



# Skin artefacts due to post-mortem damage caused by *Notiothauma reedi*: A insect of forensic importance in forest communities of Chile

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**Abstract** We selected four types of forestal areas with different botanical compositions and an anthropised prairie in a region of Chile to identify insects that participate in the decomposition of pig carcasses and that can be used as bioindicators in Chilean forensic entomology and to identify the post-mortem artefacts caused by them. We observed the presence of *Notiothauma reedi* (Mecoptera: Eomeropidae), an endemic insect of Chile, on carcasses only in the forested environment that characterised the deciduous forests, evergreen forest, *Eucalyptus nitens* plantation and *Pinus radiata* plantation from the third day of the post-mortem interval (PMI) and throughout the decomposition process. This species was not found on carcasses located in a prairie near Temuco city. Additionally, *N. reedi* caused skin lesions that had morphological similarities with ante-mortem injuries caused by cigarette burns, which change as the carcass decomposes. This study provides preliminary results on the role of this species in the decomposition of carcasses in native forests and exotic plantations in southern Chile and on the skin lesions that it causes, which should be taken into account when cadavers are found under conditions similar to those described above. In light of these findings, *N. reedi* could be a new bioindicator of forensic utility in the forest communities of southern Chile.

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## 1. Introduction

The phenomenon of post-mortem animal interference with human bodies is part of the taphonomic processes of corpses, occurring during the early and late parts of the post-mortem period. The differentiation between a vital or post-mortem origin for these injuries and therefore their recognition as post-mortem artefacts, generally present no difficulties. However,

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the attribution of a specific morphological feature of post-mortem damage to a distinct species of animal can raise questions.<sup>1</sup> Adequate training in forensic pathology requires a familiarity with the types of artefacts that may be introduced by predatory animals. In addition, when evidence of animal activity is found at an autopsy, the consideration of a wide range of possibilities is required.<sup>2</sup>

It is important to consider that post-mortem animal feeding activity may cause considerable damage to bodies, resulting in the modification of wounds, loss of identifying features and injury or removal of internal organs. Certain post-mortem lesions may appear as inflicted or non-inflicted ante-mortem injuries, with consequent potential problems for the investigative interpretation.<sup>3</sup>

The pattern of lesions may enable the identification of the particular species of animal involved<sup>4</sup>, and post-mortem artefacts produced by dogs<sup>5-7</sup>, rodents<sup>1</sup>, fishes<sup>5,8</sup>, crustaceans<sup>3</sup> and insects have been reported. Ants, for example, can be present at all stages of carrion decomposition but are typically observed shortly after death or during the early post-mortem period. Because ants can deeply affect the occurrence of cadaver entomofauna, their presence or absence should be taken into account in every case involving post-mortem interval estimates based on entomological evidence. The feeding action of ants can cause many irregular, serpiginous, scalloped areas of superficial skin loss, and small punctate and scratch-type lesions may often be observed on the body, which are the result of post-mortem ant bites. Ant injuries are typically orange-pink to yellow in colour and diffusely scattered over the skin surface. These injuries consist of small and rather shallow gnawed holes that can be easily misinterpreted as ante-mortem abrasions or as resulting from strong acids. No bleeding is associated with such skin lesions, but considerable haemorrhaging can occasionally occur, especially where the removal of superficial layers of skin occurs on congested parts of the body.<sup>9</sup>

In Chile, the development of knowledge about the insects associated with carcasses that can be applied to entomological forensic analyses is recent<sup>10-13</sup>, and there have currently been no reported post-mortem artefacts associated with the local wildlife. *Notiothauma reedi* is an endemic insect species in Chile belonging to the order Mecoptera and is a unique member of the family Eomeropidae.<sup>14,15</sup> It inhabits western portions of southern Chilean Valdivian forests (between 37° and 41°S latitude) between January and September<sup>16,17</sup> and is especially associated with the forests of *Nothofagus*.<sup>17</sup> Jara-Soto et al.<sup>18</sup> reported for the first time that this species is spatially associated with *Oryctolagus cuniculus* and *Gallus gallus* carcasses; however, they did not report the effect of *Notiothauma* on the carcasses. The aim of this investigation was to identify insects that can be used as bioindicators in Chilean forensic entomology and to identify the post-mortem artefacts caused by them. Herein, we present the first report of post-mortem skin artefacts on pig carcasses caused by *N. reedi* and the possible potential of this species as a new bioindicator for forensic entomology in this region of Chile.

## 2. Materials and methods

This investigation was performed in the winter of 2013 simultaneously in five distinct areas of the La Araucanía region.

