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Skjern River Valley, Northern Europe's most expensive wetland restoration project: benefits to breeding waterbirds

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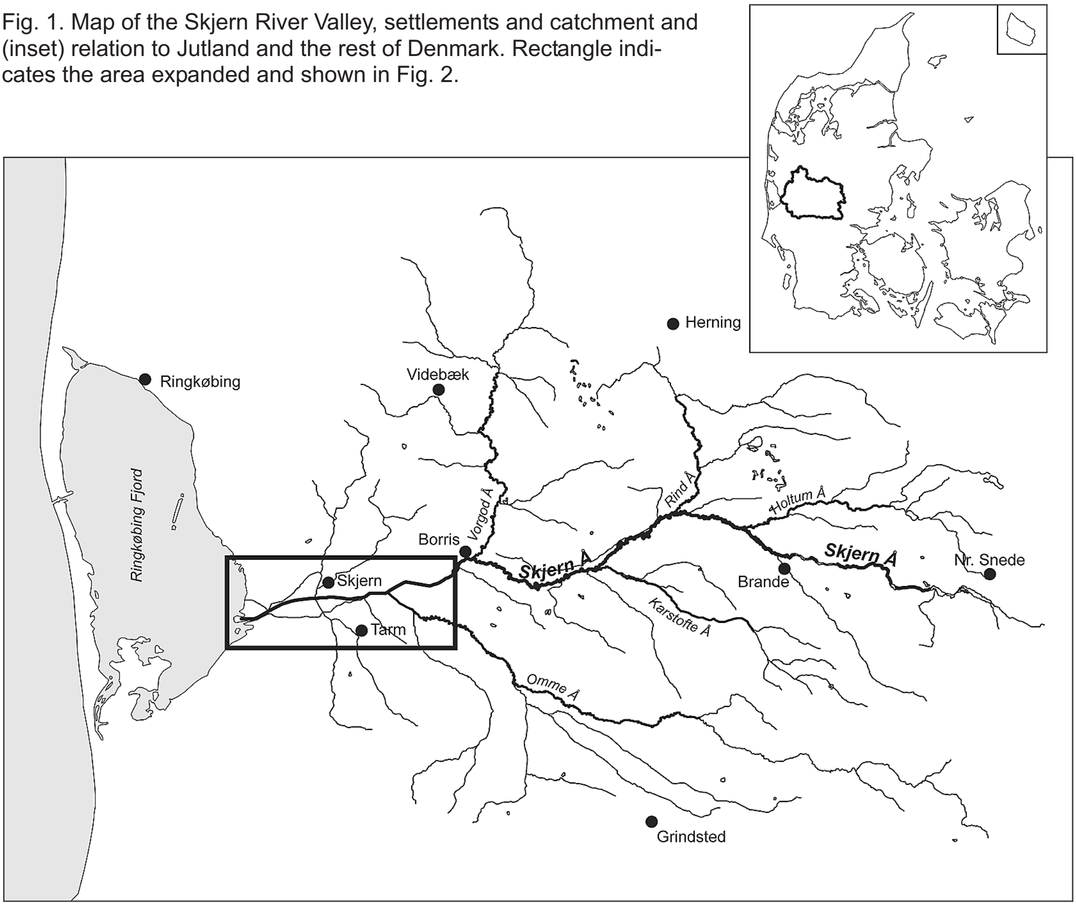
After circa 35 years of drainage and intensive arable tillage, the lower Skjern River, Denmark was re-engineered to its original meanders and flooding regime, creating 22 km^2 of lakes, shallow wetlands and seasonally flooded grazed wet grassland costing €38 million. The primary motivation was to restore the sediment/nutrient retention capacity of the river valley to reduce eutrophication of Ringkøbing Fjord at its efflux. Secondary objectives were to (i) restore breeding and staging bird habitat, (ii) enhance the self-sustaining Atlantic Salmon *Salmo salar* population and (iii) improve recreational and tourist activities. Despite lack of specific success criteria, breeding waterbird numbers increased from 134 ± 22.9 SE (n = 3) pairs before to 1,744 ± 153 SE (n = 5) after restoration (although on average 1,004 of these were Black-headed Gulls *Chroicocephalus ridibundus*), species richness and diversity also increased. Twenty-nine waterbird species returned to breed, 10 of national or international significance (Danish Red List/European Union Birds Directive Annex 1 species) now ranking Skjern River amongst the top 10 most important breeding waterbird sites in Denmark. Currently, agriculture supports cost-neutral management of the restoration area, but whilst most expected wet meadow and marsh species had returned, lack of goal-orientated management targets resulted in some additional rare and threatened species remaining absent. Breeding pair density and diversity of other species could have been greatly improved by prior planning and management intervention but at additional cost.

