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ORDINATION OF TRACE METALS IN *Syacium papillosum* (DUSKY FLOUNDER) FROM THE EASTERN GULF OF MEXICO

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ABSTRACT: Variations in the metal contents (Ba, Cd, Cr, Cu, Fe, Ni, Pb, V, and Zn) in the skeletal flesh of the demersal fish *Syacium papillosum* from 12 stations on the relatively unpolluted Mississippi, Alabama, and Florida continental margin are investigated with the aid of Q-mode ordination techniques. Gradient analysis on the station-season ordination shows that Ba, Cu, and Ni explain most of the normal variation. Of these metals only Cu and Ni increased from summer to winter; this increase may be related to decreased metabolism. The decrease of Ba (and Cd) in winter may be diet controlled. Based on ordination synthetic indices, nonparametric statistical testing indicates that the winter trace metal concentrations are multivariately distinct from those of the fall and summer sampling suites; the latter are not statistically distinguishable. The trace metal concentrations measured in the demersal fish specimens are weakly correlated (positive) with the metal concentrations measured in the weak acid digest of the study area bottom sediments.

The Bureau of Land Management (BLM) implemented the Marine Environmental Studies Programs in compliance with the National Environmental Policy Act of 1969, after being designated as the agency responsible for leasing of submerged federal lands. A prime purpose of this BLM program has been the identification of potential or ongoing impacts to the environment of the outer continental shelf (OCS) from oil and gas exploratory and development activities. Among the first large scale studies sponsored by BLM under the Marine Environmental Program was the 1974-1978 environmental baseline study of the Mississippi, Alabama, and Florida (MAFLA) OSC. This paper presents the results of trace metal analyses on skeletal flesh from the demersal fish *Syacium papillosum* (dusky flounder) collected during the summer and fall of 1977 and the winter of 1978 as part of the MAFLA program. Seasonal variation in trace metal burdens in the test species are examined with the aid of ordination, gradient-analysis, and nonparametric statistical techniques. These techniques are also utilized to relate the results of this program element to trace metal concentrations in the MAFLA area bottom sediments.

METHODS

Study Area Sampling

As the acronym suggests, the MAFLA study area encompasses the continental margin of the eastern Gulf of Mexico along the Mississippi, Alabama, and Florida coasts. Demersal fish samples for metal analysis were obtained from water depth of 33-184 m by a 10 m trawl and a 1 m dredge at the 12 stations identified in Figure 1. These widely