Because pigs display similar insect successions as humans<sup>19</sup>, it may be possible to tailor decomposition studies using animal models to more precisely mimic specific artefacts of human decomposition.<sup>20</sup> A total of 30 20-kg pigs (*Sus scrofa* Linnaeus) were used (six pigs per site). The pigs were sacrificed on site by means of encephalo-cranial trauma, in the same manner used in slaughterhouses, without creating skin lesions. The Ethics Commission of the Universidad Católica de Temuco approved this procedure. The carcasses were placed in a right lateral decubitus position in boxes consisting of metallic mesh with dimensions of 100 cm × 80 cm × 60 cm to avoid the intervention of carrion-feeding vertebrates and to allow easy access for entomofauna. The distance between the boxes containing the carcasses was 7 m. The selected areas and their botanical compositions were as follows:

Four sites were located in the Huimpil-Nielol range, near the city of Temuco, with an elevation ranging between 150 and 634 m a.s.l. Site one corresponds to a second growth evergreen native forest (38°38'41"S-72°35'21"W; 519 m a.s.l.) containing 27 species of vascular plants. Its main tree species are *Aextoxicon punctatum*, *Eucryphia cordifolia*, *Gevuina avellana*, *Dasyphyllum diacanthoides* and *Myrceugenia planipes*. The main species of shrubs, ferns and epiphytes present in this site are *Chusquea* sp., *Blechnum cordatum* and *Capsidium valdiviensis*, respectively, and the tree cover is approximately 80%. Site two is located in a deciduous native forest (38°37'56"S-72°35'13"W; 580 m a.s.l.) and contains 24 species. The tree cover is approximately 75%, with stand-out *Nothofagus obliqua* being the dominant species. Other species that are present at this site include *Persea lingue*, *Podocarpus saligna*, *Rhamnus diffusus*, *Rhaphithamnus spinosus*, *Blechnum hastatum*, *Lapageria rosea* (national flower of Chile) and *Cissus striata*. A grown-up plantation of *Eucalyptus nitens* (38°38'22"S-72°36'39"W; 476 m a.s.l.; 60% tree cover) is located in site three. This site contains 25 native and exotic species, and its main shrub is the exotic *Rubus constrictus*. *Acaena ovalifolia* is the most common herb species, and the epiphyte species *Boquila trifoliolata* is a stand-out species. Site four is located in a grown-up plantation of *Pinus radiata* (38°39'07"S-72°33'38"W; 291 m a.s.l.; 80% tree cover), which develops 15 species. In the understory, there are a few species and individuals, with *Aristotelia chilensis* and *Rubus constrictus* being the more important species. The main species of herbs are *Agrostis capillaris* and *Arrhenatherum elatius*, and the main species of epiphytes are *C. striata* and *B. trifoliolata*. Site five is located in a semi-urban area of Temuco city on the northern slopes of Mariposa Mountain (38°42'02"S-72°32'52"W; 119 m a.s.l.). This site is an anthropised prairie characterised by the presence of 24 introduced herbaceous species, predominantly *Lolium perenne*, *Achillea millefolium*, *Cichorium intybus*, *Leontodon taraxacoides* and *Taraxacum officinale*. This site does not have any tree cover and is completely exposed to the sun.

We recorded the following parameters daily: (i) the environmental temperature using a maximum/minimum thermometer, (ii) the temperature of the carcasses (measured rectally with a digital thermometer) and (iii) the rainfall and environmental humidity. Photographic recordings of the carcasses and classifications of the stage of decomposition according to the definitions of Payne<sup>21</sup> and of Anderson and Vanlaerhoven<sup>22</sup> were performed daily.

**Table 1** Temperature and humidity recorded at the experimental sites.

Experimental area	Georeference	Mean environmental temperature/range (°C)	Mean carcass temperature/range	Mean environmental humidity/range (%)
Evergreen native forest	38°38'41"S-72°35'21"W	8.8 (0.2–18.2)	9.5 (1.5–27.6)	68.3 (43.1–98.5)
Deciduous native forest	38°37'56"S-72°35'13"W	10.1 (3.3–18.2)	9.5 (3–33.6)	68 (51.7–94.2)
<i>Eucalyptus nitens</i> plantation	38°38'22"S-72°36'39"W	8.9 (0.4–23)	8.8 (2.7–30.4)	68 (47.9–88.2)
<i>Pinus radiata</i> plantation	38°39'07"S-72°33'38"W	9.6 (0.4–20.1)	9.6 (2.7–31.2)	66 (46.5–88.7)
Anthropised prairie	38°42'02"S-72°32'52"W	16.7 (9.2–22.4)	12.3 (0.5–36.8)	88 (53–98)

The identification of *N. reedi* was made using the taxonomic key of Peña<sup>15</sup> and by comparison with the species in the entomological museum of the Universidad de Concepción. The classification of the native forests and identification of vascular plants were based on Hoffman<sup>23</sup>, Marticorena et al.<sup>24</sup>, Marticorena and Quezada<sup>25</sup>, Marticorena and Rodríguez<sup>26,27</sup> and Rodríguez et al.<sup>28</sup>

### 3. Results and discussion

During this investigation, we collected all flying and crawling insects that colonised the carcasses; however, for the purposes of this report, we will focus on the findings related to *N. reedi*. The temperature recordings and environmental humidity of the five experiments are shown in Table 1. The rainfall was 147 mm for the entire region.

