

## *Neochelanus michaelsoni* (Pseudoscorpiones: Chernetidae) as a potential bioindicator in managed and unmanaged *Nothofagus* forests of Tierra del Fuego

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**Abstract.** Bioindicators could act as early warning indicators of environmental changes, ecosystem stress or taxonomic diversity. Pseudoscorpions have rarely been used as bioindicators, due to lack of information about their ecology, habitat selection, niche preferences and requirements, especially in southern *Nothofagus* forests. We studied the distribution and abundance of a pseudoscorpion species, *Neochelanus michaelsoni* (Simon 1902), in different vegetation types (*Nothofagus antarctica* and *N. pumilio* forests, grasslands and peatlands) and examined how this species responded to different forest uses (harvesting and silvopastoral management), to explore its utility as a bioindicator. The study was conducted on long-term plots located at two ranches in Tierra del Fuego, using pit-fall traps during one summer. *Neochelanus michaelsoni* abundance was higher in *Nothofagus* forests than in open ecosystems, which could be attributed to their affinity for litter and coarse woody debris. In *N. pumilio* forests, the pseudoscorpions were sensitive to harvesting, with similar abundances in harvested forests (aggregated and dispersed retentions) and grasslands. In *N. antarctica* forests, differences were not detected among unmanaged and silvopastoral managed forests, probably due to higher understory plant growth, and lesser diminishing of litter and debris by thinning than by harvesting. We conclude that the pseudoscorpion, *N. michaelsoni*, can be a good bioindicator for ecosystem conservation and for evaluating recovery rate in the ecological conditions of impacted *Nothofagus* forests, and that management practice intensities should be regulated to create more suitable habitats for pseudoscorpion diversity conservation.

**Keywords:** South Patagonia, conservation, natural vegetation types, variable retention, silvopastoral use

Bioindicators are taxa or functional groups that can reflect the state of the environment, acting as early warning indicators of changes (environmental indicator), monitoring a specific ecosystem stress (ecological indicator) or indicating levels of taxonomic diversity (biodiversity indicator). Environmental and ecological bioindicators can be divided into several categories reflecting their responses to environmental changes: detectors (naturally occurring indicators that decrease with environmental stress), exploiters (increase with environmental stress) and accumulators (organisms that take up chemicals and can be used to measure toxin levels). Bioindicators may also be used for conservation prioritization by means of spatial comparisons of a site value, or monitoring of ecosystem recovery or response to management.

To be used as a bioindicator, a well-known distribution and environmental tolerance level of a particular taxonomic group or species are needed. Taxa at a higher level of the food chain would seem to be better indicators as they indicate processes lower in the food chain. Invertebrates may often be particularly good environmental and ecological bioindicators due to their sensitivity to local changing conditions. In turn, invertebrates usually present short generation times that result in rapid numerical responses, and variability in the ecological characteristics of some species produce a wide range of specific responses related to the environment where they live. Likewise, invertebrates may reflect trends in species richness and community composition more accurately than vertebrates, as the invertebrates are more diverse and abundant, reflect levels of overall species richness and community composition, and

are more cost-effective to use. Among invertebrates, pseudoscorpions have only occasionally been used as bioindicators (Yamamoto et al. 2001; Barros et al. 2010; Ranius et al. 2011), because they are generally scarce and difficult to identify. But some studies have revealed their sensitivity to anthropogenic activities, with greatest population densities in environments with major ecological equilibrium, as in old-growth forests (Yamamoto et al. 2001).

Pseudoscorpions are one of the smaller orders of Arachnida, and sometimes occur in large numbers. Most species of pseudoscorpions live in the tropics and subtropics throughout the world (Del-Claro & Tizo-Pedroso 2009); however quite a few species live in the temperate zone. Preferred microhabitats of pseudoscorpions are leaf litter of woods and forests, crevices, nests of mammals, and logs. Only a few studies on the ecology of pseudoscorpions, habitat selection, and niche preferences have been done so far (e.g., Bell et al. 1999; Dennis et al. 2001; Derraik et al. 2001; Yamamoto et al. 2001; Tizo-Pedroso & Del-Claro 2014). There are no works about pseudoscorpions in *Nothofagus* forests of South America, although they were found in *Nothofagus truncata* litter in New Zealand (McCull 1975).

