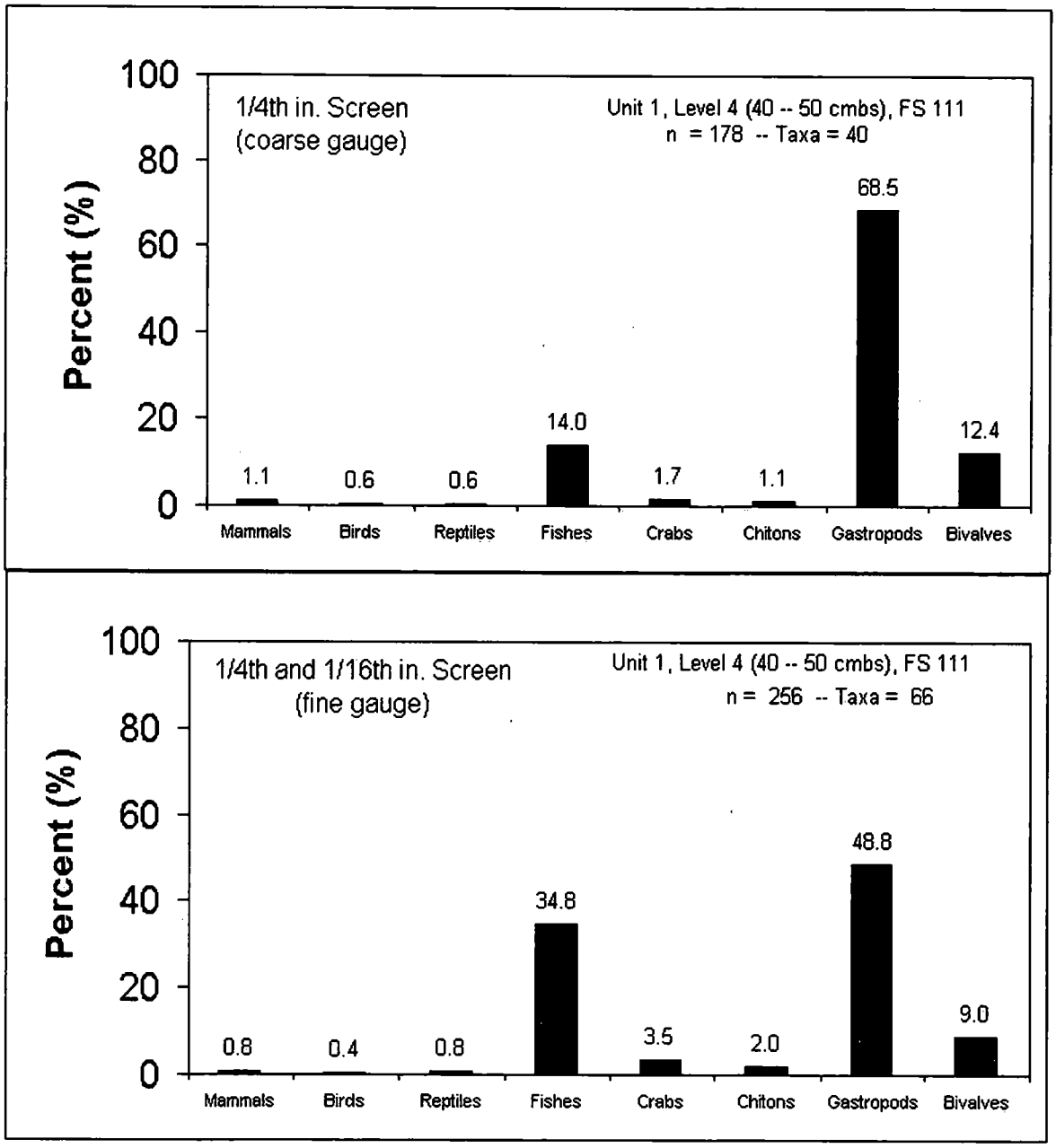
Unit 1, Level 4 (40 - 50 cmbs), FS 111

Vertebrae width (mm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	n
n	52	446	465	264	176	66	29	7	9	7	3	1	1	0	1	1	1528
%	3.4	29.2	30.4	17.3	11.5	4.3	1.9	0.5	0.6	0.5	0.2	0.1	0.1	0.0	0.1	0.1	

Unit 1, Level 10 (100 — 110 cmbs), FS 117

Vertebrae width (mm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	n
n	5.0	73.0	20.0	12.0	8.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	121
%	4.1	60.3	16.5	9.9	6.6	1.7	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Figure 3. Lateral width (mm) of fish vertebrae (mm) from Unit 1, Levels 2, 4, and 10, Cinnamon Bay, St. John, U.S. Virgin Islands. The vertical bar marks 6.35 mm or 1/4 in gauge.



Unit 1, Level 4 (40-50 cmbs), FS 111–1/4 in gauge screen

Classes	MNI	%
Mammals	2	1.12
Birds	1	0.56
Reptiles	1	0.56
Fishes	25	14.04
Crabs	3	1.69
Chitons	2	1.12
Gastropods	122	68.54
Bivalves	22	12.36
Total	178	100.00
Taxa	40	

Unit 1, Level 4 (40-50 cmbs), FS 111–1/4-1/16 in gauge screen

Classes	MNI	%
Mammals	2	0.8
Birds	1	0.4
Reptiles	2	0.8
Fishes	89	34.8
Crabs	9	3.5
Chitons	5	2.0
Gastropods	125	48.8
Bivalves	23	9.0
Total	256	100.00
Taxa	66	

Figure 4. A comparison of the minimum numbers of individuals of animals classes recovered in 1/4 in gauge screen (coarse) and 1/4 and 1/16 in gauge screen (fine) from Unit 1, level 4, FS 111, Cinnamon Bay, St. Thomas, U.S. Virgin Islands.

fishes increases from 14% in the coarse gauge screen to 35% in the fine-gauge screen.

This sieving experiment shows that fine-gauge sieving (1/4-1/16 in gauge) assures that large and small fauna have an equal chance of being recovered (Wing and Quitmyer 1985), thus providing an optimal picture of the zooarchaeological assemblage.

Minimum numbers of individuals. The three Cinnamon Bay faunal samples were hand-sorted and identified to the lowest possible taxon using the comparative collections of the Florida Museum of Natural History (Table 2). Standard zooarchaeological methods were used to quantify the faunal remains (Reitz and Quitmyer 1988; Reitz and Wing 1999; Ziegler 1973). These include a count of the identified specimens and their weight in grams. A count of the MNI is used to characterize the ranked frequency of animals that are present in the faunal assemblages. MNI represents the fewest number of individuals that can be identified from the skeletal assemblage. MNI was determined by the use of the concept of paired elements and individual size. For example, four left frontals and five right frontals of equal size from parrot fish (Scaridae) represent five MNI, while four large frontals and five small frontals represent nine MNI (Reitz and Wing 1999; Ziegler 1973).

Commensal species. It is common within most zooarchaeological assemblages to identify a suite of taxa that may be regarded as commensal species. Some are animals that are attracted to human habitation, where they gain protection or food. Other taxa may find their way into the zooarchaeological record through the acquisition of targeted species. For example, clutches of oysters may yield a microcosm of taxa that are not directly intended as a human food resource. Such a collection might include a large number of barnacles and limpets. It is difficult to determine which of these attendant species contribute to the human diet. The soft tissue of commensals would unintentionally contribute to the human diet if the clutches of oyster were boiled and the liquid and meat consumed. In contrast, the consumption of raw oysters would not include the soft tissue of commensals adhering to the oyster shells.

In the three assemblages in this study, ten species of terrestrial gastropods were identified (Table 1). With the exception of the terrestrial snail (*Polydontes lima*), none of these animals has a body dimension greater than 7 mm and most are smaller than 2 mm. These taxa were in varying stages of ontogenetic development. The evidence indicates that the landsnails are commensal species that were probably not consumed by humans. A random sample of terrestrial gastropods was sorted from each sample to identify those species in the midden. Barnacles, limpets, and corals were also identified in the Cinnamon Bay assemblages. These, too, are considered taxa that were probably not a common part of the diet. Consequently, these animals are not included as part of the analysis of human subsistence (MNI), but their identification contributes information to the natural history of the island (Table 1).

Biomass estimates. In most cases, we are presented with only a portion of the skeleton of each individual estimated in the zooarchaeological record and we are unable to measure the whole organism. Fortunately, these skeletal elements scale allometrically with body size (Peters 1983). Allometry reflects the structural and functional consequences of a change in size or in scale among similarly shaped animals (Peters 1983; Reitz et al. 1987; Schmidt-Nielsen 1984). Growth is a non-linear process through ontogeny and this allometric relationship is described by a mathematical power function, $y = a(X^b)$ (Schmidt-Nielsen 1984). In order to produce a straight line regression, this is transformed using the common log. The resulting formula is:

$$\text{Log } y = a + b(\log X)$$

Where:
b = the slope of the line,
a = the y intercept,
x = the independent variable, skeletal measurement,
y = the dependant variable, the estimated body mass.

Many vertebrate and invertebrate characteristics scale allometrically, but the most useful to this study is body mass (biomass) in relation to a measurable skeletal element. The constants used to estimate body weight from the vertebrae of teleost fishes is presented in Table 3.

Analysis of Trophic Level

Recent work by Pauley et al. (1998) has helped to identify the affects of modern fishing practices on worldwide stocks over the past 45 years. They conclude that modern fishing practices reduce the availability of taxa from high trophic levels, thus requiring the exploitation of species from lower in the food web (Pauley et al. 1998). Pauley and his associates (1998) have characterized these findings

Table 2. Presence and absence of animal taxa identified from Cinnamon Bay, St. John, US Virgin Islands.
Key: * = taxa, identified from the general levels and previous studies; X = present in the sample.

