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ORIGINAL ARTICLE

Hazel dormice (*Muscardinus avellanarius*) in a regenerating clearing: the effects of clear-felling and regrowth thinning on long-term abundance dynamics

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Abstract

The hazel dormouse (*Muscardinus avellanarius*) is a rare and threatened species in many European countries. However, it is common and widespread in Lithuania where forest management practice, particularly small-scale clear-felling, is considered to be favourable for this species. The long-term study was carried out in regenerating clearing which fell in the area of the dormouse study site. The forest plot was clear-felled in the winter 2001/2002, and regrowth was thinned in 2004, 2007, 2010 and 2014. During 2003–2019, average adult dormouse density in regenerating clearing (1.6 ± 0.7 adults/ha) was significantly higher than average density in the entire area of the study site (1.0 ± 0.3 adults/ha). Clear-felling had only short-term negative effect on dormouse abundance. It increased already in the 3rd year after clear-felling when dormouse density exceeded 2 adults/ha and reached its maximum in the 7th–9th years after clear-felling. Dormouse abundance decreased since the 14th year after clear-felling. Thinning of regrowing woody vegetation had only temporary negative impact on dormouse abundance in the current or next year depending on the timing of thinning in early summer or autumn, respectively. Practice of small-scale clear-felling could be used for the hazel dormouse conservation in countries where this species is endangered.

Keywords Common dormouse · Forest management · Population density · Lithuania

Introduction

The hazel dormouse (*Muscardinus avellanarius*), also often referred to as the common dormouse, is a small nocturnal arboreal mammal living mostly in deciduous or deciduous–coniferous forests with a well-developed understorey and in other low-growing woodlands with dense and diverse vegetation (e.g. Bright and Morris 1996; Juškaitis 2014; Holden-Musser et al. 2016). In general, the hazel dormouse is considered as a threatened species, included in Annex IV of the Habitats Directive of the European Union. In many European countries, the hazel dormouse is included in national Red Lists (see review in Juškaitis 2014). An ongoing decline in dormouse abundance has been recorded in the UK, despite a high level of species protection and widespread conservation measures (Goodwin et al. 2017). Habitat loss, habitat fragmentation and unfavourable forest management are the major threats to this species.

The hazel dormouse is a woodland species losing its habitats due to deforestation. Farmland, urban development, roads and other forms of unsuitable habitat have replaced many potentially good dormouse woodlands (e.g. Bright and Morris 1996; Bright et al. 2006; Mortelliti et al. 2011; Büchner and Lang 2014). Due to large-scale deforestation, the hazel dormouse is absent from many parts of Poland (Jurczyszyn and Wołk 1998). Species-rich forest edges and hedgerows are dormouse habitats that underwent a severe decline in some countries during the last few decades (Foppen et al. 2002; Bright et al. 2006; Ramakers et al. 2014; Dondina et al. 2016). Not only woodland fragmentation by roads and other development results in less habitats being available, but also relict parts are then isolated and often too small, resulting in local extinction (Bright and Morris 1996; Capizzi et al. 2002; Verbeylen 2006; Meinig and Boye 2009; Mortelliti et al. 2009, 2014; Encarnação and Becker 2015; Iannarilli et al. 2017).

Modern forest management systems have a negative impact on the habitats of the hazel dormouse in many regions

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where the dormouse is threatened. Coppicing, a traditional form of woodland management, which involves cutting down trees to ground level at intervals of usually 7–25 years to encourage the growth of multiple stems, is very favourable for dormice (Bright and Morris 1990; Sanderson et al. 2004; Bright et al. 2006; Sozio et al. 2016). However, it has now largely ceased in many countries, and commercial forestry has replaced it (Bright and Morris 1996; Foppen et al. 2002; Verbeylen 2006; Müllerová et al. 2015). The replacement of ancient native natural woodlands with alien coniferous plantations or conversion into single species woodlands is deleterious to dormouse populations (Bright and Morris 1996; Vilhelmsen 2003; Berglund and Persson 2012; Trout et al. 2012, 2018). The present forest management policy with more permanent forests and reduction or exclusion of clear-felling is harmful for the hazel dormouse in Austria and Germany (Spitzenberger and Bauer 2001; Lang et al. 2013).

