noticed among the different elements, it is possibly due to the differential behaviour of the elements in regard to the desorption and adsorption taking place in an environment where there is constant churning up of bottom sediments by the prevailing tidal bores.

Dissolved oxygen measurements in the bottom waters revealed highly oxygenated waters (4 to 5 ml/litre)[8]. Thus the environment in general being an oxidising one in the Gulf, the minor differences found in the elemental concentrations of the sediments may be due to the compositional differences of the individual samples than to environmental changes.

The authors thank Dr S.Z. Qasim and Shri H.N. Siddiquie for their encouragement. They are also thankful to the Captain and crew of *RV Gaveshani* for their cooperation.

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Distribution of Al, Mn, Ni, Co & Cu in the Non-lithogenous Fractions of Sediments of the Northern Half of the Western Continental Shelf of India

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Higher amounts of elements are associated with the non-lithogenous fractions of the finegrained terrigenous sediments of the innershelf region with low carbonate content than with the corresponding fractions of the coarsegrained sediments of the outershelf region with high calcium carbonate content and all the elements covary with each other in the environment. From an evaluation of the role of different processes associated with the incorporation of elements, particularly trace elements into the non-lithogenous fractions, it is inferred that in the innershelf region they are incorporated in association with the hydroxides of iron and manganese while in the outershelf region they are associated with the carbonate phase.

In continuation of reports[1,2] on elemental distributions in the surficial sediments of northern half of western continental shelf of India, distribution of Al, Mn, Ni, Co and Cu have been studied in the non-lithogenous fraction (NLF) of these sediments and the results reported here.

Fig. 1 gives location of stations from where surficial sediment samples were collected. Suitable aliquots of the oven dried samples were leached with acid reducing mixture and the test solutions prepared[3]. Al[4], Mn[5], Ni, Co and Cu[6] were estimated colorimetrically.

The results obtained are presented in Table 1 along with other essential data such as depth of sampling, texture of sediments[7] and the contributions made by the lithogenous fractions (LF) of sediments to the concentrations in the total sediment sample. This parameter has been included only to give an idea of the relative contributions made by NLF and LF to the concentrations in the total sediment samples. Concentrations of elements associated with NLF have been computed from the values given in column A and their distribution patterns for Al, Mn, Ni and Co are shown in Figs 2-5. For copper, the values are recorded in Table 1 itself under column C. Inter-elemental relationships have been worked out and the *r* values obtained are given in Table 2.

From the data presented and the distribution pattern of calcium carbonate reported earlier[2], the following inferences can be drawn in regard to the distribution pattern of the sediments and the distribution patterns of the elements in NLF of sediments:

(1) Texturally, the innershelf (0-60 to 70m) is floored by finegrained sediments of terrigenous origin (clays, silty clays, clayey silts, sandy clays and sandy silts) with low calcium carbonate content while the outershelf

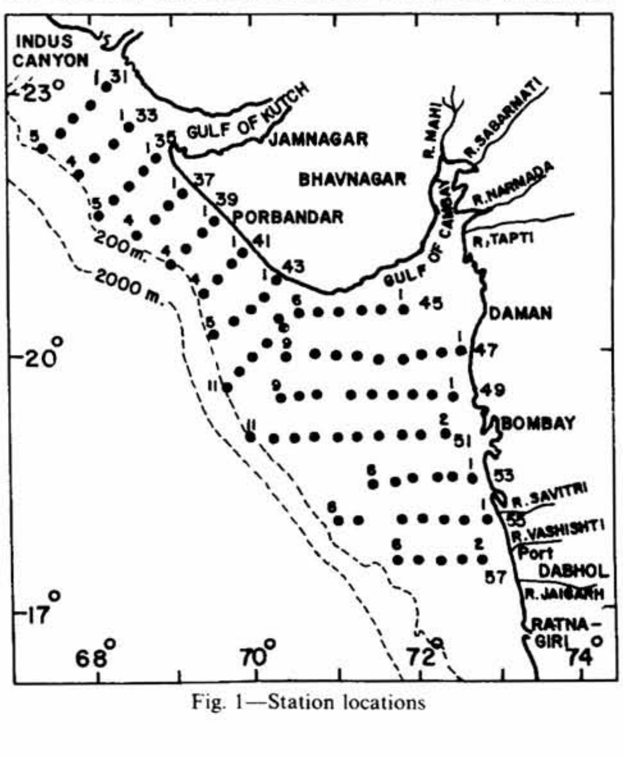


Fig. 1—Station locations

Table 1—Elemental Distribution in Different Fractions of Sediments
[Al in % while the rest in ppm]

