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COENOTIC STRUCTURE, SKULL ASYMMETRIES AND OTHER MORPHOLOGICAL ANOMALIES IN SMALL MAMMALS NEAR AN ELECTRONUCLEAR POWER PLANT

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ABSTRACT – A nuclear power plant was in operation in the Garigliano alluvial plain (Central Italy) from 1964 through 1978, a period marked by several accidents. The nuclear site is now utilized for storage of radiactive wastes of low, medium and high activity. 3626 **skulls** of small mammals were found in Barn Owl (*Tyto alba)* pellets, collected during 1987 from 8 different sites near the plant. Eight biotic indices were applied: the results show a medium-high degree of theriocoenotic diversification, a trophic level index generally within the limits of the values recorded in South-Central Italy, and a low value for the index of environmental management. In particular, the pellets found on the site closest to the nuclear power plant are characterized by a higher proportion of *Suncus etruscus* and *Rattus rattus* and show an increase of two thermoxerophyly indices, in comparison with the other sites of the district, which might be related to variations of some environmental parameters. **A** further analysis was done for each site, in comparison with other control sites, with the aim of verifying heterolateral asymmetries in the molar tooth-set and other skull anomalies. The results show a significant increase of molar asymmetries in *Microtus* savii ($p < 0.02$) and skull anomalies in *Crocidura* sp. pl. (ps0.05).

Key words: nuclear power plant sites, small mammals, biodiversity, bioindicators, morphological asymmetry.

RIASSUNTO – Stnitfiira *biocenotica, asimmetrie craniche* e altre *anomalie morfòlogiche in* piccoli *mammiferi presso un impianto elettronucleare* – La centrale nucleare della piana alluvionale del Garigliano ha funzionato dal 1964 al 1978, un periodo caratterizzato da numerosi incidenti; inoltre il sito nucleare è adibito all'immagazzinamento di scorie radioattive di bassa, media e alta attività. 3626 crani di piccoli mammiferi, selezionati da borre di Barbagianni (*Tyto alba),* sono stati raccolti nell'anno 1987 in otto siti collocati nell'area di impatto dell'installazione. **E'** stata applicata l'analisi di otto indici biotici: i risultati mostrano un grado medio-elevato di diversificazione teriocenotica, un indice di livello trofico generalmente compreso tra il limite dei valori tipici dell'Italia centro-meridionale e inoltre un basso valore dell'indice di gestione ambientale. In particolare il sito compreso nell'area di rispetto della centrale nucleare, si caratterizza per un'elevata proporzione di *Suncus etruscus* e di *Rattus rattus*; per tale sito i valori di due indici di termoxerofilia mostrano rispetto agli altri siti del comprensorio un aumento che pub essere messo in relazione con la variazione di qualche parametro ambientale. Si è quindi verificato se nelle aree considerate le asimmetrie etero-laterali delle file dentarie molari ed altre anomalie craniche fossero più elevate che in altri siti di confronto. E' stato trovato un aumento significativo delle asimmetrie ($P < 0,02$) in *Microtus savii* e delle anomalie craniche in *Crocidura* **spp.** ($P \leq 0,05$).

Parole chiave: siti nucleari, piccoli mammiferi, biodiversitb, bioindicatori, asimmetria morfologica.

INTRODUCTION

In previous studies on natural populations of Murine Rodents used as biological indicators in the impact area of the electronuclear power plant of Garigliano, mutagenicity tests and dosimetric measurements were performed on carcasses together with the study of phenetic alterations (Cristaldi and Lombardi Boccia, 1982; Cristaldi et al., 1985).

In the same area territorial contamination, due to the function of a nuclear power plant (BWR), is monitored through a radiological control of matrices correlated with human food (ENEA-DISP, 1986a). This type of plant is characterized by the release in different proportions of the radionuclides Co-60, Cs-137, Cs-134, H-3, C-14, Ni-59, Ni-63, Sr-90, Nb-94, Tc-99, 1-129 and transuranic elements (De Crescenzo and Laraia, 1989). Cs-137 and Co-60 contamination was found in sediments collected in the Gulf of Gaeta and in the Garigliano river (Anselmi et al., 1981; Papucci and Lavarello, 1983). According to Tomaselli et al. (1973) this area belongs to thermoxerophilous mediterranean region; the ecological and biocoenotic characteristics of this area were studied through the analysis of vegetation (Blasi and Fascetti, 1982). .