*Nothofagus* forests in Tierra del Fuego Archipelago are the world's southernmost forested ecosystem, and one of the last remaining pristine wilderness areas on the planet. However, there are several human-related influences that incrementally modified the original structure and natural dynamic of these ecosystems, e.g., harvesting, the presence of livestock, and the occurrence of exotic species (e.g., beaver, mink), which have

affected the entire forest system and modified biodiversity levels at understory, forest soil and canopy levels (e.g., Gustafsson et al. 2012). Silviculture focused on sustainable forest management aims to conserve biodiversity at different spatial levels. However, there is a lack of knowledge about the complete assemblage of species and their natural distribution in different ecosystems for some taxa, e.g., arachnids. This information is required to set up explicit recommendations on how to minimize impacts on natural ecosystems, mainly on endangered species (Lindenmayer et al. 2012).

We studied the distribution and abundance of a pseudoscorpion species, *Neochelanus michaelsoni* (Simon 1902) (Chernetidae) (henceforth referred to as *Ne. michaelsoni* to distinguish its generic name from that of the plants in the genus *Nothofagus*), in different natural *Nothofagus* forested and associated non-forested ecosystems. Also, we were interested in how this species responds to different forest uses (harvesting in *N. pumilio* forests and silvopastoral management in *N. antarctica* forests). The hypotheses tested here are: (1) *Ne. michaelsoni* is differentially distributed in typical vegetation types of Tierra del Fuego, and presents greater abundance in *Nothofagus* forests than in non-forested ecosystems; (2) *Ne. michaelsoni* is sensitive to environmental and ecosystem stress produced by the forest use, resulting in its reduced abundance in harvested and silvopastoral managed forests. Using this information we discuss the utility of *Ne. michaelsoni* as a bioindicator of conservation status for different vegetation types in southern Patagonia.

## METHODS

**Southern Patagonian *Nothofagus* forests.**—The austral extreme of South America, Tierra del Fuego Island, hosts the world's southernmost forested ecosystems. *Nothofagus* genus is the main component, with a wide range of natural distribution from 36°50' to 55°02'S. These forests are predominantly deciduous, mainly composed of *N. pumilio* (NP) and *N. antarctica* (NA). In the Argentinean territory of Tierra del Fuego, forests are mainly used for harvesting, cattle grazing and tourism, prioritizing economic aspects over conservation in the ecosystem management. These *Nothofagus* forests rarely constitute large continuous masses, rather the landscape is usually formed by a mosaic of several forest types and open environments, where timber and unproductive forests are mixed.

**Studied sites.**—The study was conducted on long-term plots as part of the PEBANPA network (Biodiversity and Ecological long-term plots in southern Patagonia), established at Los Cerros Ranch (54°18'S, 67°49'W) and San Pablo Ranch (54°15'S, 66°49'W), within an area of 1500 ha each. The landscape is occupied by monospecific natural *Nothofagus* forests, grasslands and peatlands. Acid brown soils are mostly of glacial origin with loess and alluvial materials at the foothills. The climate is cold, with short, cool summers and long, snowy and freezing winters; the growing season extends from November to March. Mean monthly air temperatures range from -3 to 10°C (July and February, respectively), while soil temperatures vary from 0°C (August) to 9°C (March). Precipitation (rain and snow) reaches up to 600 mm yr<sup>-1</sup> (Soler et al. 2012).

To study pseudoscorpion abundance in different vegetation types, we selected two unmanaged, old grown *Nothofagus* forests (NA and NP forests) and two associated non-forested ecosystems (grasslands and peatlands) in Los Cerros Ranch, covering an area of 5–10 ha each. In each vegetation type, six sampling sites were selected as spatial replicates, with similar characteristics in vegetation community composition and topography.