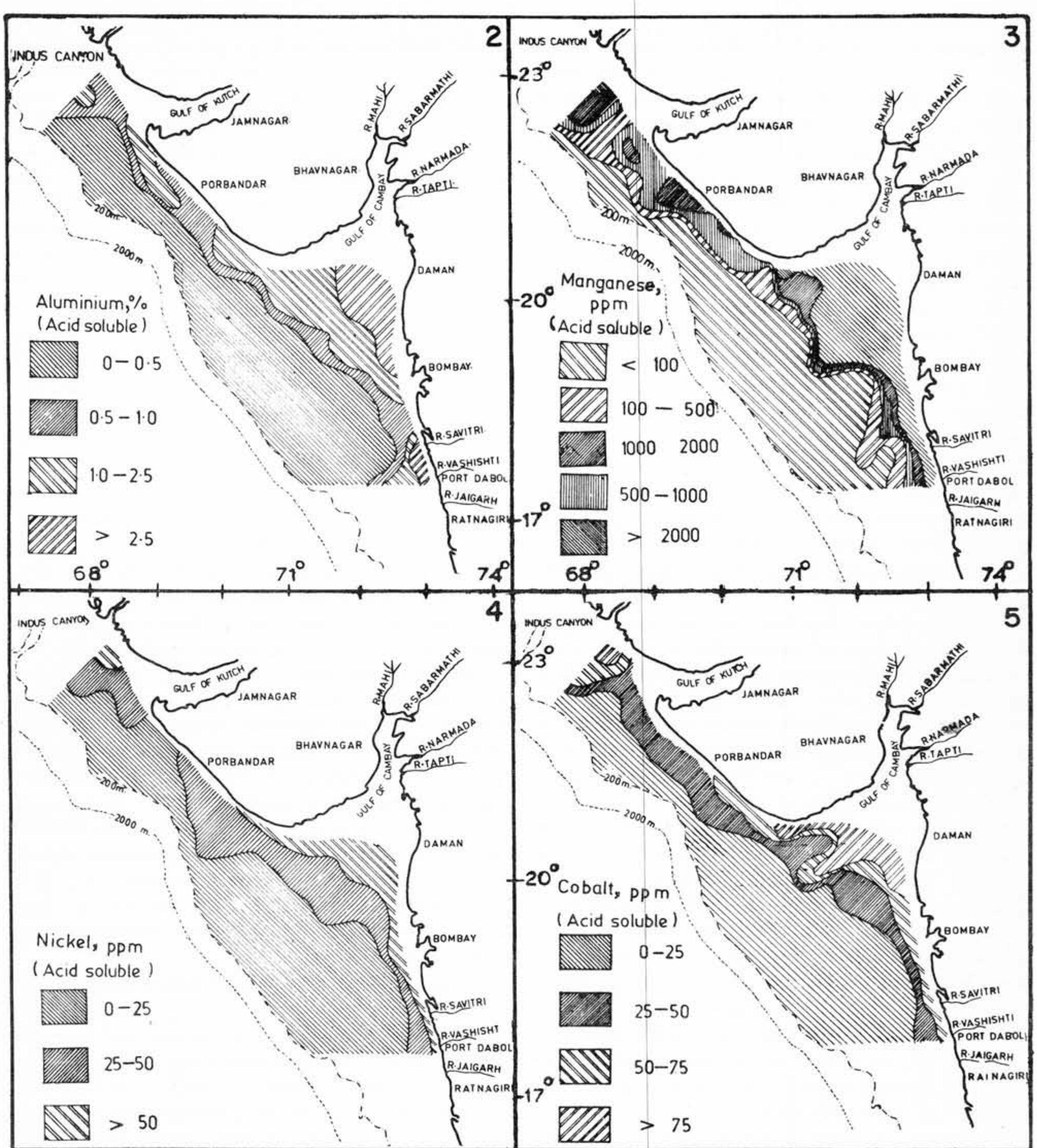
Station No.	Depth (m) & Texture	Al_2O_3		Manganese		Nickel		Cobalt		Copper		
		A	B	A	B	A	B	A	B	A	B	C
						Line 31						
01	20, a	0.11	13.31	427	597	8	63	24	84	—	—	—
02	27, b	0.17	12.89	294	497	6	78	6	32	—	—	—
03	41, b	0.13	12.82	267	291	7	78	6	29	—	—	—
04	94, a	0.15	12.21	267	—	6	76	22	40	—	—	—
05	113, c	0.13	2.32	27	939	8	50	—	—	—	—	—
						Line 33						
01	—, a	0.15	13.49	27	502	8	81	9	14	—	—	—
02	60, d	0.11	8.35	—	—	6	55	8	32	—	—	—
03	85, e	0.04	6.26	160	369	3	57	5	46	20	6	29
04	100, e	0.17	7.34	40	1019	9	57	9	28	29	12	54
						Line 35						
01	30, f	0.62	9.12	80	886	5	61	14	23	20	2	49
02	37, f	0.09	13.02	320	—	8	87	17	26	25	14	145
03	64, c	0.07	2.10	—	—	5	47	8	40	9	3	11
04	139, c	0.28	2.16	53	—	12	30	7	33	—	—	—
05	—, g	0.15	7.47	40	—	15	49	7	27	35	15	70
						Line 37						
01	30, a	0.19	12.63	27	682	6	97	8	17	—	—	—
02	54, g	0.34	10.39	133	576	5	82	8	21	21	37	77
03	65, a	0.13	9.04	267	454	9	60	8	40	5	50	17
04	90, a	0.32	8.67	—	—	9	61	8	30	13	39	27
