7. MICRO-INVERTEBRATE EVIDENCE ON THE PALEOECOLOGY OF YSIDORA LAGOON, SAN DIEGO COUNTY, SOUTHERN CALIFORNIA

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Paleoenvironmental reconstructions are powerful instruments to understand local and regional changes of the environment through time. Coastal environmental change is of major significance because not only the climate and geologic agents like tectonism and isostatic or eustatic changes of sea level have modified the coastline through time but man may also induce it. Of coastal environments estuaries are highly significant because they provide a unique source of information about the periodicity of continental and marine cycles in the short- (e.g., seasonality, human activity) and the long-term (e.g., isostatic or eustatic sea level change).

It is now clear that estuaries face accelerating human stress. Over the past century human activity along the coast of southern California has almost deprived this area of the many estuaries that characterized the region before the Anglo occupation. Of 28 estuaries reported at the start of the century, three disappeared, 10 were drastically modified and most of the remaining 15 were at risk of partial or total destruction on behalf of urbanization by 1970 (Frey et al. 1970). More than 60 percent of all estuaries in the State of California have been destroyed. However, assessing the magnitude of human impact on estuarine environments is difficult because frequently the trail of clues to environmental change disappears very quickly. Few monitoring records extend sufficiently far back in time to cover the period of change. Micro-invertebrates provide a potential tool to approach human-induced environmental change.

Understanding the nature and magnitude of environmental change requires knowing how the environment has changed in the past, particularly before human influence. Environmental change trends are registered in the geologic record. However, the recognition of estuaries in the geologic record is not easy mainly because little studies have been conducted to understand them as sedimentary environments (Maynard and Biggs 1985). As a result there are few unifying models of deposition, few clues for matching modern and ancient deposits. Schubel and Hirschberg (1978) state: “estuarine deposits rarely can now be delimited unequivocally from other shallow marine deposits in the geologic record because of their limited areal extent, their ephemeral character and their lack of distinctive features.” However, this statement is arguable because the paleontologic record of estuaries may be very distinctive; some organisms are limited to this brackish-water environment (e.g., characea [algae]; oysters [mollusks]; diatoms, and ostracodes [microcrustaceans]). Besides, it is common to find mixed marine and freshwater fossils that are unlikely to co-occur under other conditions.

The main objectives of this study were to: (1) compile abundance and diversity data for ostracodes, molluscs, and foraminifers; and (2) use these data to reconstruct Holocene paleoenvironmental conditions in the Ysidora Lagoon. The paleoecological analyses presented in this study were conducted in support of the ASM Affiliates archaeological and historical project, focused on reconstructing the effect of environmental changes on human settlement and land use.

The project area is located at 33° 30’ N, 117° 15’ W, south of Las Flores Creek, north of Camp Pendleton, and east of Vandergift Boulevard, as part of the Santa Margarita River catchment (see Figure 3). The climate of the southern California coast is classified as Mediterranean, with a temperate wet winter and a moderate dry summer. The dominant fall-winter precipitation occurs between October and March and summer rain is almost nonexistent. The high-pressure system developed west of the coast controls the climate.

MATERIALS AND METHODS

Twelve samples from YSD-1 from the Santa Margarita River basin, San Diego County, were analyzed for microfossil contents. Routine micropaleontological sample processing was conducted to extract microfossils from the sediments. A freeze-and-thaw technique was used according to Forester (1988), modified by Palacios-Fest (1994). Approximately 100 g of sediments were washed through a set of three sieves with mesh openings of 1 mm, 106 μm and 63 μm to separate the three sand fractions (coarse, medium, and fine) (Table 11). This process contributes to the recovery of microfossils more efficiently.

Routine micropaleontological techniques were used for extracting microfossils (Forester 1988; Palacios-Fest 1994). Micropaleontology samples were collected at discrete intervals based on core log description. The abundance of ostracodes and foraminifers was recognized from extremely rare to extremely abundant[1].

Residuals were examined under a low power stereoscopic microscope. Routine micropaleontological analysis was performed to determine fossil content and faunal composition. Ostracode paleoecological assemblages were defined and grouped according to species abundance following Benson (1959), McKenzie and Swain (1967), and Delorme (1969, 1989).

Foraminiferal paleoenvironments were determined based on models of Ingle (1980) and modifications by Ingle and Finger (1990). Interpretations of microenvironments were aided by a number of previous studies by Bandy (1953, 1963), Bradshaw (1957, 1980), Lankford and Phleger (1973), Scott (1973), and Scott et al. (1976).

