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Review

The impact of reed management on wildlife: A meta-analytical review of European studies

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ABSTRACT

We reviewed European studies on the effect of reed management (harvesting, burning, mowing and grazing) on reedbed wildlife, and in addition, on the performance of re-growing reed (*Phragmites australis*). Our database consisted of 21 studies conducted on 10 plant species, 17 taxonomic groups of invertebrates and 11 bird species, and published between 1982 and 2006.

We found that reed management modifies the structure of re-growing reed stands: reed stems were shorter and denser in managed sites than in unmanaged sites. However, harvesting does not have an impact on aboveground biomass. Plant species richness increased by 90% in managed stands in fresh water marshes, but not in saline water marshes.

Overall, reed management had a significant negative impact on invertebrate community, but the duration of management was an important factor determining the magnitude of the effect. Short-term management (1–2 years) had no effect on invertebrates, whereas management for longer period significantly reduced invertebrate abundance. Reed harvesting and burning reduced abundance of passerine birds by about 60%. This was probably associated with food limitation as the numbers of butterflies, beetles and some spiders were reduced. Therefore, the optimal reed management regime to preserve number of birds and invertebrates in reedbeds could be a rotation of short-term management (1–2 years). However, the optimal interval between management applications should be established in future studies.

Contents

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1. Introduction

Common reed (*Phragmites australis* (Cav.) Trin. ex Steud.) is a tall grass species of great economic and ecological importance that is widely distributed in European wetlands (Haslam, 1972). It often forms extensive stands known as reedbeds. Reedbeds represent an important habitat for plants, birds and invertebrates including many rare and vulnerable species. For example, reedbeds contain a number of rare plant species, including marsh sow thistle (*Sonchus palustris*), marsh pea (*Lathyrus palustris*), greater water parsnip (*Sium latifolium*), marsh fern (*Thelypteris palustris*) and crested buckler fern (*Dryopteris cristata*) (Cowie et al., 1992). Moreover, 700 species of invertebrates are associated with reedbeds, and some of them are of conservation interest (Hawke and José, 1996), for example some species of Lepidoptera, e.g. *Phragmataecia castaneae*, *Mythimna obsoleta* and *Papilio machaon*. Common reed also represents an important habitat for many bird species, especially passerines such as moustached warbler (*Acrocephalus melanopogon*), reed warbler (*A. scirpaceus*), great reed warbler (*A. arundinaceus*), sedge warbler (*A. schoenobaenus*), bearded tit (*Panurus biarmicus*), and reed bunting (*Emberiza schoeniclus*) (Poulin et al., 2002; Graveland, 1999). Moustached warbler and great reed warbler are considered vulnerable species in Europe. In addition, reedbeds constitute a major breeding habitat for several vulnerable and rare bird species in Europe including dalmatian pelican (*Pelecanus crispus*), purple heron (*Ardea purpurea*), red-crested pochard (*Netta rufina*), marsh harrier and great bittern (Tucker and Heath, 1994).

On the other hand, reedbed represents the early stages of succession from open water to woodland. Without management a reedbed will gradually dry out, becoming colonised by other grasses and tall herbs eventually developing into scrub and woodland (Hawke and José, 1996). In this situation, characteristic reedbed animals and plants will in time be lost and the reed will no longer be of thatching quality. Reedbed management will slow down or even reverse succession in order to maintain a balance of different habitat types or to reinstate one or more habitats, depending on the objectives. Often the dominance of reed is sought, especially where the objective is to provide habitat for reed-specific wildlife such as bittern and bearded tit or to cut reed for thatch (Hawke and José, 1996).

Reed management options include cutting, burning and grazing by cattle and geese for nature conservation to arrest the succession of reedbeds. In addition, reedbeds are annually harvested for thatching material in several western and central European countries. Numerous studies have assessed the impact of reed management on reedbed wildlife and have revealed variation in species responses to reed management. For example, densities of some reed-dwelling spider and beetle species, including the most preferred prey species for passerine birds, were lower at cut sites (Schmidt et al., 2005). However, other results showed increase in abundance and distribution of arthropods in cut sites compared to uncut sites (Poulin and Lefebvre, 2002) or no effects of reed management on the invertebrate community (Ditlhogo et al., 1992). The impact of reed cutting on birds associated with reedbeds is generally negative due to preventing nest building of early breeding passerines (Poulin and Lefebvre, 2002), increased risk of nest predation, and the delay in clutch initiation (Graveland, 1999). In contrast to invertebrates and bird species, reed cutting has positive effects on richness of plant species (Cowie et al., 1992).

A number of narrative reviews have summarized the results of studies on growth, ecology and progression of common reed, and its effects on associated plant and animal species in Europe (Haslam, 1972; Güsewell and Klötzli, 2000). Hawke and José (1996) have reviewed the effects of reed management on species associated with reed beds and demonstrated great variability in their responses. Many more studies exploring the effects of reed management on reedbed wildlife and on the performance of common reed were published since 1996. Therefore, there is a need for a critical review of the evidence of the impact of reed management on reedbed wildlife, which would identify the conditions under which reed management is likely to be most effective.

The objective of this review was to summarize the available evidence regarding the impact of reed management on wildlife in Europe. The following questions were addressed: (1) What is the impact of management on the performance of re-growing reed? (2) What is the impact of reed management on plants, invertebrates, and bird species associated with reedbeds? (3) How do the type of reed management, its timing and the duration of management period affect wildlife? (4) Do habitat, water salinity and the type of vegetation modify the effects of management on wildlife? In order to combine the results from independent studies, we used the method of meta-analysis which, unlike narrative reviews, allows to quantitatively assess the magnitude of the effect and to analyze the main sources of variation in results between studies (Gurevitch and Hedges, 1999).