						Line 39						
01	29, a	0.15	12.12	187	499	5	92	5	36	33	35	143
02	42	0.36	12.27	240	528	4	93	7	28	23	46	153
03	65, h	0.13	5.61	13	580	5	35	9	28	—	—	—
04	74, c	0.07	2.42	53	763	3	37	8	36	7	13	9
						Line 41						
01	23, a	0.25	11.15	240	481	7	91	21	19	17	54	50
02	42, a	0.28	11.18	187	639	6	87	8	26	28	49	114
03	65, g	0.04	10.87	13	784	8	81	8	35	17	52	79
						Line 43						
01	25, i	0.30	11.73	267	629	11	66	27	7	53	20	217
02	45, a	0.38	12.00	—	—	8	69	8	35	48	34	182
04	65, c	0.06	2.20	13	231	31	13	—	—	—	—	—
05	90, c	0.13	1.73	27	148	8	36	8	36	—	—	—
						Line 45						
01	27	0.32	13.07	53	1209	6	84	10	39	28	90	332
02	25, e	0.34	10.33	374	952	11	61	25	21	—	—	—
03	25, e	0.17	9.44	427	1039	6	70	4	44	33	56	254
04	34, a	0.39	11.44	387	730	11	63	5	43	—	—	—
05	41, a	0.26	11.66	454	616	7	75	23	9	23	69	173
06	51, a	0.30	11.52	40	931	10	68	8	35	20	70	83
07	84, e	0.17	9.89	40	700	7	64	—	—	33	31	87
09	70, c	0.09	2.44	45	188	4	38	7	39	19	2	22
10	82, c	0.08	2.01	43	172	4	36	7	27	—	—	—

