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TECHNICAL NOTE

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Interpretation of Postmortem Change in Cadavers in Spain

ABSTRACT: Estimating time since death is especially difficult in the examination of poorly preserved cadavers and depends on the experience of the examiner and comparison with previously documented cases showing similar characteristics.

The present study reports on information obtained over the past ten years through the work of the Laboratorio de Antropología y Odontología Forense (LAF) of the Instituto Anatómico Forense de Madrid, Spain, in particular evaluating how the type of fracture influences postmortem change.

From the original 225 forensic cases examined between 1992 and 2002 in the LAF, a sample of 29 cases were selected from various regions of the Spanish mainland.

A data collection protocol was established to reflect factors which the existing specialized literature, documenting the relation existing in the sample analyzed between time since death and the extent of postmortem change, which in the environments examined are distributed into the following phases: Phase 1 (putrefaction): one week to one month on the surface and two months in water. Phase 2 (initial skeletonization): two months on the surface and five to six months in water. Phase 3 (advanced skeltonization): six months to 1.5 years on the surface and 2.5 years buried. Phase 4 (complete skeletonization): about one year on the surface and three years buried.

This paper also provide useful information on the impact of carrion insect activity, location, climate, seasonality, and predator.

KEYWORDS: forensic science, forensic anthropology, postmortem interval (PMI), human taphonomy, Spain

Estimating time since death is one of the largest and most common problems facing forensic medical specialists, and is essential to establish the final activities of the victim and the possible identity of suspects. Unfortunately, it is also one of the most difficult issues to resolve.

The uncertainty regarding calculation of postmortem interval (PMI) increases considerably with the advance of the destructive processes. In cases of partial decomposition or total skeletonization the difficulties of assessment can be quite profound.

Numerous factors have been identified as being responsible for the postmortem change in the cadaver (9). These factors, which are intimately related, can be classified into two groups: (1) those which are dependent on the cadaver or intrinsic factors, and (2) those dependent on the postmortem environment of the cadaver or extrinsic factors (temperature, humidity, insect activity, foraging animals).

Several studies have attempted to produce objective methodology to estimate time since death in human remains. Examples include evaluation of biomarkers like lipids, nitrogen, amino acid content, neurotransmitters, and decompositional by-products (1,8,23,24), persistence of blood remnants in bone tissue (6), the extent of DNA deterioration (15), changes sustained by micro anatomical skeletal structure (25), and even C-14 (22). Although the studies provided useful information, no accepted practical method currently exists enabling determination of time since death in such cases. Such determinations must be made on an individual and empirical basis, drawing from the personal experiences of the examiner and subjective comparison of each case with others of similar characteristics.

Other studies have attempted to analyze and calibrate postmortem change, and elucidate the influencing factors. These contributions have documented the general sequence of postmortem change stages present in the assessment of time since death in a particular case. Some of these studies evaluate experimental data (e.g., 19) while others retrospectively analyze existing documented cases, noting the sequence of change (e.g., 3,18). These studies seem to show the major role played by geographical location and environmental factors in the rate and nature of postmortem change.

The aim of this contribution is to summarize our observations on postmortem change in the Spanish environment in which we work, in the Laboratorio de Antropología y Odontología Forense of the Instituto Anatómico Forense de Madrid (LAF). This analysis will allow us to understand the changes in evolution of the postmortem process in our environment and which factors must be contemplated to establish time since death in cases of advanced decomposition. Hopefully this study provides useful insights to colleagues working in other regions who face similar forensic problems.

Materials and Methods

Geographic Location

The Spanish mainland territory forms part of the southern peninsula in Europe (area: 492,991 km^2), located in the land mass separating the Atlantic Ocean and the Mediterranean Sea. Spain is

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markedly mountainous, having the second highest average altitude (600 m) in Europe, second to Switzerland.

The Iberian Peninsula is situated in the Mediterranean area, at the southern end of the jet stream's Polar Front, causing two major seasons, predominantly winter or summer weather conditions, with minimal rainfall during summer.

As regards temperature, the Iberian Peninsula reflects two distinct regimes: the temperate Mediterranean climate in coastal areas, and a continental climate in the interior, with extremely cold winters and very hot summers.

Methodology of Study

The original sample consists of 225 forensic cases examined between 1992 and 2002 in the LAF, from various regions of the Spanish mainland (Fig. 1).