Appropriate woodland management can have a positive influence on hazel dormouse populations. Studies of many woodlands across the UK have shown that populations respond positively to woodland management such as coppicing and glade management that maintain successional and diverse habitats (Goodwin et al. 2018b). Habitat restoration to re-establish native broadleaves in conifer plantations on ancient woodland sites is expected to have a positive influence on hazel dormice in the UK (Trout et al. 2012, 2018).

Lithuania is situated on the northern periphery of the distributional range of the hazel dormouse. It would be reasonable to expect that living conditions for this species are sub-optimal here in comparison with more southerly situated parts of its range and that the species should be rare in Lithuania (Juškaitis et al. 2015). However, the hazel dormouse is common and not endangered in Lithuania in contrast to situation with this species in many Western European countries. It is supposed that forest management practice is favourable for the hazel dormouse in Lithuania (Juškaitis 2007). Small-scale clear-felling is a typical technique for harvesting of timber in Lithuanian forests. Within 3 years after harvest, clear-felling sites have to be reforested. Artificial planting, natural regeneration and mixture of both methods are used for the reforesting of clear-felled sites. Later intermediate fellings (pre-commercial and commercial thinnings) are used to form forest stands of the desired species (Brukas et al. 2013; Ministry of Environment and State Forest Service 2018).

Regenerating clear-felled areas are considered to be good habitats for hazel dormice (review in Juškaitis 2007, 2014). However, regenerating clearings are thinned every few years, and until now, the long-term effect of clear-felling and thinning of regrowth on hazel dormouse population dynamics has not been studied. The aim of the present study was to assess the long-term abundance dynamics of the hazel dormouse in a regenerating clearing during 18 years after clear-felling, to evaluate the effect of regrowth thinning and to discuss the influence of small-scale clear-felling on hazel dormouse populations.

Material and methods

Study area

The research was carried out at dormouse study site situated in south-western Lithuania, Šakiai district (55° 03′ N, 23° 04′ E) within a large forest tract of about 3000 ha. The area of the study site (60 ha, the "study site") was delimited by forest edge to the east, by a stream and meadow belt to the south, by a forest road to the west and a border nestbox line to the north (Fig. 1). Over most of the study site, the forest was middle-aged (about 60 to 80 years old) and consisted of diverse deciduous-coniferous stands dominated by birches (*Betula pendula* and *B. pubescens*), Norway spruce (*Picea abies*), black alder (*Alnus glutinosa*), aspen (*Populus tremula*) and pedunculate oak (*Quercus robur*). The understorey contained many hazels (*Corylus avellana*) throughout the study area. Alder buckthorn (*Frangula alnus*), bird cherry (*Padus avium*), rowan (*Sorbus aucuparia*) and dwarf honeysuckle (*Lonicera xylosteum*) were other major species in the understorey.

A variety of forest management actions were carried out at this study site: clear-felling, selective felling, felling of all the understorey, planting of Norway spruce and pedunculate oak trees in clearings and thinning of regenerating clearings. In winter 2001/2002, an area of about 5 ha (90 × 560 m) was clear-felled within the forest body, and a half of this clear-felled area fell in the dormouse study site (Fig. 1). Trees were cut down manually using chainsaws, and the timber was transported by machine on special paths lined with tree branches.

Within the study site, the clearing (the "regenerating clearing") bordered a young birch dominated stand to the east and was surrounded by mixed Norway spruce, birch and black alder dominated tree stands to the south and west. The forest stand bordering the regenerating clearing to the west was clear-felled in winter 2009/2010, and regrowth was thinned in 2014, 2016 and 2019 (see Fig. 1).

In the regenerating clearing, birch, aspen and black alder trees regrew naturally, and some pedunculate oak and Norway spruce trees were planted by foresters. Among the shrub vegetation, hazels, alder buckthorns and raspberries (*Rubus idaeus*) were abundant (see Juškaitis and Remeisis 2005 for details). Regrowth was thinned in August–September 2004, in May 2007, in September–October 2010 and in June 2014. During these operations, some regenerating young trees and all shrubs (hazel, alder buckthorn, raspberries, etc.) were cut down.

