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APPLICATION OF THE PRINCIPAL COMPONENT ANALYSIS (PCA) TO THE ECOLOGICAL STUDY OF AN ARTIFICIAL ENVIRONMENT: THE TUNNY-FISHING NET OF CAMOGLI (LIGURIAN SEA)

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INTRODUCTION

The rational exploitation of resources in sea water and the respect of weak mechanisms regulating production need the knowledge of some factors contributing to the correct management of the marine environment. In this connection, the management of fish stocks is important, as the fishiness in marine waters and the consequent commercial exploitation of valuable fish depend greatly on the knowledge of water conditions and fish migration, as well as on food availability for fish maintenance and growth. In particular, the availability and exploitation of stocks are affected by the use of environmental resources by fish, that consent to maintain the populations to an adequate quantitative level allowing the constant activity of sampling performed with fishing activities. In this context, the tunny-fishing of Camogli is a peculiar system, as example of a structure designed for commercial fishing that also contributes to improve the trophic resources, as its coco-fibre net allows the settlement of organisms already indicated to be food for some fishes or indirectly involved in calling of valuable species (1).

On the ground of previous data (2,3), the aim of this paper is to define the composition and distribution of the populations during spring-summer 1988 using microscopical methods and multivariate analysis, and to evaluate the relationships between abundance and composition of populations and results of fishing.

MATERIALS AND METHODS

Specimen sampling and classification - Two coco-ropes like those used for net weaving, 39- and 41 m-long respectively, were plunged in April 1988; the ropes were weighed after two (June) and four (August) months respectively and kept in a formalin solution (4%). Settled organisms were classified by a Zeiss SR stereomicroscope and a Zeiss Lab16 microscope by observing a subsample 1 cm long every 50 cm of rope; totally, 160 subsamples were observed. For hydroids each colonial form was counted as a single entity. The data of fishing activity during the spring-summer 1988 were also evaluated to relate populations with fishing results.

Data transformation - Since all the variables have a high skewness, a logarithmic transformation has been applied. Since some of the data are 0's, the following transformation has been applied: $x_{tr}=\log10(x_{or}+1)$. After this transformation, all the variables have a near normal distribution.

Autoscaling - After the logarithmic transformation the data have been autoscaled. This is done by subtracting from each variable value the average of all the values for that variable and then by dividing each of such modified values by the standard deviation of that variable. After autoscaling, all the variables have the same importance, since they all have average = 0 and standard deviation = 1.

Principal Component Analysis (PCA) - Among the methods of multivariate analysis, Principal Component Analysis is one of the simplest and of the most used (4). This technique identifies, in the hyperspace of the variables in which each sample is a point defined by a number of coordinates equal to the number of variables, the directions on which the main part of the information is retained. These new directions (Principal Components) are linear combinations of the original variables and can be used as axes for a bi- or tridimensional plot allowing to display a great percentage of the information contained in the whole data set. As a result, it reduces the dimensionality of the data and extracts the most relevant part of the information.

Software - The elaboration has been performed by using programs written by one of the Authors in the Matlab (Mathworks, Natick, USA) environment.

RESULTS

Table 1 shows the composition of the settled population. In both samples the main groups were peritrich ciliates, hydroids, nematodes and copepods; starting from 21 metres depth of the first sample and in the whole second sample also foraminiferida were abundant. The peritrichs (Vorticella sp.) teemed mostly in the first sample. Tintinnid species showed a different distribution: in June Tintinnopsis campanula prevailed mostly at lower depths; in deep sections Tintinnopsis nucula and Codonella galea were also rather abundant, while other species were sporadic. In August Undella sp. and Codonella galea prevailed mostly. Hydroids were abundant and occurred at every depth, with a maximum in surface waters. In shallow waters Clytia johnstoni and Obelia geniculata prevailed, while in deepest levels Cuspidella sp. was found abundantly. In August Eudendrium sp. and Podocoryne sp. were observed in shallow sections. The Nematodes were often the dominant group in both samples. Harpacticoid copepods were distributed quite uniformly; they were quite scarce in June and increased in August in surface and at deep levels. Several nauplii were also observed.

On the whole, a global population decrease, particularly evident for peritrichs, tintinnids and gasteropods, was observed from June to August; otherwise, copepods showed a moderate increase. As concerns fishing results, Sarda sarda and Auxis rochei were frequently caught; other main species were quite scarce. Nevertheless, several species were grouped in "others", therefore it was impossible to know their abundance (tab. 2).

