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A case study of evidence for showing 'no net loss' of bird biodiversity in a development project

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Abstract

Given the development of global pressures on habitats and biodiversity, it is important that developments are accompanied with a compensation element leading to 'no net loss'. We show how (using a standardised sampling process) a statistical assessment of the biodiversity quality of the target organisms (birds) in a compensatory provision can be shown to be a compensation or not. We used the example of the Cardiff Bay Barrage (Wales) where a bay was inundated and compensation site at Newport Gwent Levels (Wales) created. Bird data for the Cardiff Bay prior to the inundation and for Newport following inundation of Cardiff Bay were analysed to create a series of biodiversity quality indices and these were compared statistically. The analysis showed the compensation habitat was better than the original. Results were poor for Dunlin and Redshank, already subject to regional decline in the Severn Estuary and estuaries in NW Europe.

Introduction

Loss of biodiversity is accelerating due to anthropogenic influence although a wide range of legal frameworks have been established for biodiversity conservation (Butchart *et al*. 2010). Habitat creation and restoration have come to be recognised as possible compensation measures in halting biodiversity loss using the concept of 'no net loss of biodiversity', which aims to equalise the biodiversity loss and gain. However, the question that needs to be asked is how to measure biodiversity as it is difficult to assess the achievement of 'no net loss' status without measuring biodiversity? Although there are many ecological indicators based on various attributes such as taxonomic difference, trophic status and coverage of ecosystems, a single measure cannot be used to capture the entirety of biodiversity (Gaston & Spicer 2004; Magurran 2004). Some clarity has been brought to this situation by Feest *et al*. (2010a, b) who refer to biodiversity as a quality of a site that can be determined by reference to a number of measured species biodiversity indices based on standardised sampling methodologies. In this approach, the characteristics of the site biodiversity are described by the indices viewed together and a set of baselines can be established and differences assessed.

Our research aims to confirm the issues in biodiversity assessment and compensatory measures by analysing a case study: the Cardiff Bay Barrage project. The project included compensatory habitat creation for the habitat loss for water-birds although the target species differed from the original species that existed at the preproject site (an out-kind compensation). In this case study, ornithological biodiversity data of the preproject site of Cardiff Bay and the new compensatory habitat, (Newport Wetlands), are compared and analysed in order to confirm how and to what extent the biodiversity loss has been compensated.

Cardiff Bay Barrage project and the environmental compensation

Cardiff Bay is located on the Northern part of the Severn Estuary and receives inflow from two main rivers, the Taff and the Ely. The bay was approximately 200 hectare (ha) in area and encompassed 150 ha of intertidal mudflats (Burton *et al.* 2002). In order to regenerate the area by converting the mudflats to a freshwater lake waterfront, a 1.1 km long barrage was constructed at the bay entrance. The construction work was started in May 1994 and it was completed in 1999.

The site formed a critical part of the wider Severn Estuary area, which is a site of international importance, and the bay itself was designated as a Site of Special Scientific Interest (SSSI is a United Kingdom designation for important biodiversity sites) since it regularly held a nationally important population of particular water-birds, and a significant proportion of the global population (Cowell 2000; Burton *et al*. 2003). Whereas rare and endangered species in the Annex 1 of the

Birds Directive were not observed in significant numbers in the bay, Dunlin and Redshank had reached nationally important numbers. The saltmarshes of Cardiff Bay were considered important as they provided shelter and roosting site in addition to food plants for bird species (EAU 1991).

Seed-eating birds were found on the saltmarshes during the winter months and large number of gulls had been seen on the bay (EAU 1991). There was not any distinctive habitat of international or national concern except that for water-bird species. The Environmental Statement (EAU 1991) pointed out that the bay would be no longer available as a feeding site for waders and wildfowl, and it was concerned about the reduction in their survival or increase of the mortality rate. In response to the serious damage to the water-bird species caused by the project, the developers were required to construct 400 ha of new wetland reserve (Newport Wetlands), which is located along the Severn Estuary about 24 km upstream from Cardiff Bay, as part of a wider compensation package. The construction work began in July 1998 and the reserve opened to public in March 2000. The goal of the compensation could not be a ‘like-for-like’ compensation due to the land availability, it was intended to achieve ‘ornithological maximisation within available resource’ (Cowell 2000, p. 699).

The new habitat compensation comprised the following three types of habitat:

(1) Eighty six hectare of wet reed bed at Uskmouth, to attract certain nationally rare breeding birds,

(2) Eleven hectare of shallow saline lagoons at Goldcliff, to provide supplementary feeding and roosting sites for the birds within Severn Estuary,

(3) One hundred and sixty hectare of freshwater wet and flooded grassland at the area called ‘Saltmarsh’, and 31 ha of wet grassland at the Uskmouth, to support nationally and internationally important numbers of some wintering waterfowl species (Crompton 2002).