Contd

Table 1—Elemental Distribution in Different Fractions of Sediments —*Contd*

Station No.	Depth (m) & Texture	Al_2O_3		Manganese		Nickel		Cobalt		Copper		
		A	B	A	B	A	B	A	B	A	B	C
Line 47												
02	35, b	0.53	12.69	107	1010	11	89	23	28	38	73	507
03	34, b	0.36	12.36	527	735	8	85	8	43	68	45	405
04	32, b	0.72	11.83	640	535	9	80	9	33	—	—	—
05	33, a	—	—	—	—	7	78	7	37	—	—	—
06	37, a	0.42	12.08	560	667	7	75	21	27	—	—	—
07	53, a	0.30	11.00	53	1128	7	78	8	40	47	41	378
08	80, e	0.15	—	40	—	2	—	8	—	—	—	—
09	78, c	0.07	2.41	40	326	4	33	7	41	9	17	12
Line 49												
01	20	0.81	12.16	774	564	10	87	16	17	—	—	—
02	29, b	0.55	12.43	934	392	8	84	4	39	93	24	353
03	30, b	0.64	11.60	720	670	10	96	8	41	36	77	104
04	45, b	0.55	11.67	53	1300	9	78	8	36	—	—	—
05	66, b	0.11	12.29	694	475	9	82	2	32	16	82	122
06	74, h	0.15	5.38	40	606	8	47	7	35	8	39	14
07	82, c	0.11	1.91	40	257	6	30	11	—	15	9	17
08	82, c	0.11	0.35	27	147	5	21	8	26	—	—	—
09	80, c	0.04	0.23	27	118	3	34	8	38	—	—	—
Line 51												
02	—	0.42	12.38	374	563	11	76	6	45	53	37	207
03	65, h	0.07	4.53	27	572	7	46	8	36	36	39	54
04	70, c	0.04	3.34	27	310	8	37	8	30	9	21	12
05	70, c	0.07	1.94	27	153	8	34	7	39	17	5	20
07	—	0.04	0.36	27	60	9	25	8	40	—	—	—
08	—, c	0.01	0.20	27	42	10	21	7	39	3	5	4
09	—, c	0.01	—	40	—	3	—	12	—	4	—	4
10	80, c	—	—	—	—	10	19	8	32	—	—	—
Line 53												
01	23, b	0.07	12.33	721	250	7	104	7	42	—	—	—
02	38, a	0.30	7.36	374	347	9	59	10	21	—	—	—
03	45, c	0.19	5.58	93	256	9	52	8	35	—	—	—
04	74, c	0.09	1.73	—	—	3	49	5	38	—	—	—
05	80, c	0.13	1.44	27	130	7	30	6	36	—	—	—
Line 55												
01	24, a	0.60	12.38	454	331	—	—	30	12	—	—	—
02	40, e	0.34	—	160	625	11	—	8	—	—	—	—
03	50, d	0.42	—	13	—	6	—	9	—	—	—	—
04	88, d	—	—	147	121	9	55	7	36	—	—	—
05	95, c	0.15	1.71	80	30	9	36	7	25	—	—	—
Line 57												
01	24, a	0.56	11.28	400	228	8	85	8	34	—	—	—
02	40, a	0.34	10.61	187	337	6	83	7	45	—	—	—
03	78, a	0.26	—	133	—	7	—	14	—	—	—	—
04	90, d	0.69	13.42	53	924	7	101	13	44	—	—	—
05	95, c	0.09	—	27	—	2	—	11	—	—	—	—
06	90, c	0.07	—	40	—	4	—	10	—	—	—	—

A = Contribution made by NLF to the concentration of elements in the total sediment sample
B = Contribution made by LF to the concentration of elements in the total sediment sample
C = Concentration of Cu in NLF
Texture: a, silty clay; b, clay; c, sand; d, clayey sand; e, sand-silt-clay; f, sandy clay; g, clayey silt; h, silty sand; and i, sandy silt



Figs 2-5—Distribution patterns of concentrations of Aluminium (2), Manganese (3), Nickel (4) and Cobalt (5) associated with the non-lithogenous fractions of sediments (Al_2O_3 in % and Mn, Ni and Co in ppm)

Table 2—Correlation Coefficient Values between Various Elements

Correlation between	r value	Correlation between	r value
Fe* and Mn	+ 0.43	Mn and Ni	+ 0.51
Fe* and Ni	+ 0.87	Mn and Co	+ 0.36
Fe* and Co	+ 0.69	Ni and Co	+ 0.80

*Values of iron associated with NLF are taken from Rao *et al.*[2]

region (70m to shelf break) is carpeted by coarsegrained sediments (sands, clayey sands and silty sands) with high calcium carbonate content. This sediment zonation is more distinct in the shelf region between Gulf of Cambay and Port Dabol than in the shelf region north of Gulf.