The same conclusions can be obtained in a much easier and faster way by applying a multivariate technique. The plots of the PCA, performed on the autoscaled log-transformed data, are shown in figs. 1 and 2; the plots of the scores on the plane of the first two Principal Components, explaining 47% of the total variance, clearly show the presence of two

Tab. 1 - Occurrence and distribution of the organisms settled on the coco-rope. Counted specimens are the sum of two subsamples of 1 cm each 50 cm of rope.

Depth	Foraminiferida		Peritrichs		Tintinnids		Hydroids		Nematodes		Gasteropods		Bivalvia		Copepods		nauplii		others	
(m)	June	Aug.	June	Aug.	June	Aug.	June	Aug.	June	Aug.	June	Aug.	June	Aug.	June	Aug.	June	Aug.	June	Aug.
0-1	0	62	49	11	0	0	458	974	317	664	0	0	7	15	50	69	22	37	5	6
1-2	0	73	415	0	0	1	743	348	793	370	1	0	8	6	48	97	22	7	6	8
2-3	0	52	199	0	0	0	461	431	252	469	1	0	4	6	29	49	8	15	23	15
3-4	1	33	217	2	0	2	469	818	433	318	0	0	4	6	9	46	17	8	10	9
4-5	2	72	52	6	0	0	871	1048	625	830	0	1	3	14	23	99	5	47	25	26
5-6	0	73	390	0	0	0	796	520	747	687	1	0	6	4	24	87	32	17	15	20
6-7	0	97	19	2	0	3	1089	1480	1179	680	2	0	5	0	15	109	11	51	6	41
7-8	0	29	338	0	0	3	1170	911	942	551	0	0	5	3	25	35	9	29	15	7
8-9	0	68	78	1	1	1	691	546	1064	348	1	1	5	15	16	28	3	17	17	10
9-10	0	74	532	0	0	0	1162	719	698	338	1	1	3	7	21	27	1	38	8	21
10-11	0	89	982	2	1	1	1563	1281	706	372	4	0	6	9	27	28	21	33	12	18
11-12	2	35	421	6	0	0	894	733	792	299	2	0	2	3	29	43	14	7	18	8
12-13	0	154	94	0	2	1	807	590	263	290	0	0	3	19	20	65	15	12	3	23
13-14	1	180	1653	0	3	0	969	283	594	158	91	0	4	2	22	18	11	3	22	2
14-15	1	164	1456	5	0	0	955	403	535	258	3	0	4	5	34	79	17	18	7	14
15-16	0	108	55	4	0	2	125	563	240	180	27	0	1	6	19	47	11	7	5	10
16-17	1	146	249	1	2	0	180	606	324	130	25	0	4	9	12	37	3	4	13	8
17-18	1	217	247	3	0	2	341	175	617	200	23	1	3	17	19	59	9	7	5	7
18-19	0	72	180	2	3	1	393	388	334	148	49	0	3	3	11	19	9	15	7	7
19-20	0	81	84	0	3	1	196	240	401	150	25	0	0	3	20	13	2	7	3	4
20-21	1	49	41	1	1	1	376	39	298	105	7	0	2	7	8	25	4	0	4	20
21-22	181	78	207	0	7	4	226	23	543	97	37	0	3	1	10	24	14	3	13	2
22-23	187	104	267	0	7	1	135	154	559	122	30	0	6	8	25	19	7	3	7	6
23-24	16	99	563	1	8	4	444	330	523	137	27	0	2	8	49	29	42	18	6	503
24-25	112	74	145	5	4	9	335	270	434	94	86	0	5	5	28	6	9	12	7	11
25-26	172	100	199	5	17	4	206	99	365	124	62	2	6	5	26	10	8	3	26	5
26-27	100	116	237	32	2	4	280	296	310	155	19	0	7	3	24	8	18	12	2	58
27-28	132	97	273	50	6	4	253	201	539	228	26	0	4	4	20	22	13	35	12	24
28-29	215	130	483	9	5	2	398	148	401	89	16	0	6	4	21	15	5	9	4	7
29-30	174	89	165	12	5	4	391	298	460	140	21	0	5	6	21	27	12	9	10	4
30-31	279	52	211	470	8	2	462	466	525	245	10	0	6	3	28	13	16	9	0	23
31-32	146	135	170	316	5	1	352	68	416	153	5	0	2	11	19	66	16	23	2	6
32-33	264	115	188	13	5	3	355	204	628	136	42	1	20	5	27	40	27	14	8	12
33-34	455	52	906	54	21	0	491	135	746	92	22	1	11	3	45	19	17	10	10	7
34-35	278	87	284	86	5	1	240	68	463	112	30	0	10	6	26	37	7	12	4	4
35-36	209	135	303	19	6	0	443	92	555	84	8	0	15	4	27	42	12	14	16	10
36-37	233	111	60	19	10	0	378	69	512	89	10	0	23	9	14	58	14	3	3	15
37-38	251	107	58	0	12	0	186	43	499	107	10	0	24	7	10	41	17	8	18	12
38-39	140	105	183	0	13	0	40	58	300	102	1	0	15	4	27	34	23	5	10	23
39-40		50		0		0		46		68		1		3		17		1		16
40-41		78		0		0		2		38		1		2		7		5		24