To analyse the pseudoscorpion responses to harvesting in NP forests, three habitat types were selected in harvested sites in Los Cerros Ranch: (i) interior of aggregated retention (AR), (ii) areas of dispersed retention (DR) in the harvested forests 20 m away from the aggregates' edges, and (iii) unharvested stands of old growth unmanaged forests (NPF), with six spatial replicates each. These sites were located on a long-term plot established in a pure NP forests (115 ha) harvested in 2005, seven years before the onset of this study. The variable retention method applied in Tierra del Fuego generates various canopy openness and micro-environmental conditions, because it retains one circular aggregate of 30 m radius per hectare (30 m<sup>2</sup> ha<sup>-1</sup> basal area), and evenly dispersed dominant trees are retained (10–15 m<sup>2</sup> ha<sup>-1</sup> basal area) between the aggregates. The studied stands were of middle-to-high site quality, with a total overbark volume of 700–900 m<sup>3</sup> ha<sup>-1</sup>, total dominant heights of 20.5–27.5 m and basal area of 60 m<sup>2</sup> ha<sup>-1</sup> (Martínez Pastur et al. 2011).

To analyse the pseudoscorpion responses to silvopastoral use in NA forests, two habitat types were selected in managed stands in Los Cerros Ranch (four spatial replicates of each habitat) and San Pablo Ranch (six spatial replicates of each habitat): (i) silvopastoral managed forests (SF), and (ii) unmanaged old growth stands (NAF). Silvopastoral managed forests had mature trees (130–180 years old) that had been handled by selective cutting and thinning (reducing 50% of the original cover) about 7–10 years before the onset of this study (Soler et al. 2012). This canopy management improved the understory biomass (annual increase of 1400 kg ha<sup>-1</sup> of dry matter), which is used as forage for cattle grazing. The old growth unmanaged forests correspond to 150–200 years old stands without forestry intervention, whose forest structure (large trees, multilayered canopy, and big coarse woody debris) is the result of natural disturbances (e.g., wind throws). Livestock carrying capacity in both ranches is about 7–8 individuals km<sup>-2</sup> (cattle), mainly of Hereford breed. The traditional grazing management is based on extensive winter and summer grazing paddocks (400–1000 ha approximately), where each paddock includes mixed habitat types (NA forests, grasslands, and peatlands). Cattle graze on grasslands during summer-autumn, but they also use *Nothofagus* forests in winter-spring. In this region, natural populations of guanaco (*Lama guanicoe*) occur, meaning that native and domestic herbivores overlap in the use of grasslands and forests habitats for feeding and shelter.

**Pseudoscorpion sampling.**—Because pseudoscorpions live primarily in litter, sampling was performed by means of pitfall traps, which mainly reflects the activity of animals walking on the soil or leaf litter surface, but was previously used for pseudoscorpion sampling (e.g., Derraik et al. 2001). In these studies, pitfall traps had two different designs. (A) in vegetation types and NP forests, at Los Cerros ranch, we

used a laterally opened cylinder (100 cm long  $\times$  15 cm diameter) placed horizontally in each site. Traps were emptied every 15 days during one summer season (six sampling periods from December 21st to March 21st, 2013, counted as days after the beginning of the study: 15, 30, 45, 60, 75 and 90 days). And (B) in NA forests, both at Los Cerros and San Pablo ranches, five plastic pots (12 cm height  $\times$  14 cm diameter) were set up 5 m apart from each other in a cross design. Pots were open during 7 days at the end of January 2013. The growing season period (November–April) was considered appropriate for arthropod sampling in *Nothofagus* forests at Tierra del Fuego due to higher temperature. Water was used as a retention agent and a few drops of commercial detergent were employed to diminish surface tension.