A data collection protocol was established to reflect factors which the existing specialized literature (2,11,12,21) suggests the strongest influence on postmortem change (Table 1). The time since death was calculated as the difference between the date of disappearance of the individual and the recovery of the cadaver; thus it is possible that the PMI has been overestimated. Regarding seasonality, given the climatologic conditions of the country, we factored in only two seasons: summer (April through September) and winter (October through March).

After examination of the entire case database, 29 cases were selected as having all of the information needed for the protocol described above. These cases could be grouped into six phases which represent successive stages of postmortem change (Table 2). The first four stages refer to cadaver decomposition (putrefaction, initial skeletonization, advanced skeletonization, complete skeletonization) and the remaining two represent processes of conservation (mummification and supponification). We have classified decomposition or putrefaction into Phase 1 since this is the earliest phase represented in the cases studied by us.

Once we had established the phase of postmortem change of each case, we examined the influence of each of the factors presumed to be involved, through the analysis of variance (ANOVA) and nonparametric test (Mann-Witney) for those variables not showing a normal distribution.

FIG. 1—*Geographic distribution of cases.*

TABLE 1—*Protocol.*

Sex	Male
	Female
Constitution	Leptosomatic
	Atletic
	Pycnic
Clothing	Present
	Absent
Insects	Present
	Absent
Predator activity	Present
	Absent
Seasonality	Winter
	Summer
Climate	Littoral
	Continental
	Mountainous
Location	Buried
	Closed structures
	Aquatic
	Open air
Postmortem interval	Difference between date of disappearance and discovery
Phases of decomposition	1. Putrefaction
	2. Early skeletonization
	3. Advanced skeletonization
	4. Complete skeletonization
	5. Mummification
	6. Adipocere

TABLE 2—*Phases of decomposition.*

Phase 1	Putrefaction: Advanced decomposition without bone exposure. Moist decomposition, nail and hair deatchment. Purge fluid emission by natural orifices.
Phase 2	Early skeletonization: Abundant decomposed tissues with some bone exposure.
Phase 3	Advanced skeletonization: Bones with greasy substance and isolated remains of decomposed tissues, cartilage or tendons.
Phase 4	Complete skeletonization: Dry bones.
Phase 5	Mummification
Phase 6	Adipocere

Results

The relation between postmortem interval and the phase of postmortem change can be observed in Figs. 2 and 3.

Phase 1 (putrefaction): Cadavers classified in this phase show a minimum PMI of eight days (disappearance in March, partially buried) and a maximum of two months (cadaver found in water). The half-time for this phase is 20 days to one month.

Phase 2 (initial skeletonization): Cadavers in this phase are in the range of one month (open air cadaver, wearing an overcoat, reported missing in April) and a maximum of six months. The cadavers corresponding to the highest intervals (five or six months) were all found in water. Cases of open air cadavers correspond to average intervals of one or two months.

Phase 3 (advanced skeletonization): The interval for this phase includes cadavers found after a minimum of two months (case of skeletonization by carnivore activity) to a maximum of two and a half years (buried cadaver). The half-time is in a range of six months to 1.5 years.

Phase 4 (complete skeletonization): Cases found in this phase are older than three years.

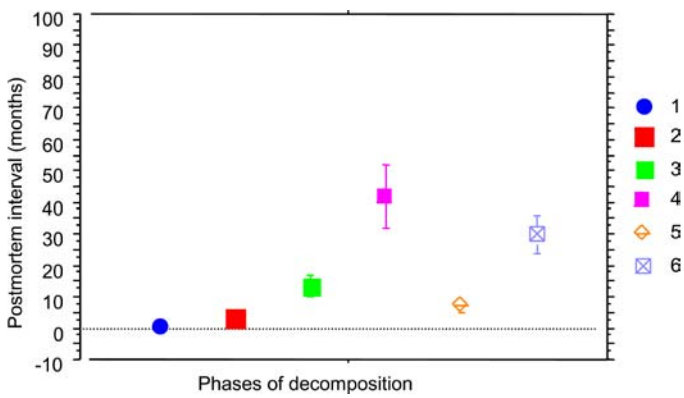

FIG. 2—*Mean (± standard deviation) of postmortem interval by phases of decomposition.*