Study methods

Long-term investigations into the hazel dormouse population were carried out from 1999 to 2019. Standard wooden nestboxes intended for small hole-nesting birds, e.g. great tit (*Parus major*) and pied flycatcher (*Ficedula hypoleuca*), were used for the studies of the hazel dormouse population. The internal dimensions of the boxes were 12 × 12 × 23 cm with an entrance hole diameter of 35 mm. The boxes were put up on tree trunks (mainly on hazel) at a height of 3–4 m with the entrance hole facing outwards. In the study site, 272 nestboxes were placed in a grid system at 50-m intervals. The nestbox density was four boxes per hectare. Nestboxes were absent in the clear-felled area in the first year after felling, but they were returned and set up on poles in previous places in spring of the second year after felling. Nestboxes situated on edges of the clear-felled area were present permanently. In total, 18 nestboxes were situated in the regenerating clearing including its edges (see Fig. 4).

The nestboxes were checked during daytime twice a month from April to October. All dormice caught were marked with aluminium rings with individual numbers (inner diameter—2.5 mm, height—3.0 mm). The rings were placed on the right hind leg over the ankle. All animals were weighed using KERN 60 g spring balances with accuracy to 0.5 g, and their sex and age were determined. Dormice were considered adults if they had survived at least one hibernation. Unmarked young-of-the-year individuals were distinguished from adults by their lower body weight, greyer fur colouration and narrower tail (Juškaitis 2014). During the entire study period, 3233 individuals were marked, and, of these, 422 individuals were recorded in the area of the regenerating clearing.

The enumeration method or the minimum number alive (MNA) method (Krebs 1999) was used for the estimation of the number of adult dormice living in the area of the study site in spring after hibernation. Adult individuals which were not recorded in spring, but were found during any subsequent nestbox inspection, were included in the calculations of the MNA in spring. The spring density of population was calculated by dividing the MNA in spring by the effective trapping area (Flowerdew 1976; Krebs 1999). The effective trapping area was calculated by adding a boundary strip to the sides of the area containing nestboxes, except when this area was delimited by forest edge (Fig. 1). The width of the boundary strip was equivalent to one-half of the mean distance moved by dormice between nestboxes. In the 50-m nestbox grid, this distance was 96 m (Juškaitis 2014), so the width of the boundary strip was taken to be 50 m, and the effective trapping area

Fig. 1 Location of the study site and regenerating clearing (white outlines) within commercial forest with clear-felled plots (light grey colour) and regenerating clearings (darker grey colour) in Lithuania (image from Google Earth 2017)

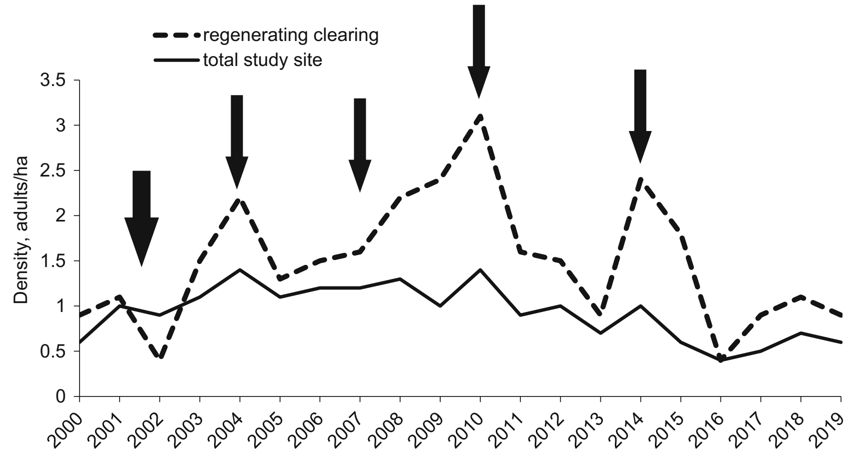


Fig. 2 Dynamics of density of adult hazel dormice in regenerating clearing and in the total area of the study site during 2000–2019. The plot was clear-felled in the winter 2001/2002, and regrowth was thinned in 2004, 2007, 2010 and 2014. Black arrows indicate years of clear-felling and regrowth thinning

of the whole study site was thus 68 ha. Similarly, the area of the regenerating clearing was 2.5 ha and effective trapping area was 5.5 ha (see Fig. 4).