After trapping, individuals were identified to species level using external morphology and linear measures (Mahnert et al. 2011) as well as the spermatheca shape (Mahnert 2001), and classified by sex–age into classes (adult male and female, proto-, deutero-, and tritonymph). Because of the small number of nymphs, all nymphal stages were regrouped in the class juveniles for analysis. Almost all individuals belonged to the species *Ne. michaelsoni*; only four individuals belonged to another species (from the genus *Serianus* Chamberlin 1930), and they were excluded from the analyses. The samples are deposited in the Museo Argentino de Ciencias Naturales “Bernardino Rivadavia”, Buenos Aires, Argentina.

**Data analyses.**—We used different ANOVA models to evaluate the abundance of *Ne. michaelsoni* (response variable) in the sampling period. Data were square root transformed to accomplish ANOVA assumptions of homoscedasticity, but non-transformed means are presented to improve interpretation. In all analyses, means were compared by the Tukey honestly significant difference test ( $p < 0.05$ ).

To investigate differences in abundance of *Ne. michaelsoni* among vegetation types and harvesting regimes in NP forests we used repeated measures ANOVAs (with spatial and temporal replications). Days after the beginning of the study was the repeated factor, while vegetation types ( $n = 4 \times 6 \times 6 = 144$ ) and harvesting regimes ( $n = 3 \times 6 \times 6 = 108$ ) were the main factors. When the sphericity test was significant in repeated measures ANOVAs, a univariate adjustment was applied to evaluate within-subjects effects (Greenhouse & Geisser 1959). As interactions occur in both repeated measures ANOVAs, the impact of one factor depends on the level of the other factor. Therefore, one-way ANOVAs were performed to evaluate differences in *Ne. michaelsoni* abundance among treatments (vegetation types and harvesting regimes) for each day after the beginning of the study, and among days after the beginning of the study for each treatment.

Moreover, we used two-way ANOVA to investigate the impact of silvopastoral management in NA forests (spatial replication), using habitat type and ranch as main factors ( $n = (2 \times 4) + (2 \times 6) = 20$ ). Subsequently, multivariate cluster analysis was done for each data set to reveal ecological relationships between ecosystems and managed forests, using Euclidean distance and Ward’s method. Statistica (Statsoft, USA) and Statgraphics (Statistical Graphics Corp., USA) software was used for these analyzes.

## RESULTS

There were 812 individuals of *Ne. michaelsoni* sampled, 718 by opened cylinders during the whole summer season, and 94 by pots during seven days in January. From these, there were 453 males, 308 females and 51 juveniles. The highest quantities of males and females occurred 30 days after the beginning of the study (89 and 62 individuals, respectively), while juveniles presented the greatest abundance 15 days after sampling began (13 individuals). Sex–age classes presented similar proportions in both trap designs (56% males, 38% females and 6% juveniles in opened cylinders, and 52% males, 40% females and 7% juveniles in pots).

Pseudoscorpion abundance differed among natural vegetation types (Repeated-measures ANOVA,  $F = 7.80$ ,  $P = 0.001$ ) and days after the beginning of the study (Repeated-measures ANOVA,  $F = 23.95$ ,  $P < 0.001$ ), although interaction was significant (Repeated-measures ANOVA,  $F = 2.57$ ,  $P = 0.014$ ) due to very low abundances at 60 days after the beginning of the study in all vegetation types, and in grasslands during the whole season. Complementary analyses revealed abundance was significantly higher in NA forest and lower in grasslands in five sampling periods (Table 1). NP forest abundance did not show differences with NA forests 30 days after the beginning of the study, while peatlands were significantly similar to grasslands 45, 75 and 90 days after the beginning of the study (Table 1). On the other hand, peatlands, NA and NP forests presented significantly higher abundances 30 days after the beginning of the study (Repeated-measures ANOVA,  $F = 7.84$ ,  $P < 0.001$  for peatlands;  $F = 3.88$ ,  $P = 0.008$  for NA forests;  $F = 3.09$ ,  $P = 0.023$  for NP forests), which was also high in NA forests at 15 days after the beginning of the study (Fig. 1a). Likewise, peatlands and grasslands had significantly lower abundances from 45 days after the beginning of the study until the end of the sampling period, except in NP forest which incremented at 90 days after the beginning of the study. Abundance was minimal and differences were not detected for grasslands (Fig. 1a).