The remaining acreage was an extension to existing habitat and not studied.

The specific targets of the compensatory habitat were; (1) to sustain at least two species (Wigeon & Shoveler) of wintering water-bird in nationally important numbers, and (2) to be eligible for Special Protection Area (SPA is an EU habitat designation) status within five years (Austin *et al*. 2006). These targets were to balance the extinction of two other nationally important species in the Taff/Ely Estuary SSSI, i.e. Dunlin & Redshank (Auditor General for Wales 2000; Cowell 2000).

In terms of ‘no net loss’, both the quality and the quantity issues were considered carefully. While the specific targets cover the quantity aspect, the quality aspect can be seen in the comprehensive goal for the compensation, which was to produce a ‘wetland of outstanding value for wintering and breeding waterfowl and for other rare or threatened bird species’ as a reflection of the outstanding values deemed to be represented in the Taff-Ely SSSI (Cowell 2000, p. 699). The SPA status represented a quality aspect to be compensated. The new reserve area is 2.5 times larger than 160 ha SSSI in Cardiff Bay and was considered a minimum requirement to create a successful reserve because artificial habitats may sustain lower bird densities compared to natural habitat (Cowell 2000; Morris *et al*. 2006).

An assessment of the status of Newport Wetlands was conducted by British Trust for Ornithology (BTO) five years after the creation of the wetland in order to check whether it has met its target (Austin *et al*. 2006). This assessment concluded that both of the targets, were considered to have been achieved: Shoveler and Black-tailed Godwit, had attained nationally important numbers across the entire reserve In March 2010, 374.2 ha of the new site were notified as an SSSI as the site supports nationally important numbers of Shoveler and Black-tailed Godwit (Country Council for Wales 2010). Figure 1 shows the boundary of the reserve and the habitat composition of the current wetland.

Method

Rationale and source of the data

In theory, a comparison of sites can be conducted by comparing the biodiversity lost due to the project, and biodiversity gain provided by the compensation. However, biodiversity is too complex to measure by one indicator (Gaston & Spicer 2004). In line with these assumptions and limitations, the research hypothesis was established as:

H_1: The bird biodiversity quality of the Newport Wetlands is equal to and not significantly worse than the Cardiff Bay it was intended to compensate.

In this hypothesis, biodiversity quality is used in the sense indicated by Feest (2006), Feest *et al*. (2010a, b) and Feest *et al.* (2012), which proposes a pragmatic way to measure biodiversity quality by using a combination of several indices, i.e. Species Richness, Evenness, Biomass, Population and Rarity (or intrinsic value) of each species. This methodology is adopted for this research. Significance will be shown by simple statistical tests.

We utilized the standardized Wetland Bird Survey (WeBS) (Bibby *et al*. 2000) Core Count data for this analysis. The data were supplied by WeBS, a partnership between BTO, Royal Society for the Protection of Birds and the Joint Nature Conservation Committee in association with the Wildfowl and Wetland Trust. WeBS Core Counts cover a wide range of wetlands in the United Kingdom, around 2500 sites annually and thus, the data is satisfactory for site assessments (Gilbert *et al*. 1998). The surveys are normally conducted once monthly, on scheduled dates, at high tide, when birds are counted easily at roost (BTO, N.A. b). The counts cover most