2. Materials and methods

2.1. The database

Relevant journal articles were found by using key-word searches in Web of Science Database and by looking through the reference lists of previous narrative reviews (Haslam, 1972; Ostendorp, 1989; Tscharntke and Greiler, 1995; Hawke and José, 1996; Güsewell and Klötzli, 2000). The following combinations of English language search terms were used: *Phragmites australis* or common reed, and either cut*, burn*, grazing, manage*, bird*, insect*, invertebrate*, vegetation, plant* or conservation. To be included in the meta-analysis, a study had to meet the following criteria: (1) a study has been made in Europe; (2) the method of reed management used has been either harvesting, mowing, burning or grazing; (3) a study had an appropriate control (unmanaged stands); (4) impact of reedbed management on either plants, invertebrates and/or birds have been assessed; (5) responses to treatments in terms of means of the experimental (=managed, X_m) and control (=unmanaged, X_u) groups, corresponding standard deviations (S_m, S_u) and sample sizes (n_m, n_u) have been reported in numerical or graphical form in the article. Data from the figures were digitized by using ImageJ 1.37 program. Our final database consisted of 21 studies conducted on 10 plant species, 17 taxonomic groups of invertebrates, and 11 bird species, and published between 1982 and 2006 (Table 1). Meta-analytical methods require that individual observations are statistically independent. Therefore, only one measurement per treatment per species per study was used. If measurements have been taken at several time points during the experiments, we chose the data corresponding to the longest follow up period. If there were more than one observation per study, for example several species of plants or birds, or taxonomic groups of invertebrates, or several treatments, the data for each observation were included in the database.

2.2. Response variables

Measures of response of common reed and other plant species included stem density, stem diameter, stem height and aboveground biomass. In addition, for other plant species, abundance and species richness have been included. These variables for common reed and other plant species were measured at the end of growing season or autumn. Invertebrate response variables were abundance (measured as number of invertebrates per pitfall trap or litter bag), density (measured only for mollusc as number of individuals in quadrats per m^2) and species richness. Insects were classified to order, sub-order and/or family. Bird response variables were colony size, number of captures, density of males, clutch size, density of nests, laying date, number of fledglings, and predation rates of nests. For further analysis, abundance and density of invertebrates have been combined and reported as a number of invertebrates. For bird species, variables such as colony size, number of captures, density of males and density of nests have been combined and reported as a number of birds, and variables such as clutch size and number of fledglings have been grouped into variable reported as a nesting success.

2.3. Explanatory variables

To explain variation in species responses to reed management, the following variables were included: (1) type of reed management (harvesting, burning, mowing or grazing); (2) time of reed management (all year, spring, summer, autumn or winter); (3) habitat (marsh, meadow, lake or polder); (4) water salinity (fresh or saline); (5) vegetation (monospecific or mixed reed stands). These variables were planned before data collection (*a priori* comparisons). In addition, invertebrate taxonomic group and duration of management period (1–2 years, 4–5 years and 7 years) were included as explanatory variables for invertebrate responses to reed management after data collection (post hoc comparisons). For reed performance, duration of management period was also included as an explanatory variable (1–2 years, 3–5 years and 6–15 years).

2.4. Meta-analysis

The meta-analysis was carried out by using the Meta Win 2.0 statistical program (Rosenberg et al., 2000). To estimate the treatment effects, the natural log of the response ratio was calculated for each study as $r = \ln(X_m/X_u)$ (Rosenberg et al., 2000), where X_m and X_u are the response mean values for managed and unmanaged sites, respectively. Negative log response ratio indicates a decrease in the response variable in response to reed management, while positive values indicate an increase. The log response ratios were combined across studies using the mixed effects model, which assumes that differences among studies within a class are due to both sampling error and random variation. In ecological data synthesis, the assumptions of mixed models are more likely to be met than those of fixed effects models, and the former are thus preferred (Gurevitch and Hedges, 1999). Bias-corrected 95% confidence intervals (CI) around the effect size were generated from 4999 iterations (Rosenberg et al., 2000). Estimates of the effect size were considered to be significantly different from zero if their 95% confidence intervals did not include zero. To test the importance of different sources of variation in determining the sign and magnitude of the treatment effect, we subdivided studies into groups on the basis of explanatory variables listed above and examined between-group heterogeneity using a χ^2-test statistic, Q_b. For the ease of interpretation, the effect size was back-transformed as $[\text{EXP}(r) - 1] \times 100\%$ and reported in the text and the figures as the percentage change from unmanaged sites.

3. Results

3.1. Effects on common reed and other plant species

When all studies were considered together, reed management tended to increase density of re-growing reed (25%, 95% CI [−1.6%; 66%], $N = 17$). There was one outlier with extremely

Table 1 – Species/taxonomic groups, habitats, salinity, vegetation (mono, monospecific reed vegetation; mixed, mixed vegetation), reed management (H, harvesting; B, burning; G, grazing; M, mowing), time of management, the duration of management period, measured parameters, countries and references used in the meta-analysis