On the other hand, pseudoscorpion abundance differed among NP harvested and unharvested forests (Repeated-measures ANOVA,  $F = 11.89$ ,  $P = 0.004$ ) and days after the beginning of the study (Repeated-measures ANOVA,  $F = 5.36$ ,  $P < 0.001$ ), but interaction was significant (Repeated-measures ANOVA,  $F = 5.20$ ,  $P < 0.001$ ) due to very low abundances in AR and DR during the whole season. Complementary analyses confirmed significant differences among NP harvesting regimes 30, 60 and 90 days after the beginning of the study, with greater values in NPF than in AR and DR (Table 1). Likewise, significant differences were found among days after the beginning of the study only for NP unharvested forests (Repeated-measures ANOVA,  $F = 3.09$ ,  $P = 0.023$ ), where abundance of *Ne. michaelsoni* was significantly higher at 30 days than at 45, 60 and 75 days after the beginning of the study, with intermediate values for 15 and 90 days (Fig. 1b).

In NA forests, significant differences in pseudoscorpion abundances were not detected between unmanaged and silvopastoral managed forests (Repeated-measures ANOVA,  $F = 1.99$ ,  $P = 0.177$ ), with the average abundance of 4.7 individuals *per* sampling unit. Likewise, significant differences were not detected between ranches (Repeated-measures

Table 1.—One-way ANOVA and Tukey test results for *Ne. michaelseni* abundance comparing different vegetation types and NP harvested and unharvested forests, at 15-day intervals after the beginning of the study. NAF = old growth NA forests; NPF = old growth NP forests; AR = aggregated retention in NP forests, DR = dispersed retention in NP forests.

Terms and factor levels	Days after the beginning of the study					
	15	30	45	60	75	90
Vegetation types						
NAF	10.7 b	11.5 b	3.7 b	1.3	2.3 b	4.3 b
NPF	3.3 ab	9.7 b	1.5 ab	0.5	0.8 ab	1.7 ab
Peatlands	1.7 ab	3.5 ab	0.2 a	0	0.0 a	0.0 a
Grasslands	0.3 a	0.5 a	0.2 a	0	0.0 a	0.2 a
<i>F</i> ( <i>p</i> )	5.28 (0.008)	6.37 (0.003)	4.92 (0.010)	3.01 (0.054)	8.65 (<0.001)	5.86 (0.005)
Habitat types						
NPF	3.3	9.7 b	1.5	0.5 b	0.8	1.7 b
AR	0.2	0.2 a	0.5	0.0 a	0.2	0.0 a
DR	0.3	0.3 a	0.3	0.0 a	0.2	0.0 a
<i>F</i> ( <i>p</i> )	1.84 (0.194)	12.18 (<0.001)	0.36 (0.707)	5.00 (0.022)	1.43 (0.270)	6.71 (0.008)

ANOVA,  $F = 3.81$ ,  $P = 0.069$ ), which had 4.4 individuals on average *per* sampling unit. Moreover, interactions were not significant in this analysis (Repeated-measures ANOVA,  $F = 0.35$ ,  $P = 0.561$ ).

Cluster analyses highlighted the similarities among *Ne. michaelseni* abundance in NP and NA forests compared to grassland and peatlands (Fig. 2a). Correspondingly, there were similarities in aggregated and dispersed retention harvesting compared to unharvested NP forests (Fig. 2b), and between unmanaged NA forests from Los Cerros and San Pablo Ranches compared with sivopastoral managed sites (Fig. 2c).

## DISCUSSION

*Neochelanops michaelseni* was the main pseudoscorpion species detected in central Tierra del Fuego forests and non-woody habitats. This species is the only native cited for Tierra del Fuego (Mahnert et al. 2011) and its habitat preferences are practically unknown. The other species recorded for Tierra del Fuego is *Chelifer cancroides* (Linnaeus 1758), which might have been introduced during colonial times, and has not been recorded in Argentina since 1905 (Mahnert et al. 2011). On the other hand, the other pseudoscorpion species detected in this study, *Serianus* sp., was not previously found in Tierra del Fuego.