On day 3 PMI, the carcasses were at the bloated stage, and the first *N. reedi* adults that were feeding on the skin of the carcasses located in the deciduous native forest, evergreen native forest, *E. nitens* plantation and *P. radiata* plantation (Fig. 1A) were found. However, no *N. reedi* adults were found in the anthropised prairie during any stage of decomposition. The adults of *N. reedi* were feeding mainly in the skin of the abdominal and inguinal surface. Rebolledo et al.<sup>16</sup> reported that this species inhabits only cold, high humidity and dark environments, all of which are characteristic of the forest communities of the Huimpil-Ñielol range and not of the anthro-

pised prairie (Table 1). Archibald et al.<sup>17</sup> indicated that this species lives a nocturnal cockroach-like existence on the *Nothofagus* forest floor, and given the association of *Nothiothauma* with *Nothofagus*, these authors considered the possibility that this species originated in the Northern Hemisphere along with *Nothofagus* and spread to South America with it. In the present investigation, we report that *N. reedi* not only inhabits and interacts with carcasses in *Nothofagus* forests but also in exotic plantations. Despite the close proximities of the experimental sites located in the forest environments of the Huimpil-Ñielol range with the prairie of Temuco city, this species is restricted to acting only on the carcasses located in the woods. Therefore, *N. reedi* could be a bioindicator for decomposition in forest communities. From day 3 PMI, the first skin lesions on the carcasses, or post-mortem artefacts, caused by *N. reedi* could be observed. The areas of the skin that were damaged by this insect were characterised as round lesions, approximately 3–5 mm in diameter, with an alopecic border. The centres of the lesions were brown–red and slightly eroded, and the lesions involved the epidermis and part of the superficial dermis (Fig. 1B). Interestingly, *N. reedi* did not appear to make deep lesions into the skin but rather to consume part of an area of the skin and then move on to do the same at another area, making these characteristic lesions (Fig. 1A). Adult *Nothiothauma* are considered phytophagous or saprophagous<sup>17</sup>, and these characteristic superficial lesions and this behaviour may be related to the



**Figure 1** (A) Pig carcass on day 3 PMI with *Notiothauma reedi* feeding at the skin surface. Scale: 5 mm. (B) Detail of an artefact on the skin surface caused by *N. reedi* on day 3 PMI. Scale: 5 mm. (C) Detail of the same skin lesion of A but 45 days later. Scale: 5 mm.



**Figure 2** *Ceroglossus chilensis* adult feeding on the skin of a carcass that had been previously injured by *N. reedi*. Scale: 10 mm.

type of mouthparts that this species possesses. Its mouth is characterised as a lanceolate form with subapical teeth<sup>27,28</sup>, which impede the increment of the depth of the erosion of the skin when the insect is feeding. Some of these lesions were deepened and expanded by the action of *Ceroglossus chilensis* (Coleoptera: Carabidae) adults (Fig. 2) and colonised by *Calliphora vicina* and *Sarconesia magellanica* larvae.

As time passed, some of these initial lesions that were not expanded by other insects changed. In advanced stages of the decomposition process (up to day 45 PMI), the edges of the lesion were raised by fungal colonies. In this state of decomposition, the skin colour is greenish with abundant yeast and hyphae from other fungi. However, in the peripheral area of the lesion, the colour is red, and in the central area of the lesion that was eroded, the colour is dark red (Fig. 1C).

The morphological characteristics of the post-mortem artefacts observed and described on the skin of the pig carcasses have similarities in size, shape and colour to ante-mortem injuries on skin caused by cigarette burns, which have been widely described by Faller-Marquardt et al.<sup>29</sup> These authors described the changes affecting this type of burn through time on live individuals and observed how this type of lesion changes as it repairs, exhibiting alterations in its structure and colouration. However, the changes that occur in lesions caused by cigarette burns on bodies or carcasses during the process of decomposition are unknown.

These artefacts on post-mortem skin caused by *N. reedi* should be taken into consideration in the thanatological analysis of cadavers found in wooded areas where this species is present, especially in cases in which the victim is suspected to have been subjected to abuse. Moreover, in a hypothetical situation in which a forensic entomologist finds this species on a decomposing cadaver (and/or the artefacts caused by it), because this species grows only in forest environments<sup>16,17</sup> it could be considered indicative of decomposition in a native forest or exotic plantation in southern Chile (e.g., in cases of the removal of cadavers and their transport to other sites, linking a suspect to the scene of a crime). Although this species was

found throughout the decomposition process without a predominance defined at any particular stage, further investigating the role of *N. reedi* in the process of decomposition in this environment and its relationship with the life cycle and process of cadaver decomposition is necessary.

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#### Conflict of interest

None declared.

#### Informed consent

There is no informed consent.

#### Ethical approval

Necessary ethical approval was obtained from the institute ethics committee.

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