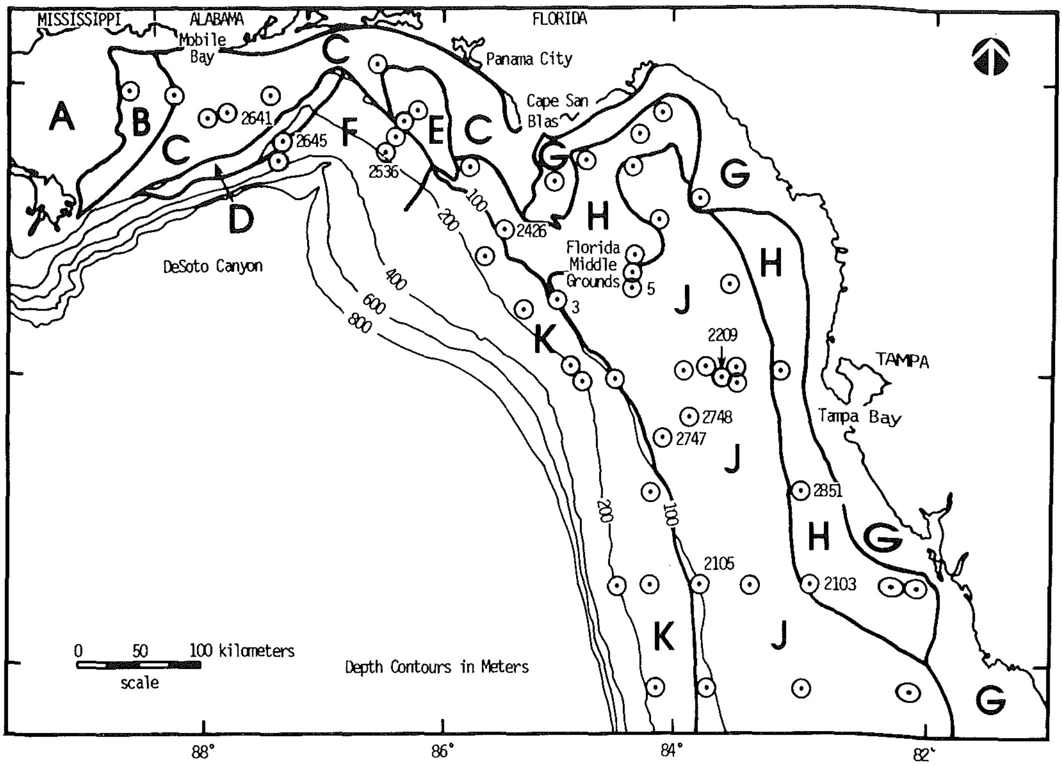

Figure 1. The MAFLA study area showing the locations of the demersal fish trace metal sampling stations. Table 1 indicates the season of station occupation. The letters refer to the bottom sediment facies (after Feldhausen *et al.*, 1979), which are:

A St. Bernard Prodelta
B MAFLA Prodelta Sand Transition
C MAFLA Sand Sheet
D MAFLA Sand Sheet Deep Water Transition
E Destin Carbonate Sand
F DeSoto Canyon Carbonate Muds
G West Florida Quartz Sand Band
H Carbonate-Quartz Sand Transition Zones
J Carbonate Sand Sheet
K West Florida Lime Muds

separated stations were sampled during each of the three cruises, summer and fall 1977 and winter 1978; most stations were sampled twice, some three times, and only three stations sampled once (Table 1).

Approximately 11 specimens of *S. papillosum,* 13-17 cm in length, were designated at each station-seasonal sampling for trace metal analysis from among the demersal fish caught. During the summer of 1977, 11 *Monolele sessilicauda* were designated as the test specimens at stations 2536, as no *Syacium* were captured. Their size and behavior are similar to *S. papillosum* (Robert Shipp, Dauphin Island Sea Lab, pers. comm.); therefore, no special distinction between the test species will be made unless otherwise noted. Results throughout this paper will be referenced to *S. papillosum.*

Metal Analysis

Seven metals were analyzed by atomic spectroscopy (Gould and Moberg, 1979): Cd, Cr, Cu, Fe, Ni, Pb, and Zn. Barium and vanadium, analyzed by neutron activation analysis (Shokes *et al.*, 1979), were also utilized in this study (Table 2). All of these metals, except perhaps Fe, can be considered toxic to varying degrees (Bowen, ;1966). At the same time, Fe, Cu, and Zn are essential elements of most organisms. Thus, the suite of metals selected by BLM for analysis

Table 1. Station Sampling Data (See Figure 1).

Station a	Sampling S-1977	Sampling F-1977	Sampling W-1978	Sediment Facies a	Depth (m)	Origin to Sample Vector Length b Fig. 3	Origin to Sample Vector Length b Fig. 4
3	X			J	90	0.492	—
5		X	X	J	39	0.579	—
7		X	X	E	91	0.403	—
2103		X		H	39	0.455	0.248
2105	X		C	J	98	0.555	0.401
2209	X	X	X	J	33	0.385	0.332
2426	X	X	X	H	83	0.335	0.320
2536c	X			F	184	0.706	0.797
2641	X	X		C	36	0.008	0.155
2645			X	D	98	0.719	0.705
2747		X	X	J	75	0.557	0.431
2748	X			J	50	0.405	0.421
						x=0.458	0.423
						s=0.042	0.038

a. Sampling station locations and the distribution of sediment facies are shown on Figure 1.
b. Normalized with respect to respective ordination diagonal length.
c. *Monolene sessilicauda* substituted for *S. papillosum.*

contains elements whose augmented presence in the environment might prove detrimental, as well as elements, which, if withheld or made less available, might also be detrimental to the local demersal fish communities.

Ordination and other statistical methods

The term ordination ("Ordnung") was probably proposed first by Ramensky (1930), and following Goodall (1954), it may be defined as an arrangement of objects in a uni- or multidimensional continuum as opposed to a classification in which the objects are partitioned into discrete classes. Samples described by many attributes (8 metal concentrations in this study) are usually arranged within a two-or three-dimenstional continuum (attribute space of Sneath and Sokal, 1973; Q-mode ordination described by Park, 1968) such that the proximity of any two samples within the ordination is proportional to their dissimilarity — similar samples lie in proximity to each other (see Figures 2 and 3 for examples). The ordination method of analysis is useful because it facilitates interpretation by reducing dimensionality and because it indicates gradational relationships among samples that may be obscured by standard classification techniques such as cluster analysis.