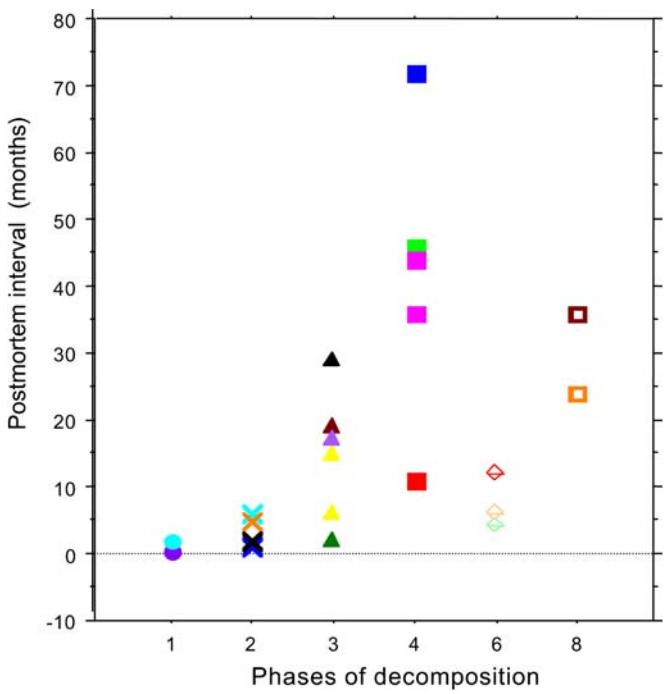

FIG. 3—*Distribution of the cases depending on the phases of evolution with respect to the postmortem interval.*

Phase 5 (mummification): The minimum interval for mummified cadavers is four months in one open air cadaver reported missing in August.

Phase 6 (saponification): The minimum interval for saponified cadavers is one and a half years for a cadaver found at the bottom of a well.

No significant differences were found regarding the correlation of sex, constitution, and postmortem change.

The influence of insect activity is expressed in Fig. 4, showing an apparent correlation with postmortem change ($p = 0.0052$). This suggests that postmortem change is faster in cadavers which have been colonized by insects than in uncolonized ones.

With regard to seasonality (Fig. 5), in Phases 1 and 2 (cadavers missing in summer) we observe a tendency of more rapid progression than those missing in winter.

It is not possible to examine the effect of the presence or absence of clothes due to the inadequacy of the sample size.

Examination of the effect of climate (Fig. 6) suggests a more rapid rate of change in cadavers located in coastal provinces (littoral climate) followed by those located in interior provinces (continental climate), and finally those in mountainous areas.

Analysis of the micro environment where each cadaver was found (open air, closed structures, buried or in water) (Fig. 7) shows that in Phases 1 and 2, the open air cadavers presented a faster rate of postmortem change than those found in closed structures or buried, and these show quicker change than those found in aquatic contexts.

Finally, we examined the correlation of evidence of animal intervention and also observed a positive relation ($p = 0.02$) in the rate of the early decomposition phases (Fig. 8).

Discussion

Although human decomposition is a continuous process, dividing it into phases is useful in order to establish a correlation between each phase and a known PMI.

In the literature consulted, we did not find papers analyzing the correlation between PMI and body decomposition in Spain, except for general descriptions, probably based on impressions founded on personal experience (4,10,16).

Micozzi (13) shows the sequences of putrefaction stages that have been suggested by different authors. Payne (14) observed six stages in cadavers exposed to insect action (fresh, bloated, active putrefaction, advanced putrefaction, dry putrefaction, and remains, and five stages of cadavers not exposed (fresh, bloated and decomposed, flaccidity and dehydrated, mummified and desiccated, and disintegrated). Johnson (7) and Reed (17) observed four phases (fresh, bloated, in putrefaction, and dry). Galloway et al. (3) in a retrospective study completed in Arizona (United States) using a sample of 189 cases, described five phases with a total of 21 stages from the fresh cadaver to skeletonization with metaphyseal loss, and exposure of the cancellous vertebral bone. Shean et al. (20) carried out a similar study with a total of 50 cases in New Mexico (United States), establishing four phases of postmortem change: decomposition of the soft tissue, exposure of the bone, remains only with connective tissue, and bone only. These four phases are in turn classified into a total of 15 stages.

In our case, we have observed the presence of four evolutionary phases, clearly differentiated within the cadaver decomposition process, assessing the processes of mummification and saponification independently, as they can be considered cadaver conserving processes. Since it is not possible to establish a direct equivalent, these four phases of decomposition correspond to a generic form of those suggested by Galloway et al. (3) and Rhine et al. (18) eliminating the fresh cadaver phase due to the characteristics and information of our sample. It has not been possible for us to evaluate more advanced phases (bone deterioration following skeletonization) because no such cases have been identified.