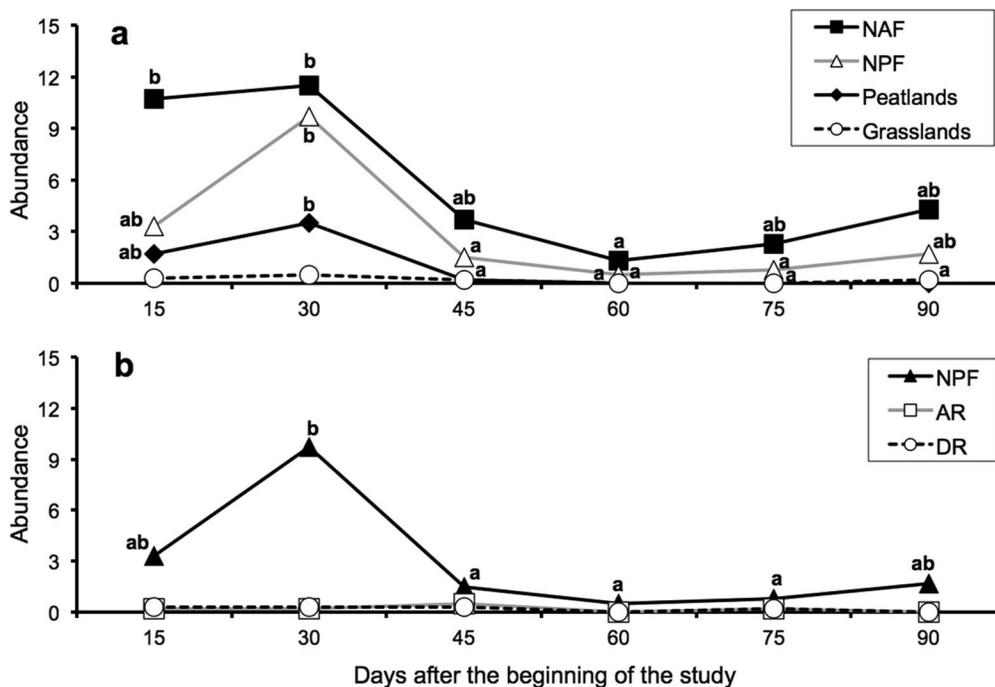


Figure 1.—Changes in mean abundance of *Ne. michaelseni* during the course of study for (a) different vegetation types, considering old growth NA forests (NAF), old growth NP forests (NPF), peatlands and grasslands, and (b) different harvesting regimes in NP forests, considering unharvested old growth (NPF), aggregated retention (AR) and dispersed retention (DR) forests. Letters corresponded to differences by Tukey test at  $p < 0.05$ .