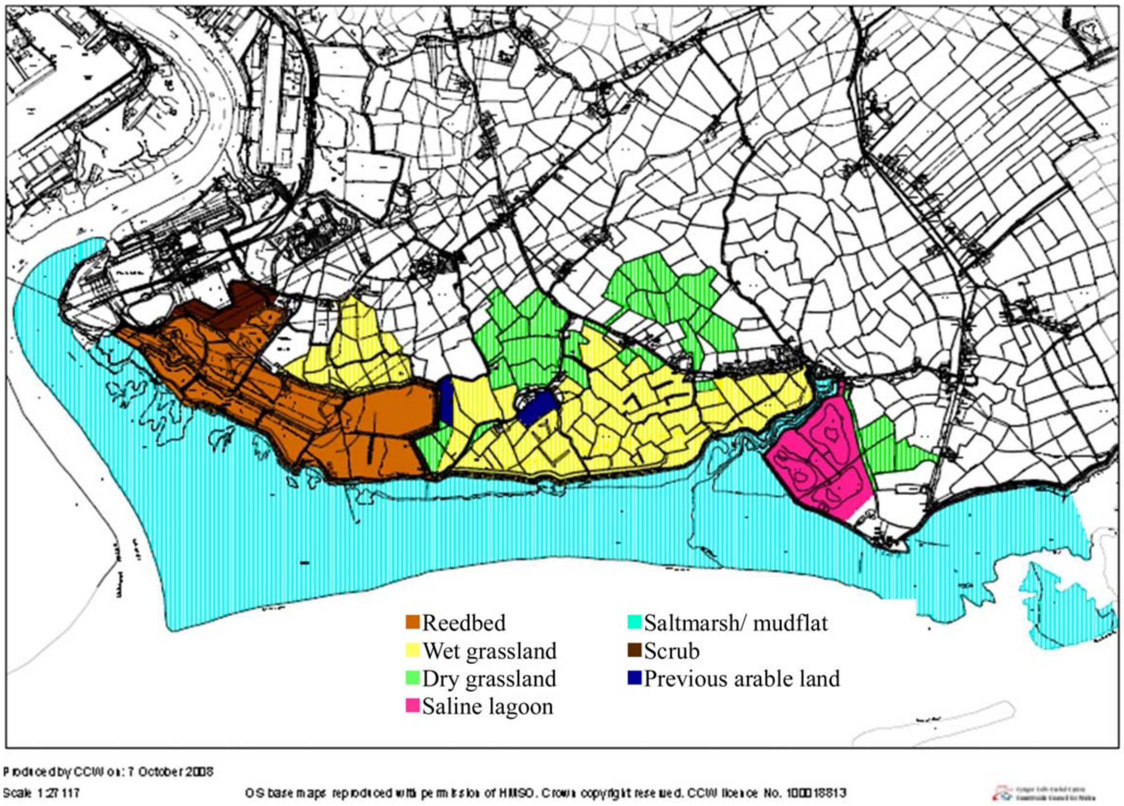

Fig. 1. Newport Wetlands Habitat. Source: CCW 7 October 2008 (Reproduced from Ordnance Survey base maps. Crown copyright reserved. CCW licence No. 100018813). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

water-bird species (divers, grebes, cormorants, herons, swans, geese, ducks, rails, waders and kingfisher but not gulls and terns) in most areas (BTO, N.A. a). The preproject site at Cardiff Bay is 207 ha and is a single area. The compensatory habitat at Newport Wetlands refers to the newly created compensatory site at Newport (95 ha of reed-beds, 145 ha of wet grassland and 33 ha of saline lagoon). Newport Wetlands consists of four counting areas (Fig. 2), including 'Uskmouth Reed bed Lagoons', 'Saltmarsh Grasslands', 'Goldcliff Saline Lagoons' and 'Nash Foreshore & Goldcliff Pill'. The former three sites are mainly newly created habitat, and 'Nash Foreshore & Goldcliff Pill' site is outside of the sea wall and already existed; data from the former three sites were used for this research.

Time span of the data and the format

The population of wintering birds fluctuates year by year; therefore, a five-year period was used in accordance with common usage of WeBS (Bibby *et al*. 2000; Austin *et al*. 2006; Banks *et al*. 2006). The data was used in the form of 'five-year peak mean' of annual count, which is defined as the mean of the five-year's peak annual counts (Austin *et al*. 2006). The figure shows 'the number of birds that a site regularly supports' and it is normally used for site assessments of wintering water-birds for the SPA and the SSSI (Austin *et al*. 2006, p. 8). For the preproject site of the Cardiff Bay Barrage, data between 1989 and 1994 were used because the construction work could affect the behaviour of water-birds (Burton *et al*. 2002), although the closure of the Cardiff Bay Barrage was in 1999. For the Newport Wetlands, the data between 2004 and 2009 were used.

Data processing by Fungib programme

The data were processed by software called Biodiversity Quality Calculator (BQC; http://www.ecosulis.co.uk/page/biodiversity-quality-calculator) which is a programme to compare biodiversity in a comprehensive manner by handling the several indices which can be used for the biodiversity quality assessment of defined taxonomic groups (Feest 2006; Feest *et al.* 2012) and in this research, the following combination of the indices is used:

Species richness

Species Richness seems to be the simplest and easiest way to measure biodiversity; however, this approach conceals the balance of individuals within each species (Feest 2006;