The present investigation studies the impact of the power plant with the aim to understand the theriocoenotic (i.e being a theriocoenosis the small mammal species composition of local community or taxocoene) alterations of that particular area through the study of the trophic systems Barn Owl - small mammals (Contoli, 1976; Aloise and Contoli, 1984; Amori and Pasqualucci, 1987). Several advantages are associated with the analysis of Barn Owl (*Tyto alba*, Strigiformes) pellets (Glue, 1970; Chaline et al., 1974), in particular, the high euriphagia of this owl and the abundance of the samples obtainable with such method (Uttendoerfer, 1952; Contoli, 1975; Cramp and Simmons, 1981).

Several investigations devoted to the study of skull asymmetries (Van Valen, 1962; Valentine et al., 1973; Cristaldi et al., 1982; Soulé, 1982; Caronna and Parisi, 1983; Patterson and Patton, 1990; Zakharov and Yablokov, 1990) evidentiated the potential use of this analysis in the detection of environmental stress (Cristaldi et al., 1985, 1992; Pankakoski, 1985; Cavedon et al., 1992; Zakharov and Graham, 1992). It should be pointed out that an increased level of fluctuating asymmetry is not restricted to the effects of radiations, but it reflects the effects of various stressfull agents on animal populations (Cavedon et al., 1990; Pankakoski al., 1992; Graham et al., 1993). In this paper an analysis of asymmetries in dental tubercles of superior molars in Savi's pine vole (*Microtus savii*) and cranial anomalies in the shrews of the genus *Crocidura* was carried out to complete the previously collected data on biological indicators.

E.I.A procedures entail the integration of very different analyses, whose sensitivity to different stress factors may not be uniform. Therefore, we decided to investigate whether possible alterations in the ecological pattern of a polluted area would be accompained by biological alterations. To this end, two methodologies were used, the evaluation of theriocoenotic structures and the analysis of skull anomalies and asymmetries.

MATERIALS AND METHODS

The impact of the Garigliano electronuclear power plant covers an area including the alluvial plain of the Garigliano river which flows into the Gulf of Gaeta, the south-western slopes of Aurunci Mountains, the Roccamonfina volcanic complex to the East and the Mt. Massico to the South. The region is scarcerly inhabited, with a few urban areas. The power plant is a 160 MW BWR type located on a meander of the Garigliano River built between 1959 and 1963 by General Electric which began to operate in 1964 under the management of the Italian Agency for Electric Power (ENEL). Waters of the Garigliano river were used for cooling and removal of liquid wastes, whereas gaseous wastes were removed through one of the two chimneys. Intermediate and high activity wastes were stored in special underground vessels within the plant area. The total estimated activity for 1990 (18.2 TBq $\div$ $87 \cdot 10^3$ TBq where 1 TBq $= 10^{12}$ **Bq)** represents the 1% of the activity present before the transfer (December 1987) of nuclear fuel to Saluggia (VC) (ENEA-DISP, 1991). During the years a number of accidents occurred, nine of which were severe with radioactive liquid and gas releases (Cristaldi, 1994). An accident occurred on August 8th, 1978 and determined the plant shut-down after 15 years of operation (CNEN, 1980). Overflowing of the river into stocking vessels followed by extensive water spills caused a further contamination of the area (De Crescenzo and Laraia, 1989). The Chernobyl accident occurred in Ukraine in April 1986 caused a negligible fall-out contamination in that area (ENEA-DISP, 1986b).

Data obtained from the contents of pellets of *Tyto alba* were collected from February to July 1987, about ten years after the interruption of power plant activity (ENEL-DPT, 1990) in eight roosting sites, four of which closer to the plant (marked "I" = internal), the other four in a coastal area (marked "E" = external). The alleged hunting territory was symbolized with a circle of **2** Km of diameter, according to Géroudet (1965). With regard to the Barn Owl of site 1 it must be underlined that only the area surrounding the power plant is possibly used for hunting, due to exceedingly overlapping of "1" and "**2**" areas (Fig. 1).