In ordination the concern is with the attributes used to describe the samples composition. Sample structure is regarded as the key to the interpretation of the environment. Thus, the choice of ordination axis end-point or reference samples is crucial to the success of an ordination, as positioning of the samples within the continum depends on their relationship to the reference samples. Samples which are dissimilar will be more useful for establishing intersample relations than will samples which are similar. Several criteria may be used to select reference samples; lowest similarity (Bray and Curtis, 1957), most dissimilar (Beals, 1960), and standard deviation (F.G. Goff, personal communication). Principal eigenvectors (Goff and Cottam, 1967) and principal components (Rowell, 1969) also have been used for ordination axis construction. The ordinations used in this paper to interpret variation in *S. papillosum* trace metal burdens were constructed with the most dissimilar criteria following the procedures outlined by Beals (1960).

Ordination has long been employed as a method of analysis in a variety of ecologic and environmental studies (of vegetation by Loucks, 1962; of bird communities by Beals, 1960; of soils by Hole and Hironaka, 1960; of para- and paleoecology by Feldhausen, 1967, and Park, 1968; and of numerical taxonomy by Kaesler, 1969, and Rowell, 1969). Goff and Cottam (1967) and Davis (1970) employed ordination techniques to examine vegetative and sedimentary grain size environmental gradients, respectively. More recently trend surfaces (Davis, 1973) have been employed to quantify gradients within ordinations (sediment grain size by Feldhausen and Ali, 1976; and bottom sediment trace metal contents by Doyle and Feldhausen, 1981).

The other statistical methods used in this study are described in Siegel (1956) and Sokal and Rohlf (1969).

RESULTS AND DISCUSSION

Trace Metals in *Syacium papillosum*

Table 2 shows the grand mean, seasonal means and seasonal coefficient of variation for eight of the metals in the skeletal flesh of *S. papillosum* expressed on a dry weight basis. Results for Pb are not included because most of the analyses were below the detection limit of 0.3 ppm. A value of one-half the detectable limit was employed in the statistical analysis when this was encountered.

Levels of trace metals are low in the skeletal tissues of the flatfish examined in this eastern Gulf study and reflect little, if any, pollution of the MAFLA study area. In general the results presented in Table 2 are equivalent to, or lower by a factor between 2 and 30, than previous results for flatfish in the Gulf of Mexico (NMFS, 1975; Horowitz and Presley, 1977). The present Cd and Cr values are about 10 and 5 to 30 times those previously reported, respectively. Although the Pb values reported here are lower than in these other Gulf studies, data of Patterson and Settle (1976) suggest that they may be higher than samples from other areas. This may be, in part, attributable to the influx of Pb from the Mississippi River. Even during periods of low river flow, the river has an average Pb concentration of 43.4 ppm, or some 3-4 times the average Pb crustal abundance (Tre-

Table 2. Seasonal variation of metal concentrations in *Syacium papillosum.*

	Trace Metals							
Seasons	Ba	Cd	Cr	Cu	Fe	Ni	V	Zn
Summer-1977								
mean (mg/kg)	1.3	0.013	0.21	1.2	8.1	0.32	0.42	16.2
cv (%)	41.6	41.6	26.4	29.0	21.7	24.5	61.6	10.7
Fall-1977								
mean (mg/kg)	1.4	0.011	0.27	1.9	9.6	0.38	0.34	17.1
cv (%)	20.5	33.8	75.0	21.4	21.9	32.6	34.4	10.2
Winter-1978								
mean (mg/kg)	0.7	0.007	0.20	1.8	7.0	0.85	0.24	15.1
cv (%)	13.5	50.2	17.8	26.3	8.7	23.8	50.1	6.5
Annual								
mean (mg/kg)	1.1	0.010	0.23	1.7	8.2	0.51	0.33	16.1
std. dev.	0.4	0.005	0.09	0.5	1.9	0.28	0.22	1.7

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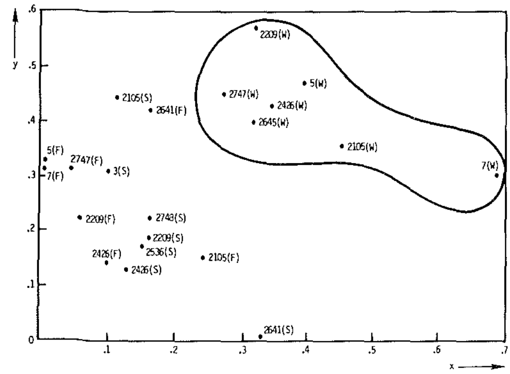

Figure 2. Q-mode ordination of 21-station-season demersal fish trace metal samples. The seasonal sampling periods are as follows: S = summer 1977, F = fall 1977, and W = winter 1978. The winter suite is distinct from both the summer and fall suites (see Table 4).

fry, 1977). Sediments in the MAFLA area show an increase in Fe, Pb, V, Mn, smectite and total organic content toward the west and west-southwest (Feldhausen *et al.*, 1979).