In our study, we did not find any influence of sex or constitution in postmortem change. It may be that there are no simple effects regarding these factors, which is why they have no graphic visual reference. It would be necessary to eliminate other stronger factors which might mask their effect. We do not have enough data to analyze the possible influence of other factors like cause of death or prior pathologies, although we know that the presence of open trauma (sharp-force trauma, gunshot wounds, open fractures), can contribute to and modify cadaver decomposition (3).

We have analyzed extrinsic factors in relation only to the first three phases, due to the characteristics of the sample.

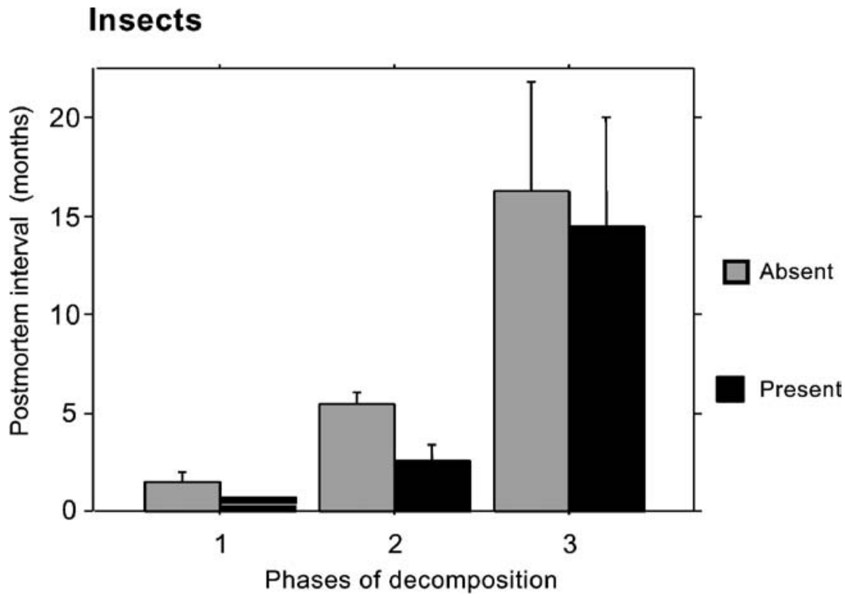

FIG. 4—*Influence of insect activity on the postmortem interval by phases of decomposition (mean 95%).*

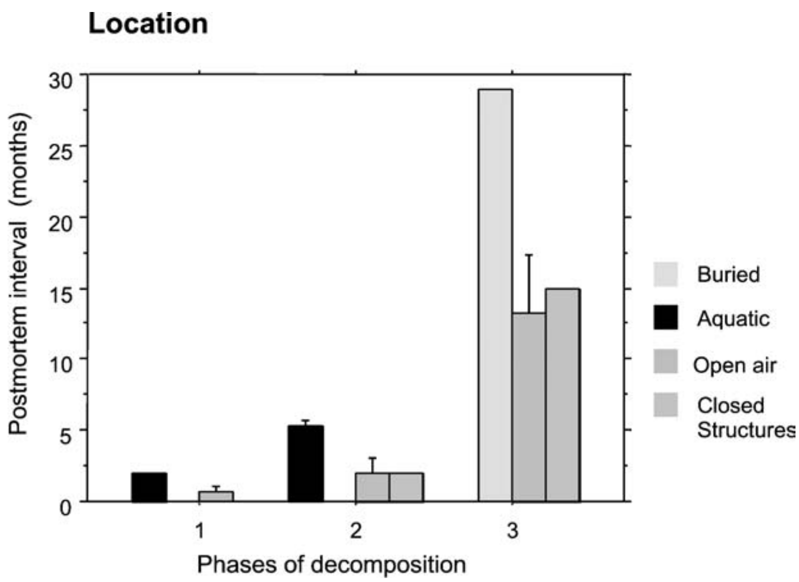

FIG. 5—*Influence of location on the postmortem interval by phases of decomposition (mean 95%).*

The positive influence of insect activity in this study concurs with that suggested by other authors (19,20) and details specific geographical patterns concerning successional and developmental cycles of different species on the cadaver in different stages of putrefaction. In our case, the most frequent species are Diptera and Coleoptera, enabling us to correlate the type of insect and the phase of postmortem change. These correlations are in Phase 1, the flies (Diptera) of the "Calliphoridae," "Sarcophagidae," and "Muscidae" families, are the most frequent; in Phase 2, the most frequent are Beetles (Coleoptera) of the "Dermestidae," "Staphylinidae," "Silphidae," and "Histeridae" families, in Phase 3, the cadaver is practically colonized by flies of the "Piophilidae" and "Sepsidae" families.