Molluscs were identified and compared with studies of modern biological composition (Ramírez 1981; Soule and Oguri 1990; Soule et al. 1991; Carter 1991). A variety of factors influence the distribution of invertebrate fauna. Occurrence of terrestrial, fresh- and brackish-water, and marine molluscs associated with the former environmental factors were used to reconstruct the paleoenvironmental history of Ysidora Lagoon.

1 *Abundance explanation: Extremely abundant (>(1001), very abundant (>501<1000), abundant (>101<500), moderately abundant (>51<100), common (>21<50), rare (>6<20), and extremely rare (<5).*

Table 11. Sample Volume, Total and by Size Fraction, Relative Abundance, Lithology and Sediment Color for Core YSD-1

Sample ID	Stratigraphic Interval (cm)	Bulk Wt. (g)	Residual Wt. (g)	> 1 mm (g)	> 106 mm (g)	> 63 mm (g)	< 63 mm (g)	> 1 mm (%)	> 106 mm (%)	> 63 mm (%)	< 63 mm (%)	Lithology	Color	Color Code
YSD-1-83	83-87	122.58	66.73	0.90	52.21	13.62	55.85	0.73	42.59	11.11	45.56	Silty Sand	Pale Yellowish Brown	10 YR 6/2
YSD-1-338	338-342	102.15	95.34	0.00	86.26	9.08	6.81	0.00	84.44	8.89	6.67	Fine Sand	Pale Yellowish Brown	10 YR 6/2
YSD-1-594	594-597	127.12	115.77	0.00	113.50	2.27	11.35	0.00	89.29	1.79	8.93	Fine Sand	Yellowish Gray	5 Y 8/1
YSD-1-721	721-724	106.69	34.15	0.10	20.43	13.62	72.54	0.09	19.15	12.77	67.99	Clayey Sandy Silt	Dark Yellowish Brown	10 YR 4/2
YSD-1-850	850-854	100.00	49.94	0.00	22.70	27.24	50.06	0.00	22.70	27.24	50.06	Clayey Sandy Silt	Dark Yellowish Brown	10 YR 4/2
YSD-1-1072	1072-1075	108.96	75.01	0.10	70.37	4.54	33.95	0.09	64.58	4.17	31.16	Silty Sand	Pale Yellowish Brown	10 YR 6/2
YSD-1-1226	1226-1229	106.69	61.49	0.20	59.02	2.27	45.20	0.19	55.32	2.13	42.37	Clayey Silty Sand	Pale Yellowish Brown	10 YR 6/2
YSD-1-1721	1721-1723	115.77	15.99	0.10	4.54	11.35	99.78	0.09	3.92	9.80	86.19	Clay	Light Olive Gray	5 Y 5/2
YSD-1-1937	1937-1940	102.15	46.10	0.70	18.16	27.24	56.05	0.69	17.78	26.67	54.87	Silty Clay	Light Olive Gray	5 Y 5/2
YSD-1-2226	2226-2229	102.15	43.93	0.80	22.70	20.43	58.22	0.78	22.22	20.00	56.99	Silty Clay	Light Olive Gray	5 Y 5/2
YSD-1-2611	2611-2614	100.00	93.67	0.60	90.80	2.27	6.33	0.60	90.80	2.27	6.33	Sand	Pale Yellowish Green	10 GY 7/2
YSD-1-3032	3032-3036	97.61	35.05	1.00	24.97	9.08	62.56	1.02	25.58	9.30	64.09	Silty Clay	Light Olive Gray	5 Y 6/1

Taphonomic features were used to distinguish allochthonous (introduced) from autochthonous (native) populations. Fragmentation, abrasion, encrustation, and coating were recorded in the ostracode and foraminifera analysis. In addition, the adult/juvenile (A/J) and carapace/valve (C/V) ratios of ostracodes were recorded to identify assemblages. Pre-Quaternary foraminifera reworked from adjacent sedimentary rock formations were excluded from consideration in this study.

Ostracodes were used to reconstruct the late Quaternary history of the Santa Margarita Lagoon, based on a qualitative estimate of environmental change. Each assemblage was assigned a relative value ranging from -2 (freshwater) to +2 (marine), based on the weighed average of each assemblage as determined by this equation:

SI = *-2(mean percent from Freshwater Assemblage [1]) - (mean percent from Brackish-water Assemblage [2]) + (mean percent from Transitional Assemblage [3]) + 2(mean percent from Marine Assemblage [4])*

RESULTS

Grain-size, lithology and color of residual sediments are shown in Table 11 and Figure 21. Lithologically, the samples range from pale yellowish brown (10 YR 6/2) to dark yellowish brown (10 YR 4/2) to light olive gray (5 Y 5/2) sand to silty clay and clay. Mainly biotite, quartz, charcoal, and shell fragments accumulate in the area. Other minerals occur occasionally (Table 12).