Species/taxonomic groups	Habitat	Salinity	Vegetation	Management	Time of management	Duration, years	Measured parameters	Country	Reference
Plants									
Carex riparia	Marsh	Fresh	Mixed	G	All year	4	Density, biomass	UK	Ausden et al. (2005)
Glyceria maxima	Marsh	Fresh	Mixed	G	All year	4	Density, biomass	UK	Ausden et al. (2005)
Inula crithmoides	–	Saline	Mixed	G	Summer, autumn	5	Abundance	France	Mesléard et al. (1999)
Juncus gerardii	Marsh	Saline	Mixed	G	Summer, autumn	5	Abundance	France	Mesléard et al. (1999)
Phalaris arundinacea	Marsh	Fresh	Mixed	G	All year	4	Density, biomass	UK	Ausden et al. (2005)
Phragmites australis	Marsh	Fresh	Mixed	G	All year	4	Density, biomass	UK	Ausden et al. (2005)
P. australis	Marsh	Fresh	Mono	H	Winter	3	Density, biomass	Sweden	Björndahl (1985)
P. australis	Marsh	Fresh	Mixed	H, B	Winter	1	Density, diameter	UK	Cowie et al. (1992)
P. australis	Marsh	Fresh	Mixed	H	Winter	7	Height	Belgium	Decleer (1990)
P. australis	Marsh	Saline	Mixed	G	Summer	4	Height, density	The Netherlands	van Deursen and Drost (1990)
P. australis	Meadow	Fresh	Mixed	M	Summer, winter	4 and 14	Density, diameter	Switzerland	Güsewell et al. (2000)
P. australis	Meadow	Fresh	Mixed	H	Summer	7	Height, density, biomass	Switzerland	Güsewell (2003)
P. australis	Polder	Fresh	Mono	B	Spring	6	Diameter, biomass	The Netherlands	Mook and van der Toorn (1982)
P. australis	Lake	Fresh	Mono	H, B	Winter	4	Density, height, diameter	Germany	Ostendorp (1999)
P. australis	Marsh	Saline	Mixed	G	Autumn	6	Density	Sweden	Pehrsson (1988)
P. australis	Marsh	Saline	Mixed	H	Winter	2	Density, diameter, height, biomass	France	Poulin and Lefebvre (2002)
P. australis	Lake	Fresh	Mono	M	Winter	1	Height, diameter	Czech Republic	Rolletschek et al. (2000)
P. australis	Marsh	Fresh	Mono	B	Winter	1	Height, diameter, density	Romania	Rolletschek et al. (2000)
P. australis	Marsh	Saline	Mixed	H	Winter	5	Height, density	France	Schmidt et al. (2005)
P. australis	Lake	Fresh	Mono	B	Winter	1	Height, diameter, density	Slovakia	Trnka and Prokop (2006)
P. australis	Lake	Fresh	Mono	H	Summer	1	Biomass	Sweden	Weisner and Granéli (1989)
P. australis	Marsh	Fresh	Mono	G	Spring	15	Biomass	The Netherlands	van den Wyngaert et al. (2003)
Salicornia europaea	Marsh	Saline	Mixed	G	Summer, autumn	5	Abundance	France	Mesléard et al. (1999)
S. fruticosa	Marsh	Saline	Mixed	G	Summer, autumn	5	Abundance	France	Mesléard et al. (1999)
Salsola soda	Marsh	Saline	Mixed	G	Summer, autumn	5	Abundance	France	Mesléard et al. (1999)
Scirpus maritimus	Marsh	Saline	Mixed	G	Summer, autumn	6	Density	Sweden	Pehrsson (1988)
Other plants	Marsh	Fresh	Mixed	G	All year	4	Species richness, height	UK	Ausden et al. (2005)
Other plants	Marsh	Fresh	Mixed	H, B	Winter	1	Species richness	UK	Cowie et al. (1992)
Other plants	Marsh	Fresh	Mixed	H	Winter	7	Species richness, height, density	Belgium	Decleer (1990)
Other plants	Meadow	Fresh	Mixed	H	Summer	7	Biomass	Switzerland	Güsewell (2003)
Other plants	Marsh	Saline	Mixed	G	Summer, autumn	5	Species richness	France	Mesléard et al. (1999)
Other plants	Marsh	Saline	Mixed	H	Winter	2	Species richness	France	Poulin and Lefebvre (2002)
Other plants	Marsh	Saline	Mixed	H	Winter	5	Species richness	France	Schmidt et al. (2005)
Invertebrates									
Acarina	Marsh	Fresh	Mixed	H, B	Winter	1	Abundance	UK	Cowie et al. (1992)
Acarina	Marsh	Saline	Mixed	H	Winter	5	Abundance	France	Schmidt et al. (2005)
Araneae	Marsh	Fresh	Mixed	H, B	Winter	1	Abundance	UK	Cowie et al. (1992)
Araneae	Marsh	Saline	Mixed	H	Winter	2	Abundance	France	Poulin and Lefebvre (2002)
Araneae	Marsh	Saline	Mixed	H	Winter	5	Abundance	France	Schmidt et al. (2005)
Araneae	Marsh	Fresh	Mixed	H	Winter	7	Abundance, species richness	Belgium	Decleer (1990)
Coleoptera	Marsh	Fresh	Mixed	H, B	Winter	1	Abundance	UK	Cowie et al. (1992)
Coleoptera	Marsh	Saline	Mixed	H	Winter	5	Abundance	France	Schmidt et al. (2005)

(continued on next page)

Table 1 – (continued)