(2) Contributions made by NLF of sediments of the innershelf region to the concentrations of the elements

in the total sediment samples are higher than the contributions made by NLF of the sediments of the outershelf region to the concentrations of elements in the total sediment samples of that region (column A, Table 1). This feature too is more conspicuous in the shelf region between Gulf of Cambay and Port Dabol than in the shelf region north of Gulf.

(3) Higher concentrations of the elements are associated with NLF of sediments of the innershelf region than with NLF of sediments of the outershelf region (Figs 2-5 and column C, Table 1).

(4) Mn, Fe, Ni and Co covary with each other. Ni and Co have a stronger correlation with Fe than with Mn (Table 2).

The amounts of the elements associated with NLF of sediments represent those incorporated into the sediments in association with carbonate phase, Fe and Mn hydroxides of authigenic origin and adsorption on clay mineral surfaces. However, since all these processes cannot be expected to be operating with the same intensity all over the shelf region, an attempt is made to evaluate the role of each of these processes with the available data.

Carbonate phase—Hashimi and Nair[8] described the distribution patterns of the insoluble residues in these sediments. When these data are considered in terms of percentages of NLF and compared with the distribution pattern of calcium carbonate content in the sediments, it is seen that a major portion of NLF of the outershelf area is composed of only calcium carbonate phase. Further, the trace element data available in respect of oolites and shells of the outershelf region which contribute to the bulk of the calcium carbonate content indicate that the abundances of the elements are of the same order as those encountered in NLF of the outershelf region. It is, therefore, concluded that all the elements in the outershelf region are incorporated into the sediments in association with the carbonate phase. The low carbonate content of the innershelf sediments precludes the possibility of this phase making any significant contributions to the amounts associated with NLF of these sediments.

Adsorption on clays—Clay mineral assemblages reported[9-11] from the study area consist of montmorillonite, illite, chlorite and kaolinite with montmorillonite and illite predominating over the other two. The composition of the clay mineral assemblage particularly the presence of montmorillonite and illite in larger percentages is favourable for adsorption of elements especially trace elements from waters and their incorporation into the sediments. However, 3 factors, viz. (i) these clay minerals are detrital in origin and are introduced into the marine environment through river systems, (ii) they may be stripped off the trace elements adsorbed by them in the fluvial environment to a greater or lesser extent on contact with sea water[12] and (iii) rapid sedimentation taking place in the innershelf region, render them ineffective as good adsorbers in the nearshore regions.

Iron and manganese hydroxides—Rao *et al.*[2] encountered higher concentrations of Fe in NLF of the innershelf region and lower concentrations in NLF of the outershelf region. They attributed higher concentrations of Fe to the flocculation of colloids of Fe hydroxides brought by the various river systems in the innershelf region and the lower concentrations to its association with the carbonate phase in the outershelf region. From the fact that the sedimentary geochemistry of manganese is similar to that of iron and that there exists a close similarity between the distribution patterns of iron and manganese in these sediments, it is inferred that Mn in NLF of sediments is being incorporated in the same way as Fe. This is further substantiated by the strong correlation that exists between these 2 elements.

The colloids of Fe and Mn hydroxides formed in the river environments are capable of adsorbing the trace elements from the solutions in the environment and when they enter the marine environment, there is considerably less desorption of the trace elements associated with them than those with the clays[12]. Further, there can be further scavenging of the trace elements by these colloids in the marine environment during their settling in the innershelf region through flocculation. Thus it is considered that removal of the elements in association with hydroxides of Fe and Mn as the most effective process in the nearshore regions for the incorporation of trace elements in NLF. Distribution patterns of Ni, Cu and Co in these sediments and the inter-relationships obtaining among them support this conclusion.

A consideration of the contributions made by LF and NLF of the sediments to the concentrations in the total sediment samples clearly indicate that the ratio between them is uniformly high in case of Al whereas in the case of other elements it is highly variable. This could be due to the fact that geochemically Al is very inactive ($< 1\%$ exchangeable) whereas the other elements can partake in the exchange processes more freely.

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Seasonal Variations in Biochemical Composition of Some Seaweeds from Goa Coast

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Carbohydrate content in *Chaetomorpha media*, *Dictyota dumosa*, *Ulva fasciata*, *Padina tetrastromatica*, *Hypnea musciformis* and *Gracilaria corticata* was almost similar. Caloric content (5218 cal/g dry wt), organic carbon (29.17%) and lipids (11.62%) were high in *H. musciformis*, whereas *P. tetrastromatica*, *C. media* and *U. fasciata* were rich in protein. The biochemical constituents in general did not show marked seasonal variations and it was attributed to the reproductive pattern of the algae studied.