For a comparison of dormouse abundance in the regenerating clearing and in adjacent forest stands, four plots of the same size, containing 18 nestboxes each, were defined. In these plots, dormouse abundance was evaluated as density per hectare and additionally as the number of individuals per 100 nestboxes (e.g. Goodwin et al. 2018b).

The numbers of adult and juvenile dormice recorded, and numbers of litters found in nestboxes situated in the regenerating clearing were other indicators of the plot's suitability for dormice. The numbers of litters were estimated according to the numbers of marked breeding females found with juveniles in nestboxes each year.

Results

Clear-felling destroyed dormouse habitat completely in the cleared area. In the first year after clear-felling, only 2 adults and 8 juveniles were recorded in nestboxes situated on the edges of the clear-felled area. However, by the second year after clear-felling, dormice had started to use nestboxes situated in the middle of the regenerating clearing. During 2003–2019 ($n = 17$ years), the average adult dormouse density in this plot (1.6 ± 0.7 adults/ha) was significantly higher than the average density in the entire area of the study site (1.0 ± 0.3 adults/ha) (Mann-Whitney test: $z = 3.01$, $p = 0.003$). In the regenerating clearing, dormouse abundance increased three times: in the 3rd, 7th–9th and 13th years after clear-felling, when dormouse density exceeded 2 adults/ha (Fig. 2).

Thinning the regrowing woody vegetation had a temporary negative impact on hazel dormouse abundance in the area of the regenerating clearing. Thinning carried out in May–June had a negative impact on the number of juveniles recorded in the autumn of that year, especially in 2004. The thinning carried out in autumn 2010 had an evident negative impact on dormouse abundance the following year. Dormouse abundance decreased in the regenerating clearing after 2015, although no thinning was carried out in this area after 2014 (Fig. 3).

In the regenerating clearing, the highest adult dormouse abundance was recorded in 2010, i.e. in the 9th year after clear-felling (Fig. 3). Dormice preferred to occupy nestboxes situated in this plot in comparison to nestboxes situated in

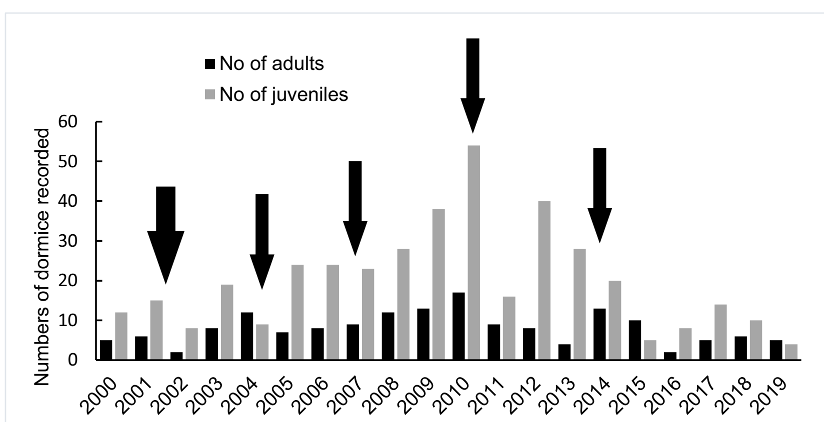


Fig. 3 Impact of clear-felling and regrowth thinning on dynamics of number of adult and juvenile hazel dormouse recorded in the area of the regenerating clearing. The plot was clear-felled in the winter 2001/2002, and regrowth was thinned in 2004, 2007, 2010 and 2014. Black arrows indicate years of clear-felling and regrowth thinning