Natural Variability

The natural variability is a complex function of size, diet, geography, season, and other non-diet inputs (Johnson, 1979). However, in the present case specimen size and home range are not believed to be overly important contributors to the natural variability. The analystic specimens were larger (13-17 cm), mature fish, probably in their second year of growth. Because these specimens are definitely biased toward the large side of the size-frequency distribution Feldhausen, 1979), a substantial portion of variability that might be attributed to size differences is eliminated. Another factor which helps in the interpretation of possible temporal and environmental effects on trace metal content is the small home range of the test organisms which is probably less than 10 km (Robert Shipp, pers. comm.).

Seasonal Variability

Seasonal variation was investigated with the aid of a Q-mode ordination of the 21 station-season samples (Figure 2) based on *S. papillosum* trace metal burdens. As noted in the methods section, the technique developed by Beals (1960) was used to extract the X- and Y-axes of this two-dimensional attribute space (Sneath and Sokal, 1973). In this case the pairwise dissimilarity index was calculated by subtracting the associative Bray-Curtis (1957; often attributed to Sorensen, 1948) similarily index from unity:

$$D_{bc} = 1.0 - 2w / (A + B), \qquad (1)$$

where w is the sum of the trace metal concentrations held in common while comparing each trace metal variable in sample "a" with corresponding variable in samples "a" and "b", respectively.

To avoid biasing the results because of the large values for Fe and Zn, compared to the other metal concentrations (Table 2), each trace metal variable "i" was normalized prior to calculating dissimilarity indicies as follows:

$X_i' + (X_i - X_{i\text{-min}}) / X_{i\text{-max}} - X_{i\text{-min}})$ for all i, individually, (2) where the Xs are the concentrations of metal "i" in all samples. Utilizing this procedure, each variable is rescaled so it varies between zero and one.

Examination of the ordination shows winter samples are concentrated exclusively in the upper right of the diagram (Figure 2). In contrast, those samples obtained during the fall and summer are in the lower left. However, the summer and fall samples show a great deal of overlap and cannot be readily separated into distinct seasonal groups within the ordination.

First order trend surfaces (Davis, 1973) were used to quantify the trace metal gradients with the ordination. The surfaces were calculated using the ordination coordinates as spatial (X,Y) coordinates and the trace metal concentrations as the Z-dependent variable which is contoured. Equations and good-