Pellets were dry sorted and skulls were separated for taxonomic identification. 3626 small mammal specimens were collected and classified using the diagnostic keys of Toschi and Lanza (1959), Chaline et al. (1974), Corbet (1978), Vesrnanis et al. (1979), Amori et al. (1986). Their distribution is shown in Tab. 1; data were analyzed using some ecological indices useful for determining environmental conditions (Tab. 2).

With regards to the morphological aspects, the species considered were:

a) *Microtus savii* - Asymmetries of dental tubercles of upper molars were recorded, taking into account 30 randomly chosen specimens for each of the seven considered sites (except site 8, owing to the small number of specimens). Reference dental types (according to Contoli, 1980a) were compared on six sites scattered all over Central and Southern Italy (Tab. 3 and dental types in Fig. 2).

b) *Crocidura* spp. - Cranial and dental anomalies on 466 specimens of lesser white-toothed shrew (*Crocidura suaveolens*) and 133 of two bicoloured

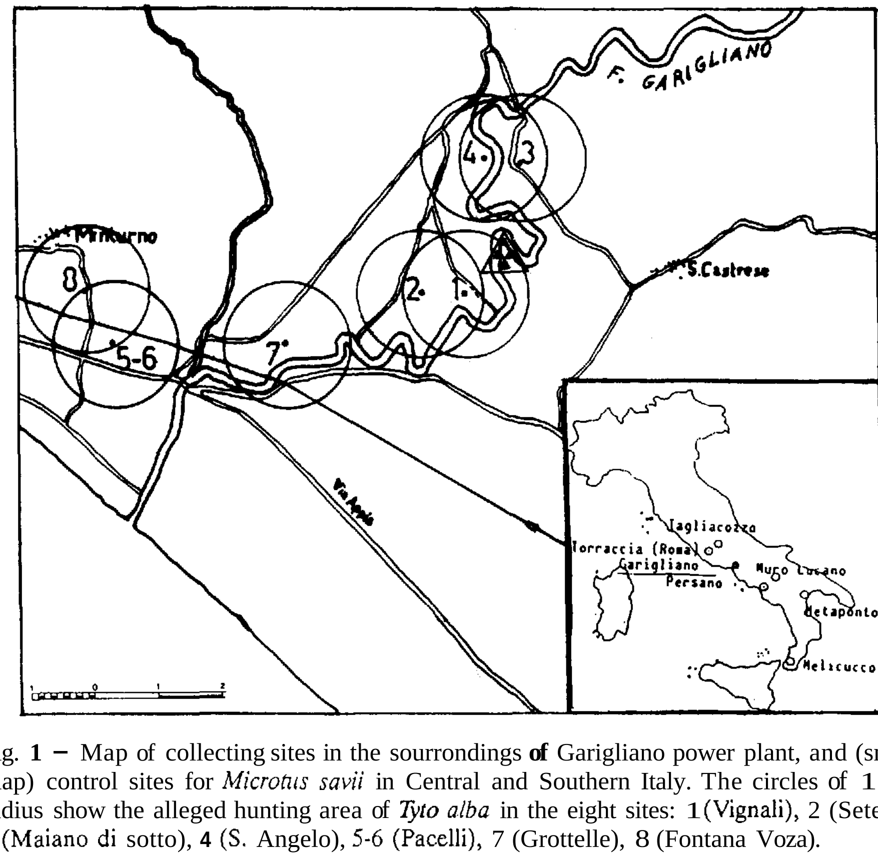

Fig. **1** – Map of collecting sites in the sourrondings **of** Garigliano power plant, and (small map) control sites for *Microtus savii* in Central and Southern Italy. The circles of 1 Km radius show the alleged hunting area of *Tyto alba* in the eight sites: 1 (Vignali), 2 (Setera), *3* (Maiano di sotto), **4** (S. Angelo), 5-6 (Pacelli), 7 (Grottelle), 8 (Fontana Voza).

white-tooted shrew (*Crocidura leucodon*) for the eight sites were recorded. **A** statistical comparison was made with data from literature (see Tab. 4).