Species/taxonomic groups	Habitat	Salinity	Vegetation	Management	Time of management	Duration, years	Measured parameters	Country	Reference
Coleoptera	Marsh	Saline	Mixed	H	Winter	2	Abundance	France	Poulin and Lefebvre (2002)
Collembola	Marsh	Fresh	Mixed	H, B	Winter	1	Abundance	UK	Cowie et al. (1992)
Collembola	Marsh	Saline	Mixed	H	Winter	5	Abundance	France	Schmidt et al. (2005)
Diptera	Marsh	Saline	Mixed	H	Winter	5	Abundance	France	Schmidt et al. (2005)
Diptera	Marsh	Fresh	Mixed	H, B	Winter	1	Abundance	UK	Cowie et al. (1992)
Diptera	Marsh	Saline	Mixed	H	Winter	2	Abundance	France	Poulin and Lefebvre (2002)
Heteroptera	Marsh	Saline	Mixed	H	Winter	2	Abundance	France	Poulin and Lefebvre (2002)
Heteroptera	Marsh	Saline	Mixed	H	Winter	5	Abundance	France	Schmidt et al. (2005)
Homoptera	Marsh	Saline	Mixed	H	Winter	5	Abundance	France	Schmidt et al. (2005)
Homoptera	Marsh	Saline	Mixed	H	Winter	2	Abundance	France	Poulin and Lefebvre (2002)
Hymenoptera	Marsh	Saline	Mixed	H	Winter	2	Abundance	France	Poulin and Lefebvre (2002)
Hymenoptera	Marsh	Saline	Mixed	H	Winter	5	Abundance	France	Schmidt et al. (2005)
Isopoda	Marsh	Fresh	Mixed	H, B	Winter	1	Abundance	UK	Cowie et al. (1992)
Lepidoptera	Marsh	Saline	Mixed	H	Winter	5	Abundance	France	Schmidt et al. (2005)
Mollusca	Marsh	Fresh	Mixed	G	All year	4	Density, species richness	UK	Ausden et al. (2005)
Mollusca	Marsh	Fresh	Mixed	H, B	Winter	1	Abundance	UK	Cowie et al. (1992)
Mysidacea	Marsh	Fresh	Mixed	H, B	Winter	1	Abundance	UK	Cowie et al. (1992)
Odonata	Marsh	Saline	Mixed	H	Winter	2	Abundance	France	Poulin and Lefebvre (2002)
Oligochaeta	Marsh	Fresh	Mixed	H, B	Winter	1	Abundance	UK	Cowie et al. (1992)
Psocoptera	Marsh	Saline	Mixed	H	Winter	5	Abundance	France	Schmidt et al. (2005)
Thysanoptera	Marsh	Saline	Mixed	H	Winter	2	Abundance	France	Poulin and Lefebvre (2002)
Thysanoptera	Marsh	Saline	Mixed	H	Winter	5	Abundance	France	Schmidt et al. (2005)
Trihoptera	Marsh	Fresh	Mixed	H, B	Winter	1	Abundance	UK	Cowie et al. (1992)
Birds									
Acrocephalus purpurea	Marsh	Fresh	Mono	H	Winter	1	Colony size	France	Barbraud et al. (2002)
A. arundinaceus	Marsh	Saline	Mixed	H	Winter	2	Number of captures	France	Poulin and Lefebvre (2002)
A. arundinaceus	Lake	Fresh	Mono	B	Winter	1	Number of captures	Slovakia	Trnka and Prokop (2006)
A. melanopogon	Marsh	Saline	Mixed	H	Winter	2	Number of captures	France	Poulin and Lefebvre (2002)
A. melanopogon	Lake	Fresh	Mono	B	Winter	1	Number of captures	Slovakia	Trnka and Prokop (2006)
A. palustris	Lake	Fresh	Mono	B	Winter	1	Number of captures	Slovakia	Trnka and Prokop (2006)
A. schoenobaenus	Marsh	–	Mixed	H	Winter	3	Clutch size, density of nest, laying date, number of fledglings, predation rates of nests	The Netherlands	Graveland (1999)
A. schoenobaenus	Lake	Fresh	Mono	B	Winter	1	Number of captures	Slovakia	Trnka and Prokop (2006)
A. scirpaceus	Marsh	–	Mixed	H	Winter	3	Clutch size, density of nest, laying date, number of fledglings, predation rates of nests	The Netherlands	Graveland (1999)
A. scirpaceus	Lake	Fresh	Mono	B	Winter	1	Number of captures	Slovakia	Trnka and Prokop (2006)
A. scirpaceus	Marsh	Saline	Mixed	H	Winter	2	Number of captures	France	Poulin and Lefebvre (2002)
Ardea purpurea	Marsh	Fresh	Mono	H	Winter	5	Colony size	France	Barbraud and Mathevet (2000)
Botaurus stellaris	Marsh	Saline	Mixed	H	Winter	2	Density of males	France	Poulin et al. (2005)
Emberiza schoeniclus	Marsh	Saline	Mixed	H	Winter	2	Number of captures	France	Poulin and Lefebvre (2002)
E. schoeniclus	Lake	Fresh	Mono	B	Winter	1	Number of captures	Slovakia	Trnka and Prokop (2006)
Locustella lusciniodes	Lake	Fresh	Mono	B	Winter	1	Number of captures	Slovakia	Trnka and Prokop (2006)
Panurus biarmicus	Marsh	Saline	Mono	H	Winter	2	Number of captures	France	Poulin and Lefebvre (2002)
P. biarmicus	Lake	Fresh	Mono	B	Winter	1	Number of captures	Slovakia	Trnka and Prokop (2006)
Remiz pendulinus	Lake	Fresh	Mono	B	Winter	1	Number of captures	Slovakia	Trnka and Prokop (2006)

low value (−62%), which was omitted for further analysis. For the remaining studies, the effect of reed management on stem density of re-growing reed was significantly positive (28%, 95% CI [12%; 45%], $N = 16$, Fig. 1a). No difference between the effects of type of reed management (harvesting, burning, grazing and mowing) on stem density was found ($Q_b = 2.3$, d.f. = 3, $P = 0.570$).