Regarding climate, we have observed that those cadavers located in coastal regions show fastest postmortem change. In these regions, the temperature is warmer and more constant and the humidity is higher, which favors the proliferation of microorganisms promoting the processes of putrefaction. Cadavers located in inland regions with a continental climate, with more extreme seasonal changes in temperature, show a slower rate of postmortem change. Apparently, postmortem change in cadavers is affected by seasonality, with very high summer temperatures accelerating the rate and very low winter temperatures slowing the process. At high altitudes, cadaver conservation is prolonged. In these regions, temperatures are lower with ice and snow in winter.

Another factor involved in postmortem change, associated with the one discussed above, is seasonality. Apparently, the high temperatures of summer promote decomposition through increased insect activity, although Rhine et al. (18) did not find a correlation between the condition of the remains and the season of disappearance and discovery. In our study, comparable data are available for Phase 2, suggesting a more rapid rate of change in summer than those reported missing in winter.

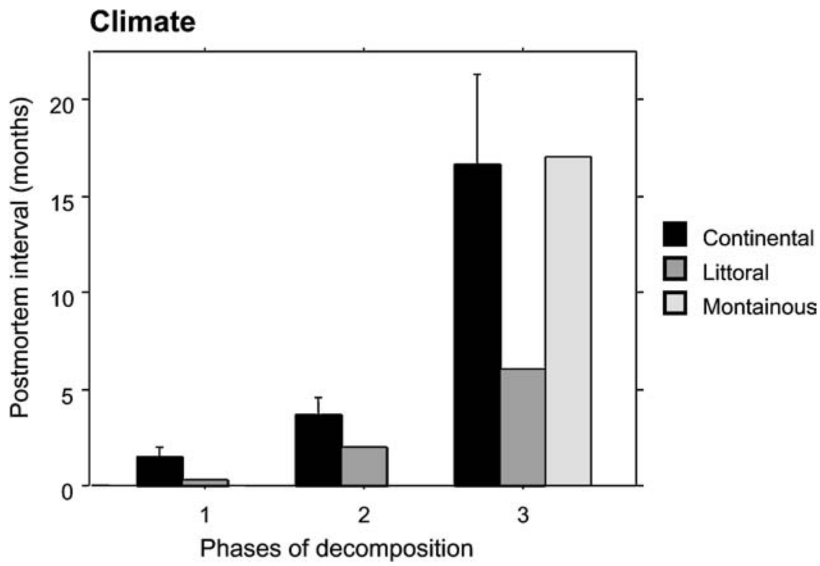

FIG. 6—*Influence of climate on the postmortem interval by phases of decomposition (mean 95%).*

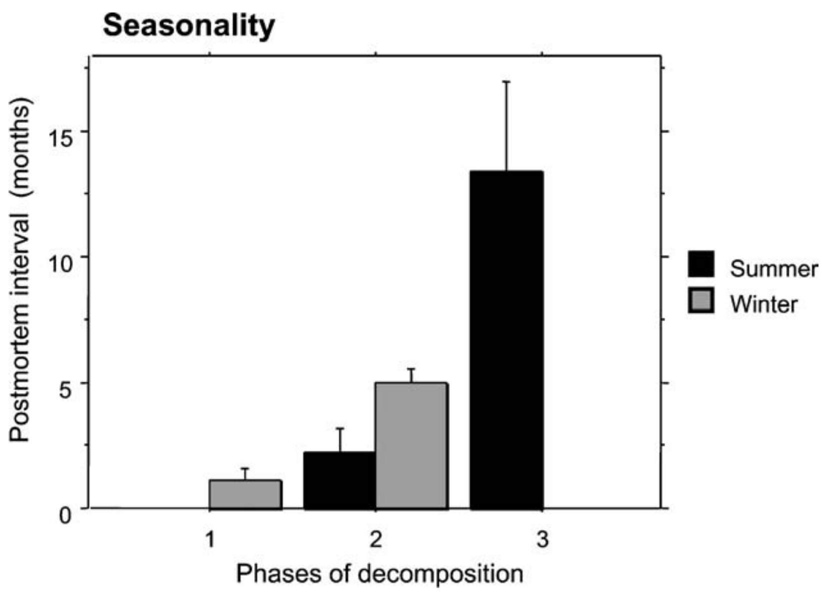

FIG. 7—*Influence of seasonality on the postmortem interval by phases of decomposition (mean 95%).*