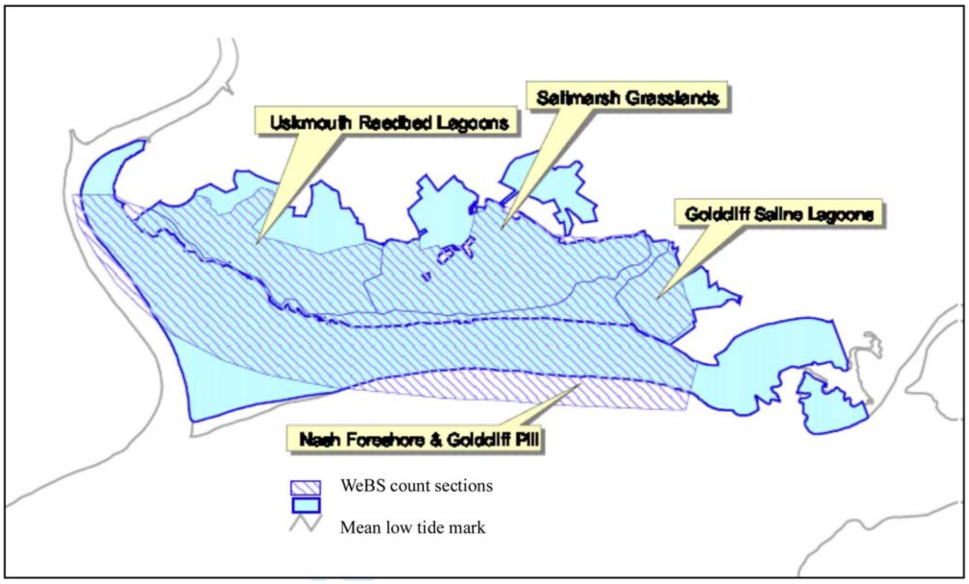

Fig. 2. Newport Wetlands: Coverage of WeBS Count (WeBS = Water birds survey)Source: BTO Report No.451 (Austin *et al*. 2006, p. 10) [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Maier 2012). In addition, species inventories tend to be biased by the sample size (Magurran 2004) and appear to make each species of equal value (Magurran 2004; Maier 2012).

Evenness

Evenness could be used to illustrate the composition of the chosen unit; however, the approach could lead to a contradiction if a site with a smaller number of species has a higher biodiversity evenness than another site with a larger number of species (Feest 2006; Maier 2012). In this research, the Simpson’s evenness index was calculated ‘by determining, for each species, their proportion of individuals or biomass that it contributes to the total in the sample’ (Harper & Hawksworth 1995, p. 10). This is also an intuitive index and preferable to the Shannon–Wiener index (Magurran 2004; Feest 2006).

Species value index

Species Value Index (SVI) is a unique feature of BQC software. Generally, diversity measurement is based on an assumption that all species have the same value (Magurran 2004; Maier 2012). An SVI of each species is designated in line with the rarity or intrinsic value such as endemicity, small local population size, habitat specialization or limitation (Feest 2006). The SVI score for a species can be anything that indicates a relational value difference between species and the mean and standard deviation of SVI for all species are calculated. The standard deviation could indicate the presence of rare species where a large number of common species contribute to lower the mean value (Feest *et al*. 2010a, b). As SVI in BQC is subjective index, recognized rarity such as the status of Red Data List is recommended (Feest 2006). The SVI was set according to two criteria: 1. The population status in the United Kingdom and Europe by referring to ‘Collins New Generation Guide to the Birds of Britain and Europe’ (Perrins 1987). SVI values from 2 to 6 were assigned based on the population size (SVI 1; Appendix 1 Table A1) In Appendix 1 Table A2 SVI 2 are values based on the conservation aspect by referring to, ‘Birds of conservation concern 3’ (Eaton *et al*. 2009), which indicates the red and amber lists of bird species for conservation concern in the United Kingdom. Consequently, SVI of the species in this red list were ranked at 10 (20 for Global Conservation Status) in the IUCN red list, and those in the amber list were assigned 6, and the remaining species were ranked at 2 (SVI 2: see Appendix 1 Table A2). The highest SVI between the SVI 1 and SVI 2, were used (see Appendix 1. Table A3).

Biomass index

Biomass measure can be considered as ‘a direct measure of resource use’ (Magurran 2004, p. 140), and closely related to the metabolism of the species; therefore, the figure could give an insight into the functional characteristics of the biodiversity quality (Saint-Germain *et al*. 2007). Biomass Index (BI) in Fungib programme simply derives a calculation from the biometrics, multiplying weights of each species (as given by Perrins 1987) by the number of the individuals. The total BI for a site is shown as the summary of the BI of each species.

The species evenness indices in Fungib are also calculated by using the BI for showing relative biomass (Feest 2006).