Unit 1 — Faunal Sample Taxa		Level 1 FS109	Level 4 FS111	Level 10 FS117	Comments
		VERTEBRATES			
		Mammals			
Mammalia	mammals	x	x		
Mammalia (medium)	medium mammals	x	x		
Nesophontes edithae	extinct insectivore	*			introduced; extinct
Homo sapiens	human	*			introduced; Taíno extinct
Rodentia	rodents		x		
Rodentia (large)	lg. rodents (e.g., hutia)	x			
Rattus spp.	European rat	*			
Cavia porcellus	guinea pig	*			introduced; extirpated
Isolobodon portoricensis	hutia	x	x	x	introduced; extinct
Cetacea	porpoise	*			
Monachus tropicalis	monk seal	*			extinct
Trichechus manatus	manatee	*			threatened
		Birds			
Aves	birds		x	x	
Aves (medium)	medium birds — e.g., dove	x			
Puffinus iherminieri	Audubon's shearwater	*			
Ardeidae	herons	*			
Rallidae	possibly flightless rail	*			extinct
Porphyrula martinica	purple gallinule	*			
Otus nudipes	Puerto Rican screech owl	* x			rare
		Reptiles			
Squamata	lizards	x			
Iguanidae	iguana	x			
Iguana iguana	iguana	*			rare on St. John
Serpentes	snake	x	x		rare on St. John
Testudines	turtles	x	x		
Trachemys spp.	pond turtle	*			introduced; rare or extirpated
Cheloniidae	sea turtle	*			
		Cartilaginous Fishes			
Chondrichthyes	cartilaginous fishes		x		
Rajiformes	sates and rays		x	x	
Lamniformes	shark	*			
Carcharhinus spp.	requiem sharks	*			
		Bony Fishes			
Osteichthyes	bony fishes	x	x	x	
Elops saurus	ladyfish		x		
Gymnothorax spp.	moray		x		
Clupeidae	shads/herrings	x	x	x	
Belonidae	needlefishes	x	x		
Holocentrus spp.	squirrelfishes	x	x		
Holocentrus adscensionis	squirrelfish		x		
Prionotus spp.	searobins		x		
Epinephelus spp.	groupers	x	x	x	
Epinephelus cuentatus	graysby	*			
Epinephelus striatus	Nassau grouper	*			
Carangidae	jacks	x	x	x	
Caranx spp.	jacks	x	x		
Caranx latus	horse-eye jack	*			
Caranx ruber	bar jack		x		
Lutjanus spp.	snappers	x	x	x	
cf. Lutjanus griseus	gray snapper	*			

(cont.)

Table 2 (cont.).

Taxa			FS109	FS111	FS117	Comments
Haemulon spp.	grunt		x	x	x	
Sparidae	porgies		x			
Calamus spp.	porgy		x	x	x	
Mugil spp.	mullet	*				
Sphyraena spp.	barracuda		x	x	x	
Labridae	wrasses			x		
Bodianus spp.	hogfish		x			
Halichoeres spp.	wrasse			x		
Scaridae	parrotfishes		x	x		
Scarus spp.	parrotfish		x	x		
Sparisoma spp.	parrotfish		x	x	x	
Scarus cf. coeruleus	blue parrotfish	*				
Sparisoma viride	stoplight parrotfish		x			
Acanthurus spp.	surgeonfish			x		
Scombridae	tuna		x	x	x	
Auxis rochei	bullet mackerel	*				
Euthynnus alletteratus	little tunny	*				
Balistidae	leatherjackets				x	
Balistes spp.	triggerfish		x	x		
Ostraciidae	boxfishes		x	x	x	
Diodontidae	porcupinefishes			x	x	
Diodon spp.	porcupinefish		x			
		INVERTEBRATES				
		Crustaceans				
Cirripedia	barnacles		x			
Balanomorpha	acorn barnacles			x		
Balanus spp.	barnacle			x		
Panulirus spp.	spiny lobsters	*				
Decapoda	decapod crabs			x	x	
Brachyura	crabs		x	x		
Callinectes spp.	blue crab	*				
Coenobita clypeatus	land hermit crab		x	x	x	
Gecarcinidae	land crabs		x	x	x	
Mithrax spp.	spider crab			x		
		Mollusks				
Mollusca	snails and clams		x	x	x	
		Chitons				
Chitonidae	Chitons			x	x	
Acanthopleura granulata			x	x		
		Gastropods				
Gastropoda	snails		x	x		
Pleurotomariacea	Archaeogastropoda				x	
Fissurellidae	limpets		x			
Diodora spp.	limpet		x		x	
Diodora listeri	Lister's keyhole limpet			x		
Acmaea antillarum	Antillean limpet		x	x	x	
Turbinidae	starsnails/turban snails		x	x		
Turbo castanea	chestnut turban		x			
Cittarium pica	West Indian topsnail		x	x	x	
Nerita spp.	nerite		x	x		
Nerita peloronta	bleeding tooth		x	x	x	
Nerita versicolor	four-tooth nerite		x	x		
Neritina spp.	nerites			x		
Neritina virginea	virgin nerite		x	x		
Cerithiidae	ceriths			x	x	
Tectarius muricatus	beaded periwinkle		x			

(cont.)

Table 2 (cont.).

Taxa		FS109	FS111	FS117	Comments
Strombus gigas	queen conch	x	x		
Crepidula spp.	slipper shells	x			
Crucibulum auricula	West Indian cup-and-saucer		x		
Naticidae	moonsnails	x			
Polinices hepaticus	brown moonsnail		x		
Muricidae	murex		x		
Cymatium muricinum	knobbed triton		x		
Chicoreus brevifrons	West Indian murex	x			
Plicopurpura patula	widemouth rocksnail		x		
Thais spp.	rocksnail	x			
Thais deltoidea	deltoid rocksnail		x		
Columbellidae	dove-shell				
Columbellidae	dovesnails	x	x		
Alcadia spp.	drop	x	x	x	
Columbella mercatoria	West Indian dovesnail			x	
Olividae	olive			x	
Fasciolaria tulipa	true tulip		x		
Conus spp.	cone	x	x		
Pupoides modicus	island dagger	x	x	x	
Hinea lineatus	dwarf planaxis		x		
Subulinidae	awlsnails	x	x	x	
Lamellaxis micra	tiny awlsnail	x	x	x	
Opeas pyrgula	sharp awlsnail	x	x	x	
Subulina octona	miniature awlsnail	x			
Bulimulus guadalupensis	West Indian bulimulus	x	x	x	
Polydontes lima	land snail — no common name	x	x	x	
Succineidae	ambersnails	x			
Xanthonycidae	land snails — no common name	x	x	x	
Sagdidae	mudcloak	x	x	x	
	Tuskshells and Toothshells				
Dentalium spp.	tuskshell	x			
	Bivalves				
Bivalvia	clams/mussels/oysters	x	x	x	
Mytilidae	mussels	x	x		
Brachidontes spp.	mussel		x		
Brachidontes exustus	scorched mussel		x	x	
Anadara notabilis	eared ark	x			
Pinctada radiata	Atlantic pearl oyster	x	x		
Arca spp.	ark shells		x		
Arca zebra	turkey wing	x	x	x	
Glycymeris pectinata	comb bittersweat		x		
Nodipecten nodosus	lions-paw scallop	x			
Codakia orbicularis	tiger lucine	x	x	x	
Chamidae	jewelbox	x	x		
Chama spp.	jewelbox	x	x		
Laevicardium spp.	eggcockle			x	
Donax denticulatus	coquina	x	x		
Asaphis deflorata	gaudy sanguin	x	x		
Veneridae	Venus clams	x	x	x	
Periglypta listeri	princess verus		x		
	Echinoderms				
Echinoidea	sea urchin	x	x	x	
	Corals				
Anthrozoa	corals	x		x	

as "fishing down the food web." Wing (2001a, 2001b) has applied the methods of Pauley et al. (1998) to the zooarchaeological record of five sites on islands in the Caribbean: 1) Tutu, St Thomas, VI; 2) Hope Estate, St. Martin; 3) Kelbey's, Saba; and 4) Indian Castle and Hichman's, Nevis (Fig. 1). The zooarchaeological remains record a decline in mean trophic level of reef resources, while there is a subsequent increase or decrease in the mean trophic level of inshore and pelagic taxa between the early and late components of the sites. When there is a measured increase in the mean trophic level of inshore and pelagic resources, tuna and other large predators predominate. In sites where a decrease in the mean trophic level of inshore and pelagic taxa occurs, there is a relative increase in the biomass of herrings (Clupeidae) and other small fishes (Wing 2001a). The trend toward the use of tuna or herring represents a shift to those species with larger biological reservoirs when compared to species from the reef habitats.

In this study, I apply the methods presented by Pauley et al. (1998) and adapted by Wing (2001a) to determine the mean trophic level of the catch of vertebrate aquatic species identified in the Cinnamon Bay faunal assemblage. The results of this experiment are compared to the studies of the St. Thomas, St. Martin, Saba, and Nevis zooarchaeological records (Wing 2001a, 2001a).

The formula for calculating the mean trophic level ($\overline{TL}$) is as follows (Pauley et al. 1998):

$$\overline{TL}_i = \acute{O}_{ij}\, Tl_{ij}\, Y_{ij} / \acute{O}\, Y_{ij},$$

where:

$\overline{TL}_i$ is the mean trophic level for year i,

(Y_{ij}) is the landings by trophic levels of individual species groups j.

The application of the trophic level formula using the zooarchaeological specimens follows a three-part process (Wing 2001a):

1) The appropriate allometric formula (Table 3) was used to calculate the average biomass for the various taxa in each sample from measurements of their vertebrae. In those rare cases where there are no measurable vertebrae present, the mean vertebral width of unidentified fish was used with the assumption that the vertebrae came from a cross section of the identified species.

2) Estimated biomass of the catch for each species was determined by multiplying the average biomass of the individuals in each species by the MNI.

3) The final step is to multiply the biomass of each for each species by the mean trophic level index (Pauley et al. 1998). Trophic level indices range from one to five. Plants are primary producers, trophic level (TL) = 1, while TL value for top predators is 5. These indices are derived from the feeding behaviors of the organisms (Pauley and Christensen 1997).

The habitat categories of fishes associated with coral reefs follow Sale (1991). The mean trophic levels were calculated only for the aquatic vertebrate component of the Cinnamon Bay assemblages. This is comparable to Wing's (2001a) analysis where her faunal samples did not include the molluscan data.

Size class analysis of West Indian topsnail (Cittarium pica). Through successive deposits of some pre-Columbian Caribbean sites the numbers of land crabs declines with the length of exposure to human habitation while the numbers of West Indian topsnail (and other mollusks) increase (Wing 2001a). Measurements were taken from the shells of the topsnails to document two temporal changes in their size classes: 1) the greatest distance from the notch in the umbilicus to the notch of the aperture; and 2) the greatest aperture height (mm). Where there are large numbers of fragmented shells, the notch of the umbilicus to the aperture notch measurement assures a larger sample size.