1. Introduction

Dynamic and highly unstable interactions between flowing waters and their physical environment support a rich biodiversity (Tockner *et al.* 2000), but are often incompatible with modern agricultural and urban landscapes (Strahler & Strahler 1973). Human modification of such systems affects biological productivity, diversity and ecosystem services, such as ground water de-nitrification, aquifer recharge, sediment capture, flood water storage, substrate shrinkage and erosion, and carbon storage (Postel & Richter 2003, Maltby & Acreman 2011). River and stream "restoration" counteracts the morphological degradation of such systems, although the motivation, scale and nature of the restorative methods vary widely (Ormerod 2003). Restoration implies "a complete

Fig. 1. Map of the Skjern River Valley, settlements and catchment and (inset) relation to Jutland and the rest of Denmark. Rectangle indicates the area expanded and shown in Fig. 2.



and structural return to a pre-disturbance state" (Cairns 1991), but success depends on the motivation and objectives set for the re-establishment of physical and biological conditions. Process-oriented restoration repairs "damage" (in terms of dynamics and diversity) without a particular end point, whereas goal-orientated restoration specifically aims to return conditions to an approximation of the original state, enabling measurement of the rehabilitation of specific features over given time (*sensu* Cairns & Hackman 1996). Billions of dollars were spent on process-orientated river restoration projects in the US (Malakoff 2004), despite little consensus (until recently) upon what constituted "success" in river restoration (Palmer *et al*. 2005).

The Skjern River drains circa 2,500 km^2 of sandy free-draining agricultural land into Ringkøbing Fjord, a shallow estuarine lagoon in west Jutland, Denmark (Fig. 1). Small scale drainage projects occurred throughout the 20th century, but before the major works of the 1960s, the lower Skjern River supported one of Denmark's richest breeding waterbird concentrations in a mosaic of water-courses, water-bodies, reed-beds, meadows, common grazing and heath, with large areas inundated at high water (Fig. 2). The lower Skjern was canalized and deepened in the 1960s, creating 40 km^2 of bottomlands for cereal production by pump drainage (Pedersen *et al*. 2007; Fig. 2). Canalization destroyed the nutrient and sediment retention characteristics of the wetlands. Loss of inundation and sediment accumulation necessitated heavy inorganic fertilizer application, runoff from which was pumped into the river. Skjern River thus became a source (rather than a sink) for nutrient and sediment from the catchment, causing adverse eutrophication and sediment problems at its outflow in Ringkøbing Fjord, along with major biodiversity loss, which in the case of the decline

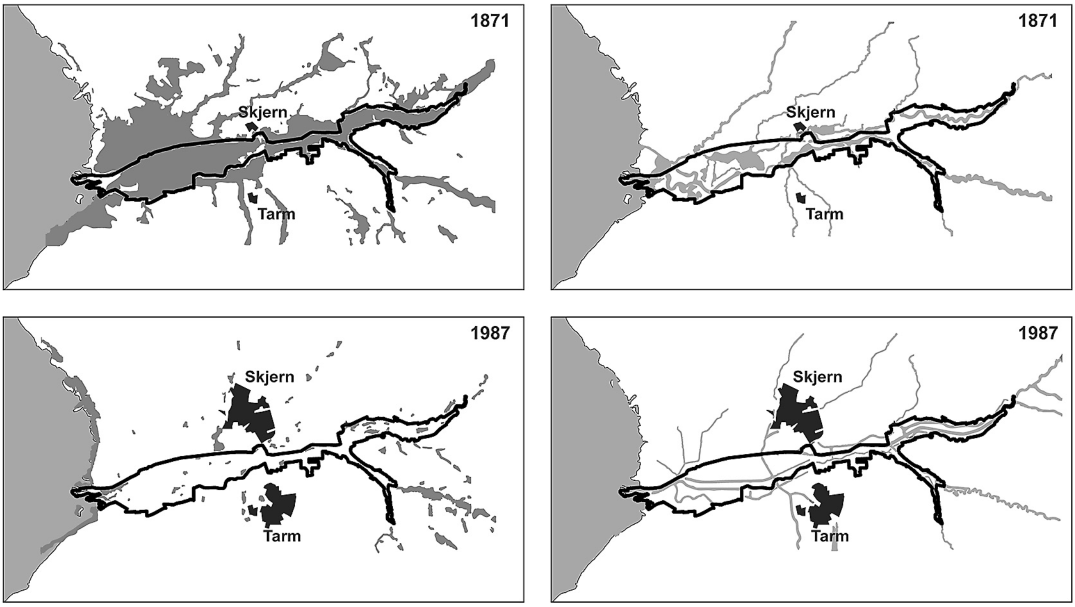


Fig. 2. Left: Extent of wet grasslands/wetlands (darker grey) and urban areas (black) in the Skjern River Valley in 1871 (left upper) and 1987 (post-drainage, left lower). Following 1960s drainage, circa 4,000 ha of wet grassland and wetlands were converted to arable agriculture and previous water courses diverted into the major canal and wet areas pumped dry. Right: maps showing the water courses and areas of open water (light grey) in the Skjern River Valley in 1871 (right upper) and 1987 (post drainage, right lower). The solid black outline defines the extent of the restoration project area.

in the Atlantic Salmon *Salmo salar* population had direct financial costs to the local community (Nielsen & Schierup 2007). These problems motivated the restoration of the river to its former course and flooding patterns, under the initial Parliament Act of 1987, with the longer term objectives to:

– Restore nutrient retention capacity (thereby reducing eutrophication in Ringkøbing Fjord; Petersen *et al*. 2008)
– Restore an internationally important wetland and habitats for breeding and staging birds (lost in the 1960s, Ferdinand 1971, Østergaard 2003)
– Promote the Ringkøbing Fjord fishery, enhancing the last self-sustaining Danish population of the Atlantic Salmon in the Skjern River (Nielsen *et al*. 2001)
– Increase local recreational and tourist activities.