Furthermore, stems of re-growing reed were 20% shorter in managed sites than in unmanaged sites (95% CI [−43%; −1.8%], $N = 12$, Fig. 1a). There was also significant difference between the effects of various types of reed management on stem height: reed burning significantly shortened stem height while reed harvesting did not ($Q_b = 5.9$, d.f. = 1, $P = 0.015$, Fig. 1a). In contrast, neither stem diameter (−3.3%, 95% CI [−14%; 7%], $N = 12$) nor aboveground biomass of re-growing reed were affected by reed management (8.8%, 95% CI [−17%; 29%], $N = 10$, Fig. 1a). Note, however, that the effect of grazing on aboveground biomass of re-growing reed was reported only in two studies (van den Wyngaert et al., 2003; Ausden et al., 2005, see Table 1). Also, no differences between the effects of type of reed management on these parameters were observed (for diameter: $Q_b = 0.69$, d.f. = 2, $P = 0.749$; for biomass: $Q_b = 0.37$, d.f. = 1, $P = 0.659$). Finally, other explanatory variables such as habitat, water salinity, vegetation, the time of management and the duration of management period did not alter the effect of reed management on the performance of re-growing reed ($P > 0.05$).

For other plant species, reed management reduced stem height, while no effects on stem density or aboveground biomass have been observed (Fig. 1b). Interestingly, in fresh water marshes, the number of plant species was high (about 10), and reed management increased plant species richness by 90% (95% CI [48%; 160%], $N = 4$, Fig. 1b). In contrast, in saline water marshes, the number of plant species was low (about 3) and reed management had no effect on it (−19%, 95% CI [−55%; 17%], $N = 4$, Fig. 1b). Other explanatory variables such as the types of reed management (grazing or harvesting) and the duration of management period did not modify the effect of reed management on plant species richness (type of management: $Q_b = 0.3$, d.f. = 1, $P = 0.572$; duration of management: $Q_b = 1.4$, d.f. = 1, $P = 0.228$). The effect of habitat, vegetation or the time of reed management on plant species richness could not be tested due to the lack of studies. Finally, abundance of other plants increased by 160%, although this

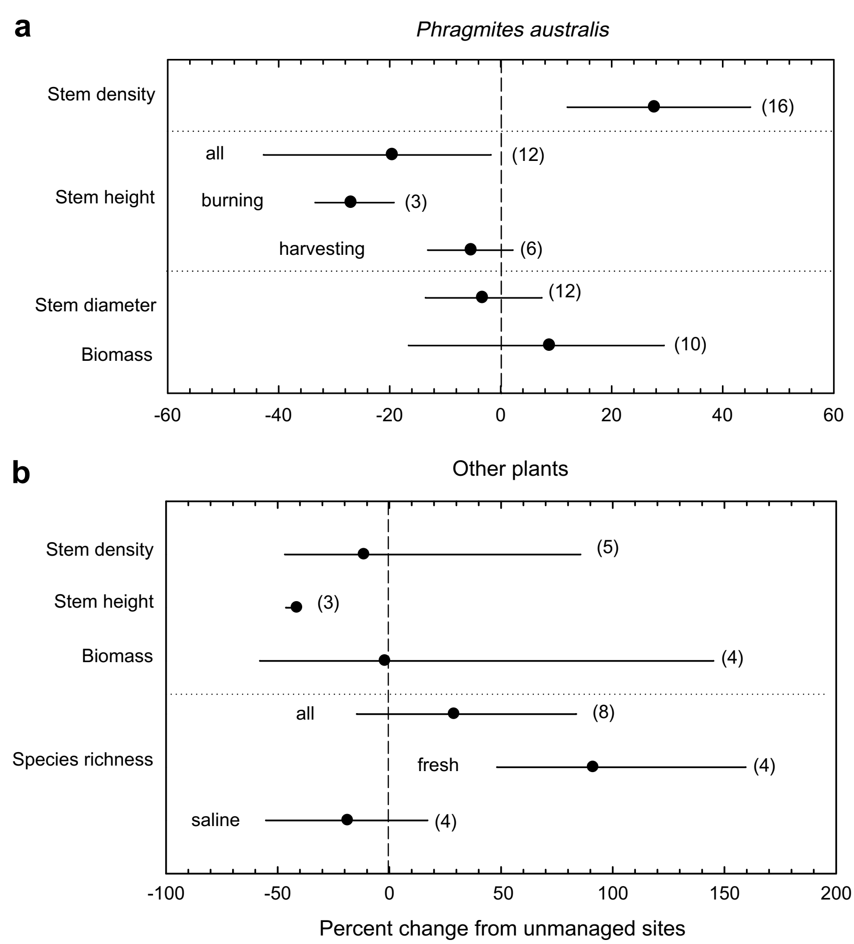

Fig. 1 – Responses of (a) re-growing common reed (*Phragmites australis*) and (b) other plants to reed management. All, an overall dataset. Further subdivision of studies was by the types of management (burning vs. harvesting) for stem height and by water salinity (fresh vs. saline) for species richness. Symbols represent the pooled weighted percentage change at reed management, the bars show the 95% confidence intervals (CIs) and the numbers in parenthesis represent numbers of observations. Means are significantly different from unmanaged sites when their CIs do not overlap 0.