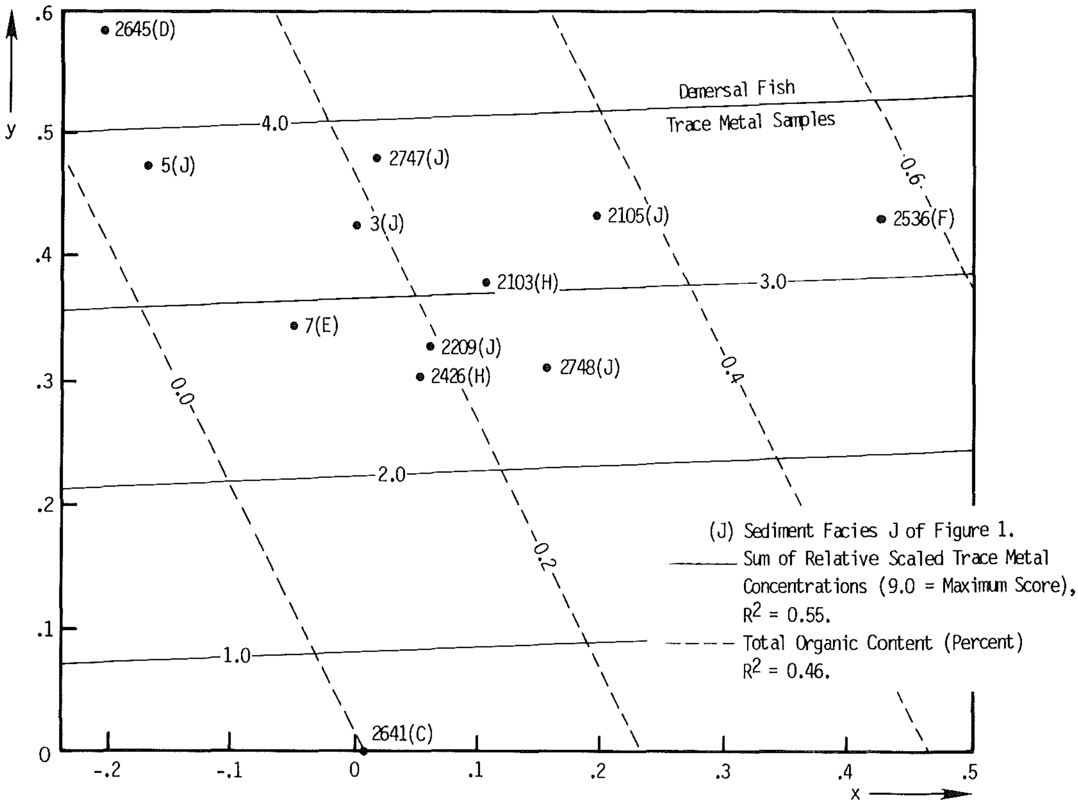

Figure 3. Q-mode ordination of 12 stations (metal grand station means) showing the bottom sediment facies associated with each station location. The facies designations are provided in Figure 1. First degree trend surfaces for the sum of the relative sediment trace metal concentrations (weak acid fraction) and the total organic content are graphed on this ordination.

ness of fit data for eight metal trend surfaces (Pb excluded) are reported in Table 3. The best linear trends for the 21 station-season ordination are for Ba, Cu, and Ni as they explain 51 to 64 percent of the variability in the data (multiple correlation coefficients of 0.71 to 0.80). By comparing the sign and magnitude of the coefficients A_X and A_Y listed in Table 3, one can visualize the linear metal ingradients within the ordination. The barium gradient, which is about 50 percent stronger along the X-axis than along the Y-axis, exhibits a decrease toward the winter samples. In contrast, the Ni gradient decreases toward the fall-summer suite of samples, with the contribution of the two axes being about equal. Copper exhibits a more complicated gradient. It decreases with increasing X-coordinates while it increases about 2.25 times as fast with increasing Y-values.

Samples in a properly constructed Q-mode ordination are separated by distances that are proportional to their dis-

Table 3. Trend surface equations for 21-station-season ordination*

Metal	Ao	Ax	Ay	R^2
Ba	1.75	-1.49	-1.01	0.51
Cd	0.015	-0.018	-0.002	0.37
Cr	0.24	-0.25	+0.14	0.13
Cu	1.15	-1.10	+2.49	0.51
Fe	8.70	-1.47	-0.004	0.08
Ni	0.062	+0.96	+0.82	0.64
V	0.51	-0.48	-0.23	0.18
Zn	17.4	-6.25	0.28	0.40

*Trend surfaces are based on X,Y coordiates of samples in 21-station-season ordination (Figure 2) and respective trace metal concentration, Z.

Trend surface equations are of the form

$$Z = Ao + AxX + AyY$$

R^2 is a measure of "goodness of fit." The multiple correlation coefficient, r, is given by $r = R^2$.

similarity (similar samples lie close to each other). Thus, sample ordination coordinates (synthetic indices of Goff and Cottam, 1967) are often the "best" descriptors of the objects in the ordination (Davis, 1970). The two coordinates for the 21 station-season samples distributed in the ordination depicted in Figure 2 can be used to represent each sample instead of the eight original trace metal variables. This suggests a quasi-multivariate method of testing the statistical significance of the differences in the trace metal burdens of *S. papillosum* based on pooled results of approximately 11 specimens for the 7 stations in each seasonal sampling, namely: (1) calculating the length of the vector from the ordination origin to the sample (normalized by the length of the diagonal); and then (2) using these values in Mann-Whitney U nonparametric statistical analysis. By using the Mann-Whitney U test, one of the most powerful nonparametric tests, the restrictive assumptions and requirements of the more familiar t-test and analysis of variance methods are avoided (Seigel, 1956).

Results of the Mann-Whitney statistical testing, presented in Table 4, show that there is no significant difference between the summer and fall samples. In contrast, the testing indicates that the winter samples differ from both the fall and summer sampling suites. Some caution, however, is in order, as station mean results are employed in the construction of the ordination and not the 203 individiual specimen analyses. If individual analyses had been employed greater overlap of the seasonal sampling suites could be expected.

The diet of *S. papillosum* can explain some of the seasonal differences in trace metal burdens. Barium and to a lesser extent Cd, tend to be lower in winter than in fall and summer (Table 2). This phenomenon may be related to seasonal changes in the trace metal content of the food organisms on which test species

Table 4. Comparison of summer, fall, and winter trace metal burdens in *Syacium papillosum* using ordination sample vector length.