The restoration of the river and its delta was a classic process-driven project, designed to markedly improve nutrient retention by restoring the physical and hydrological dynamics of the floodplain, through reworking the meanders, subjecting the valley bottom to the full water level fluctuations of the river system. Secondary benefits included restoration of lost habitats for the very many locally extinct organisms (that disappeared with the loss of open water, riverine and temporally inundated habitats), with amenity and recreational community benefits, although re-establishment of breeding bird communities was nowhere mentioned in the ultimate Parliamentary Act on the Restoration of Skjern River (Ministry of Environment and Energy 1998).

Consultation documents were published and Environmental Impact Assessments undertaken by the Danish Nature Agency (hereafter "NA" formerly the Forest and Nature Agency 1997; 1998). Although no specific biological targets were set for the project in the 1998 Act, the subsequent management plan established general aspirations, including improved conditions for migratory birds, restoration and maintenance of floodplain and wetland vegetation and the increased survival of salmonids. Although the re-establishment of breeding Corncrake *Crex crex*, Common Redshank *Tringa totanus*, Dunlin *Calidris alpina schinzii*, Black-tailed Godwit *Limosa limosa* and Ruff *Philomachus pugnax* were identified in the management plan as long-term goals, no specific success criteria for birds were ever set for the Skjern River project (Forest and Nature Agency 2004).

From June 1999, 40 km of river course were re-excavated, previous retaining dykes, weirs, pipes and pumping stations were removed and the river restored to the 1960s bed at a total cost of €38 million of tax payer's money, completed in late 2002 (Mitsch & Jørgensen 2004). Open cultivated fields were transformed into an open valley bottom with a broad meandering river (which constitutes 6% of the area), swamp (9%) and permanent shallow lakes (23%), the larger of which are independent of the river flow. Much of the permanent drier areas are now grazed meadows, some of which are winter inundated (59% of the total area, see Figure S1 in Supporting Information and Pedersen *et al*. 2007).

In the 1800s and early 1900s, wetland habitat loss for breeding waterbirds in Denmark was considerable, reflected in the extensive designation of remaining contemporary Danish wetlands under the EU Birds Directive and the Ramsar Convention (Miljø- og Energiministeriet 1995) and the many waterbird species on the Danish Red List of breeding birds (Pihl & Flensted 2011). Because of the unusual scale of this project in European terms, we here gather the available evidence to look at changes in abundance of specialist breeding waterbirds before and after the restoration of the Skjern River Valley (SRV) to its former state.

We assess the restoration of the SRV system against three success criteria in terms of improving conditions for breeding waterbirds:

- The appearance of breeding internationally/nationally important species, defined as European Union Birds Directive Annex 1 or nationally red-listed species (see Table S1 in Supporting Information for details)
- the return of strict waterbirds (open water species, i.e., those birds associated with water bodies, namely grebes, cormorant, herons and Anatidae, terns and gulls, see Table S2 in Supporting Information for classification) and
- the return of the species associated with wetland habitats (species associated with meadows and marshes, largely wader species that to tend nest in wet meadows about the periphery of water bodies, Table S2 in Supporting Information).

We also assess the degree to which former populations of breeding waterbirds were restored to the area. Only check-lists of breeding bird species exist for the SRV project area prior to the 1960s drainage, so we have no direct quantitative measure of the extent to which the restoration project has achieved its goal. For this reason, we also used our own professional nature conservation experience of breeding waterbirds at SRV and similar Danish wetlands to provide opinions about the species and their abundance that SRV could be expected to support under ideal management conditions.

Restoration schemes are subject to successional processes: after years of fertilizer application, a pool of soil nutrients will encourage growth of undesirable species or excessive biomass in the early restoration years (Jansson *et al*. 1994, Zedler 2000). Open water will gradually be lost to colonizing plants so that early conditions that attracted a broad range of breeding avian species may change. Hence, we predict a dramatic increase in breeding waterbirds immediately after restoration, but a combination of nutrient flush and succession in the longer term will support declines in species richness and diversity after initial high levels of colonization in years following restoration (e.g., Reinartz & Warne 1993). We test this using sequential breeding bird surveys carried out over a series of years before, during and after the restoration process. Finally, because the benefit to breeding birds was largely secondary to nutrient retention aims, we consider what more could have been achieved by the incorporation of more goal-orientated management planning at the initiation of the restoration project and how we might learn from this experience.