To facilitate the temporal comparison of the size classes of topsnails, the mean and the 95% confidence interval for the two shell measurements listed above were calculated for each of the 10 levels. It was then possible to rank the mean values and ascertain which of the samples were statistically different ($P \leq 0.05$) from one another by noting whether or not their confidence intervals overlapped. This procedure is straightforward, easily interpretable, and conservative.

Table 3. Allometric constants used to estimate biomass (Y) in grams. These are applied the formula log Y = log a + b(log X) where X is the measured width of the vertebrae in millimeters (Wing 1999).

Measurement	n	slope b	Y intercept a	r^2
X = width of teleost vertebrae (mm)	43	2.53	0.872	0.87

Table 4. Fauna identified from Unit 1, Level 2 (10 - 20 cmbs), FS 109 Cinnamon Bay, U.S. Virgin Islands, NPS ACC# 191, UF Accession # 510. Key: * = present in the sample, but not quantified; + = weighed as Subulinidae.

Taxon	Count	%	MNI	%	Weight (g)	%
Vertebrata	*	–	–	–	4.22	0.37
Mammalia	6	0.41	–	–	0.29	0.03
Mammalia (medium)	3	0.20	–	–	0.46	0.04
Rodentia (large)	3	0.20	–	–	0.35	0.03
Isolobodon portoricensis	7	0.48	1	0.68	1.14	0.10
Aves (medium)	1	0.07	–	–	0.05	0.00
Otus nudipes	1	0.07	1	0.68	0.05	0.00
Squamata	1	0.07	–	–	0.01	0.00
Igunidae	2	0.14	1	0.68	0.01	0.00
Serpentes	7	0.48	1	0.68	0.18	0.02
Testudines	1	0.07	1	0.68	0.20	0.02
Osteichthyes	599	40.92	–	–	61.46	5.45
Clupeidae	15	1.02	1	0.68	0.04	0.00
Belonidae	5	0.34	1	0.68	0.15	0.01
Holocentrus spp.	7	0.48	2	1.35	0.16	0.01
Epinephelus spp.	6	0.41	3	2.03	1.21	0.11
Carangidae	10	0.68	–	–	0.27	0.02
Caranx spp.	13	0.89	3	2.03	1.93	0.17
Lutjanus spp.	17	1.16	6	4.05	1.70	0.15
Haemulon spp.	24	1.64	9	6.08	1.08	0.10
Sparidae	4	0.27	–	–	0.18	0.02
Calamus spp.	5	0.34	2	1.35	0.43	0.04
Sphyraena spp.	6	0.41	1	0.68	0.10	0.01
Bodianus spp.	1	0.07	1	0.68	0.01	0.00
Scaridae	28	1.91	–	–	3.19	0.28
Scarus spp.	6	0.41	1	0.68	0.33	0.03
Sparisoma spp.	118	8.06	7	4.73	17.30	1.53
Sparisoma viride	15	1.02	8	5.41	2.99	0.27
Scombridae	20	1.37	2	1.35	3.96	0.35
Balistes spp.	12	0.82	1	0.68	0.48	0.04
Ostraciidae	5	0.34	1	0.68	0.14	0.01
Diodon spp.	1	0.07	1	0.68	0.13	0.01
Cirripedia	15	1.02	–	–	0.87	0.08
Brachyura	35	2.39	–	–	2.13	0.19
Coenobita clypeatus	32	2.19	2	1.35	2.83	0.25
Gecarcinidae	6	0.41	1	0.68	1.40	0.12
Mollusca	*	–	–	–	24.10	2.14
Acanthopleura granulata	27	1.84	4	2.70	14.90	1.32
Gastropoda	8	0.55	–	–	22.55	2.00
Fissurellidae	2	0.14	–	–	0.02	0.00
Diodora spp.	4	0.27	*	–	0.27	0.02
Acmaea antillarum	19	1.30	*	–	1.39	0.12
Turbinidae	1	0.07	–	–	2.96	0.26
Turbo castanea	1	0.07	1	0.68	3.67	0.33
Cittarium pica	180	12.30	29	19.59	678.05	60.10
Nerita spp.	3	0.20	–	–	0.89	0.08
Nerita peloronta	2	0.14	2	1.35	4.58	0.41
Nerita versicolor	3	0.20	2	1.35	1.77	0.16
Neritina virginea	30	2.05	14	9.46	10.94	0.97
Tectarius muricatus	4	0.27	4	2.70	3.18	0.28
Strombus gigas	1	0.07	1	0.68	7.84	0.69
Crepidula spp.	2	0.14	2	1.35	0.04	0.00
Naticidae	1	0.07	1	0.68	0.02	0.00
Chicoreus brevifrons	2	0.14	2	1.35	7.03	0.62
Thais spp.	1	0.07	1	0.68	11.03	0.98
Columbellidae	1	0.07	1	0.68	0.30	0.03

(cont.)

Table 4 (cont.)

Taxon	Count	%	MNI	%	Weight (g)	%
Alcadia sp.	*	–	–	–	1.27	0.11
Conus spp.	1	0.07	1	0.68	0.10	0.01
Pupoides modicus	*	–	–	–	0.04	0.00
Subulinidae	*	–	–	–	0.75	0.07
Lamellaxis micra	*	–	–	–	+	+
Opeas pyrgula	*	–	–	–	+	+
Subulina octona	*	–	–	–	+	+
Bulimulus guadalupensis	*	–	–	–	2.29	0.20
Polydontes lima	*	–	–	–	3.26	0.29
Succineidae	*	–	–	–	0.29	0.03
Xanthonycidae	*	–	–	–	0.02	0.00
Sagdidae	*	–	–	–	0.06	0.01
Dentalium spp.	1	0.07	1	0.68	0.01	0.00
Bivalvia	8	0.55	–	–	5.71	0.51
Mytilidae	10	0.68	1	0.68	1.53	0.14
Anadara notabilis	3	0.20	2	1.35	64.15	5.69
Pinctada radiata	15	1.02	3	2.03	5.38	0.48
Arca zebra	9	0.61	4	2.70	24.84	2.20
Lyropecten nodosus	1	0.07	1	0.68	0.49	0.04
Codakia orbicularis	57	3.89	4	2.70	97.01	8.60
Chamidae	2	0.14	–	–	0.25	0.02
Chama spp.	4	0.27	3	2.03	3.75	0.33
Donax denticulatus	5	0.34	2	1.35	2.78	0.25
Asaphis deflorata	2	0.14	2	1.35	0.89	0.08
Veneridae	1	0.07	1	0.68	0.07	0.01
Echinoidea	11	0.75	1	0.68	0.44	0.04
Anthrozoa	5	0.34	*	–	5.87	0.52
TOTAL TAXA Taxa = 49	1464	100.00	148	100.00	1128.20	100.00

Summary by Class	Class	MNI	%	Class	MNI	%
	Mammals	1	0.68	Crabs	3	2.05
	Birds	1	0.68	Chitons	4	2.74
	Reptiles	3	2.05	Gastropoda	61	41.78
	Fishes	50	34.25	Bivalves	23	15.75
TOTAL CLASSES					146	100.00

RESULTS

Level 2 (10–20 cmbs) FS 109

Archaeological context. The faunal sample from level 2 (FS 109) was excavated from 10 to 20 cmbs. While no radiometric (^{14}C) date has been analyzed for level 2 (Table 1), level 1 dates radiometrically to ~460 B.P. (A.D. 1490), and level 3 to 570 ±70 B.P. (A.D.1290 to 1450) (Beta 69973), thus indicating that level 2 formed sometime during this ±110-year interval. The artifacts indicate that the faunal remains are associated with the Chican Ceramic Period.

Minimum numbers of individuals. The level 2 faunal assemblage contains 49 taxa and 147 MNI (Table 4). This does not include commensal species identified in the sample. The skeletal remains are well preserved, showing few signs of abrasion, pitting, or diagenesis. Fewer than 0.5% of the remains showed signs of having been burned. The well preserved nature of the sample is consistent with materials from the deeper levels of the site.

Gastropods (41.4%), fishes (34.5%), and bivalves (15.9%) were the most frequently identified animals (MNI) from level 2 (Table 4, Fig. 5). West Indian topsnail (19.7%) was the most numerous animal identified, while four-tooth nerite (*Neritina virginea*, 9.5%) and beaded periwinkle (*Tectarius muricatus*, 2.7%) were also frequent. Parrotfishes (*Sparisoma* spp., 10.2%) are the second most abundant taxon. The relative abundance of groupers (*Epinephelus*