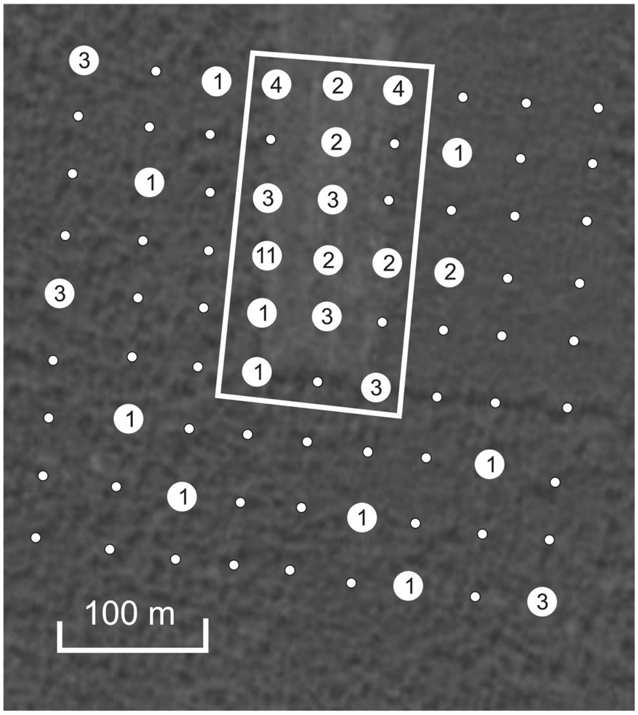


Fig. 4 Numbers of hazel dormice recorded in nestboxes situated in the regenerating clearing (white outline indicates regenerating clearing with 25 m wide boundary stripe added) and in adjacent forest stands during a single nestbox inspection on 26 September 2010 (the 9th year after clear-felling)

surrounding forest stands. During a single nestbox inspection in September 2010, 41 dormice were found in 18 nestboxes situated in the regenerating clearing (area delimited by nestboxes—2.5 ha); meanwhile, in four adjacent areas of the same size, only 3, 3–6 and 8 individuals, respectively, were found (Fig. 4). In the area of the regenerating clearing, dormouse abundance was 7.5 ind./ha or 228 ind./100 nestboxes, while in adjacent areas only 0.5–1.5 ind./ha or 17–44 ind./100 nestboxes.

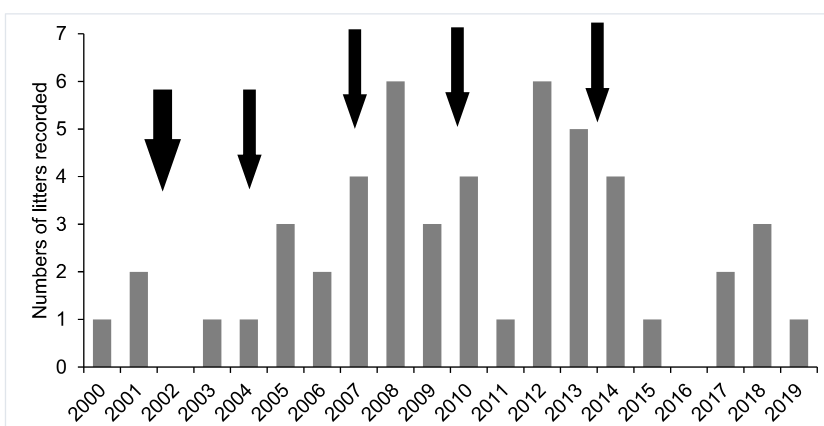
In the regenerating clearing, the highest numbers of dormouse litters were recorded in 2005–2014, i.e. during the 6th–13th years after clear-felling (Fig. 5). After thinning of regrowth in autumn 2010, the number of litters recorded decreased evidently in 2011.

Discussion

Throughout their distributional range, hazel dormice prefer the early successional stages of woody vegetation, such as regenerating clearings (reviews in Juškaitis 2007, 2014). In Moldova, the highest dormouse density (15 adults/ha) was found in regenerating clearings with 5–12-year-old regrowth (Lozan 1970). In Denmark, 56% of hazel dormouse records occurred in young 10–15-year-old woodland growths (Vilhelmsen 2003). In Romania, hazel dormice preferred forest clearings with 4–8-year-old regrowth of hazel, oak and other trees (Istrate 2005). In the current study, the highest dormouse abundance was recorded during the 3rd–13th years after clear-felling, and the peak abundance was recorded in the 7th–9th years after felling. Clear-felling had only short-term negative effect on dormouse abundance, which increased in the 3rd year after clear felling, when dormouse density exceeded 2 adults/ha.