In our statistical analyses, mainly non-parametric tests were preferred, due to the lack of information that is required to perform parametrical analyses.

RESULTS

BIOTIC INDICES

The Insectivore / Rodent ratio (Index of Trophic Level, see Contoli, 1980b) was rather high. The sites fell into the distribution range of other peninsular sites in Italy (Contoli, 1988a), with the exception of site **2** which showed an index of trophic level higher than expected (see Tab. **2).**

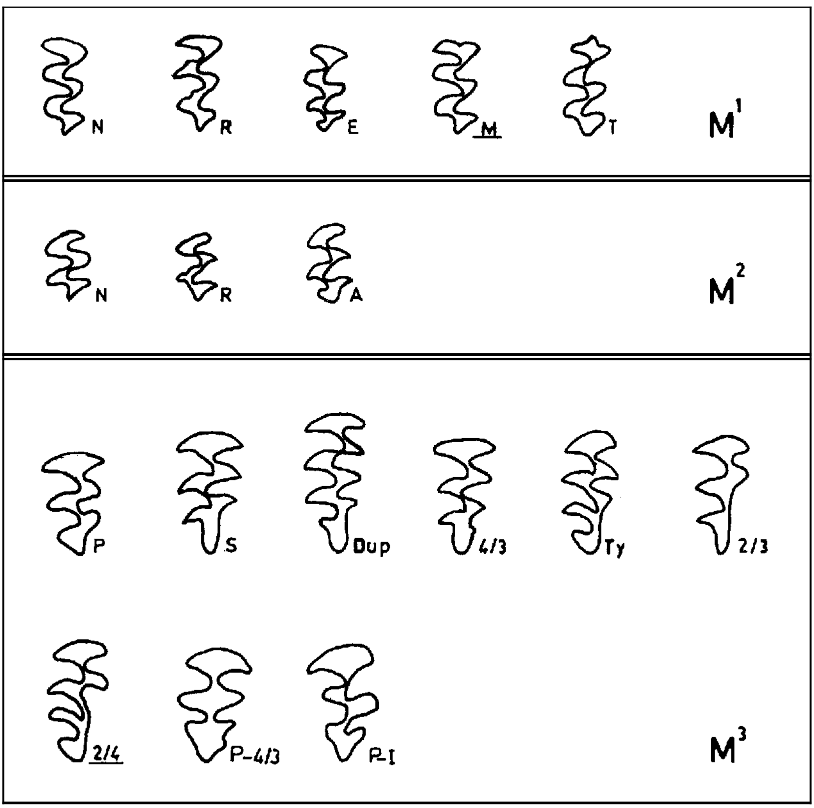

Fig. 2 – Upper left molar dental types of *Microtus savii* classified according to their shape and numbers of tubercles (Contoli, 1980a): N = "normalis"; R = "radnensis"; E = "exul"; M = "minturnae"; T = "tolfae"; **A** = "agrestis"; **P** = "persimplex"; **S** = "simplex"; Dup = "duplicata"; **4/3** = "**4** labialis /3 lingualis"; Ty = "typica"; **2/3** = "**2** labialis /**3** lingualis"; 2/4 = "2 labialis / **4** lingualis"; I = "ibericus" (the forms originally described in this study are underlined).

Tab. 1 – Numbers and percentages of small mammals in the sites studied at Piana del Garigliano.