Four samples were fossiliferous. Table 13 summarizes the fossil contents of the samples, as well as the main taphonomic parameters required to determine the origin of the specimens. Ostracodes are common to abundant. Eleven species of ostracodes occur in Ysidora Lagoon (Table 14); six are nonmarine (*Candona patzcuaro, Cyprideis beaconensis*, *Limnocythere staplini*, *Cypridopsis vidua*, *Cyprinotus salinus*, and *Ilyocypris bradyi*), and five are marine (*Puriana pacifica, Megacytherura johnsoni, Loxoconcha tamarindoidea, Aurila ? sp.,* and *Xestoleberis banda*). Of the six nonmarine species, four are eurytopic (tolerant to a wide range salinity), *I. bradyi* is stenotopic (restricted salinity tolerance: 100-4000 mg L^{-1} total dissolved solids, TDS; Delorme 1989), indicating relatively freshwater conditions, whereas *C. patzcuaro* is moderately stenotopic (200-5000 mg L^{-1}; Delorme 1989), indicating higher tolerance to saline conditions.

Foraminifera are rare; three benthic species were recovered: *Ammonia beccarii*, *Elphidium incertum*, and *Nonion* sp. No planktonic species were observed (Table 15). Molluscs are extremely rare to rare; three species were present: *Cerithidea californica*, and two unknown gastropods (Table 16).