The total BI would indicate the accumulation of maximum resource use by each species. However, the resource use by each species is spread over a year because most of the species are migratory birds; therefore, particular attention should be paid for the comparison of the BI. The body weights of bird species varies according to the feeding condition, season, geographical race and other factors such as change within a day and difference between male and female (Perrins 1987). In this analysis, the information about weight referred to Perrins (1987), and the mean weight between the maximum and the minimum was adopted as shown in Appendix 1.Table A3.

Statistical analysis

Statistical analysis was conducted for the datasets of the species richness, evenness, populations, BI and SVI of the two sites to test whether the datasets show a significant difference (see Table 4). Before applying a parametric statistical test for normal distribution, the Anderson–Darling test for normal distribution, was performed for each dataset. If the dataset showed normal distribution, the nonpaired *t*-test was adopted. Otherwise, we used the Mann–Whitney *U* test, which is a nonparametric test without assumptions about homogeneity of variances and normal distributions (Dytham 1999), The nonpaired *t*-test with base-10 log transformed data was also conducted: the *t*-tests with log transformed data is an option used in order to fit the assumptions better, instead of using a nonparametric test (Dytham 1999; McDonald 2009).

Results

Results of the data analysis by Fungib

The summary results of the biodiversity indices for the two sites are shown in Table 1. and Newport shows a higher Species Richness (more than twice that of Cardiff). For Species Richness, annual peak count numbers for both sites during the designated five years were statistically tested by thee nonpaired *t*-test and shows a significant difference ($P \leq 0.001$). The species richness of the two sites was very highly significantly different with Newport Gwent having the higher richness.

Species evenness in Newport is also higher than Cardiff; Simpson’s index is 9.339 compared to 1.754 in Cardiff. This is mainly due to the significant number of Dunlin in Cardiff (5220 five-year peak mean). Density of the two sites is similar; however, BI per ha of Newport is nearly three times more than Cardiff. This could imply that although both sites have a similar abundance of water-birds per hectare the Newport site attracts larger water-bird species than in Cardiff (the site has sufficient resource to hold the abundance). The SVI of Cardiff is higher than Newport; however, the standard deviations of both sites are large enough to suggest the difference is not significant.

For the population, SVI and BI datasets the Mann–Whitney *U* test and the *t*-tests with log-10 transformed data were Performed (Table 2). All *P* values are more than the critical level of 0.05; thus, the null hypothesis of ‘the two sets of the data are the same’ (Dytham 1999, p. 80) could not be rejected: specifically, there are no significant differences between the datasets for these indices.

To summarise, although the results of the biodiversity indices in the Table 1 show higher biodiversity quality values in Newport, the statistical analysis did not show a significant difference between the data of the two sites except for Species Richness, (Table 2).

Table 1 Summary of biodiversity indices produced by BQC for water birds at Cardiff and Newport

Site & Year Area	Cardiff 89-94 207 ha		Newport 04-09 273 ha	
Species richness	22		54	
Simpson Index	1.754	(6.023)	9.339	(10.059)
Density (per ha)	33.734		29.168	
SVI	6.364	±2.672	5.481	±2.217
BI/Kg/ha	6.099		17.902	

Indices are calculated based on five-year peak means. Figures in parenthesis represent biodiversity indices based on relative biomass and the ± indicates the SD. Density and BI are recalculated based on each area.

Difference of the individual species

Despite Species Richness indicating that Newport attracts more species than Cardiff there are some losses of species and population declines (Table 3). To assess the compensation for individual important species in Cardiff Dunlin, Knot, Lapwing, Redshank, Curlew, Shelduck and Teal were analysed for difference (indicated with bold characters in Table 3 and the nonpaired *t*-test was used. There are very significant differences for Dunlin ($P \leq 0.001$), Redshank ($P = 0.006$) and

Table 2 Results of the *U*-test and the *t*-test of datasets for Cardiff and Newport

	U-test	*t*-test with log transformed data (base-10)
Population	$P = 0.795$	$P = 0.959$
SVI	$P = 0.138$	N.A
BI	$P = 0.736$	$P = 0.650$
Species Richness	$P \leq 0.001$	$P \leq 0.001$

Population and BI are based on five-year peak means. The *t*-test with log transformed data for SVI was not conducted as the data distributes only a range between 2 and 10.

Table 3 Comparison of five-year peak means of individual species between Cardiff and Newport. Data in bold are for species of conservation importance.