Seasonal variation in the biochemical composition of marine algae is well documented from temperate waters[1] but little is known of tropical forms. The rocky coast of Goa has abundant seaweed resources[2]. Considering their availability and contribution as food for benthic invertebrates either directly or indirectly as organic detritus, it has been thought worthwhile to study the seasonal variations in biochemical constituents and energy content in some seaweeds from Goa region.

Seaweeds from different localities of Goa coast were collected at monthly intervals for 1 yr except during July and August when due to monsoon, collection was not possible. The seaweeds, viz. *Chaetomorpha media* (Ag) Kutg, *Ulva fasciata* Delile, *Dictyota dumosa* Borgesen, *Padina tetrastromatica* (Hauck), *Hypnea musciformis* (Wulfen) Lamourk and *Gracilaria corticata* J. Agardh, were washed thoroughly with distilled water and dried in an oven at 70°C to constant weight. The dried material was homogenised and estimations of organic carbon[3], lipid[4] and carbohydrates[5] were made. Ash was determined by combusting the samples in a muffle furnace at 500°C for 8 hr. Percentage protein content was calculated by subtracting the values of ash, carbohydrate and lipid. For energy estimations, dry samples were pelleted and combusted in a Parr (1200) adiabatic microbomb calorimeter.

Chaetomorpha media—No definite trend was observed (Fig. 1) in protein content except for peak values during May, November and December (18.8%). Lipid was comparatively low (3.43%) between January and June than during September to December (6.2%). The reverse was true with reference to carbohydrate. Organic carbon and caloric content showed little fluctuation during the study.

Ulva fasciata—Protein, organic carbon and ash (Fig. 1) were more or less steady. Lipid increased from February to June and fluctuated thereafter. Carbohydrate showed a declining trend between January and June. Peak values (60%) were recorded during December and January. Energy content was fairly high from March to October (av. 4438 cal/g dry wt) and declined from November onwards to reach the lowest value of 2423 cal/g dry wt in February.

Dictyota dumosa—Protein content (Fig. 2) was fairly high during January and February and showed declining trend up to December, except for the random high values in June and September. No marked seasonal changes were observed in the levels of lipids, carbohydrate and ash contents. Organic carbon showed fluctuations during the first half of the year but during the later half it showed progressive increase.

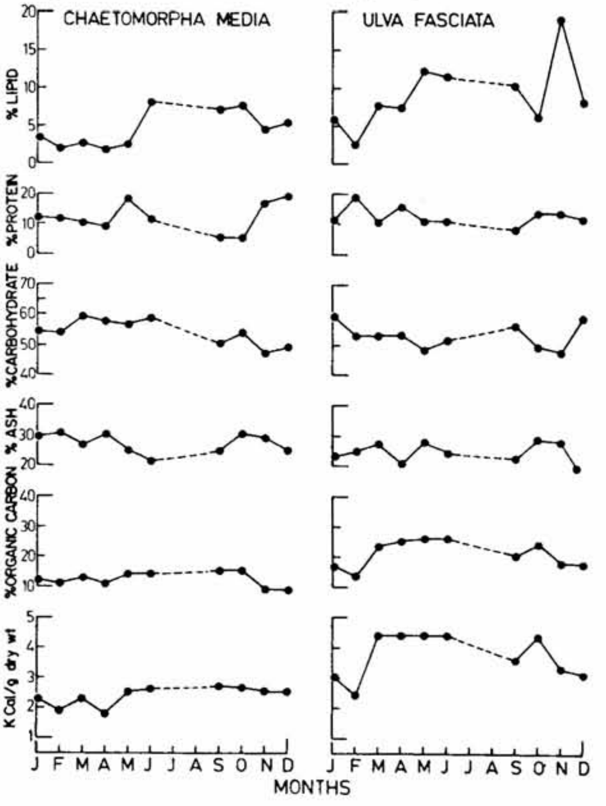

Fig. 1—Seasonal variations in biochemical composition of *C. media* and *U. fasciata*