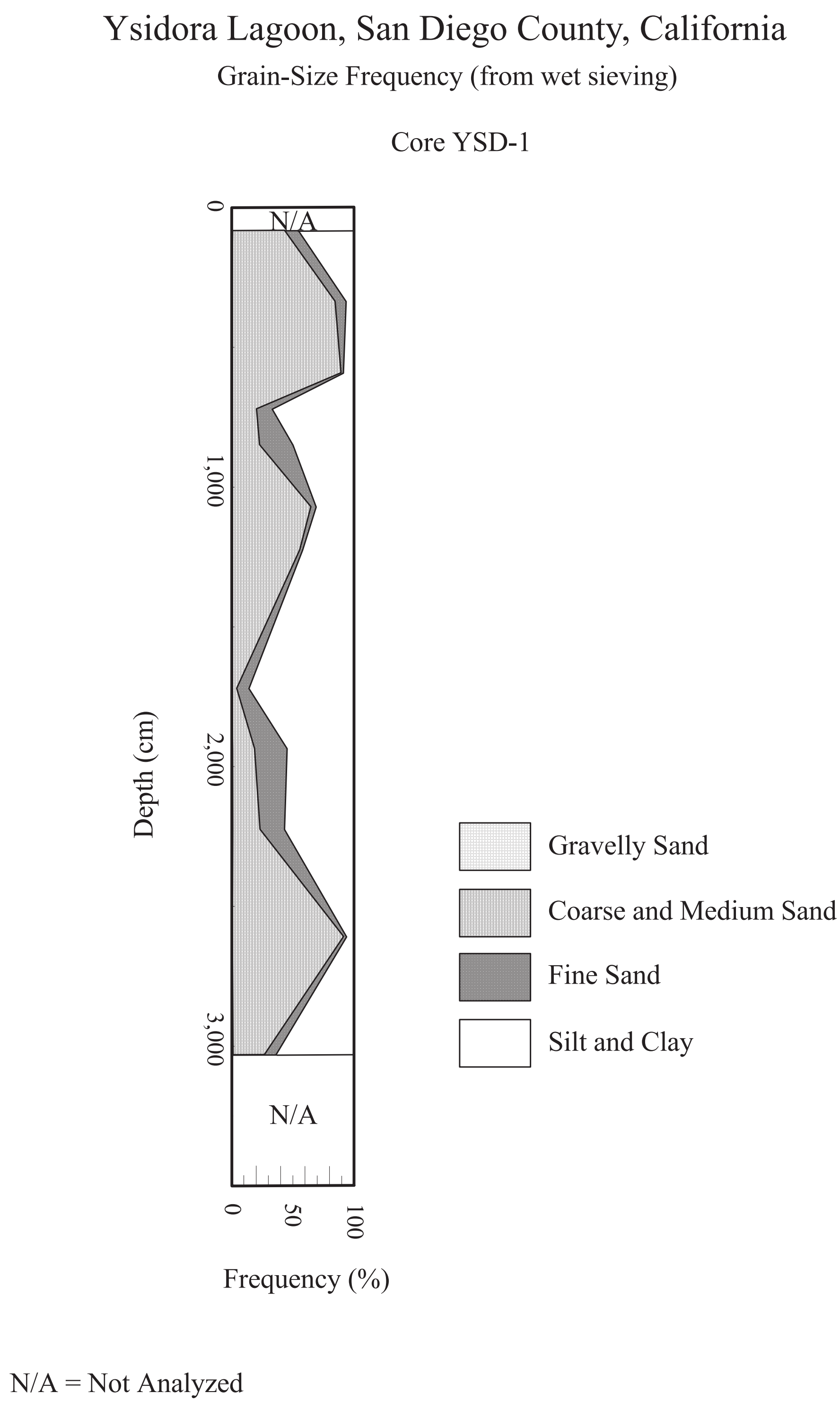

Figure 21. Grain size diagrams derived from wet sieving for Core YSD-1. 1 mm, 106 µm and 63 µm sieves were used to separate microfossils and to obtain the grain sizes plotted here.

Table 12. Main Minerals Present at Ysidora Lagoon, Observed from Core YSD-1

Sample ID	Stratigraphic Interval (cm)	Bulk Wt. (g)	Residual Wt. (g)	Quartz	Biotite	Tufa	Clay Clumps	Rock Fragments	Charcoal	Calcareous Nodules	Shell Fragments
YSD-1-83	83-87	122.58	66.73	X	X	X		X	X	X	X
YSD-1-338	338-342	102.15	95.34	X	X			X	X		
YSD-1-594	594-597	127.12	115.77	X	X			X			X
YSD-1-721	721-724	106.69	34.15	X	X				X	X	
YSD-1-850	850-854	100.00	49.94		X		X		X	X	
YSD-1-1072	1072-1075	108.96	75.01		X		X		X	X	X
YSD-1-1226	1226-1229	106.69	61.49		X		X		X		X
YSD-1-1721	1721-1723	115.77	15.99		X		X				
YSD-1-1937	1937-1940	102.15	46.10		X		X		X		X
YSD-1-2226	2226-2229	102.15	43.93		X		X		X		X
YSD-1-2611	2611-2614	100.00	93.67	X	X				X		
YSD-1-3032	3032-3036	97.61	35.05	X			X		X		

Table 13. Fossil Composition and Taphonomic Parameters Observed in Fossils from Core YSD-1 (taphonomic parameters are used to recognize the origin of microinvertebrates [allochthonous vs. autochthonous population])

Sample ID	Stratigraphic Interval (cm)	Bulk Wt. (g)	Residual Wt. (g)	Ostracodes	Foraminifera	Molluscs	Fragmentation (%)	Abrasion (%)	Encrustation (%)	Coating (%)	Redox Index	Color
YSD-1-83	83-87	122.58	66.73			2	20	0	0	0	0	White
YSD-1-338	338-342	102.15	95.34									
YSD-1-594	594-597	127.12	115.77									
YSD-1-721	721-724	106.69	34.15	108	10	8	5	5	0	5	0	Clear
YSD-1-850	850-854	100.00	49.94									
YSD-1-1072	1072-1075	108.96	75.01	34		2	5	5	0	0	0	Clear
YSD-1-1226	1226-1229	106.69	61.49	140	6	2	10	5	0	0	0	Clear
YSD-1-1721	1721-1723	115.77	15.99									
YSD-1-1937	1937-1940	102.15	46.10									
YSD-1-2226	2226-2229	102.15	43.93									
YSD-1-2611	2611-2614	100.00	93.67									

Table 14. Ostracode Total and Relative Abundance (including degree of disarticulation of valves and ontogenetic records)

Sample ID	Stratigraphic Interval (cm)	Bulk Wt. (g)	Residual Wt. (g)	Ostracodes	Ostracodes/g	*Cypridopsis vidua* #	%	A/J	C/V	*Cyprideis beaconensis* #	%	A/J	C/V	*Ilyocypris bradyi* #	%	A/J	C/V	*Cyprinotus salinus* #	%	A/J	C/V
YSD-1-83	83-87	122.58	66.73																		
YSD-1-338	338-342	102.15	95.34																		
YSD-1-594	594-597	127.12	115.77																		
YSD-1-721	721-724	106.69	34.15	108	1.01					64	59	0.31	0	2	2	1	0	2	2	0	0
YSD-1-850	850-854	100.00	49.94																		
YSD-1-1072	1072-1075	108.96	75.01	34	0.31					24	71	0.67	0								
YSD-1-1226	1226-1229	106.69	61.49	140	1.31	12	8.57	0.67	0	110	79	0.47	0.11								
YSD-1-1721	1721-1723	115.77	15.99																		
YSD-1-1937	1937-1940	102.15	46.10																		
YSD-1-2226	2226-2229	102.15	43.93																		
YSD-1-2611	2611-2614	100.00	93.67																		
YSD-1-3032	3032-3036	97.61	35.05																		