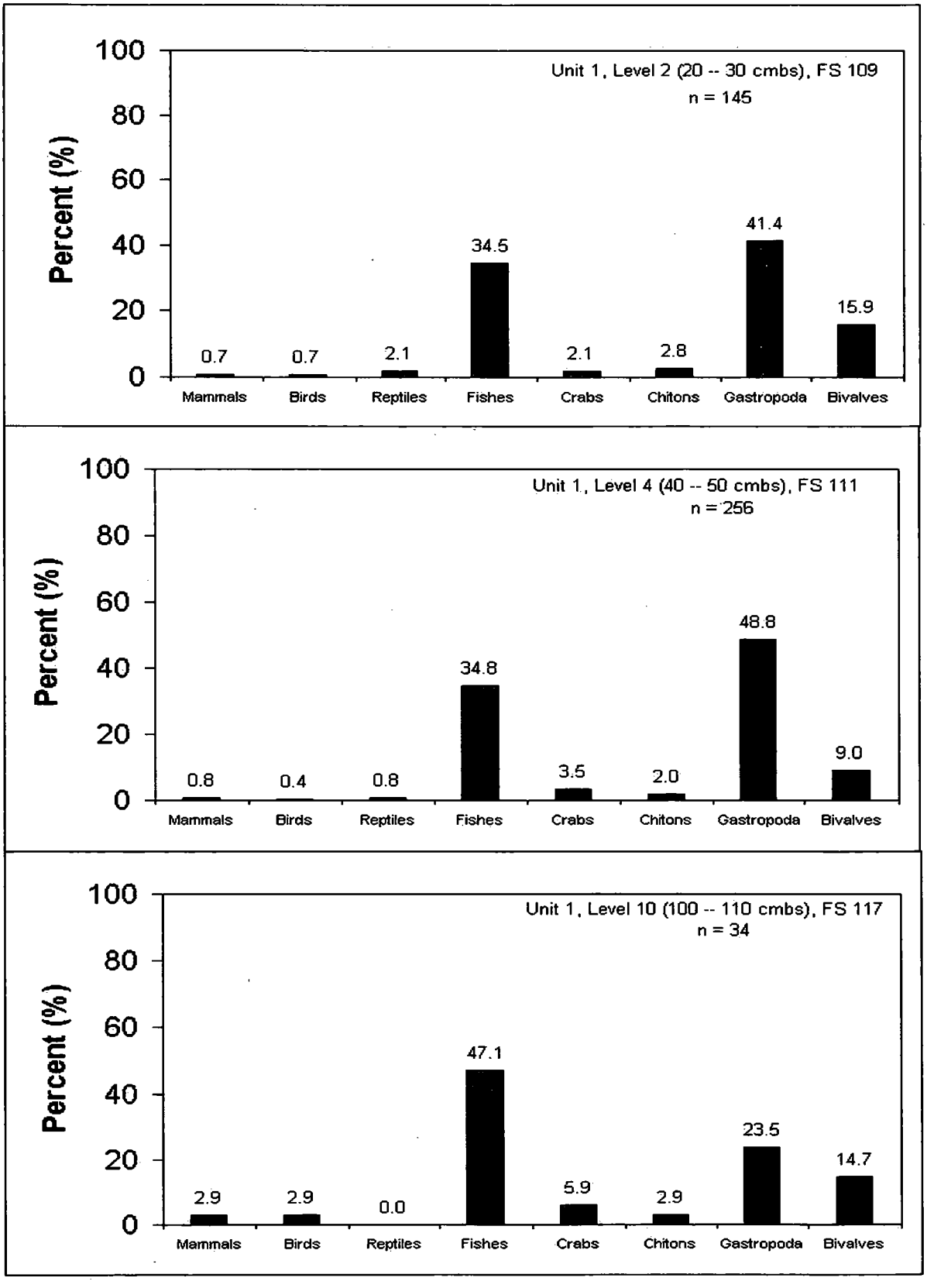


Figure 5. Summary of the minimum number of individuals (MNI) by class identified from levels 2, 4, and 10, Cinnamon Bay, St. John, U.S. Virgin Islands.

Table 5. Mean trophic level of aquatic vertebrate taxa identified from Unit 1, Level 2 (10-20 cmbs), FS 109, Cinnamon Bay, US Virgin Islands.

	Measurement X	Biomass (g)	MNI	Biomass x MNI	TL	TLijYij
REEF						
Holocentrus spp.	3.14	134.66	2	269.32	3.5	942.61
Epinephelus spp.	3.31	153.87	3	461.62	3.8	1754.16
Lutjanus spp.	3.14	134.66	6	807.95	4.6	3716.56
Haemulon spp.	3.53	181.08	9	1629.72	3.5	5704.01
Bodianus spp.	3.14	134.66	1	134.66	3.6	484.77
Scarus spp.	4.18	277.70	1	277.70	3.4	944.18
Sparisoma spp.	3.62	192.99	7	1350.92	3.5	4728.23
Sparisoma viride	3.62	192.99	8	1543.91	3.5	5403.69
Balistes spp.	3.14	134.66	1	134.66	3.5	471.30
Ostraciidae	3.14	134.66	1	134.66	3.2	430.91
Diodon spp.	3.14	134.66	1	134.66	3.2	430.91
INSHORE, PELAGIC						
Clupeidae	1.67	27.26	1	27.26	2.6	70.87
Belonidae	3.86	227.02	1	227.02	3.2	726.47
Caranx spp.	9.85	2428.81	3	7286.43	4.0	29145.73
Calamus spp.	3.14	134.66	2	269.32	3.4	915.67
Sphyraena spp.	2.47	73.37	1	73.37	4.5	330.17
Scombridae	7.52	1226.96	2	2453.92	3.8	9324.91
TOTAL SAMPLE			50	17217.09		65525.15

Reef		
Biomass x MNI	Mean $\overline{TL}$	TLijYij
6879.77	3.64	25011.33
39.96%		

Inshore, Pelagic		
Biomass x MNI	Mean $\overline{TL}$	TLijYij
10337.32	3.92	40513.82
60.04%		

spp., 2.0%), snappers (*Lutjanus* spp., 4.1%), and grunts (*Haemulon* spp., 6.1%) is somewhat less important to the calculation of MNI in level 2. Bivalves represent a minor component of the sample, with Atlantic pearl oyster (*Pictada radiata*, 2.0%), turkey wing (*Arca zebra*, 2.7%), tiger lucine (*Codakia orbicularis*, 2.7%), and jewel box (*Chama* spp., 2.0%) being among the most significant. Two species of crabs are present: land hermit crab (*Coenobita clypeatus*, 1.4%) and land crab (Gecarcinidae, 0.7%).

Mammals (0.7%), birds (0.7%), reptiles (2.1%), and crabs (2.1%) were among the rarest animals encountered in the level 2 sample. The only mammal that was identified is the hutia (*Isolobodon portoricensis*, 0.68%), introduced to the island by pre-Columbian people and now probably extinct (Wilson 1989; Wing and Wing 1997). Iguanid lizards (Iguanidae, 0.68), snakes (Serpentes, 0.68%), and turtles (Testudines, 0.68%) are the three groups of reptiles present in the assemblage. A single piece of turtle carapace was identified and its surface texture is not consistent with sea turtle. It is most likely that the sample represents the pond turtle (*Trachemys* spp.), although land tortoise cannot be ruled out. Pond turtle, introduced to the island by pre-Columbian immigrants, has been previously identified in the Cinnamon Bay zooarchaeological remains (Table 2). The Puerto Rican screech owl (*Otus nudipes*), the only volant species identified, currently is severely threatened, and possibly extirpated, from some of the Virgin Islands.

Trophic level analysis. Table 5 and Fig. 6 show trophic level analysis of the level 2 aquatic fauna. The data show that 40.0% of the fish biomass comes from reef fishes, while 60.0% is obtained from inshore/pelagic taxa. Among the reef species, parrotfish and grunts represent the largest biomass. The greatest portion of biomass from the inshore/pelagic species come from the tunas (Scombridae) and jacks (*Caranx* spp.). The mean trophic level of

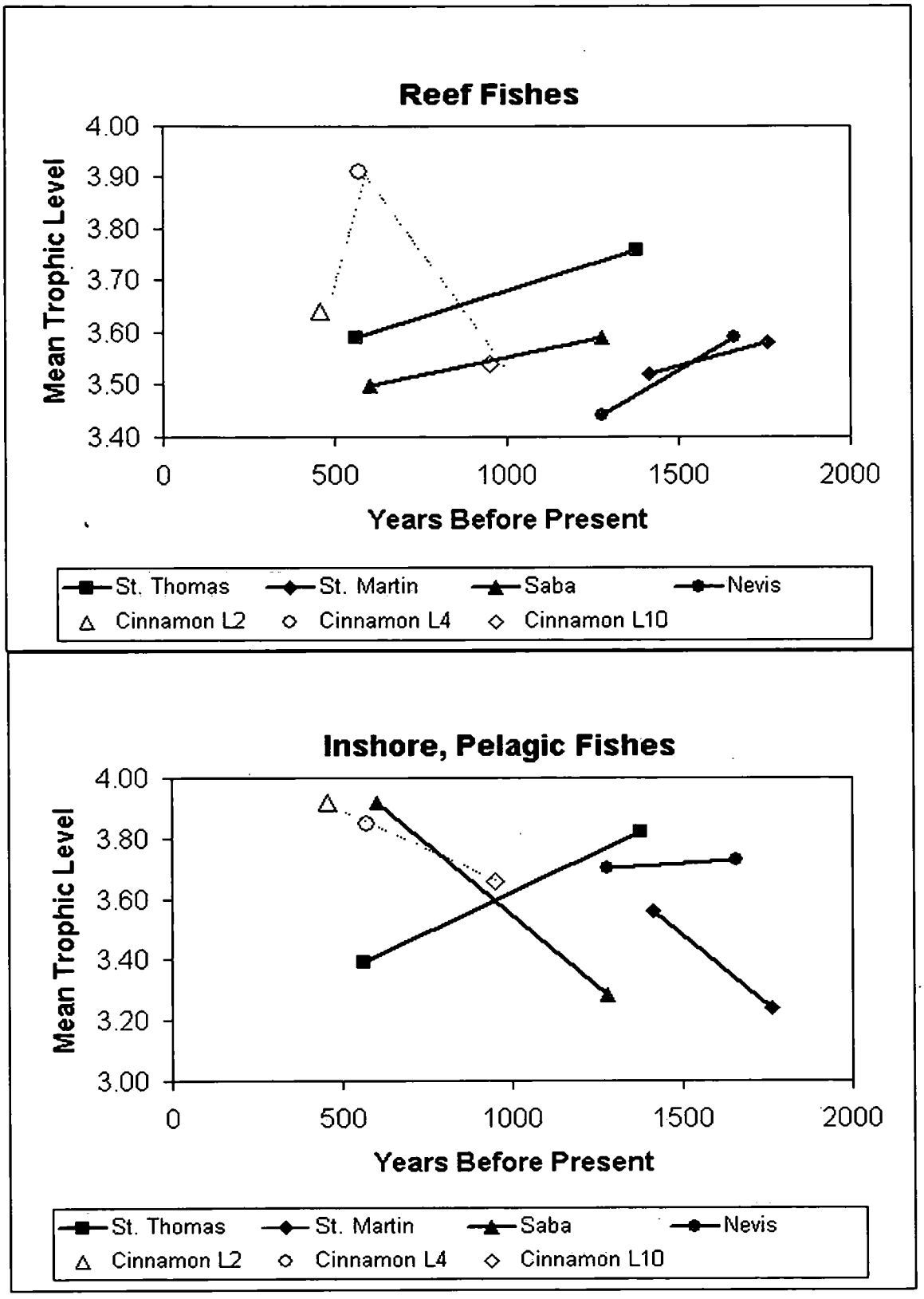


Figure 6. Comparison of trophic levels of reef and inshore/pelagic species of early and late Caribbean Island archaeological sites (Wing 2001). Open symbols represent the Cinnamon Bay site, St. John, U.S. Virgin Islands.

the reef faunal assemblage is 3.6; for the inshore/pelagic fauna it is 3.9.