Cardiff			Newport		
Species name	Population	SVI	Species name	Population	SVI
			Avocet	18	6
			Barnacle Goose	1	6
			Bar-headed Goose	1	4
Bar-tailed Godwit	1	6	Bar-tailed Godwit	35	6
			Black Swan	1	2
Black-tailed Godwit	1	10	Black-tailed Godwit	295	10
			Canada Goose	155	2
			Common Sandpiper	2	6
Common Scoter	1	10			
			Coot	227	2
Cormorant	30	2	Cormorant	11	2
Curlew	**122**	**6**	**Curlew**	**211**	**6**
			Curlew Sandpiper	3	4
Dark-bellied Brent Goose	1	2			
Dunlin	**5220**	**10**	**Dunlin**	**802**	**10**
			Gadwall	102	6
			Garganey	1	6
			Goldeneye	8	6
			Golden Plover	1	6
			Great Crested Grebe	7	2
			Green Sandpiper	3	6
			Greenshank	5	4
Grey Heron	1	2	Grey Heron	16	2
			Greylag Goose	3	6
Grey Plover	10	6	Grey Plover	85	6
			Kingfisher	1	6
			Knot	**840**	**6**
Lapwing	**93**	**10**	Lapwing	**1761**	**10**
			Little Egret	57	6
			Little Grebe	61	6
			Little Ringed Plover	2	4
			Little Stint	2	4
Mallard	164	6	Mallard	306	6
			Moorhen	83	2
Mute Swan	1	2	Mute Swan	60	2
Oystercatcher	41	6	Oystercatcher	18	6
Pintail	1	6	Pintail	50	6
Pochard	16	6	Pochard	19	6
Redshank	**515**	**6**	**Redshank**	**65**	**6**
Ringed Plover	24	6	Ringed Plover	41	6
			Ruddy Duck	4	4
Ruff	1	10	Ruff	2	10
			Sanderling	1	2
			Scaup	1	10
Shelduck	**328**	**6**	**Shelduck**	**475**	**6**
			Shoveler	260	6
			Snipe	22	6
			Spoonbill	1	6
			Spotted Redshank	1	6
Teal	**335**	**6**	**Teal**	**559**	**6**
			Tufted Duck	91	6
Tu rnstone	75	6	Turnstone	3	6
			Water Rail	8	2
Whimbrel	2	10	Whimbrel	1	10
			Wigeon	1174	6
			Wood Sandpiper	1	6

Teal ($P = 0.034$) in terms of population loss, while there is a significant difference for Lapwing ($P = 0.015$) for population gain. Knot was not observed in the designated period in Cardiff although it was previously considered as an important species in Cardiff; therefore, 840 peak mean of Knot in Newport can be considered as a noteworthy population gain. There is no significant difference between the data for Curlew ($P = 0.287$) and Shelduck ($P = 0.484$).

Discussion

Summary of the results

We have used the concept of biodiversity quality to test the following research hypothesis H_1: *The bird biodiversity quality of the Newport Wetlands is equal to and not significantly worse than the Cardiff Bay it was intended to compensate*, and it is supported by all measured elements of the biodiversity quality (see Appendix Table A7).

Most of the Newport biodiversity indices show higher values. The compensation site is at least equal to the original site given the much greater range of species, the number and population of important species for conservation, and the current SSSI status designated in 2010. Given these factors, the hypothesis for this research is supported and it would imply that Newport site is a suitable mitigation for Cardiff Bay although this has been balanced by the loss of some species.

There are several limitations in the analysis: (1) WeBS Core Counts are conducted once each month, and other species or larger populations may have been present in the intervening periods; (2) counts data of gulls and terns were excluded from the analysis due to data unavailability, although a number of these species were observed over the mudflats and open water in Cardiff (EAU 1991), and also in Newport after the habitat creation and (3) using a five-year peak mean of annual count, might cancel out the difference between the two sites by averaging the data although a five-year peak mean reveals the capacity of the sites.

Implications from the analysis

Issues related to biodiversity indices

While higher Species Richness is observed in Newport compared to Cardiff, this does not always indicate a higher or better quality of biodiversity (Magurran 2004; Feest 2006; Maier 2012). A possible measure to alleviate this problem is the use of SVI, which represents species rarity or intrinsic value. While there are some less important species for conservation interest in Newport, both sites have the same number of the species which are in the red list for the conservation concern and both Newport and Cardiff have important species and the sites are of equivalent value.

Another index which could represent the function of biodiversity is BI. As Saint-Germain *et al*. (2007, p. 330) suggest, 'biomass is strongly correlated with metabolism' and therefore, it could contribute to characterizing the biodiversity by illustrating trophic status and strength of the food chain. The BI in Cardiff shows it to be a more appropriate feature of the functional aspect of the biodiversity compared to the abundance analysis: the Simpson's index based on the population shows high dominance due to Dunlin whilst the index based on the relative biomass shows less dominance level by one species. The use of a combination of indices for measuring biodiversity is essential for site assessments thus Feest *et al*. (2010) state that the quality of biodiversity can be captured by assessing the balance and relative magnitude among several biodiversity indices.