Station	Season	Normalized Origin to Sample Vector Length*
3	S	0.323
2105	S	0.458
2209	S	0.244
2426	S	0.186
2536**	S	0.230
2641	S	0.329
2748	S	0.278
		x = 0.293
		s = 0.089
5	F	0.321
7	F	0.307
2103	F	0.286
2209	F	0.227
2426	F	0.171
2641	F	0.453
2747	F	0.315
		x = 0.297
		s = 0.088
5	W	0.610
7	W	0.758
2105	W	0.601
2209	W	0.652
2426	W	0.556
2645	W	0.512
2747	W	0.526
		x = 0.602
		s = 0.085

*Ordination shown in Figure 2.
***Monolene sessilicauda* substituted for *S. papillosum.*

Mann-Whitney U Test Results

o	Summer	Fall	Parameter
	47	58	Rank sum
	30	19	Mann-Whitney U

As Ux,f < 19 has a probability of occurrence of p = 0.267, then S and F were drawn from the same population.

o	Winter	Summer or Fall	Parameter
	77	28	Rank sum
	0	49	Mann-Whitney U

As Us,w < or Uf,w < 0 has a probability of occurrence of p = 0.000, then W was drawn from a different population than either S or F.

prey. Shrimp are a major food in the *S. papillosum* diet (Topp and Hoff, 1972). In the winter pooled Ba values for MAFLA shrimp (*Mesopenaeus tropicalis, Solenocera atlantidis, Sicyona brevirostris, Parapenaeus longirostris,* and *Penaeus setiferus*) are about 50 percent of the summer values (Johnson, 1979). Similarly, Cd in this shrimp group showed winter concentrations about 60 percent of the summer values. It appears that seasonal changes in the diet of *S. papillosum* help to explain these observed seasonal trends.

Conversely, Cu and Ni changes in the shrimp group do not take place on a seasonal basis; summer and winter averages for these metals are virtually identical (Johnson, 1979). Copper, an essential micro-nutrient, may build up in body tissues of *S. papillosum* as the metabolic rate decreases in winter. The chemistry of Ni is similar to that of Cu and its increase from summer to winter may also be metabolically controlled. The neutral trends of Zn and Cr may be related to active internal concentration regulation. Such a process has been indicated for molluscs in the case of Zn (Sheldon Pratt, personal communication).

Relations with Bottom Sediments

Geographic variation among the demersal *S. papillosum* trace metal samples and their relation to bottom sediment facies and trace metal content is also investigated with the aid of Q-mode ordination. This ordination, portrayed in Figure 3, was constructed in accordance with the procedures outlined above, but unlike the ordination shown in Figure 2, all station values were pooled prior to rescaling the variables and calculating the dissimilarity indices (see equations 1 and 2). Consequently, seasonal variations are generally excluded.

Of particular note in this ordination is the large distance (dissimilarity) separating stations 2641, 2645, and 2536. Geographically, these stations are not widely separated (Figure 1); 2641 and 2645 are neighbors, the former being from 36 m and the latter from 98 m of water. The water depth at 2536 is 184 m. Neither axis, however, represents a depth gradient as can be seen by reference to Table 1 where vector length vs. depth is tabulated. Not noted in Figure 2, but obvious in Figure 3, is the semi-outlier position of station 2536. It is an end-point of the x-axis and exhibits the highest dissimilarity to all other stations. The other x-axis end-point, station 2645, is the next most dissimilar sample. Station 2536 was sampled only during the summer cruise and, in the absence of *S. papillosum, Monolene sessilicauda* were substituted as the test specimens because the two species are taxonomically similar. When compared to the other summer samples (Figure 2 and Table 4) the pooled trace metal concentrations in *M. sessilicauda* do not appear to be appreciably different from those in *S. papillosum*. The position of station 2536 may be in part related to the distribution of organic matter (total organic content) in the bottom sediment (see Figure 3).

The 12 station ordination can be used to show a relationship between the demersal fish trace metal concentrations and the substrate sediment facies. The bottom sediment occurring at each station is plotted in Figure 3. Figure 1 shows the geographic distribution of these facies which were defined by Feldhausen *et al.* (1979) on the basis of contiguous areas with bottom sediments exhibiting similar grain size, clay mineralogy, total organic content and carbonate concentrations.

Each of the 4 end points (stations 2645-2536 and 2641-2747) is from a different sediment facies; stations from the center of the ordination are generally from the same facies. The facies-station correspondence is as follows:

- C = MAFLA sand sheet — Station 2641
- D = MAFLA sand sheet deep-water transition — Station 2645
- E = Destin carbonate sands — Station 7
- F = De Soto Canyon carbonate mud — Station 2536
- H = Carbonate-quartz sand transition zone (west Florida) — Stations 2103 and 2426
- J = Carbonate sand sheet (west Florida) — Stations 3, 5, 2105, 2747, and 2748.