2. Methods

2.1. Restoration area and framework

Approximately 22 km^2 (19.5 km^2 purchased by the NA in the mid-1990s, the remainder in private ownership under management agreement) of the original 40 km^2 of wetlands drained in the 1960s were restored to wetlands. Cultivated fields were abandoned and during 1999–2002, the main river course was "re-meandered" to its 19 km original course and allowed to overflow to restore natural flows and water level fluctuations in the river and flood plain (Pedersen *et al*. 2007). Low summer water levels rise through autumn with widespread inundation in winter as was formerly the case. Permanent waters were established throughout the flood plain because of water table restoration and substrate shrinkage, including Hestholm Lake (242 ha, mean depth 60 cm) the largest lake in the valley. The confinement of the river within fixed stretches of river banks strengthened with large boulders has removed much of the dynamic processes associated with changes in the river bed, but has not affected annual flooding events, especially those characteristic of natural delta areas. The major management intervention is cattle grazing, 1,000 cattle and 45 horses graze circa 12 km^2 of meadows in the valley, with regular mowing to keep vegetation in check over a further circa 3 km^2. Agricultural management has been sustained by subsidies and excess of income over expenditure, so maintenance of wet meadow breeding waterbird communities is cost neutral to the project.

2.2. Breeding bird surveys

Annual numbers of breeding pairs of all birds were monitored in three years prior to the restoration of the lower section of the SRV and in five of the first 11 post-restoration years (see Supporting Information Appendix S1 and Kjeldsen 2008 for methods). Before 1960, there are no complete bird surveys of SRV, only breeding species presence/absence from 1870s to 1890s (Rambusch 1900), the early 1930s (Tåning 1933–1936) and the 1960s (Ferdinand 1971) and anecdotal accounts since that time (provided in Supporting Information Table S2). Hence, we cannot define a "pristine" state pre-drainage (in terms of the numbers and diversity of breeding waterbirds at the site) as the ideal management objective for the restoration project. In the interim, several species present in SRV in the 1890s have become extinct in Denmark (such as Black Grouse *Tetrao tetrix* and Great Snipe *Gallinago media*) or extremely rare (such as Corncrake and White Stork *Ciconia ciconia*) making their reestablishment unlikely in the immediate future. Hence, instead of establishing a historical "ideal" state, as professionals with a knowledge of the breeding waterbirds of other sites throughout Denmark, three of us (ADF, PC and TB) attempted to assess the potential of the site, under the best possible management conditions, to hold our "ideal" waterbird community given the range and area of habitats represented in the present (2012) SVR project area, expressed in terms of breeding pairs of waterbirds we expect to be present, without prior detailed knowledge of the precise breeding numbers of the species present. We compared average and maximum numbers of breeding pairs of Annex 1 Birds Directive or Danish Red List species in the SVR project area post restoration with the most recent estimates of the Danish breeding population sizes from the Danish Ornithological Society web site (DOF 2014) or from Nyegaard *et al.* (2014)

2.3. Numerical analyses

We present data on untransformed species richness and overall breeding pair abundance (compared using Student *t* tests corrected for unequal variances) from these census data. Following Tuomisto (2012), we calculated a simple annual Shannon-Wiener Diversity Index, H' (Hill 1973), value for the communities of waterbirds breeding in the open water and wetland categories defined above using the following equation:

$$H' = -\Sigma P_i \ln(P_i) \qquad (1)$$

where P_i is the proportion of species i in the sample. We also calculated the maximum H' value (H'_{mx}) based on the known number of species (S) in the community at that time as:

$$H'_{mx} = \ln(S) \qquad (2)$$

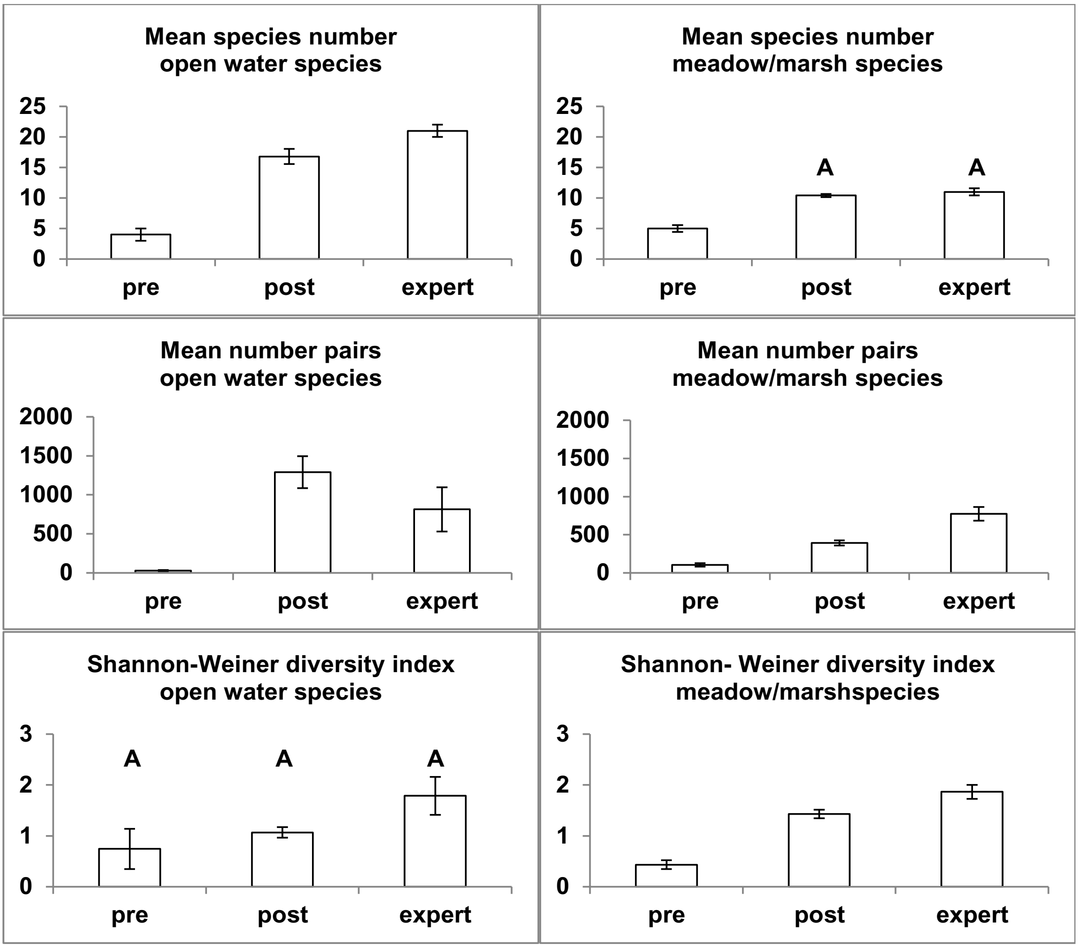


Fig. 3. Annual mean breeding species richness (upper), overall breeding abundance (middle) and diversity (lower) of all waterbirds in the Skjern River Valley during pre-restoration (n = 3 years) and post-restoration (n = 5 years), compared with three expert opinions combined of the species abundance they expect to be present (see text for details). Data are presented as mean values ± SE, partitioned between breeding species associated with open water (left) and those with meadow/marshland (right). Species in these two categories are defined in the introduction and listed in Supporting Material Table S2. Capital letters above histogram columns indicate no significant differences between means based on Student t tests at $P > 0.05$, otherwise all comparisons between means differ significantly at $P < 0.05$.

From this, we estimated the degree of evenness (E) in species abundance in the community, expressed as:

$$E = H' / H'_{mx} \quad (3)$$

E has the properties of varying from close to 0 when the vast majority of the species are rare to 1 when all are equally common (i.e., H'_{mx} Hill 1973). All statistical tests of breeding abundance and diversity were carried out using Student's two-sample t-test, corrected for unequal variances, judged significant at $p < 0.05$.

To conceptualize the development of the SRV waterbird communities present during pre- and post-restoration periods and see how this relates to expert opinions, we carried out a Detrended Correspondence Analysis (DCA, Hill and Gauch 1980) on the untransformed breeding open water and wetland bird abundance data with the "expert" data detrended by segments (without weighting or scaling) using the MSVP software (Kovach Computing Services 2011, see Supporting Information Table S3 for the raw data). Because of its large numerical contribution to the overall open water breeding bird community, we also analysed this set of species without the colonial Black-headed Gull *Chroicocephalus ridibundus* which breeds in abundance at the site.

3. Results

3.1. Post-restoration breeding waterbird abundance

Numbers of breeding waterbirds increased significantly from 134 ± 22.9 SE ($n = 3$) pairs in the pre-restoration state to 1,744 ± 153 SE ($t_4 = 10.0$, $P < 0.001$) pairs in the five surveyed years following restoration, peaking at 2,218 pairs in 2011 (Supporting Information Table S2). Since the restoration project, six Annex 1 species Eurasian Spoonbill *Platalea leucorodia* (in 3 years), Great Bittern *Botaurus stellaris*, Spotted Crake *Porzana porzana*, Pied Avocet *Recurvirostra avosetta*, Ruff (of which possibly three pairs bred in one year) and Black Tern *Chlidonias nigra* (which bred once) and 10 Danish Red List species the aforementioned plus Eared Grebe *Podiceps nigricollis*, Northern Pintail *Anas acuta* (which bred in two years), Garganey *Anas quequerdula* and Little Ringed Plover *Charadrius dubius* (which bred in four out of five years and may have benefitted temporarily from earth-moving work associated with reinstating the river bed) have bred in the project area. All 10 species have bred in numbers which, based on the average numbers of pairs from 2001–2004 and 2011, exceed 0.5% of the Danish breeding population and in single years constitute between 1.6 and 26.1% of the total Danish populations of these species (Supporting Information Table S4).

3.2. Changes in abundance and diversity of open water species

Species richness of open water species increased significantly from a mean of 4 ± 1.0 SE ($n = 3$) prior to restoration to 17 ± 1.2 SE ($n = 5$, $t_6 = 8.0$, $P < 0.001$), significantly less than the 21 ± 1.0 SE ($n = 3$, $t_6 = 2.6$, $P = 0.02$) species predicted from ex-