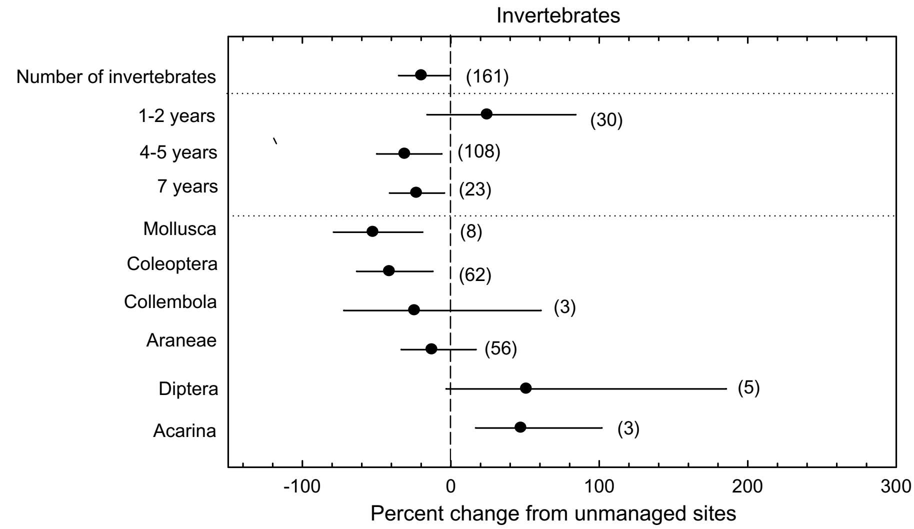

Fig. 2 – Changes in invertebrate community due to reed management. Further subdivision of studies was by the duration of reed management (1–2 years vs. 4–5 years vs. 7 years) and by invertebrate taxonomic group. Symbols represent the pooled weighted percentage change at reed management, the bars show the 95% confidence intervals (CIs) and the numbers in parenthesis represent numbers of observations. Means are significantly different from unmanaged sites when their CIs do not overlap 0.

increase was not statistically significant, probably due to the small number of studies (95% CI [−27%; 702%], $N = 5$).

3.2. *Effects on invertebrates*

Reed management significantly decreased both species richness (−30%, 95% CI [−51%; −10%], $N = 2$) and abundance of invertebrates (−20%, 95% CI [−35%; −0.5%], $N = 161$, Fig. 2), and harvesting, burning and grazing had a similar effect on their abundance ($Q_b = 2.3$, d.f. = 2, $P = 0.318$). However, changes in the number of invertebrates in managed sites varied depending on the duration of management period ($Q_b = 7.2$, d.f. = 2, $P = 0.027$): a decrease in the number of invertebrates was found after middle- (4–5 years) and long-term (7 years) reed management, but not after shorter management period (1–2 years, Fig. 2).

In addition, the effect of reed management was highly variable depending on taxonomic groups of invertebrates ($Q_b = 48.9$, d.f. = 13, $P = 0.001$). Numbers of the following groups were significantly decreased in managed sites compared to unmanaged sites: Mollusca, Coleoptera (Fig. 2), Lepidoptera (−88%, 95% CI [−93%; −84%], $N = 2$) and Hymenoptera (−44%, 95% CI [−45%; −42%], $N = 2$), whereas abundance of the following groups were significantly increased in managed sites compared to unmanaged sites: Acarina (Fig. 2), Oligochaeta (40%, 95% CI [29%; 49%], $N = 2$) and Isopoda (186%, 95% CI [100%; 300%], $N = 2$). Reed management also resulted in a 10-fold increase in abundance of Homoptera in managed sites (1110%, 95% CI [352%; 2298%], $N = 3$). Numbers of other groups of invertebrates such as Trichoptera, Diptera, Heteroptera, Araneae, Collembola, and Mysidacea were not significantly affected by reed management ($P > 0.05$).

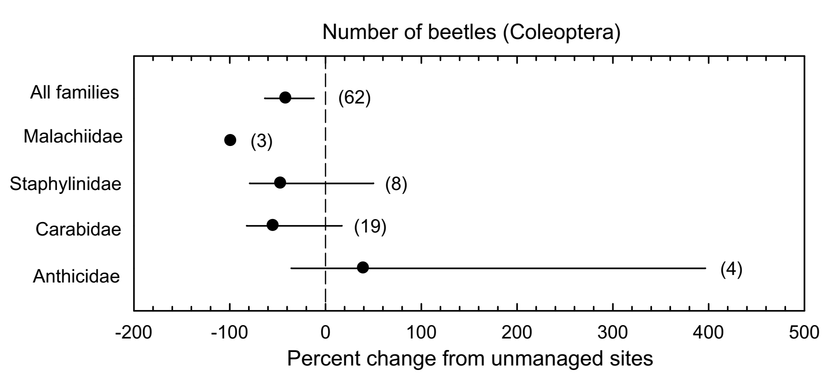

Fig. 3 – Changes in number of beetles (Coleoptera) due to reed management. Further subdivision of studies was by family. Symbols represent the pooled weighted percentage change at reed management, the bars show the 95% confidence intervals (CIs) and the numbers in parenthesis represent numbers of observations. Means are significantly different from unmanaged sites when their CIs do not overlap 0.

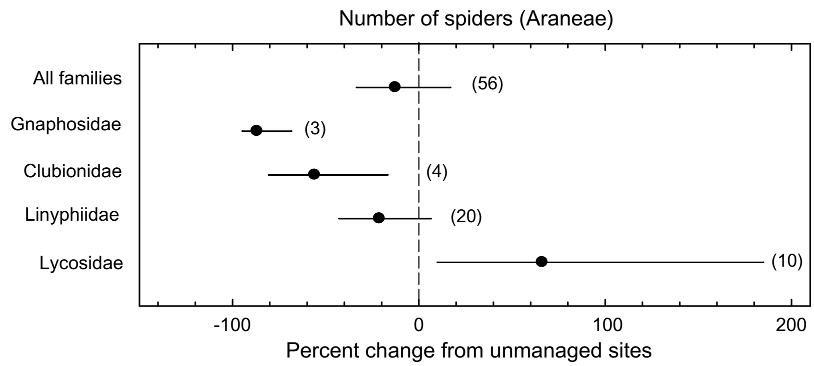

Fig. 4 – Changes in number of spiders (Araneae) due to reed management. Further subdivision of studies was by family. Symbols represent the pooled weighted percentage change at reed management, the bars show the 95% confidence intervals (CIs) and the numbers in parenthesis represent numbers of observations. Means are significantly different from unmanaged sites when their CIs do not overlap 0.