Many of the demersal fish sampling stations are located in areas with carbonate rich bottom sediments, the Destin carbonate sheet (E), the carbonate sand sheet of the west Florida shelf (J) and to a lesser extent the west DeSoto Canyon carbonate mud (F). Weak acid leaching in the laboratory suggests that metals can be extracted from carbonate sediments with relative ease by deposit feeders upon which *S. papillosum* prey.

Another facet of the MAFLA program was the analysis of trace metal extracted from the bottom sediments using a weak acid leach (see Trefry, 1979; Shokes, *et al.*, 1979). A weak acid was used to approximate the conditions found in the gut of many benthic organisms. Results of the analyses performed as part of this sediment chemistry program element are presented as a first degree trend surface on the *S. papillosum* ordination graphed in Figure 3. The linear contours of this trend surface ($R^2 = 0.55$) represent the sum of the relative weak acid trace metal concentrations in the 9 sediment sampling stations that were also locations for demersal fish sampling. The sediment at station 2645 (facies D) had one of the highest weak acid trace metal contents (of all MAFLA area sediments) for all 9 metals analyzed in the bottom sediment chemistry program element (same 9 metals analyzed in the flatfish chemistry program element). On a relative basis,

$$\sum_{i=1}^{9} (Z_i/Z_{i\text{-max}}), \qquad (3)$$

(where Zi is the i-th weak acid metal concentration in sediment and Zi-max is its maximum value) the sediment at station 2645 had a relative sum of 6.1 out of a possible score of 9.0. The other X-axis end number, stations 2536 (Figure 4), exhibited the next highest value (4.8) of the 9 stations considered. The sediment at station 2641 exhibited one of the lowest relative sums for the entire MAFLA study, only 1.2.

A positive association between the trace metal burdens of *S. papillosum* and bottom sediment chemistry can also be demonstrated by the total organic content trend surface plotted on the ordination graphed in Figure 4. Doyle and Feldhausen (1981) showed that total organic content was the most important variable (from among carbonate and smectite content, depth of water, clay fraction, and mean grain diameter) for explaining the distribution of Ba, Cr, Cu, Fe, Ni, Pb, and Zn in MAFLA bottom sediments. In the analysis of V, total organic content was chosen second in the multiple stepwise linear regression.

The two-dimensional Q-mode ordination shown in Figure 4 was constructed by the method of principal components (Davis, 1973) using the 9 weak acid trace metal concentrations measured at the sediment chemistry sampling locations as sample attributes. Only the 9 stations corresponding to the demersal fish trace metal stations are identified in Figure 4 in order to facilitate visual comparison of Figures 3 and 4.

Data for quantitatively comparing the two ordinations are presented in Tables 1 and 5. In Table 1 the vector lengths for the 9 stations held in common are tabulated.