Issues related to quantification of values

While Newport attracts many new species and populations, a significant loss of Dunlin ($P \leq 0.001$), Redshank ($P = 0.006$) and Teal ($P = 0.034$), is observed from the comparison of individual species in the two sites. Dunlin and Redshank are important species, not only in Cardiff but also in the Severn Estuary, and these species are included as features of the Severn Estuary SPA (Burton *et al*. 2010). In addition, Dunlin is ranked on the red list for conservation status in the United Kingdom (Eaton *et al*. 2009). The five-year peak mean of Dunlin in Cardiff showed 5220 birds prior to the barrage construction; however, the population of Dunlin has not been sufficiently compensated by the newly created habitat as shown in the analysis in Results section. This result had been expected prior to the project as this compensation is not 'like-for-like' compensation but 'out-kind' compensation. This is one of the most controversial and difficult issues in 'out-kind' compensation because in biodiversity terms one species cannot be replaced by others (Feest *et al*. 2010a b; Maier 2012); also a habitat cannot be completely and physically recreated (Cowell 2000).

Summary of the issues

The achievement of 'no net loss' depends on the frame of reference for the goals and the assessment measures. Selection of the compensatory measures such as 'like-for-like' compensation or maximising conservation value with 'out-kind' compensation also depend on factors including scientific and technical reasons, political decisions and social needs. It is necessary to develop: (1) clear goals and targets for 'no net loss' of biodiversity by clarifying the value of the biodiversity and the taxa in question and (2) a measurement for assessing biodiversity and the achievement level of 'no net loss' in order to deliver the policy. Finally this article has addressed issues relating birds specifically but the techniques and the issues addressed here based on the setting of baselines and targets are not limited to birds and could be utilised for other organism groups such as beetles, butterflies, spiders or bryophytes and lichens (Feest *et al*. 2010a, b, 2011; Drapeau *et al*. 2012; Feest & Cardoso 2012; Feest *et al.* 2012).

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Appendix

Table A1 Criteria for SVI 1

During the breeding season		Unit	SVI1
Order 1	Under 10	number of breeding pairs	6
Order 2	10–99		6
Order 3	100–999		4
Order 4	1,000–9,999		2
Order 5	10,000–99,999		2
Order 6	100,000–999,999		2
Order 7	Over 1,000,000		2
Outside the breeding season		Unit	SVI1
Order 1	Under 20	Recorded individual number in an average year	6
Order 2	20–199		6
Order 3	200–1,999	Estimated individual number in Britain and Ireland per year	4
Order 4	2,000–19,999		2
Order 5	20,000–199,999		2
Order 6	200,000–1,999,999		2
Order 7	Over 2,000,000		2

Reference: the classification of the population use Perrins (1987)

Table A2 Criteria for SVI 2

The red list criteria		SVI2
IUCN	Global Conservation Status. Species listed by BirdLife International as being Globally Threatened using IUCN criteria.	20
HD	Historical Decline. A severe decline in the UK between 1800 and 1995, without substantial recent recovery.	10
BDp	Breeding Population Decline. Severe decline in the UK, of more than 50%, over 25 years (BDp1) or the longer-term	10
WDp	Non-breeding Population Decline. Severe decline in the UK, of more than 50%, over 25 years (WDp1) or the longer-term	10
BDr	Breeding Range Decline. Severe decline in the UK range, of more than 50%, as measured by number of 10 km squares occupied by breeding birds, over 25 years or the longer-term.	10
The amber list criteria		SVI2
SPEC	European Conservation status. Categorised as a Species of European Conservation Concern.	6
Hdrec	Historical Decline. Red listed for HD in a previous review but with substantial recent recovery more than doubled in the last 25 years	6
BDMp	Breeding Population Decline. As for red list criteria BDp, but with moderate	6
WDMp	Non-breeding Population Decline. Ass fan red list criteria WDp, but with moderate decline (by more than 25% but less than 50%).	6
BDMr	Breeding Range Decline. As for red list criteria BDr, but with moderate decline	6
BR and WR	Rarity. UK breeding population of less than 300 pais or non -breeding population(BR) of less than 900 individuals(WR).	6
BL and WL	Localisation. At least 50% of the UK breeding (BL) or non-breeding (WL) population found in 10 or fewer sites.	6
BI and WI	International Importance. At least 20% of the European breeding (BI) or non-breeding (WI) population found in the UK	6