SPECIES	SITE 1		SITE 2		SITE 3		SITE 4		SITE 5		SITE 6		SITE 7		SITE 8	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Suncus etruscus	36	15.2	22*	9.3	37	3.0	71	8.3	33	10.3	36	12.7	63	17.0	12	11.7
Crocidura suaveolens	12	5.1	43	18.1	118	9.7	142	16.5	59	18.4	49	17.4	32	8.7	11	10.8
Crocidura leucodon	3	1.3	17	7.1	54	4.4	39	4.5	6	1.9	5	1.8	7	1.9	2	2.0
Crocidura sp.							1	0.1								
CROCIDURINAE TOT.	51	21.6	82	34.5	209	17.1	253	29.4	98	30.6	90	31.9	102	27.6	25	24.5
Talpa romana			1	0.4	7	. 0.6	4	0.5	1	0.3			2	0.5	1	1.0
TALPIDAE TOT.			1	0.4	7	0.6	4	0.5	1	0.3			2	0.5	1	1.0
INSECTIVORA TOT.	51	21.6	83	34.9	216	17.7	257	29.9	99	30.9	90	31.9	104	28.1	26	25.5
Muscardinus avellanarius					10	0.8	2	0.2								
GLIRIDAE TOT.					10	0.8	2	0.2								
Microtus savii	37	15.7	47	19.7	217	17.8	192	22.3	32	10.0	31	11.0	91	24.6	7	6.8
Arvicola terrestris	12	5.1	10	4.2	12	1.0	8	1.0	9	2.8	6	2.1	9	2.4	2	2.0
ARVICOLIDAE TOT.	49	20.8	57	23.9	229	18.8	200	23.3	41	12.8	37	13.1,	100	27.0	9	8.8
Apodemus sylvaticus	99	41.9	84	35.3	649	53.3	313	36.4	154	48.1	118	41.8	143	38.7	53	52.0
Rattus rattus	30	12.7	8	3.4	35	2.9	49	5.7	13	4.1	23	8.2	12	3.2	9	8.8
Rattus sp.			5	2.1	37	3.0	20	2.3			3	1.1	6	1.6	2	2.0
Mus domesticus	7	3.0	1	0.4	42	3.5	19	2.2	13	4.1	11	3.9	5	1.4	3	2.9
MURIDAE TOT.	136	57.6	98	41.2	763	62.7	401	46.6	180	56.3	155	55.0	166	44.9	67	65.7
RODENTIA TOT	185	78.4	155	65.1	1002	82.3	603	70.1	221	69.1	192	68.1	266	11.9	76	***14.5***
MAMMALIA TOT	236	-	238	-	1218	-	860	-	320	-	282	-	370	-	102	-

The faunistic affinity among sites (Dice-Sørensen's Index, see Dice, 1945) was high ($x = 0.92$), as well ($x = 0.80$) as the biocoenotic affinity (Renkonen Index, see Renkonen, 1938). The Mann-Whitney U test results showed no significant difference between internal and external sites, even if the number of sites is quite low.

The medium-high values of the Gini-Simpson's Index (see Gini, 1912) of biotic diversity ($0.6 < x < 0.8$) were comprised within the range of values of other Barn Owl sites in Italy (Contoli, 1988b) and within the range of medium-high values observed in other ecosystems (Odum, 1975). On the other hand, the *Microtus* / Murinae Index of Environmental Management (see Contoli et al., 1978) showed very low values for all sites, and the correspondent U test showed also a non significant difference between "I" and "**E**" sites.

As expected, the values of the thermoxerophyly indexes (see Contoli, 1980b) were lower in "I" sites than in the "E" sites closer to the coast; the only exception was site 1 where the values of thermoxerophily were higher than those of all other sites (see Tab, 2). So the site 1 seemed to be an outlier whith respect to the other sites of territory (Dixon test: $r_{11} = 0.6011$, $p < 0.05$, one tail; see Sokal & Rolf, 1981).

LEVELS OF ASYMMETRY IN *MICROTUS SAMZ*

Incidentally some new dental types (named M, 2/4, see Fig. 2) according to the reference types suggested by Contoli (1980a) were recorded. They were found in symmetrical and asymmetrical situations in the 210 examined specimens. The recorded asymmetries appeared to be associated with each of the three molars, being most common for M^3.

The frequencies of morphological asymmetries and asymmetrical animals recorded for each of the seven sites were found significantly higher (**P** < 0.02) than those of the six control sites scattered all over Central and Southern Italy (Fig. 1, Tab. 3) using the Mann-Whitney U test (see Sokal and Rohlf, 1981).

ASYMMETRIES AND OTHER ANOMALIES IN *CROCIDURA* SP. PL.

Both dental and cranial asymmetries and anomalies were observed (Tab. **4)**:

- a specimen from site 4 was so anomalous that it could not be positively identified at the species level (Fig. **3);**

- from site **4,** two specimens of *Crociduru suaveolens* had the unicuspids of one side missing, while another showed a reduction of the counterlateral unicuspids and the obliteration of the lateral nasopalatine foramina;

- from site 7 a specimen of *Crociduru suaveolens* showed alterations similar to those of site 4, associated with rostral alterations on the left side;

Tab. 2 – Values of the indices calculated for each of the studied sites. Average values for Renkonen and Dice-Sørensen indices are given; for other indices exact values are presented.