Moreover, within Coleoptera, the effect of reed management differed between families ($Q_b = 18.5$, d.f. = 8, $P = 0.018$; Fig. 3). For example, numbers of beetles belonging to families Malachiidae (Fig. 3), Curculionidae (−50%, 95% CI [−60%; −40%], $N = 2$) and Hydrophilidae (−40%, 95% CI [−70%; 0%], $N = 2$) decreased in managed sites, whereas numbers of Coccinellidae increased five times in managed sites compared to unmanaged ones (490%, 95% CI [333%; 699%], $N = 2$). Similarly, reed management effects on spiders differed between families ($Q_b = 34.1$, d.f. = 7, $P = 0.006$; Fig. 4). Numbers of Gnaphosidae, Clubionidae (Fig. 4), Araneidae (−75%, 95% CI [−83%; −62%], $N = 2$) and Salticidae (−69%, 95% CI [−86%; −43%], $N = 2$) decreased in managed sites, while number of Lycosidae was increased (Fig. 4), and numbers of Linyphiidae (Fig. 4) and Philodromidae (−25%, 95% CI [−85%; 200%], $N = 2$) did not change in managed sites compared to unmanaged sites.

Water salinity did not modify the impact of reed management on the number of invertebrates ($Q_b = 0.28$, d.f. = 1, $P = 0.662$). The effect of reed management on invertebrates could not be compared between the types of habitats (marsh vs. meadow vs. lake), types of vegetation (monospecific reed stand vs. mixed) and the time of management since all studies have been conducted during winter in marshes with mixed vegetation.

3.3. *Bird species associated with reedbeds*

Reed management reduced the number of birds by 60% as compared to unmanaged sites (95% CI [−73%; −41%], $N = 19$), and both harvesting and burning of reed affected number of birds to the same extent ($Q_b = 0.98$, d.f. = 1, $P = 0.322$). Similarly, other explanatory variables such as habitat ($Q_b = 0.95$, d.f. = 1, $P = 0.329$), water salinity ($Q_b = 0.26$, d.f. = 1, $P = 0.607$), vegetation ($Q_b = 0.80$, d.f. = 1, $P = 0.372$) and the duration of the management period ($Q_b = 2.18$, d.f. = 1, $P = 0.140$) did not modify the negative effect of reed management on number of bird species. The effect of time of management on bird number was not calculated because in all studies related to bird species reed was managed during winter.

In addition, predation rates increased by about 100% in managed sites (95% CI [66%; 200%], $N = 2$), however, the data originated from a single study on *A. scirpaceus* and *A. schoenobaenus* (Graveland, 1999). Finally, there was no effect of reed management on nesting success (−2%, 95% CI [−6%; 16%], $N = 4$) or laying date (20%, 95% CI [−11%; 21%], $N = 2$).

4. Discussion

4.1. *Effect of reed management on the performance of re-growing reed*

The results of meta-analysis demonstrated that reed management modified the structure of re-growing reed stands; reed stems were denser and shorter in managed sites than in unmanaged sites. This is consistent with previous studies (Haslam, 1972; Cowie et al., 1992; van der Toorn and Mook, 1982) reporting that management of reed shortened stems of re-growing reed and increased their density. Mechanical damage during the period of emergence, which lasts until about July, might stimulate stem density as dormant buds are activated to replace damaged shoots (Haslam, 1969).

It is expected that aboveground biomass of re-growing reed will be reduced as a result of reed management (Haslam, 1972). However, we found that despite the decrease in stem height in managed sites, stem density was increased and stem diameter was unaffected resulting in no changes in reed biomass. The lack of response in aboveground biomass of re-growing reeds in managed sites could not be explained by the limited duration of the experiments, since the duration of management period lasted up to 15 years. Therefore, management experiments (mainly harvesting) provided no evidence for the effectiveness of treatment in reduction of aboveground biomass of re-growing reeds, which is important for the areas of high conservation values where spread of common reed is undesirable.

4.2. *Effects of reed management on other plants*

High and dense stands of reed reduce air temperature and light at the marsh surface. In addition, since reed stems decompose slower than tissues of other plant species, reedbeds may deplete soil by binding limiting nutrients in organic material and making them unavailable to other plants (Meyerson et al., 2000). These factors may inhibit the germination or establishment of other plant species as well as slow decomposition of organic material (Meyerson et al., 2000). Therefore, reed management involving removal of the dead stems and reed litter is expected to increase plant species richness and abundance (Decleer, 1990; Cowie et al., 1992; Ausden et al., 2005). Our meta-analysis, in general, supported previous findings that management of reed enables to maintain floristic richness. However, it was the case only for fresh water marshes, where species richness is more diverse than in saline marshes (Meyerson et al., 2000). Detailed comparison between the effects of different types of reed management on plant species richness has not been conducted due to the lack of studies. Thus, future studies should be more focused on floristic richness under different types of reed management.

4.3. *Effects of reed management on invertebrates*

Previous studies reported variable results regarding the effects of reed management on invertebrates: neutral (Ditlhogo et al., 1992; Cowie et al., 1992), negative (Schmidt et al., 2005; Ausden et al., 2005) or positive effects (Poulin and Lefebvre, 2002). The results of meta-analysis clearly revealed an overall negative effect of reed management on invertebrate community. However, the duration of management was an important factor determining the responses of invertebrates to reed management. Short-term management (1–2 years) did not harm invertebrate community, whereas management for longer period significantly reduced invertebrate abundance. This negative effect could be explained by the fact that overwintering stages were repeatedly removed due to reed management. Another reason is that changes in reedbed structure develop during several years after reed management: stem density kept rising and stem size kept falling during the first 3 years of management (Ostendorp, 1999), while aboveground biomass of reed declined after 3 years of management (Güsewell, 2003). Since invertebrates are dependent on reedbed structure, the most significant changes in the arthropod community are expected to occur after several years of cutting (Schmidt et al., 2005).