LEVEL 4 (30-40 CMBS) FS 111

Archaeological context. Fauna from level 4 (FS 111) was excavated from 30 to 40 cmbs. While no radiometric (^{14}C) date has been analyzed for level 4 (Table 1), by inference its stratigraphic position, just before level 3 (570 ±70 B.P., A.D.1290-1450) (Beta 69973) and after level 6 (520±70 B.P., A.D. 1300-1485) (Beta 73413), suggests it formed between those times. Because the two radiometric dates overlap, level 4 fauna was deposited in a relatively short interval of time. The artifacts are consistent with the Santa Elena Ceramic Period.

Minimum numbers of individuals. Fifty-eight taxa and 256 MNI were identified from level 4 (Table 6). Commensal species are not part of the quantified sample. The faunal remains are well preserved, containing few signs of abrasion, pitting, or diagenesis. Fewer than 0.5% of the remains showed signs of being burned.

Gastropods (48.8%), fishes (34.8%), and bivalves (9.0%) were the most frequently identified animals (MNI) from level 4 (Table 6, Fig. 5). West Indian topsnail (31.9%) is most numerous. Four-tooth nerite (9.5%) also represented a frequently identified gastropod. Parrotfishes (10.4%) are the second most abundant taxon, while groupers (2.7%), snappers (6.2%), and grunts (4.2%) are important contributors to the level 4 classification of MNI. Bivalves are a minor component of the sample. Turkey wing (3.9%), tiger lucine, (1.9%), and coquina (*Donax denticulatus*, 1.2%) are among the more significant bivalve species. The land hermit crab (1.5%), and land crab (1.5%) were present in the sample.

Mammals (0.8%), birds (0.4%), reptiles (0.8%), and crabs (3.5%) are among the rarest animals occurring in the level 4 assemblage. Hutia (0.8%) is the only mammal present in the sample. A single snake and single turtle are the only two reptiles identified in level 4. Like the specimen found in level 2, the fragment of turtle carapace probably represents the pond turtle, but land tortoise cannot be ruled out.

Trophic level analysis. Table 7 and Fig. 6 present the trophic level analysis of the level 4 aquatic fauna. The mean trophic level for the reef and inshore/pelagic fauna is 3.9. Fish species common to the reef account for 79.0% of the biomass and the inshore/pelagic species represent 21.0% of the total fish biomass. Parrotfish, snappers, and grunts—all reef species—represent the largest biomass. The greatest portion of biomass from the inshore/pelagic species came from the tunas and jacks.

LEVEL 10 (90–100 CMBS) FS 117

Archaeological context. Level 10 (FS 117) fauna was excavated from 90 to 100 cmbs. A radiometric date of ca. 950 B.P. documents the earliest arrival of Monserrate ceramic-bearing people. Relative to the much denser levels 2 and 4, level 10 represents a very loose midden accumulation.

Minimum numbers of individuals. The fauna in level 10 consists of 29 taxa and 35 MNI (Table 8). Commensal species are not included in these counts. Preservation of the skeletal remains and the presence of burned elements are consistent with materials from the upper levels of the site.

Table 8 and Fig. 5 show that gastropods (24.0%), fishes (47.1%), and bivalves (14.7%) were the most frequently identified animals (MNI) from level 10. West Indian topsnail (11.4%) is the most numerous animal identified, while all other individual gastropods contribute 2.9% of the MNI (Table 8). Barracuda (*Sphyraena* spp., 5.7%), parrotfishes (5.7%), and tunas (5.7%) are the most abundant fish species. All other fish species contribute no more than 2.9% each to the MNI. Bivalves represent a minor component of the sample and no single species dominates the count of MNI. Relative to levels 2 and 4, in level 10 the land hermit crab (2.9%) and land crab (2.9%) reach their greatest percentages. Land crabs account for a total MNI of 5.9%.

Mammals (2.9%) and birds (2.9%) were less frequently identified in level 10 than in the upper levels of the deposit. Hutia (2.9%) was the only mammal represented in the sample. No reptiles were identified.

Trophic level analysis. The results of the trophic level analysis of the level 10 fauna is presented in Table 9 and Fig. 6. The mean trophic level for the reef assemblage is 3.5; for the inshore/pelagic fauna, it is 3.7. Just over one-half (51.0%) the fish biomass comes from reef fishes and 49% is contributed by inshore/pelagic species. Among the reef fishes, snappers, grunts, and triggerfish (Balistidae) are the most prevalent biomass contributors. The greatest portion of biomass from the inshore/pelagic taxa came from the jacks, barracudas, and tunas.

Table 6. Fauna identified from Unit 1, Level 4 (40 - 50 cmbs), FS 111, Cinnamon Bay, U.S. Virgin Islands, NPS ACC# 191, UF Accession # 510. Key: * = present in the sample but not quantified; + = weighed as Subulinidae (*a*) = intrusive into the sample—not included in the quantification of the remains.

Taxon	Count	%	MNI	%	Weight (g)	%
ANIMALIA	*	-	–	–	1510.60	36.40
Vertebrata	*	-	–	–	0.08	0.00
Mammalia	1	0.03	–	–	0.02	0.00
Mammalia (medium)	9	0.29	–	–	0.37	0.01
Rodentia	1	0.03	–	–	0.10	0.00
Isolobodon portoricensis	40	1.30	2	0.77	11.84	0.29
AVES	6	0.19	1	0.38	0.85	0.02
Serpentes	5	0.16	1	0.38	0.14	0.00
Testudines	2	0.06	1	0.38	0.40	0.01
Chondrichthyes	1	0.03	–	–	0.06	0.00
Rajiformes	3	0.10	1	0.38	0.06	0.00
Osteichthyes	1823	59.25	–	–	170.09	4.10
Elops saurus	1	0.03	1	0.38	0.00	0.00
Gymnothorax spp.	2	0.06	1	0.38	0.39	0.01
Clupeidae	31	1.01	1	0.38	0.08	0.00
Belonidae	8	0.26	3	1.15	0.51	0.01
Holocentrus spp.	6	0.19	–	–	0.20	0.00
Holocentrus adscensionis	1	0.03	1	0.38	0.06	0.00
Prionotus spp.	7	0.23	1	0.38	0.30	0.01
Epinephelus spp.	35	1.14	7	2.69	6.13	0.15
Carangidae	51	1.66	–	–	4.17	0.10
Caranx spp.	12	0.39	4	1.54	1.04	0.03
Caranx ruber	13	0.42	1	0.38	1.62	0.04
Lutjanus spp.	48	1.56	16	6.15	3.94	0.09
Haemulon spp.	31	1.01	11	4.23	2.01	0.05
Calamus spp.	6	0.19	2	0.77	0.78	0.02
Sphyraena spp.	23	0.75	2	0.77	0.48	0.01
Labridae	1	0.03	–	–	0.19	0.00
Halichoeres spp.	4	0.13	2	0.77	0.25	0.01
Scaridae	26	0.84	–	–	1.76	0.04
Scarus spp.	7	0.23	1	0.38	0.44	0.01
Sparisoma spp.	282	9.16	27	10.38	59.92	1.44
Acanthurus spp.	1	0.03	1	0.38	0.10	0.00
Scombridae	43	1.40	3	1.15	13.25	0.32
Balistes spp.	8	0.26	1	0.38	0.51	0.01
Ostraciidae	16	0.52	1	0.38	0.37	0.01
Diodontidae	2	0.06	1	0.38	0.36	0.01
Balanomorpha	10	0.32	–	–	1.04	0.03
Balanus spp.	1	0.03	–	–	0.38	0.01
Decapoda	7	0.23	–	–	0.00	0.00
Brachyura	11	0.36	–	–	3.09	0.07
Coenobita clypeatus	41	1.33	4	1.54	3.45	0.08
Gecarcinidae	44	1.43	4	1.54	11.67	0.28
Mithrax spp.	1	0.03	1	0.38	0.36	0.01
Mollusca	–	–	–	–	10.63	0.26
Chitonidae	34	1.10	3	1.15	11.39	0.27
Acanthopleura granulata	10	0.32	2	0.77	8.87	0.21
GASTROPODA	3	0.10	–	–	8.67	0.21
Diodora listeri	1	0.03	*	–	0.29	0.01
Acmaea antillarum	43	1.40	*	–	3.42	0.08
Turbinidae	2	0.06	1	0.38	0.15	0.00
Cittarium pica	99	3.22	83	31.92	1765.43	42.54
Nerita spp.	10	0.32	–	–	1.92	0.05

(cont.)

Table 6 (cont.)