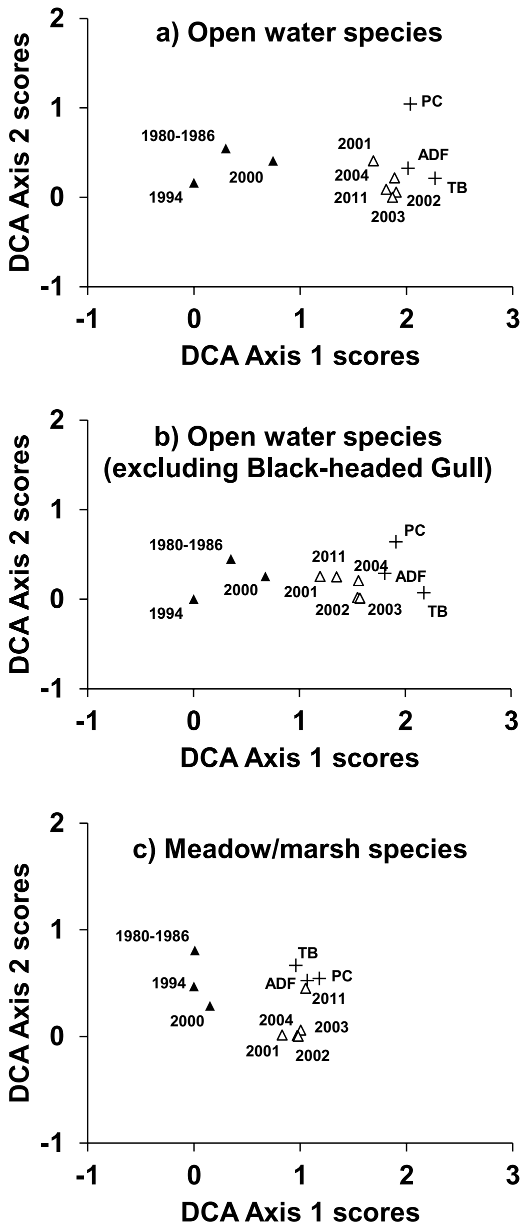


Fig. 4. Ordination of annual overall breeding waterbird communities at Skjern River Valley as a result of Detrended Correspondence Analysis (Hill and Gaugh 1980, see text for details) for a) open water species, b) open water species without Black-headed Gull and c) meadow and marsh species. Years prior to restoration are shown with filled triangles, those post-restoration by open triangles and the predictions of the experts under ideal management conditions as crosses, identified by the initials.

pert opinion (Fig. 3 upper left, see Supporting Information Table S3, although because of species turnover, 23 species bred post-restoration in all). This represented a significant increase from an average of 29 ± 8.4 SE (n = 3) pairs to 1,289 ± 205.1 SE (n = 5, t_4 = 6.1, P < 0.001) following re-meandering works, rather more than predicted by the experts (830 ± 274.2 SE, n = 3 but not significantly different t_4 = 1.3, P = 0.13) because of discrepancies in estimates of the most common species, such as Mallard *Anas platyrhynchos*, and Black-headed Gull (Fig. 3 middle left and Supporting Information Table S3). Diversity amongst open water species increased (as measured by the Shannon–Wiener diversity index) from 0.74 ± 0.40 SE (n = 3) to 1.07 ± 0.14 SE (n = 5, t_2 = 0.8, P = 0.26) post-restoration, less than predicted by the experts (1.79 ± 0.37 SE, n = 3, t_2 = 1.8, P = 0.11; Fig. 3 bottom left and Supporting Information Table S3), although none of these mean values differed significantly from each other. Although the breeding community of open water species has developed dramatically since the restoration project, the DCA ordination suggests that further improvement is possible towards the expert predictions for this group of species (Fig. 4 a, upper) even excluding Black-headed Gull from the analysis (Fig. 4 b, middle).

3.3. Changes in abundance and diversity of meadow and marshland species

Amongst the meadow/marsh species, numbers of breeding species increased significantly from a mean of 5 ± 0.58 SE (n = 3) prior to restoration to 10 ± 0.25 SE (n = 5, t_3 = 8.6, P < 0.01), not significantly different to the 11 species ± 0.16 SE (n = 3, t_3 = 1.0, P = 0.21) predicted by experts (Fig. 3 upper right, see Supporting Information Table S3). The total number of pairs of these species increased significantly from a mean of 105 ± 23.1 SE (n = 3) pairs to 393 ± 34.7 SE (n = 5, t_6 = 6.9, P < 0.001) following re-meandering works, significantly less than the 774 ± 88.4 SE (n = 3, t_3 = 4.0, P = 0.014) predicted by experts (Fig. 3 middle right and Supporting Information Table S3). Diversity amongst these species increased significantly (as measured by the Shannon–Wiener diversity index) from 0.43 ± 0.08 SE (n = 3) to 1.43 ± 0.08 SE (n = 5, t_5 = 8.4, P < 0.001) post-restoration, but was significantly less than predicted by the experts (1.87 ± 0.14 SE, n = 3, t_3 = 2.7, P = 0.037; Fig. 3 lower right and Supporting Information Table S3). Again, there was a dramatic difference between the DCA of the meadow and marsh breeding waterbird communities before and after the restoration project, but the discrepancy between the 2011 survey results and the predictions of the experts was less than might have been expected (Fig. 4 c, lower).