Sample ID	Stratigraphic Interval (cm)	Bulk Wt. (g)	Residual Wt. (g)	Ostracodes	Ostracodes/g	*Candona patzcuaro* #	%	A/J	C/V	*Limnocythere staplini* #	%	A/J	C/V	*Puriana pacifica* #	%	A/J	C/V	*Megacytherura johnsoni* #	%	A/J	C/V
YSD-1-83	83-87	122.58	66.73																		
YSD-1-338	338-342	102.15	95.34																		
YSD-1-594	594-597	127.12	115.77																		
YSD-1-721	721-724	106.69	34.15	108.00	1.01	6	6	0	0	4	4	1	0	10	9	0.2	0	4	4	1	0
YSD-1-850	850-854	100.00	49.94																		
YSD-1-1072	1072-1075	108.96	75.01	34.00	0.31	4	12	0	0	4	12	1	0								
YSD-1-1226	1226-1229	106.69	61.49	140.00	1.31	4	3	0	0	2	1	1	0	6	4	1	0	4	3	0.75	0
YSD-1-1721	1721-1723	115.77	15.99																		
YSD-1-1937	1937-1940	102.15	46.10																		
YSD-1-2226	2226-2229	102.15	43.93																		
YSD-1-2611	2611-2614	100.00	93.67																		
YSD-1-3032	3032-3036	97.61	35.05																		

Sample ID	Stratigraphic Interval (cm)	Bulk Wt. (g)	Residual Wt. (g)	Ostracodes	Ostracodes/g	*Loxoconcha tamarindoidea* #	%	A/J	C/V	*Xestoleberis banda* #	%	A/J	C/V	*Aurila ? Sp.* #	%	A/J	C/V
YSD-1-83	83-87	122.58	66.73														
YSD-1-338	338-342	102.15	95.34														
YSD-1-594	594-597	127.12	115.77														
YSD-1-721	721-724	106.69	34.15	108.00	1.01	10	9	0.80	0.40	4	4	1	1	2	2	1	0
YSD-1-850	850-854	100.00	49.94														
YSD-1-1072	1072-1075	108.96	75.01	34.00	0.31												
YSD-1-1226	1226-1229	106.69	61.49	140.00	1.31	4	3	1	0					4	3	1	0.50
YSD-1-1721	1721-1723	115.77	15.99														
YSD-1-1937	1937-1940	102.15	46.10														
YSD-1-2226	2226-2229	102.15	43.93														
YSD-1-2611	2611-2614	100.00	93.67														
YSD-1-3032	3032-3036	97.61	35.05														

Table 15. Foraminifera Total and Relative Abundance Recorded from Core YSD-1

Sample ID	Stratigraphic Interval (cm)	Bulk Wt. (g)	Residual Wt. (g)	Foraminifera	Organisms/g	*Ammonia beccarii* #	%	*Elphidium incertum* #	%	*Nonion* sp. #	%
YSD-1-83	83-87	122.58	66.73								
YSD-1-338	338-342	102.15	95.34								
YSD-1-594	594-597	127.12	115.77								
YSD-1-721	721-724	106.69	34.15	10	0.1			8	80	2	20
YSD-1-850	850-854	100.00	49.94								
YSD-1-1072	1072-1075	108.96	75.01								
YSD-1-1226	1226-1229	106.69	61.49	6	0.1	2	33.33	4	66.67		
YSD-1-1721	1721-1723	115.77	15.99								
YSD-1-1937	1937-1940	102.15	46.10								
YSD-1-2226	2226-2229	102.15	43.93								
YSD-1-2611	2611-2614	100.00	93.67								
YSD-1-3032	3032-3036	97.61	35.05								

Table 16. Mollusc Total Abundance Recorded from Core YSD-1

Sample ID	Stratigraphic Interval (cm)	Bulk Wt. (g)	Residual Wt. (g)	Molluscs	Organisms/g	*Cerithidea californica*	Gastropod sp. 1	Gastropod sp. 2
YSD-1-83	83-87	122.58	66.73	2	0.02	2		
YSD-1-338	338-342	102.15	95.34					
YSD-1-594	594-597	127.12	115.77					
YSD-1-721	721-724	106.69	34.15	8	0.07	8		
YSD-1-850	850-854	100.00	49.94					
YSD-1-1072	1072-1075	108.96	75.01	2	0.02		2	
YSD-1-1226	1226-1229	106.69	61.49	2	0.02			2
YSD-1-1721	1721-1723	115.77	15.99					
YSD-1-1937	1937-1940	102.15	46.10					
YSD-1-2226	2226-2229	102.15	43.93					
YSD-1-2611	2611-2614	100.00	93.67					
YSD-1-3032	3032-3036	97.61	35.05					