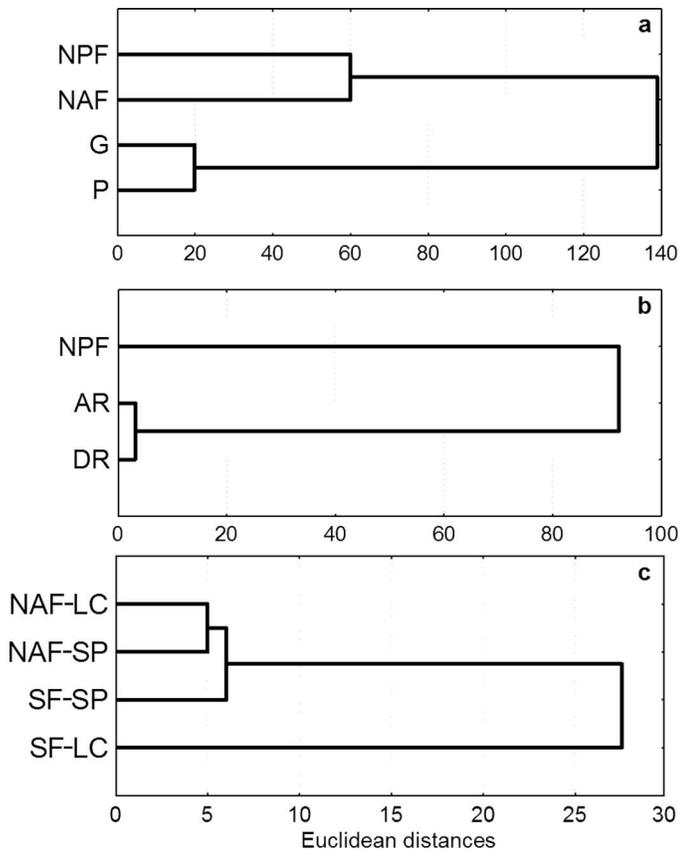


Figure 2.—Cluster analysis for *Ne. michaelsoni* abundance in Tierra del Fuego, corresponding to: (a) different vegetation types, considering old growth NP forests (NPF), old growth NA forests (NAF), grasslands (G) and peatlands (P); (b) different harvesting regimes in NP forests, considering unharvested old growth (NPF), aggregated retention (AR) and dispersed retention (DR) forests; and (c) silvopastoral management in NA forests, considering unmanaged old growth forests in Los Cerros Ranch (NAF-LC) and San Pablo Ranch (NAF-SP) and silvopastoral managed forests in Los Cerros Ranch (SF-LC) and San Pablo Ranch (SF-SP).

Our study highlights the dissimilar abundance of *Ne. michaelsoni* among typical vegetation types of Tierra del Fuego landscape, with greatest abundances in woodlands and relatively low abundance in grasslands and peatlands. Leaf litter is the ancestral habitat of pseudoscorpions, which provides an ideal stable environment (Jones 1970), and encloses a specific litter fauna that plays a very important role in the transformation of leaf litter into humus. Pseudoscorpions are at the upper level of this trophic chain, feeding on primary or secondary herbivores, such as mites, collembolans, nematodes, woodlice, millipedes, insects, and earthworms (Buddle 2005). Litter in forests could provide a more stable and richer environment than litter in grasslands and peatlands, which could explain the higher abundance of *Ne. michaelsoni* in woody vegetation types. Although a few authors have examined pseudoscorpion diversity in grasslands and other open environments around the world (Rapp 1978; Bell et al. 1999; Dennis et al. 2001), more studies are needed to explore pseudoscorpions in non-woody vegetation types.

On the other hand, pseudoscorpions of the family Chernetidae are often found in hollow stumps and hollow trees (Snow 1958; Ranius & Wilander 2000), but also under the bark of trees and logs (Buddle 2005), in leaf litter adjacent to fallen logs (Hoff 1949), and in the wood of 10 and 20 years old stumps (without hollows) (Persson et al. 2013). Indeed, some species of Chernetidae had clearly higher abundances in bark and wood than in soil or litter (Persson et al. 2013). Therefore, higher abundance of *Ne. michaelsoni* in woodlands than in grasslands and peatlands could be related to the presence of coarse woody debris, logs and stumps at different stages of decomposition, usually found in the floor of old growth *Nothofagus* forests (Lencinas et al. 2008, 2011), which could be the typical microhabitat of this species.