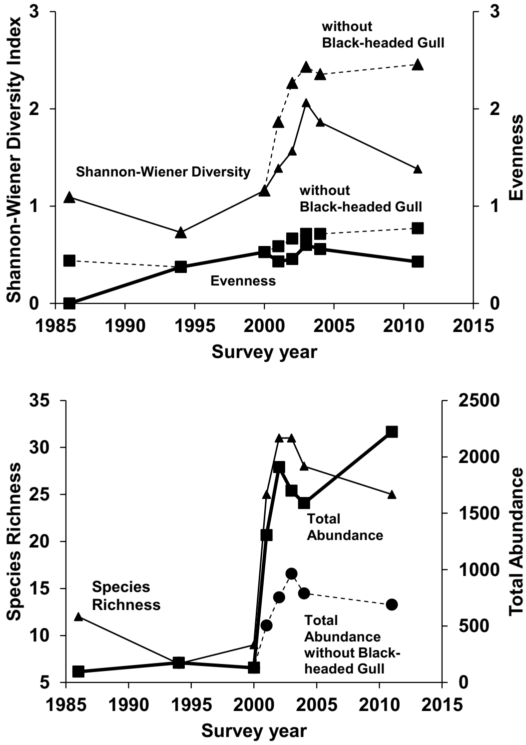


Fig. 5. Annual diversity indices (squares) and evenness (triangles, upper) and species richness (triangles) and total breeding waterbird abundance (squares, lower) as determined by annual breeding waterbird surveys in Skjern River Valley 1986–2011. Relationships are shown with (solid lines) and without (pecked lines) the colonial nesting and abundant Black-headed Gull for comparison.

3.4. Changes in abundance and diversity of all waterbirds

Species evenness and diversity increased amongst all waterbirds (i.e., open water and meadow/marsh species combined) with restoration activities to peak in 2004, since when both measures have declined (Fig. 5 upper), as has species richness (Fig. 5 lower), although the total number of breeding waterbirds surveyed in 2011 was the highest ever (Fig. 5 lower). Exclusion of the abundant Black-headed Gull results in little change in diversity or evenness after restoration (Fig. 5 upper), but a decline in overall total abundance (Fig. 5 lower).

4. Discussion

The SVR restoration restored 29 breeding waterbirds species (including 10 Birds Directive Annex I or Danish Red List breeding bird species) to the project area which were absent/infrequent during the previous 30–35 years whilst subject to drainage and intensive agriculture. All 10 rare species contribute at least 1% to the breeding Danish populations (up to 22% and 19% in the case of Eared Grebe and Spotted Crake, Supporting Information Table S4), although not all of them did so in all years (e.g., Spoonbill in three out of five years, Pintail two out of five years, Black Tern once and Ruff once in five years). The number and diversity of breeding waterbirds are only exceeded in Denmark in the Wadden Sea, at Vejlerne (north Jutland), southern Ringkøbing Fjord, Agger Tange and Saltholm. Hence, the restoration restored breeding populations of strict waterbirds to a level that constitutes the SVR as one of the five to 10 best areas for breeding waterbirds in the country.

Despite some loss of open water to *Phragmites* reed beds and to willow (*Salix*) thicket, bird communities associated with open water showed no evident changes during 2001–2004 and 2011 (Fig. 4 upper). The experts predicted Black Tern (not currently present in SVR but formerly common, Rambusch 1900), an Annex I species and a rare nesting bird in Denmark and greater numbers of grebes, ducks and Greylag Geese *Anser anser* compared to recent surveys. Provision of artificial nest islets or platforms could elevate populations of Common Tern *Sterna hirundo*, Black-headed Gull and Pied Avocet. Black Tern could benefit from provision of specialist floating vegetation that constitutes its nesting habitat, since it is a frequent migrant in SVR in spring and autumn. Greylag Geese have been increasing since restoration and will likely reach higher population levels than at present. Duck and grebe abundance shows annual variation and taken with the restricted management options, there is relatively little more besides the construction of artificial islets that could be done to enhance current breeding birds associated with open water.

Black-tailed Godwit, Ruff and Dunlin have not returned as regular breeding species, despite viable and slightly increasing breeding populations within 6–10 km of SVR (Thorup 1998, Thorup & Laursen 2012), although all are declining in breeding abundance in Denmark and neighbouring countries (Thorup 2004, Delany *et al*. 2009). Breeding godwits show an inverse relationship between abundance and fertilizer application (Laursen & Hald 2012), so SVR may still be too affected by former agricultural activities to support the species now. Godwits are also highly sensitive to human disturbance (Holm & Laursen 2009), so perhaps the establishment of the existing network of footpaths through wet grassland and hay meadows needs to be better integrated with the needs of the species. Ruff are semi-nomadic, dispersing freely amongst suitable breeding sites over long distances (Rakhimberdiev *et al*. 2011) and are seen at SVR most years, suggesting the present habitat is not appropriate yet, and more effort needs to be paid to determining their precise habitat needs and ensuring such habitats are available. Corncrake has also not returned as a breeding bird. Experts judged that present densities of breeding Northern Lapwing *Vanellus vanellus*, Common Snipe *Gallinago gallinago* and Common Redshank could be increased by 3–6 fold over those currently present, although these species take 3–10 years to gradually build local populations, even when management conditions are appropriate for providing breeding habitat (Smart *et al.* 2006, Eglington *et al*. 2009, 2010, Fisher *et al*. 2011). Studies of Northern Lapwing, Black-tailed Godwit and Common Redshank at Tøndermarsken in southern Denmark showed that while appropriate water table management was critical for the reestablishment of breeding populations, in fields that had been drained and cultivated, birds did not always respond to elevated water tables, suggesting that historical agricultural use may impede efforts to reconstruct habitats for these species (Kahlert *et al*. 2007). Water levels must be managed to retain summer surface water features, whilst grazing or cutting the sward short, to manage vegetation height and structure to meet the demands of the most vulnerable and demanding species, such as Corncrake, Dunlin, Ruff and Black-tailed Godwit (Thorup 1999, 2004). There are practical and financial limits to management, but static fencing, stock grazing density and high water tables can all influence management of optimal breeding wader habitat, and a wealth of studies of wet grassland management and grazing exists to optimize agricultural production with the needs of breeding waders (e.g., Ausden *et al*. 2001, Smart *et al.* 2006, Sabatier *et al*. 2010, O'Brien & Wilson 2011).