The taphonomic parameters indicate low to moderate fragmentation (0-20 percent). Abrasion, encrustation and coating are low (0-5 percent) in all samples. The redox index shows no alteration of microfossils after burial. Ostracode adult/juvenile (A/J) and carapace/valve (C/V) ratios as shown in Table 14 indicate an autochthonous faunal composition.

INTERPRETATION

Based on criteria provided in studies by Marinov (1964; in Puri et al. 1969), Benson (1959), Benson and Kaesler (1963), Swain (1967), and McKenzie and Swain (1967), three assemblages were identified: (1) a brackish-water assemblage consisting of species common in continental waters with a wide range of tolerance to salinity; (2) a transitional marine assemblage consisting of mixed marine and nonmarine ostracodes, and foraminifers; and (3) a marine assemblage dominantly formed by marine species unable to tolerate brackish-water conditions. This faunal association is similar to the Ballona Lagoon (Los Angeles County) assemblages that show the progressive transition and alternation of four assemblages (Palacios-Fest et al. n.d.), including freshwater associations not recorded at Ysidora Lagoon. Faunal similarities with San Elijo Lagoon are also evident, although San Elijo Lagoon shows freshwater conditions not recorded at Ysidora Lagoon.

The nonmarine ostracode species present in core YSD-1 (*C. vidua*, *C. beaconensis*, *I. bradyi*, *C. salinus*, *C. patzcuaro*, and *L. staplini*) reflect alternating “fresh” to brackish-water conditions (Figure 22). *I. bradyi* is a stream, freshwater indicator (Delorme 1989). *C. patzcuaro*, is a slow streamflow indicator that tolerates higher salinity than *I. bradyi*. *C. vidua*, *C. salinus*, *L. staplini*, and *C. beaconensis* are tolerant to a wide salinity range (Delorme 1989). *C. vidua* is also associated with slow streamflow (Delorme 1989). *L. staplini*, *C. salinus*, and *C. beaconensis* are common species in estuarine environments (Benson 1959).

The marine ostracodes present in Core YSD-1 (*P. pacifica*, *M. johnsoni*, *L. tamarindoidea*, *X. banda*, and *Aurila* ? sp.) reflect the influence of marine conditions. Marine forms are not as abundant as the nonmarine forms, indicating that the fauna was introduced in short pulses. The occurrence of a mixed adult/juvenile and articulated carapaces indicates the species established a biocenosis as marine conditions prevailed.

Dominance of *C. beaconensis* confirms a transitional assemblage that favors marine species. However, at 1072-1075 cm, no marine forms were recovered, indicating that at this time freshwater input dominated the environment. The occurrence of juveniles of *C. patzcuaro* with restricted salinity tolerance implies salinity decrease below 5000 mg L^{-1} (Delorme 1989); however, stressing conditions did not allow the species to establish a biocenosis.

Lagoonal foraminifera (*Ammonia beccarii*, *Elphidium incertum*, and *Nonion* sp.) in two samples (1226-1229 cm and 721-724 cm) are consistent with the ostracode record (Figure 23). The occurrence of *A. beccarii* may indicate freshwater influence as the species tolerates low salinity; the other species indicate marine conditions.