SITES	THERMOXEROPHILY INDEX	GINI-SIMPSON INDEX	TROPHIC LEVEL INDEX	ENVIRONMENTAL MANAGEMENT INDEX	RENKONEN INDEX	DICE-SØRENSEN INDEX
1	0.70	0.72	0.22	0.27	0.79	0.89
2	0.27	0.81	0.53	0.48	0.80	0.95
3	0.18	0.66	0.18	0.28	0.78	0.92
4	0.28	0.81	0.30	0.48	0.82	0.89
5	0.34	0.75	0.31	0.18	0.82	0.93
6	0.40	0.73	0.32	0.20	0.83	0.92
7	0.62	0.80	0.28	0.55	0.80	0.95
8	0.48	0.67	0.25	0.10	0.80	0.95

Tab. 3 – *Microtus savii*: numbers and percentages of asymmetries and asymmetric specimens collected in seven sites of Piana del Garigliano, compared with six sites of Central and Southern Italy. * The rather elevate percentage of asymmetries observed in Torraccia (Rome) - the higest among control sites - might be attributed to the vulcanic origin of the Castelli Romani area, subjected to relatively elevated levels of natural radioactivity.

SITES	NO. ANIMALS OBSERVED	NO. ASYMMETRIES	%	NO. ASYMMETRIC ANIMALS	%
1	30	6	20.0	5	16.7
2	30	5	16.6	4	13.3
3	30	5	16.6	4	13.3
4	30	4	13.3	4	13.3
5	30	5	16.6	5	16.6
6	30	7	23.3	5	16.6
7	30	11	36.7	9	30.0
CONTROL SITES					
Melicucco (RC)	30	1	3.3	1	3.3
Metaponto (MT)	30	3	10.0	3	10.0
Muro lucano (PZ)	30	1	3.3	1	3.3
Persano (SA)	30	3	10.0	3	10.0
Torraccia (ROMA)	30	6	*20.0	6	*20.0
Tagliacozzo (AQ)	30	1	3.3	1	3.3

Tab. 4 – *Crocidura* genus: numbers and percentages of anomalies and of anomalous specimens collected in Internal ("I") and External ("E) sites of Piana del Garigliano.

SITES	NO. ANIMALS OBSERVED	No. ANOMALIES	%	NO. ANOMALOUS ANIMALS	%
SITE 4 ("I")	181	16	8.8	4	2.2
SITE 7 ("E")	39	4	10.2	2	5.1
TOT. FOR INTERNAL SITES (1,2,3,4)	428	16	3.7	4	0.9
TOT. FOR EXTERNAL SITES (5,6,7,8)	171	4	2.3	2	1.2

- another conspecific specimen from site 7 showed asymmetries of the counterlateral nasopalatine foramina.

Moreover skulls collected in the peninsular Italy and belonging to the "C.M.L.C." micromammal collection (Genowais and Schlitter, 1982), were used as reference material for cranial anomalies in *Crocidura* **sp.** pl. No anomalies were found in such material. We used the collection material up to the fulfilment of the numbers requested by the significance level (**P** < 0.05) for the U test (i.e.: 20 provinces) and **P** < 0.01 for the confidence