Beside differences among vegetation types, *Ne. michaelsoni* abundance was highest in old-growth forests compared to managed or harvested stands, as was observed by Yamamoto et al. (2001) and Burghouts et al. (1992) in other forests. Disturbances affect pseudoscorpion abundance, likely due to changes in the availability of microhabitats. The reduction of canopy cover by harvesting in the original NP forest structure negatively impacts the amount of leaf litter that reaches the forest floor in harvested sites (Martínez Pastur et al. 2008), which may lead to the decrease of pseudoscorpion populations. On the other hand, variable retention harvesting in NP forest increased debris cover and biomass compared to old growth forests (Lencinas et al. 2011), mainly medium size debris and small branches (Martínez Pastur et al. 2011). Recently generated large debris probably needs time to start rooting and constitute appropriate habitats for pseudoscorpions. Because this study was performed in stands harvested seven years ago, more studies must be carried out in older harvested sites, with coarse woody debris at different stages of decay. Additionally, harvesting greatly modifies microclimate below NP canopy (Promis et al. 2010), which could generate dramatic fluctuations in the humidity and temperature regimes, with a potential negative impact on decomposition rates (Frangi et al. 1997) and pseudoscorpion abundance, even if they inhabit coarse woody debris. Timing and intensity of management may have a significant impact on the abundance of pseudoscorpions too (Bell et al. 1999).

Variable retention harvesting, a stand-level conservation approach to better integrate woody production and biodiversity conservation (Gustafsson et al. 2012), is proposed for south Patagonian forests, and applied as well in Europe, North America, Latin America, and Australia. In NP forests, variable retention was useful to improve conservation of biodiversity and natural cycles in the managed forests (e.g., Lencinas et al. 2011, 2012), mainly inside aggregates. However, similar *Ne. michaelsoni* abundances were found inside and outside aggregates at least seven years after harvesting, with comparable values to grasslands. The recovery of forest structure in secondary forests may also allow recovery of pseudoscorpion populations, probably due to deeper litter build-up over time. The longer the secondary forest has to develop, the more stable and ultimately more suitable the litter environment becomes (Jones 1970).

On the other hand, *Ne. michaelsoni* abundance did not differ significantly between silvopastoral managed and unmanaged NA forests, probably because thinning did not greatly affect

litter production or debris abundance in this system. Differences among *Nothofagus* forests must be considered, because NA forests constitute open woodland, with richer and more productive understory than NP forests (Lencinas et al. 2008). Under silvopastoral management, decrease of litter production could be also produced by livestock consumption of herbaceous plants and trampling. Additionally, thinning increases radiation at the understory level, which stimulates grass biomass production. Therefore, litter reduction is less in silvopastoral managed NA than in harvested NP forests, which could generate less impact in pseudoscorpion populations. Since Dennis et al. (2001) found abundance of pseudoscorpions to be greater in ungrazed and taller grazed swards than in short grazed swards, and Rapp (1978) determined that grazing caused a decline in the number of pseudoscorpions because of adverse changes in soil moisture and litter depth, more studies are necessary to evaluate the impact of contrasting silvopastoral management intensities in NA forests.

All sex-age classes (male, female and juveniles) of *Ne. michaelseni* were more abundant at the beginning of the sampling period (early summer). This could be related to temperature, because many species of pseudoscorpions are active throughout spring, summer, and autumn and hibernate during winter, with juveniles emerging in spring. In Tierra del Fuego, the abbreviated growing season could accelerate these processes. Precise information about the life cycles of pseudoscorpions depends on quantitative sampling over a period of years. Therefore, the present work enriches the knowledge about this almost unknown species, and offers tools for better planning of the sampling.

This study highlights the feasibility of *Ne. michaelseni* as a bioindicator for ecosystem conservation, mainly in NP forests, and generates useful and necessary information related to their presence in typical vegetation types in south Patagonian forests. Due to their small size, pseudoscorpions' ability to disperse to other environments is limited (Zeh & Zeh 1992; Del-Claro & Tizo-Pedroso 2009). Consequently, we conclude that *Ne. michaelseni* is a good detector of forest disturbances, and could be used to evaluate the recovery rate in the ecological characteristics of impacted *Nothofagus* forests. Similarly, other pseudoscorpion species were sensitive to management showing dissimilar abundances under different managements (Burghouts et al. 1992; Bell et al. 1999; Yamamoto et al. 2001; Barros et al. 2010) and in grasslands where pseudoscorpions are not abundant. Management practice intensities (mainly harvesting) should be regulated to create more suitable habitats for pseudoscorpion diversity conservation.

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