Taxon	Count	%	MNI	%	Weight (g)	%
Nerita peloronta	2	0.06	2	0.77	0.68	0.02
Nerita versicolor	7	0.23	5	1.92	3.74	0.09
Neritina spp.	9	0.29	–	–	0.44	0.01
Neritina virginea	30	0.97	23	8.85	23.73	0.57
Cerithiidae	1	0.03	1	0.38	0.20	0.00
Strombus gigas	3	0.10	1	0.38	20.39	0.49
Crucibulum auricula	1	0.03	1	0.38	1.00	0.02
Polinices hepaticus	1	0.03	1	0.38	3.30	0.08
Muricidae	2	0.06	–	–	3.58	0.09
Cymatium muricinum	1	0.03	1	0.38	2.43	0.06
Plicopurpura patula	1	0.03	1	0.38	0.32	0.01
Thais deltoidea	1	0.03	1	0.38	6.68	0.16
Columbellidae	1	0.03	1	0.38	0.04	0.00
Alcadia spp.	*	–	–	–	2.13	0.05
Fasciolaria tulipa	1	0.03	1	0.38	95.41	2.30
Conus spp.	1	0.03	1	0.38	0.06	0.00
Pupoides modicus	*	–	–	–	0.07	0.00
Hinea lineatus	1	0.03	1	0.38	0.15	0.00
Subulinidae	*	–	–	–	2.19	0.05
Lamellaxis micra	*	–	–	–	+	–
Opeas pyrgula	*	–	–	–	+	–
Bulimulus guadalupensis	*	–	–	–	1.89	0.05
Polydontes lima	*	–	–	–	3.48	0.08
Xanthonycidae	*	–	–	–	0.25	0.01
Sagdidae	*	–	–	–	0.11	0.00
Bivalvia	5	0.16	–	–	4.54	0.11
Mytilidae	1	0.03	–	–	0.16	0.00
Brachidontes spp.	4	0.13	1	0.38	0.45	0.01
Brachidontes exustus	1	0.03	1	0.38	0.60	0.01
Pinctada radiata	29	0.94	2	0.77	4.61	0.11
Arca spp.	1	0.03	–	–	22.10	0.53
Arca zebra	14	0.45	10	3.85	121.17	2.92
Glycymeris pectinata	1	0.03	1	0.38	0.02	0.00
Codakia orbicularis	61	1.98	5	1.92	137.68	3.32
Chamidae	1	0.03	–	–	0.18	0.00
Chama spp.	1	0.03	1	0.38	31.45	0.76
Donax denticulatus	5	0.16	3	1.15	1.16	0.03
Asaphis deflorata	2	0.06	2	0.77	3.05	0.07
Veneridae	2	0.06	1	0.38	0.07	0.00
Periglypta listeri (a)	1	0.03	(*a*) 1	–	25.96	0.63
Echinoidea	12	0.39	–	–	0.26	0.01
TOTAL TAXA Taxa = 58	3077	100.00	260	100.00	4149.94	100.00

Summary by Class

Class	MNI	%
Mammals	2	0.78
Birds	1	0.39
Reptiles	2	0.78
Fishes	89	34.77
Crabs	9	3.52
Chitons	5	1.95
Gastropoda	125	48.83
Bivalves	23	8.98
TOTAL CLASSES	256	100.00

Table 7. Mean trophic level of aquatic vertebrates identified from Unit 1, Level 4 (30-40 cmbs), FS 111, Cinnamon Bay, U.S. Virgin Islands.

Taxon	Measurement X	Biomass (g)	MNI	Biomass X MNI	TL	TLijYij
REEF						
Holocentrus adscensionis	3.3	153.87	1	153.87	3.5	538.56
Epinephelus spp.	4.2	279.38	7	1955.69	3.8	7431.61
Lutjanus spp.	5.8	630.49	16	10087.82	4.6	46403.98
Haemulon spp.	7.0	1019.83	11	11218.12	3.5	39263.41
Halichoeres spp.	3.3	153.87	2	307.75	3.6	1107.89
Scarus spp.	3.3	153.87	1	153.87	3.4	523.17
Sparisoma spp.	3.1	131.43	27	3548.52	3.5	12419.83
Acanthurus spp.	3.3	153.87	1	153.87	3.5	538.56
Balistes spp.	3.8	211.01	1	211.01	3.0	633.02
Ostraciidae	3.3	153.87	1	153.87	3.2	492.40
Diodontidae	3.3	153.87	1	153.87	3.2	492.40
INSHORE, PELAGIC						
Rajiformes	3.4	165.15	1	165.15	3.5	578.01
Elops saurus	2.2	52.87	1	52.87	3.0	158.62
Gymnothorax spp.	3.3	153.87	1	153.87	3.5	538.56
Clupeidae	1.7	26.85	1	26.85	2.6	69.80
Belonidae	3.1	130.36	3	391.08	3.2	1251.46
Prionotus spp.	4.4	318.00	1	318.00	3.5	1113.01
Caranx spp.	5.6	579.36	4	2317.46	4.0	9269.83
Caranx ruber	8.5	1647.96	1	1647.96	4.1	6756.65
Calamus spp.	3.3	153.87	2	307.75	3.4	1046.34
Sphyraena spp.	2.1	45.79	2	91.57	4.5	412.08
Scombridae	5.9	675.58	3	2026.75	3.8	7701.66
TOTAL			88	35597.59		138740.85
Mean trophic level					3.9	

Reef biomass x MNI	$\overline{TL}$	TLijYij
28098.27	3.91	109844.83
78.93%		

Inshore, pelagic biomass x MNI	$\overline{TL}$	TLijYij
7499.32	3.85	28896.02
21.07%		

Size class analysis of West Indian topsnail (Cittarium pica). The measurements from the notch in the umbilicus to the terminus of the aperture and the aperture height present virtually the same pattern of size class for the Cinnamon Bay topsnails. The mean values and 95% confidence interval about the mean show that samples from level 1 through level 9 are statistically similar and could have been collected from the same population (Table 10 and Fig. 7).

Although not statistically significant ($P \leq 0.5$), three trends seem to emerge in the nine samples. From level 9 to level 7 there is an increase in the mean size of the topsnails. This event corresponds to a small but persistent increase in the percentage of topsnails in levels 10 through 7 (figs. 7-8). In level 6 through level 4, specimens are smaller on average than the specimens from the previous levels. This trend correlates with the most intensive period of topsnail harvest (Fig. 8). Even so, their average size increases from level 6 through level 3. In level 4 there is an inverse correlation between the percentage of topsnails and their size. It appears that the collection strategy was to obtain only the largest possible specimens. This seems to lead to another decrease in shell size in level 2, followed by a subsequent increase in level 1, this during a period that exhibits a relatively low percentage of topsnails.

DISCUSSION

The zooarchaeological record of Cinnamon Bay presents a pattern of subsistence activity similar to that observed in other Caribbean sites (Wing 1995, 2001a, 2001b), even though for over 500 years it functioned as a ceremonial site. In other words, there

Table 8. Fauna identified from Unit 1, Level 10 (90 - 100 cmbs), FS 117, Cinnamon Bay, U.S. Virgin Islands, NPS ACC# 191, UF Accession # 510. Key: * = present in the sample but not quantified; + = weighed as Subulinidae.

Taxon	Count	%	MNI	%	Weight (g)	%
Vertebrata	2	0.32	–	–	0.91	0.89
Isolobodon portoricensis	2	0.32	1	2.86	1.48	1.45
Aves	1	0.16	1	2.86	0.05	0.04
Rajiformes	1	0.16	1	2.86	0.04	0.04
Osteichthyes	405	64.29	–	–	5.24	5.11
Clupeidae	22	3.49	1	2.86	0.05	0.05
Epinephelus spp.	1	0.16	1	2.86	0.13	0.13
Carangidae	7	1.11	1	2.86	0.33	0.32
Lutjanus spp.	2	0.32	1	2.86	0.10	0.10
Haemulon spp.	8	1.27	1	2.86	0.32	0.31
Calamus spp.	1	0.16	1	2.86	0.23	0.22
Sphyraena spp.	19	3.02	2	5.71	0.54	0.53
Sparisoma spp.	13	2.06	2	5.71	2.08	2.03
Scombridae	3	0.48	2	5.71	0.10	0.09
Balistidae	1	0.16	1	2.86	0.08	0.08
Ostraciidae	2	0.32	1	2.86	0.05	0.04
Diodontidae	2	0.32	1	2.86	0.02	0.02
Decapoda	56	8.89	–	–	3.15	3.07
Coenobita clypeatus	3	0.48	1	2.86	0.18	0.18
Gecarcinidae	22	3.49	1	2.86	3.54	3.46
Mollusca	7	1.11	–	–	4.65	4.54
Chitonidae	5	0.79	1	2.86	1.74	1.70
Pleurotomariacea	2	0.32	–	–	0.06	0.06
Diodora spp.	1	0.16	*	–	0.09	0.09
Acmaea antillarum	2	0.32	*	–	0.50	0.49
Cittarium pica	17	2.70	4	11.43	47.94	46.77
Nerita peloronta	4	0.63	1	2.86	0.87	0.85
Cerithiidae	1	0.16	1	2.86	0.12	0.12
Alcadia spp.	*	–	–	–	0.18	0.18
Columbella mercatoria	1	0.16	1	2.86	0.09	0.09
Olividae	1	0.16	1	2.86	0.02	0.02
Pupoides modicus	*	–	–	–	0.02	0.02
Subulinidae	*	–	–	–	2.67	2.60
Lamellaxis micra	*	–	–	–	+	–
Opeas pyrgula	*	–	–	–	+	–
Bulimulus guadalupensis	*	–	–	–	2.36	2.30
Polydontes lima	*	–	–	–	1.64	1.60
Xanthonycidae	*	–	–	–	0.58	0.57
Sagdidae	*	–	–	–	0.23	0.22
Gastropoda (terrestrial)	*	–	–	–	0.19	0.19
Bivalvia	2	0.32	–	–	0.15	0.15
Brachidontes exustus	1	0.16	1	2.86	0.05	0.05
Arca zebra	1	0.16	1	2.86	0.06	0.06
Codakia orbicularis	5	0.79	1	2.86	16.87	16.46
Laevicardium spp.	1	0.16	1	2.86	0.01	0.01
Veneridae	5	0.79	1	2.86	0.13	0.13
Echinoidea	1	0.16	1	2.86	0.03	0.02
Anthrozoa	*	–	–	–	2.64	2.58
TOTAL	630	100.00	35	100.00	102.50	100.00
Taxa = 29						

Summary by Class

Class	MNI	%	Class	MNI	%
Mammals	1	2.9	Crabs	2	5.9
Birds	1	2.9	Chitons	1	2.9
Reptiles	0	0.0	Gastropoda	8	23.5
Fishes	16	47.1	Bivalves	5	14.7
TOTAL CLASSES				34	100.00

Table 9. Mean trophic level of aquatic vertebrates identified from Unit 1, Level 10 (10-20 cmbs), FS 117, Cinnamon Bay, U.S. Virgin Islands.