Reference: the criteria of the red and amber lists use Eaton *et al*. (2009)

Table A3 Weight and SVI of each species for data processing

common Name	Minimum Weight g	Maximum Weight g	Mean Weight g	SVI1	Red List	Amber List	SVI2	SVI
Grebe, Little	100	200	**150**	2		Y	6	**6**
Grebe, Great Crested	750	1200	**975**	2			2	**2**
Grebe, Red-necked	700	900	**800**	4		Y	6	**6**
Cormorant	2000	2500	**2250**	2			2	**2**
Egret, Little	450	550	**500**	6		Y	6	**6**
Heron, Grey	1600	2000	**1800**	2			2	**2**
Spoonbill	1200	1700	**1450**	6		Y	6	**6**
Swan, Mute	10000	12000	**11000**	2			2	**2**
Swan, Black *	5100	6270	**5685**	2			2	**2**
Goose, Greylag	3400	3700	**3550**	2		Y	6	**6**
Goose, Barnacle	1600	2000	**1800**	2		Y	6	**6**
Goose, Canada	4300	5000	**4650**	2			2	**2**
Goose, Bar-headed *	2000	3000	**2500**	4			2	**4**
Goose, Dark-bellied Brent *	1200	2250	**1725**	2			2	**2**
Shelduck	850	1450	**1150**	2		Y	6	**6**
Wigeon	500	900	**700**	2		Y	6	**6**
Gadwall	650	900	**775**	2		Y	6	**6**
Teal	250	400	**325**	2		Y	6	**6**
Mallard	850	1400	**1125**	2		Y	6	**6**
Pintail	750	1050	**900**	2		Y	6	**6**
Garganey	300	440	**370**	6		Y	6	6
Shoveler	500	700	**600**	2		Y	6	**6**
Pochard	700	1100	**900**	2		Y	6	**6**
Duck, Tufted	550	900	**725**	2		Y	6	**6**
Scaup	700	1100	**900**	2	Y		10	**10**
Scoter, Common	1200	1450	**1325**	2	Y		10	**10**
Goldeneye	600	1150	**875**	2		Y	6	**6**
Goosander	1050	1650	**1350**	2			2	**2**
Duck, Ruddy	550	800	**675**	4			2	**4**
Rail, Water	85	190	**138**	2			2	**2**
Moorhen	250	420	**335**	2			2	**2**
Coot	575	900	**738**	2			2	**2**
Oystercatcher	400	700	**550**	2		Y	6	**6**
Avocet	250	400	**325**	4		Y	6	**6**
Plover, Little Ringed	30	50	**40**	4			2	4
Plover, Ringed	55	75	**65**	2		Y	6	**6**
Plover, Golden	140	210	**175**	2		Y	6	**6**
Plover, Grey	170	240	**205**	2		Y	6	**6**
Lapwing	150	310	**230**	2	Y		10	**10**
Knot	125	215	**170**	2		Y	6	**6**
Sanderling	45	85	**65**	2			2	**2**
Stint, Little	20	40	**30**	4			2	**4**
Sandpiper, Curlew	45	90	**68**	4			2	**4**
Dunlin	40	50	**45**	2	Y		10	**10**
Ruff	130	230	**180**	4	Y		10	**10**
Snipe, Jack	35	70	**53**	2		Y	6	**6**
Snipe	80	120	**100**	2		Y	6	**6**
Godwit, Black-tailed	280	500	**390**	2	Y		10	**10**
Godwit, Bar-tailed	280	350	**315**	2		Y	6	**6**
Whimbrel	270	450	**360**	4	Y		10	**10**
Curlew	575	950	**763**	2		Y	6	**6**
Redshank, Spotted	135	205	**170**	4		Y	6	**6**
Redshank	85	155	**120**	2		Y	6	**6**
Greenshank	140	270	**205**	4			2	**4**
Sandpiper, Green	70	90	**80**	4		Y	6	**6**
Sandpiper, Wood	50	90	**70**	4		Y	6	**6**

Table A3 *Continued*

common Name	Minimum Weight g	Maximum Weight g	Mean Weight g	SVI1	Red List	Amber List	SVI2	SVI
Sandpiper, Common	40	60	**50**	2		Y	6	**6**
Turnstone	550	900	**725**	2		Y	6	**6**
Kingfisher	40	45	**43**	2		Y	6	**6**

Reference: the minimum and maximum weights and population category except for the species marked with * use Perrins (1987) and for species marked with * use Wildlife Information Network (N.A.). Red and Amber List status use Eaton *et al*. (2009).