In addition, the meta-analysis showed that responses of invertebrates to reed management were variable depending on their taxonomic group. For example, numbers of beetles and some families of spiders (Gnaphosidae, Araneidae, Salticidae and Clubionidae) were reduced by reed management. This may be due to the removal or destruction of overwintering stages during harvest (Ditlhogo et al., 1992) or due to clearing of litter and vertical plant structures, which are important sources of potential prey, and more extreme climatic conditions at soil level (Decleer, 1990). However, some invertebrates such as Oligochaeta, Acarina, Isopoda, Homoptera, some families of beetles (Scirtidae and Coccinellidae) and spiders (Licosidae) may benefit from reed management, and their abundance increased in managed sites. Phytophagous species might benefit from reed management because re-growing reeds are of better nutritional quality due to rejuvenation, and their density is higher (Schmidt et al., 2005).

Some predators, for example Coccinellidae, may be attracted by the increased number of Homoptera on managed sites. Moreover, the ability of invertebrate species to survive reed management will depend on their ability to re-colonise managed areas once they become suitable again, and this is likely to depend on the size of patch managed, distance from sources of colonists, length of the management rotation and dispersal ability of invertebrates (Ausden et al., 2005). In fact, some species of spiders that are good colonizers may reach high density in managed sites due to reduced competition with other spiders (Schmidt et al., 2005).

4.4. *Effects of reed management on bird species*

We found an overall negative effect of reed harvesting and burning on number of birds. It has been showed that cut reed is a less suitable habitat for nesting passerine species due to the higher risk of nest predation by mammalian predators (Graveland, 1999) because no good cover and high accessibility were provided by managed reed. Another factor that might negatively affect abundance of bird species in managed sites is food limitation. As demonstrated in the present meta-analysis, numbers of butterflies (Lepidoptera), beetles (Coleoptera) and some spiders (Araneae), which are important prey groups for passerines, were reduced by 40–90% in managed sites compared to unmanaged sites. Furthermore, it was hypothesized that nesting success is higher in unmanaged sites than in managed sites (Graveland, 1999), however, the results of the meta-analysis did not support this hypothesis.

In addition to passerine birds, reedbeds constitute a major breeding habitat for several vulnerable and rare bird species including *Ardea purpurea* and *Botaurus stellaris* (Tucker and Heath, 1994). Despite the concern that the increase of reed harvested area reduces population of *A. purpurea*, effects of reed management on this species was examined only in two studies conducted by the same authors in Mediterranean France (Barbraud and Mathevet, 2000; Barbraud et al., 2002). In relation to *B. stellaris*, most of the studies analyzed the characteristics of nesting habitat preference (Tyler et al., 1998; Gilbert et al., 2005), however, the effect of reed management on number of *B. stellaris* was studied only by Poulin et al. (2005). Thus, further studies on the effect of reed management on *A. purpurea* and *B. stellaris* are needed to cover a gap in understanding the factors causing the decline of these species in Europe.

4.5. *Sources of variation in responses of re-growing reed and reedbed wildlife*

The type of reed management was an important factor determining response of some parameters of re-growing reeds, such as reed height that was significantly reduced in burned sites, but not in harvested sites. In contrast, responses of other reed parameters such as stem density, diameter and aboveground biomass were not dependent on the types of management. In relation to wildlife species associated with reedbeds, reed management decreased numbers of invertebrates and bird species regardless of the type of management. However, the duration of the management period was a factor determining variation in responses of invertebrates to reed management: longer term management significantly reduced invertebrate community, while short-term management did not influence it. This was probably due to the fact that changes in reedbed structure, which is a determining factor for invertebrates associated with reedbeds, occurred during several years after reed management (Ostendorp, 1999; Güsewell, 2003).

Another factor that is expected to modify responses of re-growing reed is time of reed management (Cross and Fleming, 1989; Güsewell et al., 2000). Although one might expect the removal of biomass during the growing season to affect reed more than removing it in winter, we did not find significant effects of time of the management on reed growth. For invertebrate and bird species, management has been conducted during winter, therefore, the effect of time of reed management was not calculated.

5. Conclusions

The results of the present meta-analysis provide us with better understanding of the effects of reed management on wildlife associated with reedbeds as well as with a scientific basis for management decisions; they also highlight gaps in research. Reed management modifies the structure of re-growing reed stands; however, there is no evidence for the effectiveness of harvesting in reduction of aboveground biomass of re-growing reed. Therefore, additional experiments are urgently needed to find out whether alternative types of reed management (grazing, burning and mowing) could be more effective in controlling undesirable reed stands. The meta-analysis did not support a prediction that time of reed management determines responses of re-growing reed.

Our meta-analysis, in general, supported previous findings that management of reed enables to maintain floristic richness. However, detailed comparison between the effects of different types of reed management on it has not been calculated due to lack of studies. Thus, future studies should be more focused on floristic richness at different types of reed management.

The meta-analysis demonstrated an overall negative effect of reed management on number of invertebrates, but this was true only after 4 years of management while short-term management (1–2 years) had no significant effect. The meta-analysis did not support a suggestion that burning is more damaging than harvesting.

The results showed an overall negative effect of reed harvesting and burning on number of passerine birds. Among other factors related to changes in reed structure due to management, such decline in number of bird species was probably associated with food limitation, since numbers of butterflies, beetles and some spiders, which are important prey groups for passerines, were reduced due to management. Therefore, in order to preserve birds and invertebrates in reedbeds, possible management regime could be a rotation of short-term management (1–2 years). However, the optimal interval between management applications must to be examined in future studies.

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