Taxon	Measurement	Biomass	MNI	Biomass x MNI	TL	TLijYij
REEF						
Epinephelus spp.	2.79	99.86	1	99.86	3.8	379.46
Lutjanus spp.	3.36	159.82	1	159.82	4.6	735.18
Haemulon spp.	2.82	102.60	1	102.60	3.5	359.09
Sparisoma spp.	2.79	99.86	2	199.71	3.5	699.00
Balistidae	3.75	211.01	1	211.01	3.0	633.02
Ostraciidae	2.79	99.86	1	99.86	3.2	319.54
Diodontidae	2.79	99.86	1	99.86	3.2	319.54
INSHORE, PELAGIC						
Rajiformes	3.8	218.20	1	218.20	3.5	763.70
Clupeidae	1.66	26.85	1	26.85	2.6	69.80
Carangidae	3.66	198.43	1	198.43	3.3	654.82
Calamus spp.	2.79	99.86	1	99.86	3.4	339.51
Sphyraena spp.	2.47	73.37	2	146.74	4.5	660.34
Scombridae	3.02	122.02	2	244.03	3.8	927.32
TOTAL			16	1906.82		6860.32
Mean trophic level					3.60	

Reef biomass x MNI	$\overline{TL}$	TLijYij
972.71	3.54	3444.84
51.01%		

Inshore, pelagic biomass x MNI	$\overline{TL}$	TLijYij
934.11	3.66	3415.49
48.99%		

are patterns of subsistence behavior that exist in the zooarchaeological record of ritually deposited fauna and in a common midden. For example, terrestrial animals were never an important part of subsistence because aquatic resources were the focal point of the zoological part of the diet at all the sites (Fig. 5) (Wing 1995, 2001a, 2001b). Collection of mollusks was probably an activity that was done by most segments of the population and required little more than a collecting container. Watercraft would have been necessary to effectively set nets and traps to catch fishes in the inshore, pelagic, and reef zones. Changes in island fauna similar to those reported by Wing (2001a) occur in the Cinnamon Bay zooarchaeological record. The relative abundance of hutia and land crabs declines over time (Table 11, Fig. 5) and there is a decrease in the relative abundance of fishes relative to the presence of mollusks (Table 11, Fig. 5).

Table 10. Measured West Indian topsnail (*Cittarium pica*) from Unit 1, levels 1 to 10, Cinnamon Bay, St. John, U.S. Virgin Islands. A comparison of the mean via the 95% confidence interval.

	Mean			Mean		
Level	n	MES 1*	95%CI	n	MES 2**	95%CI
L1	11	13.90	3.17	6	33.20	12.86
L2	21	12.38	2.21	6	29.71	14.20
L3	22	17.53	3.36	20	36.64	7.11
L4	70	15.09	1.06	18	29.93	3.87
L5	42	13.96	1.50	20	31.31	4.27
L6	85	13.84	0.96	30	28.96	3.32
L7	16	14.95	3.05	7	38.88	14.70
L8	12	13.33	2.17	8	28.89	6.14
L9	6	11.60	1.58	6	24.97	3.96
L10	3	18.21	-	1	9.30	-

*MES 1 = Greatest distance from the notch in the umbilicus to the terminus of the aperture (mm).
**MES 2 = Greatest aperture height (mm).

Faunal Changes Between the Monserrate (ca. A.D. 1000) and Santa Elena (ca. A.D. 1393) Periods.

In contrast to Caribbean sites examined by Wing (2001a), the Cinnamon Bay data show a statistically significant ($P \leq 0.05$) initial increase in the body size of all fishes between the Monserrate (level 10) and Santa Elena (level 4) periods (Fig. 9). During this time the calculated biomass of reef species increases (Fig. 10). The mean trophic level of the reef component of the sample (Fig. 6) also increases during the 300-year interval between the Monserrate (level 10) and the Santa Elena (level 4) periods. (Fig. 6). In the time subsequent to 1000 years B.P., the mean trophic level of the Monserrate (level 10) faunal

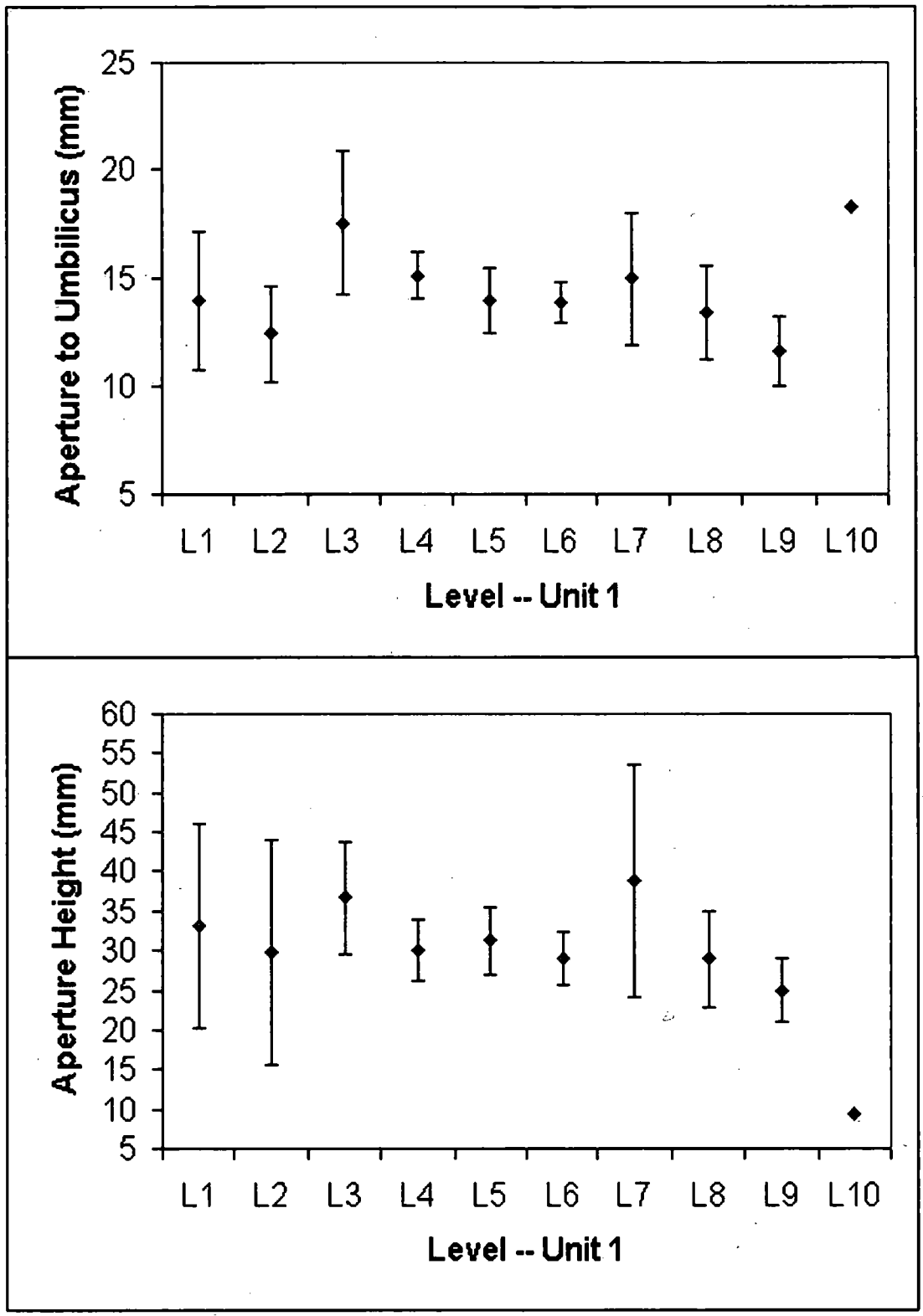


Figure 7. Measured West Indian topsnail (*Cittarium pica*) from Unit 1, levels 1 to 10, Cinnamon Bay, U.S. Virgin Islands. A comparison of the mean of the measured distance from the aperture to the umbilicus (mm) and the aperture height (mm). The error bars represent the 95% confidence interval calculated around the mean.

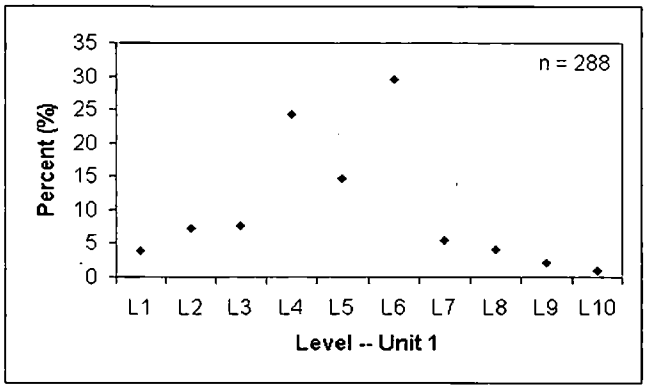


Figure 8. Percentage of West Indian topsnail (*Cittarium pica*) from Unit 1, levels 1 to 10, Cinnamon Bay, St. John, U.S. Virgin Islands.

assemblage is similar to other Late Period Caribbean sites (Wing 2001a) (Fig. 6). A mean trophic level of 3.9 for the level 4 reef component of the fauna exceeds all other values reported for the region (Wing 2001a). Taxa from inshore/pelagic habitats also show an increase in the mean trophic level (Fig. 6). The pattern outlined above follows a forty-fold increase in midden volume between the Monserrate Period (103 g) (Table 4) and the Santa Elena Periods (4,150 g) (Table 6). The midden volume charts the evolutionary direction of the site's function as a ceremonial center, implying that it required great and increasing quantities of food to fuel this enterprise. However, there appear to have been consequences associated with intensive use of reef resources.

Faunal Changes Between the Santa Elena (ca. a.d. 1393) and Chican (ca. a.d. 1490) Periods

In the approximately 97 years separating the Santa Elena (level 4) and Chican periods (level 2) at Cinnamon Bay there are distinct changes observed in the faunal assemblages, similar to changes found elsewhere in the Caribbean by Wing (2001a). Biomass of reef taxa declines, while biomass of inshore/pelagic species eventually exceeds that of the reef species (Fig. 9). With the exception of the Tutu site on St. Thomas, biomass from reef vertebrates always exceeds the inshore/pelagic zones in the sites reported by Wing (2001a). The average size classes of all fishes from the two levels (Santa Elena and Chican) are not significantly different ($P \leq 0.05$), but they trend toward slightly smaller individuals in the more recent Chican period (Fig. 9). The relative number of groupers and snappers declines, while the number of grunts and porgies increases (Table 11). These changes are reflected in the mean trophic levels of the reef component of the assemblages, which declines between the Santa Elena (level 4) and Chican (level 2) periods (Fig. 6). There is little change in the mean trophic levels of the inshore/pelagic components between the Santa Elena and Chican fauna (Fig. 6). Notably, the changes seen between the Santa Elena and Chican periods accompany a four-fold decrease in midden volume from 4,150 g (Table 6) to 1,128 g (Table 8).