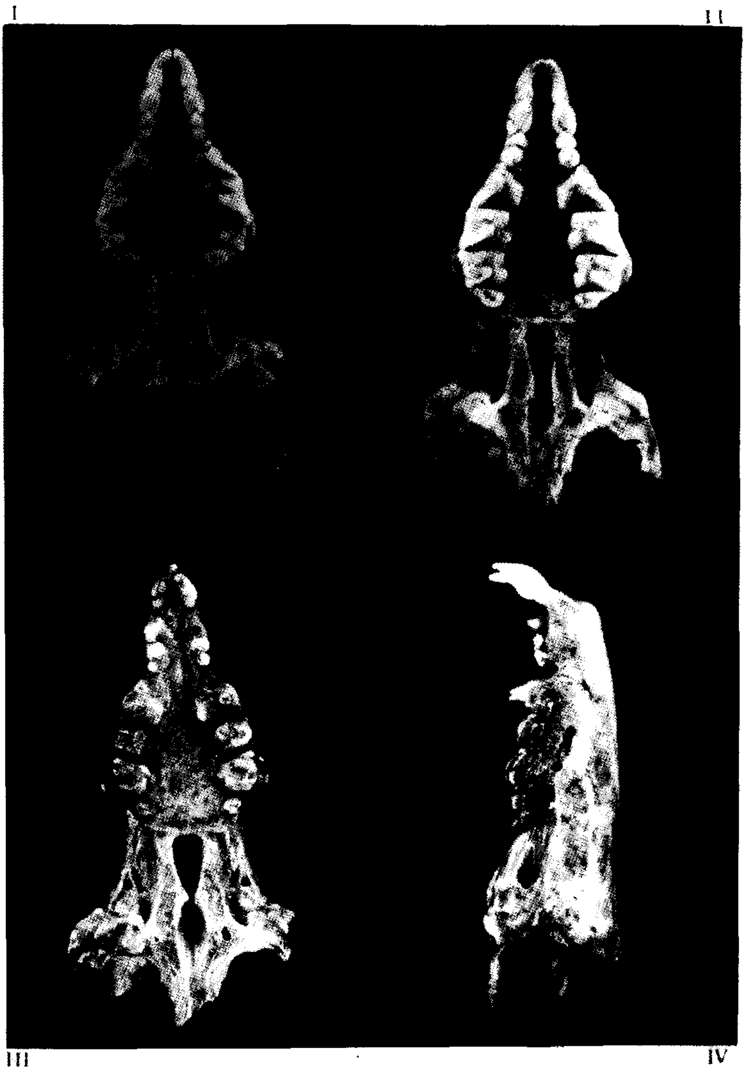

Fig. 3 — Skulls. I: norma ventralis (n.v.) of *Crocidura suaveolens* normal specimen (No. **23** from site 6); **II**: n.v. **of** *C. leucodon* normal specimen (No. 7 from site **4)**; **III**: n.v. of *Crocidura* **sp.** anomalous specimen (No. 1 from site **4)**; **IV**: norma lateralis of the left side of **the** same specimen.

limits for percentages (i.e.: 500 specimens). The null hypothesis was rejected in both instances. In fact, the differences in percentages of morphological anomalies between the study area and the reference provinces were found statistically significant by the Mann-Whithney U test ($P < 0.05$, one tail). In the above mentioned comparison the confidence limits for the percentages of anomalies (Sokal and Rohlf, 1981) were shown not to overlap ($P < 0.01$). It should be noted that the average number of observations required for the difference between observed percentages to be significant at the $P = 0.05$ or lower level (Cavalli-Sforza, 1964) are lower than the ones from the study area and the reference collection.

Moreover, when the specimens collected in the study area were statistically compared against 2157 specimens of the genus *Crocidura* analyzed by Buchalczyk (1958) and by Vesmanis and Vesmanis (1980), where only two anomalous specimens were recorded. **A** significance ($P \leq 0.05$) for difference of the alterations percentages were found using the same statistics (see Sokal and Rohlf, 1981).

DISCUSSION

Two factors need to be emphasized in the method of analyzing the content of pellets of *Tyto alba*: the Barn Owl's general euriphagia and the aspect of its hunting area, approximately located within **a** circle with a diameter of **2** Km (Géroudet, 1965; Lovari et al., 1976; Cramp and Simmons, 1981; Bunn et al., 1982; Mikkola,1983; Taberlet, 1983).

Some species were not found in the pellets (Soricinae, *Clethrionomys glareolus*, *Apodemus flavicollis*), while *Muscardinus avellanarius* was only found on more internal sites, due to the presence of open fields in the Piana del Garigliano which are totally or partially farmed.

The high and altogether homogeneous values obtained for the indices of faunistic and biocoenotic affinity are correlated with the factors mentioned above and with the geographical proximity of sites.