Clear-felling leads to an increase in soft mast production in regrowing clearings, when they are 2–9-year-old (Reynolds-Hogland et al. 2006). In regenerating clearings in Lithuania, raspberries, alder buckthorns and dwarf honeysuckles are more abundant and fruit much better than in older forest stands, where these shrubs are shaded. Fruits of these plants are favourite food sources for dormice in summer and autumn (Juškaitis and Baltrūnaitė 2013; Juškaitis et al. 2016). In Lithuania, fruits of alder buckthorn are an especially important food source for dormice because the fruiting period of these plants is very long: starting in August and lasting up to November. Young Norway spruce trees, growing in reforested clearings, are favourite nests sites for hazel dormice in Lithuania (Juškaitis and Remeisis 2007). Dormice concentrate in such regenerating clearings, and dormouse density can be several-fold higher there than in surrounding forest stands.

Fig. 5 Dynamics of number of hazel dormouse litters recorded in nestboxes situated in the regenerating clearing which was clear-felled in the winter 2001/2002, and regrowth was thinned in 2004, 2007, 2010 and 2014. Black arrows indicate years of clear-felling and regrowth thinning



In the fourth and fifth years after clear-felling, respectively, 16.2 and 11.8 dormouse nests per hectare were recorded in a 5-ha regenerating clearing (Juškaitis and Remeisis 2007). In Romania, even about 30 dormouse nests were found in an area of about 1 ha in regenerating clearing (Istrate 2005).

However, such good conditions for hazel dormice are disturbed when regenerating clearings are thinned every 3 or 4 years. Immediately after thinning, these habitats are barely suitable for dormice because all shrubs are cut down and the density of young trees is reduced. Nevertheless, coppiced shrubs regrow rather fast; alder buckthorns and raspberries start fruiting the following year, and these habitats once again become suitable for hazel dormice. However, this process is not continuous. After thinning of regenerating clearings which are older than 10 years, these habitats become less suitable for hazel dormice. The canopies of young trees shade the understorey as they regrow, and shaded shrubs are sparse and fruit poorly. For this reason, dormouse abundance declined in the focal regenerating clearing since the last thinning in 2014. An analogous decline in dormouse abundance was recorded in the adjacent forest plot where a regenerating clearing was thinned in 2004 at an age of about 13 years. The density of adult dormice can be even below average population density in such stands (Juškaitis 2008, 2014). Natural succession towards an old growth forest with a closing canopy and a declining shrub layer resulted in a decreased density of hazel dormouse nests recorded in a study area in Sweden (Berg 1996).

Nevertheless, new plots are clear-felled each year, forming new habitats suitable for dormice after a few years (Fig. 1). Regular clear-felling of different comparatively small areas of the forest creates plots with young stages of forest development, which are favourable for hazel dormice. Clear-felled areas are comparatively small: the average size of clear-cuts (excluding those < 0.5 ha) is 1.8 ha in the state forests of Lithuania (Brukas et al. 2013). In clear-felled areas, native tree species are planted, not only mainly coniferous trees (Norway spruce and Scots pine), but also pedunculate oak, less often silver birch and black alder (Brukas et al. 2013). By thinning of regrowth, mixed forest stands are developed. All these forest management activities create favourable living conditions for the hazel dormouse in Lithuanian forests, and hazel dormice are not endangered in Lithuania without any special conservation actions.

The dormouse's preference for mid-height, shrubby habitats that arise shortly after felling and clearance, emphasizes the need for active management to maintain their preferred habitats (Goodwin et al. 2018a). The Lithuanian forest management system of the building up of a patchwork of small clear-fells is favourable for the hazel dormouse because of a continuing local supply of small regenerating patches of excellent habitat quality each acting as temporary boost for the population. This practice of small-scale clear-felling could be used for the hazel dormouse conservation in countries where the species is endangered. Many studies support the importance of early stages of regenerating clear-felled areas also for other animal species, especially for small mammals (review in Bogdziewicz and Zwolak 2014) and their predators (Sidorovich et al. 2008).

In summary, clear-felling and regular thinning of regenerating clearings are forms of management that favour hazel dormice and many other animal species in the early stages of woodland succession. However, it needs to be considered in relation to the total size of woodland. Clearing too much may be harmful in smaller woodland sites that characterize fragmented countryside because too few animals are left in the remaining mature habitat. Another concern is the decline in dormouse abundance after thinning of regenerating clearings which are older than 10 years. Probably more intensive thinning is necessary to prevent the conversion of the site to closed canopy forest. Further studies on this subject are necessary.

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Compliance with ethical standards

Conflict of interest The author declares that he has no conflict of interest.

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