At Cinnamon Bay, there was not the continuous decline in the trophic level of the reef fauna that Wing (2001a) observed between the early and late period samples in her study group. Sampling protocol and archaeological context probably account for this important difference. First, the Cinnamon Bay study had the advantage of analyzing three samples representing a time series of the faunal record. This finer scale of analysis helps to illustrate an increasing demand for predatory reef fishes in the first 300 years of the site's history and that demand's inherent consequences. Second, Cinnamon Bay represents a ceremonial place where offerings of food were made to the elites, while Wing's analysis (2001a) examined the fauna from the general middens, representing common subsistence behavior. The increase in the trophic level of the reef component highlights the increasing importance of Cinnamon Bay as a chiefs' caney between the Monserrate and Santa Elena periods. But the data also show that the elites were not immune to the overexploitation of the environment, even though they probably had greater access to a diverse array of resources. Relative to their predecessors, in the last years of site occupation, the Chican elites consumed animals lower in the food web because that was what was available in the environment. The alternative for the Chicans was to consume reef fishes lower in the food chain while collecting shellfish from the inshore habitats. Pelagic species, higher in the food chain, were also more intensively caught. Fishing for pelagic species in the offshore zones presents greater personal danger than inshore or reef subsistence activities.

The Cinnamon Bay faunal assemblages show that changes also took place on land. With human colonization came the introduction of such non-indigenous animals as an insectivore (*Nesophontes*

Table 11. A summary of selected species and the percent of minimum numbers of individuals identified from Unit 1, Cinnamon Bay, St. John, U.S. Virgin Islands.

Unit 1, faunal sample		FS109 Level 2	FS111 Level 4	FS117 Level 10
Taxon	Common name	% MNI	% MNI	% MNI
Isolobodon portoricensis	hutia	0.7	0.8	2.9
Aves	birds	0.7	0.4	2.9
Reptilia	reptiles	2.0	0.8	-
Rajiformes	sates and rays	-	0.4	2.9
Clupeidae	shads/herrings	0.7	0.4	2.9
Belonidae	needlefishes	0.7	1.2	-
Holocentrus spp.	squirrelfishes	1.4	0.4	-
Epinephelus spp.	groupers	2.0	2.7	2.9
Carangidae	jacks	-	-	2.9
Caranx spp.	jacks	2.0	1.5	-
Caranx ruber	bar jack	-	0.4	-
Lutjanus spp.	snappers	4.1	6.2	2.9
Haemulon spp.	grunt	6.1	4.2	2.9
Calamus spp.	porgy	1.4	0.8	2.9
Sphyraena spp.	barracuda	0.7	0.8	5.7
Scarus spp.	parrotfish	0.7	0.4	-
Sparisoma spp.	parrotfish	10.2	10.4	5.7
Scombridae	tuna	1.4	1.2	5.7
Balistidae	triggerfishes	0.7	0.4	2.9
Ostraciidae	cowfishes	0.7	0.4	2.9
Diodontidae	porcupinefishes	0.7	0.4	2.9
Crustaceans				
Coenobita clypeatus	land hermit crab	1.4	1.5	2.9
Gecarcinidae	land crabs	0.7	1.5	2.9
Mollusks				
Chitons				
Chitonidae	chiton	2.7	1.9	2.9
Gastropods				
Cittarium pica	West Indian topsnail	19.7	31.9	11.4
Nerita peloronta	bleeding tooth	1.4	0.8	2.9
Nerita versicolor	four-tooth nerite	1.4	1.9	-
Neritina virginea	virgin nerite	9.5	8.6	-
Gastropods and Bivalves				
Gastropoda		41.4	48.8	23.5
Bivalvia		15.9	9.0	14.7

edithae), hutia, guinea pig (*Cavia porcellus*), and pond turtle (*Trachemys* spp.) (Table 2). As with modern-day travelers, there were some unintentional introductions of animals, represented by some of the commensal species present in the deposit. During the course of history, terrestrial awlsnails (Subulinidae) have been introduced into Florida and through the Caribbean (Auffenberg and Stange 1988). The timing or agents of these introductions are not well understood. Within the Santa Elena (level 4) and Chican (level 10) periods, the tiny awlsnail (*Lamellaxis micra*) and sharp awlsnail (*Opeas pyrgula*) are abundant. Tiny awlsnail is originally from South America, Mexico, and the West Indies, while the distribution of the sharp awlsnail is unknown. It appears that both species were introduced to Cinnamon Bay some time before 950 B.P. In level 2, the miniature awlsnail (*Subulina octona*) suddenly

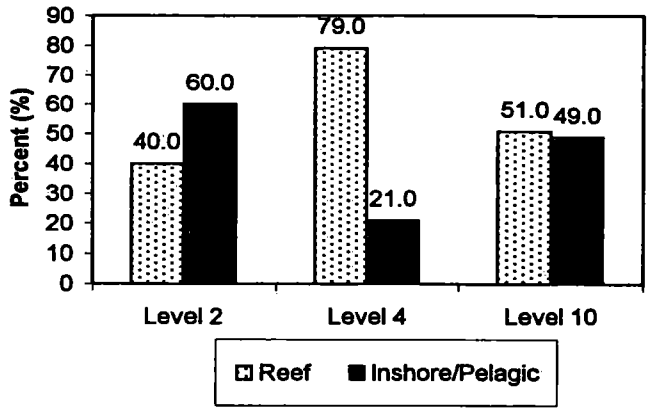
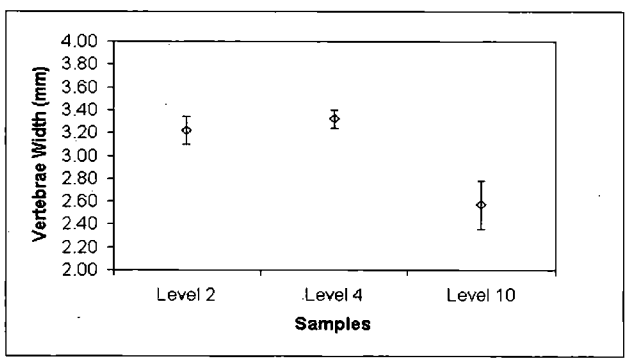


Figure 9. Lateral width of fish vertebrae (mm) from Unit 1, Cinnamon Bay, St. John, U.S. Virgin Islands. The error bars represent the 95% confidence interval around the mean.

appears around 570 ±70 B.P., during the Chican Period. The origin of the miniature awlsnail is probably South America. Its introduction into most tropical and subtropical areas of the world has been the result of horticultural and agricultural imports (Auffenberg and Stange 1988).



Descriptive Statistics

	Level 2 FS 109	Level 4 FS 111	Level 10 FS 117
Mean	3.22	3.32	2.57
Std Dev	1.54	1.60	1.17
Range	1.04–12.94	1.04–16.32	1.1–7.36
Sample n	654	1528	121
95% CI	0.12	0.08	0.21

Figure 10. A comparison of the percentage of biomass contributed by reef fishes vs. inshore/pelagic fishes, Cinnamon Bay, St. John, U.S. Virgin Islands.

With exposure to humans, a suite of native and introduced animals has become threatened, extirpated, or extinct from the island of St. John. This suite includes the pre-Columbian human populations of the Caribbean, as well as some of the animals they hunted and tended, such as *Nesophontes*, hutia, guinea pig, monk seal (*Monachus tropicalis*), manatee (*Trichechus manatus*), Puerto Rican screech owl, iguana lizard, and pond turtle. The long-term interactions of humans with their environment have exacted changes in the aquatic and terrestrial realms of St. John, changes evident in the diverse faunal assemblages examined in this paper.

SUMMARY

The faunal record of Cinnamon Bay presents a rare and important opportunity to examine the zooarchaeological record of pre-Columbian people on St. John. The purpose of this study was to address three basic questions pertinent to the faunal remains and to compare the results to other pre-Columbian Caribbean Island faunas.

1. What animal species were being consumed?

The faunal data show that fish and shellfish were the most commonly consumed species during the 500-year occupation. Groupers, jacks, snappers, grunts, and parrotfishes were the most frequently identified vertebrate species. Among invertebrates, West Indian topsnails were the most common constituents (MNI) of assemblages, although a diverse number of bivalves and gastropods were also consumed. Land hermit crabs and land crabs were a minor component of the diet. Terrestrial species were uncommon, but *Nesophontes*, hutia, guinea pig, and pond turtle were transported from other island localities. Hutia and guinea pig were probably kept by the Taíno, perhaps representing incipient domestication.

2. How were these animals obtained?

The Taíno were maritime people whose adaptation to the sea represents a very long tradition with roots on the South American coast. Based on the most common species and their habitats, boats, fish traps, nets, hook and line, spears, and gathering were the common methods of subsistence. The evidence suggests that the technology changed little over the 500 years of pre-Columbian human settlement at Cinnamon Bay and was similar to many other Caribbean Island sites.

3. Is there evidence of human impact on the local environment?

Early in the human history of Cinnamon Bay there was an exponential increase in the acquisition of aquatic resources. Vertebrates from inshore and pelagic habitats were secondary to the reef community. The size-class of fishes under exploitation increased, accompanied by an increase in the relative abundance of snappers, grunts, and parrotfishes. Subsequently the mean trophic level of animals taken from the reef increases, along with an increase in the mean trophic level of the inshore/pelagic zone. This represents a growth period during which increasing amounts of food were needed to sustain Cinnamon Bay as a ceremonial center.

The pressure of this initial growth period is recorded in the latest deposits of fauna analyzed in this study. Over time the abundance of hutia and land crab remains decreases. A decline in the relative abundance of fishes is accompanied by an increase in the use of mollusks. Relative abundance of groupers and snappers diminishes, while grunts and porgies increase. Animals from the reef are no longer the dominant component of the assemblage, rather those species from inshore/pelagic habitats predominate. The trophic level declines during the later part of the site occupation.

The faunal data from this later period in the history of Cinnamon Bay most resembles the changes that took place with the passage of time at other Caribbean sites. While all the Caribbean sites represent different time periods and places, the changes in their faunal assemblages are similar.

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Curation note. The National Park Service, St. John, Virgin Islands, will curate the Cinnamon Bay faunal remains along with other items of material culture.

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