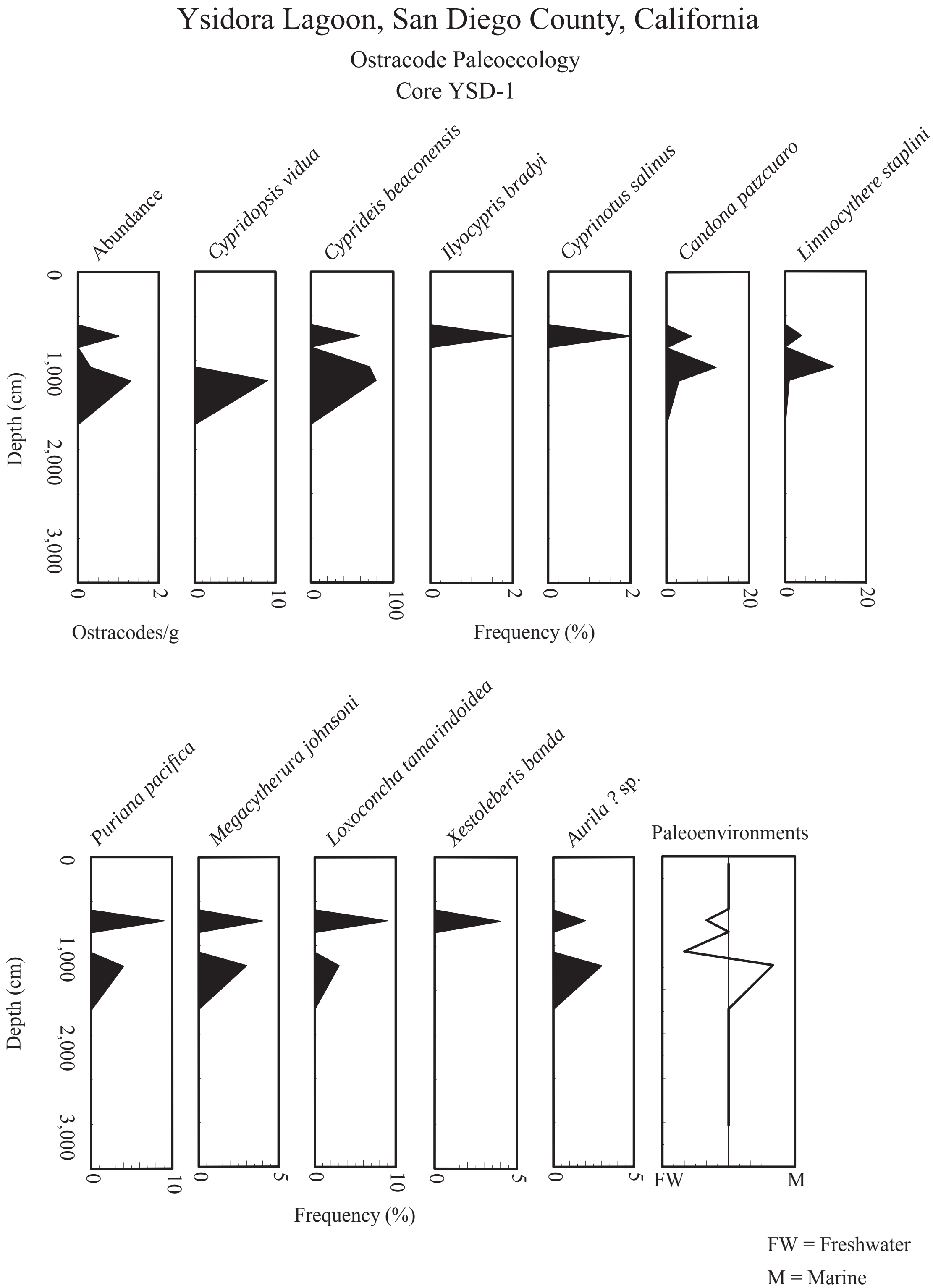

Figure 22. Ostracode relative abundance and paleoenvironmental trends from Core YSD-1. Organisms/g of sediment are plotted to the far left. FW = freshwater influence; M = marine influence.