The local environment where remains are found seems also to be a major factor in the evolution of the cadaver condition, since this represents a main determinant in the exposure to insects, predators (carnivores, rodents), and humidity (3). According to Galloway et al. (3) the complete skeletonization of an unprotected surface cadaver in the desert takes about eight months, while those found within structures generally show a slower rate in the early phase of decomposition but a faster skeletonization after four months. Other values suggested by the literature regarding the time necessary for skeletonization of an exposed body are very disparate. Lopez et al. (10) indicates that skeletonization occurs between three and five years on the ground surface and about two years in water, and increases to six or seven years for those buried in dry soils and up to 15 or 20 years in humid soils. Similar values are found in the classic texts of Legal Medicine in Spain (4,10) in which the skeletonization of cadavers on the ground surface occurs in about three years, increasing to five to ten years in buried remains (16).

In our study, in Phases 1 and 2, the cadavers found outdoors underwent a more rapid process of decomposition than those found indoors or buried, while buried cadavers decomposed more rapidly than those found in water. According to our results the earliest skeletonization (Phase 3) occurred in eight weeks, although in this case there was evidence of the action of carnivores (wild boars). In other cases, the minimum time was 24 weeks (six months), whereas the only case corresponding to a buried cadaver took place in two and a half years, and was reduced to dry bones in two to three years.

It is obvious that the action of animals on a cadaver will accelerate the process of skeletonization in any of the evolutionary phases, as suggested by the literature (5).

Conclusions

This study documents the relation existing in the sample analyzed between time since death and the extent of postmortem change,

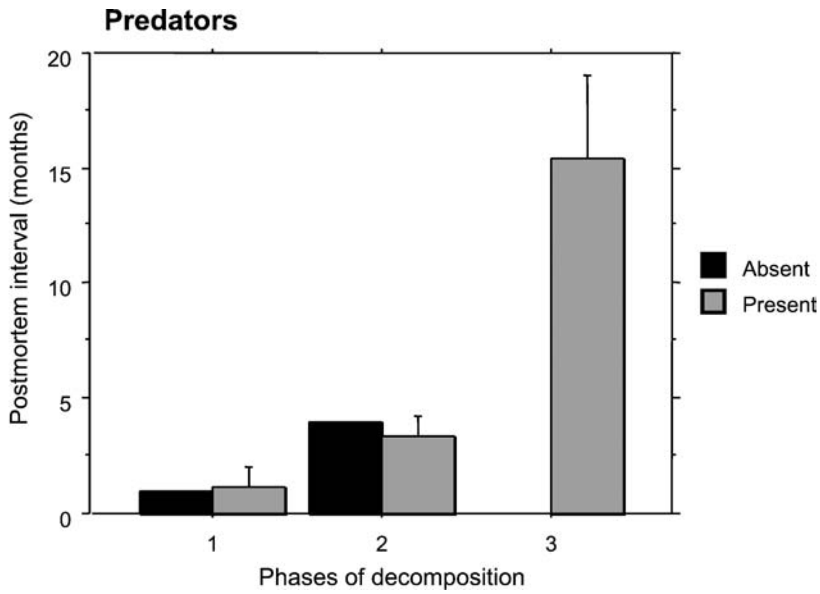

FIG. 8—*Influence of predator activity on the postmortem interval by phases of decomposition (mean 95%).*

which in the environments examined are distributed into the following phases: Phase 1 (putrefaction): one week to one month on the surface and two months in water. Phase 2 (initial skeletonization): two months on the surface and five to six months in water. Phase 3 (advanced skeltonization): six months to 1.5 years on the surface and 2.5 years buried. Phase 4 (complete skeletonization): About one year on the surface and three years buried.

With respect to the comparative studies conducted in other environments (3,18), we have found a similarity in the contributions of the following factors: insects, carnivores, high temperatures, and humidity as accelerants of the process. Low temperatures, burial, and submersion in water are decelerants of the process.

We found no influence whatsoever due to sex or constitution.

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