While it is clear that expert opinions are highly subjective, those presented here suggested species richness and diversity could be greater, dependent on further adaptive management intervention, experimentation and extra recurrent costs. There is substantial scope for further study, since many agricultural grasses persist in the wet grasslands with high annual rates of growth that reflects the nitrogen and phosphate pool in the soil from the period of tillage. Elevated removal of biomass off site to reduce this nutrient excess could improve sward structure and composition for commoner nesting waders like Common Redshank, Common Snipe and Northern Lapwing. Studies of succession in open water and emergent swamp vegetation will determine effects on the breeding bird fauna and suggest management interventions (e.g., retaining open pools in reed beds for Great Bitterns, Brown *et al*. 2012) since 2011 diversity measures were lower than those immediately post-restoration. More focused and costly management interventions may be necessary to create specific habitats to attract and retain key breeding species, such as Black Tern, Dunlin and Black-tailed Godwit as well as Ruff in large breeding numbers and habitat specialists such as Corncrake. However, the potential to attract rarer species back as breeding species depends on the strength of population sources nearby and the ability of such populations to recolonize as well as any additional targeted management interventions and resources.

In conclusion, a restoration scheme developed to restore nutrient/sediment retention characteristics to SVR recreated a wetland amongst the best 10 for breeding waterbirds in Denmark from an arable landscape supporting little wetland biological diversity, achieved without major recurring costs thanks to the management planning of the NA and cooperation of grazing tenants. Although impossible to determine pre-1960s pre-drainage breeding waterbird communities, we consider further enhancement of species abundance and diversity is feasible with additional management intervention, but this should not detract from the impressive passive gains made to date. We judge that post-restoration goal-orientated management in parts of the restored wetland would increase diversity and improve habitat for priority breeding waterbirds, accepting the risk that species may not settle or if they do so, depend on immigration to maintain a population in SVR (for example because of local predation issues, because tillage had altered soil structures or invertebrate communities or fertilizer residues need to be removed). An adaptive management plan to address such challenges would redress the lack of avian input to the original restoration plan.

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Skjern Enge – Nordeuropas dyraste våtmarksrestaurering: vilken var nyttan för häckande vattenfåglar?

I Europa har allt fler våtmarker restaurerats för att återskapa naturvärden som försvunnit i samband med utdikning och odling. På 1960-talet reglerades den västra delen av Skjern Å i Danmark för att förbättra odlingsmöjligheterna i ådalen. Cirka 35 år senare användes knappa 300 miljoner DKK på att etablera ett 22 km^2 stort område med dammar och våta ängar. Målet var att minska mängden näringsämnen som rann ut i Ringkøbing fjord, att således förbättra förhållandena för den lokala laxstammen, för häckande och flyttande vattenfåglar samt att öka områdets rekreativa värde.

Det fanns inga specifika kriterier för projektets framgång, men denna studie dokumenterar att antalet häckande arter och individer steg i och med restaureringen. Totalt 29 arter vattenfåglar återvände till häckfågelfaunan och 10 av dem uppträdde i antal av nationell eller internationell betydelse (arter rödlistade i Danmark eller i Bilaga I i EUs fågeldirektiv).

Nu är Skjern Enge ett av Danmarks 10 viktigaste häckningsområden för vattenfåglar. Med betning och slåtter försöker staten upprätthålla våtmarkernas och ängarnas attraktivitet för häckande vattenfåglar. Trots att de vanligare sump- och andfåglarna nu finns på området, har mer sällsynta arter, som sydlig kärrsnäppa, rödspov och brushane inte återkoloniserat området. Dessa arters behov kunde ha beaktats bättre, med en mer målinriktad skötsel i utvalda delar av området.

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Supporting Information

Additional Supplementary Information may be found in the online version of this article:

Appendix S1. Breeding bird survey methods

Figure S1. Map showing the current (2012) extent of habitats within the Skjern River Valley, West Jutland, Denmark following restoration.

Table S1. Information on designation criteria for EU Birds Directive Special Protection Area No. 43.

Table S2. Annual estimated numbers of breeding pairs of waterbirds in the Skjern River restoration area 1870–2011.

Table S3. Expert assessments of potential breeding waterbird communities in the Skjern River restoration area in 2011.

Table S4. Mean annual numbers of breeding pairs of 10 rare (Annex 1/Danish Red List species) in the Skjern River restoration area in 2001–2011in relation to national breeding population size.