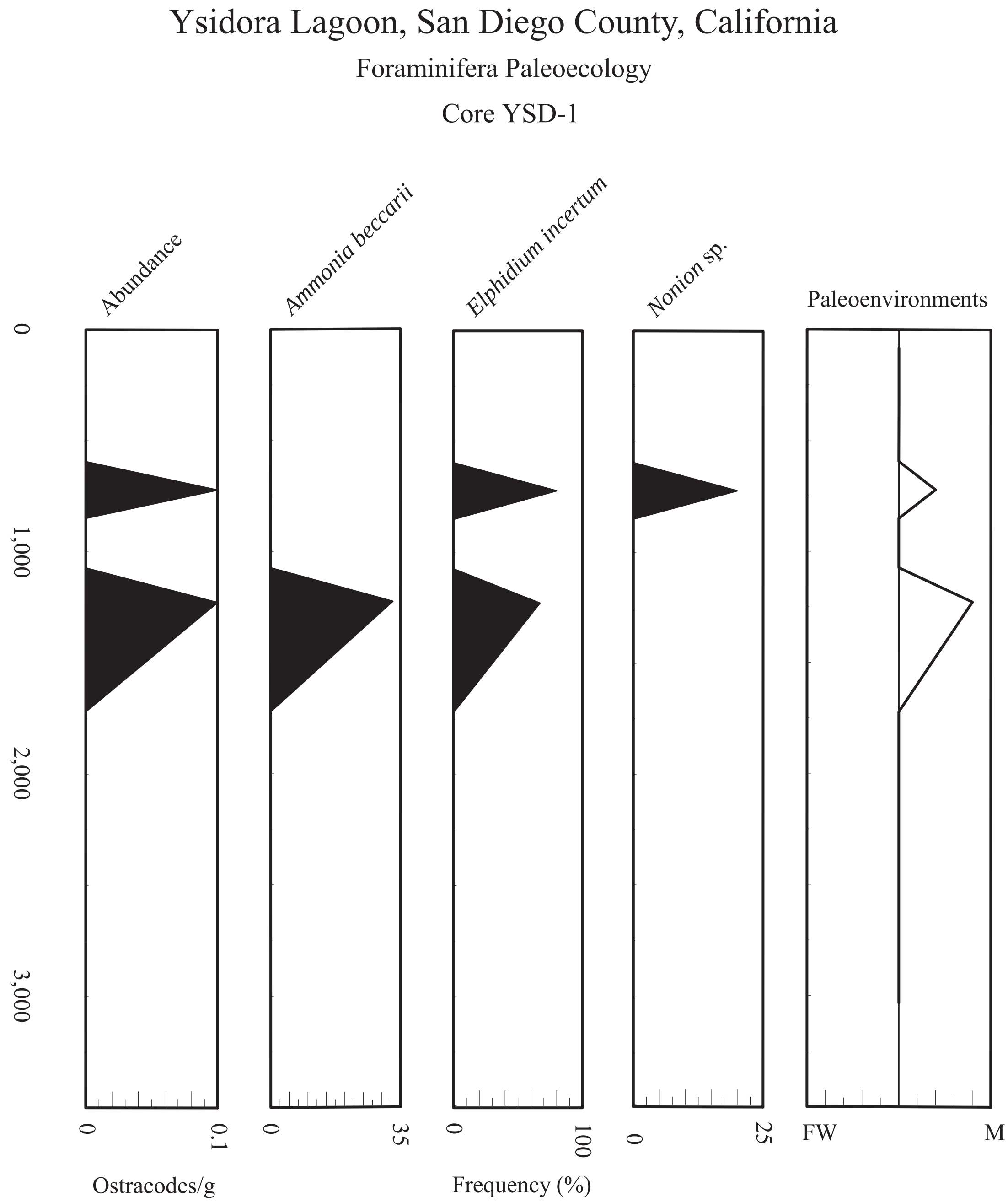

Figure 23. Foraminifera relative abundance and paleonvironmental trends from Core YSD-1. Organisms/g of sediment are plotted to the far left.

CONCLUSIONS

In recent years, the use of micro-invertebrates, especially ostracodes, as indicators of marine, brackish-, and freshwater environments has resulted in a powerful tool to understand environmental change in coastal zones. Because estuaries are poorly documented or interpreted in the geologic record, it has been uncommon to find an environmental trend. Maynard and Biggs (1985) stated the importance of unifying models of deposition and matching modern and ancient deposits. Through micro-invertebrate analysis, it is possible to reconstruct the long-term environmental evolution of Ysidora Lagoon from the late Pleistocene to the Holocene. It is also possible to present an evolutionary model for estuaries in southern California.

Ysidora Lagoon and San Elijo Lagoon, to the south, share several faunal similarities that lend evidence for the development of a model for estuarine development and change. The paleoenvironmental trends shown by the two lagoons are alike, indicating that the area was subject to marine influence earlier in the record. Environmental change to increasing continental influence at both Ysidora and San Elijo Lagoons may have resulted from regional tectonism and eustatic sea level change, similar to changes recorded at Ballona Lagoon, Los Angeles County (Palacios-Fest et al. n.d.). These processes eventually led to the siltation and alluvial sedimentation of Ysidora and San Elijo Lagoons, pushing the tidal deltas seaward as the rate of sea level rise slowed at 5,000 years ago and stabilized at about 3,000 years ago. However, at this time, the fragmented fossil record in the Ysidora cores inhibits a direct comparison. Important differences between Ysidora and San Elijo Lagoons exist. In the Ysidora cores, foraminifera and molluscs are less diverse while more nonmarine ostracode species occur (Palacios-Fest n.d.). This may have resulted from differential processes affecting the stabilization of salty marshes at Ysidora Lagoon during alternating periods of aridity and high rainfall causing extreme runoff and lagoonal discharge. Such processes inhibit lagoon and marsh stabilization that would have facilitated the establishment of different mulluscan faunal groups.