Tab. 2 - Results (in Kg) of the fishing activity in the tunny-fishing of Camogli during the campaign 1988.

month	*Thunnus thynnus*	*Auxis rochei*	*Sarda sarda*	*Xiphias gladius*	*Scomber* spp.	others
April	0	700	6290	0	95	19200
May	0	3260	4500	65	150	8700
June	0	440	870	0	320	11750
July	20	130	125	50	185	4600
August	0	985	0	0	105	2045

independent effects. In figure 1a the samples are coded with the rope number. From it, it can be seen that Principal Component 1 quite efficiently separates the two ropes, since the scores of the samples from rope 1 (June) are higher (they are on the right hand side of the plot). When taking into account also the plot of the loadings (fig. 2), this difference can be ascribed to peritrichs, tintinnids and gasteropods (variables 3, 6 and 8, respectively), whose amount was greater in June, while copepods (variable 4) are more present in August. In figure 1b the samples are coded according to the sampling depth. From it, it can be seen that this kind of information is explained by Principal Component 2, the samples at lower depths having higher scores (they are at the upper side of the plot) than the samples at higher depths. When taking into account also the plot of the loadings (fig. 2), this difference can be ascribed to nematodes, hydroids, copepods and nauplii (variables 1, 2, 4 and 7, respectively), whose amount is greater in the samples from low depth.

DISCUSSION

In this study the composition and distribution with depth and season of organisms settled on coco-rope were evaluated. Protists (foraminiferida and ciliates), hydroids, nematodes and copepods prevailed and occurred almost everywhere. Other organisms were scarce and often sporadic. From spring to summer peritrichs, tintinnids and gasteropods decreased, while copepods increased. In particular, peritrich ciliates (Vorticella sp.) showed wide distribution in spring; this greatly differs from previous results (3), that reported sporadic findings of these organisms. Ciliates were indicated to play a role in pollutant transfer and transformation in the sea (5); furthermore, they were used in toxicological and pollution studies (6); morphological and dimensional alterations of intracellular organelles as consequence of the exposition to heavy metals were also observed (7). Nevertheless, since different species of Vorticella prefer different water conditions (8), is extremely difficult to explain the reasons of the observed outbreak. As concerns the possible relationships between populations and water quality in the studied area, recent studies carried out in neighbouring zones of the Gulf of Genova (9-11) have emphasized no critical condition of the water; nevertheless, owing to the growing worsening of water quality, a qualitative alteration of environmental characteristics or a rarefaction of predators promoting the growth of these ciliates can be hypothesized. Fair quantities of Tintinnids were found, despite they are typical planktonic organisms. As concerns Hydroids, it's known that these epibenthic organisms grow remarkably on artificial substrata (12). The different composition and distribution of Hydroids found in June and August agrees with other studies that pointed out the variations with depth due to the normal biological cycle, lighting, hydrodynamic factors and competition for the substratum (13). On the other hand, as biotic and abiotic stimuli can promote settlement in Cnidaria (14), the environmental conditions and also the trophic contribution of rope population can have promoted the settlement and metamorphosis of larval Hydroids. As the occurrence of Hydroids is increased remarkably as to previous results (3), considering that interference with metamorphosis was observed in Hydrozoa subjected to xenobiotics (15), the presence of adequate environmental conditions can be supposed.