The high trophic level index observed in site 2 might be explained by the seminatural conditions of the power plant respect area situated on the right banks of Garigliano river (Blasi and Fascetti, 1982).

Lower trophic level indices obtained for sites 1 and 3 reflect different situations. Site 3 undergoes extensive farming with the certain use of pesticides, whereas site 1 is located in the surrondings of to the plant area. Futhermore, site 1 showed:

- a low index *Microtus*/Murines, typically reflecting an indirect effect of human impact on those areas where the fields have been left fall into decay (Contoli, 1976);

- very high values for the thermoxerophily index compared to sites located in the immediate surroundings of the plant. This might be due to the presence of a coniferous seminatural woodland, which could contribute to the strong thermoxerophilous connotation observed (Pignatti, 1979), and/or to a possible effect of external radiations emitted by stored radioactive wastes on the biocoenotic equilibrium (Platt, 1963): in fact the irradiated nuclear fuel has been definitively removed just in December 1987 (ENEL-DPT, 1990). This would favour radiation resistant species, such as *Rattus rattus* (see Jackson, 1969). *Suncus etruscus* and *Rattus rattus* are abundant among preys of the site 1, especially considering that their body size falls near the extreme dimensional limits of those which *Tyto alba* preys upon. This indicates the presence of a highly macrothermic and xerophylous theriocoenosis in the sourronding of the power plant.

Except for this latter aspect, no particular unexpected biocoenotic feature was evidenced in the study area. Quite different was the pattern of morphological anomalies.

A significant increase of alterations was recorded in *Microtus savii* compared with other control areas in Central and Southern Italy. Moreover, in the studied sites the alterations of *Crocidura* spp. displayed an unusual abundance (cf.: Jones, 1957; Aloise, 1986). In comparison, conspicuous teratological alterations were found in cattle in the same area (Cristaldi and Petteruti, 1981; Di Berardino et al., 1983).

These phenomena could be associated to the contamination by radionuclides of the ground, as shown by monitoring surveys (ENEA, 1980), or to external irradiation of the animals due to leaking from the radiactive waste containers placed in the vicinity of the power plant (Cavelli, 1987; ENEA-DISP, 1991). This association is strengthened by data on skull anomalies in radioecological literature (Il'enko, 1973; Temme and Jakson, 1978). More specifically, a higher incidence of fluctuating asymmetry in skulls have been attributed to the interference between biological causes (endogamy, age, developmental processes, ecological niche) and environmental disturbance by several authors (Bailit et al., 1970; Siegel and Doyle, 1975; Pankakoski, 1985; Pankakoski and Hanski, 1989; Owen et al, 1990; Cavedon et al., 1992; Cristaldi et al., 1992; Clarke, 1992; Palmer et al., 1992; Parsons, 1992).

The importance of verifying previous data obtained in mutagenic and radiometric tests on small mammals living in that area should be stressed (Cristaldi et al., 1990). In fact, the genetic damage observed in studies performed with the micronucleus test applied on wild Rodents from the Piana del Garigliano resulted among the highest recorded in Italy (Cristaldi et al., 1986; Ieradi, 1993).

CONCLUSIONS

According to the data from this and previous studies on this area, there is at present no evidence of a strong correlation between the biocoenotic characteristics and morphological alterations observed, the latter being hardly explainable as result of the former only. The morphological alterations recorded could be interpreted on the basis of stochastic effects of low dose ionizing radiations on wild animals (see Cristaldi et al., 1991). With particular reference to indirect effects of radiations on ecological communities we would like to stress the utility of joining comprehensive ecological and evolutionary studies framed into biogeographical terms with more analytical investigations. This would improve the detection of the accumulated micro- and meso-environmental variations, in a relatively short temporal scale, as documented in this and similar studies (Tziperson *et* al., 1993). On the other hand, a macroevolutionistic interpretation on karyological effects of natural radiations is offered by Vorontsov and Lyapunova (1984).

It seems necessary to further develop these kinds of integrated research based upon the monitoring of natural populations. Control networks could be established in Europe to monitor environmental quality in critical as well as in control areas (Cristaldi, 1989). In this contest small mammals could efficiently be used as biological and ecological indicators with the aid of appropriate statistical techniques (Cavedon et al., 1990).

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