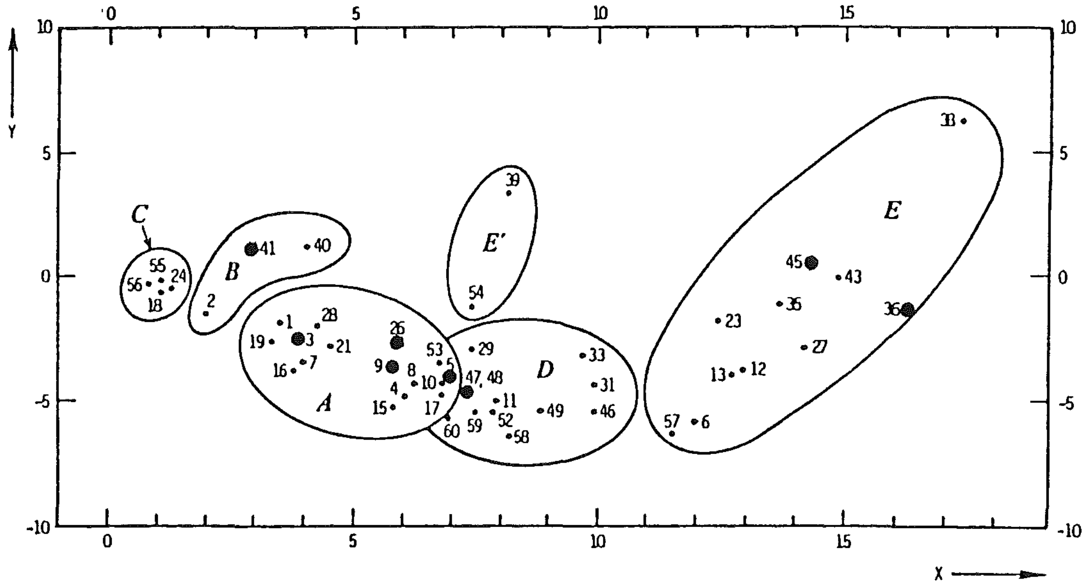

Figure 4. The location of 9 demersal fish trace metal stations in a Q-mode ordination based on bottom sediment trace metal (weak acid digest) concentrations. Large dots are used to identify the fish chemistry sampling stations. For clarity only the last two digits of the station number are used. Classes A—E were determined by cluster analysis of the sediment metal concentrations. Figures 3 and 4 are compared in Tables 1 and 5.

Mann-Whitney U testing shows that, at alpha levels of 0.05, there is no statistical difference between the two ordinations based on normalized station vector length. Thus, it can be said that the 9 stations are distributed in about the same manner; they are not tightly clustered in one diagram and spread out in the other.

In Table 5, the distances between stations (interstation distance normalized by diagonal length) are tabulated for both ordinations. A Spearman rank correlation coefficient (Siegel, 1956) of 0.94 (significant at $\alpha = 0.0005$). A Spearman rank correlation coefficient of 0.50 was calculated for the entire data set of 36 interstation distance comparisons. This coefficient (significant at $\alpha < 0.005$), as well as those calculated for partial data sets, further demonstrates the positive association between the trace metal concentrations in *S. papillosum* and the weak acid trace metal fraction leached from the bottom sediments.

CONCLUSIONS

As judged by the trace metal content of *Syacium papillosum*, the eastern Gulf of Mexico appears to be relatively free of heavy metal. The Cd and Cr levels in the muscle tissue of these flatfish are somewhat higher than has been reported for other species in other areas. This may be a natural species variation, a result of diet, or a direct influence of the Mississippi River input to the eastern Gulf of Mexico.

By use of an ordination technique, it is shown that some of the variability of trace metal content in *S. papillosum* is explained empirically on a seasonal basis — the values for the winter collections are distinctly different (in sum total) from the summer and fall conditions. It is felt that such variability is likely related to the trace metal variability in the dietary input of the fish.

Metal variability in *S. papillosum* is also shown to be weakly related to the sediment weak acid leachable trace metal fraction. Two comparisons were used to demonstrate their positive association: (1) the relative trace metal and total organic content trend surface on the demersal fish two-dimensional ordination (attribute space shown in Figure 3); and (2) comparison of trace metal ordinations (Figures 3 and 4). Twenty of the station-to-station distances within each ordina-

Table 5. Comparison of *Syacium papillosum* and sediment ordination using interstation distances.

Comparison	Station Fair	Interstation Distance SP	Interstation Distance Sed.
1	2641-2636	0.661	0.659
2	2748-2645	0.386	0.391
3	2209-2103	0.077	0.085
4	2426-2209	0.026	0.042
5	2645-2426	0.417	0.442
6	2426-2103	0.102	0.075
7	2105-2103	0.118	0.152
8	2645-2105	0.461	0.426
9	2748-2103	0.092	0.044
10	2645-2209	0.405	0.466
11	2536-2426	0.433	0.507
12	2747-2536	0.452	0.531
13	2641-2209	0.363	0.266
14	2641-2426	0.337	0.237
15	2645-2103	0.405	0.508
16	2536-2209	0.418	0.523
17	2748-2641	0.377	0.271
18	2209-2105	0.192	0.069
19	2645-2641	0.683	0.559
20	2426-2105	0.215	0.089
21	2747-2645	0.265	0.406
22	2747-2426	0.201	0.378
23	2748-2536	0.327	0.515
24	2641-2105	0.521	0.325
25	2748-2747	0.241	0.024
26	2536-2105	0.251	0.470
27	2536-2103	0.357	0.579
28	2747-2103	0.148	0.385
29	2747-2105	0.204	0.443
30	2747-2209	0.178	0.420
31	2641-2103	0.431	0.188
32	2748-2426	0.111	0.356
33	2747-2641	0.530	0.283
34	2748-2105	0.145	0.419
35	2748-2209	0.103	0.398
36	2645-2536	0.708	0.128

Comparisons	Spearman Rank Correlation Coefficient
1-20	0.94
1-27	0.75
1-36	0.50

tions (Table 5) showed a remarkably high interordination correlation (0.95). However, the overall correlation of 0.50 was not as striking. It is likely that each level of "metabolic processing" in the food web makes it less possible to make a good correlation between source of trace metals (the sediments) and the receptor site (*S. papillosum*).

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