As concerns other frequently found organisms, Nematodes increased as to previous studies (3) and were found abundantly in both samples. The massive occurrence of these organisms can have an ecological significance, as was reported that species diversity and density of nematodes is low in polluted sites (16). Copepods are distributed uniformly enough in the two samples and increased in deep levels. Bivalvia, that frequently occur in surface substrata, were found occasionally; as reported (17), this perhaps can be due to the reduction of space available for settlement occupied by other sessile organisms.

The elaboration of data showed how a multivariate technique such as PCA allows a much easier and complete interpretation of a complex data set; the existence of a "rope" and of a "depth" effect have easily been detected.

The tunny-fishing of Camogli was indicated as a "biological sampler" (1), as it is able to catch several fish species as well as tuna fish. Acquired data seem to show better fishing results as to the previous years; the correspondence with the increase of rope organisms seems to confirm their influence in the attraction of fishes (2,18).

The management of the marine environment and resource exploitation depend on the knowledge of both water conditions and ecological relationships between organisms. In the framework of fishing problems, an adequate food availability is important in order to allow maintaining and growth of fish stocks. The tunny-fishing of Camogli, owing to the coco-fibre texture of its net, can improve the trophic resources allowing the settlement of organisms eaten by fish. The distribution and composition of settled organisms was studied during the campaign 1988 by microscopical methods. The results have been elaborated by using multivariate (PCA) methods. Foraminifers, ciliates, hydroids, nematodes and copepods were the mainly observed groups. Their variations with season and depth and the relationships with caught fish species are presented. The elaboration of data by PCA allowed an easy and complete interpretation of the obtained complex data set showing the existence of a "rope" and of a "depth" effect.

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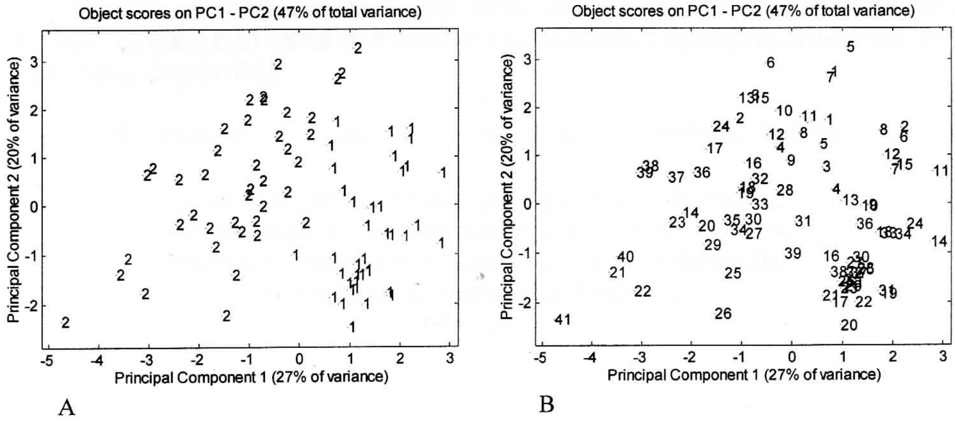

Fig. 1 - Plot of the scores on the Principal Component 1 - Principal Component 2 plane. In A the objects are coded according to the sampling period (1 = June, 2 = August); in B the objects are coded according to the depth.

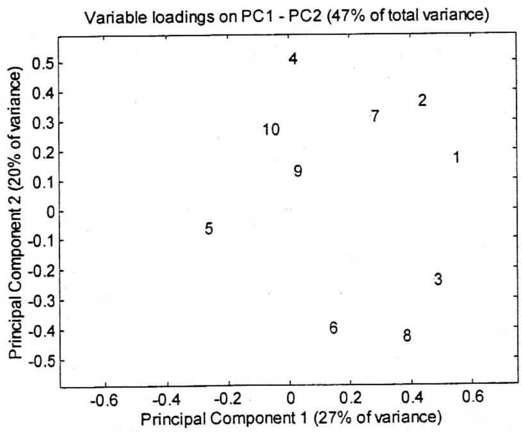

Fig. 2 - Plot of the loadings on the Principal Component 1 - Principal Component 2 plane. The code of the variables is the following:
1: nematodes, 2: hydroids, 3: peritrichs, 4: copepods, 5: foraminiferida, 6: tintinnids, 7: nauplii, 8: gasteropods, 9: bivalvia, 10: others.